Routine Post-Procedure Recovery (RPPR) Patients at Massachusetts General Hospital

by

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Submitted to the Department of Electrical Engineering and Computer Science and the MIT Sloan School of Management in partial Fulfillment of the Requirements for the Degrees of

Master of Science in Electrical Engineering and Computer Science

and

Master of Business Administration

In conjunction with the Leaders for Global Operations Program at the

Massachusetts Institute of Technology

June 2016

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Abstract

This project offers improved strategies for managing the flow of surgical patients who are categorized as Routine Post-Procedure Recovery (RPPR) in Massachusetts General Hospital (MGH). Strategies were developed by analyzing the trade-offs in resource utilization of alternative recovery pathways.

The unstandardized way in which the RPPR category is currently used creates a suboptimal utilization of hospital resources. RPPR is a booking category assigned to patients who are anticipated to be discharged within 24 hours of surgery completion. It is an internal booking category at MGH created to indicate *Outpatients* (as categorized by payers) whose recovery may mandate more than a few hours of hospital stay. The operational challenges incorporated in this patient population include: (i) vague definition of the category which leads to inaccurate classifications (booking category) of patients; (ii) high variability in booking practices among surgeons; (iii) high variability in patient length of stay; (iv) no established best-practice for recovery location or pathway.

Problem definition and main areas for improvement were identified through data collection from hospital resources. Namely, clinician shadowing and interviews with administrative staff as well as statistical data analysis - utilizing the hospital's extensive digital databases. A key component to the recommendation development process was the grouping of surgical procedures with similar recovery pathways. This was essential to the analysis which focused on key metrics of those groups, such as patient length-of-stay, overnight stay, recovery pathways, and more.

The goal of this study was optimizing the utilization of hospital resources for RPPR patients and developing actionable recommendations that would be implemented immediately. Our strategic solution approach focused on the development of a framework for establishing best practices for managing RPPR patients in increasing levels of detail. Best practices were determined for each procedure group, then for specific surgeon in each group and down to the specific patient.

Each group of surgeons and procedures were provided with specific set of recommendations including booking category, recovery location and surgery time during the day.

Through meetings with the surgeons and heads of different surgical departments, the project recommendations are being implemented in the hospital. Successful implementation will lead to improved operational efficiency in MGH, and will eventually benefit patients.

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The author wishes to acknowledge the Leaders for

Global Operations Program for its support of this work.

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Acknowledgements

This project was performed with great help from key stakeholders at Massachusetts General Hospital (MGH). These include the Perioperative Care Department, the Post Anesthesia Care Units (PACU), the MGH Admitting Department, and Case Management Department. These departments were active in defining the project and providing guidance.

This thesis would not have been possible without the generous advising and support of many. Many thanks to the exceptional academic advisors Professor Retsef Levi of the Sloan School of Management and Professor Patrick Jaillet of the Department of Electrical Engineering and Computer Science. Special thanks to then MIT Post-doctoral David Scheinker for dedicating long hours to review my work and discussing new ways to improve hospital operations at MGH.

Thank you to Peter Dunn, M.D., Bethany Daily and Cecilia Zenteno for the support of the MIT-MGH collaboration and for championing this project with great dedication.

I would like to acknowledge Ben Orcutt of the Admitting Department for contributing to the weekly efforts and development of the project. Special thank you to Janet Quigley, RN and Maureen Schnider, RN from MGH PACU for the support and contribution.

Finally, thank you to my loving family and friends for their support. To my parents, Orna and Barak and brother and sister for moral support that allowed me to complete this research and write this thesis. Final and special thank you to Li-or, my wife, who supported me and actively assisted me in completing this thesis.

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1 Introduction

1.1 Background

Massachusetts General Hospital (MGH) is the oldest and largest hospital in New England and the third oldest hospital in the United States. MGH is consistently ranked as one of the top hospitals in the country, and in July 2015 it was named America's best hospital by U.S. News & World Report[1]. The hospital is an integrated facility for patient care and research. MGH hosts approximately 48,000 inpatient admissions, 1.5 million outpatient visits annually, and more than 42,000 operations.

