AN ABSTRACT OF THE THESIS OF

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Title: Process Modeling the Physician-Patient Encounter

Abstract approved:

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The objective of this research was to provide a definitive description of the processes within the physician-patient encounter in an office setting. This description would take the form of a formal process model of the encounter in a provider's office setting, as this represents the most common situation during patient encounters. These activities are highly varied and include everything from the act of diagnosing a patient to the transfer and update of records or other media. Developing a model that can accurately describe the various situations in these encounters was chosen as modeling is a highly effective way to address and analyze the issues involved. From this model, others could analyze these situations and discern from their analyses better solutions for improving the quality and practice of healthcare encounters.

The methodology used in this research to describe and model the encounter was the IDEF0 modeling language. IDEF0 is a method designed to model the decisions, actions, and activities of an organization or system. Using this methodology, a clear picture of what happens during the healthcare encounter was revealed. Additionally, IDEF0 modeling allowed the display of the participants, tools, and procedures vital to the process, providing for consideration of virtually every element involved in the encounter. This complete description of the healthcare encounter allows one to identify areas in the process which may be improved, or to which information technologies could be applied.

The model was verified and validated by subject matter experts and its utility demonstrated by applying it to the development of a subset of requirements for the Healthcare Toolkit, which is intended to combine the assessment abilities of common medical instruments with the mobility and technology of modern handheld devices.

Process Modeling the Physician-Patient Encounter

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Xiaomin Tong, Author

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Chapter 1 Introduction

1.1 Thesis Overview

The objective of this research was to provide a formal description of the processes within the physician-patient encounter in an office setting. This description would take the form of a diagrammatical process model of the encounter in a provider's office setting, as this represents the most common situation that patient encounters occur in. The activities that take place within the context of these encounters are highly varied, and include everything from the act of diagnosing a patient to the transfer and update of records or other media. Developing a model that can accurately describe the various situations in these encounters was chosen as it was a highly effective way to address and analyze all of the issues involved. From this model, others could analyze these situations and discern from their analysis better solutions for improving the quality and practice of healthcare encounters. These solutions could lower the costs of the encounter, allow more to be achieved by the encounter in less time, increase the patient's satisfaction with the services provided, or otherwise raise the quality of physician-patient encounters.

The methodology used in this thesis to describe and model the encounter was the IDEF0 modeling language. IDEF0 is a method designed to model the decisions, actions, and activities of an organization or system. Using this model, a clear picture of what is happening during the health care encounter could be revealed. Additionally, it allowed the display of the participants, tools, and procedures vital to the process, providing for consideration of virtually every element involved in the encounter. This complete description of the healthcare encounter would allow one to identify areas in the process which may be improved. The model will also be used in the development of a medical device called the Healthcare Toolkit (refer to 2.2.2, 6.2), which is intended to provide several functions for streamlining, modernizing, and otherwise improving the physician-patient encounter.

1.2 Chapter Overview

There are three portions to this thesis, divided into five chapters. The first chapter is an introduction describing the purpose and general layout of the thesis. It is provided to help the reader maintain a clear sense of context throughout the body of the thesis, as well as provide some guidance for those seeking specific information contained within.

The second chapter, the background and motivation, briefly introduces the state of the current healthcare system, describing some of the previous research conducted and the reasons that necessitate and motivate the development of this encounter model. The rapidly advancing conditions within which physician-patient encounters occur, as well as the growing disparity between the existing research and the modernization of healthcare processes, are described in this chapter. The motivation section details some of the practical implementations that a current and accurate healthcare encounter model could be used for, and the ways in which this thesis could ultimately improve the quality of healthcare encounters conducted in the United States.

The most significant part of the first portion is contained within the third chapter, the literature review. It provides a review of the current research and publications concerning various aspects of the healthcare encounter, and is for this reason ordered by sections: to provide first a general foundation for understanding the encounter process, before increasing in detail and specificity. This chapter includes the aspects of the current physician-patient encounter that necessitate its analysis, representation, and eventual improvement. By reviewing the existing literature, researchers gain a deep understanding of the process in different healthcare domains from both the physician's and the patient's perspectives. The topic of literature reviewed in this thesis also includes a broad foundation of general healthcare information, within which the encounter modeled comprises an important facet. The literature review contains an overview of the existing healthcare condition, the current healthcare encounter process and healthcare reform in the US. Also included in this review is a discourse on the motivations, procedures, techniques, systems and tools that have been used in the healthcare industry and by physicians in their work with patients. Additionally, a review of current modeling methodologies for healthcare, and an analysis of their advantages and shortcomings are presented.

The second portion of this thesis begins with chapter 4, and describes the development of a model of the physician-patient encounter. There were three steps that were performed during the modeling preparation phase. First, the researcher reviewed and drew conclusions from all the information gained from the literature review. Secondly, the researcher reviewed the personal experience of physician-patient encounter and had informal discussions and observations of physicians, to verify that the information gathered was up to date and as accurate as possible. Finally, the researcher conducted a series of interviews with subject matter experts to identify the activities in the process and the priority of each activity. After the preparation, the researcher started to develop the model from the broadest level to the most detailed level. This included the most general description of the activities, such as performing a physical examination, to the most detailed components that make up each activity- in this example, the detailed review of the body systems and the specific actions the physician takes during the steps of the examination. The decomposition enabled by the model allowed it to provide definition for the activities, illuminating the various specific elements and mechanisms by which the activities work and the relationship between each of the processes, which are all made visually accessible by drawing a diagram of the model. The chapter also explains each part of the model by giving a brief description of the elements that comprise it.

The third portion of this thesis describes the verification and validation of the model, and finishes with the final chapter concluding the thesis and providing recommendations for the model’s improvement, which are presented with the goal of developing the methodology for increased efficiency and accuracy, developing a better testing methodology, improving its usability, and further investigating the range of its application. The verification and validation were achieved by working with subject matter experts and generating recommendations for the model. These were done using a survey. The researcher first chose 5-6 subject matter experts, physicians in this case, who were considered very experienced, each having more than 10 years in the healthcare domain. A face-to-face training session was conducted with the subject matter experts to introduce them to the IDEF0 model format and how to read the model. After the training, the survey instrument along with the model and description was delivered to the physicians. After gathering the physician's feedback, it was reviewed and analyzed to generate recommendations for future versions of the model based on the results of the validation.

Chapter 2 Background and Motivation

2.1 Background

The call to improve the efficiency of healthcare in the United States is getting stronger and louder. Healthcare reform is one of the most important and talked about issues in the country now. How to improve the quality of healthcare service and reduce the cost so that people can afford it are the two issues most brought up by the people and the two issues most in need of remedy. To speak in general terms about the quality of healthcare services in the US gives one little direction on how to improve it, so this thesis was written with the purpose of analyzing the patient-provider encounter, in order to improve the quality and efficiency of this crucial process within the healthcare system. (Baucus, 2008)

To reduce error and streamline the operations within this healthcare encounter, it is necessary to choose the most suitable system for managing and organizing healthcare and patient data. Recent trends have been the shift from using traditional manual management to a digital management system, which is supported by claims that it reduces error and costs. To further reduce the cost of healthcare for the patient, it is important to deliver more efficient service. This can be done by reducing the number of visits necessary to manage a patient's condition, and reducing the number of expensive tests needed by giving a correct diagnosis earlier on. Also, it is important to give the most accurate and effective forms of treatment, such as using the correct drugs, which can improve overall outcome of the care and improve the patient's level of satisfaction as well as reducing the cost of treatment. All of these facets of health service are present during the physician-patient encounter, which is the main means of diagnosing a patient, determining treatments, prescribing medications, and updating the patient's file and other information. The multitude of tasks that take place during this encounter makes it central to providing health services. (Hausman, 2004)

From the above, it is obvious that having a good system to support the physician-patient encounter is critical for improving the quality and reducing the cost of healthcare services. Using process modeling, which displays for analysis all of the things that take place during a process such as the encounter, it is possible to discover elements of the encounter that should be optimized. Through modeling the process, one can even infer the most useful methods of improvement, and the model of the encounter can be used to increase both its efficiency and quality. By facilitating the improvement of the central physician-patient encounter, the researcher hopes to positively impact healthcare services as a whole.

However, since the rapid development of information systems originated outside of the medical field and healthcare organizations lagged behind, the research regarding the modern healthcare encounter is often out of date (Bodenheimer & Grumbach, 2003). The existing research that deals with this encounter was in many cases conducted before internet reform had really taken place in the hospital, so much of the previous research explores the traditional paper-based management system processes and provides an in-depth analysis of them. Even though this is not the case for every hospital, the majority of them have already transferred to a digital system, which has significant differences from the traditional process (Bodenheimer & Grumbach, 2003). An ever increasing amount of human-computer interaction is taking place, and should be considered in the process. Data storage is another issue which did not exist for many of the previous researchers. The media have been changed from traditional paper documents to a range of multi-media formats, such as video, sound and digital documents. This transition has had a substantial impact on the way that patients and physicians communicate. It is often the case that the research paper gives a very detailed review of a specific topic within the healthcare system, which explores specific activities and participants in that process. However, a generic overview of the physician-patient encounter process is also critical since it forms the foundation of patient care before any special treatments can be implemented (Hausman, 2004). Up to this point, very little modeling has been done that applies to healthcare services, and research regarding modeling in this respect was almost non-existent. The process model developed for this thesis is therefore unique, in that it is one of the first cases of modeling methodologies being applied for the improvement of the physician-patient encounter, and it is a pioneering example of how process modeling can be utilized in the improvement of the healthcare industry.

2.2 Motivation

The following sections discuss the major motivations that inspired this research. The motivations all seek to accomplish the same goal: define the process so that potentially it can help healthcare organizations become more effective, by a creating a deep understanding of the human, technological, and systemic factors involved in the process.

2.2.1 Improving Healthcare Quality and Reducing Cost

To facilitate the ability of healthcare to remain a competitive and autonomous industry requires several things. Foremost is the necessity for the quality of healthcare to be as high as possible. Quality of service includes many factors: the ability of an institution to maintain a high rate of successful treatments, the competence and approachability or friendliness of physicians and other medical staff, the fast and accurate maintenance and handling of patient records and medical devices, and an ability to provide services for as low a cost as possible.

A thorough analysis of the encounter process is the first step in improving its quality (Hausman, 2004). Increasing the comfort and satisfaction a patient feels during the encounter can be addressed after identifying the processes that are most distressing to the patient, for which a model of the encounter is necessary. From the provider's viewpoint, it is equally important to increase the patient's safety and the accuracy of information given, referenced, and collected during the encounter. To improve the quality of this task, it is important to eliminate as much human error during the encounter process as possible, since healthcare is mainly driven by human beings. Creating a detailed model of the encounter is the first step in identifying the situations that contain possibilities of error and eventually improving them, to increase the safety and satisfaction of the patient as well as the precision of services rendered.

A secondary but nevertheless important motivation is to increase the efficiency of the healthcare process. If the amount of work that health care providers are burdened with can be reduced, if the cost of healthcare can be lowered, and if the positive effects of the healthcare system can be increased, this problem can be significantly lessened. The current healthcare system in the US does not provide for everyone, necessitating a reduction in the cost of health services, and this idea can and must be applied to the physician-patient encounter as well. The model will allow others to discern areas of the encounter process that can be more efficiently performed, as well as aiding in the implementation of various means of cost reduction. A descriptive model will help in decreasing the number of encounters needed between a physician and their patient, in addition to identifying tasks that could be delegated to nurses, physician assistants, or technicians to lighten the burden of the physician and reduce the cost to the patient. For example, it is common for a nurse or other professional to take basic vital signs and information before the physician-patient encounter, and then for the physician to repeat these measurements during the encounter (Arnold et al., 2011). While in many cases this redundancy is necessary, modeling allows this and other inefficiencies of the process to be clearly visible in a way that is difficult or impossible to achieve by just “thinking about it”.

In addition to optimizing the existing activities of the encounter, a process model allows the ability to see where new elements might be implemented in increasing the overall effectiveness of the process. A little-explored alternative that may increase the efficiency and effectiveness of the healthcare encounter is the utilization of technologies that have been well integrated into activities outside of healthcare, but which have yet to be truly applied in healthcare and the encounter process (Wallace, 2001). In an effort to integrate some of these useful technological advances, this thesis is further motivated by a project to create a medical device to support various aspects of the healthcare encounter. To determine the requirements that such a device should meet, the encounter must be meticulously analyzed and reviewed so that any shortcomings, redundancies, or other obstructions to the smooth operation of the healthcare process that might be improved with the device. The activities included in the encounter model serve as a guide for determining what functions the device must perform.

Chapter 3: Literature Review

The purpose of the literature review is to provide an informative summarization of the existing information and research available on the physician-patient encounter, the role it serves within the greater healthcare context, the human and technological factors that enable quality encounters, and the value of modeling in improving the quality and efficacy of the encounters. It covers a complete range of aspects that affect the development of the new physician-patient encounter process model, as well as information pertaining to the evolution of the healthcare industry in recent years, culminating in the modern encounters that the Healthcare Toolkit would be useful in improving. It is structured to provide general information first, with which by increments the reader should become more comfortable and knowledgeable while reading each following section.

The first section describes the current environment that healthcare providers and patients interact within, exploring the advantages and limitations of various provider settings that exist in the United States today. Ubiquitous to all of these settings, of course, is the physician-patient encounter. This environment constitutes most of the general framework that the encounter process modeled is a specific part of, therefore, in this section, only aspects of the healthcare environment relevant to the encounters are discussed. However, it is advantageous to the reader to comprehend the context of the healthcare system on its broadest level, which this section provides.

The second section focuses on the human factors of healthcare encounters. It delineates the roles that various health providers take within the previously described environment, and discusses in depth the process by which a patient is admitted, evaluated, and treated in a clinician's office setting. The physician-patient encounter that occurs during this office visit is the specific process for which the model was developed, but it is composed of more than the human interactions described in this section. The technical and mechanical aspects that are utilized by healthcare professionals and patients are discussed in the following section.

The third section introduces the electronic systems, aids, and networks that assist healthcare operations. Many of these advancements serve to increase the quality and efficiency of tasks within and surrounding the physician-patient encounter, though their implementation is both incomplete and imperfect. The section presents the issue of complexity in the healthcare process, providing some insight into possible remediation of it. This includes past and current efforts to streamline health operations, and the application of these electronic systems as a platform for improvement. Also included is a discussion of the current uses and origins of these systems, and a projection of some of the applications of these systems that may be used in the near future, using currently existing technology. This section is based in the belief that technology and tools can improve the quality and efficiency of the healthcare encounter, and provides evidence to support that assertion. In doing so, it demonstrates that the technology required for creating the Healthcare Toolkit is accessible, and with the research provided in this section the Toolkit will be more appropriately designed and be more capable of meeting its purposes.

The fourth section introduces the role that modeling could play in improving the modern healthcare system. Various process modeling methodologies are introduced and discussed. The IDEF0 modeling system is introduced and the reasons for its selection for this research are given, detailing the aspects of the methodology that give it the greatest applicability to the healthcare process. The goals and real world functions of process modeling are presented here in addition to the description of this process-specific model.

The fifth section of the literature review defines and clarifies the verification and validation processes that a model must go through, ensuring its accuracy and applicability before it is utilized in scholarly and professional settings. The specific purposes of both verification and validation are illuminated so that the reader can easily differentiate the two. Furthermore, the specific methods of verification and validation used for the physician-patient encounter model are discussed in this section.

3.1 Healthcare Environment

This section is a broad overview of the entire healthcare system, so that when the scope of the model is introduced and discussed the reader should have an immediate recognition of the context that these encounters occur in. The prevalence of physician-patient encounters in healthcare is described here, so that the extended effects of increasing the encounters' quality can be envisioned. As an integral part of many healthcare operations, it is important to understand the various instances where a physician-patient encounter occurs, and the function that they serve within the greater context of health services.

3.1.1 Healthcare Facilities

Most of the healthcare in the United Stated is provided by a hospital, research facility, individual clinic or building that is owned by the private sector. In each case, the manner and method of their available services vary, but each gives patients the chance to encounter a healthcare provider, who determines the state of their condition and assesses the facility's ability to relieve them. The specific role that the encounter plays for each of these institutions is fairly consistent, though the purpose of each differs, thus providing some variation between the execution of the encounter in each setting. The model represents the encounter within a general office setting, and as such had to be created so that differences in its administration could be easily represented without changing the structure of the model. The importance of the model's fluid quality and its ability to represent all aspects of the healthcare encounter is further emphasized throughout this thesis, as it models a very complex and variable process within healthcare.

Hospitals are one of the most common institutions where patients encounter health care providers. They usually provide professional, trained, and specialized staff such as physicians, nurses and medical assistants, as well as medical equipment. Many major hospitals are non-profit, or have their roots in various religious organizations. Because of their affiliation with private ventures and medical schools, these hospitals can often maintain sophisticated equipment and facilities and state-of-the-art service. In a physician-patient encounter that takes place in the hospital, multiple examinations may be performed with the assistance of assessment tools, computerized aids, specific laboratory tests, specialist exams, and a team of medical personnel to perform more basic tasks to relieve the physicians of their time. More than 35 million people are admitted to the hospital each year, according to the American Hospital Association (AHA), and hospitals employ more than 5 million people; the second largest private sector employer behind restaurants (AHA, 2008). As such, there is some variation between hospitals, and in the United States five different types currently exist. The types of hospitals that provide health services in the United States fall into these categories: General Hospitals, District Hospitals, various Specialized Centers, Teaching Hospitals and Clinics (The Health Pages 2010).

General Hospitals are the best known type of hospital, and provide treatments for a large range of illnesses and conditions. Multiple general hospitals may be located within the same city, if large enough, and most have their own ambulance capabilities and emergency treatment center for life threatening injuries or conditions. An encounter here may occur several times for a patient; first with the emergency medical technician at the scene of an injury, then with a physician to assess the patient’s ongoing condition, then perhaps with a surgical specialist who determines with the patient some of the different procedures available in rectifying the condition or injury.

A District hospital is usually a large building or campus, with facilities and accommodations for many long term patients. District hospitals have the means for extended and ongoing care that general hospitals may not.

A Specialized hospital or center usually only provides one or a few medical services for very specific needs. There are many types of specialized hospitals, such as trauma centers, rehabilitation hospitals, children's hospitals, and so on. There are even specialized centers that are specific to only a single condition, such as breast cancer or diabetes. The physicians conducting encounters in specialized hospitals usually have a great deal of experience with the patient's condition, due to the nature of the hospital. Parts of the encounter concerning the diagnostic process may be greatly simplified in this setting, though the overall encounter process is very similar.

Teaching hospitals provide a medical education for students of medicine, nurses or other health professionals and allow them to practice their skills by assisting with the patients. Teaching hospitals are often linked with medical schools, nursing schools or universities.

A clinic is usually a small health facility devoted to providing limited health services, in contrast to a large hospital. They are in many cases publicly funded, and provide outpatient services to members of a community. Most clinics have very limited resources and may refer patients to larger hospitals when necessary. This means that a clinic has no beds or other accommodations for long term patients, and can only provide on-site care or specialized services. This does not mean that the level of service is necessarily less than that of a hospital; many clinics are run by physicians who perform their entire practice there. A clinic may be the source of a patient's primary care, though specialized clinics exist to cover an extremely broad range of medical applications and patient needs. Even though they are usually limited by size, clinics are often well equipped with state-of-the-art devices and modern medical equipment. Often, a patient can be evaluated by a physician, and special tests needed to confirm a diagnosis can be performed right at the clinic. An outpatient visit might consist of the full physician-patient encounter modeled, as well as x-rays, MRIs, physical therapy, or a prescription to be filled at a local pharmacy. Most of these general practice clinics can refer patients to a specialist for any tasks that cannot be performed on site. However, there is invariably some encounter between the patient attending the clinic and a healthcare professional. The interview, examination, and diagnostic processes in the encounter model all occur here.

If a patient is able to visit a doctor through any of the above means, the encounter process is generally the same. Whether the patient is visiting a free low-income clinic or a well-established general hospital with state-of-the-art equipment, their encounter with the physician follows a fairly consistent structure. After being admitted to the healthcare provider, the patient has a brief interview with their physician during which they discuss the concerns of the patient, normally a health condition that was alarming enough for the patient to have them want to seek treatment. The physician performs an examination, makes a diagnosis, and treats the patient based on the condition, as well as the patient's comfort with or ability to afford the various options available. The following section discusses the format of this encounter, which served as a fundamental reference for the development of the healthcare process model.

This section highlights some of the interactions between the medical providers, patients, the facilities they work in, and the systems and tools they use. The physician-patient encounter follows a basic format regardless of the environment it takes place in or the specific purpose for the encounter. It serves an essential function to providing effective healthcare services: it is the primary mode of assessing a patient's health, illness, or condition, and the primary activity for determining the most effective means of restoring the patient to health. The encounter includes all of the "face time" that a patient receives with their physician, and as such is the predominant time for the patient to establish a trusting relationship with the physician, which is fundamental to the exchange of sensitive information often necessary to provide effective health services. Since many of these functions are the direct goals of healthcare service itself, the encounter is viewed in this thesis and elsewhere as the most important process in achieving quality healthcare, and as such was the specific process chosen to be modeled in this research. By potentially improving quality and efficiency of the physician-patient encounter, the researcher hopes that the overall state of healthcare will be positively impacted.

3.2 Physician-Patient Encounter

Regardless of the type of hospital, the most important aspect of the healthcare process is the many encounters between physician and patient. Since the physician is the primary provider of care, and the person playing the greatest role in the outcome of the patient's health, it is important to analyze the encounter and attempt to make each encounter as successful as possible. Because of the nature of many physician-patient encounters, it can be difficult to guarantee the comfort of the patient and their willingness to cooperate. Encounters with a physician in the hospital are unique for most people, because of 5 qualities, as identified by Hausman (2004, p.403). These encounters include: "(1) one-on-one interactions, (2) frequent encounters with the same physician, (3) exchange of intimate and sensitive information, (4) substantial variability across encounters, and (5) the requirement [for] patient cooperation to achieve successful health outcomes". Because of this unfamiliar and potentially uncomfortable situation, it is extremely important that the physician establishes a sound, trusting relationship with the patient. Establishing that relationship is one of the critical elements of the physician-patient encounter, and is shown as a functionally dominant activity in the model of the encounter.

This thesis concentrates on the one-on-one patient-provider encounters in healthcare, and as such it is concerned with the methods of addressing each of the five aforementioned aspects. In easing the patient's comfort during these situations, communication between the patient and their provider is critical for delivering high quality, effective healthcare services. It will be shown that the establishment of a positive patient-provider relationship has far-reaching effects on the delivery and outcome of the whole encounter process.

3.2.1 Physician-Patient Interview

The basis for a positive relationship is established during the beginning of the encounter, through the physician-patient interview. The purpose of the interview is not just to form this relationship, but to also begin the collection of information from the patient so that the provider can begin to think about his assessment of the condition, to take place throughout the encounter. While not all interviews are perfect, due to the variability inherent in people's personalities and physician's methods, an ideal interview will instill trust in the patient for the provider while allowing the provider to begin gathering all of the necessary information.

A well-executed patient interview will typically consist of three definable stages, during which the patient is made comfortable and information can be exchanged effectively. Early in the interview, during the first stage, an atmosphere is created that encourages the patient to speak freely and honestly about any relevant topics. This atmosphere is created by the physician, who has put aside his phone calls and ceased his other work to show respect to the patient. Remember that this is an ideal interview, and unfortunately not every physician will conduct this in the most effective manner. The physician should have a cheerful smile and friendly greeting, and engage in some amount of conversation ("small talk") to help the patient feel less nervous. The conversation should be relatively brief, however, so that the interview may be conducted in good time. (Rogers & Shuman, 2000).

Most of the medical information exchange of the interview occurs during the “middle stage”, after the patient is speaking freely and comfortably. An experienced and skillful physician will be tactful during this part of the interview, due to the often sensitive nature of the information being given. Their questions should be substantially non-directive in technique, though directness is often necessary and acceptable. It is up to the physician to ask open ended questions, to actively listen to the responses, and to paraphrase and reflect on the information given by the patient. It is vital, for both the acquisition of accurate information and the patient’s satisfaction, that no assumptions are made during this stage and that the physician and patient share a common understanding throughout the interview. (Rogers & Shuman, 2000).

The final stage is almost an extension of the middle part of the interview, but with summation in mind. The physician overviews the entire conversation, and then allows the patient a chance to correct any misgivings, or ask questions of her own. It is important for the physician to allot enough time for this at the end, because in many cases interview time may be limited. After the patient has been given a chance to ask questions, the physician will clarify any comments the patient made and finally reflect his own feelings to the patient concerning their information and condition (Rogers & Shuman, 2000).

Most communication between a physician and the patient happens through direct face-to-face discussion; the physician-patient interview. This interview is fundamental not only for successful communication, but is also the primary period for a trusting relationship to form between the patient and physician, as well as an opportune time to exchange and characterize necessary clinical information. It is important for the physician to conduct the interview properly and respectfully to allow the patient to receive the greatest benefit.

It is essential to the satisfactory outcome of the encounter and healthcare services that patients and physicians can effectively communicate with one another. It has been shown that a patient's satisfaction is substantially influenced by whether or not they feel their statements and concerns were well understood by the physician, and whether they had the opportunity to tell their physician everything they wanted to. Research has shown that high levels of patient satisfaction are correlated with how well they communicated, with specific activities shown as highly important. Researchers Comstock, Hooper, Goodwin, Goodwin, Freemon, Negrete, Davis, Korsch, Wooley, Kane, Hughes, Wright, Stiles, Putnam, Wolf, and James were cited by Rowland-Morin and Carroll (1990, p. 171-172), who identified in their work the following traits of effective communication: (1) the physician's expression of personal interest in the patient's well-being, (2) the physician's ability to actively listen- that is, to clarify and reinforce the patient's concerns or expectations, and to encourage the patient to ask questions- and (3) that the physician freely gives feedback for the information received from the patient, and clarifies that they understand the patient's answers. Also identified were (4) the physician providing an explanation and educating the patient about their condition, and (5) expressing emotional support and trust for the patient (Rowland-Morin & Carroll, 1990). Achieving favorable communication between patient and provider creates a better relationship between them, and will ultimately generate better patient outcomes. This can be gauged in both the short and long-term outcomes, from the immediate patient satisfaction and recall, to adherence and eventually a better quality of life (Beck, Daughtridge and Sloan 2002).

During the physician-patient interview, the vast majority of information is communicated verbally. Effective verbal communication is critical as it serves the three functions vital to a successful physician-patient interview. Verbal communication allows the development of a therapeutic relationship between the patient and physician, it facilitates the gathering of information throughout the interview, and it aids the physician in both explaining his decision making to the patient and managing the patient's condition (Beck et al., 2002). Patient satisfaction is a direct product of good verbal communication, and numerous studies have identified correlations between satisfied patients and certain aspects of effective verbal communication. For example, patients report higher levels of satisfaction if the physician communicates in a way that is involved and expressive, though conversely, they have reported lower satisfaction if the physician dominates the conversation (Rowland-Morin & Carroll, 1990).

Beck has shown that some behaviors in verbal communication also have been shown to have a marked positive impact on patient satisfaction. Patients who are given many opportunities to ask questions or interject comments, in the form of silent time between speaking turns in the interview, have reported being pleased with the communication. Also effective is the use of similar lexicons by the physician and patient, which implies a higher degree of understanding of the information gathered, and makes the patient feel better understood by and more involved with the physician (Beck et al., 2002). A large number of interruptions between physician-initiated and patient- initiated conversation will deter the flow of communication and negatively impact the patient's satisfaction, however, interestingly, interruptions between the physicians on same topics has been shown to bring positive influence on patient satisfaction (Rowland-Morin & Carroll, 1990).

The importance of good verbal communication cannot be stressed enough. It is fundamental to interactions directly between physician and patient and thus fundamental for the effectiveness of the entire healthcare process. Good communication maintains a balance between physician-initiated and patient-initiated conversation. It allows the patient to share their information with confidence and trust, while allowing the physician to share their medical knowledge and educate the patient. The patient will feel respected by and empathetic from the physician, and feel that their concerns are important and well understood.

Nonverbal communication, though it transfers far less technical information than verbal, can prove to be a rich source of information. It usually takes place within the first three seconds of a patient meeting a physician, and generally continues across the entire encounter. The myriad facial expressions, body language, emotional and physical cues are subtle, certainly, but together they account for as much as seventy percent of a given communication episode (SCAN Health Plan [SCAN], 2011). Specifically, non-verbal communication may include vocal intonations, proximity of the physician to the patient, or touch. It may include the position or movements of the patient's (or physician's) head, face, trunk or extremities (SCAN, 2011). A physician should understand the meaning of and be familiar with common body language cues, to more accurately infer the specific nature of the patient's condition (severity of pain, unspoken symptoms, etc.) (Beck, et al., 2002). A physician's nonverbal communication skills should allow them to perceive and understand facial expressions, body movements, and vocal emotion cues. When the patient notices the exceptional level of understanding the physician has gained (from nonverbal communication), he/she reports greater satisfaction with the entire encounter (Beck, et al., 2002). Even though non-verbal communication skills have little effect on the technical quality of care provided, it does have a positive impact on the patient's overall impression of the medical care they received. A physician who is sensitive to posture cues, body movement, and emotion, and who is good at expressing his concerns nonverbally will generally see higher patient satisfaction and retention (DiMatteo, 1980).

3.2.2 Examination

After the patient's concerns have been discussed, the physician performs a physical examination to determine the state of health the patient is in, to discover any abnormalities that might be reason for concern, and to investigate the severity of the patient's main complaint. The physical examination may vary depending on the goal established by the patient and physician during the interview. For example, a healthy 19 year old basketball player coming in for a sprained ankle would probably not require a gastrointestinal evaluation. The examination, regardless of its level of comprehensiveness, is fundamentally just a review of relevant body systems. Invariably the physician examines the patient's vital signs, and most of the time auscultates (listens to) the patient's heart and lungs to detect abnormal functioning. (Moser, 2004).

Some physical examinations include a comprehensive review of the patient's body systems. These "executive" exams are recommended for those who can afford them once a year, though many doctors debate their absolute necessity (Rank, 2008, pp. 1424-1425). They include every possible investigation into a patient's health, conducting specific tests for preventative purposes whether or not there is an indication that something may be wrong. However, the executive physical provides a complete list of the actions that a physician might take during a normal physical, and the techniques that might be utilized in the review of the patient's various body systems.

The inspection of a patient's vital signs, as previously stated, is the first part of the physical examination, and often is conducted by a nurse or assistant before the patient even begins their interview with the physician. Vital signs provide crucial information about a patient's general health. These numbers include temperature, respiratory rate, and blood pressure. In some cases blood oxygen saturation is also measured. The state of a patient's vital signs allows the physician to quickly assess the severity of any illnesses known about and how well the body is handling the stress of the illness, or may indicate to the physician an acute problem. If a patient's vital signs are consistently abnormal, the physician is alerted to possible chronic conditions, such as hypertension (high blood pressure). After the vital signs are taken, the physician continues his review of relevant body systems. (Goldberg, 2008).

The review of body systems may be completed in different orders depending on the physician's preference. Generally this examination includes some combination of chest, musculoskeletal, cardiac, abdominal, neurologic, and optical examinations, as well as a compound head, ears, eyes, nose, and throat exam. Many more specific examinations exist, such as breast, rectal, or mental status exams, though these are not be covered in this literature review as they are less common and not vital to understanding the examination portion of the clinical visit. (Cavanagh, Arnold, Rathe, Hagen, Duerson & Pauly 2004).

The chest examination's primary purpose is to assess pulmonary function in the patient. The physician listens to the patient's breathing at various areas of the lungs to discover signs of abnormal function, as well as visually inspecting the patient's chest and performing percussive special tests. Palpation (investigating by touch), while important to other examinations, plays a relatively minor role while inspecting the chest, because the important organs of the system (the lungs) are almost completely encased by the rib cage. (Goldberg, 2008).

The cardiac examination is separate and distinct from the chest exam, but because of its proximity is often performed at about the same time. The physician again uses auscultation, palpation, and observation in his assessment, but for the cardiac examination percussion (tapping) serves no purpose. The most informative technique by far is auscultation, as a physician is able to discern from the sound of the heartbeat any irregularities with relative ease. Pulse and blood pressure, while already recorded as part of the patient's vital signs, may be investigated further as important indications of the patient's cardiovascular health. (Cavanagh et al., 2004).

A musculoskeletal examination will be conducted if the patient reports any sort of joint pains, a physical deformation is observed, or if the patient has suffered some sort of injury. It is not usually part of a routine physical examination. During the musculoskeletal examination, the affected area(s) is tested for normal function after being visually and palpably inspected. These inspections are always done bilaterally (on both sides of the patient) so that what is normal for that patient can be separated from potential injuries. The physician applies his knowledge of anatomy and structural mechanisms to discern the cause of discomfort or the nature of an injury in the area. The physician might use resistance tests to find weakness or strain in the patient's muscles, or various special tests designed to assess ligamentous (of the ligaments), bone, tendonous (of the tendons), or other types of abnormalities. (Minnesota State University [MSU], 2011).

Another common examination performed by the physician during this time is the abdominal exam. The abdominal examination is extremely important when dealing with physical illnesses as most of the affected organs are located in the abdomen. The patient's middle is auscultated in different quadrants that the physician mentally assigns to determine the location of various organs. Then they are palpated and percussed in a similar fashion to the chest exam, with the physician of course seeking specific responses or anomalies depending on the organs being inspected. Various inflamed organs, firm points, or other signs will give the physician useful information in making his assessment of the patient's condition. (Goldberg, 2008).

It is common practice for a physician to perform the neurologic examination simultaneously with the head, eyes, ears, nose, and throat exams because of their location and interrelation. The neurological exam consists of several tests of the patient's motor functions, designed to determine dysfunction in any of the twelve cranial nerves. When this is done, or before it, the physician visually inspects the patient's ears, nose, and throat for swelling or other indications of illness or injury. Common problems that are found in this exam are inflamed tonsils, ear infections, or breath symptoms indicative of other internal problems, as well as many others the physician is familiar with. (Children's Hospital Boston, 2005).

This review of the patient's body systems can be as in depth or cursory as necessary or requested by the patient. It is critical along with the interview in helping the physician determine the patient's illness or condition. After the examinations, laboratory tests may be ordered to help confirm any suspected abnormalities, and the physician begins his task of making a final diagnosis.

3.2.3 Diagnosis

The hardest activity that a physician performs in his daily routine is the diagnosis of the patient. This is difficult because the physician must determine an exact condition that the patient suffers from, which is often very similar in appearance and symptoms to other problems. To do this, the physician considers minute differences and signs that the diseases present, the rarity of all possibly conditions, and the specific situation that each patient brings with them. In some cases, the physician is able to recognize the distinct pattern that represents an illness and make a hypothesis which can be simply confirmed by special tests, as in the case of a patient with Down's Syndrome. More often, however, he must make a deduction using the patient's complete history in addition to all of the information that he has gathered from the physical examination, and often these deductions take excessive further testing to confirm. The examination he performs and the tests that the physician orders help him eliminate unlikely conditions, with each one ideally reducing his options to the most likely diagnosis. The diagnosis process commonly works in this way, by narrowing down a set of possible diagnoses to the most probable one. (Baerheim, 2001).

This abundance of information to be processed is further compounded by the patient's individual ability to accurately describe his symptoms during the interview. This reaffirms the importance of good communication skills and techniques during the physician-patient interview. Sometimes, the physician may be tempted to use various "rules of thumb" to recall or understand knowledge, which may cause them to deviate slightly from standard cognitive reasoning. Fortunately, most physicians have access to references and diagnostic aids that allow them to minimize this human error and provide the patient with accurate information regarding possible conditions. Once the physician is able to interview the patient again concerning the differences in the hypotheses, he can usually come to a correct diagnosis and implement an appropriate treatment. (Summerton, 2004).

3.2.4 Treatment

Treatment of a patient varies widely and is extremely specific based on the patient's condition. After the physician has come to a diagnosis, he will collect all available information related to treatment options and present them to the patient. Here again the physician can employ the use of aids and references to confirm that every possible treatment is examined and discussed for its relevance and appropriateness for the patient. The treatment selection is normally a cooperative process, as many factors exclusive of the physician are involved. To name just a few examples, a patient may be allergic to the recommended medications for their illness, or physically unable to participate in a therapy because of other unrelated conditions. Other factors may come into play during this process that have nothing to do with the physical state of the patient or its relation to the treatment options. Especially in the United States, where the current state of health insurance is fluid and highly variable, the different costs of treatments may play an important factor in which the patient prefers to undergo. For instance, it may be the policy of an insurance company not to cover the primary recommended treatment for a condition, causing the patient to choose a secondary and often less optimal option, or in many cases, the patient may not be insured at all and would rather prefer the most inexpensive available option. (Charles, Gafni & Welan, 1999).

Again, effective communication and trust between the patient and provider are essential here. A patient must trust that his provider is doing the best job possible within their limitations and the patient's means. Often, a skilled and sympathetic physician will be able to recommend only the specific necessary treatments to be effective, that minimize the cost and discomfort that the patient has to bear.

The encounter between patient and physician, from initial interview to successful treatment, is clearly a long and complicated one. To aid the physician in his evaluation of the patient, various tools and references have been developed. Each individual physician cannot reasonably be expected to clearly recollect every piece of information available to contemporary medical practice. There are thousands of drugs available to patients, and countless interactions between them, necessitating some sort of system for cataloguing them and preventing adverse reactions. Additionally, new treatments are constantly being developed all over the world, requiring a method for immediately informing physicians of all available options. With the explosion of computer-based technologies in the past two decades, practitioners have a vast array of useful tools and programs to aid them in their delivery of medical services.

3.3 Complexity of the Encounter

The way that health care is delivered has changed significantly over the last 30 years (Bauer, 2009). There is a range of views on complexity in health care. At one end are those people who regard health care as a complex adaptive system, and use the term complexity in the sense of complexity science. The goal of complexity science is to take something as particular, detailed, and massive as the healthcare industry and improve the quality of service it provides, as well as optimizing clinical governance. There is some agreement about the sources of complexity in health care, even though there is no single definitive list. This is partly because of the wide range of stakeholders involved in health care, many of whom will have different perspectives on the issue of complexity. The World Health Organization refers to broad clusters of safety process measures that are applicable to health care. If these are combined with the factors which overlap with the important generic factors that affect complexity, we can produce a general list of sources of complexity in health care (Hollnagel, 2005). This list would include the technology and tool factors addressed by the Healthcare Toolkit, as well as all of the human, task, environmental, and organizational factors (Hollnagel, 2005) included in the model.

The Healthcare Toolkit is intended to be a mobile, wireless device that streamlines the activities during the physician-patient encounter. In order to better understand and help generate the requirements for this device, this thesis gives a great deal of focus to the technology and tool factors that are becoming ever more present in modern healthcare operations. New technology such as E-health serves as an advanced system in healthcare is widely developed and deployed. There are two main reasons for this attention: the first, these systems provide the opportunity for the technological advancement of communications-integrated technologies and devices. Until very recently, healthcare providers have used an overwhelmingly paper-based organizational system when dealing with patient records, test results, doctor’s notes, etc., causing a great deal of inefficiency in transferring and updating the information it contains. Secondly, an insufficient system could only add to the complexity of healthcare, increasing the time required at almost every step, slowing down communication, requiring a great deal of effort to organize and maintain the physical records, and leaving a significant chance of error or data loss.

Fortunately there has been a significant effort made in the last ten years to improve the healthcare system's information infrastructure. For example, most paper-based organizational systems have gradually transferred to an electronic medium. Another obvious implication is the inclusion of digital media in the healthcare process, such as video and audio files included in a patient's history or electronic aides for healthcare professionals. An electronically based system also provides an easy platform to connect new devices, tools or products to using a digital interface. The advancement of healthcare's information system is a relief to organizational and time problems that have been common in healthcare services, and the advancement provides an opportunity for untold development and the integration of new technologies. These improved systems can help to reduce human vulnerabilities that affect current healthcare operations, and provide a malleable structure to apply the concepts of industrial and information systems engineering to ultimately increase the performance and efficiency of a significant part of the healthcare system. To achieve this end, new research must be done to investigate the ways physicians utilize these new systems and tools, because of the significant impact E-health has had on the way healthcare encounters are performed.

This study of the modernizing physician-patient encounters is also necessary to successfully create the Healthcare Toolkit. Although the improvements made in the technology surrounding the encounter provide a great opportunity for the creation of the Toolkit, its effectiveness in attaining its functional goals will not be achieved without carefully reviewing the advantages and disadvantages of the incorporated technology. The following section describes some of the various advancements and technologies available to contemporary physicians, as well as their possible future applications. These systems, tools, and networks are directly related to the device for which this thesis attempts to generate requirements.

3.4 Advanced Technology in Healthcare

This section discusses some of the technological advancements that have grown from and been integrated into healthcare operations, as they have had a significant impact on the manner in which physician-patient encounters are carried out. Notably, the electronic systems, aids, and networks have been integrated into the encounter in an effort to streamline its activities, as well as to address the pressing issue of complexity within the encounter. This section not only discusses past and presents cases where these systems and methods have been implemented, but also contemplates some of their possible applications that may be implemented in the future, using currently existing technologies.

Most relevant to this thesis are the possibilities for integrating some of these advancements into the Healthcare Toolkit device. The various advanced systems present today are discussed to promote an understanding of the ways the Toolkit may be used, and additionally provide several opportunities for the Toolkit to augment the preexisting systems in ways that previously remained relatively unexplored. The collective term for these systems, and the services provided through them, is E-Health, of which the Healthcare Toolkit could become a noteworthy component.

3.4.1 E-Health

Traditionally, healthcare operations, both a part of and apart from the physician-patient encounter, have relied heavily on paper documentation. Extraordinary amounts of patient data, reference texts, operational procedures, aids, legal policies and more were dealt with using hard copies and physical documents, and much of this is still the case today. However, with a massive increase in the usage of computers in the twenty-first century, an ever increasing number of hospitals have rapidly been adopting and involving Information Technology (IT) in their operations. IT is the combination of computing and telecommunications technology, and has proved useful in many aspects of the health care process including the physician-patient encounter. E-health is a relatively new term used to describe the healthcare services supported by electronic processes and communications (Della Mea, 2001). E-health is an emerging field that is comprised of medical informatics, public health and health business, which is executed through information technology (Eysenbach, 2001). There are many services that fall under this simple but broad definition, from the electronic medical records used every day in modern hospitals to online health applications intended to inform patients about possible conditions based on their symptoms. E-health also includes telemedicine, consumer health informatics, decision making aid applications, mobile health, and virtual healthcare teams. (Eysenbach, 2001).

An article by Bodenheimer and Grumbach (2003) reveals the need for development of a new method of documenting interactions between healthcare providers and patients to follow the trend of advancing healthcare. “In 2001, acknowledging the slow progress of medical record computerization [in the United States], the Institute of Medicine recommended that public and private sectors of the health care economy ‘make a renewed national commitment to building an information infrastructure…[that will] lead to elimination of most handwritten clinical data by the end of the decade.’” (Bodenheimer & Grumbach, 2003). This is one aspect of the much larger, growing trend called E-health. As a part of this trend, electronic medical record systems link laboratories, x-ray departments, hospitals, specialists, and pharmacies. This greatly improves the convenience, accessibility, integration and accuracy of data. (Bodenheimer & Grumbach, 2003). As an integral part of E-health, electronic medical records are explained in detail in the following section.

3.4.1.1 Electronic Medical Records

A component that is updated by and included in many activities of the physician-patient encounter is something called Electronic Medical Records. Electronic Medical Records (EMRs) are a digitalized version of a patient’s medical records. Healthcare service organizations such as hospitals create and maintain them for all of the patients they provide care for. An EMR is a systematic electronic collection of a patient’s health information, and allows that information to be readily and easily shared with other health professionals, provided they have the appropriate authority and the patient has consented to the information's release. EMRs contain a variety of data and useful information. They can be exhaustive and comprehensive, or appear in summarized form. A patient's EMR might include their personal background, medical history, current and previous medications, allergies, physical and laboratory test results, immunizations, or anything that might have traditionally appeared in a patient's paper "file".

An EMR has many advantages when compared to a traditional paper-based record. It has a lower cost of data storage, taking up less physical space in virtual memory and less actual material with the absence of paper. An EMR may contain richer formats for data, with possibilities of conveniently accessible visual and auditory data storage. With an EMR it is easier for health professionals to access, retrieve, or centralize a patient's medical information, with less or no information lost when a patient uses multiple health providers over time. It is easier to transmit the data to remote providers and to manage the information contained in the EMR. It can directly improve the quality of healthcare provided by reducing medical errors that arise from poor handwriting, and can easily be analyzed to assess quality of previous care. (Hillestad, 2005).

Electronic Medical Records provide access to a tremendous amount of clinical data for physicians to collect and compile. This alone accelerates the level of medical knowledge forward and provides information for developing more effective medical practices. These numerous benefits have been noticed by the United States government, which has been heavily promoting EMRs for several years. As a key part of the American Recovery and Reinvestment Act of 2009, Congress created a formula of incentives for the use of EMRs and penalties for continued use of paper records (U.S. Department of Health and Human Services [US DHS], 2009). This is sure to cause a large increase in the number of providers using EMRs, as well as advances in the related software applications to maintain and manage them.

The existing platforms for managing EMRs consist mostly of the software on desktop and laptop computers at the point of care, which use hospital-based servers and computer networks, causing some issues in the rapid retrieval of information for physicians (Della Mea, 2001). Integration of tools to interact with a patient's EMR would be a useful component of the Healthcare Toolkit, allowing physicians to access EMRs from the point of care. EMRs are a primary example of how E-health has affected the physician-patient encounter, and are another reason that researching the effect of E-health is so important, especially for its relevance to the Toolkit.

