2009

# Development of a framework to identify patient pathways through a segment of the health care cycle

Abhik Bhattacharya
*University of South Florida*

# Development of a Framework to Identify Patient Pathways through a Segment of the Health Care Cycle

by

Abhik Bhattacharya

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Industrial Engineering
Department of Industrial and Management Systems Engineering
College of Engineering
University of South Florida

Co-Major Professor: José L. Zayas-Castro, Ph.D.
Co-Major Professor: Peter J. Fabri, M.D., Ph.D.
Ali Yalcin, Ph.D.

Date of Approval:
March 10, 2009

Keywords: health care, care cycle, patient flow, clinical pathways, medical databases

**Dedication**

To my parents and brother.

## Acknowledgements

I would like to thank Dr. José L. Zayas-Castro for his continued support and guidance through the years. I would like to thank Dr. Peter J. Fabri for his invaluable insight into the health care domain. I would also like to thank Dr. Ali Yalcin for his help and support over the years.

I would also like to thank my parents for their support through all these years. Nothing in my life would have been possible without their constant encouragement and support.

Finally, thanks to my friends and colleagues for their help in completing this study.

## Table of Contents

## List of Tables

## List of Figures

Development of a Framework to Identify Patient Pathways through a Segment of the Health Care Cycle

Abhik Bhattacharya

## ABSTRACT

The US spends more money on health care than other industrialized nations. Nevertheless, the US lags behind them in life expectancies, access to care, and other health indicators. This can be attributed to the numerous issues that afflict the US health care sector – the lack of a universal health coverage, increasing medical errors, over and under-treatment of patients, lack of standardization, and so on.

It is believed that the structure of health care delivery as it exists in the US is broken, which consequently reduces the quality of provided care and increases costs. There is a growing consensus among the different players in the sector that a complete overhaul of the health care system is required. This study presents an approach to identify patient treatment over a cycle of care.

Every medical condition has a care cycle over which treatment is provided. The complete cycle of care of most medical conditions comprise of both inpatient and ambulatory care and start from the onset of the disease to its resolution. There are established guidelines that state what care should be provided during various points of

this cycle. It is important to identify and analyze the flow of patients through this cycle of care. Once the flow is identified, various analyses can then be conducted to identify bottlenecks, delays, redundancies and other issues that reduce efficiency and increase costs.

Unfortunately, due to the fact that medical data is collected for either medical or billing purposes and not for an operational analysis, it is very difficult to analyze the flow of patients over this cycle of care. This study developed a framework to extract relevant patient medical information from existing administrative databases of health care organizations. This was used to create patient flow paths across a segment of the care cycle to enable the analysis of the care treatment. A case study was conducted at a federal health care provider to identify and map the flow over the care cycle of patients with lung cancer.

# Chapter 1 Introduction

The United States spends significantly more on health care than other developed countries in the world (OECD, 2007). In 2006, the national health care expenditures amounted to $2.1 trillion and formed 16 percent of the Gross Domestic Product (GDP) (National Center for Health Statistics, 2007). Despite the staggering amount spent on health care, the US lags behind other developed nations and the UN Human Development Report mentions that “countries spending less than the US have healthier populations…” (United Nations Development Program, 2005). One of the major issues with health care in the US is the lack of universal health insurance as the US is the only industrialized country in the world without a universal health insurance system (Hoffman, Hoffman & Hoffman, 2005). In a CBS/New York Times poll conducted in 2007, 90 percent of Americans believe the American health care system is broken and needs fundamental changes or needs to be completely rebuilt and 64 percent said that the government should guarantee health insurance for all (CBS/NYT, 2007).

A lot of interest and energy in recent years has been focused on reducing the number of uninsured in the US, but that may not be the only solution to the problem. Porter & Teisberg (2006) mention that “while the vast majority of attention has been focused on insurance, we believe that the structure of health care delivery is the most fundamental issue. The structure of health care delivery drives the cost and quality of the entire system, and ultimately the cost of insurance and the amount of coverage that is feasible.

The fundamental problem in the U.S. health care system is that the structure of health care delivery is broken. This is what all the data about rising costs and alarming quality are telling us."

The World Health Organization (WHO) defines health care delivery as "one of the functions of the health system, which deals with the medical and therapeutic measures intended to preserve or improve the health condition of a patient." WHO mentions that the objectives of reforming health care delivery are "to provide health care that is oriented towards outcome; based on evidence and focused on effectiveness and efficiency; to increase the availability of services, patient satisfaction and the quality of care."(World Health Organization - Europe, 2006)

Providing timely care is important to prevent adverse outcomes. Unfortunately, the broken structure of health care delivery coupled with the high demand for health care has led to overcrowding and delays, and timely care is not always provided. Identifying delays in the system at the provider level and addressing the root causes behind them helps in delivering care on time.  A significant way to identify delays is to study the flow of patients. Patient flow analysis has been defined as that representing "the study of how patients move through the health care system" (Hall, 2007). This study presents an approach to study patient flow over the care cycle, with the aim of reducing unnecessary delays and improving efficiency at the provider level. Once flow has been identified and understood, different approaches can then be used to balance utilization across the process, make it more patient-centric, reduce costs, and improve quality and so on. The next few sections describe the US health care sector and the various challenges it faces.

## 1.1 The Health Care Sector

In 2006, the national health care expenditures amounted to $2.1 trillion and formed 16 percent of the Gross Domestic Product (GDP) (National Center for Health Statistics, 2007). Health care expenditures rose 6.7 percent from the previous year (2005) and are forecasted to grow at the same rate until 2017. In comparison, the overall US economy was expected to grow at 4.9 percent through the same period. At this rate, health care expenditures would total more than $4.3 trillion in 2017; or 19.5 percent of the GDP. In contrast, in1960 the health care expenditures totaled $27.5 billion, just 5.2 percent of the GDP. During that period, the US population has grown from 186 million to 300 million resulting in the per capita increase on health care from $148 (in 1960) to over $7000 (in 2006) and is expected to go over $13,000 in 2017 (National Center for Health Statistics, 2007).

Health care consists of two major segments: outpatient (or ambulatory) and inpatient services. In 2006, hospital care expenses fell to less than 31% of total expenditures while physician expenses rose to 21%. The average length of stay for inpatients drastically decreased from 11.4 days in 1975 to 6.5 days in 2005, while outpatient visits increased from 254 million to 673 million in that period. Significantly, outpatient surgeries increased from 16.3% in 1980 to 66.3% in 2005 (National Center for Health Statistics, 2007), confirming a trend towards more ambulatory services. Unfortunately, higher expenditures have not translated into providing greater access to health care nor significantly improved its quality.

## 1.2 Issues in Health Care

In 2005, more than 40 million adults could not afford health care (National Center for Health Statistics, 2007). Life expectancies haven't improved – the US has among the lowest life expectancy rates in all industrialized nations (World Health Organization, 2008).

Regrettably, the issues do not end there. Medical errors are on the rise and the Institute of Medicine (IOM) estimates that between 44,000 to 98,000 people die annually due to medical errors (Committee on Quality of Health Care in America, Institute of Medicine, 2000). Additionally, over and under-treatment of patients have become commonplace. Americans receive only about 55 percent of care suggested by established medical standards (Porter & Teisberg, 2006). The low quality of provided care leads to avoidable adverse medical conditions resulting in additional care, and thus, even higher expenses. There are wide variations in medical practice and costs, with differences in the patterns of practice and variation in the frequency of specialist care and hospitalization that drive regional variations in spending.

Additionally, malpractice premiums and lawsuits, which increase the cost of care, promote 'defensive medicine' by inducing unnecessary tests and over-diagnosis, which result in excessive care and expenses. Therefore, it is not surprising to read that US consumers report higher dissatisfaction with their health care system than do consumers in other developed nations (CBS/NYT, 2007). The list of concerns afflicting US health care keeps increasing, and the above are only a few that need to be addressed.

### 1.2.1 The US Hospital Care System

The US health care system is made up of both outpatient facilities (clinics, doctor's offices) and inpatient facilities (hospitals). There has been a downward trend in the number of operating hospitals in the US. The number of community hospitals has decreased from 5813 in 1981 to 4927 in 2006, decreasing the number of available beds during the same period by about 200,000 (American Hospital Association, 2008). This has led to only 2.68 beds per 1000 persons in 2006 compared to 4.37 in 1981. National expenditures on hospital care have increased from 3.4% in 1996 to 7% in 2006, (American Hospital Association, 2008).

Even though the US population has increased by about 70 million from 1981 to 2006, inpatient admissions have decreased (from more than 36 million in 1981 to about 35 million in 2006). The average inpatient stay has reduced significantly from 7.6 days to 5.6 during the same period, showing a growing trend towards more outpatient care. Outpatient visits increased from 202 million in 1981 to almost 600 million in 2006. More surgical procedures are being done in ambulatory care, as inpatient surgeries decreased from over 15 million in 1981 to 10 million in 2006, while ambulatory surgeries increased from 3.5 million to over 17 million during the same period (American Hospital Association, 2008).

Hospital systems are facing myriad problems that affect the quality of care received by patients. About 25% of hospitals reported negative revenue margins in 2006 (American Hospital Association, 2006). Delays in emergency departments (EDs) are routine and have become expected. There were about 600 less EDs in 2006 than in 1991 reflecting the downward trend (American Hospital Association, 2008), though the number of ED visits have risen from 88.5 million in 1981 to 118.4 million in 2006, a 33 percent increase. This has resulted in considerable delays in accessing timely care in EDs. The Centers for Disease Control and Prevention (CDC), in their 2005 survey found that the average waiting time for a patient in the ED was almost an hour and has been increasing steadily from 38 minutes in 1997. Twelve percent of those ED visits resulted in inpatient admission, while almost half of hospital admissions were through the ED in 2006, up from 36 percent in 1996 (Pitts et al., 2008).

One of the major reasons for ED overcrowding has been attributed to the lack of inpatient bed capacity, which blocks new patients from being treated (American College of Emergency Physicians, 2006). Forty-seven percent of hospitals in 2007 reported their ED at or over capacity and 36 percent of all hospitals had to go on ambulance diversion. Fifty-nine percent of hospitals reported that the ambulance diversion was due to either an overcrowded ED or lack of staffed critical care beds (American Hospital Association, 2008).

Research shows that the real gridlock in emergency department crowding is a "throughput" problem, caused by the lack of inpatient bed capacity in hospitals. The General Accountability Office (GAO) reported in 2003 that "boarding" of critically ill patients causes overcrowding, tying up staff and resources, making them unable to treat any more patients from the waiting room or from an ambulance (United States General Accounting Office, 2003).

### 1.2.2 The Overarching Grand Challenges in the Health Care Sector

To conclude, the US health care sector is facing many challenges and it is very important that effective solutions be found to combat those challenges and ensure that people receive proper and timely care. In turn, these difficulties reduce the quality of care received. About 44 million Americans (17 percent of the total population) do not have health coverage (National Center for Health Statistics, 2007). In summary, health care costs have been escalating by about 7 percent annually, many individuals are unable to access basic medical care due to these rising costs, and errors and mistreatments in medical practice have been creeping up.

Another challenge is the lack of standardization in health care. There are wide regional variations in cost, access, physician visits, and procedures. Medical standards do exist for treatment of specific medical conditions, but, there is significant over and under-treatment of patients, resulting in unnecessary and avoidable interventions that increase costs. The quality of care also suffers due to preventable adverse events. The fragmented nature of the health care system results in minimal information sharing among the different providers, increasing the possibility of over-treatment or of losing critical health information.

A multipronged effort is required to tackle the challenges mentioned. As has been said by several people, a complete revamp of the US health care sector is needed. One way of reducing costs and increasing efficiency is to reduce variations in treatment. Variations can be determined by assessing the treatments patients receive, which form the flow of a patient through their care cycle. Information obtained from patient provider interactions can be used to improve the provided care. This study addresses the need to evaluate patient flow over the treatment care cycle. By identifying and analyzing flow, decisions can be made to improve the efficiency, effectiveness and the timeliness of care.

## 1.3 Overview of Research Objectives

Information sharing among different providers is the only way to create patient pathways, where all treatments can be chronologically identified and arranged. Unfortunately, the fragmented nature of health care has resulted in information 'silos' where information is not easily shared among different providers. Hence, it is not an easy task to trace a patient's path through multiple episodes of care. The flow identification is an insurmountable task when patients have to go to different unaffiliated providers during the course of their treatment.

The objective of this study is to develop a framework to identify patient flow over a cycle of care from fragmented databases. This framework can be used to track patient flow for any diagnosis or treatment. The subsequent analysis of the flow can be used to make the care delivery more patient-centric. Further details on the study objective can be found in chapter 3.

## 1.4 Thesis Organization

This thesis is organized into six chapters. Chapter 2 is a review of pertinent literature on patient flow in both outpatient and inpatient settings. Sections on clinical pathways and electronic medical records (EMR) are also presented. Chapter 3 introduces the research objectives, methodology and the corresponding benefits of this study. Chapter 4 describes the patient data obtained on implementing the rules for patients who underwent a lung resection. Chapter 5 outlines the framework rules. The first section of chapter 5 describes the protocols and rules for identifying relevant information of patients undergoing lung resection. The second section of chapter 5 expands these rules and describes the protocol to follow to identify relevant patient information for any intervention. Conclusions and future work are discussed in chapter 6.

# Chapter 2 Literature Review

This chapter outlines the major efforts that have been made towards improving health care delivery, especially in the area of improving patient flow. The first section reviews studies on patient flow, while sections 2.2 and 2.3 are devoted to clinical pathways and electronic medical records (EMR).

## 2.1 Patient Flow

Increased focus on improving efficiency in health care delivery came about in the 1980s when the federal government adopted a prospective payment system (PPS) that resulted in fixed payments for medical services. Consequently, providers had to focus on efficiency to reduce costs due to delays (Cote, 2000). This resulted in a surge in studies on improving flow in the delivery of health care services, since analyses had shown that just adding resources would not improve the situation, as the delays are due to problems in flow and not necessarily with resources (Haraden & Resar, 2004). Multiple approaches and techniques have been used to enhance flow, including discrete-event simulation (DES), scheduling, optimization, Markov chains, linear programming, queuing theory, and data mining. Smoothing demand for elective surgeries (ES), reducing wait times, allocating resources, and achieving timely and efficient transfer of patients have been the common areas of focus (Haraden & Resar, 2004). Jun, Jacobson & Swisher (1999) provide a comprehensive survey of studies that have been conducted by using DES, which has become a widely used tool for modeling patient flow. Hall (2007) expands upon that survey and provides updates. The next two sub-sections outline studies in outpatient and inpatient segments.

### 2.1.1 Outpatient Flow

Many of the papers on improving health care delivery are in the outpatient or ambulatory sector. The ambulatory sector comprises doctor's offices, single and multiple clinic systems, and ambulatory surgery systems. Most studies in this area are in improving the scheduling of appointments, reducing waiting times, the 'callback' of patients in the waiting room, improving the layout in ambulatory clinics, and reducing demand peaks for ambulatory ES.

Cayirli & Vera (2003) provide a comprehensive review of studies on appointment scheduling in outpatient services. Aharonson-Daniel, Paul & Hedley (1996) built a simulation model in MedModel of an outpatient clinic in Hong Kong to demonstrate the use of DES to reduce patient's waiting time to see a physician. Clague et al. (1997) used a computer simulation model to study the effects of changes in clinic size, consultation time, patient mix, appointment scheduling and non-arrivals on the patient and physician waiting times. They discovered that a 1 in 4 ratio of new to follow-up patients reduced the patient waiting time considerably and new patient appointments should be optimally spread throughout the clinic to have a significant impact on the waiting time of patients. Dexter (1999) provides guidelines on designing appointment systems for pre-anesthesia evaluation clinics. According to this author, the major factors that lead to long patient waits are patient punctuality, provider tardiness and walk-on patients. With the help of a simulation, he demonstrated that wait times can be reduced by decreasing the standard deviation of consultation times (some of which, in his study, were as high as the mean consultation time itself) and deliberately reduce provider productivity by scheduling breaks or longer appointment times to take into account walk-on patients.

Edward et al. (2008) used two simulation models to reduce the maximum waiting time to 10 minutes for 95% of all patients in a pre-operative assessment clinic. Edwards et al. (1994) used a simulation model of two outpatient clinics and was able to reduce waiting time by 30%. Harper & Gamlin (2003) evaluated multiple scenarios or policies by building simulation models to reduce patient waiting time in an Ear, Nose and Throat (ENT) clinic in the UK. Klassen & Rohleder (1996) built a simulation model of a dynamic medical outpatient environment to efficiently schedule different ‘types’ of patients and found that the least waiting time occurred if patients with large service time standard deviations were scheduled towards the end of the appointment session.

One of the major issues in outpatient care delivery has been patient walk-ins and no-shows, which disrupt appointment schedules. As a result, many clinics now provide open access scheduling where patients make appointments only a few days before seeing the physician. Kopach et al. (2007) studied the effects of four variables – fraction of patients served on open access, the scheduling horizon, provider care groups, and overbooking on the waiting time, and concluded that correctly configured open access scheduling leads to improvements in patient throughput.  Rohrer et al. (2007) studied the difference in access between clinics with traditional scheduling systems and those with open access scheduling. Studies have also been conducted on how staffing policies and resource allocations affect waiting time. Huarng & Lee (1996) built a simulation model to study how changes in the appointment system, staffing policies and service units affected the patient waiting queues. Swisher et al. (2001) used simulation to conduct 'what-if' analyses on staffing levels, facility design, scheduling policies and operating hours in a family practice health care clinic.

### 2.1.2 Inpatient Flow

As with outpatient facilities, a number of studies have been done in the inpatient segment or hospitals. Most studies in these facilities are on scheduling admissions, bed planning, optimizing the emergency department (ED), reducing admission and discharge delays, and smoothing demand for ES. The common areas of focus have been the ED, the operation room (OR), and the acute care units (ACU). Magerlein & Martin (1976) published a comprehensive review of ES scheduling studies. Lowery (1996) used a simulation model to design an admissions scheduling system that reduces variability in hospital occupancy.

The ED has been the most common focus of inpatient flow studies. Cowan & Trzeciak (2005) review the causes and effects of ED overcrowding in the US and explores its impact on critically ill ED patients. Trzeciak & Rivers (2003) also conducted a review of studies on ED overcrowding and came to the conclusion that overcrowded EDs compromise patient safety and jeopardize the reliability of the entire US emergency management system (EMS). Schneider et al. (2003) and Spaite et al. (2002) also studied the level of crowding in EDs. Ambulance diversions have increased as more overcrowded EDs stop seeing new patients. Fatovich, Nagree & Sprivulis (2005), Olshaker & Rathlev (2006a) and Schull et al. (2003) studied the relationship between ED overcrowding and ambulance diversions and offered solutions to reduce them. Eckstein et al. (2005) studied the impact of crowding on EMS personnel who are unable to transfer their patients to an ED. Multiple studies have evaluated or identified factors to reduce ED overcrowding. Terris et al. (2004) studied the impact on the patient wait time when an emergency medicine consultant and an ED nurse assisted in triage. The US General Accounting Office (United States General Accounting Office, 2003) identified “the inability to transfer emergency patients to inpatient beds once a decision has been made to admit them as hospital patients rather than to treat and release them” as the factor most commonly associated with ED overcrowding. Olshaker & Rathlev (2006b) and Schafermeyer & Asplin (2003) offer solutions to reduce ED overcrowding. Miller, Ferrin & Szymanski (2003) and Howell, Bessman & Rubin (2004) studied two approaches to reduce ED overcrowding. The former utilized simulation and a six sigma approach to evaluate multiple scenarios to improve ED performance, while Howell et al. implemented a new direct admission system based on telephone consultation between ED physicians and in-house hospitalists and were able to reduce average admission time to 18 minutes compared to the previous average of 2.5 hours.