For the past 10 years, MGH and Massachusetts Institute of Technology (MIT) have been collaborating in an effort to address the complex operational challenges within the hospital. Faculty, postdoctoral research fellows and interns from the Leaders of Global Operations (LGO) program have teamed with Perioperative Services and other departments at MGH to study and redesign patient care processes to benefit the hospital and its patients. The research that led to this thesis is part of an IRB-approved study[2] of the MGH-MIT collaboration team.

1.2 Routine Post-Procedure Recovery (RPPR)

This project is focused on surgical patients who are categorized as *Routine Post-Procedure Recovery* (RPPR) patients. RPPR is a booking category used to classify patients undergoing

[1] http://health.usnews.com/best-hospitals

[2] MIT Protocol #12010014856, "MGH-MIT Collaboration: Surgical Inpatient Flow" Principal Investigator: Retsef Levi; MGH Protocol #2011P001124, "MGH-MIT Collaboration: Inpatient and Ambulatory Patient Flow and Capacity Optimization" Principal Investigator: Peter Dunn, MD.

procedures with up to 24 hours of recovery within the hospital after surgery. RPPR category represented approximately 10% of all surgical patients between 2010-2014. The goal of the project is to determine optimal booking, scheduling and patient flow strategies for surgical RPPR patients by analyzing the trade-offs in resource utilization of alternative recovery pathways.

As surgical patients are booked for surgery, they are assigned a specific category according to the anticipated flow the patient will go through from admission until discharge from the hospital. Categories are determined by the surgeons or their office according to the surgical procedure a patient will undergo, individual patient characteristics, and other considerations. The existing booking categories are: (i) *Same Day Admit* – patient arrives from home on the day of the surgery, and will be spending at least one night at the hospital after the surgery. (ii) *Inpatient* – patient is already admitted to the hospital and will be transferred to the operating room for surgery after which the patient will be transferred back to the appropriate inpatient floor. (iii) *Ambulatory* – patient arrives to the hospital from home, and is expected to be discharged from the hospital several hours after waking up from anesthesia without spending a night at the hospital. (iv) *RPPR* – assigned to a patient who is anticipated to be discharged within 24 hours of surgery completion. RPPR category does not specify the exact time of discharge from the hospital, which creates obscurity as to whether the patient will need to stay overnight in the hospital.

Unlike the other three booking categories, which are formally visible to payers for billing purposes, RPPR is an internal booking category at MGH. It was created to indicate specific *Outpatients* (as they are acknowledged by payers) whose recovery may mandate more than

a few hours of hospital stay. With this inherent ambiguity in definition, the RPPR category creates high variability in the planning and execution of patient flow, since some patients will have a need for a bed in an inpatient floor and some will not. Moreover, the unstandardized way in which the RPPR category is currently used creates a suboptimal utilization of hospital resources.

This research focuses on surgical RPPR patients. However, the RPPR category can be used in MGH as a booking category for non-surgical patients as well, including patients undergo procedures in the Catheterization and Electrophysiology Laboratories.

1.3 Methodology

The first phase of the project was data collection, in order to identify the key challenges and the main areas for improvement. Data was obtained through shadowing clinicians at the Post Anesthesia Care Unit (PACU) and the Operating Rooms (ORs), and interviewing administrative staff from all departments that are involved in the postoperative patient flow.

In the second phase, we utilized the hospital's extensive digital databases. The information collected in the data collection phase was integrated with statistical data analysis in order to establish the current state as well as to quantify respective challenges. Many efforts were focused towards understanding the surgical patient flow and pathways at MGH.

After gathering the data and mapping the surgical patient flow, we were able to partition the surgical procedures with RPPR patients into groups with similar recovery pathways. This was important for the recommendation development process. The analysis is focused

on key metrics related to these groups, such as patient length-of-stay, overnight stay, recovery pathways as well as surgeon and practice specific metrics.