3.4.2 Telemedicine

Telemedicine, like E-health, is another relatively new term, and can be defined as the exchange of information and delivery of healthcare services through telecommunication equipment and technology (Perednia and Allen, 1995). Telemedicine often includes real time interactive communication between the patient and the physician or health service provider at a distant site (Perednia and Allen, 1995). Telemedicine is, in many cases, considered a more efficient method of conducting healthcare practices when compared to traditional face-to-face appointments. Besides the obvious logistical advantages, telemedicine can help a physician acquire medical data, such as a medical image, from another healthcare provider to better understand a patient's condition and give more accurate assessment. The capacity for remote monitoring is another commonly used application of telemedicine. Remote monitoring allows the physician to monitor a patient remotely and get immediate updates of patient's condition without physically being on site. This can be particularly useful in some special cases, such as a patient with a transferable disease. Other circumstances, such as difficulties or complications in moving the patient, are often better addressed by interactive telemedicine, allowing the physician to deliver healthcare without high preparation costs or serious delay. (Vladzymyrskyy & Pavlovich, 2009).

Telemedicine can be applied to benefit many medical disciplines. For example, telecardiology is an increasingly popular telemedicine technology that is capable of transmitting electrocardiographs by using telephone and wireless technology. Teleradiology is also very common, in which electronic versions of radiographic images such as X-rays, CT scans, MRIs, etc. are sent from one location to another. (Shanker, Makhija & Mantri, 1982).

Because of the networking capabilities present, telemedicine can be extremely beneficial for people who are living in the isolated communities and remote regions. Access to necessary telecommunication equipment is often far easier to provide than access to local healthcare professionals. It is a great tool for physicians or other medical professionals to use in exchanging knowledge concerning certain cases, or to gain expertise from others in the field. Telemedicine can also serve as a teaching tool, allowing medical students to observe and learn in other locations in real time, by observing and learning from a subject expert. (Vladzymyrskyy & Pavlovich, 2009).

These applications of telemedicine have not yet been combined into a single device, but the Healthcare Toolkit provides a mobile platform on which this may be possible. By combining the intended data collection tools of the Toolkit (see 3.4.3) with the wireless data-exchanging capabilities of telemedicine, a single streamlined method of collecting and managing patient information would be created. The potential for such a device to reduce the time required for physician-patient interviews is great. Additional consequences of this would be the partial elimination of errors in the patient's EMR, specifically those that occur during the transcription of a physician's notes into the EMR, and the ability of a physician to immediately consult with remotely located specialists for additional reference on the patient's condition.

3.4.3 Mobile Health

Mobile health, also written as m-health, is the term used to describe a healthcare service supported by a mobile device. It is a segment of E-health that uses information and communication technology to improve the efficiency of healthcare processes. In the past few years, with the appearance of more sophisticated wireless and network technologies, mobile devices are already everywhere in our daily lives. The number of cellphone, laptop, and mp3 users has grown to never-before-seen levels. Until 2010, there were more than 223 million people using cellphones, and of those mobile devices, 18% were smartphones (The Nielsen Company [N Co], 2010). The tremendous rise in mobile device ownership has been due largely to the evolution of mobile telecommunication networks, and the capability for mobile internet. These technologies have expanded existing internet sales and services to a more immediate and personalized mobile environment. This could offer healthcare a more responsive and effective solution for many of its concerns, and mobile healthcare may help to bring the healthcare industry further into the 21st century.

The actual applications made possible by m-health are far more than simple messages between doctors. While m-health certainly allows doctors, nurses or other medical personnel to consult with or keep each other immediately updated, it can provide even better accessibility, such as allowing a doctor on a remote outpatient visit to access his organization's databases on the go. M-health provides a possibility for broad mobile health management for consumers, too. The ability to get or change a prescription, access insurance information, or even receive notifications when to take their medicine are all available to consumers. Doctors may consult their colleagues, access a patient's complete medical and family history, and can do so wherever they happen to be at the time. (N Co, 2010)

The future of m-health is even more promising. With technology that exists today, it would be possible to make a mobile, even wearable device capable of monitoring a patient's vital signs, and that device could keep medical staff updated in real time to the patient's condition. This would also be extremely useful in improving a hospital's response time to an emergency, as such a device could notify the hospital instantly if there were any sudden abnormalities. M-health could have the potential to dramatically increase the responsiveness and accessibility offered by healthcare.

Implementing existing m-health technology and applications into the Healthcare Toolkit would increase the range of situations that it could be utilized in. M-health fundamentals could guide the design of the Toolkit, so that its enhancements to the physician-patient encounter could be mobilized and perhaps bring healthcare services to previously isolated regions. This possibility arises from the integrated sensor technologies of the Toolkit synergistically combining with the mobility and data-transferring systems of E-health and m-health operations. The intended design and possible applications of the Healthcare Toolkit are described in the following section.

3.4.4 Healthcare Toolkit

When a patient sees a doctor for an ailment, the physician typically assesses the patient's condition with his direct senses, supplemented with traditional instruments such as a stethoscope, blood pressure cuff, thermometer, otoscope (device for examining the ears), and ophthalmoscope (device for examining the interior of the eye). Information collected in this way, along with existing patient medical records and information given verbally by the patient, is used to make diagnoses and to prescribe treatment. Traditionally, exam documentation has been handwritten and included in a patient’s physical file. Although simple cases are dealt with quickly and accurately by traditional methods, more challenging conditions may require information and expertise that the physician does not have readily at hand. As a result, delays may occur or incorrect decisions may be made. If the patient’s condition is serious or urgent, dangerous complications may result. With the advent of compact sensor technology, wireless networks, EMRs, mobile technology and cellular coverage, a door has been opened for vastly improved methods of collecting data from patients, examining them, and coming to appropriate diagnoses and treatment decisions. According to Fischer et al. (2003), “patient data management and sign-over between physicians is an area in which the risk of errors is high and in which PDAs [(Personal Digital Assistants)] may play a significant role.”(Fisher, Stewart, Mehta, Wax, & Lapinsky, 2003)

It is this new avenue of health care that creates an opportunity for the development of the Healthcare Toolkit (Bauer, 2010). This device could combine the data collecting ability of traditional on-site instruments with the mobility of smartphones and other portable devices prevalent in today’s world, and be integrated into the developing online and in-house networks utilized by the health care industry. The idea for the Healthcare Toolkit arises from potentially implementing existing technology in a device that could offer physicians a more effective and efficient means of monitoring and interacting with their patients in a physician-patient encounter.

Fisher et al. discuss the potential roles for handheld computing in medicine and evidence to support their use. One role is to provide instantaneous access to evidence-based information at the point of care, such as medical journal articles, reference texts, physician guidelines, diagnostic codes, and medication information. Another important role these devices could fill is e-prescribing, which shows significant potential in reducing medication error rates (Fischer et al., 2003). The use of software capable of optimizing health care could ultimately reduce errors and save time, with programs that provide drug lists for a particular diagnosis, potential dosages, drug interactions, and whether the patient's insurance accepts that drug (Bodenheimer & Grumbach, 2003).

In regards to sensor technology and wireless communication, Gao et al. discuss the development of a wireless blood pressure cuff used to continuously monitor patient vital signs at the scene of a disaster and until the patient has been admitted to a hospital (Gao, Greenspan, Welsh, Juang & Alm, 2005). The data is wirelessly sent to a first responder's tablet PC and is recorded into an electronic patient record database. This article confirms the existence of a wireless blood pressure cuff (Gao et al. 2005). There is evidence that handheld devices are currently being used to accurately interpret wirelessly transmitted EKGs. Fisher et al. reported that "computer-based applications and wireless technology have allowed the transmission of 12-lead EKG waveforms from remote locations to hospitals" for successful interpretation using a handheld device. (Fischer, et al., 2003, p. 139-149). This shows the possibility of transmitting medical data collected by a traditional instrument, and the Toolkit could expand the types of data to include information collected by otoscopes, blood pressure cuffs, ophthalmoscopes, and more.

As the credibility and possibility of a device like the Healthcare Toolkit is established, its designers must find the most effective way to integrate it into the modern healthcare system. While this may not seem very difficult, the extreme complexity of healthcare provides many varied areas where such a device might be used, and determining where it will help rather than hinder is in itself a long and complicated procedure. For example, it does not seem to make sense to implement a (probably expensive) mobile device with a physician's office that can already do all the same things. But whereas more traditional instruments can provide all of the same data collecting information and an in-office computer can be used to update the patient's records or the physician's notes, if the Toolkit can do it more efficiently while costing less to patients and providers than traditional instruments, then it is indeed sensible to implement it. Because of the natural limitations to human thought, it is crucial to systematically delineate the various operations within healthcare on some permanent medium, so that it may be studied for opportunities to use the Healthcare Toolkit effectively. To be feasible, implementing the Toolkit must be a cost-effective means of improving the quality and efficiency of the physician-patient encounter.

Apart from the specific task of implementing the Healthcare Toolkit effectively, the nature of complexity in the healthcare industry is driving health organizations to look for ways to increase the quality of the services they deliver to patients, and to provide better overall outcomes and higher satisfaction. Also, an ever increasing amount of attention has been drawn to optimizing the healthcare process to reduce the cost and provide more efficient services. Therefore, it is essential for us to gain a deep understanding of the existing healthcare process before one can decide what needs to be improved. While the Toolkit would probably be capable of improving quality and optimizing the healthcare process, it cannot be applied without this understanding. Many researchers have conducted studies in diverse fields to explore the benefits of developing a process model for the subject, before one actually starts to work on it. Various modeling methodologies have been developed by these researchers in order to identify the most important factors involved in the process. This thesis proposes a model to describe process of a physician-patient encounter in the office setting. This encounter process model could serve as a reference for other research done on the physician-patient encounter, as well as the overall healthcare process. The process model could be examined and analyzed for areas that could be significantly improved by a device like the Healthcare Toolkit. Additionally, by using this model, other researchers could find what activities are in this process, learn who is participating in which activities, and identify what the control factors are and what can go wrong. This methodology is to be applied to (but not limited to) healthcare processes to identify which elements have a key impact, and also to prioritize and optimize the process. The next section describes the utilization of process modeling studies in the modern healthcare environment, the modeling methodologies, and the advantages of modeling that motivated this research.

3.5 Modeling

Healthcare, as an essential service that provides life-altering care for people, should be safe, effective, patient-focused and efficient. (Jun, Ward, Morris, & Clarkson, 2009) The call for improving healthcare efficiency and quality has been extensively heralded (Baucus, 2008). It has been recognized that a systematic understanding of how the process works is critical to effecting improvements, and this idea of system analysis has become increasingly more common in the last ten years.

Recently, many methods of modeling have been applied in the healthcare field in order to methodically look at processes and find the defects in them (Afantenos, Karkaletsis, & Stamatopoulos, 2005). Moreover, modeling is the foundation for determining a system's requirements and a key step in creating solutions for improving its efficiency and effectiveness (Seymour, 2001). Modeling can build an understanding of how people and resources interact to achieve the process goals. There are indispensible benefits that can be brought to the healthcare domain by applying analytical thinking: the systemic perspective on the healthcare process, a structured means for problem-solving, and the enabling of continuous system improvements by applying feedback through analysis of the model (Wu, 1994).

In an industry such as healthcare, where unintended effects might have catastrophic repercussions, it is vital to have a systematic approach in evaluating and improving it. The most important aspect of that systematic approach is the thorough understanding of the process from the perspective that it is a system, and can be analyzed with existing tools and techniques. Process modeling is one of these techniques that can be utilized in understanding and representing the activities that make up a process. Models can be used as a reference in locating inefficiencies and human vulnerabilities within a process, as well as predicting the consequences of changing various parts of the process. (Mutic, Brame, Oddiraju, Michalski & Wu 2011).

3.5.1 Process modeling

A process model is representation that shows the operations within a process, which is created using a specific modeling language that describes each aspect of that process. It describes how things are done, using clear language and definitions that allow the reader to understand what is really happening during the activities. The process model is created by an objective observer so that the activities that the modeled process's participants conduct are described in a non-biased way. It can also be used to help determine what could be performed to improve the overall process, causing it to more effectively reach its goals and outcomes. This utilization arises from the clear representation of the process's workings, allowing the specific causes and effects within the process to be determined. Process modeling also provides explanations about the mechanisms of processes by establishing explicit links showing the relationship between different activities. The qualities of a process can be difficult to evaluate thoroughly, however, there are standards of process modeling in practice that help to accomplish this.

Morice provides three distinct qualities of process models. The first one is the syntactic quality, which is simply an assessment of the model's coherence to the grammar rules of the modeling language being used. The second one is the semantic quality of the model, which means that the ideal model accurately represents the process in reality and can be agreed upon among the involved parties in the modeling domain. The third is a pragmatic quality, to evaluate if the model can be sufficiently understood by all the relevant stakeholders in the modeling process (Morice, 1970). The model should be interpreted for those commissioning its development, so that it can fulfill their specific needs.

Understanding the current process that is used to deliver a solution is one of the most important steps before any improvements in that process can be conceived and implemented. Process modeling is a method that can be immediately administered to understand and improve the healthcare encounter. In the healthcare domain, the process model can influence knowledge across multiple departments by providing a document that directly explains the activities, times, and sources of elements within the process. It can be used to determine the procedure of the process and identify failures and errors that may occur within the process. This understanding, while so crucial, is lacking even within related healthcare fields. In fact, research suggests that each year about one million people are injured or misdiagnosed due to the lack of an understood process (Pandey, 2008). Another benefit in using process modeling is that it is able to determine areas that need to be improved, or that need reduced constraints such as resources, time etc. Process modeling should be used as a 'living' map for future process changes.

Despite growing recognition of the value of modeling in healthcare, using correct and appropriate process modeling methods for different purposes still needs to become more common to streamline understanding between stakeholders and better apply the model in practice. Since the operations within the healthcare system can become so complex and the elements that perform them so varied, it is extremely important to model the process using a methodology fully capable of its accurate representation. The healthcare process is one of a nearly infinite number of processes that occur in human life or in nature, and because of this not all modeling systems are designed to represent, or are even capable of representing, its unique characteristics. Following this, various modeling methodologies are discussed so that reasons behind choosing the one most capable of portraying this particular process are clearly identified and confirmed.

3.5.2 Flow Diagrams and Hierarchical Task Analysis Diagrams

There are a large number of methodologies and applications that support the purpose of process modeling and are used in various domains based on the preference and experience. Two major different types of process modeling methods which represent the two main ways of structuring task information through the combination of graphics and text are flow diagrams and hierarchical task analysis diagrams. (Colligan, Anderson, Portts & Berman, 2010).

Flow diagrams present discrete steps as boxes of various forms and are organized by connecting these boxes with arrows to show the flow of respective process. This type of modeling can easily display the development of information gained by conducting interviews and observation. This type of modeling language has consistently been demonstrated to be favorable in terms of both usability and utility and therefore is widely used in current healthcare domain (Jun et al., 2009). It is considered particularly helpful when understanding the sequence of activities and the interaction between various parties and components of those activities.

Data flow diagrams are one type of flow diagram that graphically show the transition of data through an information system. They provide information such as the timing of activities and how the process will be executed, such as in sequence or in parallel. They allow the reader to determine what operation will be performed in which way and under what circumstances. However, they do not describe the sources of the data nor the kinds of data to be input, output and stored in the system. (Jun et al., 2009). One of the limitations of a data flow diagram that prevents it from being ideal for the physician-patient encounter is that it is easy to overlook key data elements. At best, creating a complete and balanced model without appropriate software is difficult and can be misleading (Davis, 1994). Figure 1 gives an example of a data flow diagram.

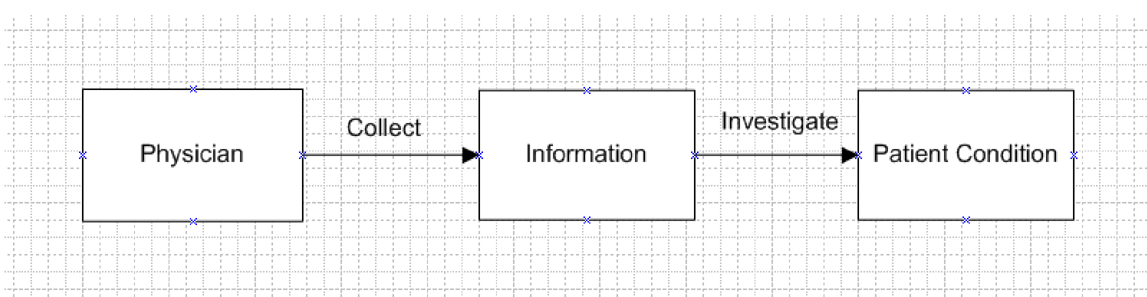

Figure 1: Data Flow Diagram

Functional flow is another type of flow diagram that shows the activities, actions, relations, and operations of a target process. They have been extensively used to discover information needs, help identify opportunities and establish basic requirements for products and services (DOD records management, 1995). The IDEF0 language is a great example of functional flow modeling and will be explained in detail later in this section. Figure 2 gives an example of functional flow chart, and Figure 3 provides an example of a top-level diagram in an IDEF0 model.

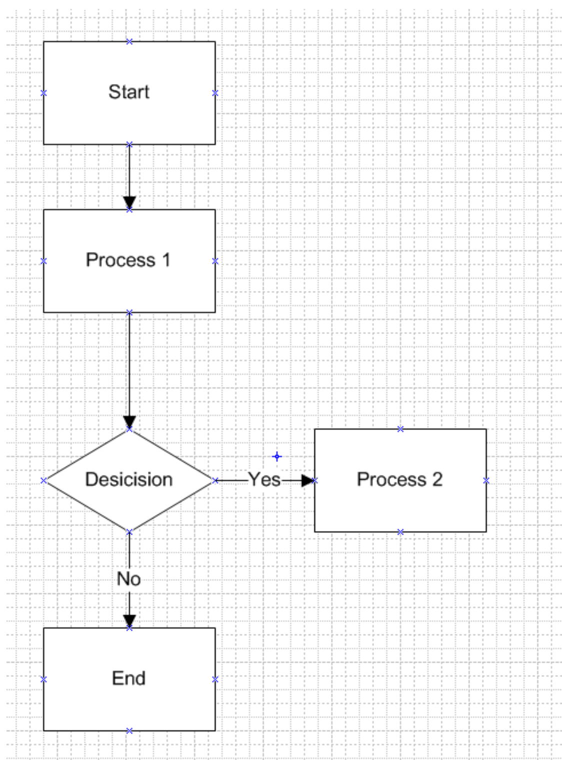

Figure 2: Functional Flow Diagram

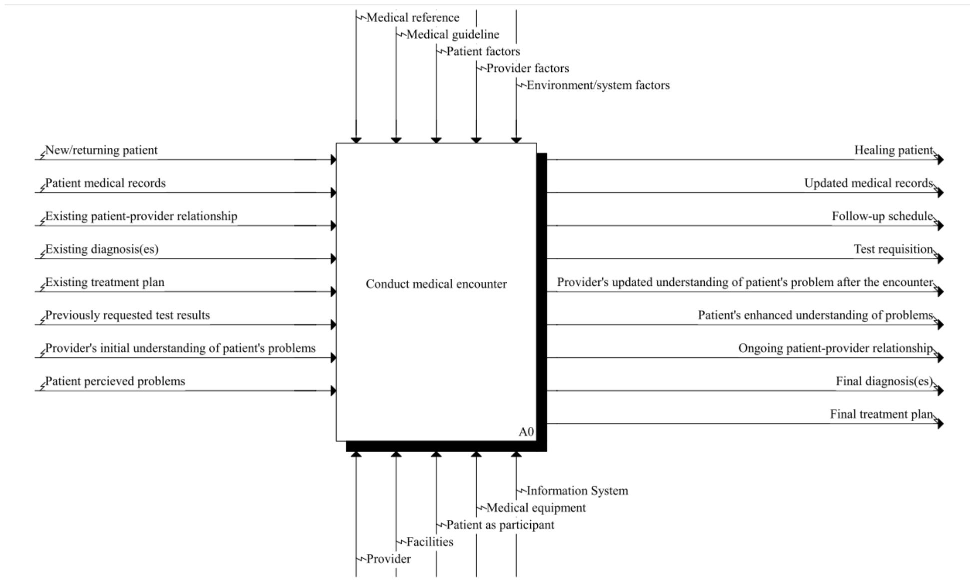

Figure 3: IDEF0 Language

The Unified Modeling Language (UML) is used to specify, visualize and modify the architecture of a system, and includes elements such as activities and actors (Foldoc, 2009). It uses a standard notation for the modeling of existing processes and objects, and it is accepted as the industry standard for object oriented programs (Foldoc, 2009). UML defines various types of diagrams including Use-case diagrams, Class diagrams, Sequence diagrams, Statechart diagrams, Activity diagrams, Component diagrams, and Deployment diagrams. Although UML is widely used and provides significant benefits such as visualization, complexity management and clear communication, it is also widely criticized as being hard to learn and adopt, and having poor linguistic and formatting standards (Alex E. Bell, 2004). As the physician-patient encounter model is intended for use as much by medical professionals as by engineers, a language that is difficult to learn and adopt is not ideal.

Hierarchical Task Analysis (HTA) diagrams are a structured and objective way of describing users' performance of tasks (Hornsby, 2010). The result of this method is a hierarchical diagram that displays the human work in a process and is organized by the activity goals. The sub-goals of the process will be carried out in order to reach the higher level goal, to indicate the dependencies between different levels (Colligan, et al., 2010). It exposes the various possible paths and approaches to completing the same task so that an objective comparison among different approaches can be made based on the numbers and types of steps they require (Hornsby, 2010). It is also highly structures so that revisions in the future can be done easily, and it provides flexibility in representing important goals which did not correspond to other tasks or performers. This capability allows any ongoing issues to be triggered at any time, such as a physician's cognitive activities. The representation of goals in the HTA provides context and motivation for healthcare professions to improve their system, since many healthcare processes (such as the physician-patient encounter) depend on regular optimization. However, HTAs cannot represent concurrent processes because of their dependent format. In the medical encounter, where activities may occur in variable orders or simultaneously with other activities, it is impossible to represent every relationship between the activities using a HTA diagram. Figure 4 shows an example of a HTA diagram.

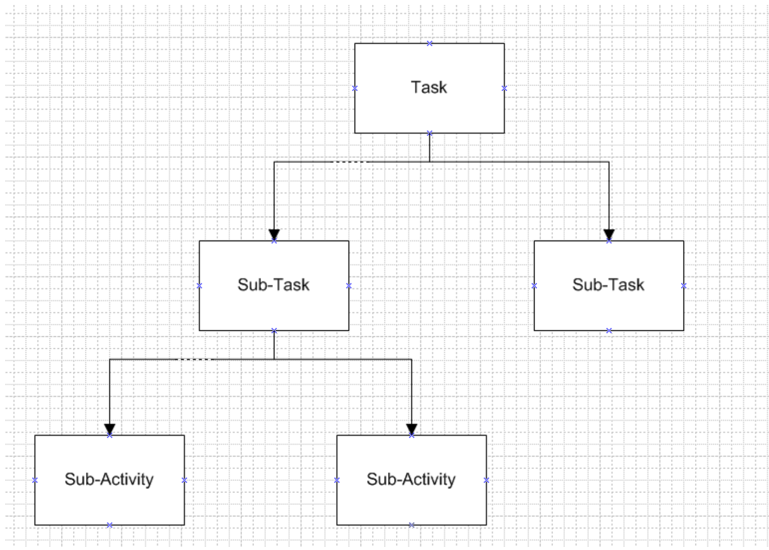

Figure 4: Hierarchical Task Analysis Diagrams

3.5.3 IDEF Languages

During 1970s, the Integrated Computer Aided Manufacturing (ICAM) Program, founded by the U.S. Air Force, aimed to increase manufacturing productivity through systematic approaches and identified the need for better analysis and communication with the people involved in manufacturing processes. As a result, a series of modeling languages known as IDEF (Integrated Definition) was developed. In 1991, this modeling language was selected for the Federal Information Processing Standards (FIPS) by the National Institute of Standards and Technology (NIST), and received support from the U.S. Department of Defense. (FIPS, 1993). The IDEF family has more than 10 different languages that range from IDEF0 to IDEF14. Some of the languages have been developed completely, but some are just primary designs upon which to found a language (Hanrahan, 1995). The three most common languages in IDEF family are IDEF0, IDEF1X and IDEF2.

IDEF0 is a functional modeling language structured to represent the functions, activities, processes and relationships within the modeled domain. IDEF1X is an information modeling language that illustrates the structure and semantics within the modeled process. IDEF2 is a dynamic modeling language that provides the time-varying behavioral characteristics and a framework for specifications of mathematic models based on simulations. IDEF0 and IDEF1X are currently widely used in the government and various industries (FIPS, 1993). As it is more suited to complex process modeling, IDEF0 was chosen for this research and will be described in more detail in the following section.

3.5.3.1 IDEF0 Modeling

IDEF0 modeling provides engineers and experts on the subject matter a common space and language to develop a working model of a process. The development of an IDEF0 model relies greatly on a convergence of shared purpose, vision and understanding of a process between the various parties. Unlike many other process modeling techniques, IDEF0 is dominated not chronologically but logically. The most dominating and governing tasks are listed from upper left, cascading to lower right. These higher level tasks are then broken down into more specific actions with each new level providing more specific detail or decomposition. When tasks are broken down sufficiently the individual task and individual contributor can be detailed and further analyzed, for example, by failure modes and effects analysis.

As described previously, a major key to enhancing healthcare and the healthcare encounter is the ability to visualize and fully understand the workings of the process. This requires a perspective that only a systematic approach can give. As the acceptance of this fact grows, so do the requisites for process modeling tools, languages, and methods of their application. The advancement of these modeling tools and techniques is especially necessary for healthcare processes, as their inherent complexity challenges the capabilities of modeling systems to accurately portray the processes. A modeling methodology must be logical, exhaustive, and easily read before it can meet broad acceptance for healthcare processes. (Mutic et al., 2011).

There are several advantages that IDEF0 provides that fit particularly well for healthcare delivery systems. First, its comprehensive graphical format of representation can be easily learned and adopted by healthcare professionals who are not familiar with system modeling methods. The model uses simple language in English and is intuitive to follow. It also has the capability to display all necessary information across a variety of healthcare services and institutions of different sizes, and can decompose that information to any level of detail. IDEF0 can represent a wide range of activities and the relationships among them, to transfer abstract concepts into practice. The flexibility of the model allows it to facilitate the interactions between process, human being, machines and variety other factors. The representation of this interaction is especially important for the healthcare domain since all healthcare providers need to interact with these systems at some point to perform their daily jobs. (Jin, Kagioglou, & Aouad 2006). The IDEF0 language has constantly gained reputation during its usage through many years in government and private industries (Mutic, et al., 2011). Another great feature of IDEF0 is that it can be used as a foundation for readily available and relatively inexpensive commercial software programs designed to support its application, and that provide all kinds of interpretation and analysis that bring extra value to the model (Mutic, et al., 2011). All those features demonstrate that IDEF0 meets the requirements for modeling the physician-patient encounter, and that the language can be used by healthcare professionals to model their clinical operations (Mutic, et al., 2011).

However, none of the above can be achieved unless the model is correctly representative of the process and useful in understanding and improving it. Since the barriers between the developer and executer in terms of the implementation of modeling techniques are usually substantial (Galvan, Bacha, Mohr & Barach, 2005), all models must go through a rigorous check of their applicability and integrity by two very important inspections. These are called verification and validation, and are meant to insure that a prospective model will be useful and accurate as well as relevant to the real-world operation of a process. Verification ensures the accuracy of the model, which is important as it will be used as a reference when analyzing the physician-patient encounter. Validation makes certain that the model is relevant and valuable to the physician patient encounter, by confirming that it has useful applications in improving the encounter process. Both verification and validation are elucidated in the following section.

3.6 Verification and Validation

The two most important parts of confirming the quality of a process model are verification and validation. The purpose of model verification is to ensure that the process model is accurate and complete. Model validation ensures that a model represents its initial requirements in terms of the methods employed and the results obtained. This means that it will be truly useful for what it was intended to achieve. Validation will be further described later in this section.

The accuracy of a model is vital as all the elements in the model must correctly represent the current process. There can be no mistakes in the details or diagrams such as spelling and terminology as well as the relationship between each element being accurately described. A model is not complete until all the important elements have been included in the process.

Without verification, there is very little to tell what might not have been included yet. However, the verification process does not ensure that the important problems or mistakes have been solved, only that they meet a specified set of model requirements and correctly reflect the working of a real world process. One point should be kept in mind: there is no model that can be fully verified, guaranteeing 100% error-free implementation. The end result of verification is technically not a verified model, but rather a model that has passed all the verification tests. There is a method that can be used during the verification phase to increase the quality of the model. Statistics indicate that the more cases that are tested, the better performance of verification that can be achieved

(Afantenos, et al., 2005). Also, a properly structured testing program increases the level of certainty that a verified model is accurate to acceptable levels. In addition, having all possible cases and automated testing process will help in better implementing the verification process.

It is essential for the whole development of one's process model to verify the model. Many models, especially those typical of the academic research domain, are developed by a student or professor familiar with the process. However, this familiarity normally comes from observation of the process's participants or by reading literature on the subject. Both observation and literature review are constrained in their applicability, creating the need for verification and validation. The limitations of developing a process model based on review of literature are obvious. Foremost, the time between completion of researcher's study and the actual publication of their findings in a journal takes an average of a year. Since real-world processes are dynamic, fluid, and ever evolving, a model based on literature would start out at least a year behind and a year less accurate, no longer precisely representing the process. Direct observation of a process provides current data on it, but this data is normally much too small in scope to be very useful. Developing a process based on this direct observation can result in it being incomplete or biased, because only a small group of people are observed in a short amount of time. The process developers would easily bias the model by the sample of people they were simulating. (Afantenos, et al., 2005).

There are several methods by which a process model can be verified. One is relatively simple in concept, and that is cross checking the data in the model with original data sources, or using a third party that has a vested interest in the accuracy of the data to do the cross checking. The second common method of verification is through the use of subject matter experts, as in the case of physicians for the physician-patient encounter model. By presenting the model for scrutiny by experts on the modeled process, it can be verified as accurate and complete. Other means of verification include comparing the model to previously established and verified models, and in processes that can be easily repeated checking the model numerous times against the actual process for accuracy. (Macal, 2005).

Once the model has been verified, assuring that all the content is virtually correct, the model validation should be conducted. The ultimate goal of model validation is to make sure that the model is useful and addresses the right problem, that it provides helpful information about how the system being modeled functions, and how to actually use the model in the future. A model that is finished in its development and ready to apply to practice, a model that will be acceptable in supporting one's decision making, must be validated: experience shows that models without validation are extremely unlikely to be adopted or match the real world setting. In many cases a model will simply be rejected, sent back to the drawing board because of its inconsistency with the practical process. The reason for applying validation to the model is this: people in general are constrained by linear thinking. This means that it is very hard for us to think "out-of-the-box" after we have a plan already. We tend to limit our thinking into a certain scale and ignore other factors which do not fall into those categories. As result, we cannot imagine all the possibilities that the real system could exhibit. It is also difficult to understand how all the various parts of a system interact and add up to the whole. (Afantenos, et al., 2005).

Our mental models do not enable us to foresee the full effects of a process, and what a given interaction might ultimately imply can only be made clear with the development of a validated model. Validation ensures that the model will have the greatest chance of giving insights into the causes and effects between the variables that thought space could never account for. A model will be used to make predictions about the future of the system, which is completely impractical in a model lacking validation. (Macal, 2005)

Both verification and validation can increase the credibility of the model. Unlike physical systems, for which there are well-established procedures for model validation, no such guidelines exist for modeling social processes. In the case of models that contain elements of human decision making, they become a matter of establishing credibility in the model. Verification and validation work together by removing barriers and objections between model development and model use. The task is to establish an argument that the model produces sound insights and sound data. This can be done based on a wide range of tests and criteria that “stand in” for comparing model results to data from the real system. One such example, used for this model, is the survey. (Macal, 2005)

3.6.1 Survey

The survey is an important method for conducting a detailed inspection or investigation of a model. It usually collects a general or comprehensive view of certain issues that the researcher wants to examine, and a sample of data or opinions considered to be representative of a particular population, usually through a system of standardized questions.

The preliminary considerations of survey should detail the needs of the survey, for example, to assess the subject matter experts' views on the accuracy and potential usefulness of the model. Considering that surveys can be costly in some ways, it is critical to review other studies conducted on the topics of interest by contacting experts knowledgeable in the field (Fairfax County, 2003). The American Association for Public Opinion Research (AAPOR) provides guidelines for producing a successful survey. The following questions should be asked to determine if the survey is necessary or not before it is actually started: Have the studies of this subject done previously and if the literature enough to answer all the questions? Can the desired information actually be collected by a survey or would another format of research be more appropriate? Is there adequate time or other resources available to execute the survey without skipping any steps? Once a survey is confirmed to be necessary and feasible, the goal of the survey needs to be established. The goals of the project determine who will be surveyed and what will be asked of them. Once the goals are established, the researcher needs to decide what kind of people to interview, as avoiding a biased sample is paramount to a successful survey since it would have produce biased results. It is important to keep the target of the survey random and include as much variety as possible. (AAPOR, 2011).

After defining the survey's goal and selecting the survey sample, one needs to decide what interview method will be used. A personal survey is when the interviewer asks the questions face-to-face with the interviewee and can be taken in various locations such as home, shops or even on the street. In personal interviews, researchers are able to interact with the interviewees and clarify any questions that they do not understand well. If there is a product involved in the survey, the personal interview allows the participant to test, feel and see it directly. However, it costs more per interview than other methods. Phone surveys are the most popular method in the USA and are usually faster and easier to conduct. However, many people are reluctant to answer phone surveys or are not willing to spend a long time to finish the survey. Direct computer/web-based interviews are a new method of survey which is becoming ever more popular with the development of computer and internet technology. It is easier to reveal the interviewee's real opinion on the subject since there is no direct human communication involved. It can also eliminate the interviewer biases due to different ways that different interviewers may ask questions. However, the precondition of having access to a computer and internet make the available sample limited. It is also difficult to really engage the interviewee and make sure they are serious about the survey. (Creative Research Systems [CRS], 2010)

In terms of the questionnaire design, several components should be included. The survey's introduction and motivation should include a brief introduction of what this survey is about and why it needs to be conducted. Simple, clear instructions should describe the procedure to complete the survey. The main body of the survey is comprised of the actual questions. There are three main types of questions. The multiple choice type is where a question is asked and a list of answers is provided for the interviewee to choose from. The numeric open ended question has a quantitative question, such as how many miles one drives. It has an open ended answer with numerical information provided by interviewee. Textual open-ended questions are presented as the question and a space for the interviewee to answer large enough for a sentence or two. (CRS, 2010).

Rating Scales and Agreement Scales are two common types of questions that some researchers treat as multiple choice questions and others treat as numeric open end questions. An example of this type of question is:

> All the activities included in the model are correct.
>
> Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree

3.7 Conclusion

The research done in compiling this chapter has served many valuable purposes. As it provided the background and foundation for the researcher to create the physician-patient encounter model, it also informed the reader more clearly of the purpose and context surrounding that model. Through reviewing the existing literature prior to and used during this thesis, the motivation to create the encounter model was made much more clear, and the development of the Healthcare Toolkit device was shown to be useful and relevant to the modern physician-patient encounter. By reading this chapter, an understanding of the changing state of healthcare should have been reached, and the various human aspects and technological advancements relevant to the encounter should be demystified.

Knowing the process of developing revising, and reviewing the model is important because it lends a level of confidence to the reader and end user of the model. This literature review was intended to give an introduction to the uses and advantages of modeling in general and the IDEF0 methodology, in particular showing its applicability to this process and clarifying the model itself. Through providing this relevant information, and a context and background of this thesis, this chapter hopes to elucidate the rest of the thesis, which deals with the specifics of the model on a much more technical level.

Chapter 4 Modeling

4.1 Chapter Overview

The objective of this research was to develop a process model using IDEF0 to represent the general healthcare encounter process in a medical office setting. This process is named "Conduct medical encounter" and includes all the activities that happen after the patient is accepted, from the reception until the end of the office visit.

There are three sections in the chapter to explain the modeling methodology and provide a description of the model. The first section is a description of the information collection methodology used during this modeling process. The second section contains detailed instructions on how to read and understand the IDEF0 model. The third section presents the result of the modeling process including an overview and an explanation of the individual parts of the model.

4.2 Information Collection

The development of the model took one year, beginning October 2009. The first phase of this research was to gather information regarding the physician-patient encounter to gain a deep understanding of this process, including the role it fills within the healthcare system and its contribution to healthcare services. All the information gathered in this phase provided a baseline for developing the model.

4.2.1 Preliminary model

The first step of model development was to generate a preliminary model. This preliminary model contained the skeleton of the encounter information and was the foundation for the final model. It was developed based on a combination of personal experience as a patient, an informal discussion with and observations of physicians and the literature review (refer to chapter 2).

4.2.2 Model Reviews

A crucial part of insuring the accuracy of the model was a series of reviews that took place between the subject matter experts and the model's author between December 2009 and May 2010. The model reviews allowed a critical scrutiny of the model as it was being created, so that expert feedback could be gathered and applied to it as it was being written. Each review facilitated new and necessary changes to the model, with each review taking place after about every two or three revisions.

Dr. Kenneth Funk and Dr. James Bauer were the two experts conducting the model reviews. Dr. Funk has extensive experience in industrial engineering, specializing in ergonomics, health care human factors, aviation psychology, and systems engineering, and is currently an associate professor of engineering at Oregon State University. Dr. Bauer is a practicing physician at Peace Harbor Hospital and specializes in obstetrics and gynecology, and is the proprietor of the Healthcare Toolkit intellectual property. The reviews were held in Dr. Funk's office with Dr. Bauer and the model's author often participating by remote conference.

During the first two interviews, the physician-patient relationship was discussed in detail. The patient-provider relationship had been included in the original first draft of the model; however, the emphasis and importance of that relationship had not been adequately represented. Dr. Bauer made it clear during those initial interviews that the relationship established between physician and patient was of the utmost importance. The level of trust a patient has for her physician greatly affects the amount and accuracy of information that the patient is willing to share, and the physician needs complete and accurate information to make his best diagnosis. Since a correct assessment of the patient’s condition is perhaps the most vital step towards that patient’s recovery, the relationship shared between patient and provider is truly fundamental to the medical encounter. The model was altered to represent this integral concept by representing the establishment of the patient provider relationship as a controlling factor for all of the remaining activities, and its effect on the quality and efficacy of those events was then readily apparent.

The discussions that took place during the interviews touched on a broad range of topics relating to the medical encounter, and one of the most prominent of these topics was the initial interview with a new patient. One of the qualities that distinguished the initial interview from other parts of the encounter, or from interviews that take place in subsequent encounters, is the establishment of a goal for the encounters that both the physician and patient understand and agree to. This goal, which would later be implemented as another control factor affecting most of the model, is the overall outcome that the patient would like to achieve from the encounter. The goal differs between patients and encounters, and might include achievements such as reduced pain, increased functionality, or the restoration of the patient to full health (curing). The physician plays an important role in creating this goal, as he is most knowledgeable on what actually and realistically might be achieved. The physician can inform the patient of his specialty, the treatments he might be able to provide, or the medications available and their real effects and limitations. Together, a common tangible goal can be established as the focus of the encounter and a reference for deciding the course of action to be taken; in the model's terminology (described in more detail below), it is implemented as a control factor.

The interviews between the model author and the experts helped to identify aspects of the healthcare encounter that had not yet been included in the model, as well as to accurately represent the specific functions, causes, or effects that concern those aspects. One concept that needed to be integrated into the model was the patient's own knowledge concerning her physical state and medical condition. A necessary part of the encounter between physician and patient is educating the patient about the condition, correcting any misconceptions and detailing information that the patient might be missing. The necessity of this action arises from the patient's own management of her condition; if a patient is better informed and knowledgeable concerning her health, she is better able to protect herself and prevent exacerbations of her condition while away from the doctor's office. Furthermore, it was in the experience of the physicians that the more information they provided to a patient about the condition, the more trust that patient would develop for the physician, and the relationship between them would be further solidified. It follows that in the best practices, the physician communicates as much as he can with his patient, informing her of all necessary, practical, and useful information regarding her condition.

Having established the importance of a patient's own understanding of her physical state, the next problem to be addressed in these interviews was the integration of that concept into a readable form within the model. It was decided that the most accurate representation of this developing knowledge, and its effects, would be as IDEF0 input and output surrounding the activities that it affects (described below). This would allow the graphical display of both the continuing change and expansion of the patient's self-knowledge, as well as the direct effect that knowledge has on the model's other processes.

The conferences held with Dr. Funk and Dr. Bauer aided significantly in the integration of a large number of activities and concepts into the model, arising from the complexity of the interactions between each element. Another such instance where a concept was known to be significant, but its integration proven troublesome, was the significance of medical devices and tools and the roles they fulfill during the encounter. They are clearly an important component; necessary for accurate physical findings and indispensible in the collection of information regarding the patient's condition. The specific instruments ranged from the most basic blood pressure cuffs and stethoscopes to more advanced tools designed to serve very specific roles, but all had to be integrated and accurately portrayed by the model. The information collected using these instruments are critical in the rest of the encounter, as these data are the evidence on which a diagnosis is made and the treatment implemented. With regards to the IDEF0 model, it was decided between the experts and the author that the “mechanism” function of IDEF0 (described below) would be the best representation of the role these devices fill. Each specific device was then integrated as a mechanism for the actions and processes they affect.

The end result of this overview was a better understanding of the general procedures for conducting the physician-patient encounter. This resource, combined with the research done so far on the encounter process, allowed the model’s author to firmly understand, in a general sense, the medical encounter from beginning to end. Following is a basic description of the encounter.

4.3 Encounter Overview

This section is a general description of the physician-patient encounter, to provide a basic understanding of the encounter process before discussing the encounter model in detail later in this chapter.

The healthcare encounter begins with an informal greeting and brief introduction by the physician to open up communication between him and the patient. The physician asks general questions regarding the patient’s background, such as her professions, habits, health insurance coverage and any other information that could possibly affect this encounter. During this conversation, the physician’s goal is to establish some trust with the patient, so that the patient will cooperate as much as possible later in the encounter. Benefits of the encounter are identified to motivate the patient’s participation and a shared goal should be determined to guide activities throughout the rest of process.

After the brief informal talk with the patient, the physician continues the encounter by beginning to collect the patient's clinical information. The patient is asked to characterize the symptoms of urgent problems and afterwards her comprehensive medical history is reviewed by the physician. A review of organ systems is conducted to gather more in-depth information regarding the patient's health condition. If necessary, a physical examination is then performed to confirm her condition and discover other issues. Based on the needs of the physician and the patient's condition, the examination may contain multiple system reviews such as cardio-pulmonary status, gastrointestinal status, skin and body condition, head and neck condition, genitourinary system and neurologic and mental status. The patient's vital signs are assessed, including body temperature, respiration, pulse, and blood pressure. The physician uses visual inspection, palpation (feeling with touch), auscultation (listening), and percussion (tapping) as methods of investigation during each examination. After collecting the physical findings, the physician assesses any treatment plans available in remedying the disease, analyzing the effectiveness of each in remedying the symptoms present during this encounter. Once all the necessary clinical information has been found, the provider integrates all of them and uses this as a baseline for the diagnosis.

Before the physician starts to form the diagnosis, the previously integrated patient information is evaluated to determine why and how the condition occurred, what the patient's symptoms represent, etc. All the useful information in the patient's medical history, as well as the symptoms and physical findings of the current encounter, are then included in the physician’s assessment and further analyzed. Also, the shared goal established during the initial communication is continuously reviewed to reinforce the expected outcome of the encounter. During the time the physician is processing all of this information, he is remaining vigilant to determine if there is ambiguous or incomplete information which may lead to misdiagnosis. Then the physician generates several diagnostic hypotheses, which include all possible guesses he has as to what the patient’s condition may be. The physician then begins to refute the unlikely hypotheses by probing information and evidence from the patient, through further interview and examination, in order to reject any wrong hypotheses. If there are still alternative diagnoses existing, the physician confirms the most likely diagnosis by assessing the possibility of each remaining one. The final diagnosis is reviewed and discussed with the patient to gain feedback and also educate the patient on her condition and what she can expect.

Once the diagnosis is formed, the physician works with the patient to decide the best treatment plan. Possible treatment plans are generated after reviewing the patient’s information. Research may be needed to form the possible treatment plan, which requires that medical references be consulted. Before the final treatment plan is decided, the physician discusses it with the patient and gets her feedback and approval. Simple treatments are implemented directly by the provider during that encounter, such as freezing off warts or relieving subungual hematomas (piercing a fingernail or toenail to relieve pressure from blood collecting under them, usually from an injury). If further treatment is needed, the provider establishes a follow-up plan, most likely another encounter with the patient.

While the vast majority of physician-patient encounters follow this description, it was realized that among the various processes followed by physicians is some variation of sequence, as well as repetition of certain processes. Many activities undertaken by different physicians take place in a different chronological order, and some important steps must be repeated several times throughout the medical encounter. Fortunately, one of the inherent benefits of using the IDEF0 language, as described below, is its ability to allow the representation of all events that comprise the process without consideration of the sequence. This combined with the repetitive nature of certain processes led to the decision to set the boundary for this model as a single encounter instance. With this in mind, if a patient revisits the physician, it would be treated as a separate encounter and the model could be applied to it as such.

4.4 IDEF0 Background

IDEF0 is a language and methodology designed to model complex processes. It provides engineers with an accessible and clear approach when performing system and process analysis at all levels of a process. Due to the complex nature of the process to be demonstrated, it is important to understand the concepts and rules that are contained within the model.

As a graphical modeling language, the IDEF0 representation is comprised of a system of boxes and arrows that make up the language and syntax of the modeling methodology. It produces reference documentation that a user can read and understand to easily analyze or learn a process. Three components that are keys to the language's use are the box and arrow diagrams and the textual descriptions and the glossaries that describe each diagram. The model is structured to expose ever more specific details by decomposing each of the boxes, which in themselves represent a specific activity. Every diagram is supported by text descriptions to ensure a rigorous and precise description of the process. In addition to the activities, the models show control factors as well as content that relates and affects each diagram. Each portion of the diagram is uniquely labeled to distinguish their differences as well as connect data and objects.