Effective allocation of beds has become an important point to consider, since ineffective bed utilization has consequences on various other areas within a hospital. Proudlove, Gordon & Boaden (2003) concluded that an effective bed management system solved the ED overcrowding issue. Marshall, Vasilakis & El-Darzi (2005) reviewed studies on length of stay-based patient flow models. Christodoulou & Taylor (2001) used a continuous time hidden Markov process to model bed occupancy of geriatric patients. Simulation models have also been used to improve bed allocation in hospitals (Dumas, 1984; el-Darzi et al., 1998; Mackay & Millard, 1999; McClean & Millard, 1995; Ridge et al., 1998; Mackay & Lee, 2005).

## 2.2 Clinical Pathways

Clinical pathways are quickly gaining favor among practitioners as an effective tool to reduce delays and improve treatment efficiency. (Coffey et al., 2005) define a clinical pathway as an 'optimal sequencing and timing of interventions by physicians, nurses, and other staff for a particular diagnosis or procedure, designed to minimize delays and resource utilization and to maximize the quality of care'. Cheah (2000) mentions that 'clinical pathways have been shown to reduce unnecessary variation in patient care, reduce delays in discharge through more efficient discharge planning, and improve the cost-effectiveness of clinical services'. Further arguments state that clinical pathways delineate a plan to execute the best practices in patient care. Granted the pathways must have flexibility since they represent the majority, but not all patients.

Numerous studies have been done on the impact of implementing a clinical pathway. Walter et al. (2007) successfully implemented a clinical pathway for patients having total joint arthroplasty, and were able to not only reduce the length of stay and costs, but also increase patient satisfaction. Chen et al. (2000) found similar results on implementing a pathway approach for patients undergoing head and neck oncologic surgery. Konishi & Agawa (2000), Chang et al. (1999), Kim et al. (2003), Husbands et al. (1999), Rauh et al.

(1999) and Calligaro et al. (1995) studied the impact of clinical pathways on various surgical procedures and concluded that pathways not only reduce length of stay and costs, but also increases patient and provider satisfaction. Zehr et al. (1998) found that the implementation of a standardized clinical pathway for major thoracic surgeries reduced hospital length of stay and costs. Collier (1997) found similar results for major vascular surgeries. But not all pathway implementations have been successful. Bailey et al. (1998) found no significant difference in length of stay between pathway and non-pathway patient groups after the implementation of a clinical pathway in asthma, though they did observe cost savings due to increased use of alternate treatment options. Weingarten et al. (1998) also observed a mix in success rates in reducing length of stay for patients having hip or knee replacements.

Cardoen & Demeulemeester (2008) developed a DES model of a consultation and surgical suite in a Belgian hospital to evaluate the efficiency of clinical pathways and their complex interdependencies of resource usage and patient throughput. Napolitano (2005) outlines the creation of clinical pathways from national guidelines into a local setting for the management of patients undergoing common surgical procedures. Forkner (1996) mentions the liabilities associated with clinical paths, while Sheehan (2002) provides a liability checklist for ensuring safe and responsible use of pathways. Eccles & Mason (2001) explores the methods to incorporate cost issues within clinical guidelines. Asadi & Baltz (1996) provides a methodology to create pathways that combine both clinical and financial data to measure how efficiently human, material and capital resources are allocated to provide services. Smith & Hillner (2001) conducted a review of studies on improvements in oncology treatment processes or outcomes and found a mix of successful and unsuccessful attempts. They mention that "programs that have not succeeded have relied on voluntary change in practice behavior without incentives to change or have had no accountability component". Every et al. (2000) and Butterworth (1997) present guidelines on creating clinical pathways and successfully implementing them. Kingston, Krumberger & Peruzzi (2000) explored the benefits and barriers to using clinical guidelines and examines processes that are critical to constructing valid tools. Barnette & Clendenen (1996) provides an example of a community behavioral center's transition to clinical pathways.

## 2.3 Electronic Medical Records

EMRs are garnering widespread discussion, with researchers, providers, and the public increasingly identifying it as a way to improve the quality of care, reduce costs and ensure a continuum of care for the patient. Numerous studies have been conducted that identify the benefits of EMRs. Strategies for implementation and surveys of EMR adoption rates are also widely discussed in the literature.

Kazley & Ozcan (2008) compared quality outcome between hospitals using EMR with those that do not use EMR in 3 clinical conditions – acute myocardial infarction, congestive heart failure, and pneumonia. They found a positive significant relationship between EMR use and increased quality in the first two conditions. Asch et al. (2004) studied 12 VHA health care systems and concluded that VHA patients received higher quality care due to the introduction of an integrated EMR. Spencer et al. (1999) found that EMRs along with continuous quality improvement lead to improvements in the screening and documentation for smoking status at a clinic. Kinn et al. (2001) studied the impact of EMR on patient outcomes at an outpatient cardiology clinic and found that patients with EMRs received significantly more appropriate care than those without. Garrido et al. (2005) evaluated the impact of EMR implementation on the use and quality of ambulatory care at Kaiser Permanente and concluded that "readily available, comprehensive, integrated clinical information reduced use of ambulatory care while maintaining quality…" Several other studies have also come to similar conclusions.

Besides improving the quality of care, EMRs also have the potential to reduce costs. Wang et al. (2003) estimated the net cost benefit from using an EMR in primary care for a 5 year period was $86,400 per provider. Even though there are potential benefits in implementing EMRs, only about 24 percent of physicians in ambulatory care and 5 percent of hospitals used EMRs through 2005 (Jha et al., 2006). Burt & Sisk (2005) analyzes the relationship between EMR adoption rates and physician and practice characteristics.

Providers cite various factors that affect their decision to implement EMRs. These factors include a lack of national health care policy, multiple EMR informatics standards, EMR implementation costs, privacy, and data entry issues. Vishwanath & Scamurra (2007) developed a comprehensive empirically based conceptual model of the barriers that affect EMR adoption among physicians. Unless these issues are sorted, EMR adoption rates would not significantly increase.

### 2.4 Summary

The studies previously reviewed have been conducted to improve the delivery of care. Various methodologies and approaches have been used towards that aim. Most of these studies have been limited to individual clinics or units within a hospital. Only a few address multiple units within an organization or multi-clinic facilities. The literature barely focuses on the entire care cycle of a patient's medical condition from an operational viewpoint, though there are numerous papers from a medical perspective. As Porter & Teisberg (2006) mention, "value can only be measured over the care cycle, not for an individual procedure, service, office visit, or test." They define value as "the health outcome per dollar of cost expended." Therefore, there is an opportunity for studies on the entire care cycle of the patient's medical condition, as that is the only way to identify if the provided care is effective.

Technological advances have made it possible to conduct procedures or interventions that could be highly beneficial to a patient's treatment. These advantages, though, come at a higher cost, and decisions have to be made regarding the effectiveness of these procedures to alleviate the patient's medical condition. These decisions can be better made when the entire care cycle of the patient is analyzed, and the different treatment options weighed. For example, it could be more cost-effective to have an expensive intervention now and improve the patient's condition that reduces the level (and cost) of future care.

However, the health care system is not structured to collect information over a patient's entire care cycle. Most providers store their own facility's information, which is episodic in nature. Information beyond their network is stored in paper form; scanned and stored electronically, but as an object that is neither easily accessible nor searchable; or worse, are shredded and relegated to the trash bin. It is believed that a universal electronic medical record (EMR) will improve information sharing among providers.

Thus, to enable the analysis of the care cycle and improve care delivery, information not only needs to be shared and easily accessible among the different providers, but also a way has to be developed to glean pertinent information from these multiple variant databases. This study attempts to address the latter by developing a framework to extract information from databases. It is believed that this will serve as a foundation for increased studies on developing methods to extract relevant information from medical databases that will enable the evaluation of care over the care cycle. This will enable further analysis, including effectiveness, costs, and other factors.

## Chapter 3 Problem Statement

3.1 Introduction and Motivation

Every medical condition has a treatment care cycle with guidelines that state the type of care or treatment to be provided. Treatment is usually provided through multiple interventions within the cycle. The care cycle starts from the onset of the disease and ends with its resolution or the patient's death. For a majority of medical conditions, especially those considered serious, the care cycle encompasses both ambulatory and inpatient care. Figure 1 illustrates the care cycle.

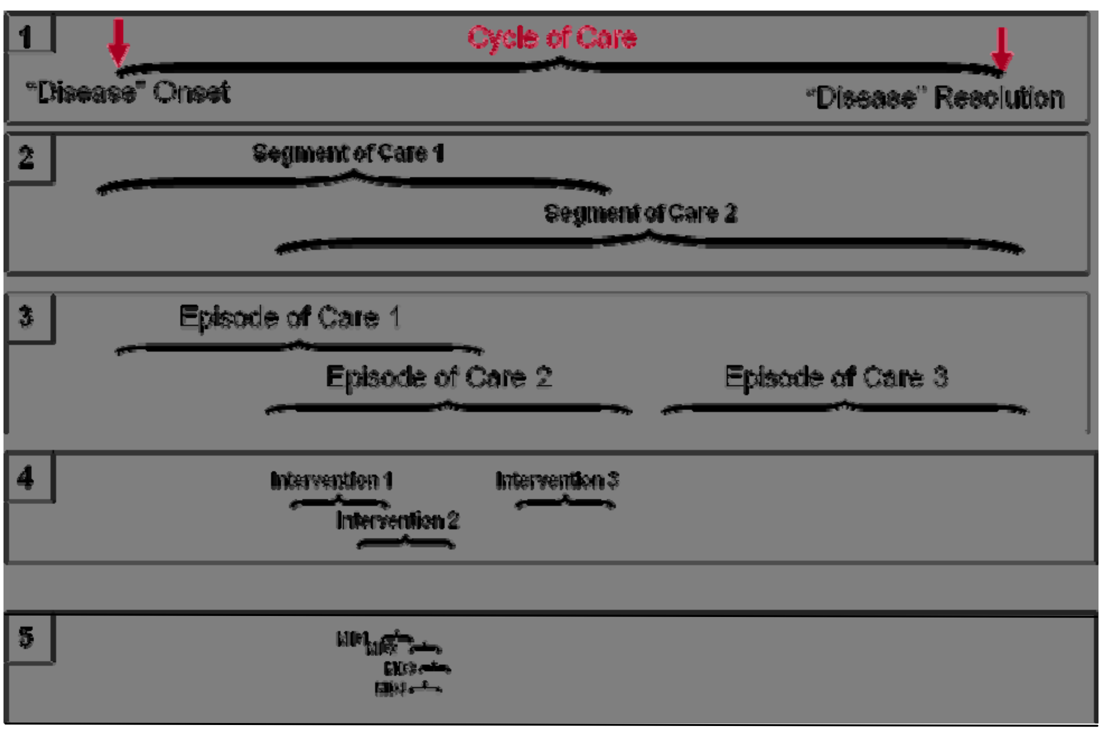


Figure 1. The Care Cycle (Source: (Fabri, 2008))

In figure 1, insert 1 depicts the complete care cycle, while inserts 2-5 are smaller portions that together comprise the entire care cycle – the multiple episodes of care (insert 3), interventions (insert 4) or physician visits (insert 5).

In insert 2 of figure 1, we introduce a 'segment of the care cycle'. The segment of care can be defined as being comprised of multiple episodes of care, and is equal to or smaller than the complete cycle of care. Often patients visit multiple providers for receiving care pertaining to the same medical condition, and due to the non-sharing of data among providers, it is not always possible to obtain all care information of a patient. Hence, this makes it difficult to identify the specific event(s) or encounter(s) that started, ended or form part of the care cycle. In situations where that information is available, and one can say with a certain degree of confidence that the care cycle started and concluded with an identifiable specific encounter and all care pertaining to the cycle is available, the segment of care is equal to the complete care cycle. In other cases, and this is often the case, it is smaller than the care cycle.

To analyze the operational aspects of the treatment, it is necessary to identify and study the flow of patients through the care cycle for a particular medical condition. An analysis of this kind will help to identify bottlenecks, redundancies, and unnecessary delays in the system, all of which constitute some of the major causes for exploding costs in the health care sector. Further, the actual treatments during the care cycle can be compared with the established guidelines to identify variations in the expected patient pathways. Over and under-treatment of patients can also be identified through such an analysis. Yet, conducting a study of this nature could be a daunting task due to the inaccessibility of pertinent patient treatment information.

One of the major problems is obtaining a patient's care information from the multitude of providers treating him/her for the same medical condition. This makes it impossible to obtain information on every encounter that a patient undergoes during his/her treatment. The reason behind this is that the fragmented nature of health care has resulted in information 'silos' where information is not easily shared among different providers. Even among in-network providers, the information is stored in disparate databases that often do not lend themselves to easy portability. This problem becomes even more acute when patients go to out-of-network providers during the course of their treatment.

Fortunately, a few providers have developed an integrated network where all care can be provided within the network itself, and the patient's EMR is shared among them. By accessing the patient's EMR in these integrated networks, one can identify all clinic visits, inpatient admissions, and clinical or surgical procedures that the patients have undergone over several years in that specific network.

This study attempts to remove this barrier by developing a set of 'rules' that govern a framework to enable the extraction of pertinent information from the fragmented databases of providers and use it to create a pathway of patients undergoing treatment in a specific care cycle.

## 3.2 Research Objective

As figure 3.1 shows, the complete care cycle is comprised of smaller episodes of care. Information on these episodes can be obtained through patient records, but due to the fragmented nature of the collected data, it is not an easy task. The main objective of this study is to develop a set of ‘rules’ that form a framework to extract pertinent information from databases to identify and map patient pathways over a segment of the care cycle for a specific medical condition. The framework outlines how data from administrative (even fragmented) databases of health care organizations could be structured to identify relevant patient provider interactions that are part of the care cycle. It will enable providers, patients, medical researchers, and other stakeholders to identify and analyze the patient’s care over the care cycle. The set of ‘rules’ are implementable if all patient encounters are stored electronically. Paper records need to be entered into the electronic system for it to be used in the process.

It is expected that this could be a foundation that will pave the way to better address some of the issues, including delays, rising costs, and medical errors that are plaguing the health care sector, and provide timely, effective, efficient, and patient-centric care – four of the six aims identified by the Institute of Medicine for improving the quality of care (Committee on Quality of Health Care in America, Institute of Medicine, 2001). The benefits that can be achieved by being able to identify the flow of patients across the care cycle are outlined in the next section.

### 3.3 Benefits of the Research

The benefits of this analysis are as follows:

- identify the expected flow of patients on a particular care cycle
- help providers make resource allocation decisions based on the expected flow

- help providers in comparing current treatment guidelines to the care provided, and identify variations in a particular patient group.

The framework can be modified to map patient flow for various procedures and medical conditions across diverse inpatient and outpatient settings. Additional analyses, that would help reduce overcrowding and delays, can be conducted on the identified flow of patients.  In addition, adherence to appropriate standards should reduce the wide variation in treatment that is common today, reducing costs and delays, and increasing patient and staff satisfaction. Overall the treatment will be more patient-centric, thus improving the quality of care.

### 3.4 Research Methodology

This research was conducted using information obtained from a Veterans' Health Administration (VHA) medical facility. VHA is one of the largest health care organizations in the US and has a nationwide network of more than 1400 medical facilities (Department of Veteran Affairs, 2008). Though the information used in this research came from a single facility, it can be duplicated at other VHA facilities since the electronic medical record system is identical across the network. James A. Haley Veterans' Affair's Hospital (JAHVAH), where this study was based, stores patient treatment data into separate computer "packages". These are categorized according to the type of data stored. There are more than a dozen packages with self-explanatory titles. For example, patient data related to operations are in a package titled 'surgery', inpatient movements are in another called 'patient movement file', outpatient appointments in the package are titled 'appointments', and so on. Since the packages were designed for specific transactions, multiple encounters of a patient often need to be obtained from different packages, yet redundancies also exist. A list of the packages was obtained from JAHVAH, from which a shortlist was created of those relevant for the study. After receiving the necessary IRB approval, JAHVAH provided the data, which was retrieved from the packages shown in figure 2.

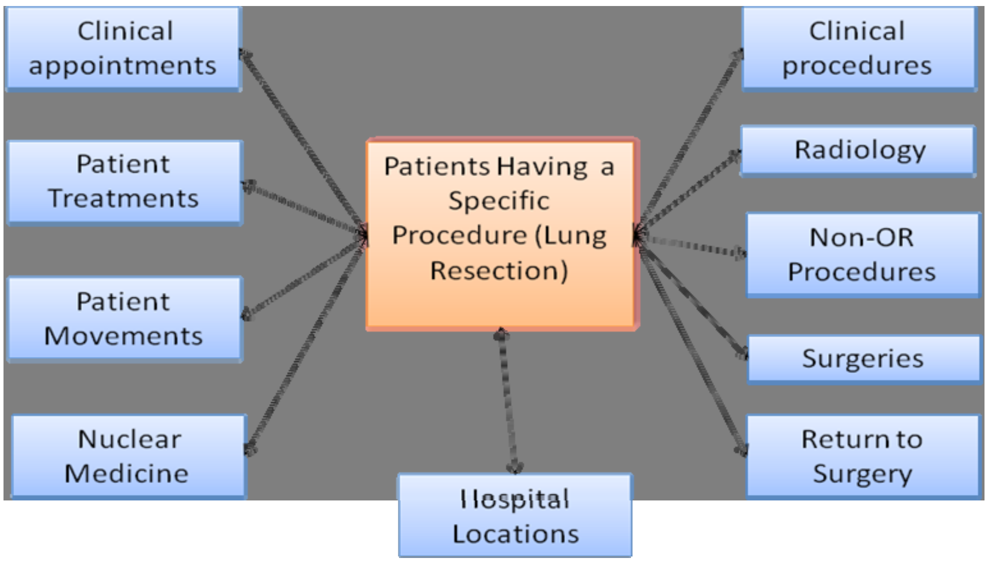


Figure 2. The Data Packages Used in the Extraction Process

The VHA uses a unique patient identification number called Internal Entry Number (IEN), given to each and every patient obtaining treatment at a VHA facility. The IEN is provided at the first point of contact of the patient with a VHA facility, and is thereafter used for every transaction with any VHA facility (which assures that users cannot identify the patient).Through the use of IENs, it was possible to track patients' care treatments over multiple episodes of care. For the purposes of this study, it was assumed that the patients included in the study got all their medical care requirements from a VHA facility, though, in reality, this might not always be the case.

The research team decided to use lung cancer as the medical condition, restricted only to patients who underwent a lung resection. The reasoning was that lung resection is a specific and identifiable event. Also, an overwhelming majority of patients undergoing lung resection have lung cancer and the treatment period is short and easily identifiable. From the surgery package, we developed a list of de-identified patients who had a lung resection during the calendar year 2007 by using Current Procedural Terminology (CPT) codes for lung resection procedures. A total of 49 lung resections were identified along with the 48 patients who underwent them. Then the other packages were queried for those particular patients.

Using the IENs, the different packages were linked together with the help of a database application. The resulting datasets were arranged chronologically and each encounter (visit, test, or procedure) was analyzed to determine if it was related to the lung resection.

### 3.4.1 Development of the Timeline

The first step in developing the timeline was to classify the care cycle into three distinct periods:

- The pre-admission period – the period prior to the admission for the lung resection.
- The surgical period – the inpatient episode that included the lung resection.
- The post-discharge period – the period after discharge from the lung resection.

The three periods are shown in table 1.

Table 1. The Three Periods in the Segment of the Care Cycle

| Pre-Admission Period | Surgical Period | Post-Discharge Period |
|---|---|---|

The pre-admission and post-discharge periods were further classified into three distinct phases or chronologic "windows" based on the following:

- the window closest to the resection was defined as having all encounters during that phase related to the resection – this is "Window 1"

- the next window was defined as having encounters that were likely related to the resection except a few that were clearly identified as unrelated – this is "Window 2". Most encounters in this window were included.