Finally, we recommended strategies to optimize the utilization of hospital resources allocated to RPPR patients. Each group of surgeons and procedures were given a specific set of recommendations in matters such as: booking category, recovery location, and time of surgery.

1.4 Current State and Key Challenges

After collecting the data, we were able to establish the current state and identify several major challenges related to surgical RPPR patients. Following is a summary of the key findings of our analysis (the findings are explained in detail in Chapter 3 under Key Findings).

1. **Ambiguous booking category definition**: the definition of RPPR is not completely clear to the hospital staff, which makes it challenging for them to determine the right booking category for a specific patient. Booking patients under an inappropriate category creates suboptimal patient flow in the hospital and misuse of resources.

   An analysis of the booking category distribution for different procedures often reveals inconsistent and unnecessary use of the RPPR category. Moreover, we discovered that booking categories often dictate decisions related to patient care and therefore have a strong influence on how the case is managed by the clinical care teams.

   In particular, patients who are booked as RPPR have an expectation to stay in the hospital overnight. That, combined with the fact that a bed is often reserved for them, there is a tendency to ultimately keep the patient overnight even if the clinical condition

allows them to be discharged. Through our analysis we were able to detect and recommend the most appropriate booking practices for each procedure group.

2. **Bed assignment challenges**: Since there is some probability that RPPR patients will stay overnight in the hospital, they are often assigned a bed in the respective service floor. However, there is high variability in the recovery length of RPPR patients, and many are ultimately discharged home from the PACU without using the beds assigned to them. This leads to an unnecessary burden on the floors, as well as on the communication between the PACU and the floors. Moreover, it creates a waste of the floor beds that are unnecessarily blocked during the day, whereas other patients experience an increased wait time.

   In some cases, RPPR patients stay in a general floor bed longer than 24 hours for both clinical and non-clinical reasons, with the approval of the respective surgeon. This creates longer wait-times for other patients who may need the inpatient floor bed. The problem is even more significant on busy days when PACU nurses make extra efforts to transfer patients out of the PACU faster. Reducing the number of RPPR patients and the variability of their Length of Stay (LOS) will be useful in alleviating these phenomena.

3. **Determination of recovery location**: MGH does not have a standard protocol for determining the recovery location of RPPR patients. The decision of whether to keep RPPR patients in the PACU (recovery area for patients immediately after surgery) or transfer them to an inpatient floor is made ad-hoc. This creates further variability in patient flow which leads to a waste of resources.

   Generally, RPPR patients are transferred to the PACU immediately post-surgery. The next recovery location varies by surgeon and procedure. The decision about recovery

location has an inherent tradeoff attached to it: while transferring RPPR patients to inpatient beds blocks the beds for other patients, keeping all RPPR patients in PACU may block the PACU and eventually disrupt the surgical schedule.

We tested the differences in Length of Stay (LOS) and chances to stay overnight, based on the choice of recovery location. Generally, the LOS of patients who were transferred to a floor bed is larger than the LOS of patients who were discharged home directly from the PACU.

4. **Non-standard clinical recovery process**: Non-standard processes create variability in the system, which leads to inefficiencies in the hospital operations related to RPPR patients. For this project we identified and mapped the post-operative flow of RPPR patients in the hospital until discharge. We described the hospital entities involved as well as the IT systems used to communicate between different parts of the chain.

   Different patterns of post-operative overnight stay at the hospital are rooted in different causes, including: specific booking practices, surgical techniques and post-procedure order practices for specific surgeons. We evaluated the root causes and developed recommendations to standardize practices to normalize patient Length-of-Stay differences between surgeons.

   In addition, overnight stay is influenced by the time of the surgery. There is an increased probability that a patient will spend the night at the hospital if the surgery was performed later in the day, and we were able to identify cut-off times for different procedures.

5. **Financial challenges**: Unless the hospital changes the booking category of an RPPR patient after the surgery for a justified clinical reason, payers consider them *Outpatients* and do not reimburse for inpatient hospital stay.