The main components of the model are its boxes and arrows. The box is constructed with solid lines containing a verb or verb phrase in the center that summarizes the activity of this box, and the box number for reference is displayed at the lower right corner of the box.

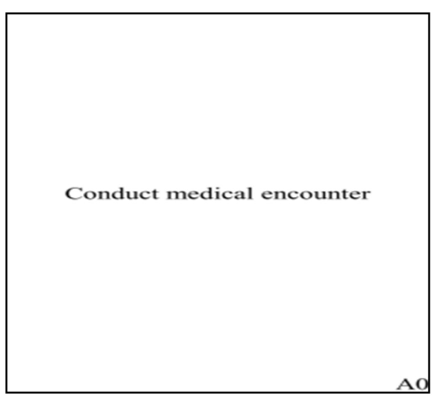

Figure 5: IDEF0 Structure-Box

There are four types of arrows, as shown in Figure 6. The straight arrow points directly to the box with a label on top of it describing some element that will affect or be affected by the activity. The bent-note arc has same meaning as the straight arrow. The forked arrow is applied when one arrow decomposed to two elements. The joined arrow is used when two separate arrows are composed into one.

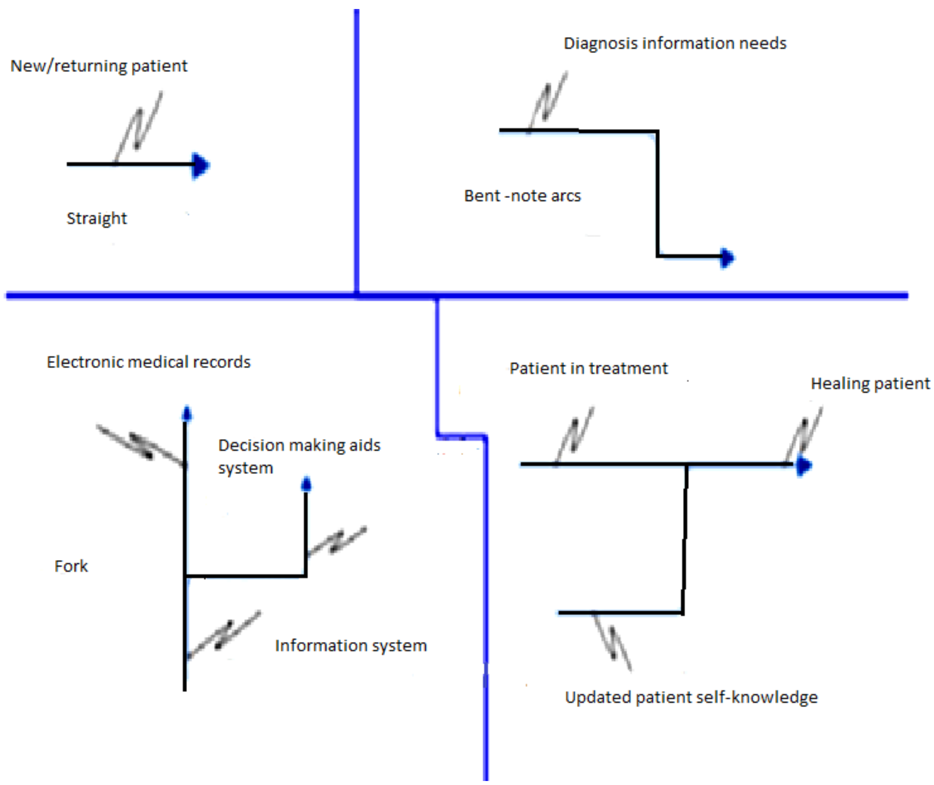

Figure 6: IDEF0 Structure-Arrow

The semantics of the IDEF0 language are shown in Figure 7. The representation consists of six major elements that are interrelated and used to describe all aspects of a model. The middle box represents the main activity or event that happens at this point during a particular process. Input is something that is transformed by the process such as matter, energy, information or system state. The control can be anything that guides, facilitates, limits or constrains the process. The output is something that results from the process. The mechanism is a means by which the process is performed.

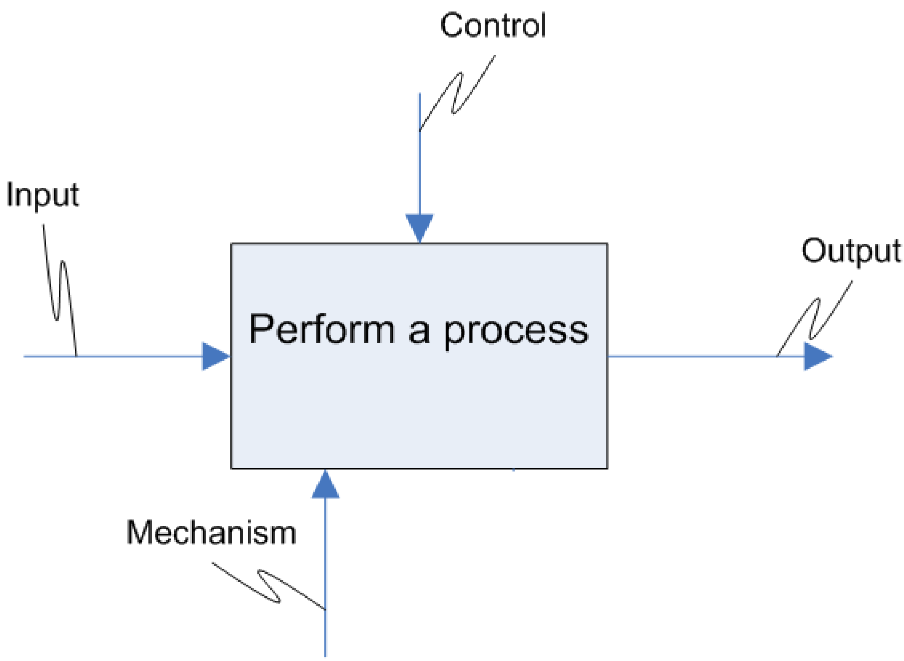

Figure 7: IDEF0 Semantics

Figure 8 is an example of an activity in the encounter model and is explained in further detail. The main task here is the activity “Conduct medical encounter” which is placed in the activity box as a verb phrase in the center. The number of this box is A0. All the objects being transformed through this encounter process are listed to the left of the activity box as the inputs: “New/returning patient”, “Patient medical records”, “existing patient-provider relationship”, “Existing diagnosis(es)”, etc. The control factors are listed above the activity box and include “Medical reference” and “Medical guideline” which provide guidance for the operation, “Patient factors” and “Provider factors” which affect the quality of the service delivered, and “Environment/system factors”. The mechanisms below the activity box, here “Information System”, “Medical equipment” , “Patient as participant”, etc., are the objects performing the process. The items to the right of the activity box are the results and outcomes after performing this activity, such as “Healing patient” and “Updated medical records”. For example, the input “Patient medical records” is transformed by the physician and information system, two mechanisms. While this is done, the controls “Medical reference”, “Patient factors”, “Provider factors”, and “(Environment/) System factors” all affect what is done to the patient’s medical records by the physician and information system. The outcome of all this is “Updated medical records”.

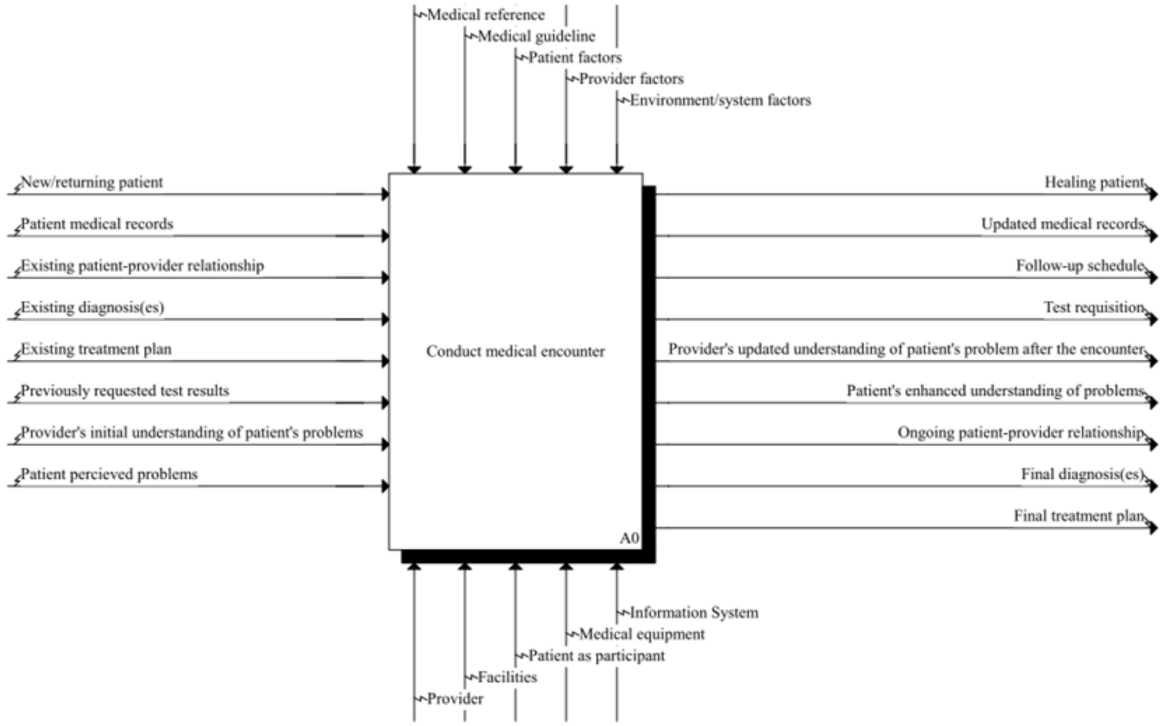

Figure 8: IDEF0 Conduct Medical Encounter

An IDEF0 box and all of the arrows relating to it comprise a context diagram which can be decomposed to sub-levels based on the generality or specificity of the activity. The relationship between the diagrams can be described as child and parent relationship. The top-level context diagram contains the subject of the entire model represented by a single box with bounding arrows and is termed A-0 (A minus zero). This diagram illustrates the orientation of the model as well as its scope and boundary. The box and arrows in A-0 are usually very general to give the reader an overall idea of what is demonstrated. The diagram should be accompanied by a short description of both purpose and viewpoint to give people an overview of the process. The single process in the context diagram (A-0) may be decomposed into sub-processes and modeled in a child (A0) diagram. Each process in the A0 diagram may be decomposed further into sub-processes and modeled in (grand)child (A1, A2,… A6) diagrams. Each (grand)child process may be decomposed further into sub-processes and modeled by (great-grand)child diagrams (A11, A12,… A16), and so on.

Figure 9 shows the relationship between parent and child diagrams in IDEF0. The top-level A-0 is decomposed to A0 which here contains five sub-diagrams: A1 "Establish and maintain patient provider relationship", A2 "Collect and integrate clinical information", A3 "Diagnose condition", A4 "Treat patient", and A5 "Plan follow-up". Each can be decomposed further into its child diagrams, here, A3 "Diagnose condition" is shown decomposed to another 6 diagrams: A31 "Evaluate integrated patient information", A32 "Evaluate shared goal and define overall diagnosis task", A33 "Generate diagnostic hypotheses", A34 "Refute unlikely hypotheses", A35 "Confirm most likely diagnosis" and A36 "Discuss and explain diagnosis with patient".

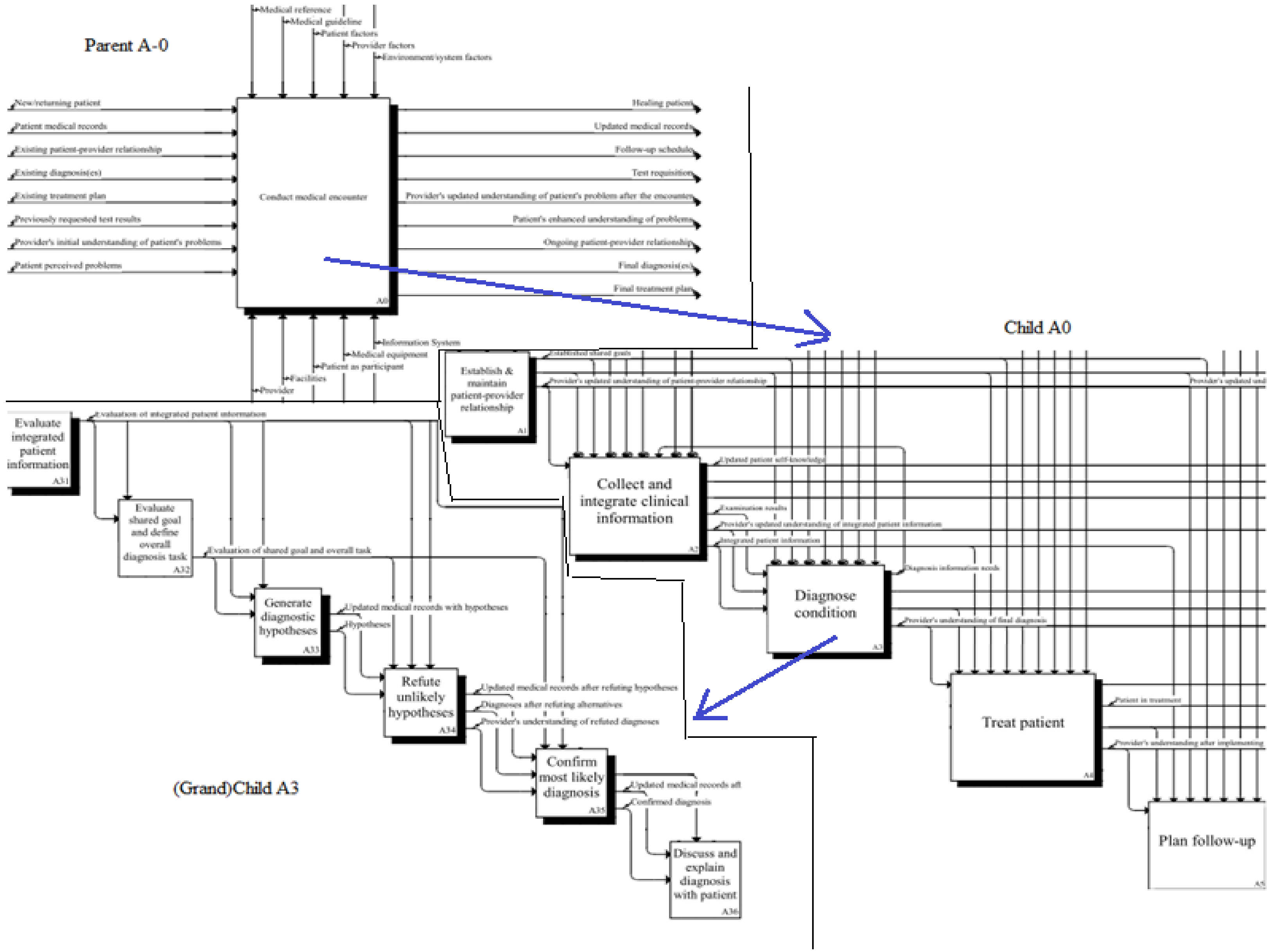

Figure 9: IDEF0 Parent and Child Structure

While reading IDEF0 diagram, it is really important to read the A-0 level first, as it describes what the objective of this model is. In A-0, the overall purpose and viewpoint of this process are described as text and general input, output, control and mechanism are listed clearly. A0 contains a set of boxes decomposed from A-0 which includes all major sub-levels of the model. By reading A0, the major activities and events are revealed and relationship between each one can be understood.

The best way to read the IDEF0 model is to scan the boxes included in the diagrams A-0 and A0 of the process and critically analyze them to understand what is being described. After reading through the boxes and arrows, one should mentally walk through the diagrams from upper left to lower right, paying attention to the how the arrows interact with each box and determining if there are secondary paths between each of the activities. In many cases, an output of one activity box becomes an input or control for another. Also, the child diagram should always be referred back to the parent diagram to understand the context of the activities it contains. Sometimes, parent boxes and child boxes share the same arrow which means they are affected by the same factors. While reading the arrows of the diagram, it is critical to identify the most important inputs, controls and outputs and determine if there is a main path linking them. While the modeler or a subject matter expert reads the model, they should also verify that the story being told by diagram is consistent with how the process is handled in reality.

4.5 Model Description

The following section explains the model of a general healthcare encounter in an office visit setting. In this section, A-0 is “Conduct medical encounter” and A0 are described in greater detail.

The IDEF0 model provides a representation of a process from a basic description outlining the main activities to its most specific and detailed elements. The IDEF0 model consists of separate diagrams that are each made up of separate elements supported by a textual description in the glossary. For example, the element “Electronic medical record system” is a mechanism of A22 “Review comprehensive medical history”. The glossary entries describe this mechanism as “An electronic medical record (EMR) is a computerized medical record created in an organization that delivers care, such as a hospital and doctor's surgery. Electronic medical records tend to be a part of a local stand-alone health information system that allows storage, retrieval and modification of records”.

As the model represents both a general description of the overall process as well as the myriad detailed elements that make up very specific activities in the process, it was very important to define the overall scope that this model reflects, in order to give a general contextual reference for the development of the rest of the model. During the interviews, a great deal of discussion was given towards the most general levels in the model, A-0 and A0. A-0 is the level containing the most basic and succinct statement of the process and the elements that affect it, and as such almost solely defines the scope of the model. It was decided that A-0 would be titled “Conduct Medical Encounter”, defining the scope of the model as an individual medical encounter in accordance with the decision regarding the model’s boundaries. Any subsequent visits by a patient to a physician would be treated as a new encounter, and the process diagrammed by the model could then be applied to each one individually.

With the uppermost A-0 level now defined, it was possible to create the A0 level, which in very broad terms delineates the steps or sub-processes that comprise the conducting of the medical encounter. A0 is a term that refers to the sub-processes collectively, with each process having its own specific designation. Of the diagram A0 “Conduct medical encounter” of this model, the sub-processes are: A1 “Establish patient provider relationship”, A2 “Collect and integrate clinical information”, A3 “Diagnose condition”, A4 “Treat patient”, and A5 “Plan follow-up”. Denominating the A-0 and A0 levels has set the boundary for the model clearly, so that only the necessary information would be included and a context for the rest of the model provided.

In A-0 (shown in figure 10), the verb phrase “Conduct medical encounter” is displayed as the most general activity and object of this model. By conducting a single medical encounter, the physician helps a patient to resolve a (perceived) medical problem. During the encounter, the patient is either returning, which means she has been assessed by the physician before, or a new patient that is assessed during the encounter.

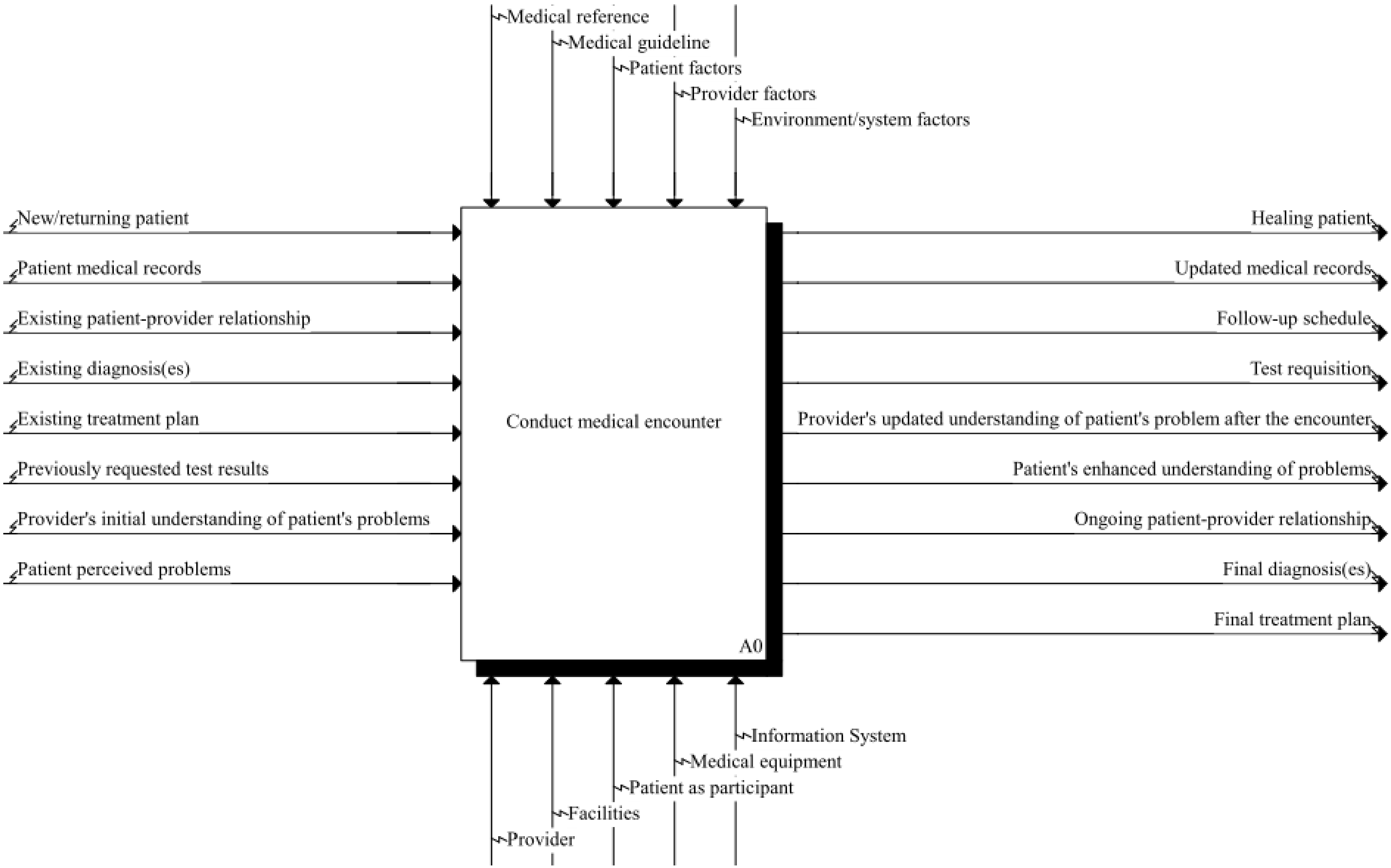

Figure 10: A-0 Conduct Medical Encounter

The model is structured to indicate the progressive changes in each of the elements that a particular activity concerns. The state of various inputs ranging from a “New/returning patient” to her relationship with the provider, as well as all of the existing data concerning her condition (diagnoses, existing treatment plans, test results, etc.) are affected in some way through conducting the medical encounter. These changes are indicated by the state of each element as it is output from the activity, i.e., the “Updated medical records”, the “Provider’s updated understanding of patient’s problems after the encounter”, the “Patient’s enhanced understanding of problems”, the state of the “Ongoing patient-provider relationship”, and so on.

Also, there is oftentimes an “Existing patient-provider relationship” before the medical encounter is conducted. The nature of this relationship may include the trust, confidence, understanding and caring between physician and patient. This relationship is constantly developed during the encounter and affects the quality of service given during the encounter.

Another instance where a change is represented between the inputs and outputs of the activity is the “Provider’s initial understanding of the patient’s problems”, as well as the “Patient perceived problems”. Usually, a patient’s perception of her problem are directly based on her physical feelings such as sour, painful or nauseous-- which can be different from the provider’s perception about the symptoms arising from his education. During the encounter, with communication between provider and patient, both of their understandings are updated with input from the other party.

The activity is represented displaying the titles of different mechanisms affecting the inputs, as well as any control factors that affect the activity. For instance, a healthcare provider plays a significant role in the execution of conducting a medical encounter, and is represented as a mechanism. The provider directly confers with the “new/returning patient”, references and updates the “patient medical records”, further develops their “existing patient/provider relationship”, and so on, affecting in some way each of the inputs.

The control factors affecting the operation of a medical encounter include “Medical references” and “Medical guidelines” which provide information to support the encounter. They also include factors related to the patient (“Patient factors”) that affect the encounter process and include age, gender, education, anatomy, medical history, attitude, personality, motivation for healing, etc. Factors related to the provider that can affect the encounter (“Provider factors”) include training, specialty, experience, recent experiences, motivation, attitude, personality, fatigue, sensory abilities, cognitive abilities, motor abilities, etc. Factors related to the environment and equipment used in the encounter can also affect the encounter process. “Environmental factors” include lighting, temperature, humidity, noise, aesthetics, etc. “Equipment factors” include type of equipment used, its functional capabilities and limitations, its technical performance, etc.

A0, the second diagram of this model shown in Figure 11, serves as a more detailed overview of this process. Within A0, the following activities are delineated: A1 “Establish & maintain patient-provider relationship”, A2 “Collect and integrate clinical information”, A3 “Diagnose condition”, A4 “Treat patient” and A5 “Plan follow-up”.

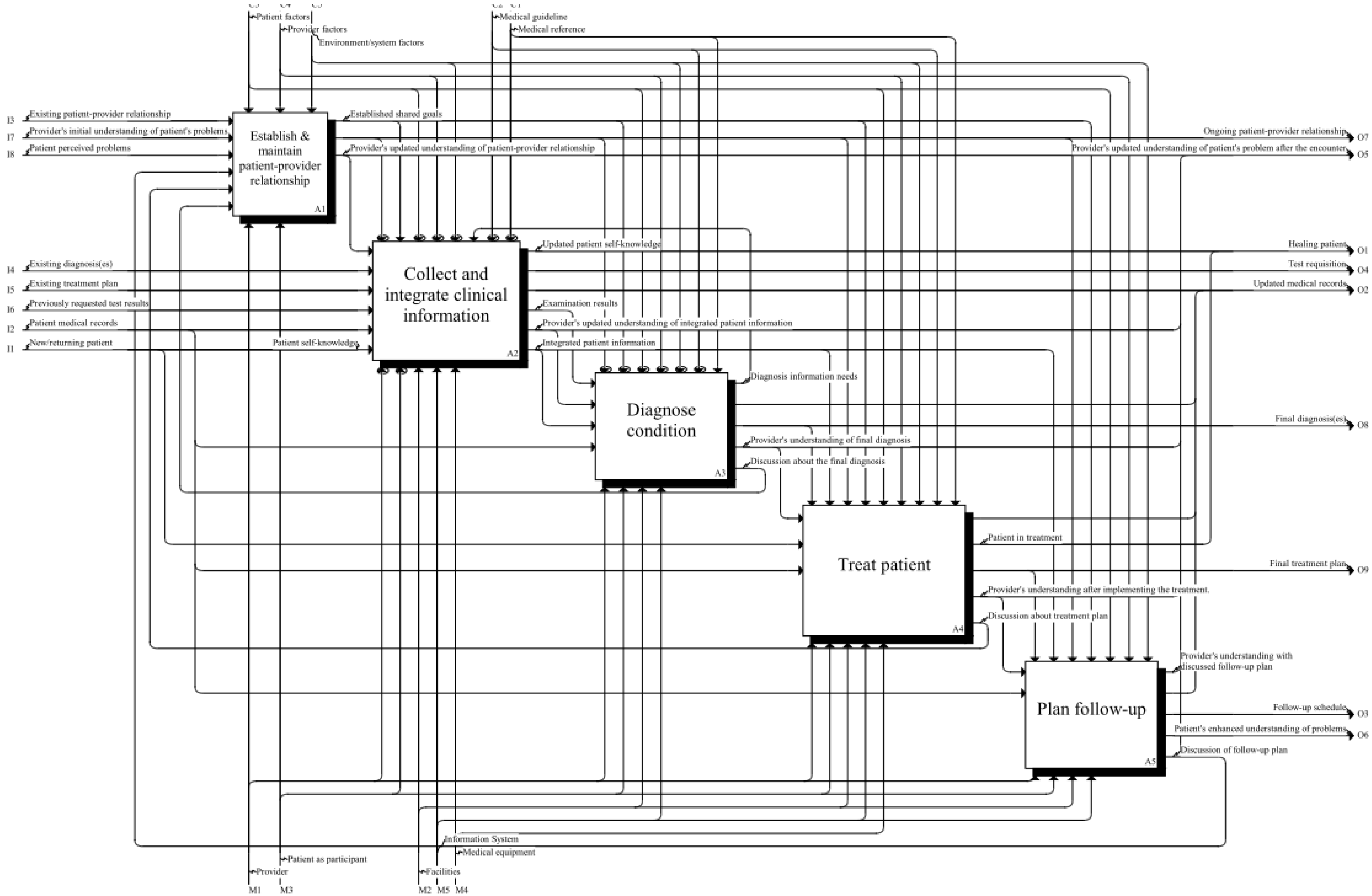

Figure 11: A0 Conduct Medical Encounter

Looking at A0, one can see that it is dictated by logical flow which, here, almost mirrors the chronological flow of the process. However, one advantage of the IDEF0 language is that it can display the interrelationship between each activity even when several processes are performed simultaneously. For example, Figure 12 shows that an output of box A3 “Diagnose condition”, called “Diagnosis information needs”, is simultaneously used as a control for box A2. This demonstrates the real process, where the activity of diagnosing a condition may require several cases of collecting and integrating information, while the diagnosis is being performed.

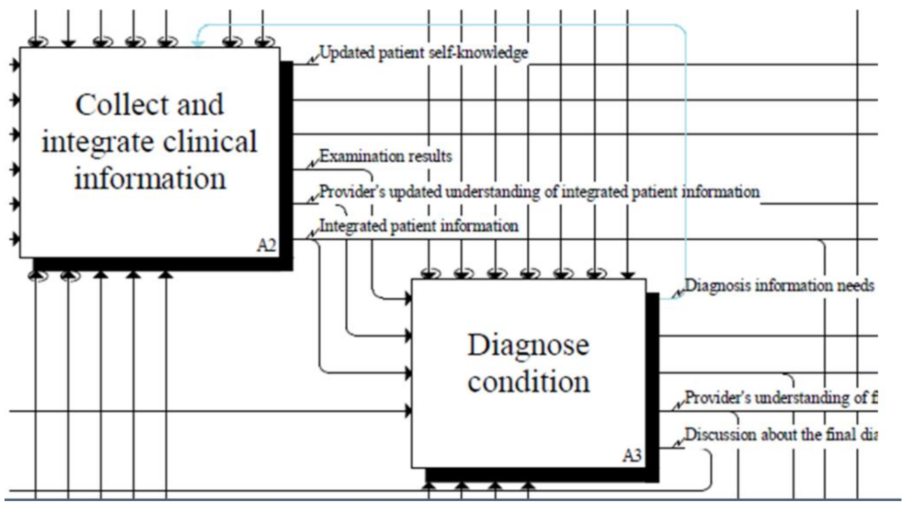

Figure 12: A2 and A3 Relationship

When a patient comes in to see her physician, a good patient-provider relationship is established and maintained, represented in Figure 12 by the activity box A1 “Establish patient provider relationship”. Most of this relationship is usually formed during an interview with questions regarding the patient’s background. It is a checking point for the patient to see if the physician has the ability to solve her problems. The provider also gets an impression of whether or not the patient will cooperate during this process. An established shared goal is one of the outcomes of this activity, which becomes the guidance and motivation for the rest of the encounter. In the model, this is shown by the output “Established shared goals” becoming a control for many of the following diagrams.

After a very brief interview between provider and patient, a series of investigatory questions regarding the patient’s medical information are asked. This is shown in box A2 “Collect and integrate clinical information”. “Medical guidelines”, “Medical references” and the “Established shared goals” from the previous activity serve as the guidance for what information is needed and how the information needs to be collected. All of the “Existing diagnoses”, “Existing treatment plans”, “Previously requested test results” and “Patient medical records” are reviewed in this activity. The “Provider” and “Patient as participant” are two participants in this event and “Medical equipment” is used to conduct the physical examination. All the information collected is integrated and updated in the “Patient’s medical record” by using the “Information system”. During this process, the “Physician’s understanding of patient’s condition” and “Patient self-knowledge” are both updated with this integrated clinical information.

The third activity described on this model diagram is the diagnosis of the patient’s condition. The “Provider” and the “Patient as a participant” play a significant and obvious role in this through their interactions with one another, while the physician employs the “Information system” and other tools in his facility as further mechanisms to aid in his assessment. The “Examination results” are considered together with the information and understanding gained from the previous activity, and checked against the various reference systems available and knowledge that the physician has collected and maintained from the patient. This leads the physician to conclude his diagnosis, updating the patient’s medical record and discussing his conclusions and understanding with the patient. In the event that the physician does not have enough information to form an accurate diagnosis, he may repeat some or all of the second activity described (A2 “Collect and integrate clinical information”).

Once the “Final diagnosis” is formed, the provider chooses and discusses treatment options with the patient. “Patient medical records” are reviewed again to ensure all the essential information is captured, such as allergy history. “Medical guidelines”, “Medical references” and “Integrated patient information” serve as guidance for this activity. “Patient factors”, “Provider factors” and “Environment/system factors” need to be taken into consideration while generating the treatment. “Medical equipment” may be used to treat the patient and the “Patient’s medical record” is updated in the “Information systems”. The physician and patient’s understanding of this encounter are both updated again after implementing the treatment.

The provider also plans a follow-up (A5 “Plan follow up”) with the patient and a follow-up schedule is confirmed after this activity. The patient and provider discuss and plan the follow-up by using the “Information system” and “Facilities” in the clinics. This follow-up plan is heavily influenced by all the information and results from previous activities as well as medical guidance and medical reference. The patient's knowledge of her condition is enhanced ("Patient's enhanced understanding of problems") after this encounter and the "Provider's understanding of patient's problem after the encounter" is updated with newly scheduled follow-up plan.

One activity vital to the encounter process can be viewed in detail in the A2 "Collect and integrate patient information" diagram of the model (Figure 14). This activity is strongly influenced by the "Diagnosis information needs" as well as the "Established shared goals" in the first interviewing phase. The first sub-process of this activity is shown: A21 "Characterize symptoms of urgent problems". This includes questions about the nature of what the patient is feeling, such as the timeframe around the symptoms' onset and duration, frequency, any activities that alleviate or aggravate the symptoms, etc., and leads into a comprehensive review of the patient's medical history. The ongoing update of the patient's medical records throughout this activity can be seen in the form of several outputs from each of the activity boxes. During A22 "Review comprehensive medical history" the physician collects information about any past surgeries, medications, allergies, previous diagnoses, and the patient's family history, along with anything in the patient's history relevant to this encounter. The encounter then continues with A23 "Conduct review of organ systems". This normally includes a lot of subjective information given by the patient about her symptoms, which can be useful when conditions are less susceptible to or difficult to discern from diagnostic tests. The next activity in the collection and integration of clinical information is A24 "Conduct physical examination". This is to evaluate the current health condition of the patient after collecting relevant information, and is complex enough to warrant its own decomposition in the model. At this point, if the patient has had previous treatments for her condition, the physician performs A25 "Assess treatment plan effectiveness" to help understand the reasons for its apparent ineffectiveness. Once all of this clinical information is collected, the provider integrates it into his formation of a diagnosis and into the patient's medical records (A26 "Integrate patient information").

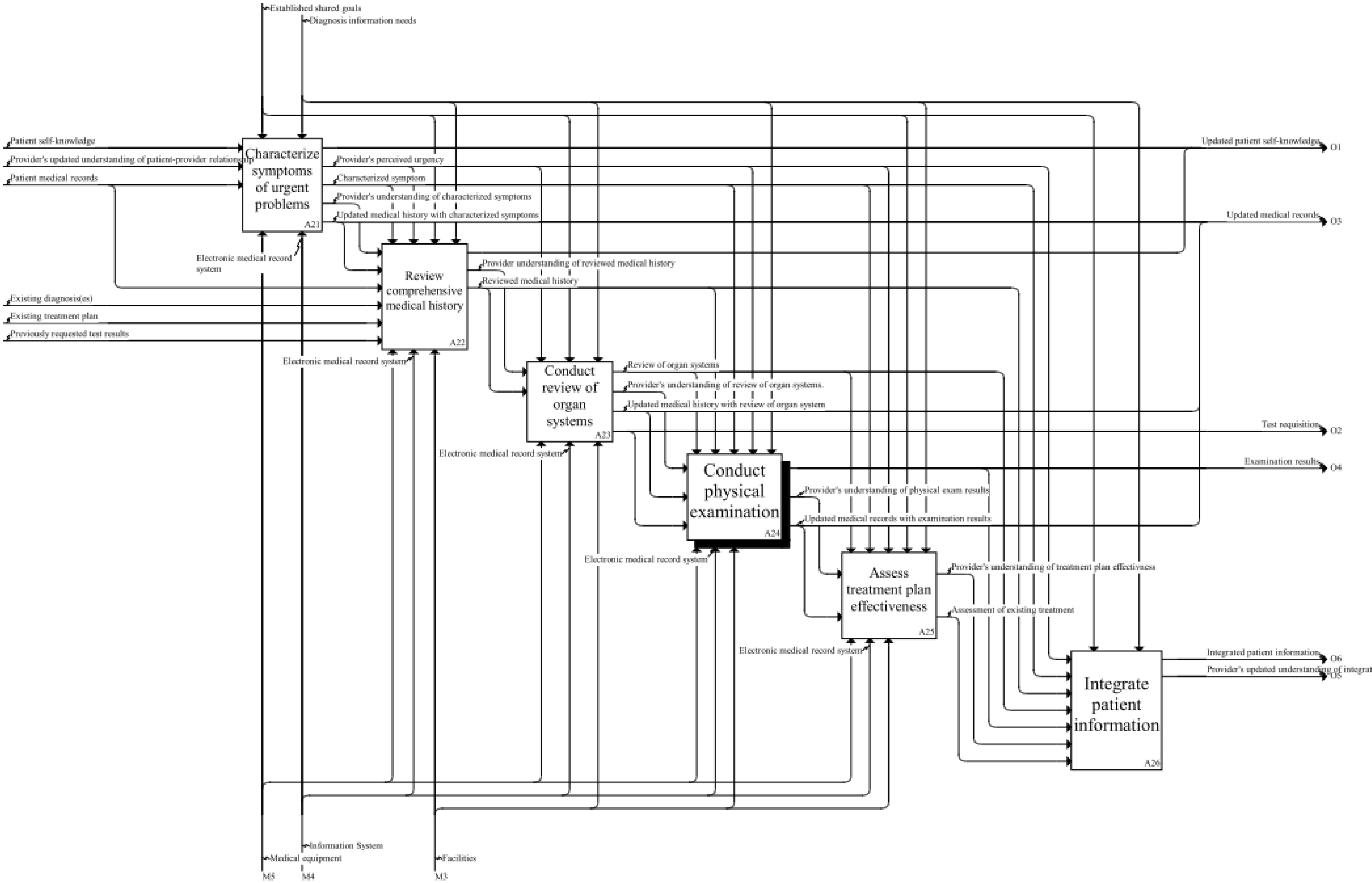

Figure 13: A2 Collect and Integrate Clinical Information

The A24 level of the model, shown in Figure 14, details the activity “Conduct physical examination” in the patient room based on what the physician’s “Diagnosis information needs”. This model diagram depicts the possible activities in this process; however, there is no standard method for performing all of the exams, nor a standard sequence that they are performed in. The provider performs A241 “Check cardio-pulmonary status” through various means, such as listening to heart and lung sounds. The condition of the patient’s stomach and intestine are evaluated if they are relevant to the patient’s condition (A242 “Evaluate gastrointestinal status”). Examinations of skin, body, head and neck are conducted during the physical examination (A243 “Examine skin and body condition” and A244 “Examine head and neck”). The health conditions of the sexual and urinary organs are often evaluated for various reasons (A245 “Evaluate genitourinary system”), and sometimes the neurologic and mental status of the patient is assessed (A246 “Conduct neurologic and mental status examination”). All of the elements of the process and interactions between them can be examined by reading the A24 model diagram. As is shown, the patient’s medical records are updated after each examination is performed, and the provider’s understanding is updated with the test results as well. The information collected from the previous activities along with test requisition and diagnosis information needs guide the provider to choose what examinations are to be executed. The facility’s electronic medical record system is the main system used to store all the test information media, which may include the actual sounds from the exams, pictures, results and any comments that the physician may have entered. The medical equipment shown in the model diagram includes the various tools used to do the exams.

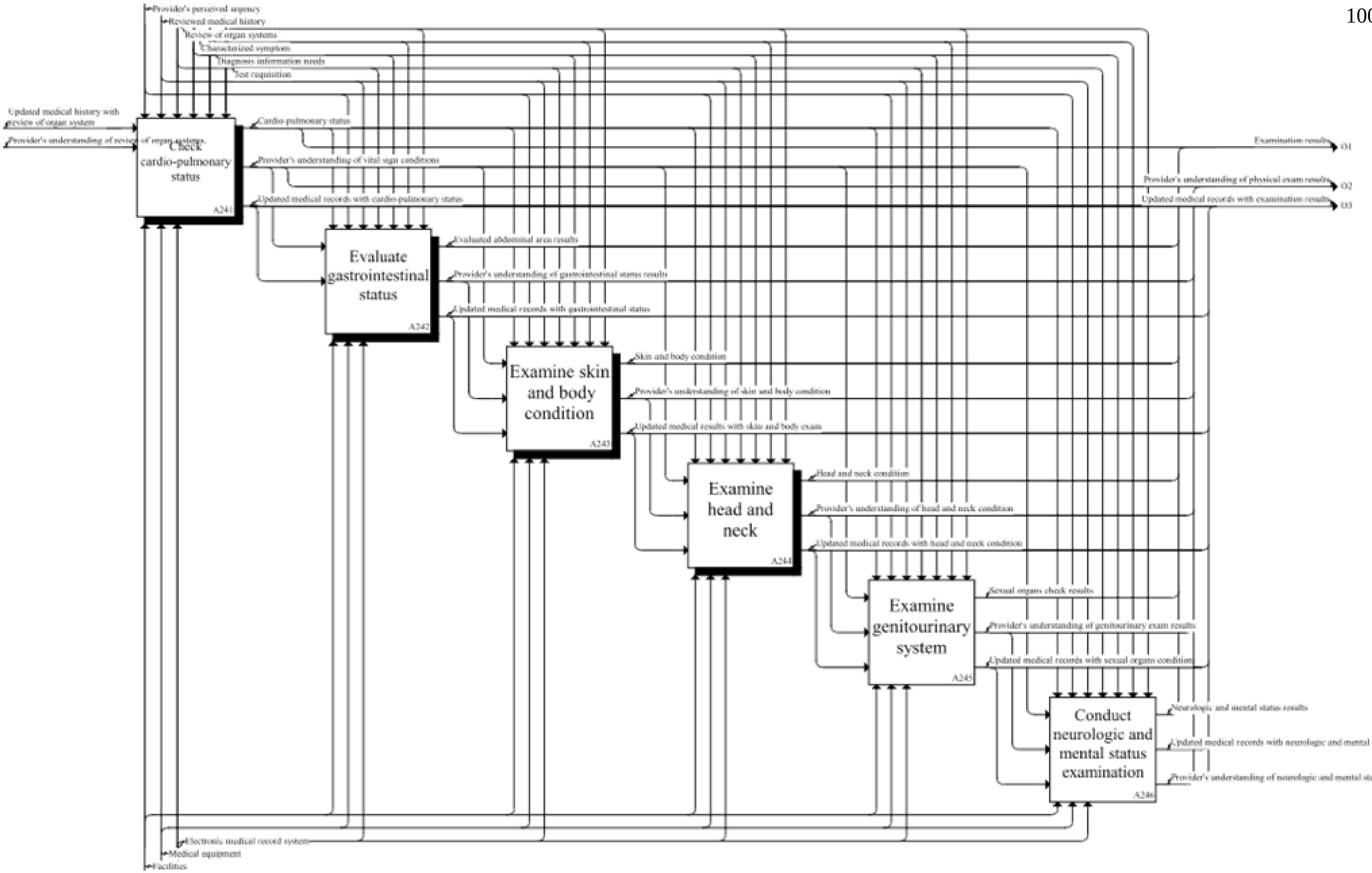

Figure 14: A24 Conduct Physical Examination

Another example of the model’s ability to represent a process in detail can be seen in Figure 15, the A3 diagram, “Diagnose condition”. In this activity, the provider uses the “Integrated patient information”, “Examination results” and “Patient medical records” to form his “Final diagnosis(es)”. The provider firstly performs A31 “Evaluate integrated patient information” to analyze details regarding the patient’s condition, determining why and how the condition occurred and what the symptoms really represent, rather than simply recording the information. Also, the physical findings are assessed and researched to obtain necessary evidence for the possible diagnoses. The physician A32 “Evaluate[s] shared goals and define[s] overall diagnosis task” to reinforce the expected outcome of the encounter, and also determines whether there is ambiguous or incomplete information that may lead to a misdiagnosis. Several hypotheses are generated based on the patient's integrated information and defined shared goals (A33 “Generate diagnostic hypotheses”). As many hypothetical diagnoses as possible are refuted by probing for information and evidence which rejects each hypotheses (A34 “Refute unlikely hypotheses”). After the unlikely diagnoses have been rejected, the provider gathers any additional information and evidence necessary to rank the possibilities of each remaining diagnosis and proceeds to A35 “Confirm most likely diagnosis”. Once the diagnosis is confirmed, the provider discusses and explains the results with the patient to get feedback (A36 “Discuss and explain diagnosis with patient”). During the diagnostic process, more relevant information may be needed to form the diagnosis. These “Diagnosis information needs” may prompt the provider to collect more clinical information from the patient or conduct additional physical examinations. “Medical references” are another important resource for when the provider needs extra information to assist with the process. The medical records are updated with all the diagnostic information generated from each step to trace provider's thoughts. "Decision making aids" are assistant tools to provide help for the physician in forming an accurate diagnosis.