- the window furthest from the resection was defined as having encounters that were not likely related to the resection except a few that were clearly identified to be related – this is "Window 3". Most encounters in this window were excluded.

The structure of this classification is shown in table 2.

Table 2. The Care Cycle Windows

| **Window 3** | **Window 2** | **Window 1** | **Surgical Episode** | **Window 1** | **Window 2** | **Window 3** |
|---|---|---|---|---|---|---|
| | | Pre-Admission Period | | Post-Discharge Period | | |
| Clinic Visits | Clinic Visits | Clinic Visits | Surgery | Clinic Visits | Clinic Visits | Clinic Visits |
| Procedures | Procedures | Procedures | | Procedures | Procedures | Procedures |
| Tests | Tests | Tests | | Tests | Tests | Tests |

The probability of an event being related to the lung resection decreases as we move from window 1 to window 3 in both pre-admission and post-discharge periods. To develop a timeline for the care cycle, relative “dates” were assigned to each encounter based on their relation to the resection and is discussed in the next chapter.

Based on the final version of the related events, a clinical pathway (over a segment of the cycle) was developed for the patients undergoing lung resection at JAHVAH; the results are mentioned in the next chapter.

# Chapter 4 Identifying the Flow of Lung Resection Patients

The patient flow data were analyzed and the results evaluated to identify flow patterns among the 48 patients undergoing lung resection at the hospital. The flow includes every encounter, i.e., a clinic visit, a test, or a procedure, related to the surgery. This flow represents a segment of care of the patient, and can be broken down into inpatient and outpatient episodes. Every patient had their lung resection as an inpatient, and that episode was further analyzed to identify flow patterns during that particular episode of care. As mentioned in the previous chapter, the segment of care was categorized into three periods – the *pre-admission* period which leads to the admission for surgery, the *surgical inpatient* episode that includes the lung surgery, and the *post-discharge* period following discharge from the hospital after the resection. To develop a timeline for the care cycle, relative "dates" were assigned to each encounter based on their relation to the surgery.

## 4.1 Creating the Timeline

The following rule was used to create the timeline.

- The inpatient episode of care, which includes the lung resection, is considered a time interval.

    - This interval is from admission to discharge of the patient and includes the lung resection.
    - This interval differs for each patient, and could vary from a few days to several weeks.
    - This characterization ensures consistency, since all encounters on the timeline are episodic. Also, it creates a clear demarcation point between the pre-admission period, the surgical episode and the post-discharge period.

- The day of every encounter that occurs before admission, viz., the pre-admission period, has been assigned negative numbers according to their chronological order from the admission date. For example, '-1' is one day prior to the admission, '-2' is two days prior and so on.

- Similarly, encounters after discharge from the resection – the post-discharge period, were assigned positive numbers, e.g., '+1' is one day after discharge, '+2' is two days after discharge, and so on.

The timeline is exemplified in table 3.

Table 3. Relative Days in the Segment of Care Cycle

| Pre-Admission Period | | | | | Surgical Episode | Post-Discharge Period | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -365 | … | -3 | -2 | -1 | | 1 | 2 | 3 | … | 365 |

Based on the nature of cancer progression and the treatment options for lung cancer, the pre-admission period was considered to be a maximum of one year (365 days). The post-discharge period was truncated after one year (365 days) since treatment is usually an ongoing process after surgery. The sections that follow describe the results for the inpatient surgical episode, the pre-admission and post-discharge periods.

## 4.2 Determining the Windows

The length of each window in both the pre-admission and post-discharge periods was determined separately by the following process:

- All encounters that a patient had were arranged chronologically.
    - Pre-admission encounters were arranged from the patient's first encounter up to a year before surgery and leading to the surgical admission.
    - Post-discharge encounters were arranged from the surgical discharge going forward one year after discharge.
- Every encounter was classified as being either related or not related to the lung resection. It is important to note that encounters had to be related to the lung resection but not the lung cancer.
- The related encounters were extracted into a matrix, with encounters as rows and the relative dates as columns.
    - The first occurrence of encounters that due to their nature had periodic occurrences was included in the matrix. An example is visits to an

- The encounters were clustered into 30 day blocks based on their relative dates (e.g., relative dates 1-30 were grouped into block 1, relative dates 31-60 became block 2, and so on). 30 day blocks were chosen since they are generally used to define timelines.

- The frequencies of the related encounters in each month were determined and were sorted in descending order. The frequencies were used to determine the time lengths that formed each of the windows defined earlier.

The windows for each period were determined as follows:

- Pre-admission period (days before surgical admission)
  - Window 1: Days (-1) to (-30)
  - Window 2: Days (-31) to (-180)
  - Window 3: Days (-181) to (-365)
- Post-discharge period (days after surgical discharge)
  - Window 1: Days 1-30
  - Window 2: Days 31-180
  - Window 3: Days 181-365

Even though the data were analyzed separately for pre-admission and post-discharge periods, both periods were found to have similar window lengths. The next three sections explain the encounters that were identified after applying the rules in the three periods defined above.

## 4.3 The Pre-Admission Flow

The pre-admission period starts 365 days before admission to surgery and ends the day before the admission of the patient to lung resection. As mentioned before, this period was divided in three windows based on the analysis of the data, and shown in table 4.

Table 4. Windows in the Pre-Admission Period

| Window 3 | Window 2 | Window 1 | Admission for Lung Surgery |
|---|---|---|---|
| Days 365-181 | Days 180-31 | Days 30-1 | |
| Clinic Visits | Clinic Visits | Clinic Visits | Surgery |
| Procedures | Procedures | Procedures | |
| Tests | Tests | Tests | |

This period is comprised of outpatient or ambulatory encounters, viz., clinic visits, tests, and outpatient procedures. After grouping similar encounters, there were a total of 535 encounters, out of which 25 were unique. The encounters are listed in table 5. Appendix 1 depicts the classification of these encounters. Appendix 2 shows the flow of each patient in the pre-admission period.

Table 5. Frequency of Each Encounter in the Pre-Admission Period

| Encounter Name | Number of Total Encounters | | Encounter Name | Number of Total Encounters |
|---|---|---|---|---|
| All Encounters | 535 | | Myocardial Perfusion | 10 |
| Xray | 63 | | Cardio ABG | 7 |
| Oncology | 62 | | Gated Spect | 6 |
| CT | 58 | | CT Guidance | 4 |
| Lung Nodule Clinic | 48 | | Stress Test | 4 |
| Pre-Op Clinic | 48 | | Lung Biopsy | 2 |
| PACM | 48 | | Barium | 1 |
| Pre-Anesthesia Clinic | 48 | | Bone Scan | 1 |
| PFT | 41 | | Bone Surv Comp | 1 |
| Radiology | 26 | | EKG | 1 |
| PET | 20 | | MRI | 1 |
| Pulmonary Procedure | 19 | | Quantitative Perfusion | 1 |
| Thoracic Surgery | 14 | | Urology Oncology | 1 |

Table 6 shows the encounters in each of the windows. Figure 3 shows the frequency of the encounters in each window. Appendix 7 provides a detailed view of the frequencies of each encounter in the pre-admission timeline.

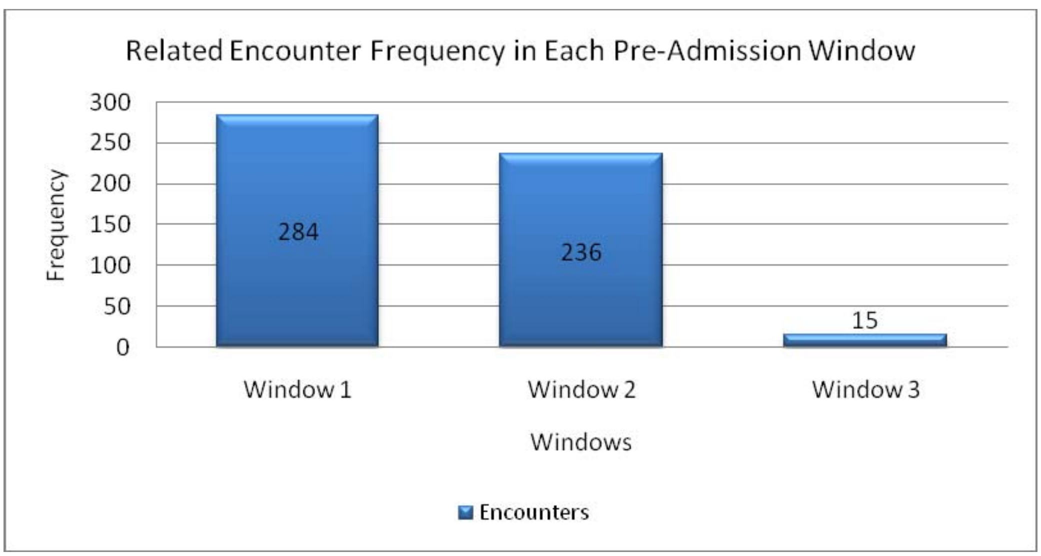


Figure 3. Encounter Frequency in Pre-Admission Windows

Table 6. Encounters in Each of the Pre-Admission Windows

| Days | Clinic Visits | Procedures | Tests |
|---|---|---|---|
| Window 3 (360-181) | Oncology | Pulmonary Procedure | PFT |
| | Radiology | | |
| | Lung Nodule | | |
| | Thoracic Surgery | | |
| Window 2 (180-31) | Oncology | Pulmonary Procedure | CT |
| | Lung Nodule | Myocardial Perfusion | Xray |
| | Radiology | Cardio ABG | PFT |
| | Thoracic Surgery | Gated Spect | PET |
| | | Lung Biopsy | Stress Test |
| | | BA | CT Guidance |
| | | Gastronomy Tube PACS | |
| | | Bone Surv Comp | |
| | | Quantitative Perfusion | |
| Window 1 (30-1) | Pre-Op | Pulmonary Procedure | Xray |
| | PACM | Gated Spect | PFT |
| | Pre-Anesthesia | Myocardial Perfusion | CT |
| | Lung Nodule | Cardio ABG | PET |
| | Oncology | | CT Guidance |
| | Thoracic Surgery | | Bone Scan |
| | Urology Oncology | | EKG |
| | | | MRI |
| | | | Stress Test |

## 4.4 The Inpatient Episode: Admission, Resection and Discharge

The inpatient episode corresponds to the period when the patient was admitted to the hospital and underwent lung surgery. This period starts with the admission of the patient and ends with the discharge of the patient. During that period, the patient was transferred from one unit or ward to another to undergo the resection.

There were a total of 12 units having at least one patient visit. Figure 3 depicts the number of visits that were made to each of the above 12 areas of the hospital, categorized into pre- and post-surgery. Appendix 3 provides a description of these units.

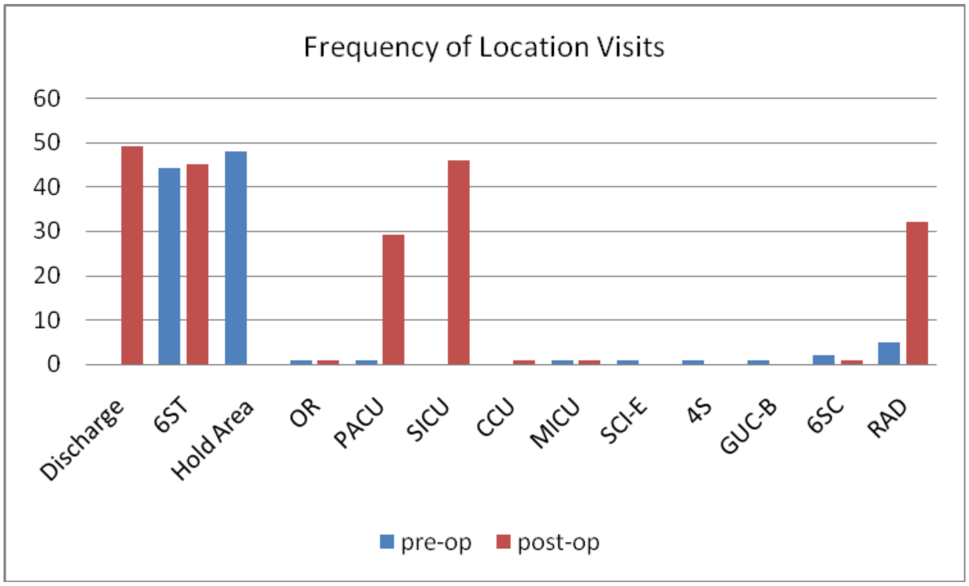


Figure 4. Number of Visits Made to Each Inpatient Unit

The usual flow for patients without any complications is depicted in figure 4. Table 7 shows the frequency of patients following specific paths. Appendix 4 shows the detailed flow of each inpatient episode.

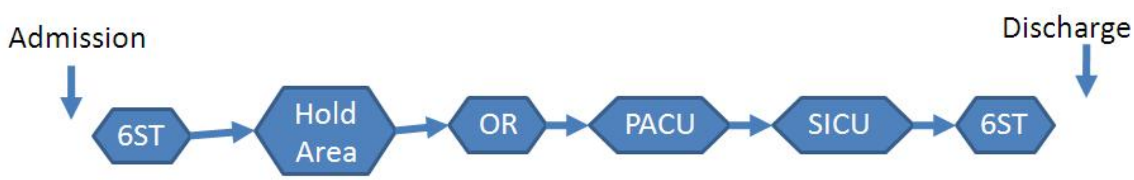


Figure 5. Expected Flow of Inpatients Undergoing Lung Surgery

Table 7. Common Inpatient Flows and their Frequencies

| Series Number | Inpatient Flow | Number of Patients | Percentage of all Patients |
|---|---|---|---|
| 1 | 6ST-Hold Area-OR-PACU-SICU-6ST-Discharge | 13 | 26.5 |
| 2 | 6ST-Hold Area-OR-SICU-6ST-Discharge | 5 | 10.2 |
| 3 | 6ST-Hold Area-OR-PACU-SICU-6ST-RAD-6ST-Discharge | 4 | 10.2 |
| 4 | 6ST-Hold Area-OR-SICU-6ST-RAD-6ST-Discharge | 4 | 8.2 |
| 5 | 6ST-Hold Area-OR-PACU-SICU-6ST-RAD-6ST-RAD-6ST-Discharge | 3 | 6.1 |
| 6 | 6ST-Hold Area-OR-PACU-Discharge | 2 | 4.1 |
| 7 | 6ST-Hold Area-OR-PACU-6ST-Discharge | 2 | 4.1 |
| | Unique Single Patient Paths | 17 | 34.7 |

4.5 The Post-Discharge Flow

The post-discharge period starts the day after the discharge of the patient from surgery and extends 365 days after discharge. Similar to the pre-admission period, the post-discharge period has also been divided into three windows as shown in table 8.

Table 8. Windows in the Post-Discharge Period

| Discharge from Lung Surgery | Window 1 | Window 2 | Window 3 |
|---|---|---|---|
| Day 0 | Days 1-30 | Days 31-180 | Days 181-365 |
| Surgery | Clinic Visits | Clinic Visits | Clinic Visits |
| | Procedures | Procedures | Procedures |
| | Tests | Tests | Tests |

The encounters in this period are outpatient episodes including clinic visits, tests and procedures. There were a total of 439 encounters, out of which 25 unique encounters were identified after grouping similar encounters. Table 9 shows the different encounters and their frequencies. The classification of these encounters can be seen in Appendix 1, while a detailed flow of patients in the post-discharge period can be found in Appendix 5.

Table 9. Frequency of Each Encounter in the Post-Discharge Period

| Encounter Name | Number of Total Encounters | | Encounter Name | Number of Total Encounters |
|---|---|---|---|---|
| All Encounters | 439 | | PACM | 3 |
| Oncology | 115 | | Pre-Anesthesia | 3 |
| Xray | 72 | | PET | 2 |
| CT | 68 | | Bone Surv Comp | 1 |
| Thoracic Surgery | 68 | | CT Guidance | 1 |
| Oncology Procedure | 50 | | ER | 1 |
| Radiology | 15 | | Fluoro | 1 |
| Resp Care/Home Oxygen (1BS) | 9 | | Lung Biopsy | 1 |
| Pulmonary Procedure | 8 | | Lung Nodule | 1 |
| Bone Scan | 5 | | PCC Women | 1 |
| MRI | 4 | | Scan | 1 |
| PFT | 4 | | Urgent Care | 1 |
| Pre-Op | 4 | | Urology Oncology | 1 |

Figure 6 displays the frequency of the encounters in each window. Table 10 shows the encounters in each of the windows. Appendix 8 provides a detailed view of the frequencies of each encounter in the post-discharge timeline.

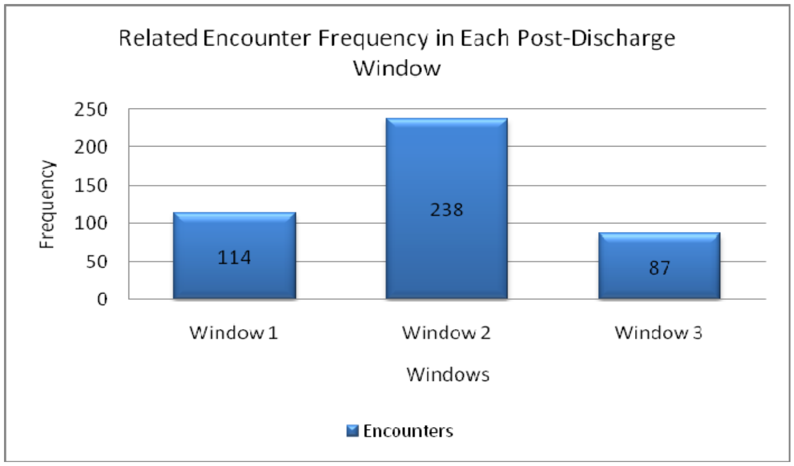


Figure 6. Encounter Frequency in Post-Discharge Windows

Table 10. Encounters in Each Post-Discharge Window

| Days | Clinic Visits | Procedures | Tests |
|---|---|---|---|
| Window 1 (1-30) | Thoracic Surgery | Pulmonary Procedure | Xray |
| | Oncology | Oncology Procedure | CT |
| | Radiology | | PFT |
| | Resp Care/Home Oxygen (1BS) | | MRI |
| | PCC Women | | |
| | PACM | | |
| | Pre-Op | | |
| | Pre-Anesthesia | | |
| | Urology Oncology | | |
| | Urgent Care | | |
| | ER | | |
| Window 2 (31-180) | Oncology | Oncology Procedure | CT |
| | Thoracic Surgery | Pulmonary Procedure | Xray |
| | Radiology | Lung Biopsy | Bone Scan |
| | Resp Care/Home Oxygen (1BS) | Bone Surv Comp | MRI |
| | PACM | | PET |
| | Pre-Op | | PFT |
| | Pre-Anesthesia | | Bone Scan |
| | | | CT Guidance |
| Window 3 (181-360) | Oncology | Oncology Procedure | CT |
| | Thoracic Surgery | Pulmonary Procedure | Xray |
| | Radiology | Fluoro | |
| | Resp Care/Home Oxygen (1BS) | | |
| | Pre-Op | | |
| | Pre-Anesthesia | | |
| | PACM | | |
| | Lung Nodule | | |

# Chapter 5 The Framework Rules

This chapter describes the ‘rules’ that were developed to govern the framework to identify and extract relevant patient information from medical databases. The first section outlines the protocol and rules to identify relevant patient encounters for patients undergoing a lung resection, while section 2 delineates a generic version of those rules that can be used for patients undergoing any intervention.

## 5.1 Rules for Patients Undergoing Lung Resection

This section describes the protocol for identifying relevant patient information from medical databases for patients undergoing a lung resection. These rules can be easily implemented for VHA databases, while a slight modification, viz., changing the VHA clinic names to the provider’s corresponding names, might be needed for other extracting the information from other provider’s databases.