1.5 Solution Approach and Recommendations

In order to improve hospital operations and address the abovementioned challenges, we developed actionable operational recommendations. The process of constructing the recommendations followed the data gathering and analysis processes. To generate relevant recommendations, we developed an analysis method to evaluate each procedure group, in a way that will address the key operational and clinical issues. This method consisted of three levels of analysis:

Procedure level: We analyzed the influence of surgery time on patient LOS for each specific procedure and booking category.

Surgeon level: We analyzed the variability in each specific surgeons' booking and clinical practices.

Patient level: We took into consideration the patients' surgical groups as well as patient specific metrics.

For each surgical procedure with a significant number of RPPR patients, this solution approach aimed to answer the following questions: (i) How should that specific group choose a booking category? (ii) How should that specific group determine the recovery location? (iii) At what time of the day should surgeries be prioritized to be scheduled? The nature of the recommendations we provided is such that most of them are procedure-specific, and often surgeon-specific. The recommendations aim to minimize process-

variability by establishing standards and best-practices to the manner in which these patients are booked and handled throughout the recovery process. Through meetings with the surgeons and heads of different surgical departments, the project recommendations are being implemented at the hospital. A successful implementation will lead to improved operational efficiency in MGH, and will eventually benefit patients.

1.6 Thesis Outline

This thesis begins with a literature review in Chapter 2. Chapter 3 describes the current-state analysis of the hospital operations related to RPPR patients, including the processes, the stakeholders and the challenges. The analysis provides metrics and quantifies the magnitude of these issues. Next, in Chapter 4, we describe the methodology used to develop recommendations to alleviate some of the challenges. In Chapter 5 we detail those recommendations and practical ways to implement these ideas in order to improve the system. Finally, the thesis will close with suggestions for future research and conclusions in Chapter 6.

2 Literature Review

Routine Post-Procedure Recovery (RPPR) is an internal booking category to MGH. Therefore, there is no significant body of literature that directly researched the different aspects of this particular patient population. However, some of the characteristics and challenges related to RPPR patients are common to more general practices, and have been investigated by several researchers.

Studies have established that surgical patient flow in hospitals is indeed an operational challenge. These studies examined the underlying reasons for patient flow challenges in hospitals as well as possible approaches to optimize patient flow. Some focus on preventing unnecessary use of hospital beds while other focus on decreasing hospital Length of Stay (LOS) by creating mechanisms to predict LOS. Specifically to MGH, important aspects of patient flow were explored by previous projects and research performed by the MIT-MGH collaboration team. Such projects are becoming a growing body of knowledge of the specific operations within MGH.

An important part of understanding the operational patient flow requires grasping the clinical aspects of it. Mainly, the surgical recovery pathways. For example, many studies have been done on prediction of clinical recovery of Total Thyroidectomy, one of the largest RPPR procedures.

2.1 Operational Challenges

Haraden et al (2004) [1] claims that while hospitals often try to solve the issues of wait-times, delays and cancellations by adding resources, the underlying problem is in many cases a problem in proper patient flow. Working with more than 60 hospitals in the United

States and the United Kingdom, Haraden and his team developed methods for improving patient flow. One of the top goals of their project was to smooth the flow of elective surgery. According to their results, one of the key complications in understanding patient flow in hospitals is the inherent variability found in the healthcare delivery system. Interestingly, they conclude that the variability introduced by the very structure of the system itself far outweighs the variability caused by the randomness of patient arrivals and the pace of their clinical progression. Haraden and his team suggest that variation from the randomness of disease can possibly be accommodated by managing demand based on historical data and queuing methods.

In an effort to address patient flow challenges, a number of researches offered different methods of simulating and optimizing patient flow in hospitals. While different approaches were somewhat successful, none found a solution that encompassed all types of patients and challenges. Thomas et al. (2013) [2] used a mixed-integer goal-programming approach to develop a prototype bed-assignment solution. The solution periodically recommends bed-patient assignments based on analytical decision support tools with embedded mathematical models. Bachouch et al. (2012) [3] investigated the management of hospital bed planning and proposed a decision support tool based on an integer linear program. Harper et al. (2002) [5] characterize the internal dynamics of a hospital as a complex nonlinear system.