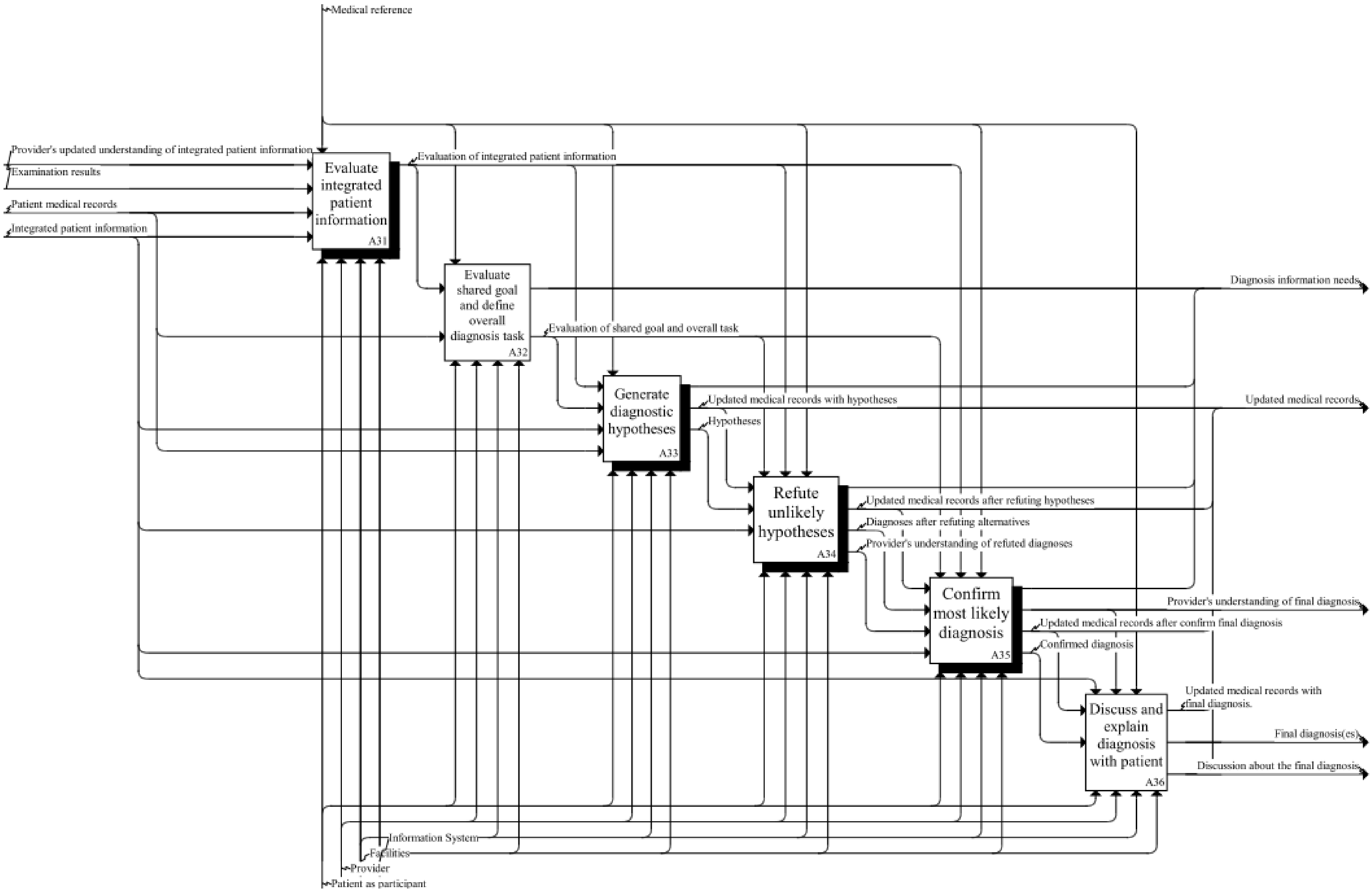

Figure 15: A3 Diagnose Condition

On the complete pages of the model, additional information is displayed using headers and footers,which are contained in the border of the model. The headers contain information such as the model’s author, project name, date, time and so on. The footers contain information such as the node number, diagram title, and page number. The complete model, including all diagrams and text, is contained in Appendices A and B.

4.6 Conclusion

This chapter is intended to show the overall process of developing the model of the physician-patient encounter. It provides a description of the model and modeling process, delineating the components of the model and providing examples of the interrelated activities. Portions of the model were described in terms of activities, performers, tools, control factors, and the relationships between each activity, with the hope that the reader will have an increased understanding of the process and the IDEF0 language. The capabilities of IDEF0 in modeling complex processes by graphically decomposing them into more basic activities and elements were described. It is hoped that the reader recognizes the potential for IDEF0 to build a bridge between engineers and healthcare professionals so that each can communicate their perspective and help to improve the overall process. The successful use of this language for the physician-patient encounter strongly indicates the high applicability of IDEF0 modeling for other process in the healthcare domain. However, without verifying and validating the model, it lacks credibility and cannot be applied to the existing process. The next chapter describes the process of verifying and validating this encounter process model.

Chapter 5 Model Validation and Verification

5.1 Introduction:

The goal of the developed model was to formally describe the physician-patient encounter, as it is a vital part of the healthcare process. The encounter process can be highly variable and is usually quite complicated. During the literature review and data collection phases, it became apparent that while guidance and various procedures exist for a physician to follow in providing service, there is no precise standard process or uniform method by which all physicians conducts the encounter process. When faced with similar situations, different physicians will conduct their practice with some variance due to their own preference, and the diversity of those situations only adds to the complex nature of the healthcare process. Fortunately, the IDEF0 modeling methodology is able to include the activities and events in a process without restrictions from chronology or concurrence. While the ability to model events that vary in order or simultaneity is a key advantage of this particular methodology, it is because of this that the verification and validation of the model is even more important, as the chaotic array of events that occur during the physician-patient encounter must still be completely represented. Because of the importance of creating as accurate a model as possible, and the involvement required in the verification process, the survey completed for this purpose is examined and presented here.

A group of physicians was surveyed to verify and validate the model, to examine and ensure its complete inclusion of all the activities and elements of the encounter as well as the correct representation of those elements, and certify the usefulness and applicability of the methods. The participants were chosen for their expertise on the model's subject, each having conducted many physician-patient encounters, and each specializing in a different branch of medicine. This chapter describes the specific method of verifying the model and validating the IDEF0 language used, provides the reasons for choosing that method, and examines the feedback obtained from the subject matter experts and the application of that feedback to the model.

This chapter is structured to provide a clear understanding of the verification and validation process that took place for this model. It shows the verification process from selecting a method, selecting the experts to take part in the verification, carrying out the survey method chosen, collecting the information from the experts, and integrating that information into the model. An overview of the survey is provided that includes its format and the types of questions asked, and the results obtained by the survey are both given and analyzed.

5.2 Verification and Validation Method

The model's author chose to provide a survey to the participants as a means of verifying the accuracy and completeness of the model, and included in the survey were questions validating the usefulness of the IDEF0 methodology and the usefulness of the model as a whole. This method was chosen over others for several reasons. As mentioned, one among them was the ease of including a validation of the IDEF0 methodology in the survey, gathering evidence that such a language would be capable of describing the process, and that a model written with such would be useful in its application to optimization of the encounter process. The survey was also deemed most appropriate because it allowed the respondents to provide objective, detailed, and quantifiable information. The non-confrontational approach provided more opportunity for the respondents to answer truthfully and to be comfortable in their criticism, while the format given for many of the answers allowed numerical and quantifiable data to be collected. This data can be analyzed to find the parts of the encounter model that are most in need of revision. Open-ended questions of the survey also provided a chance for the respondents to offer specific criticisms, and provided the author with a greater sense of the significant portions of the model, as opposed to relatively minor elements whose inclusion would be tedious and time consuming, detracting from the intended purpose of the model. The survey allowed the subject matter experts to provide what motivates them, so that the author can gain insights into important and significant areas of the process and provide a correct and complete representation of them.

5.3 Survey respondents

The first step of the survey was to determine the population that would respond to it. The survey needed to gather information regarding the model from subject matter experts, necessitating a respondent population with a high degree of knowledge and experience of the physician-patient encounter in a medical office setting. For this model, the only available people who perform the encounter process on a daily basis, and who make up the ideal recipients of this survey, are physicians with a great amount of experience with diagnosis in an office setting. Including a greater number of physicians to participate in the survey leads to a greater degree of completeness in the feedback generated, and a more complete review of the model. However, due to the already laborious schedule that most physicians maintain, there was some difficulty in collecting a sufficient number of experts to complete the survey. Thankfully, with the help of Dr. Bauer, a total of six physicians were found by means of personal communication, and e-mail that were willing to take the survey. All the physicians who responded have more than 5 years of professional practice experience, and specialize in a diverse range of disciplines including family medicine, internal medicine, general surgery, anesthesia, and nursing management. While each of the physicians selected currently practice at Peace Harbor Hospital in Florence, Oregon, their broad experience and backgrounds allowed them to provide a relatively exhaustive review of the model. Each has considerable experience with the physician-patient encounter in an office setting, and providing experts who specifically practiced within the scope of the model contributed significantly to its thorough validation.

5.4 Survey Design

The survey was given in a questionnaire format. A questionnaire is a research method consisting of a series of questions and other prompts for the purpose of gathering information from respondents. The reasons that this format was selected over other types of surveys included the questionnaire's inexpensive nature, the ease of completing questionnaires compared to telephone or verbal surveys, and the questionnaire's common inclusion of standardized answers that allow the simple compilation of data. Included in this survey were three sections designed to generate usable and quantifiable feedback, while providing areas that could allow the incorporation of more detailed responses about the model in order to provide a level of specificity to the data collected. The participants were allowed to complete the survey at their own convenience, so that they could provide thorough and detailed answers. The first portion of the survey assessed the experts' understanding of the IDEF0 methodology and its presentation in this specific model. The second part consisted of the majority of the questionnaire, which gathered feedback to perform the actual verification of the model. This section of the survey was designed to determine the accuracy of the activities, inputs, outputs, controls and mechanisms that make up the model. It ensured that each element was correct, significantly relevant to the process, and that all important items were included. Each element was stated with these conditions, and the answers to this section were given in a Likert scale format that ranged from "Strongly Agree" to "Strongly Disagree". This allowed an immediate review of the strengths and weaknesses of each area of the model according to the subject matter's experts. The third section allowed the experts to write specific comments and feedback, as well as their recommendations for the continued development of the model.

5.4.1 Survey Construction

The questions were all designed to test the integrity of the main components that make up the model: the activities, inputs, outputs, controls and mechanisms that together describe the relationships that make up the overall physician-patient encounter process. Every single diagram of the model was evaluated in this manner by at least two participants so that any flaws could be quickly located, investigated, and corrected. The survey was set up to maintain a consistent positive tone, allowing the respondents to answer easily and objectively when reviewing the model. The A-0 and A0 levels were evaluated by all six participants and the remaining diagrams were evaluated by two participants each. This division of the model's evaluation helped to allow its timely completion, while still providing feedback from multiple experts concerning each section of the model.

For every model diagram, each of the five main components of the model had to be reviewed for accuracy. These components are the activities themselves, and the inputs, outputs, controls, and mechanisms that together affect their operation. In order to establish that each of these components correctly reflected the real-life process, the following accuracy statements were designed and applied to each part of the model, for the experts to provide a review:

- All the activities are correct in the model [diagram, eg.A0, A32].
- All the inputs are correct in the model [diagram].
- All the outputs are correct in the model [diagram].
- All the controls are correct in the model [diagram].
- All the mechanisms are correct in the model [diagram].

Each statement was rated individually on the level of agreement the expert had with the statement, with five levels ranging from "Strongly Disagree" to "Strongly Agree". The Likert scale given as the main method of answering the survey's inquiries was designed to determine the participants' attitudes toward the model. Five degrees of assent were chosen to ensure that the participants were provided with an option that accurately described their concurrence with the statement. The answers provided were derivative of three simple attitudes the participants might have: agreement, disagreement, or neutrality. Since the evaluators were from differing backgrounds and may not have been completely familiar with all aspects of the model, neutrality was offered as an option to select if the expert had no opinion on that aspect. The extremities “Strongly Agree” and “Strongly Disagree” were provided to determine which parts of the model were entirely correct, and which parts need a complete revision. The “Agree” and “Disagree” answers are simple representations of general assent or dissent, alluding to only a moderate degree of certainty in that answer. The scale was arranged in a logical progression as follows:

- Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree

Without regard to the individual elements of the whole process, it was important for the IDEF0 model to logically represent the flow of each activity. The activities are connected by arrows describing their interrelationship, with the outputs from parent diagrams or preceding activities in the process affecting activities that occur further in sequence. Some outputs may become a control for other events, and some controls may become the input for a child diagram. The model must accurately display the dynamic relationship between each activity and set of activities in the process. The participants surveyed were given an additional accuracy statement to reflect whether the relationship between the activities in each module was correctly described:

- Read[ing] from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.

Even though the model was initially developed to include all potential activities and other components of the process as completely as possible, the encounter process is simply too complex and recording every minute possible occurrence would be overwhelming and counterproductive to those interpreting the model. Therefore, it was critical during the validation period to gather opinions from the subject matter experts regarding the relevance of included activities, so that all the included elements were significant parts of the process, and that the model did not include insignificant or irrelevant details. The following significance statements, provided for each diagram, were designed to verify the inclusion and relevance of each aspect in the model:

- All the activities significantly impact the process.
- All the inputs significantly impact the process.
- All the outputs significantly impact the process.
- All the controls significantly impact the process.
- All the mechanisms significantly impact the process.

To each of these statements the possible responses were:

- Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree

Additionally, it was likewise important to confirm that all important activities had been included in the model. While it aims to provide a generic view of the overall physician-patient encounter, any missing information in the model will affect its application in the real world and cause the model to lose credibility. Since the physicians surveyed all come from different backgrounds and specialize in varied practices, it was advantageous to inquire of the completeness of the process model and the inclusion of all necessary information. These completeness statements were intended to discover quickly which portions of the model needed further investigation or illumination. For each diagram, these completeness statements were provided, similarly using the Likert scale for assessment:

- All the important activities are included in the diagram. There are no important activities missing.
- All the important inputs are included in the diagram. There are no important inputs missing.
- All the important outputs are included in the diagram. There are no important outputs missing.
- All the important controls are included in the diagram. There are no important controls missing.
- All the important mechanisms are included in the diagram. There are no important mechanisms missing.

Because of the importance of the reader's knowledge concerning the syntax and operation of the IDEF0 methodology, it was necessary to establish that the participants were able to easily interpret the whole model for review during the survey. A single statement evaluating the training that they underwent in reading IDEF0 was included to make sure the model was completely comprehended during validation. Responses to this statement were provided on the same Likert scale as above: Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree. The statement provided was:

- After training, you [could] understand IDEF0 and the model very well.

After evaluating the model, it was necessary to confirm that the function of IDEF0 as a modeling methodology was appropriate in modeling this particular process. As the main method chosen by the researcher, it needs to have the capacity to accurately and appropriately describe the physician-patient encounter, in order to deliver all necessary information to its audience. This was one component of the validation of the model; ensuring that it would be useful and applicable to the physician-patient encounter, and able to provide a complete representation of the encounter process. The following statement, with the same Likert scale for responses, was provided to the subject matter experts to evaluate IDEF0 as the tool for modeling this process:

- IDEF0 method is a good way to express the encounter process.

Another aspect of the IDEF0 model that must be validated is whether it would help to improve the overall quality of the physician-patient encounter. This statement and same Likert scale responses for this validation was provided in this part of the survey:

- This encounter model will be useful for improving the quality of physician-patient encounter.

It was discovered very early in the initial research stage of this topic that no model existed that describes the overall encounter process in a manner that is complete and up to date. One of the most important criteria that the model must meet is its reflection of facts in the real world. Because of this, the participants were asked to step back and determine if the model accurately displays their real experience during their work, after having completed the evaluation of the model in great detail. Along with the same Likert scale responses previously described, the statement to determine this is provided below:

- The model correctly reflects your experience in the real world.

An area was then provided and required for the participants to complete, allowing them to make comments to share their individual viewpoints on the model.

5.4.2 Survey Orientation

Before the respondents could be given the questionnaire, an orientation to the overall project was needed. They had to be informed of the relevance of the survey to their practice, and the role that the survey filled within the overall process of writing this thesis and improving the physician-patient encounter. The participants were given a presentation to familiarize them with the subject and purpose of the model, an overview of the thesis, and a description of the research done up to this point. The hospital in Florence was again visited to meet all the respondents and describe the concept of this research. The presentation was given in a conference room that contained a projector, used for a slide presentation. The researcher brought copies of the relevant documents for the presentation, including the actual presentation material, the IDEF0 training material, the model itself and a sample of the questionnaire.

The presentation was about an hour in duration, with eight people able to attend it until its completion. While only six were participating physicians in the survey, the hospital's manager and vice president also expressed an interest in the project and were in attendance throughout the presentation. The first portion detailed the introduction of the researcher's thesis. The content of the thesis was described and the purpose behind the research given, including its background and motivation. The participants were reassured that their frustration with the current process and information system used in the healthcare process was understood by the researcher, having study and experience in human factors engineering as well as system engineering. The goal of the research was elucidated for them, and the ultimate implications of that goal. This is that the model is designed to accurately define and represent the healthcare process so that it may potentially help healthcare organizations increase the quality of their services, while any advances in efficiency made from the model could lessen the workload that healthcare professionals must perform. Because of this purpose, it was necessary to make certain the participants grasped the importance of this validation. They were provided opportunities to ask questions of the researcher, and were answered accordingly. Among the inquiries the participants had were questions about the origin of the research, the context of the research, and the original ideas that led to the research's conduction. All participants had developed an appreciable understanding of the overall research at the conclusion of the first portion of the presentation.

The second portion of the presentation was the training of the participants in interpreting the IDEF0 model. Initially, the participants were provided with a history of the modeling methodology and given the reason that the researcher chose to use IDEF0 as her main method. Secondly, the IDEF0 concepts and characteristics were introduced. This included the syntax that IDEF0 operates with and the way it represents an activity. A part of this training, for example, concerned the elements, structure, form and semantics of the model, such as the meaning behind each of its terms. In the syntax part, the structure of the model was illustrated, such as the meaning and function of boxes and arrows, as well as all the relative rules and semantics that guide and describe the boxes and arrows. The concept of child and parent diagrams was brought up along with the method by which the process decomposition is displayed. After illustrating the theory and rules of the IDEF0 methodology, the model developed during this research was presented as an example for the participants to better comprehend those concepts so that they could begin to interpret the model itself. Several questions were asked to review their understanding of the model, such as the relationship between child and parent diagrams or determining the difference between controls and mechanisms. When it had been determined that the participants had a firm grasp of the concepts in the training, the presentation continued with the third section.

The third portion was a summary of the best practices to be employed in reading the IDEF0 model. It was provided as simple tips from the researcher in order for the participants to generally understand the model without being overwhelmed by its level of detail. The following highlights were made in the presentation:

- Scan boxes of diagram to gain an impression of what is being described.
- Refer to parent diagram for the context of what is being read.
- Trace all the lines down (especially output and input) to see if the relationship is correct.
- Mentally walk through the diagram, from upper left to lower right.
- Refer to the glossary to understand the meaning of each box and arrow.

The fourth part of the presentation was the communication of the importance of verification and validation, and a delineation of their roles. Each participant was provided with a copy of the questionnaire at the beginning of the presentation, and the survey's questions and responses were explained during the process. Every participant was to complete the first section of the questionnaire, which concerned the overall accuracy and completeness of the model with a focus on the most general levels A-0 and A0. The remaining sections, each consisting of separate detailed questions on the rest of the model's diagrams, were assigned two participants a piece to review and answer. In order to insure a thorough and timely completion, the following critical steps were reinforced:

- Reading through the model to really verify that it makes sense and matches the physician's daily practice.

- Marking on the model directly, if/when necessary.
- Filling out the survey questionnaire.
- Scanning the model diagram and survey paper so that they could be returned to the researcher before the end of March 2011.

The last part of the presentation was a designated section for questions and answers, so that some of the confusion could be resolved concerning both the model itself and the verification and validation process. The tasks were assigned to each participant and the deadline for providing results was given as well. The participants responded favorably to the concept of the model research, and expressed enthusiasm for the potential it had to impact the encounter process. They agreed to fill out the survey to validate the model, and apply their expertise during the development process. The participants indicated that they now had a rudimentary understanding of the IDEF0 methodology and its role in systematically describing the encounter. Having expressed their understanding of the IDEF0 language, the encounter, and their individual given tasks, the participants were then given the survey itself.

5.4.3 Distribution of Survey

After thorough instruction had been provided on the procedure for reading and evaluating the model, and an overview given on the purpose of the survey, the physicians participating in the survey were provided with the questionnaire to be completed for the verification of the model. This was done in a redundant manner: a physical paper copy of the model and survey were provided after the presentation, as many of the participants preferred to complete it on a traditional paper format, and a matching questionnaire was distributed in an electronic medium so that the involved parties would be able to easily trace, modify and update it. This allowed the participants to write their answers directly on the questionnaire and make any marks or notations they wished to on the model itself, while the convenience and mobility of the electronic format remained available. Throughout the time while the survey was being completed, after the presentation and before the results were collected, communications between the survey's researcher and the respondents were effected in order to give more instruction on the verification process and remind the respondents of the timeframe under which the survey must be completed.

The evaluation kit that was distributed included the following documents:

- The encounter model
- The description of the encounter model
- Survey questionnaire
- The training presentations
- Survey introduction and purpose

5.4.4 Survey Data Collection

The subject matter experts were given nearly a month to complete the survey, so that it could be given sufficient attention to ensure the accuracy and completeness of the responses. The survey was distributed to the respondents on March fourth and was to be collected by April first.

Email communication played a significant role during the verification and validation because of its convenience and accessibility. Three major emails were sent out to each participant to remind them of their tasks during the verification. The first email was sent after the presentation and contained information concluding and restating key parts of the presentation. This email highlighted the purpose and motivation of the model's verification and validation, how to read the model, and the steps included in the verification and validation process. A document kit was attached to the email that included all the documentation and references needed for this validation. The second email was a reminder of this process that included their specific tasks and the survey questions associated with those tasks. The last email was sent out a week before the results were to be collected to ensure that the verification and validation would be completed on time.

Instead of using US mail to collect the results, the respondents were directed to scan the entire final document to be sent back to the researcher by email. In this way, the chance of lost or delayed responses was reduced. The finished surveys were collected at the end of March. All the participants returned the questionnaire paper, having completely answered the questions and provided additional comments.

5.5 Survey Results

The survey provided two types of data because of the format of its questions. The first was quantifiable due to the Likert scale answers to the questions. The second type of response provided was specific comments from the participants that were provided with the completed surveys. The accuracy, completeness and significance of each component in the diagram were verified using the Likert scale questions. The quantitative data from these scales was analyzed mathematically to provide a general level of agreement for each portion of the model. Each level of assent was assigned a numerical value of zero through four, from “Strongly Disagree” to “Strongly Agree” respectively. These values were used to generate an average percent of agreement (A), which was determined from the total sum of the values within a section (T_S) and the total possible sum of those values (T_P, determined by multiplying the number of questions by four), using the following formula: $A=100\%*(T_S/ T_P)$. For example, with this formula, if all questions were answered with “Strongly Disagree” the resulting percentage would be 0%, if all questions were answered neutrally the resulting percentage would be 50%, and if all questions were answered with “Strongly Agree” the resulting percentage would be 100%. The average agreement was converted to a percentage in this way to provide a clearer idea of the overall correctness and completeness of the model. Apart from the quantifiable data provided by the participants, comments given in the survey were reviewed by the model’s author and the recommendations made therein were considered in the revision of the model.

5.5.1 Survey Results Overview

This section provides an overview of the survey results by providing the calculated level of agreement for different diagrams of the model, coupled with the qualitative information provided by the participants for each section. Their specific comments are included verbatim, and give particular information concerning adjustments recommended for the model. A review of the data collected from the survey follows. The model was divided into modules, which included a module for the top levels that was comprised of both A-0 and A0, and a module each for the sublevels A1 through A5. In total, there were 6 participants that responded to the survey, and all of them reviewed the top level of the model. The remaining modules were reviewed by two participants each. Other than the verification results, this section also shows the assessment of the training and two questions that validated the IDEF0 methodology. Every participant responded to those three questions and gave positive feedback.

5.5.1.1 Level A-0, Overview of "Conduct Medical Encounter"

There were a total of 6 participants included in the evaluation of this model diagram and each one answered 16 Likert scale questions regarding this diagram. Of these 16 questions, 6 were meant to examine the accuracy of the diagram, 5 were meant to examine the significance of the included elements, and 5 were meant to examine the completeness of the diagram. The given results ranged from:

- "Agree" to "Strongly Agree" for accuracy with a level of agreement of 97.2%.
- "Agree" to "Strongly Agree" for significance with a level of agreement of 99.1%.
- "Disagree" to "Strongly Agree" for completeness with a level of agreement of 87.5%.

The average level of agreement was 94.6%.

The bar graph in Figure 16 shows the percentage of each answer was responded.

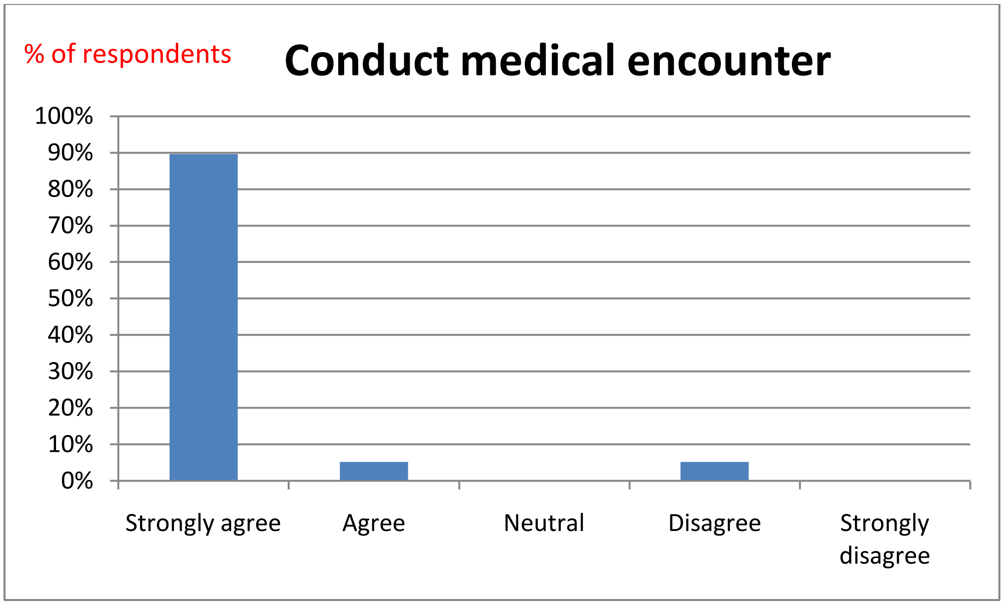

Figure 16: Survey Results, A-0

The following comments were made concerning this diagram, with major points in bold for clarity:

> Existing medications should be added as [an] input to the activity. This medication includes prescription, over-the-counter, herbals and dietary supplements that the patient is consuming either on a regular or [an] as needed basis. Also, the financial/billing record should be listed. This would include the costs of care already incurred by the patient as well as their insurance data such as coverage & expected coverage of the type of event that is the subject of the encounter. Radiology films and interpretive results should be exclusively listed since they are usually not included in the patient medical records. The patient's habits are very important since

they greatly impact health and stratify risk to disease entities. Such [habits] would include exercise, diet, tobacco use history, [illicit] drug use history, sexual activity and orientation history, caffeine use, [and] occupation. Social identity should be considered since we need to include a broader treatment of patient culture which characterizes the individual ethnicity, religious beliefs, level of education, aspirations, occupation, hobbies and overall social identity. It is important to appreciate the human characteristics since they are expressions of the underlying psychology of the patient.

As outputs, since patient medical records would include such items as existing/established diagnosis, existing treatment plans, prescribed medications (which may differ from what the patient actually takes), radiology results/films, [and] laboratory results, it's not necessary to list out all the components at this high level. Patient perceived problems allude to the concept of "chief complaint" which is the symptoms and worries that motivate the visit/encounter. The name "Final treatment" should be modified since it may not be so final; possibly it is the most current or the most updated treatment plan.

As controls, it's important to include legal statutes and requirements pertaining to the medical practice. Hospital resource constraints and institutional operational policy/guidelines should be considered as well. Insurance coverage or governmental treatment rules are another important factor to [be] taking into consideration since these rules determine financially covered disease entities, types of treatment and medications allowable.

As mechanisms, the input of supporting physician consultants, nursing staff physical therapy, nutritionists, occupational therapists, audiologists, speech pathologists, medical social workers, and other professional staff that could have input need to be addressed in the model. Some consultants first provide advice and information and then become a part of the treatment and follow-up. An example would be a cardiologist who first provides advice on what tests are required, which then the primary physician makes a referral to and eventually the cardiologist handles the problem. The term information systems include electronic and paper-based methods supporting both patient care records and financial records. These two categories of records should be segregated to maintain patient confidentiality.

5.5.1.2 Level A0, "Conduct Medical Encounter"

There were a total of 6 participants included in the evaluation of this model diagram, and each one answered 16 Likert scale questions regarding this diagram. Of these 16 questions, 6 were meant to examine the accuracy of the diagram, 5 were meant to examine the significance of the included elements, and 5 were meant to examine the completeness of the diagram. The given results ranged from:

- "Agree" to "Strongly Agree" for accuracy with a level of agreement of 97.2%.

- “Agree” to “Strongly Agree” for significance with a level of agreement of 95.0%.
- “Disagree” to “Strongly Agree” for completeness with a level of agreement of 83.3%.

The average level of agreement was 80.6%.

The bar graph in Figure 17 shows the percentage of each answer was responded.

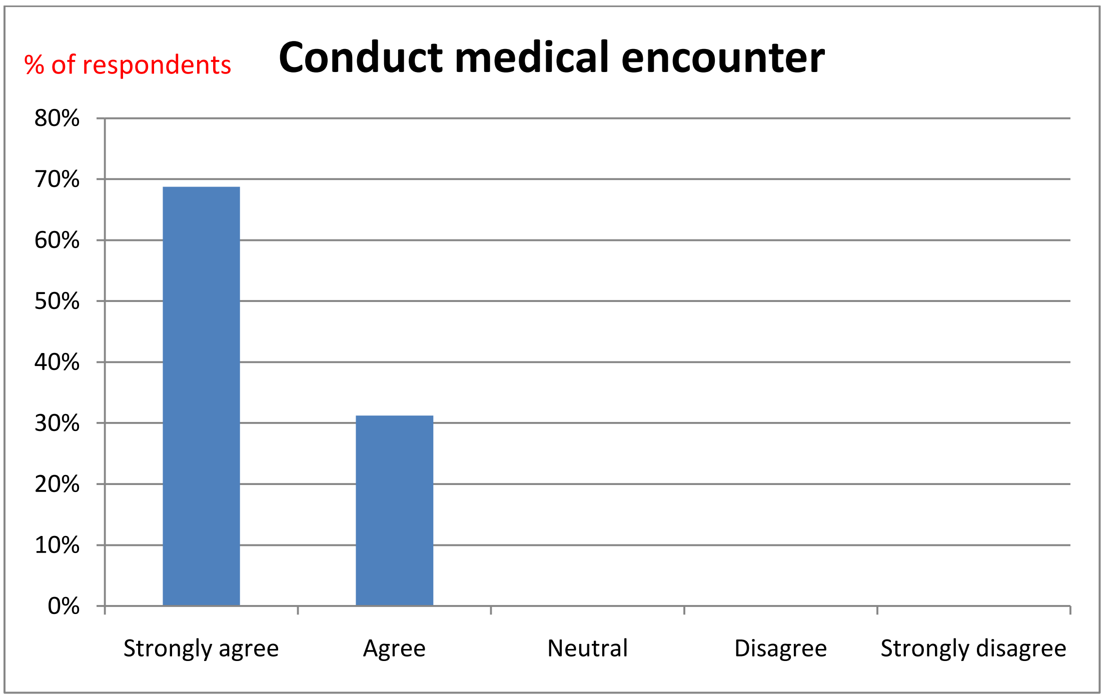

Figure 17: Survey Results, A0

The following comments were made concerning this diagram:

> The “New/returning patient” as input for A2, A3, A4 and A5 should also go into the A1 “Establish/maintain patient-provider relationship”. In the mechanism of A3, it’s not very necessary to include the facility and medical equipment since the provider forms [a] diagnosis based on his own knowledge or information in the workstation. Also, the patient’s

understanding of final diagnosis should be [a] control factor for A4 and A5 as well. The "Discussion of final diagnosis", "Discussion about treatment plan" and "Discussion about follow-up plan" should merge into the "Ongoing patient-provider relationship. The "Discussion of treatment" should be control factor for "Plan follow-up"

5.5.1.3 Level A1, "Establish & maintain patient-provider relationship"

There were a total of 2 participants included in the evaluation of this model diagram, and each one answered 16 Likert scale questions regarding this diagram. Of these 16 questions, 6 were meant to examine the accuracy of the diagram, 5 were meant to examine the significance of the included elements, and 5 were meant to examine the completeness of the diagram. The given results ranged from:

- "Agree" to "Strongly Agree" for accuracy with a level of agreement of 89.5%.
- "Agree" to "Strongly Agree" for significance with a level of agreement of 92.5%.
- "Disagree" to "Strongly Agree" for completeness with a level of agreement of 90.0%.

The average level of agreement was 90.6%.

The bar graph in Figure 18 shows the overall results of this part.

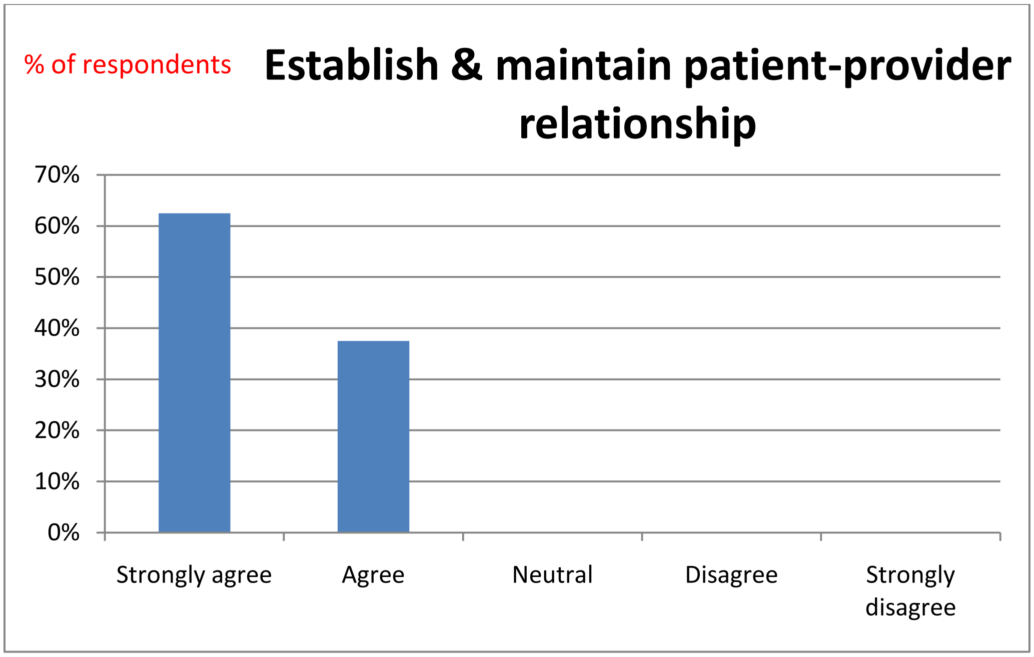

Figure 18: Survey Results, A1

The following comments were made concerning this diagram:

> In block A1, the "Patient perceived problems" should be a control for all the activities and "Patient's enhanced understanding of problem" should be [a] control for all the activities in A1.

5.5.1.4 Level A2, "Collect and integrate clinical information"

There were a total of 2 participants included in the evaluation of this model diagram and its six child diagrams, and each one answered 112 Likert scale questions regarding this diagram and its child diagrams. Of these 112 questions, 42 were meant to examine the accuracy of the diagrams, 35 were meant to examine the significance of the included elements, and 35 were meant to examine the completeness of the diagrams. The given results ranged from:

- "Agree" to "Strongly Agree" for accuracy with an average level of agreement of 80.0%.
- "Agree" to "Strongly Agree" for significance with an average level of agreement of 84.6%.
- "Disagree" to "Strongly Agree" for completeness with an average level of agreement of 80.3%.

The average level of agreement was 81.6%

The bar graph in Figure 19 shows the percentage of each answer was responded.

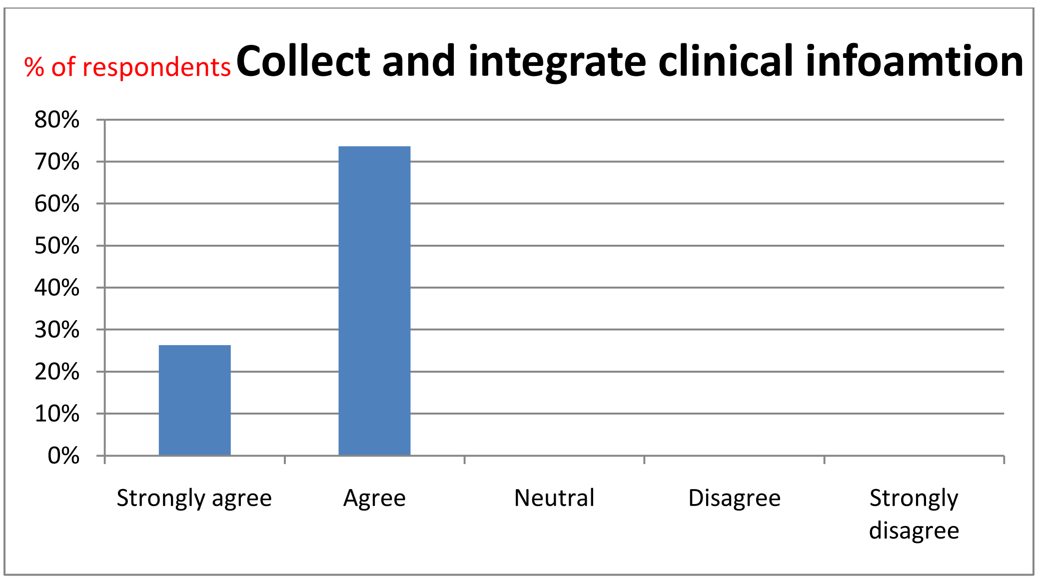

Figure 19: Survey Results, A2

The following comments were made concerning this diagram:

> This model refers to collect and integrate clinical information. Actually the collection integrates the data points into a "medically" standardized pattern from which the physician/provider can recognize an established and known diagnostic entity. The manner in which the information is

assembled often dictates the eventual diagnosis. In the assembly mental process is where the human factors mischiefs, informational transmission/receiver distortion and observer bias arises. If the diagnostic questions are formulated in a clear and not [mis]leading manner possibly some of that distortion and bias could be minimized. Questions and patient responses are the least expensive and yet most revealing diagnostic instruments we have. A new paradigm for medicine is clear and unambiguous communication that demands thoughtful patient responses. All symptoms and complaints have a time course, inter-associations, intensity, aggravating factors and alleviating factors. If the patient can provide enough information, patterns of known disease[’s] natural histories should emerge.

In all scientific literature there is a move towards quantification of data, this is also true of the behavioral sciences and finds application in characterizing patient responses. Responses could include a gradient that reflects the intensity and degree of life disruption caused by a given symptom. A prerequisite testing of the patient's response to common problems may help normalize their response to a data standard “average” patient. There could be standardization of overall impression and also prospective diaries to capture the frequency, intensity and characteristics of any given symptom.

> The term “Characterize symptoms of urgent problems” was used in the model to represent the process of characterizing [the] chief complaint [and] should be changed to the term that physicians are all familiar with such [as] “Characterize chief complaint”. It is the primary components of symptom or what really troubles the patient and motivates the visit. For the most part, the chief complaint keeps the physician centered on the problem that bothers the patient most and is most likely the primary clue to the underlying pathology. Many times defining the chief complaint requires provider interpretation of the data given by the patient. In this regard, one needs to realize that communication is multi-channel with components of gesturing and facial expression. These unspoken words help the physician structure the data provided by the patient's spoken word.

5.5.1.5 Level A3, “Diagnose condition”

There were a total of 2 participants included in the evaluation of this model diagram, and each one answered 80 Likert scale questions regarding this diagram and its children diagrams. Of these 80 questions, 30 were meant to examine the accuracy of the diagrams, 25 were meant to examine the significance of the included elements, and 25 were meant to examine the completeness of the diagrams. The given results ranged from:

- “Agree” to “Strongly Agree” for accuracy with a level of agreement of 79.5%.
- “Agree” to “Strongly Agree” for significance with a level of agreement of 91.0%.
- “Disagree” to “Strongly Agree” for completeness with a level of agreement of 81.5%.

The average level of agreement was 84.0%

The bar graph in Figure 20 shows percentage of each answer was responded.

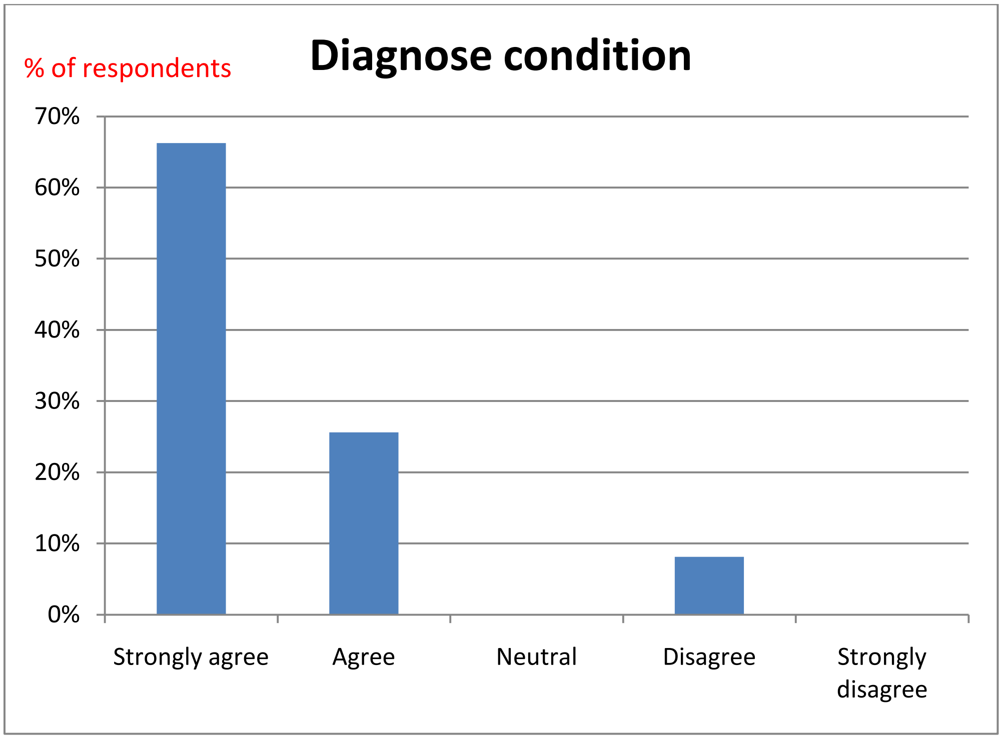

Figure 20: Survey Results, A3

The following comments were made concerning this diagram:

> In block A3, in actuality one formulates a diagnosis and works along a probabilistic pathway[,] which test results help mark branch points along the way. It is a mixture of probability and logic. The term diagnostic hypothesis seems foreign to most medical providers though the verbiage is conceptually correct. The "diagnostic hypothesis" corresponds to the concept of "differential diagnosis" commonly used by medical professionals. When one assembles the bits of patient symptom data into a commonly recognized pattern, such as chest pain, a list of possibilities

> follow. The list of possibilities is called the "differential diagnosis" and can be found in textbooks or the Merck manual. The differential diagnosis then becomes the starting point to whittle down the list based on follow[ing] questions (more exact characterization of symptoms, prior medical history and family history) as well as seeking out associated physical exam findings, laboratory tests verification or exclusion, and radiological imaging results. Block A33 is a[n] intellectually synthetic activity. It would be more accurate to say the physician generates then further works a differential diagnosis set into a diagnostic hypothesis.

Furthermore, comments specific to the child diagrams of this diagram were included in sufficient occurrence that they will be provided below, as subsections of Level A3.

5.5.1.5.1 Diagram A31, "Evaluate integrated patient information"

The following comments were made concerning this diagram:

> As noted before, the physician/practitioner integrates the information to form a recognizable pattern associated with a known clinical entity. That that pattern can feed into a broad diagnosis such as "viral rhinitis, the common cold" or if the data is rich enough narrow to an exact diagnosis, "vulvar lichen sclerosis et [Atrophicus]". For the purpose of the model, it's important to understand where the assembly of the information occurs. If the pattern assembly and recognition is in the diagnosis node then the children nodes need to be expanded to include this task. Another alternative would be to alter the A26 "Integrate patient information" to be

titled as “Integrate patient information into a recognized clinical pattern”. A33 “generate diagnostic hypotheses” represent[s] formulating the “differential diagnosis” which may be more appropriate as A31. Controlling/informational inputs should include [the] physician[’s] experience base. This would include the individual’s general fund of knowledge, specific experience with similar clinical problems, level and specific area of clinical training.

An arrow flows out of node A31, “evaluation of integrated patient information”, in fact this information is the differential diagnosis which needs to be evaluated by logic and probability to arrive at the most likely diagnosis. Possibly, A31 should be matching the clinically recognized pattern such as “chest pain” to the differential diagnosis list (myocardial infarction, coronary artery disease, Tietze syndrome, chest wall muscle strain, radiculopathy and so on).

The assessment of patient’s condition from “provider’s own knowledge” and “provider’s understanding of treatment” don’t need to be input[s] for “generate evaluation” A315 since it already contains [the] provider’s understanding with more relevant medical information and more relevant information.