The segment of care (a two year time frame) was broken down into pre-admission period, surgical inpatient period, and post-discharge period. The next sub-sections describe the rules in each of these periods.

### 5.1.1 The Pre-Admission Period

This period starts 1 year (365 days) before the surgical admission and culminates with the admission for lung resection. The three windows in this period were determined as described in section 4.2.

The related encounters (clinic visits, tests and procedures) were identified as:

- Clinic Visits – Table 11 identifies the clinic visits that are related whenever they occur in the pre-admission period, while table 12 identifies clinic visits that are related only if they occur within 30 days prior to the surgical admission.

Table 11. Related Clinic Visits Irrespective of When They Occur

| Clinic Visits |
|---|
| Oncology |
| Lung Nodule |
| Thoracic Surgery |
| Radiology |

Table 12. Related Clinic Visits Only if they Occur Within 30 days of Admission

| Clinic Visits |
|---|
| Pre-Op |
| PACM |
| Pre-Anesthesia |
| Urology |

- Procedures – Table 13 identifies procedures that are related whenever they occur in the pre-admission period.

Table 13. Related Procedures Irrespective of When They Occur

| Procedures |
| --- |
| Pulmonary Procedure |
| Lung Biopsy |

- Tests – Table 14 identifies tests that are related whenever they occur in the pre-admission period**.**

Table 14. Tests that are Related Whenever they Occur in the Pre-Admission Period

| Tests | Tests | Tests |
| --- | --- | --- |
| Xray | CT Guidance | Stress Test |
| CT | EKG | BA |
| PFT | MRI | Bone Scan |
| PET | Cardio ABG | Bone Surv Comp |
| Myocardial Perfusion | Gated Spect | Quantitative Perfusion |

5.1.2 The Surgical Inpatient Period

The surgical inpatient period was divided into 3 categories:

- Pre-surgical stay: Admission to surgery
- Surgery
- Post-surgical stay: Surgery to discharge

Table 15 shows the units that were visited by patients during the surgical admission period.

Table 15. Units that were Visited by Patients During the Surgical Admission Period

| Pre-Surgical Stay | Surgery | Post-Surgical Stay |
|---|---|---|
| 6 South Thoracic ward | OR | Post Anesthesia Care Unit |
| 6 South Cardio ward | | Surgical Intensive Care Unit |
| 4 South Thoracic ward | | Medical Intensive Care Unit |
| Medical Intensive Care Unit | | Radiology |
| Spinal Cord Unit ward | | 6 South Thoracic ward |
| Genito-Urinary Clinic | | 6 South Cardio ward |
| Pre-Op Hold Area | | |

### 5.1.3 The Post-Discharge Period

This period starts from the discharge from lung resection and culminates 1 year (365 days) after the surgical discharge. The three windows in this period were determined as described in section 4.2.

The related encounters (clinic visits, tests and procedures) were identified as:

- Clinic Visits – Table 16 identifies the clinic visits that are related whenever they occur in the post-discharge period, while table 17 identifies clinic visits that are related only if they occur within 30 days after the surgical discharge.

Table 16. Related Clinic Visits Irrespective of When They Occur

| Clinic Visits |
|---|
| Oncology |
| Thoracic Surgery |
| Lung Nodule |
| Radiology |
| Resp Care/Home Oxygen |

Table 17. Related Clinic Visits Only if They Occur Within 30 Days of Discharge

| Clinic Visits |
|---|
| ER |
| Urgent Care |
| Urology |
| Primary Care Clinic |

- Procedures – Table 18 identifies procedures that are related whenever they occur in the post-discharge period.

Table 18. Related Procedures Irrespective of When They Occur

| Procedures |
|---|
| Oncology Procedure |
| Pulmonary Procedure |
| Lung Biopsy |

- Tests – Table 19 identifies tests that are related whenever they occur in the post-discharge period, but only if they are requested by oncology, thoracic surgery or lung nodule clinics**.** PFT is related only if it occurs within 2 months of the resection.

Table 19. Tests that are Related Whenever They Occur in the Post-Discharge Period

| Tests | Tests |
|---|---|
| Xray | PET |
| CT | Bone Surv Comp |
| Bone Scan | CT Guidance |
| MRI | Fluoro |

These rules were used to determine the flow of each of the 48 patients during the selected care cycle. An example of the flow is shown in table 20. It depicts flow in the three periods defined above. The identified care cycle starts 133 days before surgical admission and ends 319 days after surgical discharge. In each of the periods, the column on the right is the encounter type and the column on the left is the relative date of occurrence of that encounter. In the inpatient episode, the 'i' denotes an inpatient episode where the surgery was given a relative date of zero in that period.

Table 20. Flow of a Patient in the Care Cycle

| Pre-Admission Period | | Inpatient Episode | | Post-Discharge Period | |
|---|---|---|---|---|---|
| -133 | Xray | -0i | 6ST | 11 | Thoracic Surgery |
| -98 | CT | -0i | Hold Area | 20 | PCC Women |
| -79 | Thoracic Surgery | 0i | OR | 20 | Oncology |
| -73 | Oncology | 0i | PACU | 46 | Thoracic Surgery |
| -52 | PET | 0i | SICU | 139 | Oncology |
| -51 | PFT | 3i | 6ST | 139 | Xray |
| -51 | Pulmonary Procedure | 6i | RAD | 247 | Oncology |
| -38 | Oncology | 6i | 6ST | 262 | Oncology |
| -11 | CT | 7i | RAD | 319 | Oncology |
| -9 | Lung Nodule | 7i | 6ST | | |
| -3 | PACM | 8i | Discharge | | |
| -3 | Pre-Op | | | | |
| -3 | Pre-Anesthesia | | | | |
| -3 | Xray | | | | |

Table 21 shows the path followed by another patient. This patient's identified care cycle started 175 days before surgical admission and culminated 335 days after the discharge from the surgical episode.

Table 21. Care Cycle Flow of Another Patient

| Pre-Admission Period | | Inpatient Episode | | Post-Discharge Period | |
|---|---|---|---|---|---|
| -175 | Radiology | -0i | 6ST | 6 | Urgent Care |
| -151 | Oncology | -0i | Hold Area | 6 | ER |
| -151 | Xray | 0i | OR | 6 | Xray |
| -95 | RAD CT | 0i | SICU | 12 | Thoracic Surgery |
| -94 | CT | 3i | 6ST | 12 | Xray |
| -88 | Oncology | 4i | CCU | 13 | Resp Care/Home Oxygen (1BS) |
| -62 | CT Guidance | 7i | 6ST | 25 | Resp Care/Home Oxygen (1BS) |
| -62 | Lung Biopsy | 10i | Discharge | 41 | Oncology |
| -61 | Xray | | | 74 | Xray |
| -60 | Oncology | | | 74 | CT |
| -59 | Xray | | | 95 | Oncology |
| -47 | Lung Nodule | | | 117 | PET |
| -18 | Oncology | | | 139 | Oncology |
| -14 | PACM | | | 139 | Resp Care/Home Oxygen (1BS) |
| -14 | Pre-Op | | | 140 | CT Guidance |
| -14 | PFT | | | 140 | Lung Biopsy |
| -13 | Xray | | | 153 | Pulmonary Procedure |
| | | | | 188 | Oncology |
| | | | | 227 | CT |
| | | | | 242 | Xray |
| | | | | 265 | Oncology |
| | | | | 328 | Resp Care/Home Oxygen (1BS) |
| | | | | 333 | Oncology |
| | | | | 335 | Oncology |

\

A comparison of the two paths (table 20 & 21) shows the differences in the path of the patients. These paths can be further studied by medical experts to identify variations and standardize care. The complete paths of all 48 patients are provided in Appendices 2, 4 and 5. This section described the rules for determining the flow of lung resection patients in a segment of the care cycle. The next section describes the generalized rules that can be implemented in any organization and for any intervention

## 5.2 The Universal Framework Rules

This section lists the rules that govern the framework for extracting pertinent information from databases. The following rules have been generalized for implementation in any organization and for any intervention. The first sub-section describes the protocol to identify and arrange the sample of patients. The second sub-section describes the rules for identifying the related encounters (to the intervention) of that patient and the time frames during which they are related. It is important to keep in mind that before embarking on such a study, it might be essential to obtain the necessary IRB approvals.

### 5.2.1 Identifying and Arranging the Sample

Following is the procedure to identify the sample of patients that are going to be studied:

- Identify an intervention that a set of patients underwent during their care cycle, e.g., an inpatient or outpatient procedure. Define this as the *event*.
- Determine the period of study depending on the nature of the medical condition and its associated care cycle, e.g., 1 year before and after the event.
- Identify all occurrences of that event using CPT codes from the list of all patients undergoing interventions.
- From that list, identify the IENs of all those patients (for patients outside the VA system, IENs are the same as patient IDs or numbers)
- Identify all encounters by querying for those IENs in all patient data files, e.g., clinic appointments, operations, admissions, tests, clinical procedures.
- Create a chronological order of all patient encounters during the period under study

- Identify and remove encounters that are clearly unrelated to the event. The remaining list now consists of mostly related encounters. Call this List 1.
- Group encounters that have the same purpose, e.g., lung nodule clinic and pulmonary nodule clinic serve the same purpose and can be grouped together.
- Divide the care cycle segment into 3 categories
  - Pre-intervention period
  - Intervention period
  - Post-intervention period

5.2.2 The Pre-Intervention Period

This sub-section provides rules to determine the related encounters and to further classify the time frames of each of the periods – the pre-intervention period, the intervention period and the post-intervention period.

The following are the rules for the pre-intervention period.

- Create a matrix of all related pre-intervention encounters, with the encounters as rows and relative dates as columns.
- Identify encounters that have periodic occurrences and only retain the first occurrence. Call this list 2.
- From list 2, determine the frequencies of the encounters and arrange them in descending order. It might be easier to group the dates into larger time periods, e.g., months rather than days.
- Divide the pre-intervention period into 3 groups or clusters.

        - The first group (closest to the intervention) should have all encounters within it related to the event. This is group 1.
        - The second group (next closest to the intervention) should have almost all encounters related to the event except a few clearly identified as unrelated. This is group 2.
        - The third group (furthest from the intervention) should have only a few clearly identified encounters related to the event from all encounters within it. This is group 3 and will also form the end of the period under study.

- From list 1, extract encounters in the pre-intervention period and classify them into clinic visits, procedures and tests
    - Clinic Visits, Procedures and Tests
        - Identify clinic visits, procedures and tests that are related to the event, e.g., an encounter might be related to the event throughout the entire period, while another might be related only if it occurs within a certain time frame from the event.

5.2.3 The Intervention Period

Depending on where the intervention occurred, in an ambulatory or inpatient setting, there are two ways to identify patient movements during this period.

- Intervention in an inpatient setting:
    - Divide the intervention interval into 3 categories:
        - Pre-intervention stay: Admission to intervention

        - Intervention (the "*event*")
        - Post-intervention stay: Intervention to discharge
    - Identify all patient movements during the period of the intervention and classify them according to the three categories defined in the above step.
    - Establish the dates in the intervention period relative to the date of the event. Hence, all inpatient movements from the admission to the intervention will have negative numbers and inpatient movements from the intervention to discharge will have positive numbers.
    - To differentiate this numbering policy from the previous one, denote all inpatient episodes with a subscript 'i'. For example, $-1_i$ would be an inpatient encounter occurring one day before the intervention. Similarly, $1_i$ is the inpatient encounter occurring one day after the intervention.
- Intervention in an ambulatory setting:
    - Interventions in the ambulatory setting are same day interventions and patients do not stay overnight.
    - If desired, the patient movements can also be identified in the ambulatory setting starting from prepping the patient for the intervention, the intervention itself and the subsequent recovery from the intervention. These encounters will occur with hours (or minutes) as the time unit since all encounters in this period will occur on the same day.
    - To differentiate these ambulatory encounters, the relative dates can be denoted by the subscript 'a' in the time line, e.g., $-1_a$ will be one hour (or

another time unit) before the intervention and $1_a$; $2_a$ will be one hour and two hours after the intervention (or event), respectively.

### 5.2.4 The Post-Intervention Period

The rules in this period are similar to the pre-intervention period, except that the encounters occurred after the intervention.

- Create a matrix of all related post-intervention encounters, with the encounters as rows and relative dates as columns
- Identify encounters that have periodic encounters and remove them from the list of encounters for the frequency analysis. Call this list 2.
- From list 3, determine the frequencies of the encounters and arrange them in descending order. It might be easier to group the dates into larger time periods, e.g., months rather than days.
- Divide the post- intervention period into 3 groups or clusters.
    - The first group (closest to the intervention) should have all encounters within it related to the event. This is group 1.
    - The second group (next closest to the intervention) should have almost all encounters related to the event except a few clearly identified as unrelated. This is group 2.
    - The third group (furthest from the intervention) should have only a few clearly identified encounters related to the event from all encounters within it. This is group 3 and will also form the end of the period under study.

- From list 1, extract encounters in the post-intervention period and classify them into clinic visits, procedures and tests
    - Clinic Visits, Procedures and Tests
        - Identify clinic visits, procedures and tests that are related to the event, e.g., an encounter might be related to the event throughout the entire period, while another might be related only if it occurs within a certain time frame from the event.

The above section defined the protocol to follow to extract relevant patient medical information for identifying patient flow during a care cycle. The best way to do it is by going through each patient's medical records. Unfortunately, that is not an efficient approach when dealing with large datasets (at a regional or national level). The approach described above provides a set of rules that can be implemented to extract information from large datasets. It is hoped that researchers will utilize these rules to develop patient pathways in the care cycle to enable further understanding of the care delivery system. Conclusions and future work are discussed in the next chapter.

# Chapter 6 Conclusions and Future Work

Aspects related to rising health care costs, lack of standardization, increasing medical errors, growing delays, and reduced access have diminished the quality of the US health care delivery system. As stated before, numerous studies have been conducted to seek ways to improve care delivery. Unfortunately, most of them have been limited to single clinics or units, with barely any focus on the health care cycle. We reiterate that focusing on the health care cycle, and not the individual episodes within it, is what provides value to the patient. The highest value that a patient obtains is when (s)he receives the highest quality at the lowest cost. However, one major gap that patients, providers, researchers and other stakeholders confront is the lack of access to congruent health and operational information over the care cycle. The current collection and storage of health information makes it very difficult or even impossible to derive relevant information over the care cycle. The fragmented nature of data gathering processes and of the supporting information systems has led to minimal sharing of information among providers. This results in the loss of critical health information often proving detrimental to the quality of the provided care. Unless systems and mechanisms are developed to improve information gathering and extraction that helps illustrate and document the entire care cycle, the quality of care delivery will continue to be crippled. What has been accomplished in this research is a step to fill the need for coherent data in a patient's care cycle.

The authors of this study developed a set of rules that govern a framework that enables providers and researchers to extract meaningful information from the ‘disconnected’ database systems to create patient pathways through the care cycle of a patient.

A specific event (lung resection) was chosen and encounters related to that event were identified and chronologically arranged to create the pathway of the patients undergoing that event. Rules were determined such that they can be utilized with other databases to extract similar information. These rules can be modified and adapted to other medical conditions, as well as to other environments and/or providers.

The research team successfully overcame the challenges of accessing data from disparate sources in a care cycle and demonstrated how the extracted data can be utilized to construct care paths. An example on how these care paths can be developed is presented for lung resection patients. The research contributes to the analysis of care cycles by developing an approach to obtain relevant clinical information so as to subsequently identify patient flow over the entire care cycle, not just individual interventions.

This research leads to various opportunities for further work.  One possible next step is to implement these rules in bigger datasets that will permit larger sample sizes, using a bootstrapping technique to refine the rules. A relevant approach is to access a large dataset (e.g., a national dataset of lung resection patients) and randomly select a sample of patients and apply these rules. Subsequent re-sampling from the database can be used to derive estimates of commonalities or differences, errors, perhaps confidence intervals and other information to refine the rules presented in this work. The modified set of rules can be implemented in other (including non-VHA) database systems to obtain more comprehensive and accurate data over the care cycle, as well as to compare the federal and the private health care sector.

Another consideration is to utilize the extracted clinical information to create the pathway of patients during a specific care cycle. Two kinds of analysis, from two distinct perspectives, can be conducted on the individual pathways. From an operational viewpoint, the pathways can be evaluated to identify instances of delays, and further analysis may be conducted to determine the causes of those delays. Reducing, if not altogether removing the delays will greatly lessen the time it takes for patients to receive proper care, thus, significantly reducing the potential for a deterioration of the patient's health condition. Also, historical information on the flow of patients will enable providers to adjust their resources to the demand patterns, improving the timeliness of the provided care. In addition to improving the quality of care and increasing patient satisfaction, it could assist in identifying and linking sources of costs in the longer term.

From a treatment policy perspective, these pathways can be analyzed by medical subject matter experts (SMEs) to evaluate various aspects of care and improve existing treatment practices. Through the use of outcome data, one can evaluate the effectiveness of the differing pathways in a care cycle. Linking cost data, as discussed below, to the pathways (and the care cycle) will allow cost-benefit analyses. For example, one could use the quality-adjusted life year (QALY) indexes but extended over the care cycle rather than just a single medical intervention. An important consideration of this approach is that patients with different co-morbidities may significantly deviate from the expected care path. Analysts have to ensure that the cost-benefit analysis does not overlook these deviations and any policies that are developed should have sufficient flexibility to incorporate the needed variations.

A third possibility is to focus on effective ways to estimate costs linked to each encounter and allow for the analysis and evaluation of the true cost of the entire care cycle. It is apparent that much of the operational “cost data”, either derived or estimated, is in the form of billing (or claims), and does not necessarily represent the actual cost over the care cycle. As said before, many of the estimates of the rising costs of healthcare are at an aggregate (macro) level, but very little is really known or understood at the operational or care cycle level.

By undertaking this study, the research team addressed the current challenge of unavailability of care cycle data to close the gap in studies on care delivery over the health care cycle. It is believed that this will form the foundation for further studies on reconciling medical information from current medical database systems. It is expected that these rules will be used by providers and researchers to identify treatments over the complete care cycle and provide greater insight into the efficiency, effectiveness and timeliness of the care delivery system. Consequently, delays and costs will reduce and more standardized care will be delivered, resulting in an improvement in the quality of provided care and making it more patient-centered.

# List of References

Aharonson-Daniel, L., Paul, R.J. & Hedley, A.J. 1996, "Management of Queues in Out-Patient Departments: The Use of Computer Simulation", *Journal of Management in Medicine,* vol. 10, no. 6, pp. 50-8, 3.

American College of Emergency Physicians 2006, March 31, 2006-last update, *Gridlock in Nation's Emergency Departments Caused by Lack of Inpatient Bed Capacity, Not Patients with Nonurgent Medical Conditions* [Homepage of ACEP], [Online]. Available: http://www.acep.org/pressroom.aspx?id=25662 [2008, .

American Hospital Association 2008, *TrendWatch Chartbook*, American Hospital Association.

American Hospital Association 2006, "Annual Survey Data", .

Asadi, M.J. & Baltz, W.A. 1996, "Activity-Based Costing for Clinical Paths: An Example to Improve Clinical Cost & Efficiency", *Journal of the Society for Health Systems,* vol. 5, no. 2, pp. 1-7.

Asch, S.M., McGlynn, E.A., Hogan, M.M., Hayward, R.A., Shekelle, P., Rubenstein, L., Keesey, J., Adams, J. & Kerr, E.A. 2004, "Comparison of Quality of Care for Patients in the Veterans Health Administration and Patients in a National Sample", *Annals of Internal Medicine,* vol. 141, no. 12, pp. 938-945.