Carmen et al. (2015) [4] suggest a decision support tool based on Discrete Event Simulation, with a focus on the Emergency Department. They emphasized that planning and management of bed capacities must be evaluated within an environment of

uncertainty, variability and limited resources, and especially with high variability in Length of Stay (LOS) that makes it hard to plan bed assignments.

A different approach to optimize patient flow was offered by several research groups (Hendy et al. (2012) [7], Majeed et al. (2012) [8]) who attempted to quantify the cost resulting from intraday and multiday discharge delays. While these studies identify some of the reasons underlying the delays, they generally do not propose specific solutions. Borghans et al. (2012) [9] propose a multitude of approaches for addressing discharge delays and reducing length of stay. However, the effectiveness of the proposed solutions is not quantified and prioritization of the different interventions is therefore not easily possible.

Some researchers investigated methods to predict LOS with high accuracy in order to be able to better plan the allocation of resources throughout the patient flow. Evelene et al. (2013) [6] looked for indicative and predictive factors for LOS, using Total Knee Replacements as an example. They found valuable characteristics, that when used in a negative binomial model, are predictors of LOS. These characteristics include age, gender, physician, discharge destination and ethnicity. Among patients who stayed 4–6 days in the hospital, the model predicted the length of stay with 75% accuracy. According to this model, the research recommends the development of a decision making tool for hospital operators interested in optimizing patient flow. The tool would use the predictors as input, and would plan and assign beds according to the predicted LOS.

Several projects by previous MIT Leaders of Global Operations (LGO) students in the MIT - MGH collaboration developed important insights into the patient flow dynamics and work processes at MGH. Schwartz (2012) [10] proposed a redesign of surgical patient flow through multiple Post-Anesthesia Care Units (PACUs) focusing on expediting the flow of outpatients. Range (2013) [11] focused on investigating ways surgeons could potentially schedule their cases within a given Operating Room time block. She found that availability of bed in the general hospital floors is the most significant bottleneck in the system, with *Same Day Admits* (patients who will be admitted as inpatients to the hospital post-surgery) waiting for hospital beds in the PACU for more than 60 minutes on average after being medically cleared to depart the PACU. Using a simulation model that evaluates the downstream effects, she recommended scheduling rules and discharge processes that could decrease wait times for patients. Hiltrop (2014) [12] developed a detailed patient flow simulation based on historical data from MGH, focused on the Neuroscience units. Different interventions were tested based on the simulation model, including: assigning available inpatient beds to newly admitted patients adaptively on a just-in-time basis, and discharging patients earlier in the day. McNichols (2015) [13] built on Hiltrop's work and developed a bed assignment algorithm and processes aimed to reduce intraday patient wait times by assigning beds on a just-in-time (JIT) basis.

2.2 Clinical Challenges

Other than the operational patient flow through the hospital, the clinical recovery process is key for understanding and designing the hospital operations around RPPR patients. A large body of literature discusses the process of recovery from a surgical procedure. A

number of researchers focused specifically on methods to predict the process according to clinical measures of the patient, or to make it more operationally-efficient.

For example, at MGH Thyroidectomy is a common procedure, where the majority of the patients are booked as RPPR and stay in the hospital overnight. A number of researchers have tried to assess the chances of complications and extended stay according to clinical test results post-surgery. Vescan et al. (2009) [14] and Sitges-Serra et al. (2007) [15] studied the possibility of using levels of parathyroid hormone (PTH) in the blood, measured short time after Thyroidectomy, as a predictor for clinical complications and to potentially determine the feasibility of early discharge home from hospital.

Snyder et al. (2010) [16] claim that while Thyroidectomy has traditionally been performed as an inpatient hospital procedure, low risk and high patient tolerance make it acceptable as an outpatient procedure. In a publication by the American Thyroid Association, Terris et al. (2013) [17] claimed that Thyroidectomy may be undertaken safely as an *outpatient* procedure if performed under certain precautionary measures. They suggest a number of postoperative factors that should be taken into account, including discharge criteria and recognition of complications, especially bleeding, airway distress, and hypocalcemia.