5.5.1.5.2 Diagram A32, “Evaluate shared goal and define overall diagnosis task”

The following comments were made concerning this diagram:

> The intent was to reconcile the diagnostic process with the goals and desires of the patient. The concept of "chief complaint" is a device and term of art in medical practice that keeps the diagnostic inquiry centered on what bothers the patient most. The chief complaint serves as a starting point as well as [a] reference.
>
> Within the context of the node A32, exists an ascertainment of what are the patient's goals & expectations, what tests are acceptable (in terms of expense, discomfort and invasiveness), what treatments are acceptable and unacceptable and what eventual outcomes are acceptable and unacceptable. This "informed diagnosis" task moves beyond simple mental manipulation of facts in the mind of the physician. It seems this aspect is an explanation of the differential diagnosis to the patient from which the patient can make inputs to alter the course of the diagnostic inquiry, such as declining specific tests and radiology studies. This aspect of diagnosis may be a component of node A36. Possibly A32 should be eliminated and fold[ed] into node A36. Typically, the first physician's visit is where the patient is interviewed and examined to determine the appropriate laboratory and radiology tests to be ordered. During patient follow-up, the new lab results are integrated into the evaluation of the differential diagnosis.

5.5.1.5.3 Diagram A33, "Generate diagnostic hypotheses"

The following comments were made concerning this diagram:

> As explained before this family of hypotheses is termed the differential diagnosis. Thus far the model has sought to mirror the diagnostic process taught in medical textbooks. If [the idea that] conventional thinking can generate new knowledge about [a] disease is questionable, in that [rationale] the current paradigm may not be able to recognize new patterns in pathology. Would computerization of the current method just more quickly produce the same old results? The terminology of the model formulated such as hypothesis is to mirror more a scientific approach that associates symptom and laboratory data points into useful diagnostic and treatment patterns. The conventional medical thought dissects entities through legalistic logic based on the current rules of understanding. Human beings are poor computers of probability problems; our Paleolithic brains are ill equipped. There may be deep flaws in the current approach termed clinical science. Despite the flaws, the current method can be easily communicated between physician and patient as well as physician and consultants. The current methods are very human and therefore transparent to all involved.

5.5.1.5.4 Diagram A34, "Refute unlikely hypotheses"

The following comments were made concerning this diagram:

> The purpose of A34 is to pare down the differential diagnostic list by eliminating the obvious and not so obvious possibilities. In pruning, one identifies reasons for a specific diagnosis to be a bad fit given the situation.

> One reason would be a mismatch between the natural history of a disease process and the clinical situation as defined by symptoms, symptom evolution, patient risk factors and presence/absence of specific physical exam findings associated with the disease process. Note that all these criteria have a subjective component and therefore [are] a bit fuzzy. In some cases a worrisome diagnosis such as myocardial infarction (a heart attack) must be excluded since the consequence of missing the particular diagnosis could be catastrophic. In cases of potentially missing a catastrophic diagnosis, the physician continues to test towards exclusion until a reasonable degree of certainty is reached. The further testing may include more pointed questioning, all laboratory tests, EKGs, radiology, and a family history and past medical records search. Many times it's just as important to know what you don't have. Take the example of a lump in the breast, the biggest question is [whether there is] a cancer [present], yes or no.

5.5.1.5.5 Diagram A35, "Confirm most likely diagnosis"

The following comments were made concerning this diagram:

> If we use the differential diagnosis process, generally the list is rank ordered according to the probability of the diagnosis being present given the demographics of the patient, symptoms and physical findings/appearance. The probabilities reflect the prevalence of the particular disease entity in a specific population of patients. For example,

> an overweight middle-age male diabetic smoker presenting with "chest pain" would have a much higher probabilistic weighting of myocardial infarction than a slender healthy 20-year-old non-smoker. The clinical studies and databases that establish the p [(predictive)] value for a specific diagnosis (myocardial infarction), given different groupings of patients presenting to the clinic or emergency room with a recognized constellation of symptoms (chest pain), will be extremely helpful in that case. Further testing instruments (questions, lab, tests, radiology) all have sensitivities and specificity values that must include prevalence to arrive at positive and negative predictive values. The predictive value is what the patient and clinician wants to know from a test. Clinical science is a matter of sorting out and manipulating possibilities to arrive at a set of useful probabilities. Clinical science is a[n] interactive game.

5.5.1.6 Level A4, "Treat patient"

There were a total of 2 participants included in the evaluation of this model diagram, and each one answered 32 Likert scale questions regarding this diagram and its child diagram. Of these 32 questions, 12 were meant to examine the accuracy of the diagrams, 10 were meant to examine the significance of the included elements, and 10 were meant to examine the completeness of the diagrams. The given results ranged from:

- "Agree" to "Strongly Agree" for accuracy with a level of agreement of 93.7%.
- "Agree" to "Strongly Agree" for significance with a level of agreement of 90.0%.

- “Disagree” to “Strongly Agree” for completeness with a level of agreement of 68.7%.

The average level of agreement was 84.1%.

The bar graph in Figure 21 shows percentage of each answer was responded.

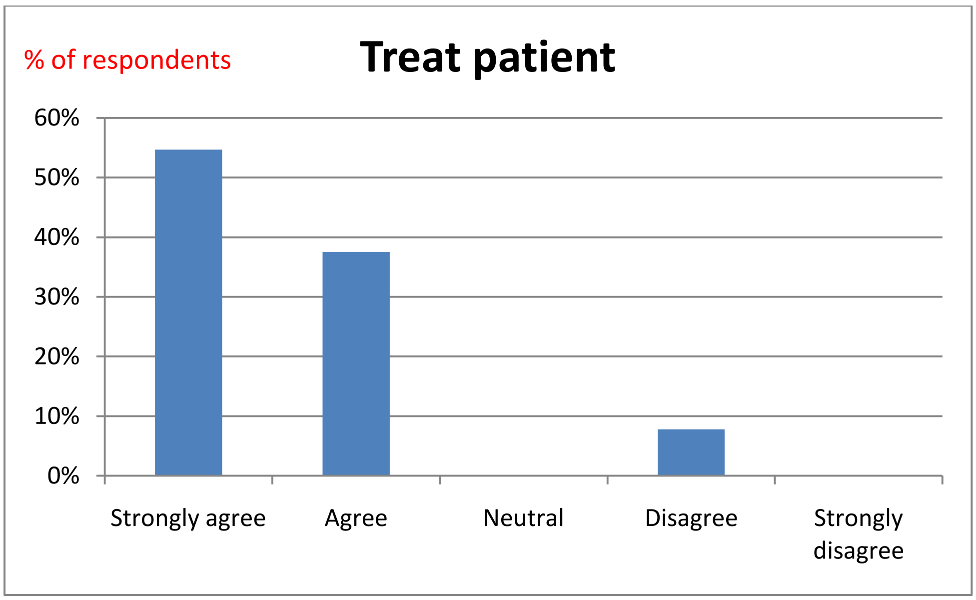

Figure 21: Survey Results, A4

The following comments were made concerning this diagram:

> The diagram of “Treat patient” is simple and direct. However, the idea of understanding [the] treatment plan from the patient[’s point of view] doesn’t come into play. In a lot of cases the patient is the primary driver for what treatment plan will be chosen. Also, the patient’s belief and culture and established shared goal should be concentrated in patients factors as well.

5.5.1.7 Level A5, “Plan follow-up”

There were a total of 2 participants included in the evaluation of this model diagram, and each one answered 16 Likert scale questions regarding this diagram. Of these 16 questions, 6 were meant to examine the accuracy of the diagram, 5 were meant to examine the significance of the included elements, and 5 were meant to examine the completeness of the diagram. The given results ranged from:

- “Agree” to “Strongly Agree” for accuracy with a level of agreement of 93.7%.
- “Agree” to “Strongly Agree” for significance with a level of agreement of 97.5%.
- “Disagree” to “Strongly Agree” for completeness with a level of agreement of 95.0%.

The average level of agreement was 95.4%

The bar graph in Figure 22 shows percentage of each answer was responded.

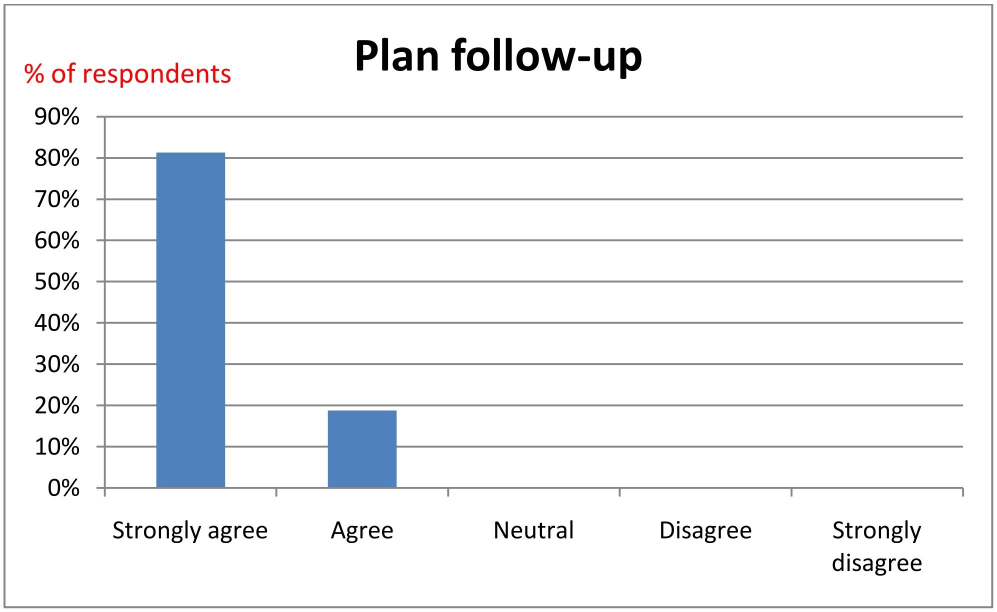

Figure 22: Survey Results, A5

The following comments were made concerning this diagram:

> The "Plan follow-up" is also simple and direct. Possibly a better verb phrase would be to "arrange" follow-up. The terms plan and arrange are fairly equivalent but in medical jargon[,] arrange is used more frequently.

5.5.1.8 Training Assessment

There were a total of 6 participants included in the evaluation of training effectiveness, and each one answered 1 Likert scale question regarding their understanding of IDEF0 and the model after the training. The given results ranged from "Agree" to "Strongly Agree" with an average level of agreement of 95.8%.

The bar graph in Figure 23 shows the percentage of each answer was responded.

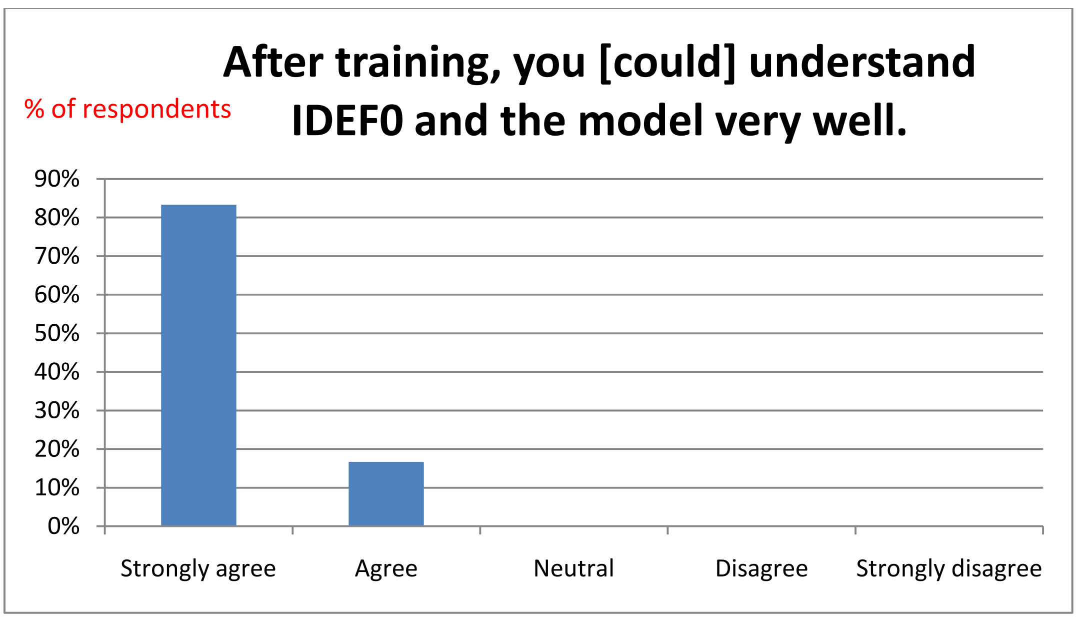

Figure 23: Survey Results, Training

The following comments were made concerning this question:

The training was helpful to understand what the IDEF0 model is and how to read the encounter model. However, the actual questionnaire was filed more than 2 weeks after the training, so some of training content had faded while actually doing the work.

5.5.1.9 IDEF0 Method Validation

There were a total of 6 participants included in the evaluation of training effectiveness, and each one answered 2 Likert scale questions: to validate whether the IDEF0 language is a good tool for modeling the healthcare encounter, and whether it could potentially be used to improve the overall quality of this process. The given results ranged from “Agree” to “Strongly Agree” with an average level of agreement of 93.8%.

The bar graph in Figure 24 shows percentage of each answer was responded.

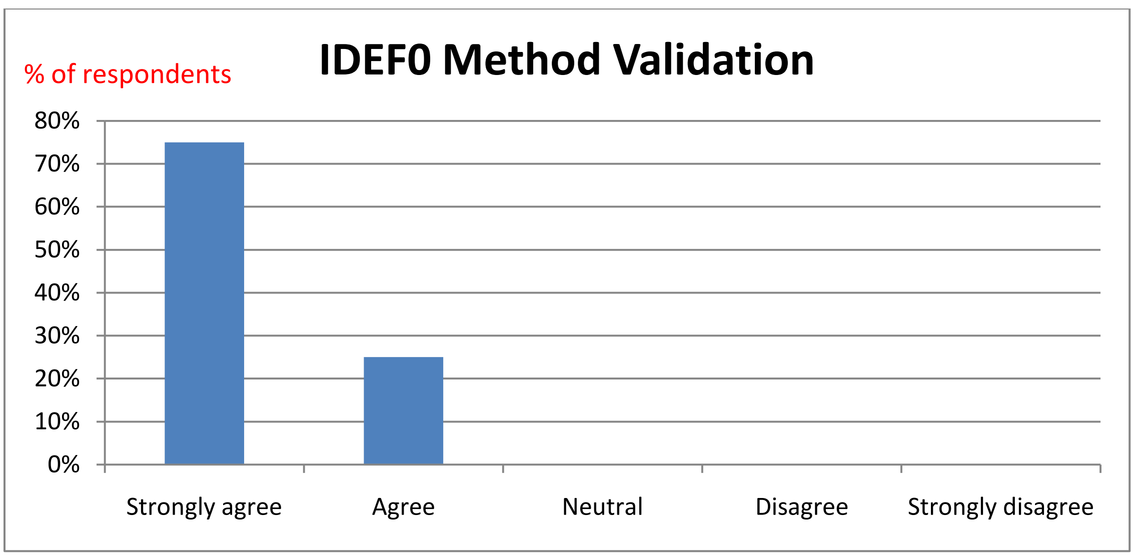

Figure 24: Survey Results, Validation

The following comments were made concerning this validation:

> The IDEF0 language provides a graphic representation of the encounter process which physicians can examine to clarify what is actually happening. I could see it being used as a foundation for further analysis performed to improve the quality of this process.

5.6 Conclusion

Overall, the goals of the survey in validating the content of the model and verifying its utility were achieved. All of the survey participants returned the questionnaire on time, and in spite of their own busy schedules, provided excellent usable feedback for the model. They were all strongly motivated by the purpose of the research and, though previously unfamiliar with it, were interested in using the IDEF0 language to represent the process they perform on a daily basis.

However, due to the time constraints of the participants' schedules and their limited resources, the participants were only able to attend a one hour training session prior to the survey completion period, and the actual survey was finished independently without face-to-face assistance. Additionally, the amount of time provided for completion of the survey had an adverse effect that was not intended. In the three weeks provided to the participants for completing the survey, the first week or two was often spent going about their normal schedule with little attention given to the survey, causing the effectiveness of the training to be decreased by the time the survey and model were given a detailed review. Several participants suggested that a scheduled time for the researcher to meet with the participating physicians would be better than an exclusively remote survey. In that case, the participant would have a clearer time for dedicated work on the model, would be given more opportunities for the developer to explain any points of confusion. Also, the model was printed on standard A4 paper and the diagram had to be shrunk to fit the paper. In this case, A3 or even larger paper would have been better to fully display whole diagrams. The diagram itself had some terminology developed for this process, and the descriptions were provided to the participants so that they could understand the meaning of those terms. However, the descriptions were given in the glossary separately from the diagrams, causing difficulty in applying them to the model. If all the particular descriptions were attached to their specific diagram, that would be easier for the participants to refer to the necessary information.

Despite these concerns, the verification and validation of the model returned favorable results. The next chapter will discuss these results and their implications in more detail.

Chapter 6 Model Application

6.1 Chapter Overview

According to Presley and Liles, the IDEF0 modeling methodology began to see use in generating functional requirements from its process models about fifteen or twenty years ago. Usually, efforts to develop specifications and requirements are varied and specific, depending largely on the subject at hand (Presley and Liles, 1995). In this chapter, the utility of IDEF0 applied to generating the specific requirements for the Healthcare Toolkit will be illustrated.

This chapter shows how the IDEF0 model is useful in generating requirements for the Healthcare Toolkit. To support this, preliminary examples of requirements derived from the model are provided. Additional requirements are available for review in the appendix, but it should be noted that both here and in the appendix the requirements are not finalized. They must be further revised, verified and validated by subject matter experts, and are provided here for illustrative purposes.

6.2 The Healthcare Toolkit

The idea of the Healthcare Toolkit originates in the myriad and sometimes cumbersome assortment of instruments used during physician-patient encounters. It is intended to combine the assessment abilities of these instruments with the mobility and technology of modern handheld devices, such as smartphones and PDAs. The benefits of such a device would be many: the increased convenience and ease of gathering vital information for physicians, the ability to carry around most of the functionality of a medical office in a handheld platform, and the instant integration of data into a medical provider’s records, to name a few. Moreover, the creation of a single portable device for medical data collection creates countless opportunities to increase the efficiency of medical encounters, and could reduce many healthcare costs related to time and special equipment needed.

6.2.1 Motivation behind the Healthcare Toolkit

Traditionally, coming to a diagnosis and making a full assessment of a new patient can often be a tiresome and tedious process. The physician must use specialized instruments for each bit of information gathered in the assessment of a patient: a stethoscope and blood pressure cuff to evaluate heart function and circulation, ophthalmoscope to view the eyes, an otoscope for the ears, thermometers, goniometers, spirometers, scales, and the list goes on. All of the information gathered with these tools is generally hand-written into a patient's physical file, which is also referenced when making the physician's diagnosis and can be many pages long. Although some cases are simple and can be handled quickly by these traditional methods, more challenging examinations may require an arsenal of tools, information, and expertise that may or may not be readily available to the physician. This can cause complications and delays that may be both expensive and dangerous, if the patient's condition is urgent enough.

In addition to the complexity of collecting data from a patient, several experts have shown concern over the integrity of that data as it is transcribed and managed over time. Handwriting and sign-over between physicians, among other factors, has led to a high risk of error in handling patient data (Fischer, Stewart, Mehta, Wax, Lapinsky, 2003).

Here, collecting the information and transferring it digitally from the same PDA-like device could significantly reduce those errors (Fischer, et al 2003). This combined with existing wireless and networking technology could greatly improve the efficiency and accuracy of patient examinations. As early as 2001, the Institute of Medicine recognized the value of an accessible electronic information infrastructure to be used in health care operations (Bodenheimer and Grumbach 2003).

Another implementation possible in the Healthcare Toolkit, mentioned earlier, is the functionality of providing instant access to reference information, at the point of care (Fischer, et al 2003). The ability of a physician to have medical journal articles, diagnostic codes, physician guidelines, and medication information literally in the palm of their hand could be an invaluable asset in increasing the quality of health services they can provide a patient. This would allow a physician to avoid adverse reactions between medications they prescribe, quickly reference the latest or most affordable treatments available, and could even allow a “second opinion” from a specialist in a greatly reduced amount of time, by transferring the information collected on-site instantaneously to another provider (Fischer, et al 2003).

With the invention of the Healthcare Toolkit, a possible platform for new medical software could be introduced as well. Similar software exists on all of today’s smartphones and PDAs, and specialized programs could be implemented into the Healthcare Toolkit to aid physicians. One example would be the transition of drug list programs to a handheld platform that provide information about the dosages, interactions, indications and contraindications of a drug, and even drug insurance coverage of various providers and plans (Bodenheimer and Grumbach, 2003).

There has already been some discussion of developing wireless devices to aid in medical operations, the functionality of which could be incorporated into the Healthcare Toolkit. For instance, a blood pressure cuff was explored that could continuously monitor a patient's vital signs (as in a disaster situation) until the patient has been admitted to a hospital (Gao, Greenspan, Welsh, Juang, Alm, 2005). The data could be wirelessly transmitted from the first responder's tablet PC and recorded into a database while being monitored remotely by physicians (Gao, et al 2005). Another case was catalogued in which 12-lead EKG waveforms were wirelessly transmitted and successfully interpreted using handheld devices (Fischer, et al 2003).

Having established the credibility and possibility of a device such as the Healthcare Toolkit, its designers must find the most effective means of integrating it into modern healthcare encounters. While this may not seem very difficult, the extreme complexity of healthcare encounters provides many areas where such a device might be used, and determining where it will help rather than hinder is in itself a complicated procedure. Because of the natural limitations to human thought, it is necessary to study the various operations within these encounters so that they may be analyzed for areas that could be made more efficient by the Healthcare Toolkit. The process of generating the requirements for this device starts with an accurate model of the physician patient encounter. That model, as previously described, now exists.

6.3 Developing Good Requirements

"Requirement" is a term used by engineering disciplines to describe what a product, be it a physical device or a service of some sort, needs to accomplish or be (Hooks, 1993). In the case of the Healthcare Toolkit, the requirements refer to the capabilities, dimensions, and other attributes that need to be incorporated into the design of the Toolkit so that it can be most effectively used in the healthcare encounter. Requirements are used and referred to several times in the development of a new product. The set of requirements make up many of the inputs during the design stages of development, and are referenced during the verification process by tests that assess the product's fulfillment of each requirement. They are the essential functions of a product, and the elements that must be integrated into a product's design (Hooks, 1993).

The requirements for the Healthcare Toolkit can be generated from the IDEF0 model of the encounter, but they need to be formatted and stated in such a way that they are clear and easy to comprehend. This means that all of the desired functions and sub-functions of the Healthcare Toolkit should be systematically described in a simple manner, telling exactly *what* each aspect of the Toolkit needs to do or achieve. The clearest way to state these requirements, then, is in simple sentences:

The Healthcare Toolkit (HT) shall provide (some information, service, etc.).

The HT shall provide means to (some function or action, etc.).

The HT shall incorporate (some existing or external functionality, etc.).

The HT shall weigh no more than (some amount).

While it may be tempting to simply provide a list of all the things the Healthcare Toolkit should do, each requirement will be individually tested and verified in the development process, and therefore each needs to be described by a separate statement. These statements are not explanations of how the device should operate, design ideas, or anything other than *what the device needs to do and be*. The other explanations have their place in rationale, or in an introduction to a set of requirements. To avoid confusion between requirements and other, often similar information, certain characteristics are provided that distinguishes well written requirements. (Hooks, 1993)

Foremost, a requirement describes an essential function or attribute of the device. It must have a reason that it is a requirement, and must be needed by the device. A simple question can determine whether a requirement is truly “required” of a device: What is the worst consequence of the device not meeting this requirement? If it is difficult to come up with an answer, the requirement may indeed be extraneous. Secondly, each and every requirement must somehow be verifiable. It has to be tested, analyzed, examined, or demonstrated to ensure the device meets that requirement. This means that the written requirement must be objective; requirements with wording open to interpretation are poorly written and unverifiable. Subjective adjectives such as “light”, “simple”, “useful”, etc. should not be used in a requirement. Requirements need to be tangible, quantifiable, and capable of being absolutely verified through some method. A tertiary quality to all good requirements is their real feasibility. It must be attainable with existing technology, and be possible considering all of the constraints of a project, such as the time schedule or budget. Each requirement should be researched to ensure that its implementation is actually possible, as there is no point in writing a requirement that cannot be met. And finally, as stated before, a requirement should be clearly and explicitly written. It should take the form of a simple sentence devoid of ambiguous or uncertain terms. (Hooks, 1993)

There is another important distinction that must be made when writing requirements: they are only concerned with *what* the device must do, not *how* it is to be done. While this seems simple, there are some cases where the distinction is difficult to detect, that can ultimately lead to an unintended design, or worse, missing important requirements. For example, a requirement concerning an attribute of the device might be written as such: The Healthcare Toolkit shall include a database. While this seems to be a good requirement (it has a reason for being, it is verifiable, feasible, and clearly stated), it concerns *how* something is done, not *what* it is that needs doing. The database may be included as a means to manage patient data, but then the requirement should be this: The Healthcare Toolkit shall have a means for managing patient information. If a database is the best way to do this, the engineers will implement it whether it is mentioned or not. However, if there is a better method, such as an interface to interact with remote servers that manage patient data and that are shared by the hospital’s records system, then requiring a database may cause the device to lose potential functionality, or otherwise inhibit it from reaching its intended conception. The other danger is even more difficult to detect. If the implementation stated (the *how*) does not sufficiently meet the requirement intended (the *what*), important requirements may be altogether excluded. In the database example, the functionality (*what*) desired may be the interaction with that remote database, in which stating the requirement of a database would not necessarily deliver what is wanted from the device. (Hooks, 1993)

6.3.2 Avoiding Requirement Pitfalls

Requirements serve as the guiding features for the rest of the design process, and as such are keys to a successful product. It is important that they are as efficient and useful as possible, and even very intelligent engineers can write substandard requirements if the correct conditions are not met. The three most common situations that lead to poor requirements are: sensing a lack of management interest, lack of necessary information, and lack of knowledge concerning requirements themselves and their applications. For the requirements generated for the Healthcare Toolkit, these pitfalls were consciously avoided in several ways.

These pitfalls are outlined by Hooks (1993). The first pitfall, sensing a lack of management interest, is a common condition of authors working on a tight schedule. Their supervisors have placed a great deal of emphasis on the timeframe; getting a list of specifications written so that the acquisition of the product may continue. The quality of the requirements is not stressed, and often the engineers have never seen a correctly done requirements list, nor seen the adverse effects of a poor one. Even an intelligent engineer making their best effort can hardly be expected to write flawless requirements given limited information, time, and guidance. The requirements will likely have to be rewritten several times before the project is completed. (Hooks, 1993).

However, in this research, a clear motivation was established from the outset and reinforced throughout the research process. The research took place over a year and a half, from the generation of the model to the requirements, while the researcher, professor, and multiple subject matter experts were involved to ensure the success of this research.

Hooks describes the second common pitfall to writing good requirements as a lack of information. The research plan is essential for all of the activities and components included, and without a grasp of this plan, it is impossible to create good requirements. The author must have a clear understanding of the scope of the research, its mission, and its operational concepts. She must know the overall goals, the current objectives, and the constraints associated with the project. In addition, the product itself must be thoroughly researched and all necessary background information and desired applications need to be known before requirements can be generated. If there is no access to, or a lack of appropriate information while forming the requirements, it is likely that incorrect assumptions will be generated, which can lead ultimately to a failed product. (Hooks 1993)

This was avoided during the Healthcare Toolkit research, as the objectives and goals of the requirements were clearly established: create a device that can improve the overall performance and efficiency of the healthcare encounter process. All designs of the product, even from different perspectives, serve that same goal. The product's constraints have been carefully reviewed by conducting research into currently available technologies relevant to the intended operation of the device, and all requirements can be verified for successful adoption into the actual product design. Dr. Bauer and other subject matter experts were heavily involved in correlating the ideas of the product with the intended function for the end user. A great deal of literature was reviewed to ensure that as many factors as possible were considered in the project, and the exploration of the feasibility of similar technologies can be examined in the E-health section of the literature review.

Finally, Hooks states that a lack of knowledge concerning requirements themselves can very obviously lead to poorly written requirements. Engineers are frequently asked to write, review, design according to, or verify requirements without having received the necessary training and instruction regarding requirements. They may have even made it through college without ever hearing the word "requirement" used in this practical sense. Intelligence gives them an idea of what should be done, but those ideas and the examples they think they have of existing requirements may be misinformed, misleading, or altogether wrong. Some engineers with many years of experience still lack an appreciation of the importance and qualities of well-written requirements. (Hooks, 1993).

6.4 Using the IDEF0 Model to Generate Requirements

The IDEF0 methodology is useful for generating requirements due to several of its inherent qualities. The first is that it often demonstrates a process from the perspective of the user. In this IDEF0 model, all activities are performed by the user; the physician performs each step of the medical encounter modeled and is the intended end user of the Healthcare Toolkit. A fundamental purpose of generating requirements is to better serve the end user and increase his satisfaction with the product, which correlates well with the IDEF0 perspective, as both address the end user's needs. The model shows the factors that affect the end user and the process, making it easy to identify the requirements of the activities and which areas of the process can be assisted by the device.

IDEF0 modeling provides a systematic way to view the activities and events during a process and facilitates the elicitation of information from a broad scope of the process to its detailed activities. All the important activities during the process are presented in the model, so if the model indicates that some activity is an important part of the process, the requirements of the Healthcare Toolkit should provide all the necessary functions to perform that activity. Also, the mechanism element of the model directly displays where an existing device is actually involved so that the requirements can focus on those activities.

Requirements should also be able to prevent the potential errors that could happen during the process. It is important that these errors be identified through an objective means, such as a process model, because the same fallibilities of subjective examination are the ones that cause human errors in the process (Lee, 2008). Several methods of human error identification use IDEF0 modeling as guideline to support their analysis, such as HEIM (human error identification method). By taking the results of error analysis into consideration during the generation of the requirement, the overall performance of the product will likely be improved.

To generate the requirements in this research, the activities in the medical encounter IDEF0 model were carefully reviewed for two qualities: their purpose and their potential risk of error. The purposes of those activities were collected and considered in terms of functionality, and then the specific functions were reviewed intensively as to whether or not they should be included as a requirement of the device. An informal error analysis was also conducted on the process model using information from the literature review, as well as input from the subject matter experts. Requirements were then generated from that analysis that was specifically designed to address those potential errors found in the process.

6.5 Requirements Overview

There are two major traits of the Healthcare Toolkit that the requirements concern. One is the physical properties of the device, such as its intended length, width, height, and weight, as well as the materials that it should consist of. For this physical set, the example guidelines were determined with the intended concept of a small, lightweight, and portable device. The other main trait that the requirements focus on is the functionality of the device. These features and capabilities were developed based on the model of the physician-patient encounter, taking into account the purpose of the major activities and then contriving functions or attributes of the Healthcare Toolkit that would be able to help achieve those purposes. The five preeminent activities of the encounter model formed the basis for five sets of requirements; one set each for "Establish patient-provider relationship", "Collect and integrate clinical information", "Diagnose condition", "Treat patient", and "Plan follow-up". Some of these requirements could not be fully developed because of a lack of parameters that depend upon further research, and where these specific parameters were not fully available *TBD* (To Be Determined) was presented as a placeholder. *TBD* indicates apportion of the requirement that must be replaced with a specific value upon further research, experimentation, and consultation with subject matter experts before requirement is finalized. Even though these specific parameters have not yet been determined, by using *TBD* as a placeholder these initial requirements can still be presented as examples for illustrating the process of generating them. While a detailed list of preliminary requirements can be found in the Appendix, this section provides examples of requirements from each set and demonstrates how they were generated using the IDEF0 model.

6.5.1 A1: "Establish patient-provider" relationship

In the A1 diagram (refer to Figure 12 in previous chapter), many control factors are established for the following activities, such as "shared goal" and "patient background".

The reinforcement of the importance of patient-provider communication occurs in this first activity because of the emphasis placed on it unanimously by physicians during the interview and observation periods. One set of requirements from this part of the model comes from avoiding any disruptions to the quality of communication between provider and patient. Researchers have found that interruptions during the patient-provider interview, while frequent, are harmful to both physicians and patients alike, and should be regarded as a major threat to the quality of the relationship between physician and patient (Urkin, Elhayany, Ben-Hemo, & Abdelgani, 2002). Additionally, the Healthcare Toolkit has the potential to become more disruptive due to its technological nature. According to Rhoads, et al, during the average doctor's office visit a medical professional looks at the computer at least once per visit, with an average of 66% of appointments involving use of a computer. Additionally, computer use during the office encounter accounts for more interruptions than any other type, including phone calls and knocks on the door (Rhoades, McFarland, Finch, & Johnson, 2001). As an electronic device, the Toolkit could be a source of interruptions while the provider is entering patient information, looking up information, or otherwise using the device. The set of requirements derived from the A1 diagram therefore focuses on facilitating this communication, and avoiding the interruption of it. When the physician is using the Toolkit to record a patient's information, it is important that the functions and features of the device are provided in a user-friendly interface that is simple, fast, and easy to operate.

Two examples of requirements in generated from this module are:

- The Healthcare Toolkit shall not require more than *TBD* seconds to process the information input by the physician on each page.

After information is collected from the patient, it needs to be transferred into the patient's electronic medical records. A long transfer time would decrease the efficiency of the encounter and jeopardize the patient-provider relationship. The specific amount of time will be determined based on several factors including the capabilities of mobile electronics processors, the impact interruptions of various length have on the patient-provider relationship, the number of pages that must be processed, and the frequency of processing periods during the encounter.

- The Healthcare Toolkit shall not require the provider to spend more than *TBD*% of the total time of an encounter in data entry.

The requirement is generated to guide how much data is required to be input by its users, affecting the amount of time the user needs to spend on the device. The user should not delegate more than a certain percentage of the encounter's time to the Toolkit, therefore, the preceding requirement was generated. The percent of encounter time will be determined based on research concerning the data entry times of currently used methods, and observation by subject matter experts of the length of time acceptable to record data during the encounter.

6.5.2 A2: "Collect and integrate clinical information".

The area that was focused on in this module was the interaction between the end user and the EMR system that occurs while conducting the medical examination. EMR systems have been widely used in the modern healthcare system because of their advanced data management capabilities and ease of use. This computerized medical record allows a physician to store, retrieve and modify clinical records. Even though the computerized medical record is not standardized in the United States, it is perceived favorably by physicians, and increases user and patient satisfaction, which leads to higher quality of the health service (Delpierre et al., 2004). The Toolkit needs to provide access to a patient's EMR so that the physician can easily review the patient's complete clinical history. Also, all the information captured in this encounter must be recorded in the medical record for future reference. So in addition to accessing a patient's EMR, the device should be able to update it. An intended function of the Healthcare Toolkit is to provide a physician with the functionality for physical examinations, and to allow the physician to record the actual data from an exam, such as audio and spatial data instead of the text-based results analyzed by the physician. By having the original data from the exam, the physician can view and reproduce the situation to make their own judgment, or more easily share the data with colleagues, to better understand patient's condition. To do this, the device must be able to not only record the examination data, but transfer this information (often analog) captured in the examination into digital data which a computer can reproduce and record in the patient's EMR.

The following example requirements are generated based on the diagram A24 "Conduct physical exam":

- The device shall display the patient’s vital signs (heart rate, blood pressure, respiration rate, and temperature) for the physician to review after conducting the exam.
- The device shall provide means to record the visual and auditory evidence collected from inspection and auscultation during the exam.
- The device shall provide means to transfer examination data to the patient's electronic medical records.

The physical examination is an essential part of the patient-provider encounter and happens in nearly every instance of it. Some examinations are performed in the patient room by the physician, and some tests are ordered from the lab which takes a longer time. In the diagram A24, “Conduct physical examination”, the most common examinations performed by the provider in the patient room have been represented. One of the included mechanisms of A24 is the tools needed to perform those exams. The Healthcare Toolkit is to be a wireless instrument that can be used in place of traditional instruments while performing a physical exam. To do this, it must be able to capture the examination information such as sounds, pictures or videos. This information should be displayed by the device while the user finishes the exam so that he can review the information to ensure the quality of the test. Also, the Toolkit must allow the physician to store that information and transfer it to the patient’s EMR records.

6.5.3 A3: Diagnose condition

The requirements generated for this diagram focused on how to provide decision aids to formulate better diagnoses. During the diagnostic process, the physician needs to generate alternate diagnostic hypotheses (the differential diagnosis), refute the unlikely diagnoses and eventually form the final diagnosis. Because of the complexity of this process and the amount of mental work involved, the potential for human errors is great without intelligent system assistance. Therefore, the Toolkit should help the user follow a systematic decision process that involves categorizing decision situations, selecting procedures, applying procedures, evaluating goals and alternatives, and collecting information about a specific decision situation (Power, 1998). The Healthcare Toolkit, as a device for aiding medical decisions, is acknowledged as a valuable approach to improving the quality of decisions and reducing the costs of the diagnostic process.

One example of the requirement from this module is:

- The HT shall allow the physician to review all the patient's clinical information collected and recorded during the encounter and other data existing in the EMR system.

This requirement is generated based on the A31 diagram, “Evaluate patient integrated information”, in which the physician reviews the information collected during the encounter and incorporates it with the existing information into the EMR.

Another example is:

- The device shall provide the symptoms of expected diagnostic hypotheses to compare with the patient's condition and symptoms.

This requirement is generated based on the diagram A34 “Refute unlikely hypotheses” and A35 “Confirm most likely diagnosis”. During these two activities, a list of expected symptoms for each possible diagnosis can be compared with what the patient is currently presenting. If there is any conflict between two, then the hypothesis could be rejected. Also, the hypothesis that has the closest matching symptoms could then be considered as one of the most likely diagnoses.

6.5.4 A4: Treat patient

The requirements generated for this diagram focused on how to provide all the necessary information to the user when choosing the treatment plan. Before generating this plan, the user must review the diagnosis and all the patient’s information to ensure that the treatment plan implemented is most effective in addressing the patient’s condition. Therefore, the Healthcare Toolkit should provide functions for the user to review patient clinic information at any time. It should also provide information concerning the contraindications of the possible treatment plans and medications to help endure the patient’s safety. Also, during this process the user often needs external resources to help make more accurate decisions. These resources include additional medical references or peer consultants who have specialized in the relevant areas. One requirement example derived from this module is:

- The HT shall allow the physician to review all the patient clinical information collected and recorded during the encounter.

This requirement is generated based on diagram A412 “Evaluate patient comprehensive information”, in which the physician needs to thoroughly review all the available patient clinical information before generating any treatments. The Healthcare Toolkit should provide these functions for the physician. Another example is:

- The HT shall present contraindications for any treatment that is being considered.

When the physician is choosing a treatment plan, the contraindications must be reviewed very carefully since overlooking this information may cause serious consequences, such as allergic reactions or even death. The Toolkit needs to provide these possible contraindications in order to avoid errors and implement more effective treatments.

6.5.5 A5: Plan follow-up.

The requirement generated for this diagram was focused on how the device can help the user to arrange follow-up plan with the patient. More often than not, a patient's condition cannot be remedied during a single encounter, and a series of consultations or an ongoing treatment may be required. To help orchestrate and organize this process, the Toolkit should have features that facilitate the smooth planning and scheduling associated with the follow-up. One example of a requirement that helps to achieve this is:

- The HT should have a calendar with the physician's schedule.

At the end of the encounter, the provider and patient will make a follow-up plan which invariably contains the date and time of the next appointment. To help the user keep track of this, the device shall have the provider's calendar with the schedule available so that the plan can be easily made.

6.6 Finalizing Requirements

The requirements presented in this chapter and in the appendix are preliminary examples developed from the model. Before they can be implemented into a final set of requirements for use in developing the Healthcare Toolkit, they will need to go through many phases of refinement and scrutiny. The *TBD* values must be researched and replaced with specific parameters to guide the development of the Toolkit, and each requirement must be verified and validated by subject matter experts. The process of finalizing a set of requirements for the Toolkit will involve a coordinated effort by engineers, subject matter experts, and researchers, and is outside the scope of this thesis. However, the process for generating them from the IDEF0 model as well as examples providing the form and utility of the Healthcare Toolkit requirements have been provided in this chapter.

Chapter 7 Discussion and Conclusion

This chapter consists of a discussion of the results of the modeling verification and validation, focusing on the opinions and feedback given by the subject matter experts. The details and data collected from them concerning the correctness and completeness of the model are examined, and their feedback summarized. This feedback offered valuable information regarding several aspects of the healthcare encounter model. Among these are the overall effectiveness of the IDEF0 methodology and its strengths and weaknesses as a tool used to simulate the healthcare encounter, an assessment of the impact and value of the research during the creation of the thesis, and the recommendations for the improvement of the model and requirements of the Healthcare Toolkit. The recommendations are presented with the goals of further developing the methodology to increase its accuracy and efficiency, refining the methods of testing the model, improving its usability, and further investigating the range of its application. A thorough discussion of the model and IDEF0 is provided to assist in their overall improvement, and details of the model are used to help generate an expanded set of requirements.

7.1 Discussion of the Model

The physician-patient encounter model was created to be several things: a systematic approach to understanding the encounter process, a tool for the generation of the Healthcare Toolkit's requirements, an example of applying IDEF0 to the healthcare field, and a reference for future research concerning healthcare or the encounter. This section offers a review of the model in its ability to fulfill those roles, examining its quality, accuracy, and limitations. Much of this discussion is derived from the comments and scrutiny of the subject matter experts, so their specific criticisms are provided and addressed in this section.

7.1.1 Quality and Application of the Model

The model of the physician patient encounter was generally agreed upon by the physicians to be complete and accurate. Overall, 57% of the statements concerning these qualities were agreed with by the subject matter experts, and an additional 41% of the statements in the survey were strongly agreed with. The remaining 2% of answers showed disagreement with the statements in the survey. This indicates that the model well represents the encounter process conducted by these physicians in their daily practice. As such, it is extremely applicable to this environment, which specifically is an encounter between one patient and one provider in an office setting. As this environment represents the virtual entirety of clinical encounters, the encounter model can be used as a correct reference for researchers concerned with the encounter, and a means for generating useful and appropriate requirements for the Healthcare Toolkit.

However, in rare instances where the environment of the encounter does not correspond with that described, the actual process may deviate from the one modeled. While the literature reviewed for this thesis indicated that the general encounter process is the same throughout the country, the majority of tangible observation, as well as the practice of the subject matter experts, was located in a relatively small rural hospital. Though there was nothing to indicate this in the research, it is unknown whether the process might be modified in instances of large, high volume hospitals. The goals of the process should remain the same in these environments, but the added objectives of time management and serving large populations could cause the encounter to be conducted in slightly different ways. Another instance of the environment not corresponding to that modeled is when the encounter takes place outside of an office setting. While uncommon, atypical house visits or public emergency encounters (such as on an airplane), may depart from the encounter model. Since no research indicates this however, and the occurrence of such encounters is rare, the model can still be said to provide a reasonably complete and accurate representation of the physician-patient encounter.

7.1.2 Limitations of the Model

Models can help to improve the quality of medicine practiced, and better practice is a hoped-for effect of efforts to analyze and examine the encounter process. However, it must be recognized that these representations do have flaws and limitations. The encounter model matches well with current medical knowledge and the procedures used by clinicians in their practice, and the results of the clinical study could well be used to guide a physician's performance of the diagnostic process. The limits to the model arise in situations that are unexpected and unprepared for even within the scope of medical practice. For instance, many times in medicine a set of symptoms will overlap multiple diagnoses, and may be indicative of multiple pathologies in the patient. While this is conceivably represented by the model, the complex process of determining multiple conditions simultaneously is not, nor is the concept of investigating conditions previously unknown to medicine. How should the model deal with pathologic entities not clearly delineated in the list of known or recognized diagnoses?

Another limitation is not directly a part of the model, but comes from the perceived purpose of it. One of the surveyed subject matter experts provided a consideration for the model that was the inclusion of specific algorithms used in diagnosing and treating a patient's condition. While these algorithms could form key nodes in the diagnosis and treatment modules of the model, their inclusion could easily lead to an overwhelming amount of information, and their relevance to the scope of the model is questionable. The procedures and processes represented in the model describe the practice of the physician-patient encounter, and it is not intended to be a guide in the treatment and diagnosis of specific conditions. Representing how a physician responds to a specific symptom, i.e. "chest pain", is an activity that falls in the grey area between decomposing the activities of the model and using the model to provide medical advice, which it was never intended to do.

Despite the specific changes proposed to the model that cannot be incorporated due to scope, there are other limitations for the encounter model. First of all, the model was developed by an engineering student who has limited medical background. More medical background information should be researched, especially concerning the diagnosis generation process, so that the model better represents the standard procedures that were integral to the physician's medical education, instead of the interpretation of those procedures from an engineering perspective. Also, as previously stated, the information collected during the interviews and observation was from a specific rural hospital, which limits the variety of the resources. Furthermore, the boundaries of the model limit it to representing only one-on-one encounters, making it less applicable to conferences between multiple physicians or specialists, or encounters between a physician and the patient's family, as are common with minor patients.

7.1.3 Criticism of the Model and Response

This section is an overview of the specific comments provided by the subject matter experts during the verification and validation process. The experts gave useful information in improving the model on a detailed level, and much of their feedback will be incorporated into future versions of the model. However, some of the criticisms given concerned aspects that were outside the scope and relevance of the model, or that the implementation of which would detract from the intended purposes of the model. The following discusses these comments and addresses their incorporation into, impact on, or exclusion from the model.

The experts provided several specific points of interest concerning the model. Relating to the two broadest levels, A-0 and A0, the physicians verified the correctness of the included elements in both their accuracy and significance to the encounter process, though in terms of completeness some additional advice was given. The inclusion of items such as the patient's financial information and insurance status was suggested, along with prescribed medications, legal guidelines and requirements, consulting physicians, and additional medical staff.