Bailey, R., Weingarten, S., Lewis, M. & Mohsenifar, Z. 1998, "Impact of Clinical Pathways and Practice Guidelines on the Management of Acute Exacerbations of Bronchial Asthma", *Chest,* vol. 113, no. 1, pp. 28-33.

Barnette, J.E. & Clendenen, F. 1996, "Making the Transition to Critical Pathways: A Community Behavioral Health Center's Approach", *Best Practices and Benchmarking in Healthcare,* vol. 1, no. 3, pp. 147-156.

Burt, C.W. & Sisk, J.E. 2005, "Which Physicians And Practices Are Using Electronic Medical Records?", *Health Affairs,* vol. 24, no. 5, pp. 1334-1343.

Butterworth, J. 1997, "Clinical Pathways for the High-Risk Patient", *Journal of Cardiothoracic and Vascular Anesthesia*, vol. 11, no. 2 Suppl 1, pp. 16-8; discussion 24-5.

Calligaro, K.D., Dougherty, M.J., Raviola, C.A., Musser, D.J. & DeLaurentis, D.A. 1995, "Impact of Clinical Pathways on Hospital Costs and Early Outcome after Major Vascular Surgery, , ,", *Journal of Vascular Surgery*, vol. 22, no. 6, pp. 649-660.

Cardoen, B. & Demeulemeester, E. 2008, "Capacity of Clinical Pathways - A Strategic Multi-level Evaluation Tool", *Journal of Medical Systems*, vol. 32, no. 6, pp. 443.

Cayirli, T. & Vera, E. 2003, "Outpatient Scheduling in Health Care: A Review of Literature", *Production and Operations Management*, vol. 12, no. 4, pp. 519.

CBS/NYT 2007, *US Health Care Politics*.

Chang, P.L., Wang, T.M., Huang, S.T., Hsieh, M.L., Tsui, K.H. & Lai, R.H. 1999, "Effects of Implementation of 18 Clinical Pathways on Costs and Quality of Care Among Patients Undergoing Urological Surgery", *The Journal of Urology*, vol. 161, no. 6, pp. 1858-1862.

Cheah, J. 2000, "Clinical Pathways: An Evaluation of its Impact on the Quality of Care in an Acute Care General Hospital in Singapore", *Singapore Medical Journal*, vol. 41, no. 7, pp. 335-346.

Chen, A.Y., Callender, D., Mansyur, C., Reyna, K.M., Limitone, E. & Goepfert, H. 2000, "The Impact of Clinical Pathways on the Practice of Head and Neck Oncologic Surgery: The University of Texas M. D. Anderson Cancer Center Experience", *Archives of Otolaryngology - Head & Neck Surgery*, vol. 126, no. 3, pp. 322-326.

Christodoulou, G. & Taylor, G.J. 2001, "Using a Continuous Time Hidden Markov Process, with Covariates, to Model Bed Occupancy of People Aged over 65 Years", *Health Care Management Science*, vol. 4, no. 1, pp. 21-24.

Clague, J.E., Reed, P.G., Barlow, J., Rada, R., Clarke, M. & Edwards, R.H. 1997, "Improving Outpatient Clinic Efficiency using Computer Simulation", *International Journal of Health Care Quality Assurance*, vol. 10, no. 4-5, pp. 197-201.

Coffey, R.J., Richards, J.S., Remmert, C.S., LeRoy, S.S., Schoville, R.R. & Baldwin, P.J. 2005, "An Introduction to Critical Paths", *Quality Management in Health Care*, vol. 14, no. 1, pp. 46-55.

Collier, P.E. 1997, "Do Clinical Pathways for Major Vascular Surgery Improve Outcomes and Reduce Cost?", *Journal of Vascular Surgery,* vol. 26, no. 2, pp. 179-185.

Committee on Quality of Health Care in America, Institute of Medicine 2001, *Crossing the Quality Chasm: A New Health System for the 21st Century,* National Academies Press.

Committee on Quality of Health Care in America, Institute of Medicine 2000, *To Err Is Human: Building a Safer Health System,* National Academy Press.

Cote, M.J. 2000, "Understanding Patient Flow", *Decision Line,* vol. 31, no. 2, pp. 8.

Cowan, R.M. & Trzeciak, S. 2005, "Clinical Review: Emergency Department Overcrowding and the Potential Impact on the Critically Ill", *Critical Care,* vol. 9, no. 3, pp. 291-295.

Department of Veteran Affairs 2008, *VA Organizational Briefing Book*. Available at http://www.va.gov/ofcadmin/docs/vaorgbb.pdf

Dexter, F. 1999, "Design of Appointment Systems for Preanesthesia Evaluation Clinics to Minimize Patient Waiting Times: A Review of Computer Simulation and Patient Survey Studies", *Anesthesia and Analgesia,* vol. 89, no. 4, pp. 925-931.

Dumas, M.B. 1984, "Simulation Modeling for Hospital Bed Planning", *Simulation,* vol. 43, no. 2, pp. 69-78.

Eccles, M. & Mason, J. 2001, "How to Develop Cost-Conscious Guidelines", *Health Technology Assessment*, vol. 5, no. 16, pp. 1-69.

Eckstein, M., Isaacs, S.M., Slovis, C.M., Kaufman, B.J., Loflin, J.R., O'Connor, R.E. & Pepe, P.E. 2005, "Facilitating EMS Turnaround Intervals at Hospitals in the Face of Receiving Facility Overcrowding", *Prehospital Emergency Care,* vol. 9, no. 3, pp. 267-275.

Edward, G.M., Das, S.F., Elkhuizen, S.G., Bakker, P.J., Hontelez, J.A., Hollmann, M.W., Preckel, B. & Lemaire, L.C. 2008, "Simulation to Analyse Planning Difficulties at the Preoperative Assessment Clinic", *British Journal of Anaesthesia,* vol. 100, no. 2, pp. 195-202.

Edwards, R.H., Clague, J.E., Barlow, J., Clarke, M., Reed, P.G. & Rada, R. 1994, "Operations Research Survey and Computer Simulation of Waiting Times in Two Medical Outpatient Clinic Structures", *Health Care Analysis,* vol. 2, no. 2, pp. 164-169.

el-Darzi, E., Vasilakis, C., Chaussalet, T. & Millard, P.H. 1998, "A Simulation Modelling Approach to Evaluating Length of Stay, Occupancy, Emptiness and Bed Blocking in a Hospital Geriatric Department", *Health Care Management Science*, vol. 1, no. 2, pp. 143-149.

Every, N.R., Hochman, J., Becker, R., Kopecky, S. & Cannon, C.P. 2000, "Critical Pathways: A Review", *Circulation,* vol. 101, no. 4, pp. 461-465.

Fabri, P.J. 2008, "Cost-Effectiveness Analysis", *First Annual Healthcare Engineering Symposium,* Research Triangle Park, NC, April 6-8, 2008.

Fatovich, D.M., Nagree, Y. & Sprivulis, P. 2005, "Access Block Causes Emergency Department Overcrowding and Ambulance Diversion in Perth, Western Australia", *Emergency Medicine Journal,* vol. 22, no. 5, pp. 351-354.

Forkner, J. 1996, "Clinical Pathways: Benefits and Liabilities", *Nursing Management,* vol. 27, no. 11, pp. 35-38.

Garrido, T., Jamieson, L., Zhou, Y., Wiesenthal, A. & Liang, L. 2005, "Effect of Electronic Health Records in Ambulatory Care: Retrospective, Serial, Cross-sectional Study", *British Medical Journal,* vol. 330, no. 7491, pp. 581.

Hall, R.W. (ed) 2007, *Patient Flow: Reducing Delay in Healthcare Delivery,* 1st edn, Springer.

Haraden, C. & Resar, R. 2004, "Patient Flow in Hospitals: Understanding and Controlling it Better", *Frontiers of Health Services Management,* vol. 20, no. 4, pp. 3-15.

Harper, P.R. & Gamlin, H.M. 2003, "Reduced Outpatient Waiting Times with Improved Appointment Scheduling: A Simulation Modeling Approach", *OR Spectrum,* vol. 25, no. 2, pp. 207.

Hoffman, R., Hoffman, D. & Hoffman, C. 2005, *The Impact of Health Insurance Coverage on Health Disparities in the United States*.

Howell, E.E., Bessman, E.S. & Rubin, H.R. 2004, "Hospitalists and an Innovative Emergency Department Admission Process", *Journal of General Internal Medicine,* vol. 19, no. 3, pp. 266-268.

Huarng, F. & Lee, M.H. 1996, "Using Simulation in Out-Patient Queues: A Case Study", *International Journal of Health Care Quality Assurance,* vol. 9, no. 6, pp. 21-25.

Husbands, J.M., Weber, R.S., Karpati, R.L., Weinstein, G.S., Chalian, A.A., Goldberg, A.N., Thaler, E.R. & Wolf, P.F. 1999, "Clinical Care Pathways: Decreasing Resource Utilization in Head and Neck Surgical Patients", *Otolaryngology - Head and Neck Surgery,* vol. 121, no. 6, pp. 755-759.

Jha, A.K., Ferris, T.G., Donelan, K., DesRoches, C., Shields, A., Rosenbaum, S. & Blumenthal, D. 2006, "How Common Are Electronic Health Records In The United States? A Summary Of The Evidence", *Health Affairs,* vol. 25, no. 6, pp. w496-507.

Jun, J.B., Jacobson, S.H. & Swisher, J.R. 1999, "Application of Discrete-Event Simulation in Health Care Clinics: A Survey", *The Journal of the Operational Research Society,* vol. 50, no. 2, pp. 109-123.

Kazley, A.S. & Ozcan, Y.A. 2008, "Do Hospitals With Electronic Medical Records (EMRs) Provide Higher Quality Care? An Examination of Three Clinical Conditions", *Medical Care Research and Review,* vol. 65, no. 4, pp. 496-513.

Kim, S., Losina, E., Solomon, D.H., Wright, J. & Katz, J.N. 2003, "Effectiveness of Clinical Pathways for Total Knee and Total Hip Arthroplasty: Literature Review", *The Journal of Arthroplasty,* vol. 18, no. 1, pp. 69-74.

Kingston, M.E., Krumberger, J.M. & Peruzzi, W.T. 2000, "Enhancing Outcomes: Guidelines, Standards, and Protocols", *AACN Clinical Issues,* vol. 11, no. 3, pp. 363-374.

Kinn, J.W., O'Toole, M.F., Rowley, S.M., Marek, J.C., Bufalino, V.J. & Brown, A.S. 2001, "Effectiveness of the Electronic Medical Record in Cholesterol Management in Patients with Coronary Artery Disease (Virtual Lipid Clinic)", *The American Journal of Cardiology,* vol. 88, no. 2, pp. 163-165.

Klassen, K.J. & Rohleder, T.R. 1996, "Scheduling Outpatient Appointments in a Dynamic Environment", *Journal of Operations Management,* vol. 14, no. 2, pp. 83-101.

Konishi, T. & Agawa, S. 2000, "Clinical Pathways in Oncology", *Gan to Kagaku Ryoho:Cancer & Chemotherapy,* vol. 27, no. 5, pp. 655-670.

Kopach, R., DeLaurentis, P.C., Lawley, M., Muthuraman, K., Ozsen, L., Rardin, R., Wan, H., Intrevado, P., Qu, X. & Willis, D. 2007, "Effects of Clinical Characteristics on Successful Open Access Scheduling", *Health Care Management Science,* vol. 10, no. 2, pp. 111-124.

Lowery, J.C. 1996, "Design of Hospital Admissions Scheduling System using Simulation", *Simulation Conference, 1996. Proceedings. Winter*, pp. 1199.

Mackay, M. & Lee, M. 2005, "Choice of Models for the Analysis and Forecasting of Hospital Beds", *Health Care Management Science,* vol. 8, no. 3, pp. 221-230.

Mackay, M. & Millard, P.H. 1999, "Application and Comparison of Two Modelling Techniques for Hospital Bed Management", *Australian Health Review,* vol. 22, no. 3, pp. 118-143.

Magerlein, J.M. & Martin, J.B. 1976, "Surgical Demand Scheduling: A Review", *Health Services Research,* vol. 11, pp. 53.

Marshall, A., Vasilakis, C. & El-Darzi, E. 2005, "Length of Stay-Based Patient Flow Models: Recent Developments and Future Directions", *Health Care Management Science,* vol. 8, no. 3, pp. 213-220.

McClean, S. & Millard, P.H. 1995, "A Decision Support System for Bed-Occupancy Management and Planning Hospitals", *IMA Journal of Mathematics Applied in Medicine and Biology,* vol. 12, no. 3-4, pp. 249-257.

Miller, M.J., Ferrin, D.M. & Szymanski, J.M. 2003, "Simulating Six Sigma Improvement Ideas for a Hospital Emergency Department", *Simulation Conference, 2003. Proceedings of the 2003 Winter*, pp. 1926.

Napolitano, L.M. 2005, "Standardization of Perioperative Management: Clinical Pathways", *The Surgical Clinics of North America,* vol. 85, no. 6, pp. 1321-7, xiii.

National Center for Health Statistics 2007, *Health, United States With Chartbook on Trends on the Health of Americans*.

OECD 2007, "Organisation for Economic Cooperation and Development (OECD) Health Data", .

Olshaker, J.S. & Rathlev, N.K. 2006a, "Emergency Department Overcrowding and Ambulance Diversion: The Impact and Potential Solutions of Extended Boarding of Admitted Patients in the Emergency Department", *The Journal of Emergency Medicine,* vol. 30, no. 3, pp. 351-356.

Olshaker, J.S. & Rathlev, N.K. 2006b, "Emergency Department Overcrowding and Ambulance Diversion: The Impact and Potential Solutions of Extended Boarding of Admitted Patients in the Emergency Department", *The Journal of Emergency Medicine,* vol. 30, no. 3, pp. 351-356.

Pitts, S.R., Niska, R.W., Jianmin, X. & Burt, C.W. 2008, *National Hospital Ambulatory Medical Care Survey: 2006 Emergency Department Summary*, National Center for Health Statistics, Hyattsville, MD.

Porter, M.E. & Teisberg, E.O. 2006, *Redefining Health Care: Creating Value-Based Competition on Results,* Harvard Business School Publishing.

Proudlove, N.C., Gordon, K. & Boaden, R. 2003, "Can Good Bed Management Solve the Overcrowding in Accident and Emergency Departments?", *Emergency Medicine Journal*, vol. 20, no. 2, pp. 149-155.

Rauh, R.A., Schwabauer, N.J., Enger, E.L. & Moran, J.F. 1999, "A Community Hospital-Based Congestive Heart Failure Program: Impact on Length of Stay, Admission and Readmission Rates, and Cost", *The American Journal of Managed Care,* vol. 5, no. 1, pp. 37-43.

Ridge, J.C., Jones, S.K., Nielsen, M.S. & Shahani, A.K. 1998, "Capacity Planning for Intensive Care Units", *European Journal of Operational Research,* vol. 105, no. 2, pp. 346-355.

Rohrer, J.E., Bernard, M., Naessens, J., Furst, J., Kircher, K. & Adamson, S. 2007, "Impact of Open-Access Scheduling on Realized Access", *Health Services Management Research,* vol. 20, no. 2, pp. 134-139.

Schafermeyer, R.W. & Asplin, B.R. 2003, "Hospital and Emergency Department Crowding in the United States", *Emergency Medicine*, vol. 15, no. 1, pp. 22-27.

Schneider, S.M., Gallery, M.E., Schafermeyer, R. & Zwemer, F.L. 2003, "Emergency Department Crowding: A Point in Time", *Annals of Emergency Medicine*, vol. 42, no. 2, pp. 167-172.

Schull, M.J., Lazier, K., Vermeulen, M., Mawhinney, S. & Morrison, L.J. 2003, "Emergency Department Contributors to Ambulance Diversion: A Quantitative Analysis", *Annals of Emergency Medicine,* vol. 41, no. 4, pp. 467-476.

Sheehan, J.P. 2002, "A Liability Checklist for Clinical Pathways", *Nursing Management,* vol. 33, no. 2, pp. 23-25.

Smith, T.J. & Hillner, B.E. 2001, "Ensuring Quality Cancer Care by the use of Clinical Practice Guidelines and Critical Pathways", *Journal of Clinical Oncology,* vol. 19, no. 11, pp. 2886-2897.

Spaite, D.W., Bartholomeaux, F., Guisto, J., Lindberg, E., Hull, B., Eyherabide, A., Lanyon, S., Criss, E.A., Valenzuela, T.D. & Conroy, C. 2002, "Rapid Process Redesign in a University-Based Emergency Department: Decreasing Waiting Time Intervals and Improving Patient Satisfaction", *Annals of Emergency Medicine*, vol. 39, no. 2, pp. 168-177.

Spencer, E., Swanson, T., Hueston, W.J. & Edberg, D.L. 1999, "Tools to Improve Documentation of Smoking Status: Continuous Quality Improvement and Electronic Medical Records", *Archives of Family Medicine*, vol. 8, no. 1, pp. 18-22.

Swisher, J.R., Jacobson, S.H., Jun, J.B. & Balci, O. 2001, "Modeling and Analyzing a Physician Clinic Environment using Discrete-Event (visual) Simulation", *Computers & Operations Research*, vol. 28, no. 2, pp. 105-125.

Terris, J., Leman, P., O'Connor, N. & Wood, R. 2004, "Making an IMPACT on Emergency Department Flow: Improving Patient Processing Assisted by Consultant at Triage", *Emergency Medicine Journal*, vol. 21, no. 5, pp. 537-541.

Trzeciak, S. & Rivers, E.P. 2003, "Emergency Department Overcrowding in the United States: An Emerging Threat to Patient Safety and Public Health", *Emergency Medicine Journal*, vol. 20, no. 5, pp. 402-405.

United Nations Development Program 2005, *Human Development Report 2005: International Cooperation at the Crossroads - Aid, Trade and Security in an Unequal World*, UNDP.

United States General Accounting Office 2003, *Hospital Emergency Departments: Crowded Conditions Vary among Hospitals and Communities*, GAO.

Vishwanath, A. & Scamurra, S.D. 2007, "Barriers to the Adoption of Electronic Health Records: Using Concept Mapping to Develop a Comprehensive Empirical Model", *Health Informatics Journal*, vol. 13, no. 2, pp. 119-134.

Walter, F.L., Bass, N., Bock, G. & Markel, D.C. 2007, "Success of Clinical Pathways for Total Joint Arthroplasty in a Community Hospital", *Clinical Orthopaedics and Related Research*, vol. 457, pp. 133-137.

Wang, S.J., Middleton, B., Prosser, L.A., Bardon, C.G., Spurr, C.D., Carchidi, P.J., Kittler, A.F., Goldszer, R.C., Fairchild, D.G., Sussman, A.J., Kuperman, G.J. & Bates, D.W. 2003, "A Cost-Benefit Analysis of Electronic Medical Records in Primary Care", *The American Journal of Medicine*, vol. 114, no. 5, pp. 397-403.

Weingarten, S., Riedinger, M.S., Sandhu, M., Bowers, C., Ellrodt, A.G., Nunn, C., Hobson, P. & Greengold, N. 1998, "Can Practice Guidelines Safely Reduce Hospital Length of Stay? Results from a Multicenter Interventional Study", *The American Journal of Medicine*, vol. 105, no. 1, pp. 33-40.

World Health Organization 2008, *World Health Statistics*, World Health Organization.

World Health Organization - Europe 2006, July 18, 2006-last update, *Health Care Delivery*. Available: http://www.euro.who.int/healthcaredelivery [2008, December 3] .

Zehr, K.J., Dawson, P.B., Yang, S.C. & Heitmiller, R.F. 1998, "Standardized Clinical Care Pathways for Major Thoracic Cases Reduce Hospital Costs", *Annals of Thoracic Surgery*, vol. 66, no. 3, pp. 914-919.