It was recommended that the financial and billing history of the patient be included as inputs for level A-0, the overview of “Conduct medical encounter.” The participant also suggested including the patient’s insurance coverage as a control during this activity, and stated that the financial information of the patient should be segregated as a mechanism from the term included in the model, “Information systems”. The complicated aspect of healthcare concerning insurance providers and the various means of organizing health providers according to the state of patient insurance was indeed researched during the literature review process. However, it was later excluded for various reasons concerning the shifting state of insurance and the intended purposes of the model. One of these reasons is the current fluidity of health insurance providers and laws in the United States. Since the entire system is in a state of transition, i.e. the oft broadcasted “Healthcare Reform” taking place in the government, patient insurance information that is relevant now may be much less so in as little as 3-5 years. Additionally, while this financial information may affect the availability of specific treatments and medications, it does not affect the means of executing the activity A4 “Treat Patient”. The procedures and goals of the activities A41 “Create possible treatment plan” through A45 “Implement initial treatment” are unchanged by a patient’s financial information. Additionally, the control “Patient factors” is provided in its place, which affects each of the activities during the process of determining treatments and medications, and as a control “Patient factors” logically includes the ability of the patient to afford their treatment. If the reform of healthcare causes specific insurance information to become less relevant, “Patient factors” will remain completely applicable to the model of the healthcare encounter. One participant offered a great proposition for the method that the “Diagnose condition” diagram (A3) is represented. In order to make the model more accessible and transparent to physicians, the module that deals with the evaluation of clinical information (A31) needs to smoothly integrate the concepts of medicine into the model. By correlating the nodes therein with the terminology and approaches used by medical textbooks, the physicians reading it would achieve an instant recognition of the module’s content, when compared with the terminology currently provided in the model to describe the process. It would be beneficial to the subject matter experts to use the textbook phrases and actions to refer to compiling a medical history, incorporating the findings from the physical exams, forming a “differential diagnosis” and paring that down to a most probable diagnosis, and arranging follow-up care. Using common medical terminology like “Chief Complaint” instead of “Patient perceived problems” or “Generate Differential Diagnosis” instead of “Generate diagnostic hypotheses” would aid the physicians in better understanding the concepts in the model. This criticism is relevant to the goals of the model, and incorporating it into the model would increase the accessibility to physicians and strengthen the bridge between the medical and engineering fields that is present throughout this research.

Another comment concerned an aspect of diagnosing in a clinical setting and stated that it could have been better represented using this methodology. This aspect is the mental process that the physician goes through in forming his list of hypotheses, his “differential diagnosis”. The model provides terminology such as “Updated physician understanding”, but the subject matter expert stated that this poorly expresses the thought processes of the physician. The majority of mental work that the physician performs is in sorting and logically manipulating the clinical data. He does this based on the specific characteristics of the patient: their medical history, symptomatology (the set of symptoms present in the patient that indicate specific conditions), family history, physical findings and characteristics, lab results or other tests. A great example provided in the feedback for the model was the diagnosing and treatment of a patient with chest pain. If two different patients came in the same day complaining of chest pain, the lifelong smoking, overweight patient with a family history of high blood pressure would be assessed much differently from the vegetarian who runs half-marathons once a year. The integration of this information and the process of mentally forming a probabilistic prediction could be more clearly shown in the model, but due to the quirks and inconsistencies of human thought and performance, the full decomposition of this process could probably not be provided. In future revisions of the model, A31 “Evaluate integrated patient information”, A33 “Generate diagnostic hypothesis”, and A35 “Confirm most likely diagnosis” should be updated with mechanisms, inputs, and outputs that more specifically reference the cognitive process of the physician.

7.2 Discussion of IDEF0 Methodology

The capabilities of the modeling methodology chosen are crucial in creating a complete and representative model of the encounter, so the IDEF0 methodology must be closely examined for its ability to achieve a quality model of the encounter. Since this model is used not only for representing the process, but also in generating requirements for a medical device, the utility of IDEF0 for performing this function must also be addressed. While the subject matter experts' response to the model indicated an approval of the language for modeling this encounter, there existed nonetheless some difficulties and limitations of the methodology that will be addressed in this section.

7.2.1 Suitability for the Encounter Model

The survey showed that the physicians agree or strongly agree with IDEF0 as a good tool to represent the process of the physician-patient encounter. Overall, it was capable of completely representing the encounter process with a high degree of accuracy. However, some problems arose in using the methodology from a non-engineering standpoint, and the utilization of the methodology for modeling a healthcare process proved to be tedious and time-consuming. Here the adequacy and appropriateness of the IDEF0 language for modeling the physician-patient encounter is analyzed.

7.2.1.1 Advantages of IDEF0 Methodology

The IDEF0 language can represent the flow of activities and accurately describe the relationships between them, including the dependencies of certain activities on others and the elements that are crucial to a given process. This is useful in modeling the physician-patient encounter because of the large quantity of elements present at each stage of the encounter. For instance, during the specific activity A21 “Characterize symptoms of urgent problems”, the activity is affected by the provider’s and patient’s understandings of the symptoms, the patient’s medical history, the facilities, tools, and environment that the activity takes place around or in, the equipment and EMR systems present, etc. The outcome of this activity then affects the following four activities in different ways, and all of these relationships can be accurately represented by IDEF0.

Another key advantage of IDEF0 is its capability of providing the flow of information in both a hierarchical sense and a parallel one, for dependent processes or simultaneous ones. This is useful for the encounter when activities might be conducted in different orders or excluded altogether, as in the case of the A24 “Conduct physical examination” diagram. The complete decomposition of this level provides numerous examinations and the elements used in performing them, but their relationship to the encounter and overall purpose remains clear. It can also provide a description of the mental processes undertaken by the physicians, updating these processes after each activity performed in the encounter. In possessing these capabilities it is a good tool for modeling the physician-patient encounter.

7.2.1.2 Limitations of IDEF0 Methodology

While capable of representing the encounter process well, the IDEF0 language has some drawbacks when applied to medical processes. As a product of engineering disciplines, the accessibility of the language to medical experts is somewhat obstructed by differences in education and experiences. Since it is used here as a bridge providing an engineer's analysis of a physician's process, the information it displays must be available to both parties. The subject matter experts for this process were all physicians, not engineers. They reported during the survey that IDEF0 is not a readily intuitive language for them, with concepts of the methodology being difficult for them to apply to their own practice. Of particular concern was the relationship of the parent-child diagrams. For the subject matter experts, the terminology "parent-child" is confusing and the concept of decomposition between the diagrams was not readily grasped. Because of the physician's extensive training in a non-engineering profession, the adoption of the model may take some time for them, familiarizing themselves with the recondite language and concepts of the methodology.

A second disadvantage of the IDEF0 methodology is the amount of time required to create a detailed process model. In order for the complexity of the physician-patient encounter to be fully delineated, each element must be repeatedly addressed for its application and effects on the activities within the process. When compared to methods commonly used to develop process models in other fields, this takes a great deal of time and repetition. While some of this may be a product of the relative complexity of medical processes, it can nonetheless lead to an overwhelming amount of information that must be assimilated into each activity and ordered correctly, and the resulting product can be difficult to navigate while keeping conscious of the overall scope and concepts of the model. It is easy for the reader to deviate and lose track of the content, due to the complexity of the IDEF0 encounter model.

Thirdly, the IDEF0 language is relatively inflexible when trying to incorporate information that doesn't directly affect the process. As an example in the encounter model, trying to represent the ongoing thought process that the physician has during the process of finding a diagnosis was difficult to adequately represent. A compromise had to be made by creating "Physician's updated understanding" as an output of various activities. The original intent was to provide much more information, to represent the actual changes and thoughts that occur while the physician manipulates clinical data. However, there is no notation in IDEF0 to constantly add and update this information, and no way to implement one.

7.2.2 Utility of IDEF0 for Generating Requirements

IDEF0, in addition to guiding the development of the model and the representation of the process, needed to be used as a tool for generating the requirements for the Healthcare Toolkit. It fulfills this role well, providing the framework for generating both functional and system requirements. So long as the technology available to the Toolkit was applicable to the process, requirements for the toolkit could be drawn from the goals of those processes. By including functions that are conducive to attaining the individual purpose of each activity, or functions that simply perform that activity, the Healthcare Toolkit can be engineered to be an effective instrument in increasing the efficiency and quality of the physician-patient encounter.

However, using this approach to generate the requirements from the IDEF0 model is limited in what it can provide. The conditions that satisfy the necessary elements of the requirement are limited only to providing the necessary functions to perform the task, as these requirements are found by determining if a given activity goal can be benefited by an available technology. While this clearly helps determine what the Healthcare Toolkit needs to do, it provides very little insight into what the Toolkit needs to be. Physical characteristics of the device are difficult to determine from function alone, and a great deal of examination and insight are required to draw this information from the model. For example, the need of the device to be small enough as not to obstruct any part of the encounter is obvious, but the specifics of its necessary size and weight are difficult to determine from the process model alone. Subject matter experts, researchers, and engineers must all play a role in determining specific parameters.

The Healthcare Toolkit should also help to reduce the errors that may occur during the encounter by providing solutions to minimize those possibilities. To draw these requirements from the IDEF0 model, an in-depth error identification analysis must be conducted and the remediation of each error found must be researched. This has not been completed yet for the encounter model. Though the IDEF0 model can directly provide requirements for the primary functions of the device, it must be extensively analyzed for other functional and physical requirements. Because of the extra procedures that must be undertaken to form a more complete set of requirements from the IDEF0 methodology, it is not an optimal utility for generating them.

One final consideration is the verification and validation of the requirements generated from the model. As previously stated, there is some difficulty for medical professionals in conceptually understanding IDEF0, but it is these experts who must verify and validate the requirements from the model. As the accuracy and relevance of each requirement is contrived from the related elements in the IDEF0 model, a thorough grasp of the methodology is needed to review them. From a physician’s standpoint, this is not very conducive to a straightforward verification and validation, as the physician must familiarize himself with the IDEF0 language to a high degree in order to correlate requirements with the model elements they are drawn from.

7.2.3 Criticism of IDEF0 and Response

The participants provided relatively little comment on the IDEF0 language apart from their initial concerns with the means it uses to conceptually represent the activities. While the “parent-child” diagram structure was initially foreign and confusing to the physicians, they eventually achieved a level of understanding and comfort with it necessary for evaluating the model. While seemingly minor, the accessibility of the modeling language to healthcare professionals should be addressed and improved upon.

One possible remediation of this could be the incorporation of the medical professional's point of view in the initial IDEF0 training. Some of the confusion from this training was due to it being given from a purely engineering perspective and background, while the participants were educated and experienced from a medical standpoint. By having medical experts consult the design and delivery of the IDEF0 presentation, points of confusion could be eliminated from the training by using concepts and terminology more familiar to medicine. A bridge could be made between the engineering terms using explanations relevant to a medical background. Some of the confusion that arose here could be due in large part to the engineering perspective of the IDEF0 training for this thesis and survey.

7.3 Contributions

The research completed for this thesis has made several contributions to the human factors engineering and process modeling fields. Foremost is the establishment of the IDEF0 methodology as a capable and compatible tool for approaching the systematical modeling of processes in the healthcare domain. The versatility of this trans-discipline methodology provided an opportunity for engineers and healthcare professionals to utilize one another's specialties and apply this cooperation in improving this healthcare process. There has been a growing acceptance of systematic modeling as an approach to developing more efficient and higher quality services, and this model solidifies this acceptance by demonstrating the usefulness of the system modeling concept.

Throughout this thesis research, the role that IDEF0 can play in generating the requirements for a device was demonstrated. The IDEF0 model is constructed using a series of principal activities of a process and providing all of the details and elements that allow that process to happen: the controls that guide the process, the mechanisms that allow it to happen, and the relationships between the process that are given in IDEF0 as inputs and outputs. This allows the specific functions of a device to be derived from the model, as the goals of the activities and the way that they are executed are completely described. Also because of the inclusive construction of the language, the model can be expanded far beyond the scope of the medical encounter, and future models concerning healthcare or the encounter could easily integrate the contained information into their own representations. Throughout this thesis, the basic concept of enhancing knowledge supported by the process model was developed and tested, and in doing so the methodology was shown to be applicable and relevant not only to the physician-patient encounter but to healthcare services as a whole.

Specifically, this model gave a context and a definite guide for the creation of the Healthcare Toolkit. The preliminary requirements were readily gleaned from the goals of the modeled processes, and the additional information given about those processes helped to generate more specific requirements for the device. It is likely that the applicability and efficiency of the device will be positively impacted by the model, as it would be used to prevent possible conflicts between characteristics of the device and the conduct of the medical encounter. Likewise, modeling the process formed a reference to help prevent human errors from occurring during the actual physician-patient encounter. This suggests that the contributions and impact of this model and the IDEF0 methodology to healthcare organizations and the individuals involved in the process would be significant and positive. Evaluation of the IDEF0 methodology by the physicians suggested that it is effective, practical, and applicable to the healthcare industry in general.

7.4 Conclusion

Though imperfect, the physician-patient encounter model and the IDEF0 language used to create it were very probably the best means for representing this process. The great majority of the model was complete, correct, and understandable by the physicians, and its utility in the ongoing improvement of the encounter process is easily perceivable. It has been demonstrated that IDEF0 is a capable methodology for describing healthcare processes, despite the inconveniences associated with its use. For generating requirements, however, it definitely leaves some room for improvement.

Most of the drawbacks of the model and language arise from the initiative nature of this thesis, and can easily be remedied in future research and healthcare modeling projects. As an early attempt to model a healthcare process, the encounter model pioneered a bridge between the capabilities of industrial engineering to improve a process, and the vastly complicated operations of healthcare, specifically the physician-patient encounter. The difficulties that arose from this were for the most part based in misunderstandings between the two disciplines. The integration of medical experts into more of the model development processes would be a key step to be taken in creating models that are more accessible to healthcare professionals, and that alone would prevent much of the hindrance present during the creation of this model.

The following chapter presents recommendations for changes to future versions of this model and future attempts to model healthcare processes in general. These recommendations, when implemented, will help solidify the connection between engineers and healthcare professionals, and should be conducive to a more fluid and easily conducted modeling process.

Chapter 8 Recommendations

This chapter discusses the areas in the model where improvements could be made. The recommendations are presented with the goal of developing a more advanced and detailed model, developing more analytical methods to generate requirements, and creating more complete requirements and a more comprehensive survey.

8.1 Improving IDEF0's Utility

While clearly capable of representing all the information vital to the encounter process, the IDEF0 language has a couple of minor problems. It causes difficulty when presenting information to non-engineering disciplines, it is difficult to derive complete requirements from, it is cumbersome in places due to its large amount of detail, and it is inflexible when additional forms of data are wanted. For example, if the author of an IDEF0 model wanted to include notes of a specific mental development that coincides with the process modeled (such as a physician's thoughts while diagnosing), there is no syntax available for this information, and no means of modifying the language to include it.

One troubling characteristic when using IDEF0 for developing the model and generating requirements for the healthcare toolkit is the amount of time it requires. The research, undertaken by a graduate student who divided her time between coursework, research and internship, lasted close to one year. This is a significant amount of time when compared to methods commonly used to develop process models and generate requirements, and if the methodology is to be widely used in the healthcare industry, it needs to be more time efficient. A possible remedy of this issue could be compacting the methodology, which requires that each attribute of and process included in the methodology be examined. Several points should be kept in mind if this is done, including the complete description of the medical encounter process, or the significance and value of requirements added to the Healthcare Toolkit for its user. An accelerated IDEF0 modeling process would significantly increase the value of the methodology for healthcare organizations. Possibly there are ways of analysis that could more quickly generate requirements that have not been investigated, and future versions of the IDEF0 model should give consideration to the possibility of better integrating the requirements process with the methodology.

Another improvement that could be made to the methodology is the integration of a means of error identification. Currently, to derive certain requirements from a model necessitates an error identification analysis to be done, requiring additional software and resources. This analysis finds the possible consequences that can arise from the process when the something in the process goes wrong. Similarly, the language would benefit from an integrated Failure Mode and Effects Analysis (FMEA), which would identify the areas of the process that are most at risk of deviation from the expected outcome. By integrating these procedures into the IDEF0 modeling process, the utility of IDEF0 for generating requirements would be significantly increased.

Another recommended change to the IDEF0 language would be to increase its flexibility. Some processes require additional information that simply does not fit within the boundaries of “box and arrow” diagrams. As given with the previous example, the developing mental process is constantly changing, and requires a notation separate from “mechanism”, “control”, “input”, or “output”. By providing a means to apply additional, ongoing, or separate information or notes to a single element (i.e. “Physician’s updated understanding”) at different points in the model, this could be resolved.

8.2 Improving the Encounter Model

While the encounter model created during this thesis research is generally complete and accurate, it has many areas that should be improved upon. The model should be able to better represent the tools, systems, and human activities that the process consists of, by providing more detailed descriptions of each. Simple references and titles are sufficient to represent the process, but the model needs an area of detailed description for concepts that are not representable by a simple verb phrase. For this model, much of the confusion or inaccuracies were a product of using engineering terms to describe a medical process. By having subject matter experts become more involved in the creation of the model, rather than only its verification and validation, the terminology used in the model would be more identifiable and familiar from a medical perspective. Additionally, more medical references need to be researched and observation of the physician-patient encounter should be continuously conducted in several different environments. The application of this model is limited by the specific environment observed, and to increase that application range requires observation and verification in several different settings. Also, more participants need to be involved in the survey since the process performed by individual physicians is extremely varied, and only a larger number of the participants can increase the credibility of the validation results.

Another recommendation for increasing the utility of the model would be to provide parallel models that are tailored towards different medical specialties. While this may at first be an arduous process, using the generic model as a baseline would significantly reduce the work needed to create these models. The benefit of this would be a greater degree of accuracy when dealing with the many specialties in medical practice, allowing a specific model to show only the exams and procedures relevant to that specialty and reduce the amount of cumbersome excess information, while increasing the amount of relevant information that is specific to the specialty encounter.

8.3 Improving the Verification and Validation Processes

Another area that needs to be improved is how this research was validated. Points of concern include the construction of the questionnaire, the generation of questions for the questionnaire based on both a verification perspective of the model to ensure it is correct and complete, and the validation perspective of the model to ensure if the methodology is applicable to the healthcare encounter process. The questionnaires that were given to the physicians consisted of two types of questions: degree of agreement and open ended comments. Based on the results, almost 80% of the questions were answered as agreed to, from which some doubt arises that the participants gave a necessary degree of attention. Another related issue regarding the questionnaire is the way the questions were formulated. In many cases, a single question was designed to probe for all of the components included in a diagram, which in some cases were more than 20 in number in complex modules. Even though the list of individual components was presented after the question, it is very likely that some components were missed while the physician scanned over the diagram.

To remedy this issue, it could be advantageous to limit the time to answer the verification and validation survey to a specific period that follows briefly after the instruction. The participants should be given sufficient time to review the model, but not more than a day or two, so that the focus given to the model and survey is increased. By then completing the survey shortly after that careful review, the training should still be fresh in the participants' minds, and their focus should not have drifted too far from the model or survey. Additionally, the validation of the model should be conducted by more specific questions in the survey. Instead of the general questions about the model's usefulness, the validation should consist of its own section with an area for open-ended comments. The questions therein should address specific applications of the model, such as its utility in generating requirements, or its ability to provide a reference for other researchers, rather than a simple "will the model be useful" or "does the model apply to the process".

8.4 Improving the Healthcare Toolkit Requirements

Lastly, the requirements of the Healthcare Toolkit were not validated due to the research mainly focusing on providing real example of applying the model to this healthcare process. However, without the validation, the value of the requirements is significantly decreased. Later versions of the requirements should contain much more detail in order to specify what should be included in the Toolkit and what needs of the encounter the Toolkit should meet. The requirements should also be generated based on a scientific analysis of the model. One advantage of the IDEF0 model is that there is a large number of independent analysis applications that can applied for this purpose that use existing models as a foundation. One good example is the Human Fallibility Identification and Remediation Methodology (HFIRM) database (Thompson, 2008), which contains an extensive collection of human fallibilities, and provides the analyst with instances of human fallibilities in the model and their remediation. This analysis should be performed on the IDEF0 model to identify the possible human errors present during the process, and used in generating requirements to remedy these potential errors.

To improve the quality of the requirements, research and interviews with subject matter experts need to be conducted to find specific parameters in place of "*TBD*", to be determined. Research should be done on errors during an encounter, and what caused those errors, in order to avoid them through requirements. Another investigation that should be made is that into existing devices that are similar in nature or function, and the problems that those devices commonly cause or have. Requirements can then be made for features that eliminate or minimize those problems.

Finally, a thorough verification and validation should be performed on the requirements by both subject matter experts and experts on writing requirements. This would ensure the quality, usefulness, and applicability of the requirements list.

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Appendices:

A: Physician-Patient Encounter Model

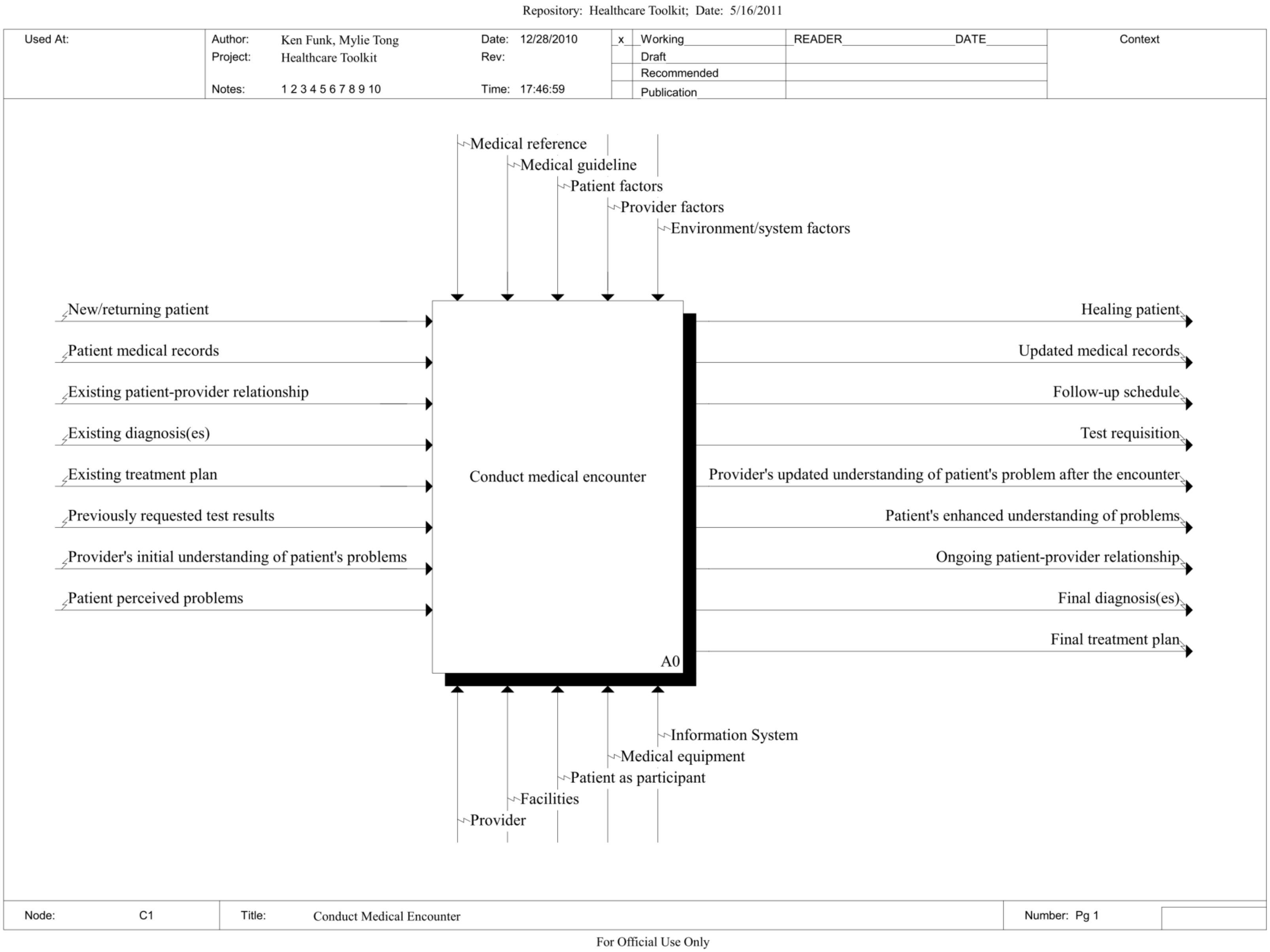
B: Model Description

C: Survey Questionnaire

D: Healthcare Toolkit Requirements

E: IRB Exemption Letter

Appendix A: Physician-Patient Encounter Model



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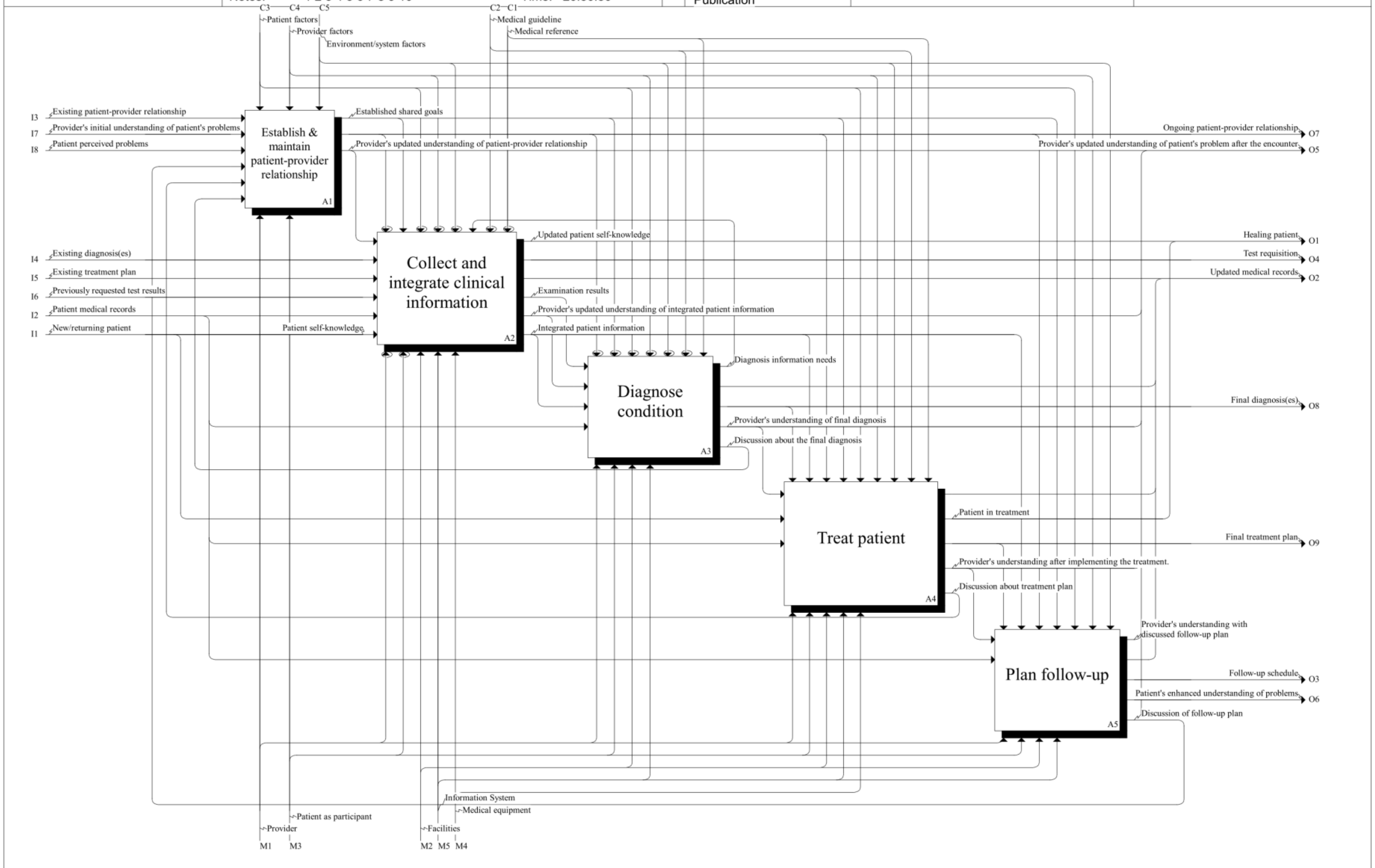

Node: C2	Title: A0: Conduct medical encounter	Number: Pg 2

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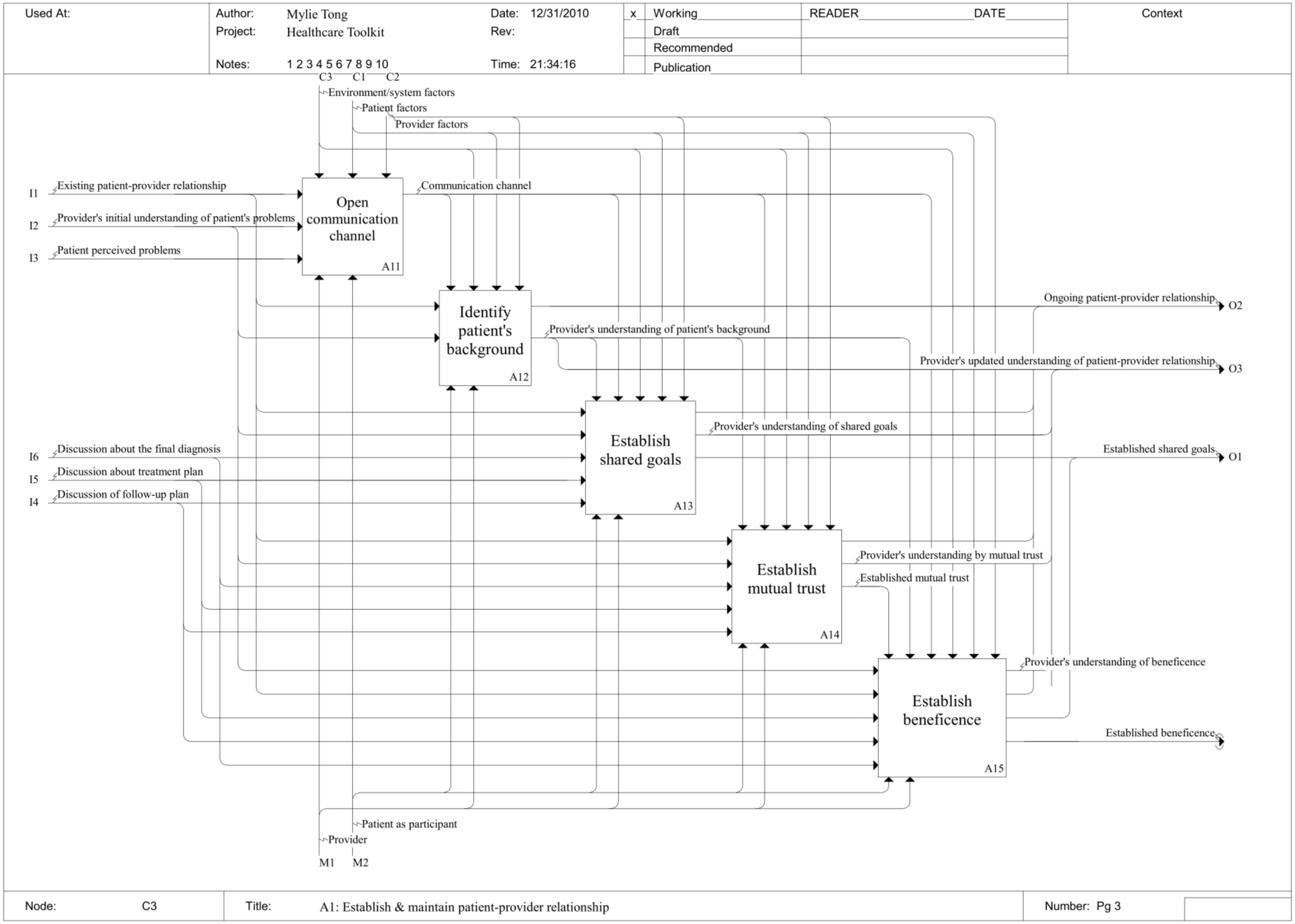

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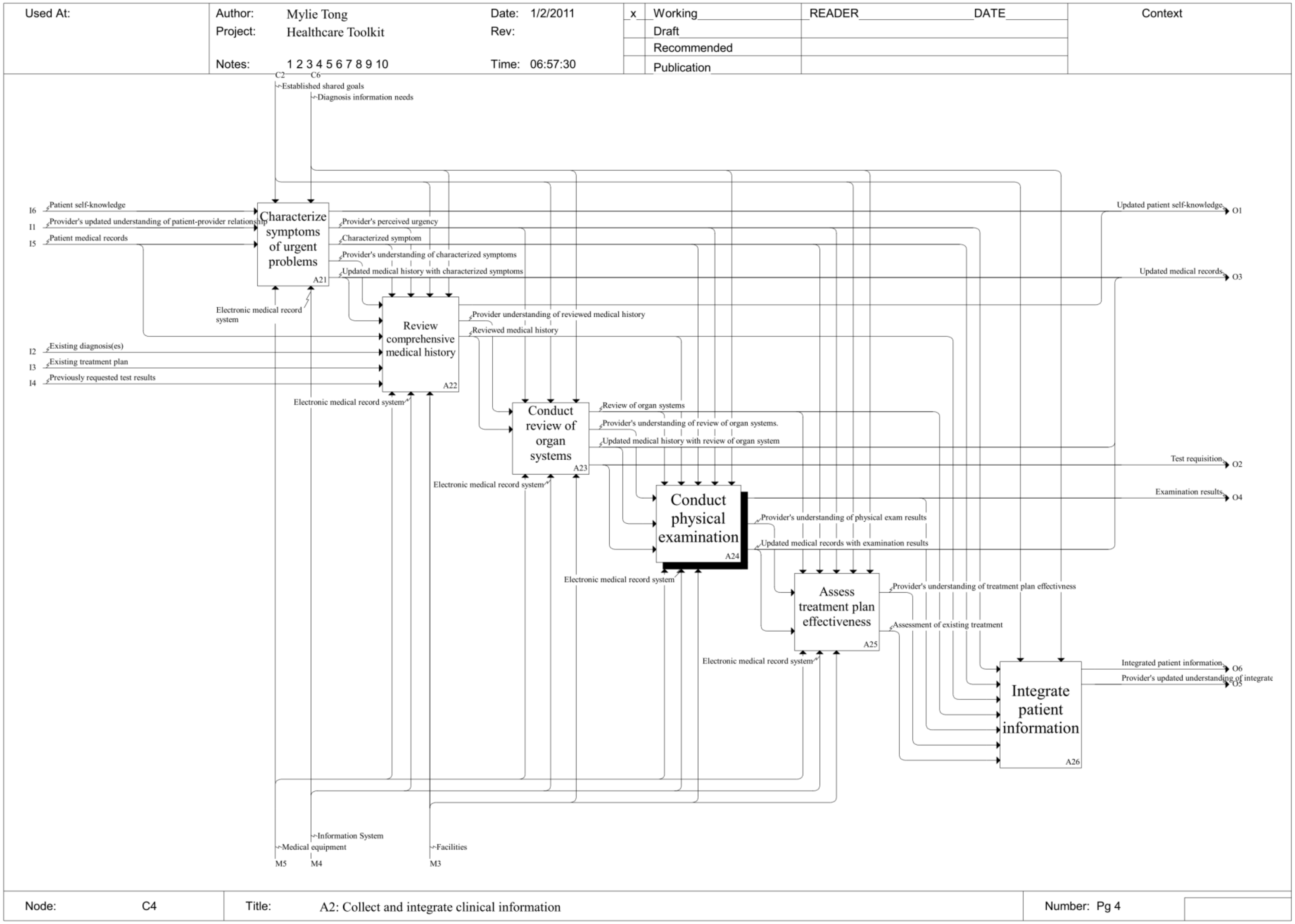

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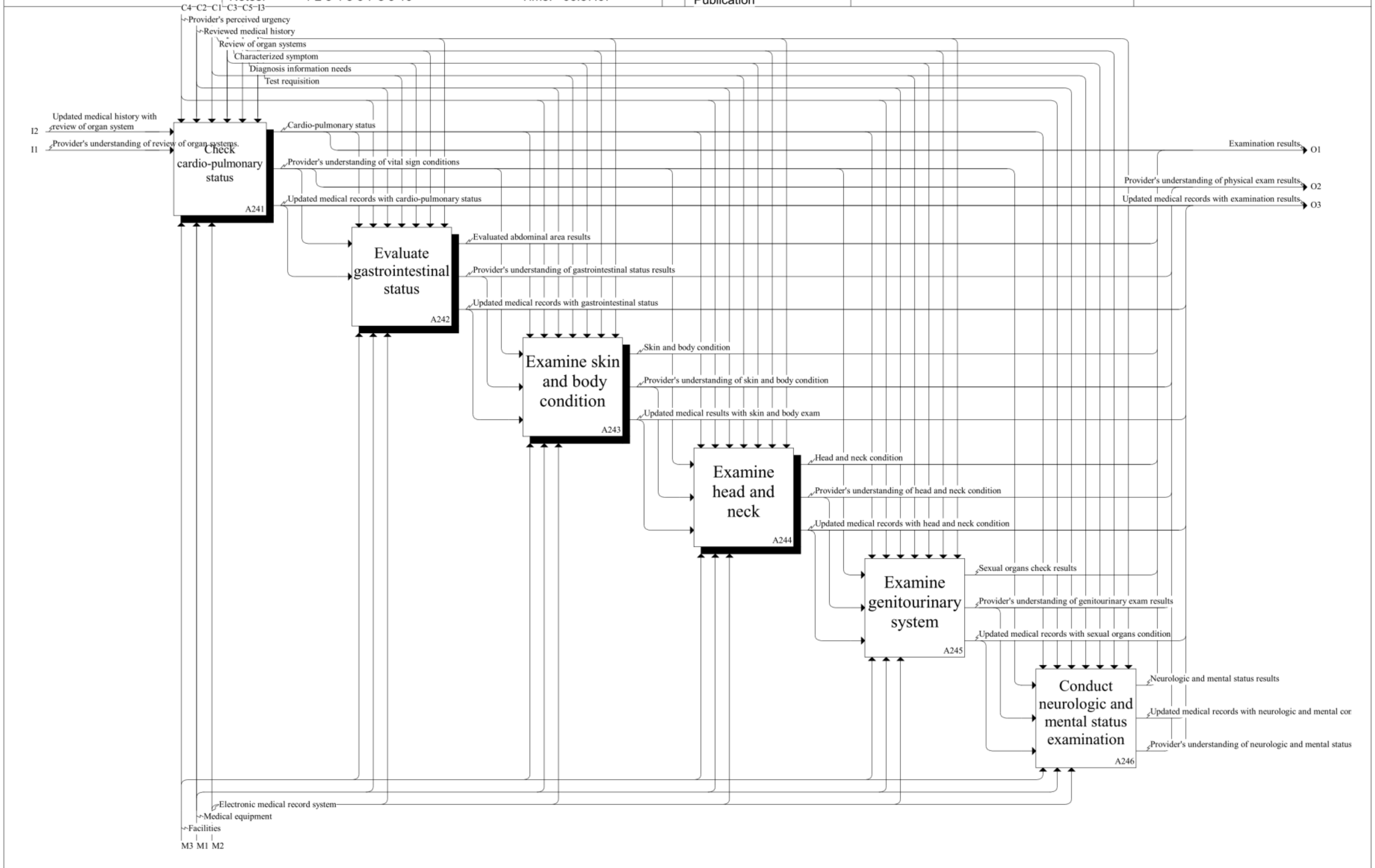

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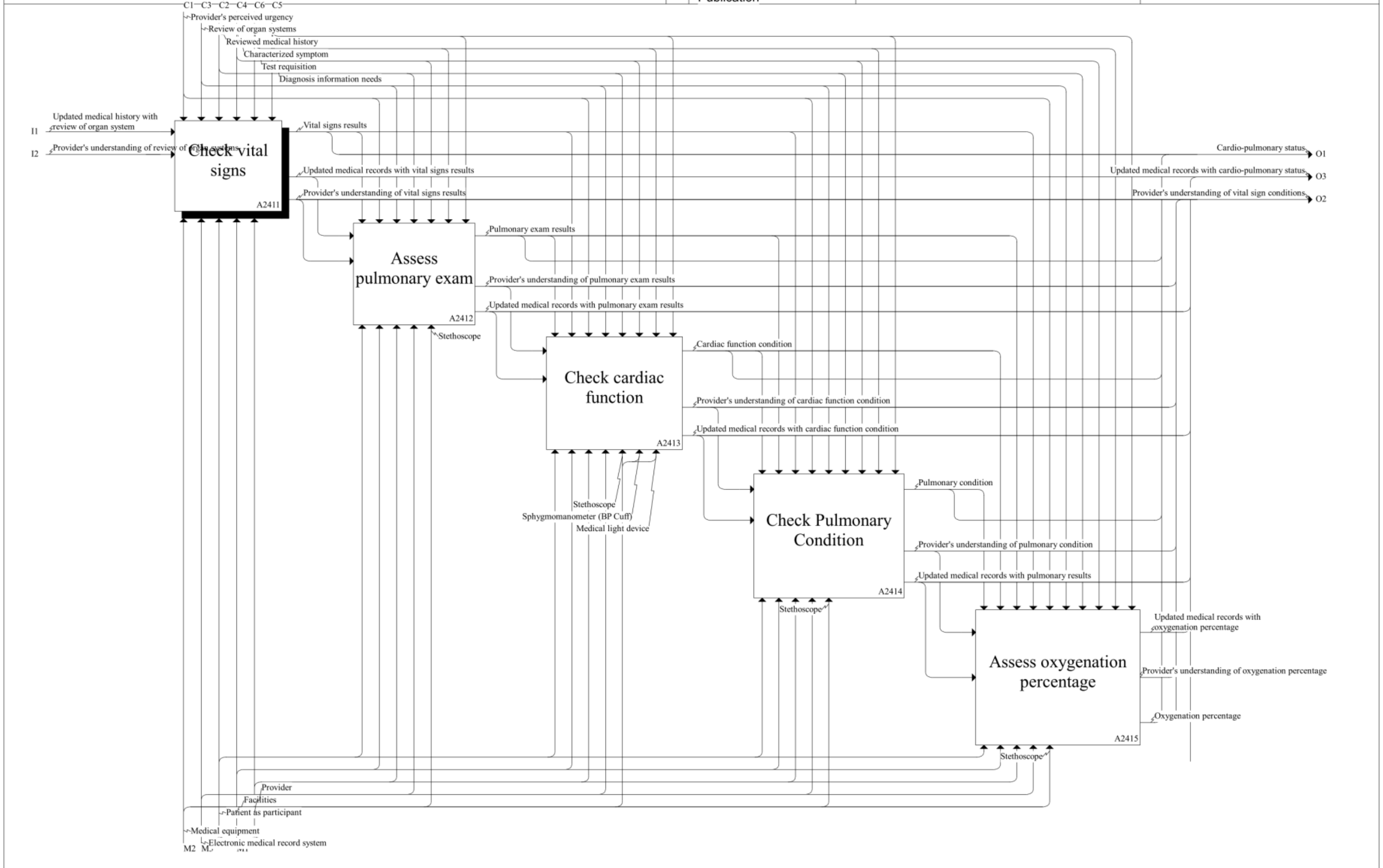

Node: C11	Title: A241: Check cardio-pulmonary status	Number: Pg 6

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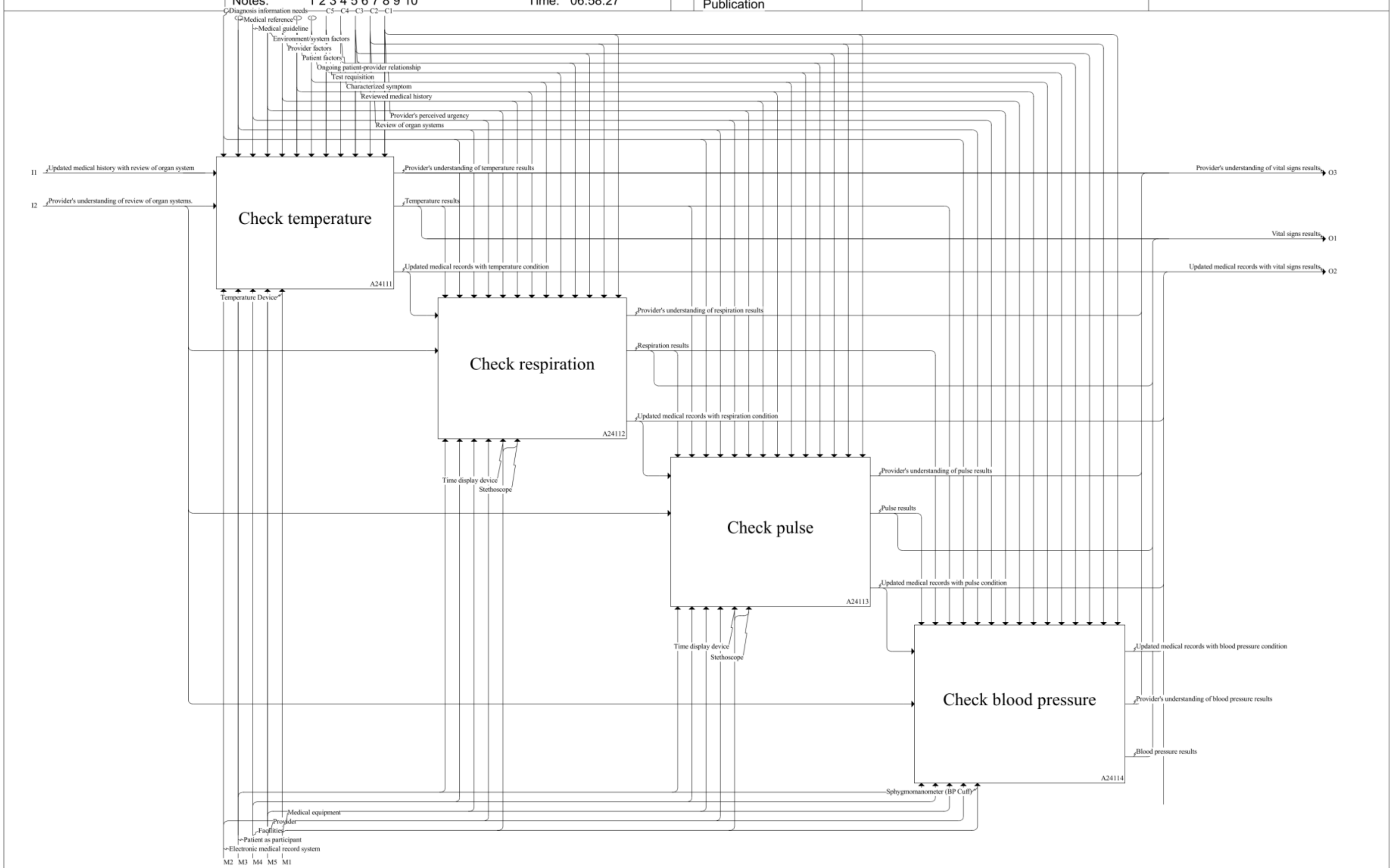