# APPENDICES

## Appendix 1: Encounter Grouping

Below is the grouping of encounters into three types: visits, procedures and tests.

Table 22. Encounter Grouping

| Clinic Visits | Procedures | Tests |
|---|---|---|
| Oncology | Pulmonary Procedure | Xray |
| Lung Nodule | Lung Biopsy | CT |
| Pre-Op | Oncology Procedure | PFT |
| PACM | | PET |
| Thoracic Surgery | | Myocardial Perfusion |
| Radiology | | CT Guidance |
| Resp Care/Home | | Cardio ABG |
| ER | | Gated Spect |
| Urgent Care | | Stress Test |
| Primary Care Clinic | | Barium/Fluoro |
| | | Bone Scan |
| | | Bone Surv Comp |
| | | EKG |
| | | MRI |
| | | Quantitative Perfusion |

## Appendix 2: Pre-Admission Patient Flow

Below are the detailed flows of each patient in the pre-admission period. For each patient, the column on the left is the number of days before the surgical admission. The column on the right is the encounter type.

Table 23. The Flow of Patients (1-3) in the Pre-Admission Period.

| Patient 1 | | Patient 2 | | Patient 3 | |
|---|---|---|---|---|---|
| -133 | Xray | -168 | Oncology | -175 | Radiology |
| -98 | CT | -162 | Pulmonary Procedure | -151 | Oncology |
| -79 | Thoracic Surgery | -147 | Oncology | -151 | Xray |
| -73 | Oncology | -125 | Lung Nodule | -95 | RAD CT |
| -52 | PET | -77 | Xray | -94 | CT |
| -51 | PFT | -62 | Lung Nodule | -88 | Oncology |
| -51 | Pulmonary Procedure | -48 | Xray | -62 | CT Guidance |
| -38 | Oncology | -12 | Oncology | -62 | Lung Biopsy |
| -11 | CT | -5 | PACM | -61 | Xray |
| -9 | Lung Nodule | -5 | Pre-Op | -60 | Oncology |
| -3 | PACM | -5 | Pre-Anesthesia | -59 | Xray |
| -3 | Pre-Op | -5 | Xray | -47 | Lung Nodule |
| -3 | Pre-Anesthesia | | | -18 | Oncology |
| -3 | Xray | | | -14 | PACM |
| | | | | -14 | Pre-Op |
| | | | | -14 | PFT |
| | | | | -13 | Xray |

**Appendix 2: (Continued)**

Table 24. The Flow of Patients (4-6) in the Pre-Admission Period.

| Patient 4 | | Patient 5 | | Patient 6 | |
|---|---|---|---|---|---|
| -7 | Lung Nodule | -126 | Oncology | -151 | CT |
| -7 | PFT | -123 | CT | -151 | CT |
| -1 | PACM | -123 | CT | -143 | Oncology |
| -1 | Pre-Op | -122 | Pulmonary Procedure | -136 | Radiology |
| -1 | Pre-Anesthesia | -115 | Oncology | -136 | Gastronomy Tube PACS |
| -1 | Xray | -115 | Xray | -134 | PFT |
| | | -97 | Cardio ABG | -130 | Radiology |
| | | -89 | Lung Nodule | -130 | Barium |
| | | -76 | PET | -128 | Lung Nodule |
| | | -21 | Oncology | -102 | PET |
| | | -5 | PACM | -80 | Oncology |
| | | -5 | Pre-Op | -59 | Radiology |
| | | -5 | Pre-Anesthesia | -58 | Radiology |
| | | | | -49 | CT |
| | | | | -45 | CT |
| | | | | -16 | Thoracic Surgery |
| | | | | -7 | PACM |
| | | | | -7 | Pre-Op |
| | | | | -7 | Xray |
| | | | | -7 | Pre-Anesthesia |
| | | | | -7 | PFT |
| | | | | -4 | Pulmonary Procedure |

**Appendix 2: (Continued)**

Table 25. The Flow of Patients (7-9) in the Pre-Admission Period.

| Patient 7 | | Patient 8 | | Patient 9 | |
|---|---|---|---|---|---|
| -125 | CT | -33 | Lung Nodule | -162 | Radiology |
| -104 | Lung Nodule | -20 | PACM | -137 | Cardio ABG |
| -88 | RAD CT | -20 | Pre-Op | -56 | Radiology |
| -70 | PET | | | -53 | Myocardial Perfusion |
| -61 | PFT | | | -53 | Myocardial Perfusion |
| -18 | Xray | | | -48 | Oncology |
| -15 | PACM | | | -27 | Pulmonary Procedure |
| -15 | Pre-Op | | | -27 | Thoracic Surgery |
| | | | | -27 | Xray |
| | | | | -1 | PACM |
| | | | | -1 | Pre-Op |
| | | | | -1 | Pre-Anesthesia |
| | | | | -1 | Xray |

Table 26. The Flow of Patients (10-12) in the Pre-Admission Period.

| Patient 10 | | Patient 11 | | Patient 12 | |
|---|---|---|---|---|---|
| -172 | Pulmonary Procedure | -53 | PET | -75 | Lung Nodule |
| -171 | CT | -49 | Cardio ABG | -60 | Oncology |
| -129 | Oncology | -48 | Oncology | -58 | Stress Test |
| -114 | Lung Nodule | -25 | Cardio ABG | -58 | Myocardial Perfusion |
| -107 | Xray | -15 | Oncology | -58 | Gated Spect |
| -59 | Oncology | -13 | Lung Nodule | -27 | PFT |
| -42 | Stress Test | -8 | PACM | -26 | Lung Nodule |
| -42 | Myocardial Perfusion | -8 | Pre-Op | -7 | PACM |
| -42 | Gated Spect | -8 | Xray | -7 | Pre-Op |
| -15 | CT | | | -7 | Pre-Anesthesia |
| -4 | PACM | | | -7 | Xray |
| -4 | Pre-Op | | | | |
| -4 | Pre-Anesthesia | | | | |
| -4 | PFT | | | | |
| -3 | Xray | | | | |

**Appendix 2: (Continued)**

Table 27. The Flow of Patients (13-15) in the Pre-Admission Period.

| Patient 13 | | Patient 14 | | Patient 15 | |
|---|---|---|---|---|---|
| -43 | Lung Nodule | -138 | PFT | -136 | Xray |
| -34 | Lung Nodule | -71 | CT | -66 | CT |
| -20 | PET | -19 | CT Guidance | -66 | CT |
| -7 | PACM | -19 | CT Guidance | -59 | Xray |
| -7 | Pre-Op | -19 | CT | -48 | CT |
| -7 | PFT | -6 | PACM | -24 | PET |
| -7 | Pre-Anesthesia | -6 | Pre-Op | -5 | Thoracic Surgery |
| -7 | Xray | -6 | Pre-Anesthesia | -3 | PACM |
| | | -6 | Xray | -3 | Pre-Op |
| | | | | -3 | Pre-Anesthesia |
| | | | | -3 | PFT |
| | | | | -3 | Xray |

Table 28. The Flow of Patients (16-18) in the Pre-Admission Period.

| Patient 16 | | Patient 17 | | Patient 18 | |
|---|---|---|---|---|---|
| -168 | Xray | -35 | Pulmonary Procedure | -159 | Oncology |
| -137 | CT | -28 | Pulmonary Procedure | -40 | CT |
| -120 | Oncology | -15 | Radiology | -40 | CT |
| -63 | PET | -2 | CT | -40 | CT |
| -51 | PFT | -2 | CT | -40 | Oncology |
| -37 | Thoracic Surgery | | | -27 | Lung Nodule |
| -18 | Stress Test | | | -18 | Bone Scan |
| -18 | Gated Spect | | | -15 | PET |
| -18 | Gated Spect | | | -6 | PACM |
| -18 | Myocardial Perfusion | | | -6 | Pre-Op |
| -18 | EKG | | | -6 | Pre-Anesthesia |
| -17 | Myocardial Perfusion | | | -6 | PFT |
| -16 | Thoracic Surgery | | | | |
| -2 | PACM | | | | |
| -2 | Pre-Op | | | | |
| -2 | PFT | | | | |
| -2 | Pre-Anesthesia | | | | |
| -2 | Xray | | | | |

**Appendix 2: (Continued)**

Table 29. The Flow of Patients (19-21) in the Pre-Admission Period.

| Patient 19 | | Patient 20 | | Patient 21 | |
|---|---|---|---|---|---|
| -148 | CT | -134 | Oncology | -120 | CT |
| -146 | PFT | -78 | RAD | -86 | Oncology |
| -28 | CT | -30 | Lung Nodule | -41 | Oncology |
| -27 | Thoracic Surgery | -30 | PFT | -22 | Radiology |
| -11 | PACM | -15 | PACM | -21 | Radiology |
| -11 | Pre-Op | -15 | Pre-Op | -15 | Thoracic Surgery |
| -11 | Xray | | | -7 | Pre-Op |
| -3 | MRI | | | -7 | PFT |
| | | | | -7 | Pre-Anesthesia |
| | | | | -1 | PACM |
| | | | | -1 | Xray |

Table 30. The Flow of Patients (22-24) in the Pre-Admission Period.

| Patient 22 | | Patient 23 | | Patient 24 | |
|---|---|---|---|---|---|
| -57 | Lung Nodule | -102 | CT | -98 | Radiology |
| -56 | Oncology | -86 | Lung Nodule | -85 | Radiology |
| -56 | Pulmonary Procedure | -73 | PET | -84 | Xray |
| -55 | Xray | -72 | Thoracic Surgery | -84 | CT |
| -49 | Oncology | -65 | PFT | -64 | CT |
| -16 | PET | -18 | PACM | -58 | PFT |
| -15 | CT | -18 | Pre-Op | -50 | Oncology |
| -15 | CT | -17 | Xray | -41 | Pulmonary Procedure |
| -8 | PFT | | | -27 | Thoracic Surgery |
| -1 | PACM | | | -1 | PACM |
| -1 | Pre-Op | | | -1 | Pre-Op |
| -1 | Pre-Anesthesia | | | -1 | Pre-Anesthesia |
| -1 | Xray | | | -1 | Xray |
| -1 | PFT | | | | |

**Appendix 2: (Continued)**

Table 31. The Flow of Patients (25-27) in the Pre-Admission Period.

| Patient 25 | Patient 26 | | Patient 27 | |
|---|---|---|---|---|
| | -144 | CT | -148 | Lung Nodule |
| | -144 | CT | -120 | Lung Nodule |
| | -144 | CT | -114 | PET |
| | -47 | CT | -77 | RAD |
| | -26 | Lung Nodule | -37 | CT Guidance |
| | -4 | PACM | -37 | Lung Biopsy |
| | -4 | Pre-Op | -37 | Xray |
| | -4 | Pre-Anesthesia | -37 | Xray |
| | -4 | PFT | -29 | Lung Nodule |
| | -4 | Xray | -14 | CT |
| | | | -3 | PACM |
| | | | -3 | Pre-Op |
| | | | -3 | Pre-Anesthesia |
| | | | -3 | PFT |
| | | | -3 | Xray |
| | | | -2 | Radiology |
| | | | -2 | Myocardial Perfusion |
| | | | -2 | Gated Spect |

**Appendix 2: (Continued)**

Table 32. The Flow of Patients (28-30) in the Pre-Admission Period.

| Patient 28 | | Patient 29 | | Patient 30 | |
|---|---|---|---|---|---|
| -48 | Lung Nodule | -138 | Radiology | -153 | Oncology |
| -20 | PFT | -137 | CT | -118 | CT |
| -8 | Pre-Op | -130 | Oncology | -97 | Oncology |
| -8 | PACM | -117 | Pulmonary Procedure | -76 | Pulmonary Procedure |
| -7 | Xray | -115 | Xray | -76 | Xray |
| | | -109 | Oncology | -62 | Oncology |
| | | -109 | Cardio ABG | -19 | Lung Nodule |
| | | -84 | PET | -7 | PACM |
| | | -83 | Lung Nodule | -7 | Pre-Op |
| | | -81 | Oncology | -7 | Pre-Anesthesia |
| | | -78 | Radiology | | |
| | | -77 | Myocardial Perfusion | | |
| | | -77 | Myocardial Perfusion | | |
| | | -75 | Oncology | | |
| | | -19 | Pre-Op | | |
| | | -19 | Xray | | |
| | | -12 | Oncology | | |
| | | -1 | PACM | | |
| | | -1 | Pre-Op | | |
| | | -1 | Pre-Anesthesia | | |

Table 33. The Flow of Patients (31-33) in the Pre-Admission Period.

| Patient 31 | | Patient 32 | | Patient 33 | |
|---|---|---|---|---|---|
| -145 | Oncology | -60 | Xray | -124 | Lung Nodule |
| -62 | CT | -39 | Bone Surv Comp | -39 | CT |
| -62 | CT | -34 | PFT | -33 | Lung Nodule |
| -62 | CT | -34 | PFT | -12 | Lung Nodule |
| -43 | Oncology | -20 | Lung Nodule | -12 | PET |
| -35 | Oncology | -20 | Oncology | -5 | PACM |
| -29 | Pulmonary Procedure | -7 | PACM | -5 | Pre-Op |
| -21 | PET | -7 | Pre-Op | -5 | Pre-Anesthesia |
| -19 | Thoracic Surgery | -7 | Pre-Anesthesia | -5 | Xray |
| -6 | PACM | -7 | Xray | | |
| -6 | Pre-Op | -5 | Oncology | | |
| -6 | Pre-Anesthesia | -1 | RAD | | |
| -6 | PFT | | | | |
| -6 | Xray | | | | |

**Appendix 2: (Continued)**

Table 34. The Flow of Patients (34-36) in the Pre-Admission Period.

| Patient 34 | | Patient 35 | | Patient 36 | |
|---|---|---|---|---|---|
| -177 | Oncology | -169 | Radiology | -53 | Xray |
| -105 | Oncology | -116 | Radiology | -46 | CT |
| -92 | Lung Nodule | -100 | Lung Nodule | -26 | Lung Nodule |
| -57 | Lung Nodule | -93 | Cardio ABG | -18 | Oncology |
| -48 | Pulmonary Procedure | -30 | Lung Nodule | -5 | PACM |
| -44 | Stress Test | -11 | PACM | -5 | Pre-Op |
| -44 | Myocardial Perfusion | -11 | Pre-Op | -5 | Pre-Anesthesia |
| -44 | Gated Spect | | | -5 | Xray |
| -38 | Quantitative Perfusion | | | | |
| -37 | CT | | | | |
| -35 | Oncology | | | | |
| -22 | Lung Nodule | | | | |
| -6 | PACM | | | | |
| -6 | Pre-Op | | | | |
| -6 | Pre-Anesthesia | | | | |
| -5 | Xray | | | | |

Table 35. The Flow of Patients (37-39) in the Pre-Admission Period.

| Patient 37 | | Patient 38 | | Patient 39 | |
|---|---|---|---|---|---|
| -53 | Xray | -322 | Oncology | -84 | Lung Nodule |
| -26 | Lung Nodule | -154 | Oncology | -84 | PFT |
| -11 | Oncology | -115 | Oncology | -69 | Oncology |
| -11 | PFT | -104 | Pulmonary Procedure | -69 | Pulmonary Procedure |
| -5 | PACM | -99 | Lung Nodule | -69 | Xray |
| -5 | Pre-Op | -99 | PFT | -32 | PET |
| -5 | Pre-Anesthesia | -71 | Oncology | -30 | PACM |
| -5 | Xray | -50 | Lung Nodule | -30 | Pre-Op |
| -5 | PFT | -30 | CT | -29 | Xray |
| | | -30 | CT | -6 | Urology Oncology |
| | | -30 | CT | | |
| | | -29 | Lung Nodule | | |
| | | -22 | Thoracic Surgery | | |
| | | -17 | PET | | |
| | | -10 | PACM | | |
| | | -10 | Pre-Op | | |
| | | -10 | Xray | | |

## Appendix 2: (Continued)

Table 36. The Flow of Patients (40-42) in the Pre-Admission Period.

| Patient 40 | | Patient 41 | | Patient 42 | |
|---|---|---|---|---|---|
| -122 | Oncology | -100 | Lung Nodule | -41 | CT |
| -88 | Radiology | -86 | PFT | -41 | CT |
| -45 | Xray | -25 | Radiology | -41 | CT |
| -36 | Xray | -9 | Lung Nodule | -34 | Lung Nodule |
| -35 | CT | -3 | PACM | -8 | PACM |
| -30 | Pulmonary Procedure | -3 | Pre-Op | -8 | Pre-Op |
| -21 | Pulmonary Procedure | -3 | Pre-Anesthesia | -8 | Xray |
| -16 | Pre-Op | -1 | Xray | -8 | PFT |
| -16 | PACM | | | | |
| -14 | PFT | | | | |

Table 37. The Flow of Patients (43-45) in the Pre-Admission Period.

| Patient 43 | | Patient 44 | | Patient 45 | |
|---|---|---|---|---|---|
| -141 | Oncology | -36 | Lung Nodule | -174 | Radiology |
| -133 | Oncology | -22 | Thoracic Surgery | -168 | Xray |
| -90 | Oncology | -20 | PET | -98 | CT |
| -89 | CT | -20 | PFT | -98 | CT |
| -82 | Pulmonary Procedure | -6 | PACM | -98 | CT |
| -64 | Oncology | -6 | Pre-Op | -76 | Oncology |
| -53 | PET | -6 | Pre-Anesthesia | -49 | PET |
| -32 | Cardio ABG | -6 | PFT | -47 | Thoracic Surgery |
| -32 | Oncology | -6 | Xray | -34 | PFT |
| -22 | Oncology | | | -34 | Oncology |
| -13 | Lung Nodule | | | -33 | Xray |
| -5 | PACM | | | -8 | PACM |
| -5 | Pre-Op | | | -8 | Pre-Op |
| -5 | Xray | | | | |
| -5 | Pre-Anesthesia | | | | |

**Appendix 2: (Continued)**

Table 38. The Flow of Patients (46-48) in the Pre-Admission Period.

| Patient 46 | | Patient 47 | | Patient 48 | |
|---|---|---|---|---|---|
| -118 | PFT | -16 | Lung Nodule | -170 | CT |
| | | -16 | PFT | -170 | CT |
| | | | | -130 | Radiology |
| | | | | -115 | Radiology |
| | | | | -63 | CT |
| | | | | -52 | PFT |
| | | | | -51 | Oncology |
| | | | | -51 | Radiology |
| | | | | -51 | Xray |
| | | | | -37 | Lung Nodule |
| | | | | -1 | PACM |
| | | | | -1 | Pre-Op |
| | | | | -1 | Pre-Anesthesia |
| | | | | -1 | PFT |
| | | | | -1 | Xray |

## Appendix 3: Inpatient Ward Descriptions

The descriptions of each of the units or wards within the hospital that were visited by at least one of the patients during their inpatient episode of care:

- Ward 6 South Thoracic (6ST) – a surgical ward that is the most common point of admission for patients undergoing elective surgery (ES) of the lung
- Ward 6 South Cardio (6SC) – ward that shares space with 6ST and is for cardiac patients
- Ward 4 South (4S) – ward for most patients undergoing ES
- Spinal Cord Injury Service (SCI) –ward for patients with spinal cord injuries
- Pre-Operation Hold Area – the unit that is responsible for prepping the patient before surgery, including administering anesthesia
- Operation Room – the designated area for surgeries
- Post Anesthesia Care Unit (PACU) – unit patients are wheeled into post surgery to recover from anesthesia and for observation
- Surgical Intensive Care Unit (SICU) – an acute care unit (ACU) for patients to recover from the surgery
- Critical Care Unit (CCU) – an ACU for cardiac patients

**Appendix 3: (Continued)**

- Medical Intensive Care Unit (MICU) – an ACU for patients that do not fall under surgical or cardiac care
- Genito-Urinary Clinic (GUC) – unit/clinic for patients with genitor-urinary problems
- Radiology (RAD) – the radiology unit within the hospital

## Appendix 4: Inpatient Flow during Surgical Episode

Below are the detailed flows of each patient's inpatient episode for lung resection. For each patient, the column on the left is the order of each encounter and the corresponding unit where the encounter occurred. The OR (where the resection took place) is step 0.

Table 39. Detailed Flow of Patients (1-5) in the Inpatient Surgical Episode

| Patient 1 | | Patient 2 | | Patient 3 | | Patient 4 | | Patient 5 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area |
| 0 | OR | 0 | OR | 0 | OR | 0 | OR | 0 | OR |
| 1 | PACU | 1 | SICU | 1 | SICU | 1 | SICU | 1 | SICU |
| 2 | SICU | 2 | 6ST | 2 | 6ST | 2 | 6ST | 2 | 6ST |
| 3 | 6ST | 3 | CCU | 3 | Discharge | 3 | RAD | 3 | RAD |
| 4 | RAD | 4 | 6ST | | | 4 | RAD | 4 | 6ST |
| 5 | 6ST | 5 | Discharge | | | 5 | 6ST | 5 | Discharge |
| 6 | RAD | | | | | 6 | Discharge | | |
| 7 | 6ST | | | | | | | | |
| 8 | Discharge | | | | | | | | |

Table 40. Detailed Flow of Patients (6-10) in the Inpatient Surgical Episode

| Patient 6 | | Patient 7 | | Patient 8 | | Patient 9 | | Patient 10 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area |
| 0 | OR | 0 | OR | 0 | OR | 0 | OR | 0 | OR |
| 1 | PACU | 1 | SICU | 1 | PACU | 1 | SICU | 1 | PACU |
| 2 | SICU | 2 | 6ST | 2 | SICU | 2 | 6ST | 2 | SICU |
| 3 | 6ST | 3 | Discharge | 3 | 6ST | 3 | RAD | 3 | 6ST |
| 4 | Discharge | | | 4 | RAD | 4 | 6ST | 4 | Discharge |
| | | | | 5 | 6ST | 5 | Discharge | | |
| | | | | 6 | RAD | | | | |
| | | | | 7 | 6ST | | | | |
| | | | | 8 | Discharge | | | | |

**Appendix 4: (Continued)**

Table 41. Detailed Flow of Patients (11-15) in the Inpatient Surgical Episode

| Patient 11 | | Patient 12 | | Patient 13 | | Patient 14 | | Patient 15 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area |
| 0 | OR | 0 | OR | 0 | OR | 0 | OR | 0 | OR |
| 1 | PACU | 1 | SICU | 1 | PACU | 1 | PACU | 1 | PACU |
| 2 | SICU | 2 | 6ST | 2 | SICU | 2 | SICU | 2 | SICU |
| 3 | 6ST | 3 | Discharge | 3 | 6ST | 3 | 6ST | 3 | 6ST |
| 4 | RAD | | | 4 | RAD | 4 | RAD | 4 | RAD |
| 5 | 6ST | | | 5 | 6ST | 5 | 6ST | 5 | 6ST |
| 6 | RAD | | | 6 | Discharge | 6 | Discharge | 6 | Discharge |
| 7 | 6ST | | | | | | | | |
| 8 | RAD | | | | | | | | |
| 9 | 6ST | | | | | | | | |
| 10 | Discharge | | | | | | | | |

**Appendix 4: (Continued)**

Table 42. Detailed Flow of Patients (16-20) in the Inpatient Surgical Episode

| Patient 16 | | Patient 17 | | Patient 18 | | Patient 19 | | Patient 20 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -1 | SCI-E | -2 | 6ST | -2 | 6ST | -2 | 6ST |
| -1 | Hold Area | 0 | OR | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area |
| 0 | OR | 1 | PACU | 0 | OR | 0 | OR | 0 | OR |
| 1 | SICU | 2 | SCI-E | 1 | PACU | 1 | PACU | 1 | PACU |
| 2 | OR | 3 | Discharge | 2 | 6ST | 2 | Discharge | 2 | SICU |
| 3 | SICU | | | 3 | Discharge | | | 3 | 6ST |
| 4 | RAD | | | -2 | 6ST | | | 4 | Discharge |
| 5 | SICU | | | -1 | Hold Area | | | | |
| 6 | 6ST | | | 0 | OR | | | | |
| 7 | CP | | | 1 | PACU | | | | |
| 8 | 6ST | | | 2 | SICU | | | | |
| 9 | RAD | | | 3 | 6ST | | | | |
| 10 | 6ST | | | 4 | Discharge | | | | |
| 11 | SICU | | | | | | | | |
| 12 | RAD | | | | | | | | |
| 13 | SICU | | | | | | | | |
| 14 | 6ST | | | | | | | | |
| 15 | MICU | | | | | | | | |
| 16 | SICU | | | | | | | | |
| 17 | 6ST | | | | | | | | |
| 18 | SICU | | | | | | | | |
| 19 | RAD | | | | | | | | |
| 20 | SICU | | | | | | | | |
| 21 | 6ST | | | | | | | | |
| 22 | Discharge | | | | | | | | |

**Appendix 4: (Continued)**

Table 43. Detailed Flow of Patients (21-25) in the Inpatient Surgical Episode

| Patient 21 | | Patient 22 | | Patient 23 | | Patient 24 | | Patient 25 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6SC | -2 | 6ST | -2 | 6ST | -4 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -3 | RAD |
| 0 | OR | 0 | OR | 0 | OR | 0 | OR | -2 | 6ST |
| 1 | SICU | 1 | SICU | 1 | PACU | 1 | PACU | -1 | Hold Area |
| 2 | RAD | 2 | 6ST | 2 | SICU | 2 | SICU | 0 | OR |
| 3 | 6ST | 3 | Discharge | 3 | 6ST | 3 | 6ST | 1 | PACU |
| 4 | Discharge | | | 4 | Discharge | 4 | Discharge | 2 | SICU |
| | | | | | | | | 3 | 6ST |
| | | | | | | | | 4 | RAD |
| | | | | | | | | 5 | 6ST |
| | | | | | | | | 6 | RAD |
| | | | | | | | | 7 | 6ST |
| | | | | | | | | 8 | Discharge |

Table 44. Detailed Flow of Patients (26-30) in the Inpatient Surgical Episode

| Patient 26 | | Patient 27 | | Patient 28 | | Patient 29 | | Patient 30 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area |
| 0 | OR | 0 | OR | 0 | OR | 0 | OR | 0 | OR |
| 1 | PACU | 1 | PACU | 1 | PACU | 1 | SICU | 1 | PACU |
| 2 | SICU | 2 | SICU | 2 | SICU | 2 | Discharge | 2 | Discharge |
| 3 | 6ST | 3 | 6ST | 3 | 6ST | | | | |
| 4 | CP | 4 | Discharge | 4 | Discharge | | | | |
| 5 | 6ST | | | | | | | | |
| 6 | RAD | | | | | | | | |
| 7 | 6ST | | | | | | | | |
| 8 | SICU | | | | | | | | |
| 9 | 6ST | | | | | | | | |
| 10 | Discharge | | | | | | | | |

**Appendix 4: (Continued)**

Table 45. Detailed Flow of Patients (31-35) in the Inpatient Surgical Episode

| Patient 31 | | Patient 32 | | Patient 33 | | Patient 34 | | Patient 35 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area |
| 0 | OR | 0 | OR | 0 | OR | 0 | OR | 0 | OR |
| 1 | PACU | 1 | SICU | 1 | PACU | 1 | PACU | 1 | SICU |
| 2 | SICU | 2 | 6ST | 2 | SICU | 2 | SICU | 2 | 6ST |
| 3 | 6ST | 3 | RAD | 3 | 6ST | 3 | 6ST | 3 | RAD |
| 4 | RAD | 4 | 6ST | 4 | RAD | 4 | Discharge | 4 | 6ST |
| 5 | 6ST | 5 | Discharge | 5 | 6ST | | | 5 | RAD |
| 6 | Discharge | | | 6 | Discharge | | | 6 | 6ST |
| | | | | | | | | 7 | Discharge |

Table 46. Detailed Flow of Patients (36-40) in the Inpatient Surgical Episode

| Patient 36 | | Patient 37 | | Patient 38 | | Patient 39 | | Patient 40 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6ST | -2 | 6ST | -6 | 4S | -2 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -5 | Hold Area | -1 | Hold Area |
| 0 | OR | 0 | OR | 0 | OR | -4 | GUC B | 0 | OR |
| 1 | PACU | 1 | PACU | 1 | SICU | -3 | PACU | 1 | PACU |
| 2 | SICU | 2 | 6ST | 2 | PACU | -2 | 4S | 2 | SICU |
| 3 | 6ST | 3 | Discharge | 3 | SICU | -1 | Hold Area | 3 | 6ST |
| 4 | Discharge | | | 4 | Discharge | 0 | OR | 4 | Discharge |
| | | | | | | 1 | SICU | | |
| | | | | | | 2 | 6ST | | |
| | | | | | | 3 | Discharge | | |

Table 47. Detailed Flow of Patients (41-45) in the Inpatient Surgical Episode

| Patient 41 | | Patient 42 | | Patient 43 | | Patient 44 | | Patient 45 | |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST | -2 | 6ST |
| -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area | -1 | Hold Area |
| 0 | OR | 0 | OR | 0 | OR | 0 | OR | 0 | OR |
| 1 | PACU | 1 | SICU | 1 | SICU | 1 | SICU | 1 | PACU |
| 2 | SICU | 2 | 6ST | 2 | 6ST | 2 | 6ST | 2 | SICU |
| 3 | 6ST | 3 | Discharge | 3 | RAD | 3 | Discharge | 3 | 6ST |
| 4 | Discharge | | | 4 | 6ST | | | 4 | Discharge |
| | | | | 5 | Discharge | | | | |

**Appendix 4: (Continued)**

Table 48. Detailed Flow of Patients (46-48) in the Inpatient Surgical Episode

| Patient 46 | | Patient 47 | | Patient 48 | |
|---|---|---|---|---|---|
| -8 | MICU | -2 | 6SC | -2 | 6ST |
| -7 | RAD | -1 | Hold Area | -1 | Hold Area |
| -6 | MICU | 0 | OR | 0 | OR |
| -5 | RAD | 1 | PACU | 1 | PACU |
| -4 | MICU | 2 | SICU | 2 | SICU |
| -3 | RAD | 3 | 6ST | 3 | 6ST |
| -2 | RAD | 4 | Discharge | 4 | RAD |
| -1 | MICU | | | 5 | 6ST |
| 0 | OR | | | 6 | RAD |
| 1 | PACU | | | 7 | 6ST |
| 2 | 6SC | | | 8 | Discharge |
| 3 | RAD | | | | |
| 4 | 6SC | | | | |
| 5 | RAD | | | | |
| 6 | 6SC | | | | |
| 7 | EMG | | | | |
| 8 | 6SC | | | | |
| 9 | Discharge | | | | |

## Appendix 5: Detailed Post-Discharge Flow of Patients

For each patient, the column on the left is the number of days after discharge from the surgical inpatient episode. The column on the right is the encounter type.

Table 49. Detailed Flow of Patients (1-3) in the Post-Discharge Period

| Patient 1 | | Patient 2 | | Patient 3 | |
|---|---|---|---|---|---|
| 11 | Thoracic Surgery | 6 | Urgent Care | 31 | Oncology |
| 20 | PCC Women | 6 | ER | 45 | CT |
| 20 | Oncology | 6 | Xray | 65 | Resp Care/Home Oxygen (1BS) |
| 46 | Thoracic Surgery | 12 | Thoracic Surgery | 94 | Oncology |
| 139 | Oncology | 12 | Xray | 151 | CT |
| 139 | Xray | 13 | Resp Care/Home Oxygen (1BS) | 151 | CT |
| 247 | Oncology | 25 | Resp Care/Home Oxygen (1BS) | 151 | CT |
| 262 | Oncology | 41 | Oncology | 171 | Oncology |
| 319 | Oncology | 74 | Xray | 269 | Oncology |
| | | 74 | CT | | |
| | | 95 | Oncology | | |
| | | 117 | PET | | |
| | | 139 | Oncology | | |
| | | 139 | Resp Care/Home Oxygen (1BS) | | |
| | | 140 | CT Guidance | | |
| | | 140 | Lung Biopsy | | |
| | | 153 | Pulmonary Procedure | | |
| | | 188 | Oncology | | |
| | | 227 | CT | | |
| | | 242 | Xray | | |
| | | 265 | Oncology | | |
| | | 328 | Resp Care/Home Oxygen (1BS) | | |
| | | 333 | Oncology | | |
| | | 335 | Oncology | | |

**Appendix 5: (Continued)**

Table 50. Detailed Flow of Patients (4-7) in the Post-Discharge Period

| Patient 4 | | Patient 5 | | Patient 6 | | Patient 7 | |
|---|---|---|---|---|---|---|---|
| 12 | Thoracic Surgery | 27 | Thoracic Surgery | 7 | Oncology | 5 | Xray |
| 14 | CT | 32 | Xray | 15 | Radiology | 8 | Radiology |
| 14 | Xray | 49 | Oncology | 196 | Oncology | 9 | Pulmonary Procedure |
| 19 | Pulmonary Procedure | 62 | Thoracic Surgery | 209 | Radiology | 19 | PFT |
| 40 | Thoracic Surgery | 94 | Xray | | | 24 | Thoracic Surgery |
| 42 | Xray | 124 | Oncology | | | 25 | Xray |
| 46 | Oncology | 215 | CT | | | 59 | Thoracic Surgery |
| 61 | Thoracic Surgery | 223 | Oncology | | | 123 | CT |
| 67 | Radiology | 295 | Oncology | | | 123 | CT |
| 69 | MRI | | | | | 299 | Pulmonary Procedure |
| 82 | Thoracic Surgery | | | | | 310 | Oncology |
| 100 | CT | | | | | | |
| 100 | CT | | | | | | |
| 100 | CT | | | | | | |
| 112 | Oncology | | | | | | |
| 209 | Resp Care/Home Oxygen (1BS) | | | | | | |
| 209 | CT | | | | | | |
| 209 | CT | | | | | | |
| 235 | Oncology | | | | | | |
| 326 | Oncology | | | | | | |

Table 51. Detailed Flow of Patients (8-11) in the Post-Discharge Period

| Patient 8 | | Patient 9 | | Patient 10 | Patient 11 | |
|---|---|---|---|---|---|---|
| 15 | Thoracic Surgery | 11 | Thoracic Surgery | | 35 | Radiology |
| | | 11 | Xray | | 35 | Oncology |
| | | 32 | Oncology | | 35 | Xray |
| | | 54 | MRI | | 63 | Oncology |
| | | | | | 63 | Xray |
| | | | | | 108 | CT |
| | | | | | 130 | Xray |
| | | | | | 155 | Oncology |

**Appendix 5: (Continued)**

Table 52. Detailed Flow of Patients (12-15) in the Post-Discharge Period

| Patient 12 | | Patient 13 | | Patient 14 | | Patient 15 | |
|---|---|---|---|---|---|---|---|
| 10 | Thoracic Surgery | 0 | Xray | 27 | Oncology | 0 | Xray |
| 10 | Xray | 12 | Xray | 31 | Xray | 9 | Thoracic Surgery |
| 24 | Oncology | 29 | Thoracic Surgery | 41 | Xray | 9 | Xray |
| 38 | Thoracic Surgery | 64 | Thoracic Surgery | 47 | CT | 36 | Oncology |
| 39 | Xray | 106 | Thoracic Surgery | 47 | CT | 43 | Xray |
| 46 | Bone Scan | | | 47 | CT | 44 | Thoracic Surgery |
| 50 | CT | | | 47 | Thoracic Surgery | 98 | CT |
| 50 | CT | | | 54 | Bone Scan | 102 | Oncology |
| 50 | CT | | | | | | |
| 50 | Oncology | | | | | | |
| 74 | Oncology | | | | | | |
| 80 | Oncology | | | | | | |
| 99 | Oncology Procedure | | | | | | |

Table 53. Detailed Flow of Patients (16-19) in the Post-Discharge Period

| Patient 16 | | Patient 17 | | Patient 18 | | Patient 19 | |
|---|---|---|---|---|---|---|---|
| 160 | Oncology | 91 | CT | 7 | Oncology | 12 | Thoracic Surgery |
| | | 213 | CT | 18 | PACM | 13 | Xray |
| | | 316 | CT | 18 | Pre-Op | | |
| | | | | 18 | Pre-Anesthesia | | |
| | | | | 18 | Xray | | |
| | | | | 41 | Thoracic Surgery | | |
| | | | | 42 | Xray | | |
| | | | | 49 | CT | | |
| | | | | 49 | CT | | |
| | | | | 70 | Oncology | | |
| | | | | 154 | Oncology | | |
| | | | | 154 | CT | | |
| | | | | 154 | CT | | |
| | | | | 154 | CT | | |

**Appendix 5: (Continued)**

Table 54. Detailed Flow of Patients (20-21) in the Post-Discharge Period

| Patient 20 | | Patient 21 | |
|---|---|---|---|
| 14 | Oncology | 15 | Thoracic Surgery |
| 19 | Oncology Procedure | 15 | Xray |
| 40 | Oncology Procedure | 45 | Oncology |
| 63 | Oncology | 45 | Xray |
| 70 | Oncology Procedure | 79 | CT |
| 91 | Oncology | 85 | Oncology |
| 91 | Oncology Procedure | 142 | Oncology |
| 112 | Oncology Procedure | 177 | Oncology |
| 133 | Oncology | | |
| 133 | Oncology Procedure | | |
| 154 | Oncology Procedure | | |
| 175 | Oncology Procedure | | |
| 175 | Oncology | | |
| 175 | Xray | | |
| 264 | CT | | |
| 273 | Oncology | | |
| 299 | CT | | |
| 299 | CT | | |

**Appendix 5: (Continued)**

Table 55. Detailed Flow of Patients (22-25) in the Post-Discharge Period

| Patient 22 | | Patient 23 | | Patient 24 | | Patient 25 | |
|---|---|---|---|---|---|---|---|
| 12 | Xray | 13 | Thoracic Surgery | 20 | PFT | 6 | Thoracic Surgery |
| 12 | Thoracic Surgery | 14 | Xray | 20 | Radiology | 7 | Xray |
| 14 | MRI | 48 | Thoracic Surgery | 21 | Xray | | |
| 33 | Oncology | 53 | Xray | 28 | Oncology | | |
| 60 | CT | 76 | Xray | 28 | Thoracic Surgery | | |
| 60 | CT | 83 | Thoracic Surgery | 47 | Radiology | | |
| 66 | Oncology | | | 47 | PFT | | |
| 68 | Oncology Procedure | | | 47 | Xray | | |
| 69 | Oncology Procedure | | | 47 | Radiology | | |
| 70 | Oncology Procedure | | | 48 | CT | | |
| 89 | Oncology Procedure | | | 48 | CT | | |
| 89 | Oncology | | | 48 | CT | | |
| 90 | Oncology Procedure | | | 49 | Thoracic Surgery | | |
| 91 | Oncology Procedure | | | 50 | Oncology | | |
| 136 | Oncology Procedure | | | 61 | Oncology Procedure | | |
| 136 | Oncology | | | 82 | Oncology Procedure | | |
| 137 | Oncology Procedure | | | 82 | Oncology | | |
| 138 | Oncology Procedure | | | 103 | Oncology Procedure | | |
| 157 | Oncology Procedure | | | 103 | Oncology | | |
| 157 | Oncology | | | 124 | Oncology Procedure | | |
| 158 | Oncology Procedure | | | 124 | Oncology | | |
| 159 | Oncology Procedure | | | 167 | Oncology | | |
| 297 | Oncology | | | 258 | Oncology | | |
| 322 | Oncology | | | | | | |
| 350 | Oncology | | | | | | |
| 355 | Oncology Procedure | | | | | | |
| 356 | Pre-Op | | | | | | |
| 356 | Oncology Procedure | | | | | | |
| 357 | Oncology Procedure | | | | | | |