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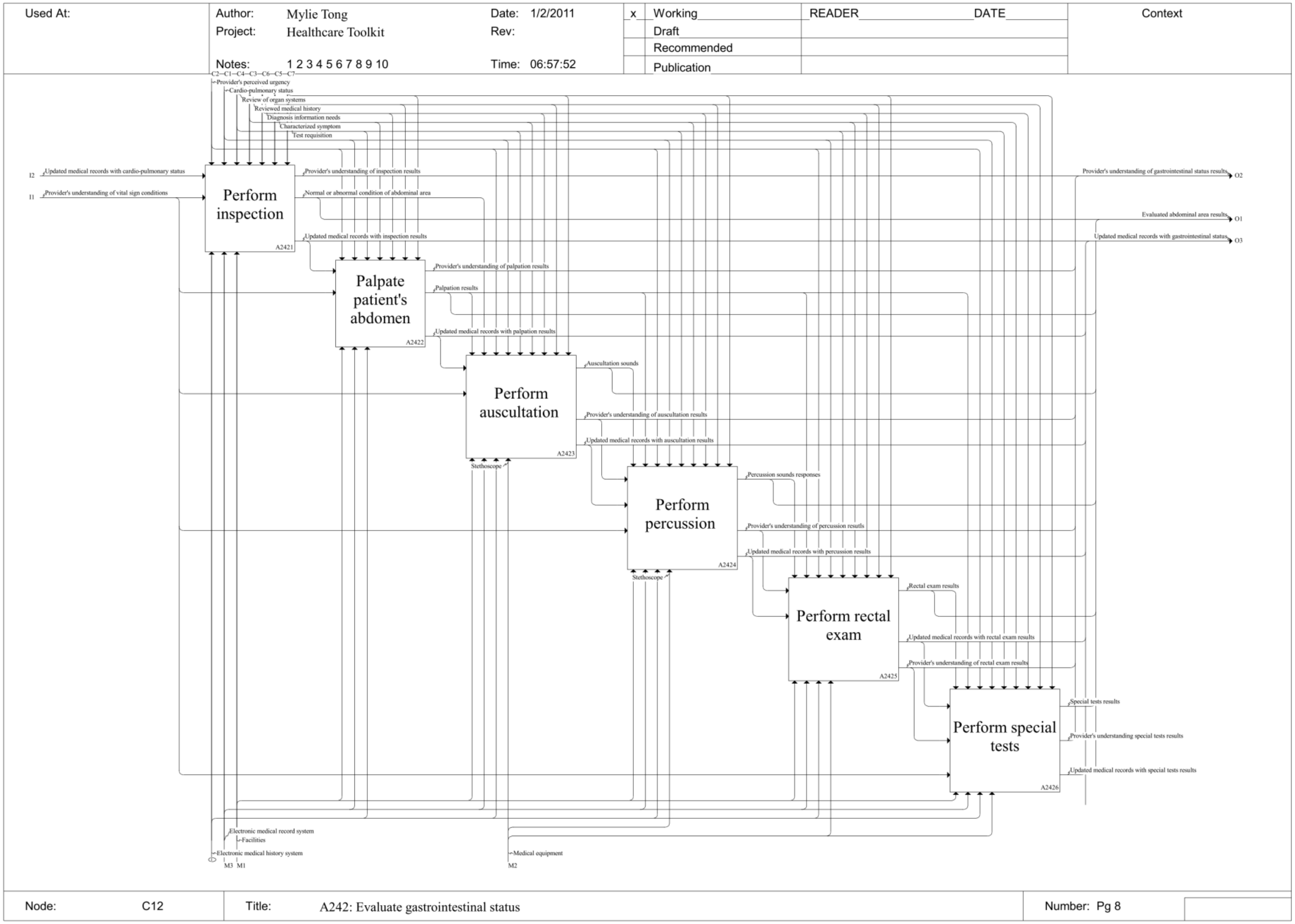

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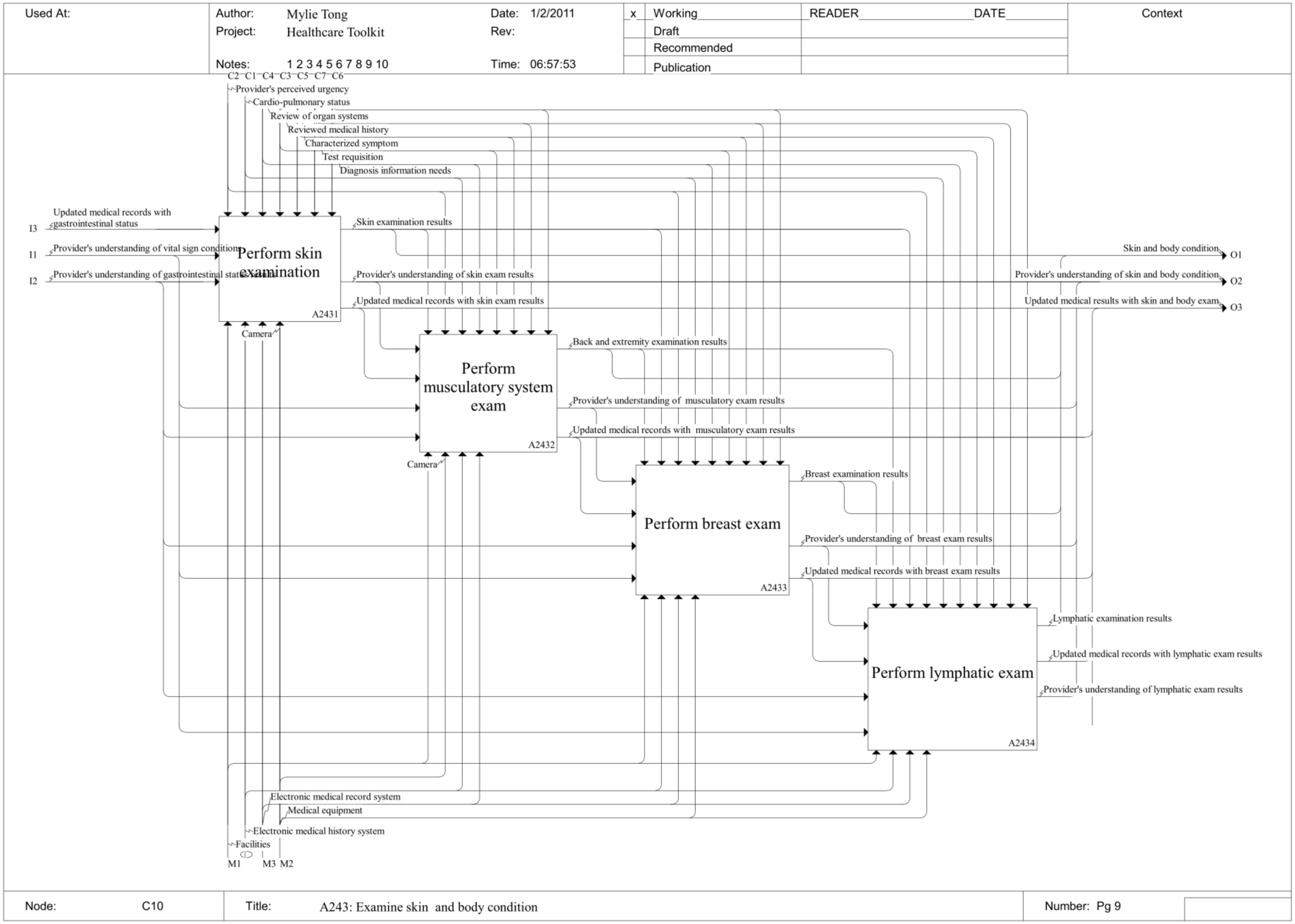

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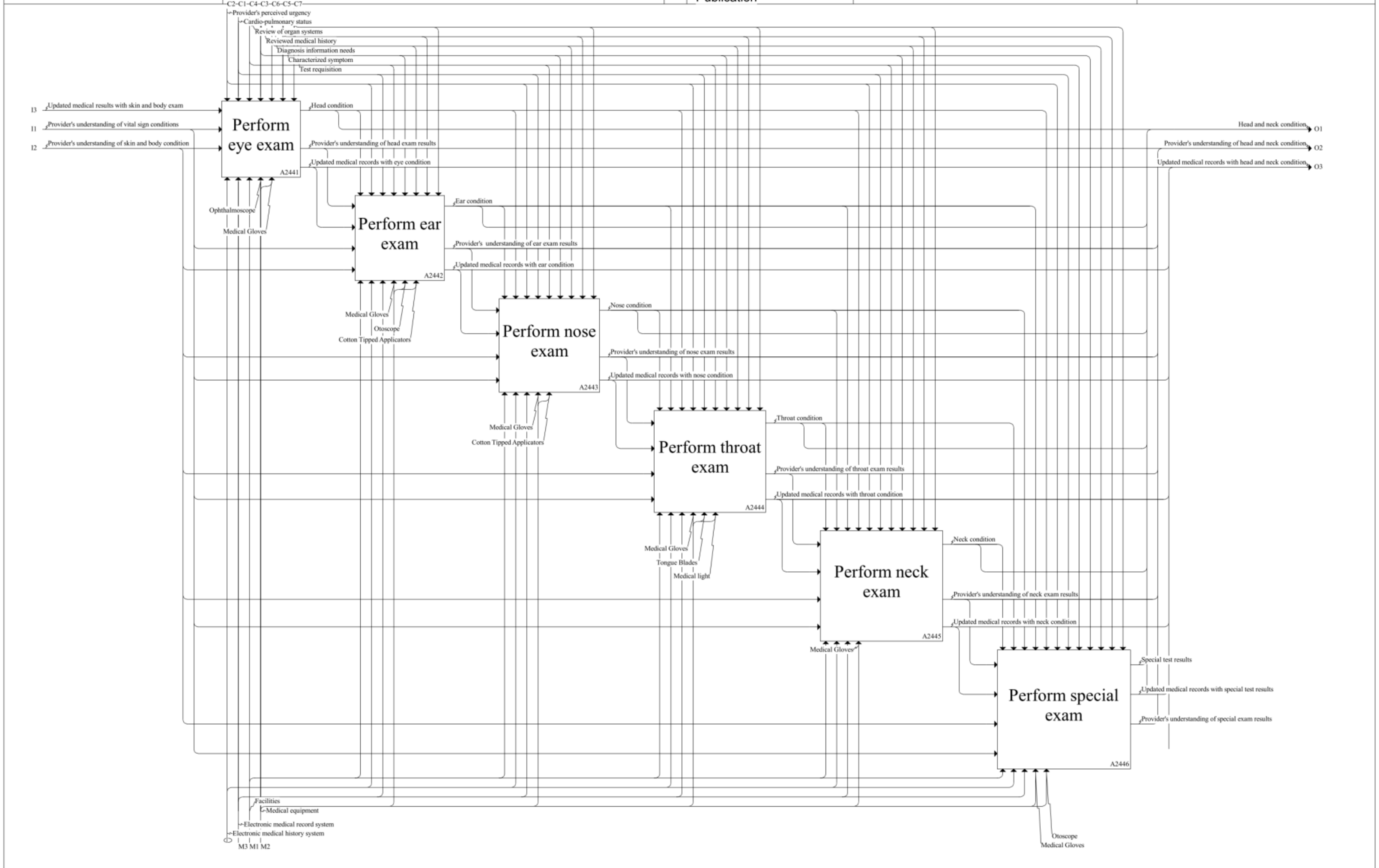

Node: C13	Title: A244: Examine head and neck	Number: Pg 10

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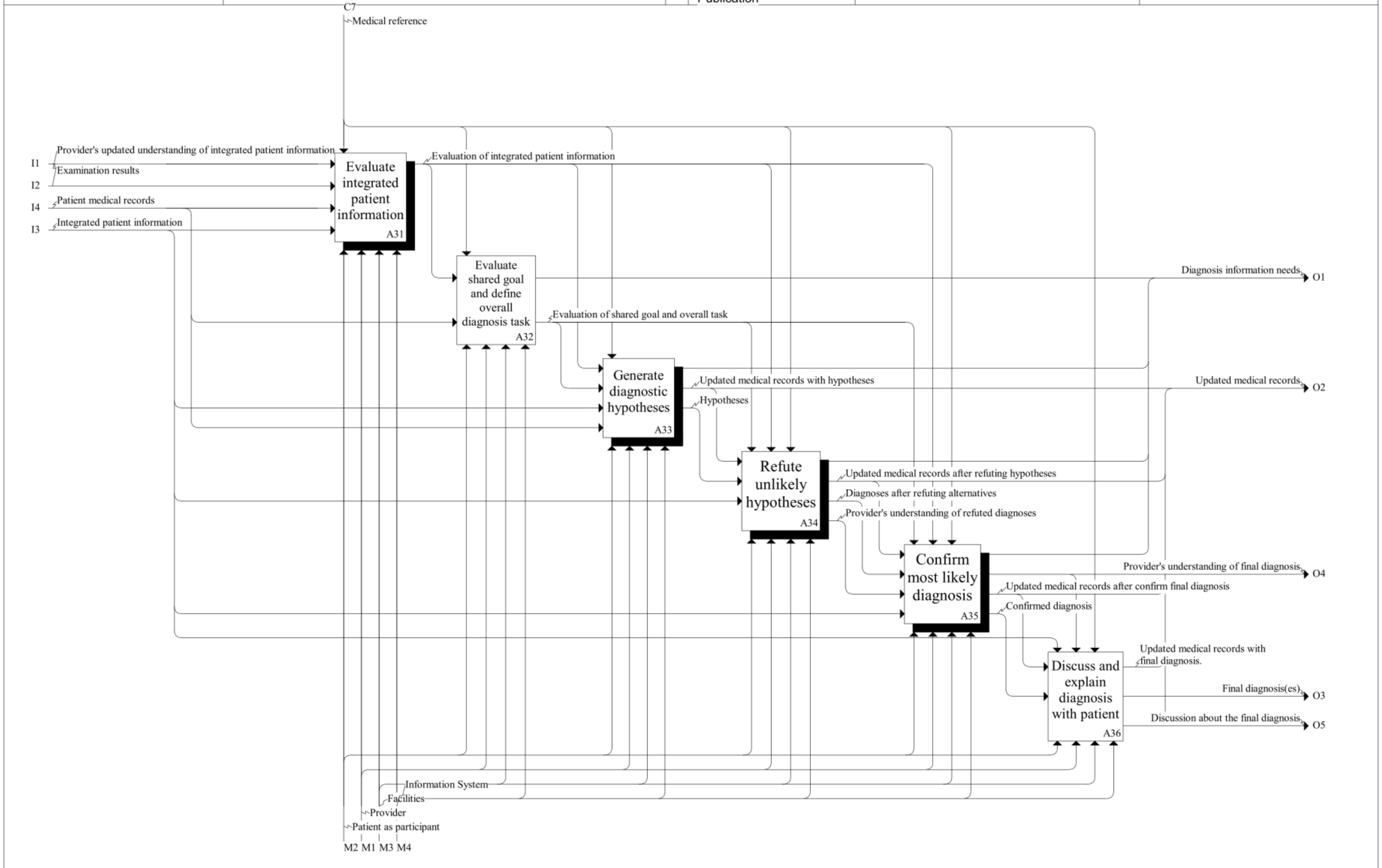

Node: C5	Title: A3: Diagnose condition	Number: Pg 11

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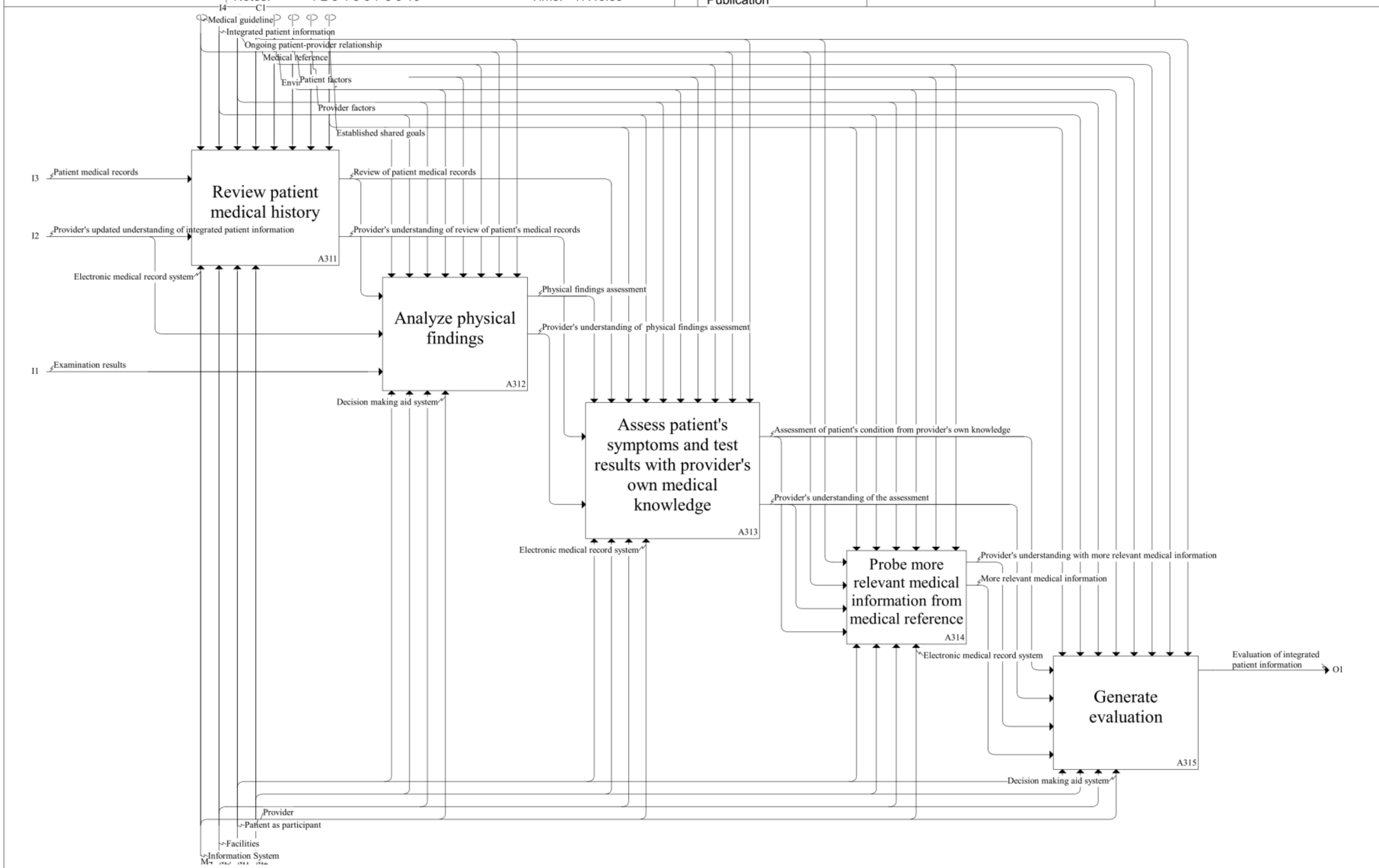

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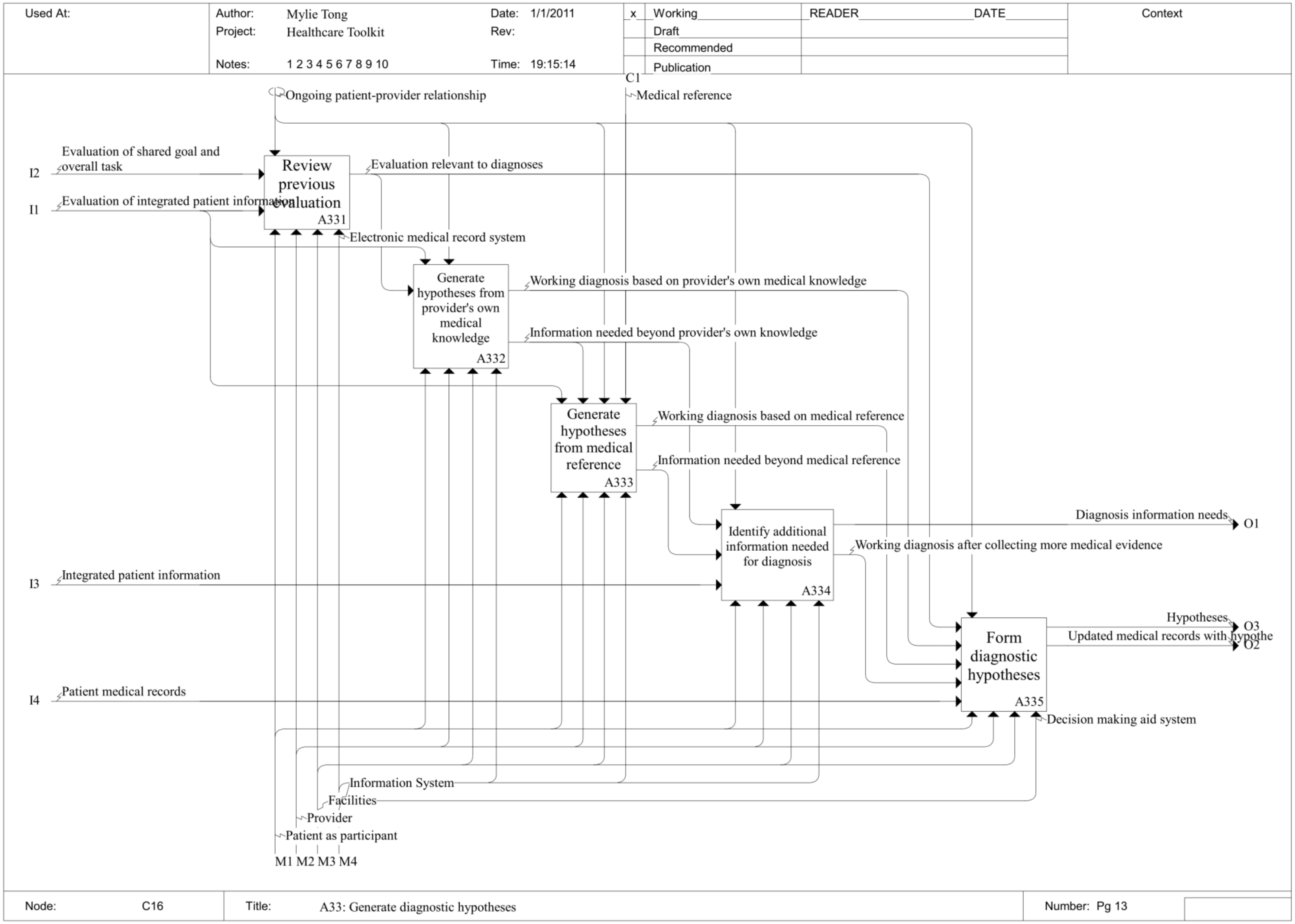

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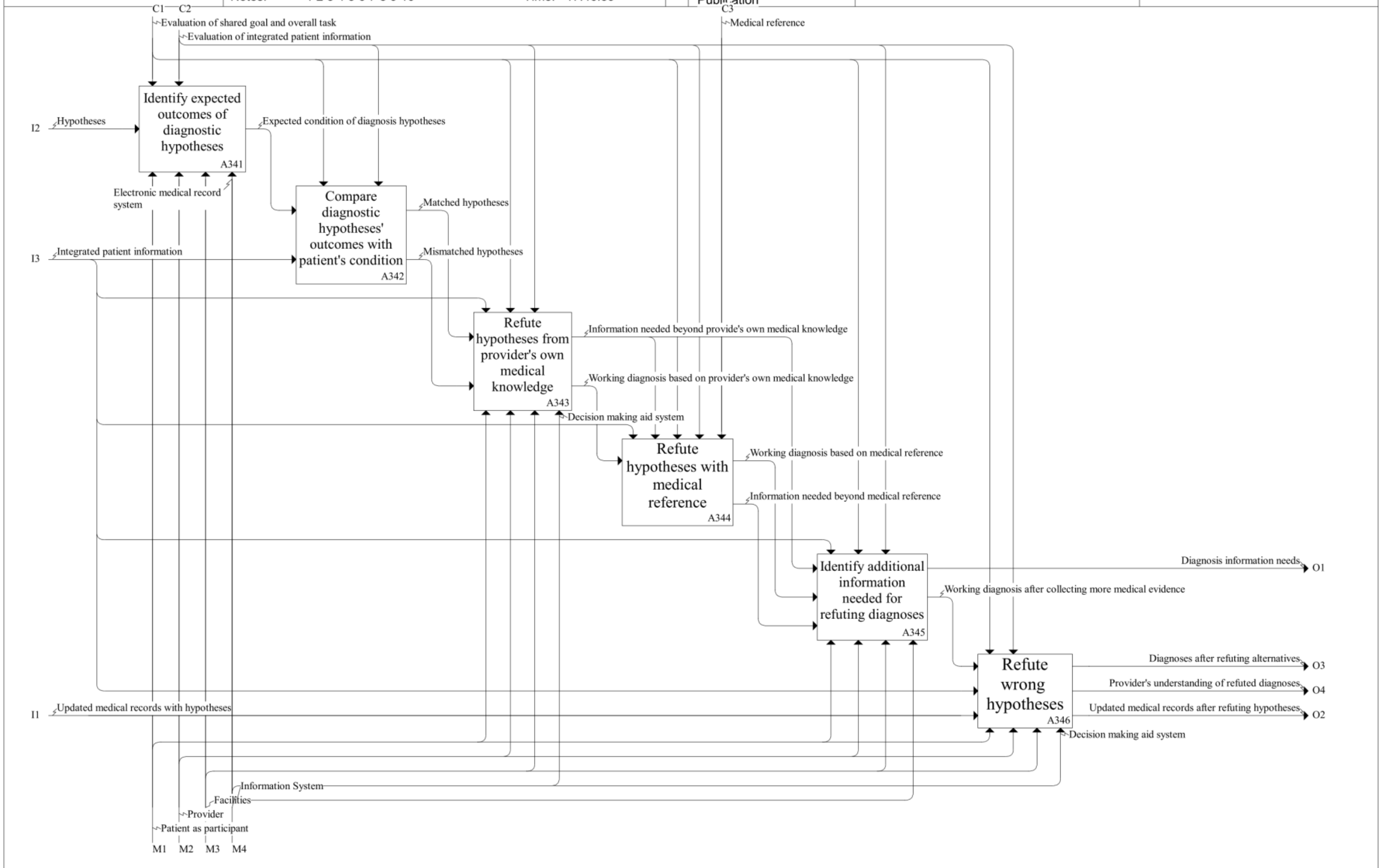

Node: C17	Title: A34: Refute unlikely hypotheses	Number: Pg 14

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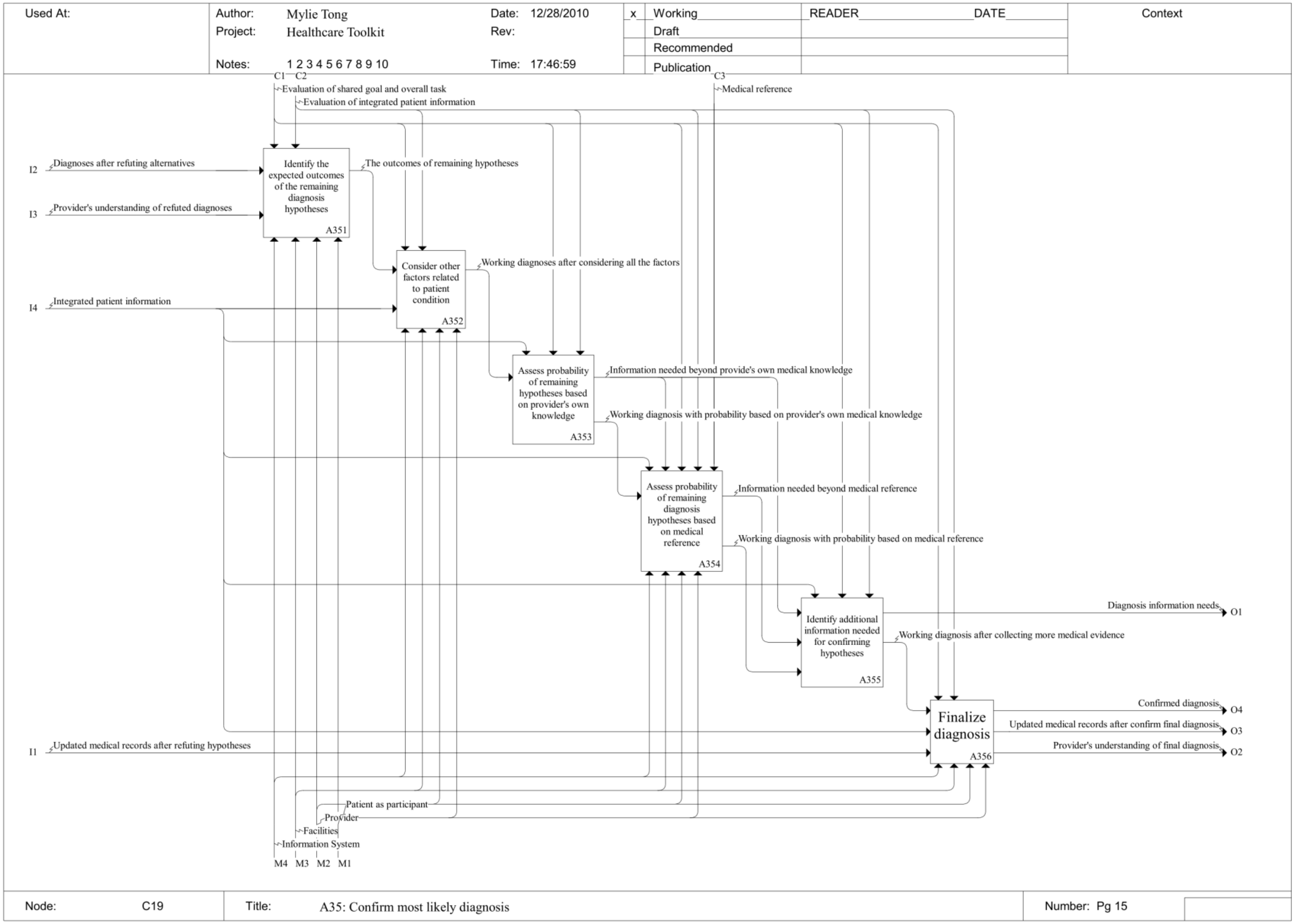

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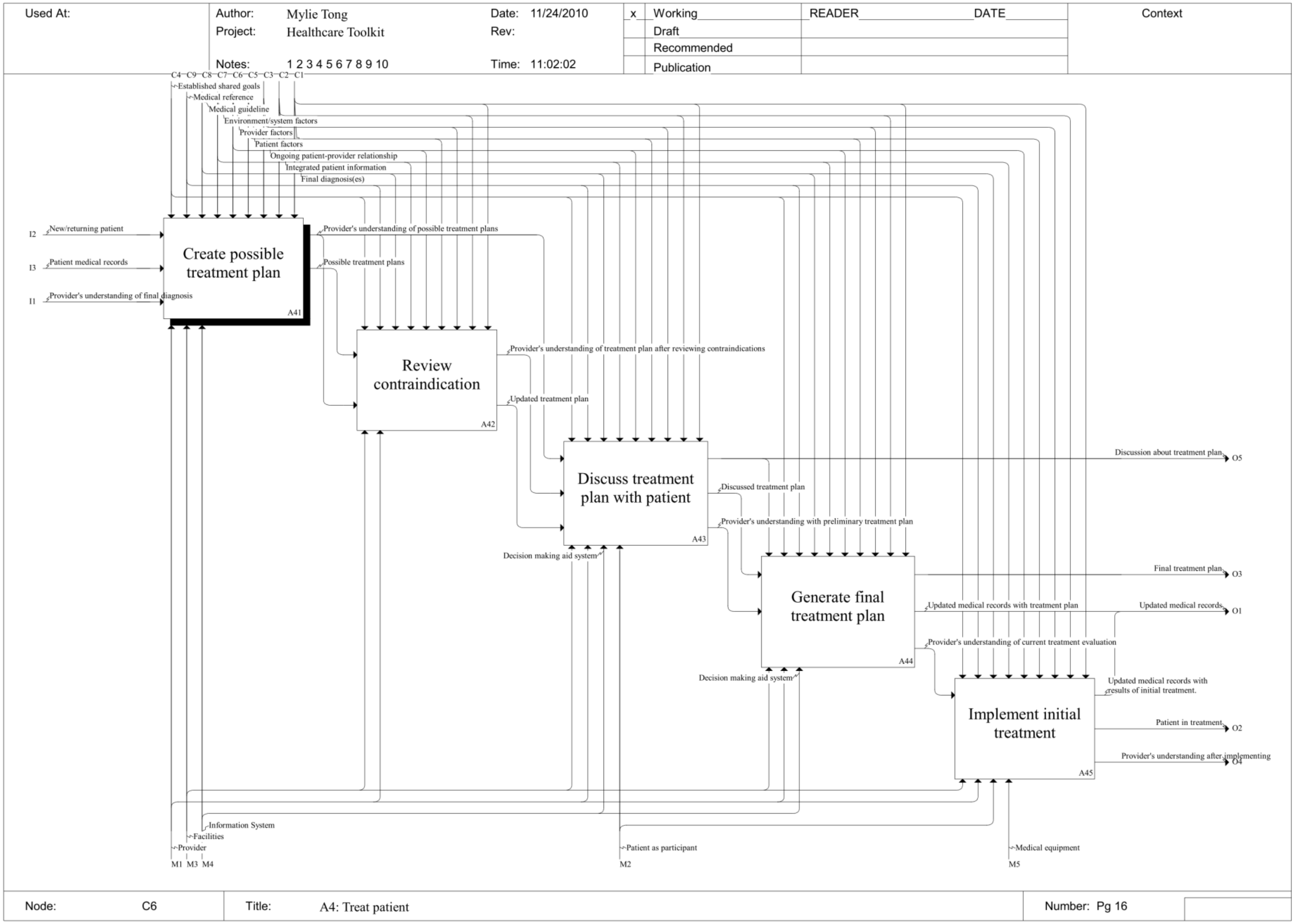

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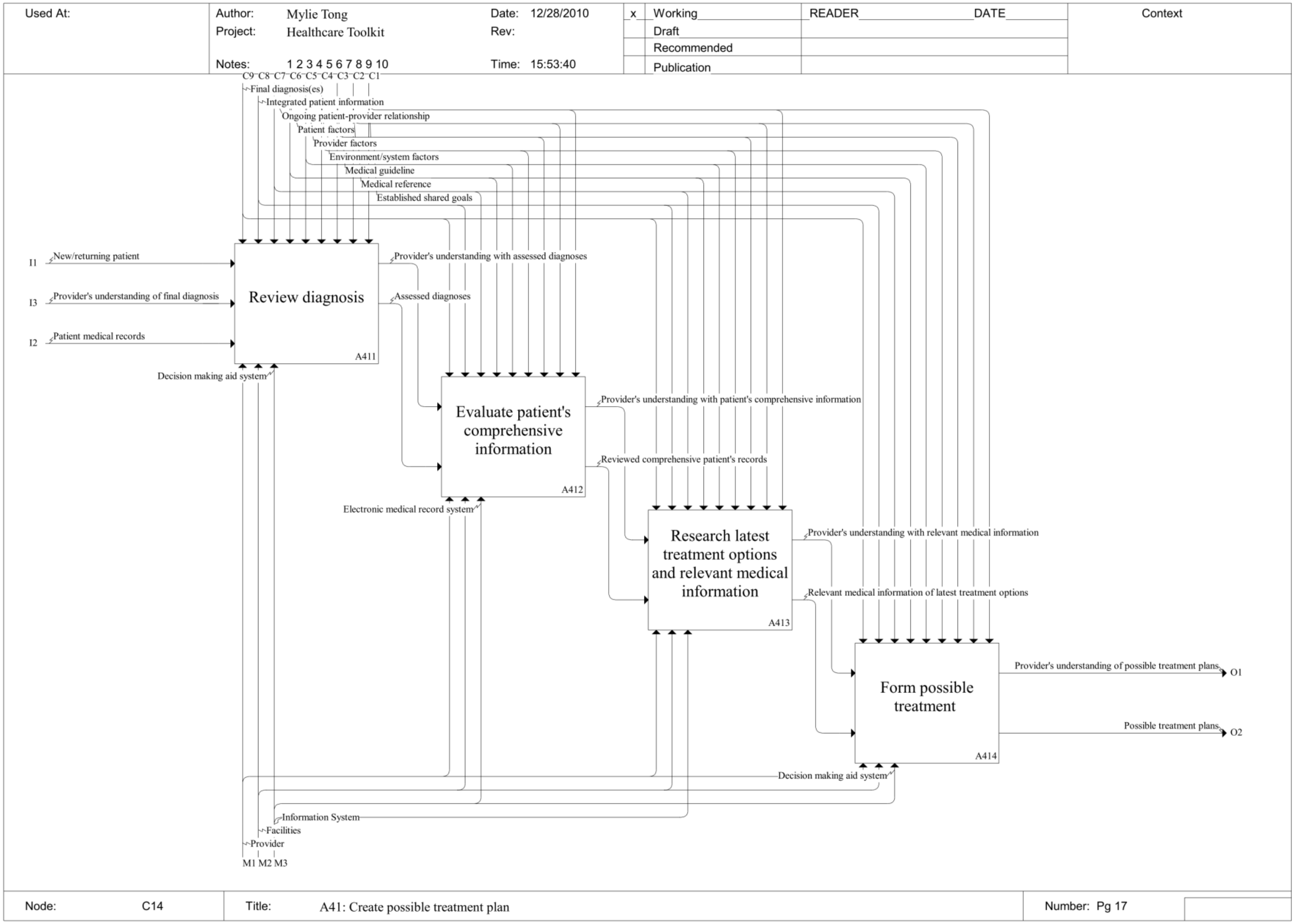

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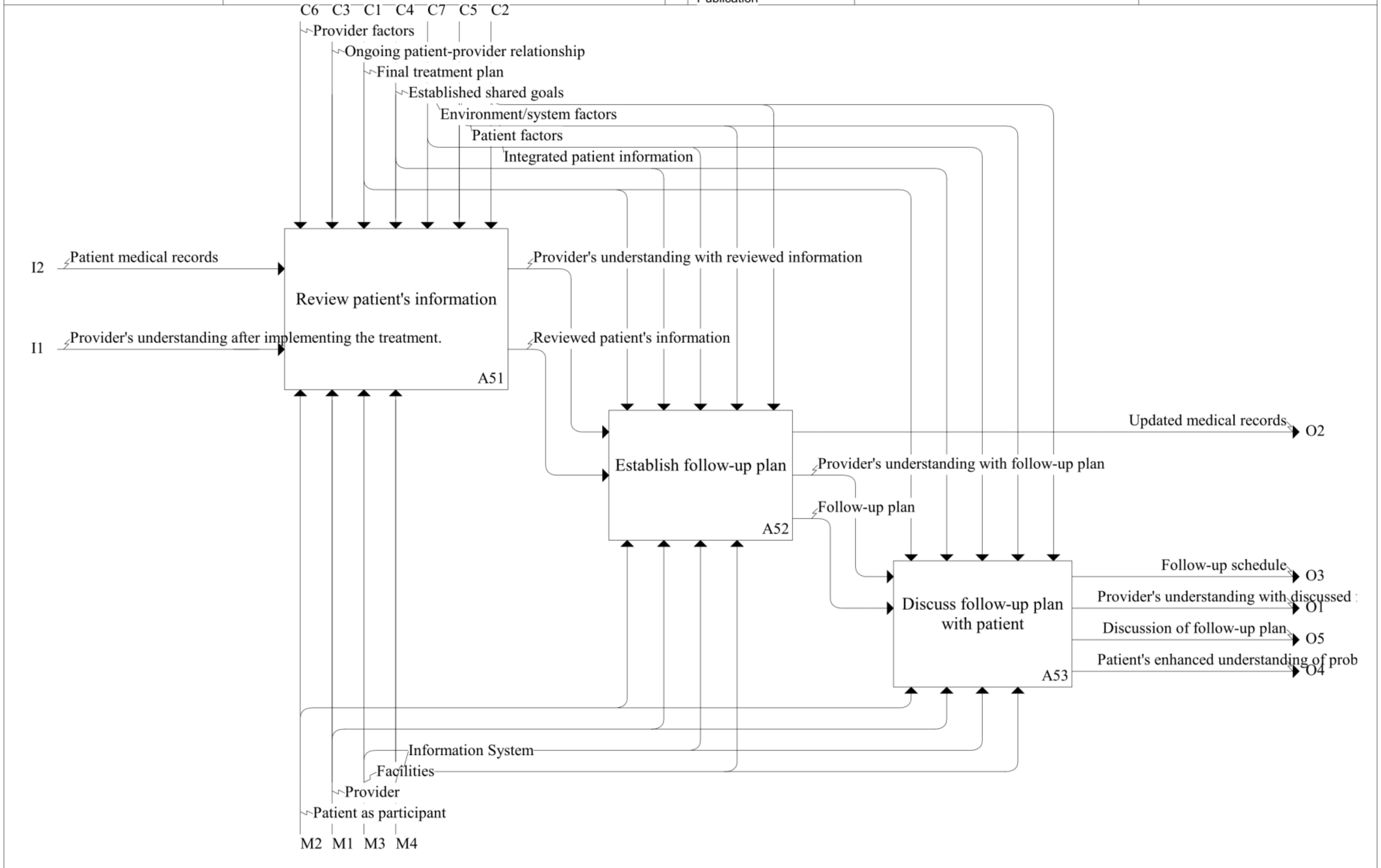

Node: C7	Title: A5: Plan follow-up	Number: Pg 18

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Appendix B: Model Description

Analyze physical findings
Review and assess all the results of patient's exam.

Assess integrated patient's information
Physician try to assess the integrated patient’s information collected previous by using his medical knowledge and experience.

Assess oxygenation percentage
This percentage represents the assessment of oxygenation (level of oxygen in the blood) within 24 hours prior to or after hospital arrival. Early assessment helps with earlier detection of an insufficient oxygen level in the blood, and having enough oxygen in your blood is important to your health. Giving supplemental oxygen has been shown in many cases to decrease death rates among patients.

Assess patient's symptoms and test results with provider's own medical knowledge
The process of assessing patient's symptoms and test results by provider's own medical knowledge

Assess probability of remaining diagnosis hypotheses based on medical reference
Assign probabilities to each remaining hypothesis based on medical references.

Assess probability of remaining hypotheses based on provider's own knowledge
Assign probabilities to each remaining hypotheses based on provider's own knowledge.

Assess pulmonary exam
The provider assesses patient's lung condition by using stethoscope.

Assess treatment plan effectiveness
Review and discuss the effects of the existing treatment plan.

Characterize symptoms of urgent problems
Characterize relevant information regarding patient's symptoms: onset, duration, intensity, what alleviates/intensifies, and other specifics.

Check blood pressure
Blood pressure is a force exerted by circulating blood on the walls of blood vessels, and is one of the principal vital signs. During each heartbeat, BP varies between a maximum (systolic) and a minimum (diastolic) pressure.

Check cardiac function
This check is used to determine and disclose evidence of exertion-related cardiac hypoxia. It can be also used to demonstrate areas of perfusion abnormalities.

Check cardio-pulmonary status
The provider checks the adequacy of blood volume ejected from the heart's ventricles and exchange of carbon dioxide and oxygen at the alveolar level in the lungs of the patient.

Check Pulmonary Condition
The physician will observe the rate, rhythm, depth, and effort of breathing, listen for obvious abnormal sounds with breathing such as wheezes, observe for retractions and use of accessory muscles (sternomastoids, abdominals), observe the chest for asymmetry, deformity, or increased anterior-posterior (AP) diameter.

Check pulse
Check patient's pulse by using a watch displaying seconds and a stethoscope. An irregular pattern to the pulse could be a sign of atrial fibrillation.

Check respiration
Check patient's respiration by using stethoscope and watch displaying seconds. It determines if a person is breathing normally or breathing erratically, in what are called atonal gasps representing cardiac arrest.

Check temperature
Examine patient's internal body temperature by using themometer.

Check vital signs
Checking vital signs is the processing of measuring body temperature, pulse rate, respiration rate, and blood pressure.

Collect and integrate clinical information
Collect information about the patient and his/her medical condition: review the medical records, interview the patient for symptoms, conduct a review of systems, integrate results of diagnosis and treatment, etc.

Compare diagnostic hypotheses' outcomes with patient's condition
Compare the expected outcomes and the existing outcomes of hypotheses and look for contradicting conditions.

Conduct medical encounter
Conduct a single encounter to help a patient resolve a (perceived) medical problem: information collection, diagnosis, the initiation of treatment, and preparation for follow-up encounter(s).

Conduct neurologic and mental status examination
Conduct the examination of patient's neurologic and mental status.

Conduct physical examination

The process of evaluating the general health of the patient including measuring blood pressure, palpation, listening to the chest and heart, and observing dermatological artifacts such as skin discoloration or markings.

Conduct review of organ systems
Review a component of an admission note covering the organ systems, with a focus upon the subjective symptoms perceived by the patient (as opposed to the objective signs perceived by the clinician). It can be particularly useful in identifying conditions that don't have precise diagnostic tests.

Confirm most likely diagnosis
The process of probing information and evidence to rank the possibility of each remaining diagnoses and confirm the most likely diagnosis

Consider other factors related to patient condition
Considering other factors that may cause patient's condition which should be excluded while confirming the hypotheses.

Create possible treatment plan
Generate the possible treatment plan regarding the diagnosis

Diagnose condition
Diagnose the patient's medical problem.

Discuss and explain diagnosis with patient
Get feedback from the patient regarding the diagnoses.

Discuss follow-up plan with patient
Get feedback from the patient regarding the follow-up plan.

Discuss treatment plan with patient
Get feedback from the patient regarding the preliminary treatment plan.

Establish & maintain patient-provider relationship
Establish and maintain a relationship of trust and free communication between the patient and provider.

Establish beneficence
The physician and patient will establish the beneficence they can get after the encounter such as reduced pain, cured disease and etc.

Establish follow-up plan
Decide if further encounters are necessary and what is needed to do next.

Establish mutual trust
Establish and discuss what the benefit the physician can bring to the patient such as heal the patient , reduce the pain and etc.

Establish shared goals
Discuss and establish what the patient wants and what the physician can achieve.

Evaluate gastrointestinal status
The provider evaluates the condition of patient's stomach and intestine.

Evaluate integrated patient information
The process of generating evaluation of all the integrated patient information collected earlier, such as why and how the condition occurred, what the symptoms represent, etc. All the information such as medical history, symptoms and physical findings will be analyzed and researched to look for necessary information for diagnostic purposes.

Evaluate patient's comprehensive information
The process is to gather and review all of the patient's information relevant to the diagnosis.

Evaluate shared goal and define overall diagnosis task
The physician reviews the shared goals to reinforce the expected outcome of the encounter, and also determine if there is ambiguous or incomplete information which may lead to misdiagnosis.

Examine genitourinary system
Conduct the examination of the health condition about the sexual organs

Examine head and neck
Conduct the examination of head and neck, including the condition of eye, ear, nose, throat and neck.

Examine skin and body condition
Conduct the examination of body and skin including skin exam ,musculatory system exam, breast exam and lymphatic exam.

Finalize diagnosis
The final diagnosis is generated.

Form diagnostic hypotheses
Generate hypotheses based on all the existing information and evidence.

Form possible treatment
The physician forms a treatment plan based on all previously collected information.

<u>Generate diagnostic hypotheses</u>
The process of generating serveral hypotheses based on patient's integrated information and defined shared goals.

<u>Generate evaluation</u>
The process of evaluating all the previous collected patient's information which should contain provider's understanding and acknowledgement of patient's medical history, physical findings, symptoms and all related conditions.

<u>Generate final treatment plan</u>
Development of a plan that may include monitoring the patient, prescribing medication, prescribing physical or occupational therapy, recommending surgery, or educating the patient.

<u>Generate hypotheses from provider's own medical knowledge</u>
The process to diagnose a patient's condition by using assessment results from physician's own medical knowledge in head

<u>Generate hypotheses from medical reference</u>
The process of probing further information from medical reference if the physician can't be certain and must seek more evidence or information.

<u>Identify additional information needed for confirming hypotheses</u>
More information is needed from patient to confirm the hypotheses.

<u>Identify additional information needed for diagnosis</u>
Once the physician generates a hypothesis, they may need more information from patient to support it.

<u>Identify additional information needed for refuting diagnoses</u>
More information is needed from patient to refute the hypotheses.

<u>Identify expected outcomes of diagnostic hypotheses</u>
The process of identifying all the possible outcomes of the hypotheses such as symptoms, reactions, relevant examination results, etc.

<u>Identify patient's background</u>
Indentify patient's background information, including social information, family information, education, financial situation, etc.

<u>Identify the expected outcomes of the remaining diagnosis hypotheses</u>
The process of identifying all the possible outcomes of the remaining diagnostic hypotheses such as symptoms, reactions, relevant examination results, etc.

Implement initial treatment
Use medical equipment to apply the treatment to the patient.

Integrate patient information
Integrate information about the patient and the patient's condition from the medical record, medical history, interview, physical examination, diagnosis, etc.noise of abdominal area

Open communication channel
The physician interviews the patient to understand the backgroud information of the patient. They will try to build trust and establish shared goals during the interview, which will be beneficial for the physician to fully understand patient's situation and get all the necessary and accurate information during future encounters.

Palpate patient's abdomen
Palpation is used as part of a physical examination in which an object is felt to determine its size, shape, firmness, or location.

Perform auscultation
Auscultation is performed for the purposes of examining the circulatory system and respiratory system (heart sounds and breath sounds), as well as the gastrointestinal system.

Perform breast exam
Breast exam is a screening method used in an attempt to detect early breast cancer. The method involves the provider to look at and feel the breast for possible lumps, distortions or swelling.

Perform ear exam
The exam is performed to assess the condition of the ear

Perform eye exam
The exam is performed to assess the condition of the eye.

Perform eye examination
An eye examination is a battery of tests performed by an ophthalmologist, optometrist, or orthoptist assessing vision and ability to focus on and discern objects, as well as other tests and examinations pertaining to the eyes.

Perform inspection
The process of looking for scars, striations, hernias, vascular changes, movement associated with peristalsis or pulsations. In abdominal area.

Perform lymphatic exam

The physician looks for signs of breathlessness, discomfort or pain. They examine face, eyes and mouth for signs of clinical anaemia, cyanosis, xanthelasmata, corneal arcus and malar flush. They also examine hands to assess circulation using warmth and capillary refill. Looks for evidence of peripheral cyanosis, nicotine staining, clubbing, splinter haemorrhages, koilonychia (nail spooning.)

Perform musculatory system exam
This is the assessment of muscle strength. Generally speaking, significant differences in strength between limbs are a sign of current or prior injury. Hip flexion, hip abduction, hip adduction and shoulder abduction will be performed during the exam.

Perform neck exam
The exam is performed to assess the condition of the neck.

Perform nose exam
The exam is performed to assess the condition of the nose.

Perform percussion
Percussion is a method of tapping on a surface to determine the underlying structure, and is used in clinical examinations to assess the abdomen.

Perform rectal exam
A rectal examination or rectal exam is an internal examination of the rectum by a physician or other healthcare professional.

Perform skin examination
A skin examination will involve visually examining the skin's color, texture, turgor, moisture, pigmentation, lesions, hair distribution and warmth in order to assess general health and detect local and systemic disease.

Perform special exam
The special tests include facial tenderness, sinus transillumination and temporomandibular joint exams.

Perform special tests
The tests includes rebound tenderness, costovertebral tenderness, shifting dullness, psoas sign and obturator sign.

Perform throat exam
The exam is performed to assess the condition of the thorat

Plan follow-up
Schedule one or more follow-up encounters to assess the effects of the treatment and to modify the treatment plan, as necessary.

Probe more relevant medical information from medical reference
Provider research the medical reference in form of books, articals, peer's help and etc to probe more information regarding to patient's condition and test results

Refute hypotheses from provider's own medical knowledge
Reject diagnostic hypotheses based on provider's own medical knowledge.

Refute hypotheses with medical reference
Reject hypotheses based on medical references.

Refute unlikely hypotheses
The process of probing information and evidence to reject previous hypotheses.

Refute wrong hypotheses
The process of rejecting hypotheses which don't match existing information or evidence.

Research latest treatment options and relevant medical information
The physician researches the latest and best treatment options and medical information to aid in forming a treatment plan.

Retrieve medical records
Retrieve related information from patient's medical records

Review comprehensive medical history
Review patient's medical history, including surgical history, medications, allergies, family history and social history.

Review contraindication
Review patient's comprehensive medical records to evaluate the contridictions between possible treatment plan and patient's condition.

Review diagnosis
The process of reviewing diagnosis to make sure it's fully understood by the provider. The diagnosis is the foundation of creating a treatment plan.

Review patient medical history
The process of reviewing the patient's comprehensive medical history to ensure that the physician fully understands patient's medical situation. Pertinent information would include surgical history, medications, allergies, family history, social history and past medical history.

Review patient's information
Review the patient's comprehensive medical information and the effects of the previous treatment.

Review previous evaluation
Review previous evaluation of patient's integrated information to search for information relevant to diagnoses

Treat patient
Begin treatment of the patient by developing a treatment plan, prescribing medications, referring the patient to other providers, etc.

Assessed diagnoses
The diagnoses that have been assessed by the physician.

Assessed Test Results
The analyst of the performed tests

Assessment of existing treatment
An assessment of the effectiveness of existing treatments.

Assessment of patient's condition from provider's own knowledge
The assessment which physicians generate based on their own medical knowledge.

Auscultation sounds
The sound of circulatory system and respiratory system (heart sounds and breath sounds), as well as the gastrointestinal system (bowel sounds).

Back and extremity examination results
The results of back and extremity examination. It includes text and visual data.

Blood pressure
The results of patient's blood pressure test. An average blood pressure of 112/64 mmHg was found, which is in the normal range.

Breast examination results
The results of chest and lung examination. It includes text, visual and auditory data

Camera
A camera is a device that records images. These images may be still photographs or moving images such as videos or movies. It will be as small as possible and attached to another device.

Cardiac function condition
The results of cardiac function exam includes if there are exertion-related cardiac hypoxia or perfusion abnormalities.

Cardio-pulmonary status

The status of patient's vital signs, pulmonary and cardiac function, circulation, and oxygenation percentage.

Characterized symptom
Collected patient information regarding all patient's concerns.

Communication channel
The communication channel built during the very beginning interview between the physician and the patient. It will affect the effectiveness of all the following activities between patient and physician.

Confirmed diagnosis
The most likely diagnosis confirmed by the physician.

Cotton Tipped Applicators
The topical applicators are used for cleansing of ears and wounds, and applications of ointments and liquids.

Decision making aid system
Decision making aids are patient-based tools developed to support and streamline the medical decision-making process. It has been proven that the use of decision aids improves decision quality.

Diagnoses after refuting alternatives
The remaining hypotheses which don't have reject evidence.

Diagnosis information needs
New information is requested to be used to confirm the previous hypothesis or warrant a new diagnosis.

Discussed treatment plan
After discussing the treatment plan with patient, the feedback from the patient regarding the updated treatment plan has been considered.

Discussion about the final diagnosis
The physician will discuss the confirmed diagnosis with patient and reach a common agreement with the patient.

Discussion about treatment plan
The physician will discuss the confirmed treatment plan with the patient and reach a common agreement.

Discussion of follow-up plan

The physician will discuss the follow-up plan with patient and reach a common agreement with the patient.

<u>Ear condition</u>
The results of ear exam such as the sound or the picture of abnormal symptoms. It includes text and visual data.

<u>Electronic medical record system</u>
An electronic medical record (EMR) is a computerized medical record created in an organization that delivers care, such as a hospital or doctor's surgery practice. Electronic medical records tend to be a part of a local stand-alone health information system that allows storage, retrieval and modification of records

<u>Environment/system factors</u>
Factors related to the environment and equipment used in the encounter that can affect the encounter process. Environmental factors include, lighting, temperature, humidity, noise, aesthetics, etc. Equipment factors include type of equipment used, their functional capabilities and limitations, their technical performance, etc.

<u>Established beneficence</u>
The expected beneficence is established during the interview between the physician and the patient. It is the motivation for patient to participate more during the encounter.

<u>Established shared goals</u>
Description
The common goals established at the beginning of the encounter to give directions for the rest of treatment.

<u>Established mutual trust</u>
The physician establishes mutual trust with the patient. This is very important because the more trust the physician has from the patient, the more complete the information he can get from the patient. Likewise, the more trust the patient has, the more comfortable he feels opening up during the encounter.

<u>Evaluated abdominal area results</u>
The results of abdominal examination which can be visual or auditory.

<u>Evaluation of integrated patient information</u>
The relevant patient information included in generating a diagnosis and the assessment of this information in terms of why and how it relates to patient's symptoms, examination results, etc.

<u>Evaluation of shared goal and overall task</u>
The overall idea of what should be achieved during the encounter.

Evaluation relevant to diagnose
All the useful and related evaluations to generate diagnostic hypotheses.

Examination results
The results of all the tests that have been conducted.

Existing diagnosis(es)
Existing diagnosis refers to both the process of determining the identity of a possible disease or disorder, and to the opinion reached by this process. This may refer to an initial or updated diagnosis(es).

Existing patient-provider relationship
The patient-provider relationship that exists at the beginning of the encounter, which may not exist in the case of the initial encounter, or may be well developed as the result of many previous encounters between this patient and this physician.

Existing treatment plan
This plan attempts remediation of a health problem, usually following a diagnosis. The plans described may be initial or updated.

Expected condition of diagnosis hypotheses
All the possible expected outcomes of the hypotheses such as symptoms, reactions, relevant examination results, etc.

Eye examination results
The results of eye exam. It includes text and visual data

Facilities
Description
The facilities (building, room) and equipment used in the encounter for information collection, diagnosis, treatment, communication, etc.

Final diagnosis(es)
The accepted diagnosis that is the basis for treatment.

Final treatment plan
The treatment plan generated by the physician based on the diagnosis.

Follow-up plan
The follow-up plan includes what to do next to better heal the patient and secure a positive outcome of the current encounter.

Follow-up schedule

A schedule for follow-up encounter(s) to assess the effects of treatment and modify the treatment plans as necessary.

Head and neck condition
The results of head and neck exam such as the sound or visualization of abnormal symptoms. It includes text, visual and auditory data.

Head condition
The results of head exam such as the sound or the picture of abnormal symptoms. It includes text, visual and auditory data.

Healing patient
The patient currently undergoing treatment, therapy, or otherwise in the healing process. May return for a follow up encounter.

Hypotheses
All the hypotheses.

Information needed beyond medical reference
More information is requested because of the limitation of medical references or incompleteness of patient's information.

Information needed beyond provider's own medical knowledge
More information is needed due to the limitation of provider's own medical knowledge.

Information needed beyond providers own knowledge
More information is requested because of the limitation of provider's own medical knowledge or incompleteness of patient's information.

Information System
The information system operated on all the computers or electronic devices in the hospital, that include patient's electronic medical records, decision aids, organizational tools, etc. They are designed to help physician to diagnose and treat patient in a more efficient way.

Integrated patient information
Information about the patient and the patient's condition, integrated from the medical record, medical history, interview, physical examination, diagnosis, etc.

Lymphatic examination results
The results of lymphatic examination. It includes text, visual and auditory data.

Matched hypotheses
Hypotheses whose outcomes match the expected outcomes.

Medical equipment
The set of equipment used to aid in the diagnosis, monitoring or treatment of medical conditions.

Medical Gloves
Medical gloves are disposable gloves used during medical examinations and procedures that help prevent contamination between caregivers and patients.

Medical guideline
Medical guidance information, including proper practices, clinical guidelines, protocols, algorithms, etc.

Medical light
A light, especially of pollution or radiation, occupying a very small area and having a concentrated output.

Medical light device
The light source can be moved around so the physician can use without limitation.

Medical reference
Information obtained from medical references, including drug references, disease information, study findings, etc.

Mismatched hypotheses
Hypotheses whose outcomes don't match the expected outcomes.

More relevant medical information
More useful medical information or evidence that has been found from medical references.

Neck condition
The results of neck exam such as the sound or the picture of abnormal symptoms. It includes text and visual exam.

Neurologic and mental status results
The examination results of patient's neurologic and mental status. It includes text,visual and auditory data.

New/returning patient
A patient with a (perceived) medical problem, entering the encounter either for the first time or returning for a follow-up.

Normal or abnormal condition of abdominal area
The results of the abdominal area inspection includes the picture of abnormal symptoms

<u>Nose condition</u>
The results of nose exam such as the picture of abnormal symptoms. It includes text and visual data.

<u>Ongoing patient-provider relationship</u>
The on-going relationship between the patient and the provider which affects trust, confidence, free flow of information, etc.

<u>Ophthalmoscope</u>
The ophthalmoscope (or funduscope) is an instrument used to examine the eye.
Its use is crucial in determining the health of the retina and the vitreous humor.

<u>Otoscope</u>
An Otoscope is a medical device which is used to look into the ears

<u>Oxygenation percentage</u>
The oxygen saturation of a patient's blood.

<u>Palpation results</u>
The results of palpation exam including the sound of abnormal symptoms.

<u>Patient as participant</u>
The patient as an active participant in the encounter, taking part in information collection, diagnosis, and the initiation of treatment.

<u>Patient factors</u>
Factors related to the patient that affect the encounter process, including age, gender, education, anatomy, medical history, attitude, personality, motivation for healing, etc.

<u>Patient in treatment</u>
The patient, during the encounter, after treatment has been initiated.

<u>Patient medical records</u>
The patient's medical records, including medical history, current treatment plan, tests ordered, test results, chart notes, etc.

<u>Patient perceived problems</u>
The patient's own physical and emotional perceptions and their opinion of their own condition.

<u>Patient self-knowledge</u>
What the patient may know about him/herself and his/her medical condition.

<u>Patient's enhanced understanding of problems</u>

Patient's understanding of the diagnosis of their symptoms, the treatment and the follow-up plan after the encounter.

Peak Flow Meter
A peak flow meter is a small, hand-held device used to monitor a person's ability to breathe out air. It measures the airflow through the bronchi and thus the degree of obstruction in the airways.

Percussion sounds response
The results of percussion exam include the picture or sound of abnormal symptoms

Percussion sounds responses
The sounds of percussion exam. Physical findings assessment

Physical findings assessment
General assessment result has been analyzed.

Possible treatment plans
The initial treatment plan based on the diagnosis.

Previously requested test results
The test results ordered by physician during previous encounters. Can also include tests that still must be sent to the lab.

Provider
The healthcare provider, which may be a physician, nurse-practitioner, nurse, EMT, etc.

Provider factors
Factors related to the provider that can affect the encounter process, including training, specialty, experience, recent experiences, motivation, attitude, personality, fatigue, sensory abilities, cognitive abilities, motor abilities, etc.

Provider mental model with assessment of integrated patient's information
The mental model is updated after assessing overall patient's clinical information

Provider understanding of assessment of treatment
The mental model is updated after assessing the previous treatment plan

Provider understanding of reviewed medical history
The provider's understanding is updated after reviewing medical history.

Provider understanding with evaluation of integrated patient information
The mental model is updated after creating preliminary assessment

Provider's understanding of ear exam results
Provider's understanding is updated after conduction ear exam.

Provider's initial understanding of patient's problems
It is an explanation of provider's thought process about how this encounter will develop, and the provider's working understanding of the patient's problem. This is the sum of the provider's observations, past experience, or intuition, and includes a working and changing mental model of the patient's condition. This may help form the basis for decision making related to the problem.

Provider's perceived urgency
The prioritization of the level of urgency of patient's symptoms.

Provider's understanding after implementing the treatment.
Provider's understanding is updated after implementing treatment plan.

Provider's understanding by mutual trust
Provider's understanding is updated by the mutual trust established with the patient.

Provider's understanding of breast exam results
Provider's understanding is updated by breast exam results.

Provider's understanding of musculatory exam results
Provider's understanding is updated by musculatory exam results.

Provider's understanding of physical findings assessment
Provider's understanding is updated after analyzing physical findings.

Provider's understanding of auscultation results
Provider's understanding is updated by auscultation results.

Provider's understanding of beneficence
Provider's understanding is updated by beneficence

Provider's understanding of blood pressure results
Provider’s understanding is updated with the results of the blood pressure exam.

Provider's understanding of cardiac function condition
Provider's understanding is updated by cardiac funtion condition.

Provider's understanding of characterized symptoms
The provider's understanding is updated after characterizing symptoms.

Provider's understanding of current treatment evaluation

Provider's understanding is updated after creating treatment.

Provider's understanding of diagnoses hypotheses
The mental model is updated after establishing possible diagnoses

Provider's understanding of final diagnosis
Provider's understanding is updated after discussing the diagnosis with the patient.

Provider's understanding of gastrointestinal status results
Provider's understanding is updated by gastrointenstinal status results

Provider's understanding of genitourinary exam results
Provider's understanding is updated after examine sexual organs.

Provider's understanding of head and neck condition
Provider's understanding is updated after examine head and neck.

Provider's understanding of head exam results
Provider's understanding is updated after conducting head exam.

Provider's understanding of inspection results
Provider's understanding is updated by the results of inspections includes if there is scars, striae, hernias, vascular changes, movement associated with peristalsis or pulsations.

Provider's understanding of lymphatic exam results
Provider's understanding is updated by lymphatic exam results.

Provider's understanding of neck exam results
Provider's understanding is updated after conduction neck exam.

Provider's understanding of neurologic and mental status
Provider's understanding is updated after conducting neurologic and mental status exam.

Provider's understanding of nose exam results
Provider's understanding is updated after conducting nose exam.

Provider's understanding of oxygenation percentage
Provider's understanding is updated by blood oxygenation percentage.

Provider's understanding of palpation results
Provider's understanding is updated by the results such as an object's size, shape, firmness, or location.

Provider's understanding of patient's background

The provider's understanding is updated by including patient's background information.

Provider's understanding of percussion results
The provider's understanding is updated after performing the percussion exam.

Provider's understanding of physical exam results
Provider's understanding is updated after conducting physical exams

Provider's understanding of possible treatment plans
Provider's understanding is updated after creating a possible treatment plan.

Provider's understanding of pulmonary condition
Provider's understanding is updated by the pulmonary condition.

Provider's understanding of pulmonary exam results
Provider's understanding is updated by pulmonary exam results.

Provider's understanding of pulse results
Provider's understanding is updated by pulse results.

Provider's understanding of rectal exam results
Provider's understanding is updated after evaluating the rectal condition.

Provider's understanding of refuted diagnoses
Provider's understanding is updated after refuting initial diagnoses.

Provider's understanding of respiration results
Provider's understanding is updated by respiration results.

Provider's understanding of review of organ systems.
Provider's understanding is updated after review of organ systems.

Provider's understanding of review of patient's medical records
Provider's understanding is updated after reviewing patient's medical records.

Provider's understanding of shared goals
Provider's understanding is updated after establishment of shared goals, and they have knowledge of what is needed to be achieved during the encounter.

Provider's understanding of skin and body condition
Provider's understanding is updated after examine skin and body condition.

Provider's understanding of skin exam results
Provider's understanding is updated by skin exam results.

<u>Provider's understanding of special exam results</u>
Provider's understanding is updated after conducting special tests.

<u>Provider's understanding of temperature results</u>
Provider's understanding is updated by temperature results.

<u>Provider's understanding of the assessment</u>
Provider's understanding is updated after assessing patient's symptoms and test results with provider's own medical knowledge.

<u>Provider's understanding of throat exam results</u>
Provider's understanding is updated after conduction throat exam.

<u>Provider's understanding of treatment plan after reviewing contraindications</u>
Provider's understanding is updated after reviewing contraindications. The updates include the acknowledgement of patient's allergy history, prescribed medication, etc.

<u>Provider's understanding of treatment plan effectiveness</u>
Provider's understanding is updated after assessing the treatment plan's effectiveness.

<u>Provider's understanding of vital sign conditions</u>
Provider's understanding is updated by cardio-pulmonary status.

<u>Provider's understanding of vital signs results</u>
Provider's understanding is updated by results from vital signs.

<u>Provider's understanding special tests results</u>
Provider's understanding is updated after conducting special test.

<u>Provider's understanding with assessed diagnoses</u>
Provider's understanding is updated after assessing diagnoses.

<u>Provider's understanding with discussed follow-up plan</u>
Provider's understanding is updated after discussing the follow-up plan with patients.

<u>Provider's understanding with follow-up plan</u>
Provider's understanding is updated after establishing follow-up plan.

<u>Provider's understanding with more relevant medical information</u>
Provider's understanding is updated after probing more medical information from medical references.

<u>Provider's understanding with preliminary treatment plan</u>

Provider's understanding is updated with the discussion about the treatment plan with patient.

Provider's understanding with relevant medical information
Provider's understanding is updated after researching latest treatment options and relevant medical information.

Provider's understanding with reviewed information
Provider's understanding is updated after reviewing previous information.

Provider's updated understanding of integrated patient information
Provider's understanding is updated after collecting and integrating patient's clinical information.

Provider's updated understanding of patient's problem after the encounter
The understanding of the patient's problem is updated after the encounter.
The physician has established a relationship with the patient and gained knowledge of the patient's diagnosis, treatment and follow-up plan.

Provider's updated understanding of patient-provider relationship
The provider's understanding is updated after the initial interview between patient and medical provider.

Pulmonary condition
The rate, rhythm, depth, and effort of breathing.

Pulmonary exam results
The sound of patient's lung and surrounding area.

Pulse results
The results of patient's pulse examination.

Rectal exam results
The results of internal rectal exam includes if there is rectal tumors, other forms of cancer, or prostate disorders; notably tumors, benign prostatic hyperplasia or an acute abdomen.

Relevant medical information of latest treatment options
The information researched by the physician regarding options for treatment of the diagnosis.

Respiration results
The results of respiration examination.

Review of organ systems

A component of an admission note covering the organ systems, with a focus upon the subjective symptoms.

Review of patient medical records
The patient's medical records are reviewed and understood by the physician.

Reviewed comprehensive patient's records
Patient's comprehensive medical records reviewed by the physician for relevance to diagnosis.

Reviewed medical history
The medical history collected from the comprehensive medical history regarding the patient's specific conditions.

Reviewed patient's information
All the patient's information in the system is reviewed again before the provider forms the follow-up plan.

Sexual organs check results
The results of sexual organs examination. It includes text and visual data.

Skin and body condition
The results of skin and body condition examination includes skin, musculatory system, breast and lymphatic exam.

Skin examination results
The results of skin examination. It inclues text and visual data.

Snellen Eye Chart or Pocket Vision Card
A Snellen chart is an eye chart used by eye care professionals and others to measure visual acuity.

Special test results
The results of special tests such as the sound or the picture of abnormal symptoms. It includes text, visual and auditory data.

Special tests results
The results of special tests include the picture or sound of abnormal symptoms.

Sphygmomanometer (BP Cuff)
Sphygmomanometer is a device used to measure blood pressure, comprising an inflatable cuff to restrict blood flow, and a mercury or mechanical manometer to measure the pressure.

Stethoscope
The stethoscope is an acoustic medical device for auscultation, or listening to the internal sounds of an animal body.

Temperature Device
The device that measures temperature or temperature gradient using a variety of different principles such as thermometer.

Temperature results
Temperature results.

Test requisition
Tests ordered after preliminary assessment of the patient.

The outcomes of remaining hypotheses
The expected symptoms, conditions, etc. of the patient if the remaining hypotheses are correct.

Throat condition
The results of throat exam such as the sound or the picture of abnormal symptoms. It includes text and visual data.

Time display device
A device can count time as precise as seconds such as a watch display.

Tongue Blades
A narrow, wooden instrument used by the patient to clean the tongue. Can also be used during an examination to aid in inspection of the teeth, gums, and oral cavity.

Updated medical history with characterized symptoms
The patient's medical records, updated with characterized symptoms.

Updated medical history with review of organ system
The patient's medical records, updated with review of organ systems.

Updated medical records
The patient's medical records, updated with information collected in the encounter.

Updated medical records after confirm final
The record of confirmed likely diagnoses which may or may not officially be stored in patient's medical electronic records.

Updated medical records after refuting hypotheses

The recording of hypotheses after refuting unlikely ones which may or may not officially be stored in patient's electronic medical records.

Updated medical records with musculatory exam results
The patient's medical records, updated with musculatory exam results.

Updated medical records with auscultation results
The patient's medical records, updated with auscultation results.

Updated medical records with blood pressure condition
The patient's medical records, updated with blood pressure condition.

Updated medical records with breast exam results
The patient's medical records, updated with chest and lung exam results.

Updated medical records with cardiac function condition
The patient's medical records is updated by cardival function condition.

Updated medical records with cardio-pulmonary status
The patient's medical records, updated with cardio-pulmonary status.

Updated medical records with ear condition
The patient's medical records, updated with ear condition.

Updated medical records with examination results
The patient's medical records, updated with physical examination results.

Updated medical records with eye condition
The patient's medical records, updated with head condition.

Updated medical records with eye exam results
The patient's medical records, updated with eye exam results

Updated medical records with final diagnosis.
The patient's medical records, updated with the final diagnosis.

Updated medical records with gastrointestinal status
The patient's medical records, updated with gastrointestinal status.

Updated medical records with head and neck condition
The patient's medical records, updated with head and neck condition.

Updated medical records with hypotheses

The record of all hypotheses which may or may not officially be stored in patient's electronic medical records.

Updated medical records with inspection results
The patient's medical records, updated with inspection results

Updated medical records with lymphatic exam results
The patient's medical records, updated with lymphatic exam results.

Updated medical records with neck condition
The patient's medical records, updated with neck condition.

Updated medical records with neurologic and mental condition
The patient's medical records, updated with neurologic and mental condition.

Updated medical records with nose condition
The patient's medical records, updated with nose condition.

Updated medical records with oxygenation percentage
The patient’s medical records, updated with blood oxygenation percentage.

Updated medical records with palpation results
The patient's medical records, updated with palpation results

Updated medical records with percussion results
The patient's medical records, updated with percussion results.

Updated medical records with pulmonary exam results
The patient medical records, updated with pulmonary exam results.

Updated medical records with pulmonary results
The patient's medical records is updated by pulmonary results.

Updated medical records with pulse condition
The patient's medical records, updated with pulse condition.

Updated medical records with rectal exam results
The patient's medical records, updated with rectal exam results.

Updated medical records with respiration condition
The patient's medical records, updated with respiration condition.

Updated medical records with results of initial treatment.
The patient's medical records, updated with results of implementing initial treatment.

Updated medical records with sexual organs condition
The patient's medical records, updated with sexual organs condition.

Updated medical records with skin exam results
The patient's medical records, updated with skin exam results.

Updated medical records with special test results
The patient's medical records, updated with special test results.

Updated medical records with special tests results
The patient's medical records, updated with special tests results.

Updated medical records with temperature condition
The patient's medical records, updated with temperature condition.

Updated medical records with throat condition
The patient's medical records, updated with throat condition

Updated medical records with treatment plan
The patient's medical records, updated with treatment plan.

Updated medical records with vital signs results
The patient's medical records, updated with the results from vital signs.

Updated medical results with skin and body exam
The patient's medical records, updated with skin and body exam

Updated patient self-knowledge
The patient's self-knowledge, updated from what is learned in the encounter.

Updated treatment plan
The treatment plan is updated after the physician review the counter indication

Vital signs results
Vital signs results are indicators of one's overall health. They offer clues to diseases and help evaluate progress toward recovery.

Working diagnoses after considering all the factors
Hypotheses after considering all other factors

Working diagnosis after collecting more medical evidence
Hypothesis which matches the addition of newly collected information.

Working diagnosis based on medical reference

The hypotheses which match medical references.

Working diagnosis with probability based on provider's own medical knowledge
The hypotheses that match provider's own medical knowledge.

Working diagnosis with probability based on medical reference
The hypotheses that match provider’s own medical reference

Appendix C: Survey Questionnaire

Model Validation

After training, you [could] understand IDEF0 and the model very well.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

IDEF0 method is a good way to express the encounter process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

This encounter model will be useful for improving the quality of physician-patient encounter.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

A-0 Conduct Medical Encounter (Page 1)

Activities- Conduct Medical Encounter
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Characterize symptoms of urgent problems; Review comprehensive medical history; Conduct review of system; Conduct physical examination; Assess treatment plan effectiveness; Integrate patient information

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Existing diagnosis/es; Existing treatment plan; Previously requested test results; Provider's initial understanding of patient's problems; Patient perceived problems

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Updated patient self-knowledge; Examination results; Provider updated understanding of integrated patient information; Integrated patient information

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference; medical guidelines; Patient factors; Provider factors; Environment/system factors; Established shared goals; Ongoing patient-provider relationship

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Provider; Facilities; Patient as participant; Medical equipment; Information system; Facilities

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

A0 Page 2

Activities- Establish & maintain patient-provider relationship
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Existing patient-provider relationship; Provider's initial understanding of patient's problems; Patient perceived problems; Discussion about the final diagnosis; Discussion about the treatment plan; Discussion of follow-up plan

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Established shared goals; Provider's updated understanding of patient-provider relationship.

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Patient factors; Provider factors; Environment/system factors

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Provider; Patient as participant.

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Collect and integrate clinical information
All the activities are correct in the model
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
New/returning patient; Patient medical record; Existing diagnosis/es; Existing treatment plan; Previously requested test results; Provider's initial understanding of patient's problems;

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Updated patient self-knowledge; Test requisition; Updated medical records; Examination results; Provider's updated understanding of integrated patient information; Integrated patient information

Control

All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference; medical guidelines; Patient factors; Provider factors; Environment/system factors; Established shared goals; Diagnose information needs; Ongoing patient-provider relationship

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Provider; Facilities; Patient as participant; Medical equipment; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Diagnose condition
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Examination results; Provider's updated understanding of integrated patient information; Integrated patient information

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:

Diagnosis information needs; Updated medical records; Final diagnosis(es); Provider's understanding of final diagnosis; Discussion about the final diagnosis

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference; medical guidelines; Patient factors; Provider factors; Environment/system factors; Established shared goals; Provider's updated understanding of patient's problem after the encounter; Ongoing patient-provider relationship

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Provider; Facilities; Patient as participant; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Treat patient
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
New/returning patient; Patient medical records; Provider's understanding of final diagnosis;

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

All the outputs are listed as below:
Updated medical records; Patient in treatment; Final treatment plan; Provider's understanding after implementing the treatment; Discussion about treatment plan

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference; medical guidelines; Patient factors; Provider factors; Environment/system factors; Established shared goals; Provider's updated understanding of patient's problem after the encounter; Ongoing patient-provider relationship; Final diagnosis(es); Integrated patient information.

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Provider; Facilities; Patient as participant; Medical equipment; Information system

Relationship

Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Plan follow-up
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Provider's understanding after implementing the treatment; Patient medical records;

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Provider's understanding with discussed follow-up plan; Follow-up schedule; Patient's enhance understanding of problems; Discussion of follow-up plan; Updated medical records

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Patient factors; Provider factors; Environment/system factors; Final treatment plan; Established shared goals; Provider's updated understanding of patient's problem after the encounter; Ongoing patient-provider relationship; Integrated patient information.

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below

Provider; Facilities; Patient as participant; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Establish & maintain patient-provider relationship
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram are listed as below
Open communication channel; Identify patient's background; Establish shared goals; Establish mutual trust; Establish beneficence.

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Existing patient-provider relationship; Provider's initial understanding of patient's problems; Patient perceived problems; Discussion about treatment plan; Discussion about follow-up plan; Results of discussion of diagnoses

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Ongoing patient-provider relationship; Provider updated understanding of patient-provider relationship; Established shared goals;

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Patient factors; Provider factors; Environment/system factors

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Provider; Patient as participant;

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Collect and integrate clinical information
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Characterize symptoms of urgent problems; Review comprehensive medical history; Conduct review of system; Conduct physical examination; Assess treatment plan effectiveness; Integrate patient information

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing

Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Existing diagnosis/es; Existing treatment plan; Previously requested test results; Provider's initial understanding of patient's problems; Patient perceived problems

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Updated patient self-knowledge; Examination results; Provider updated understanding of integrated patient information; Integrated patient information

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference; medical guidelines; Patient factors; Provider factors; Environment/system factors; Established shared goals; Ongoing patient-provider relationship

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Provider; Facilities; Patient as participant; Medical equipment; Information system; Facilities

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Conduct physical examination
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Check cardio-pulmonary status; Evaluate gastrointestinal status; Examine skin and body condition; Examine head and neck; Examine genitourinary system; Conduct neurologic and mental status examination

Input
All the input is correct in the model.

Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Updated medical history with review of system; Provider understanding of review of system

Output
All the ouput is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Examination results; Provider understanding of physical exam results; Updated medical records with examination results

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls

missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Provider's perceived urgency; Reviewed medical history; Review of systems; Characterized symptom; Diagnosis information needs; Test requisition

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Medical equipment; Electronic medical history system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Check cardio-pulmonary status
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Check vital signs; Assess pulmonary exam; Check cardiac function; Check circulation; Assess oxygenation percentage

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
The inputs are listed as below
Updated medical history with review of system; Provider understanding of review of system

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Cardio-pulmonary status results; Provider understanding of cardio-pulmonary status; Updated medical records with vital signs condition

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Provider’s perceived urgency; Reviewed medical history; Review of systems; Characterized symptom; Diagnosis information needs; Test requisition

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Medical equipment; Electronic medical history system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Check vital signs
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Check temperature; Check respiration; Check pulse; Check blood pressure

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Updated medical history with review of system; Provider understanding of review of system

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Provider understanding of vital sign results; Updated medical records with vital signs

results; Vital sign results

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Provider's perceived urgency; Reviewed medical history; Review of systems; Characterized symptom; Diagnosis information needs; Test requisition; Medical reference; Medical guidance; Environment/system factors; Provider factors; Patient factors; Ongoing patient-provider relationship

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Medical equipment; Electronic medical history system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

Activities- Evaluate gastrointestinal status
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Perform inspection; Palpate patient's adamant; Perform auscultation; Perform percussion; Perform rectal exam; Perform special tests

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
The inputs are listed as below
Updated medical history with vital signs condition; Provider understanding of cardio-pulmonary statues

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Evaluated abdominal area results; Provider understanding of gastrointestinal status results; Updated medical records with vital signs condition

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Provider's perceived urgency; Cardio-pulmonary status; Reviewed medical history; Review of systems; Characterized symptom; Diagnosis information needs; Test requisition

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Electronic medical history system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Examine skin and body condition
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Perform skin examination; Perform musculatory system exam

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Updated medical history with gastrointestinal status; Provider understanding of cardio-pulmonary status results; Provider's understanding of gastrointestinal status results

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Skin and body condition; Provider understanding of skin and body condition; Updated medical records with musculatory exam

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Provider's perceived urgency; Cardio-pulmonary status; Reviewed medical history; Review of systems; Characterized symptom; Diagnosis information needs; Test requisition

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Medical equipment; Electronic medical history system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Examine head and neck
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Perform eye exam; Perform ear exam; Perform nose exam; Perform throat exam; Perform neck exam; Perform special exam

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree

Comment
The inputs are listed as below
Updated medical history with musculatory exam; Provider's understanding of cardio-pulmonary status results; Provider's understanding of skin and body condition

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Head and neck condition; Provider understanding of head and neck condition; Updated medical records with head and neck condition

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Provider's perceived urgency; Cardio-pulmonary status; Reviewed medical history; Review of systems; Characterized symptom; Diagnosis information needs; Test requisition

Mechanism
All the mechanisms are correct in the model.

Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Medical equipment; Electronic medical history system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Diagnose condition
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Evaluate integrated patient information; Evaluate shared goal and define overall diagnosis task; Generate diagnosis hypotheses; Refute unlikely diagnosis hypotheses; Confirm most likely diagnosis; Discuss and explain diagnosis with patient

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
The inputs are listed as below
Provider's updated understanding of integrated patient information; Examination results; Patient medical records; Integrated patient information

Output
All the ouput is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Diagnosis information needs; Updated medical records; Provider's understanding with final diagnoses; Final diagnosis/es; Results of discussion of diagnoses

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Evaluate integrated patient information
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Review patient medical history; Analyze physical findings; Research symptoms and test results; Review medical guidance and medical reference; Generated evaluation

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
The inputs are listed as below
Provider's updated understanding of integrated patient information; Examination results; Patient medical records;

Output
All the ouput is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Evaluation of integrated patient information

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls

missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference; Medical guideline; Integrated patient information; Ongoing patient-provider relationship; Environment factors; Patient factors; Provider factors; Established or shared goals

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Generate diagnosis hypotheses
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

All the activities are listed as below
Review previous evaluation; Generate hypotheses from provider's own medical knowledge; Generate hypotheses from medical reference; Identify additional information needed for diagnosis; Form diagnosis hypotheses

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
The inputs are listed as below
Evaluation of shared goal and overall task; Evaluation of integrated patient information

Output
All the ouput is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Diagnosis information needs; Diagnosis hypotheses; Updated medical records with diagnosis hypotheses

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree

Comment
All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
All controls are listed as below
Ongoing patient-provider relationship

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Refute unlikely diagnosis hypotheses
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Identify expected outcomes of diagnosis hypotheses; Compare diagnosis hypotheses outcomes with patient's condition; Refute diagnosis hypotheses from provider's own medical knowledge; Refute diagnosis hypotheses from medical reference; Identify additional information needed for refuting diagnoses; Refute wrong hypothese

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
The inputs are listed as below
Diagnosis hypotheses; Integrated patient information; Updated medical records with diagnosis hypotheses

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Diagnosis information needs; Diagnoses after refuting alternative; Provider's

understanding of refuted diagnoses; Updated medical records after refute diagnosis

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment
All controls are listed as below
Medical reference

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Information system; Decision making aid system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Treat patient
All the activities are correct in the model including

Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Create possible treatment plan; Review counter indication; Discuss treatment plan with patient; Generate final treatment plan; Implement initial treatment

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
New/returning patient; Patient medical records; Provider's understanding with final diagnoses

Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs

missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Discussion about treatment plan; Final treatment plan; Updated medical records; Patient in treatment; Provider's understanding after implement the treatment

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Medical reference; medical guidelines; Patient factors; Provider factors; Environment/system factors; Established shared goals; Ongoing patient-provider relationship; Integrated patient information; Final diagnosis/es; Established shared goal

Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Activities- Plan follow-up
All the activities are correct in the model including
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important activities are included in the diagram. There are no important activities missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the activities are listed as below
Review patient's information; Establish follow-up plan; Discuss follow-up plan with patient

Input
All the input is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the inputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important inputs are included in the diagram. There are no important inputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

The inputs are listed as below
Patient medical records; Provider's understanding after implement the treatment
Output
All the output is correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important outputs missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the outputs are listed as below:
Updated medical records; Follow-up schedule; Provider's understanding with discussed follow-up plan; Patient enhanced understanding problems; Discussion of the follow-up plan

Control
All the controls are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the controls in the diagram significantly contribute to the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important outputs are included in the diagram. There are no important controls missing
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All controls are listed as below
Final treatment plan; Patient factors; Provider factors; Environment/system factors; Established shared goals; Ongoing patient-provider relationship; Integrated patient information; Established shared goal
Mechanism
All the mechanisms are correct in the model.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the mechanisms have a significant impact on the process.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

All the important mechanisms are included in the diagram. There are no important mechanisms missing
Strongly agree, agree, neutral, disagree, strongly disagree

Comment

All the mechanisms are listed as below
Facilities; Provider; Patient as participant; Information system

Relationship
Read from upper left to bottom right, the relationship among the activities accurately represents the process of conducting medical encounters.
Strongly agree, agree, neutral, disagree, strongly disagree
Comment

Appendix D: Healthcare Toolkit Requirements

Requirement	IDEF0 Diagram	Comments
The Healthcare Toolkit (HT) shall not require more than *TBD* seconds to process the information input by the physician on each page	A1	TBD = To Be Determined
The HT shall not require the provider to spend more than *TBD*% of the total time of an encounter in data entry.	A1	TBD = To Be Determined
The HT shall remind the user to establish shared goals with the patient.	A1	
The HT shall remind the user to establish benefits with patient.	A1	
The HT shall allow the user to navigate all the patient information with no more than *TBD* clicks.	A1	TBD = To Be Determined
The HT shall display the patient's heart rate for the physician to review after conducting the exam.	A2	

The HT shall display the patient’s blood pressure for the physician to review after conducting the exam.	A2	
The HT shall display the patient’s respiration rate for the physician to review after conducting the exam.	A2	
The HT shall display the patient's temperature for the physician to review after conducting the exam.	A2	
The HT shall provide means to examine the patient's heart rate.	A2	
The HT shall provide means to examine the patient's blood pressure.	A2	
The HT shall provide means to examine the patient's respiration rate.	A2	
The HT shall provide means to examine the patient's temperature.	A2	
The HT shall provide means to record the visual and audio evidence collected from inspection and auscultation during the exam.	A2	
The HT shall provide means to transfer examination data to the patient's electronic medical records.	A2	

The HT shall provide means to transfer examination data to the patient's electronic medical records.	A2	
The HT shall provide the symptoms of expected diagnostic hypotheses for comparison with the patient's condition and symptoms.	A3	
The HT shall provide access to medical references such as Physician Desk Reference or online resources at anytime during the encounter.	A3	
The HT shall allow the physician to review all the patient's clinical information collected and recorded during the encounter.	A4	
The HT shall provide contraindications for any treatment that is being considered.	A4	
The HT shall provide means to record and interact with the physician's schedule and the patient's scheduled encounters and treatments.	A5	

Appendix E: IRB Exemption Letter

OSU Oregon State UNIVERSITY

Institutional Review Board • Office of Research Integrity
B308 Kerr Administration Building, Corvallis, Oregon 97331-2
Tel 541-737-8008 | Fax 541-737-3093 | IRB@oregonstate.edu
http://oregonstate.edu/research/ori/humansubjects.htm

NOTIFICATION OF
RESEARCH DETERMINATION

January 24, 2011

Principal Investigator:	Kenneth Funk	Department:	Industrial Engineering
Project Title:	Healthcare modeling validation		

The above referenced proposal was reviewed by the OSU Institutional Review Board (IRB) Office. The IRB has determined that your project does not meet the definition of "research involving human subjects" under the regulations set forth by the Department of Health and Human Services 45CFR46.102.

Further review of this proposal is not required and you may proceed with the project as it was described in this submission.

Please note that amendments to this project may impact this determination.

If you have any questions, please contact the IRB Office at IRB@oregonstate.edu or by phone at (541) 737-8008.