Table 56. Detailed Flow of Patients (26-30) in the Post-Discharge Period

| Patient 26 | | Patient 27 | | Patient 28 | | Patient 29 | Patient 30 | |
|---|---|---|---|---|---|---|---|---|
| 24 | CT | 8 | Thoracic Surgery | 28 | Xray | | 2 | Xray |
| 24 | CT | 43 | Thoracic Surgery | 28 | Thoracic Surgery | | 15 | Thoracic Surgery |
| | | | | 63 | Oncology | | 16 | Xray |
| | | | | 65 | Xray | | | |

**Appendix 5: (Continued)**

Table 57. Detailed Flow of Patients (31-33) in the Post-Discharge Period

| Patient 31 | | Patient 32 | | Patient 33 | |
|---|---|---|---|---|---|
| 10 | Thoracic Surgery | 3 | Oncology | 20 | Thoracic Surgery |
| 15 | Radiology | 3 | Oncology Procedure | 22 | Xray |
| | | 8 | Xray | 82 | Resp Care/Home Oxygen (1BS) |
| | | 37 | Oncology | 156 | Xray |
| | | 51 | Xray | 208 | Resp Care/Home Oxygen (1BS) |
| | | 52 | Xray | | |
| | | 52 | Xray | | |
| | | 58 | Bone Surv Comp | | |
| | | 65 | Oncology | | |
| | | 107 | Oncology | | |
| | | 120 | Xray | | |
| | | 127 | Pulmonary Procedure | | |
| | | 135 | Oncology | | |
| | | 162 | PET | | |
| | | 166 | Pulmonary Procedure | | |
| | | 170 | Oncology | | |
| | | 191 | Oncology | | |
| | | 199 | Oncology | | |
| | | 221 | Oncology | | |
| | | 227 | Thoracic Surgery | | |
| | | 256 | Lung Nodule | | |
| | | 269 | Pulmonary Procedure | | |
| | | 275 | Oncology | | |
| | | 277 | Oncology | | |
| | | 288 | Oncology | | |
| | | 288 | Oncology Procedure | | |
| | | 291 | Oncology Procedure | | |
| | | 305 | Oncology Procedure | | |
| | | 312 | Oncology | | |
| | | 312 | Oncology Procedure | | |
| | | 333 | Oncology | | |
| | | 333 | Oncology Procedure | | |
| | | 354 | Oncology Procedure | | |
| | | 354 | Oncology | | |
| | | 359 | Oncology Procedure | | |

**Appendix 5: (Continued)**

Table 58. Detailed Flow of Patients (34-36) in the Post-Discharge Period

| Patient 34 | | Patient 35 | | Patient 36 | |
|---|---|---|---|---|---|
| 1 | Xray | 12 | Thoracic Surgery | 8 | Thoracic Surgery |
| 5 | Xray | 13 | Xray | 9 | Xray |
| 5 | Xray | 17 | Radiology | 36 | Oncology |
| 7 | Thoracic Surgery | 47 | Thoracic Surgery | 43 | Thoracic Surgery |
| 17 | Xray | 122 | Xray | 133 | CT |
| 22 | Xray | 235 | CT | 316 | CT |
| 24 | Xray | 346 | Radiology | | |
| 42 | Oncology | 346 | CT | | |
| 42 | Thoracic Surgery | | | | |
| 63 | Oncology | | | | |
| 63 | Bone Scan | | | | |
| 92 | Resp Care/Home Oxygen (1BS) | | | | |
| 156 | CT | | | | |
| 161 | Oncology | | | | |
| 245 | CT | | | | |
| 252 | Oncology | | | | |
| 329 | Thoracic Surgery | | | | |

Table 59. Detailed Flow of Patients (37-40) in the Post-Discharge Period

| Patient 37 | | Patient 38 | | Patient 39 | | Patient 40 | |
|---|---|---|---|---|---|---|---|
| 13 | Thoracic Surgery | 8 | Xray | 15 | Thoracic Surgery | 13 | Thoracic Surgery |
| 19 | CT | 8 | Thoracic Surgery | 16 | Xray | 13 | Xray |
| 19 | CT | 29 | Thoracic Surgery | 16 | Urology Oncology | | |
| 20 | CT | 30 | Xray | 50 | Thoracic Surgery | | |
| 36 | Oncology | 99 | Thoracic Surgery | 121 | Oncology | | |
| | | 101 | Xray | 154 | CT | | |
| | | 288 | Oncology | 154 | CT | | |
| | | 288 | Thoracic Surgery | 154 | CT | | |
| | | | | 157 | MRI | | |
| | | | | 226 | Oncology | | |
| | | | | 328 | Oncology | | |
| | | | | 358 | PACM | | |
| | | | | 358 | Pre-Op | | |
| | | | | 358 | Pre-Anesthesia | | |

**Appendix 5: (Continued)**

Table 60. Detailed Flow of Patient (41) in the Post-Discharge Period

| Patient 41 | |
|---|---|
| 8 | Thoracic Surgery |
| 8 | Xray |
| 72 | Xray |
| 72 | CT |
| 113 | Scan |
| 120 | Thoracic Surgery |

Table 61. Detailed Flow of Patients (42-45) in the Post-Discharge Period

| Patient 42 | | Patient 43 | | Patient 44 | | Patient 45 | |
|---|---|---|---|---|---|---|---|
| 17 | Thoracic Surgery | 9 | Thoracic Surgery | 9 | Xray | 18 | Thoracic Surgery |
| 17 | Xray | 11 | Xray | 9 | Thoracic Surgery | 18 | Xray |
| 31 | Oncology | 25 | Oncology | | | 38 | PACM |
| 38 | Radiology | 119 | Oncology | | | 38 | Pre-Op |
| 38 | Xray | 165 | CT | | | 38 | PFT |
| 45 | Thoracic Surgery | 212 | Oncology | | | 38 | Pre-Anesthesia |
| 58 | Radiology | | | | | 38 | Xray |
| 58 | Bone Scan | | | | | 67 | Thoracic Surgery |
| 65 | CT | | | | | 83 | Oncology |
| 65 | CT | | | | | 100 | Oncology |
| 65 | CT | | | | | 101 | Oncology Procedure |
| 66 | Oncology | | | | | 116 | Oncology Procedure |
| 94 | Oncology | | | | | 116 | Oncology |
| 129 | Oncology | | | | | 118 | Oncology Procedure |
| 134 | CT | | | | | 125 | Oncology Procedure |
| 134 | CT | | | | | 130 | Oncology Procedure |
| 134 | CT | | | | | 132 | Oncology Procedure |
| 136 | Thoracic Surgery | | | | | 151 | Oncology Procedure |
| 150 | Oncology | | | | | 151 | Oncology |
| 178 | Oncology | | | | | 153 | Oncology Procedure |
| 206 | Fluoro | | | | | 165 | Oncology Procedure |
| 206 | CT | | | | | 165 | Oncology |
| 206 | CT | | | | | 172 | Oncology Procedure |
| 206 | CT | | | | | | |
| 206 | CT | | | | | | |
| 213 | Oncology | | | | | | |
| 291 | Radiology | | | | | | |
| 291 | Radiology | | | | | | |
| 297 | Oncology | | | | | | |
| 360 | Oncology | | | | | | |

**Appendix 5: (Continued)**

Table 62. Detailed Flow of Patients (46-48) in the Post-Discharge Period

| Patient 46 | | Patient 47 | | Patient 48 | |
|---|---|---|---|---|---|
| 2 | Xray | 55 | Thoracic Surgery | 20 | Thoracic Surgery |
| | | 70 | Oncology | 22 | Oncology |
| | | 103 | CT | 22 | Xray |
| | | 207 | CT | 35 | Oncology Procedure |
| | | 223 | Thoracic Surgery | 54 | Oncology |
| | | 237 | Pulmonary Procedure | 55 | Oncology Procedure |
| | | 244 | Thoracic Surgery | 76 | Thoracic Surgery |
| | | 328 | Thoracic Surgery | 77 | Oncology Procedure |
| | | 329 | Oncology | 99 | Oncology Procedure |
| | | | | 99 | Oncology |

## Appendix 6: Pre-Admission Encounter Frequencies

Table 63. Encounter Frequencies in the Pre-Admission Period

| | Block 1 | Block 2 | Block 3 | Block 4 | Block 5 | Block 6 | Block 7 | Block 8 | Block 9 | Block 10 | Block 11 | Block 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Xray | 37 | 13 | 5 | 3 | 2 | 3 | | | | | | | 63 |
| Oncology | 10 | 17 | 12 | 6 | 10 | 6 | | | | | | 1 | 62 |
| CT | 12 | 14 | 10 | 8 | 9 | 5 | | | | | | | 58 |
| Lung Nodule | 18 | 12 | 6 | 7 | 4 | | | | | | 1 | | 48 |
| Pre-Op | 48 | | | | | | | | | | | | 48 |
| PACM | 48 | | | | | | | | | | | | 48 |
| Pre-Anesthesia | 48 | | | | | | | | | | | | 48 |
| PFT | 24 | 7 | 4 | 2 | 3 | | | | 1 | | | | 41 |
| Radiology | 2 | 2 | 1 | 2 | 3 | 6 | | 4 | | 3 | 1 | 2 | 26 |
| PET | 8 | 5 | 5 | 2 | | | | | | | | | 20 |
| Pulmonary Procedure | 5 | 5 | 3 | 2 | 1 | 2 | | | | 1 | | | 19 |
| Thoracic Surgery | 10 | 1 | 2 | | | | | | | 1 | | | 14 |
| Myocardial Perfusion | 3 | 5 | 2 | | | | | | | | | | 10 |
| Cardio ABG | 1 | 2 | | 3 | 1 | | | | | | | | 7 |
| Gated Spect | 3 | 3 | | | | | | | | | | | 6 |
| CT Guidance | 2 | 1 | 1 | | | | | | | | | | 4 |
| Stress Test | 1 | 3 | | | | | | | | | | | 4 |
| Lung Biopsy | | 1 | 1 | | | | | | | | | | 2 |
| Barium | | | | | 1 | | | | | | | | 1 |
| Bone Surv Comp | | 1 | | | | | | | | | | | 1 |
| EKG | 1 | | | | | | | | | | | | 1 |
| Bone Scan | 1 | | | | | | | | | | | | 1 |
| MRI | 1 | | | | | | | | | | | | 1 |
| Quantitative Perfusion | | 1 | | | | | | | | | | | 1 |
| Urology Oncology | 1 | | | | | | | | | | | | 1 |
| Total | 284 | 93 | 52 | 35 | 34 | 22 | 0 | 4 | 1 | 5 | 2 | 3 | 535 |

**Appendix 6: (Continued)**

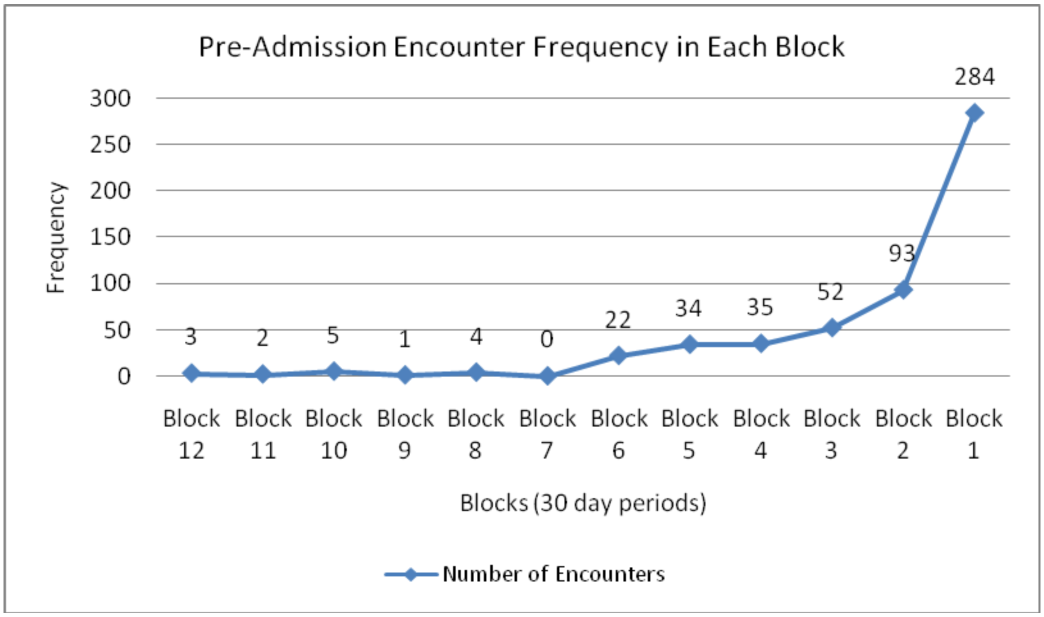


Figure 7. Frequency of Encounters in Each Block of the Pre-Admission Period

## Appendix 7: Post-Discharge Encounter Frequencies

Table 64. Encounter Frequencies in the Post-Discharge Period

| | Block 1 | Block 2 | Block 3 | Block 4 | Block 5 | Block 6 | Block 7 | Block 8 | Block 9 | Block 10 | Block 11 | Block 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oncology | 10 | 17 | 15 | 12 | 11 | 13 | 4 | 6 | 6 | 8 | 7 | 6 | 115 |
| Xray | 42 | 16 | 5 | 3 | 3 | 2 | | | 1 | | | | 72 |
| CT | 6 | 14 | 6 | 7 | 6 | 11 | 7 | 4 | 2 | 2 | 2 | 1 | 68 |
| Thoracic Surgery | 35 | 16 | 7 | 3 | 1 | | | 2 | 1 | 1 | 2 | | 68 |
| Oncology Procedure | 2 | 3 | 9 | 9 | 8 | 9 | | | | 2 | 2 | 6 | 50 |
| Radiology | 5 | 3 | | 1 | 1 | 2 | | 2 | 1 | | | | 15 |
| Resp Care/Home Oxygen (1BS) | 2 | | 2 | 1 | 1 | | 2 | | | | 1 | | 9 |
| Pulmonary Procedure | 2 | | | | 1 | 2 | | 1 | 1 | 1 | | | 8 |
| Bone Scan | | 3 | 1 | | | | | | | | | | 4 |
| MRI | 1 | 1 | 1 | | | 1 | | | | | | | 4 |
| PFT | 2 | 2 | | | | | | | | | | | 4 |
| Pre-Op | 1 | 1 | | | | | | | | | | 2 | 4 |
| PACM | 1 | 1 | | | | | | | | | | 1 | 3 |
| Pre-Anesthesia | 1 | 1 | | | | | | | | | | 1 | 3 |
| PET | | | | 1 | | 1 | | | | | | | 2 |
| Bone Surv Comp | | 1 | | | | | | | | | | | 1 |
| CT Guidance | | | | | 1 | | | | | | | | 1 |
| ER | 1 | | | | | | | | | | | | 1 |
| Fluoro | | | | | | | 1 | | | | | | 1 |
| Scan | | | | 1 | | | | | | | | | 1 |
| Lung Biopsy | | | | | 1 | | | | | | | | 1 |
| Lung Nodule | | | | | | | | | 1 | | | | 1 |
| PCC Women | 1 | | | | | | | | | | | | 1 |
| Urgent Care | 1 | | | | | | | | | | | | 1 |
| Urology Oncology | 1 | | | | | | | | | | | | 1 |
| Total | 114 | 79 | 46 | 38 | 34 | 41 | 14 | 15 | 13 | 14 | 14 | 17 | 439 |

**Appendix 7: (Continued)**

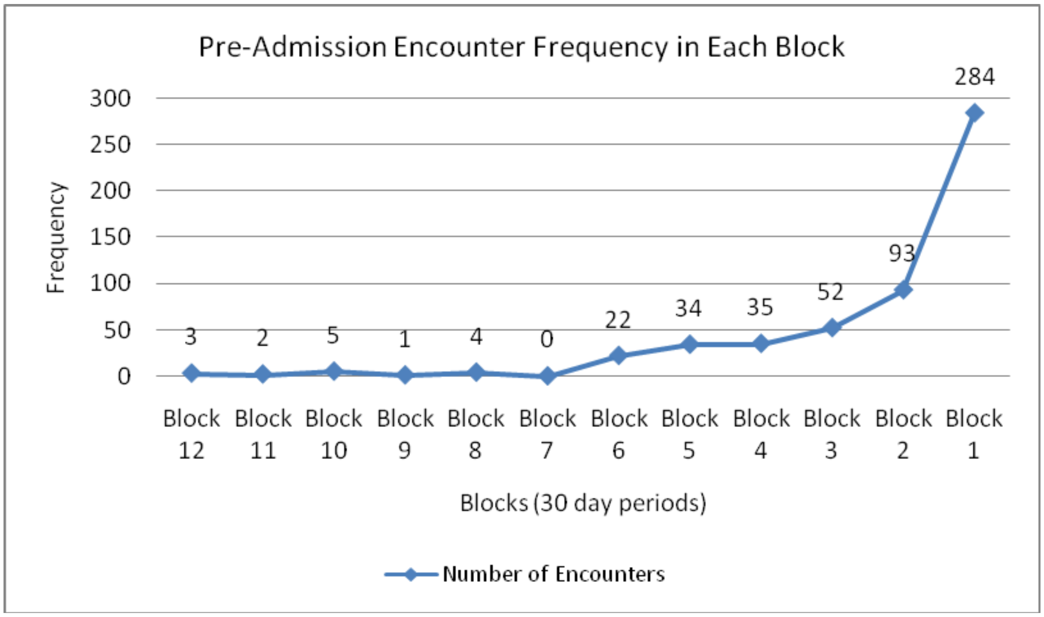


Figure 8. Frequency of Encounters in Each Block of the Post-Discharge Period

## Appendix 8: Information from the Observed Patient Flow

Below are the information obtained regarding the flow paths of the lung resection patients. Table 65 identifies basic statistical information on the length and the number of encounters each patient had in the pre-admission period. Table 66 is for patients in the post-discharge period.

Table 65. Basic Statistical Information of the Pre-Admission Period

| | Number of Days | Number of Encounters |
|---|---|---|
| Average | 178.1 | 9.5 |
| Max Value | 360 | 35 |
| Min Value | 2 | 1 |
| Std. Dev. | 129.1 | 8.5 |

Table 66. Basic Statistical Information of the Post-Discharge Period

| | Number of Days | Number of Encounters |
|---|---|---|
| Average | 116 | 10.9 |
| Max Value | 322 | 22 |
| Min Value | 7 | 1 |
| Std. Dev. | 58.9 | 4.6 |

Tables 67 and 68 identify the expected encounters that a patient undergoing lung resection will have in each of the windows of the pre-admission and post-discharge periods respectively. This is based on our observation of the patients sample and is ordered according to most frequent.

**Appendix 8: (Continued)**

Table 67. Expected Encounters in the Pre-Admission Period

| | Clinic Visits | Procedures | Tests |
|---|---|---|---|
| Window 3 | Radiology | | |
| Window 2 | Oncology | Pulmonary Procedure | CT |
| | Lung Nodule | | Xray |
| Window 1 | Pre-Op | | Xray |
| | PACM | | PFT |
| | Pre-Anesthesia | | |

Table 68. Expected Encounters in the Post-Discharge Period

| | Clinic Visits | Procedures | Tests |
|---|---|---|---|
| Window 1 | Thoracic Surgery | | Xray |
| Window 2 | Oncology | Oncology Procedure | CT |
| | Thoracic Surgery | | Xray |
| Window 3 | Oncology | Oncology Procedure | CT |