3 Current State Analysis

In this chapter, we will provide a comprehensive description of our findings of hospital operations related to surgical RPPR patients. In the process of establishing the current state, we shadowed and interviewed hospital staff, as well as analyzed data from relevant MGH IT systems.

3.1 Data Collection

Our methodology of establishing and analyzing the current state was based on data collection from MGH resources. Data collection was performed with the goal of generating a comprehensive analysis of the hospital operations related to RPPR patients. Our data collection methodology was based on two main approaches: i) Shadowing and interviewing key stakeholders; ii) Extracting and aggregating data from the hospital IT and database systems. An extended overview of our analysis methodology is presented in Chapter 4.

3.2 Routine Post-Procedure Recovery Definition

Routine Post-Procedure Recovery (RPPR) is a booking category used to classify patients undergoing procedures with up to 24 hours of recovery within the hospital after surgery. These patients are classified as *outpatients* by payers, which means that they are expected to be discharged home on the day of the surgery. RPPR is an entirely internal booking category to MGH, created in an effort to identify *outpatients* who are likely to require an extended recovery stay within the hospital (compared to *ambulatory* patients who are likely to be discharged home a few hours after the procedure).

The operational complexity in managing the flow of RPPR patients stems from the variability in recovery times, and the non-negligible probability that a patient would ultimately stay overnight. Had these patients been classified as *outpatients* per payer classification, the hospital might not have been ready with all the required resources to keep the patient overnight if the need arises. In the latter scenario, the main resource at risk is having an appropriate inpatient bed reserved. The RPPR category is primarily a category to signal the hospital that a certain patient might need a bed.

MGH is not reimbursed for RPPR patients' overnight stay because all RPPR patients are acknowledged as *outpatients* by payers. By definition, *outpatients* are to be discharged home from the hospital at the day of the procedure, unless there has been a change in their clinical status.

It should be noted that this thesis focuses on surgical RPPR patients, although RPPR category can be used for non-surgical patients who undergo an elective procedure. Specifically, non-surgical procedures that are booked as RPPR include Electrophysiology (EP) and the Catheterization Laboratories.

3.3 Causes for Extended Stay

Following are explanations of the majority of issues that may lead to an extended stay of an RPPR patient (as opposed to standard *ambulatory* patient stay). For didactic simplicity we categorized them according to the cause of the extended stay - patient non-specific reasons usually depend on the type of procedure whereas patient specific reasons depend on the medical and health characteristics of the specific patient.

3.3.1.1 Patient non-specific reasons

1. Physiologic-based monitoring – some procedures require close monitoring of a patient for specific indications that the recovery is going as expected. For example, after Transurethral Resection of the Prostate (TURP) urine is examined to ensure clearing of the bleeding. Another example is post-procedure airway monitoring serialization of vocal cords after certain Otolaryngology procedures.
2. Pain management – one of the requirements for discharge from MGH is that the pain levels can be managed via oral medications. However, there are procedures that are expected to cause high levels of post-surgical pain, known to be difficult to manage via oral medications. It should be noted that pain management is improving significantly in recent years, gradually reducing the time patients are required to stay at the hospital.
3. Time dependent lab testing – some surgeries or complications require specific time-sensitive post-operative testing. These require a patient to stay until all tests are performed and results are back, to establish an appropriate course of post-surgery care. For example, post Total Thyroidectomy calcium check is required and is crucial for the post-surgery management of patients.
4. Symptom management – much like pain-management, there are other symptoms whose severity can influence the length of stay. Some symptoms and their severity are more prevalent in some procedures than in others. For example, sever nausea and vomiting associated with some pelvic procedures should be managed prior to a patient's discharge.

3.3.1.2 Patient-specific reasons

5. Medical history – each case is evaluated according to the patient's unique condition and background. Some patients are at higher risk of postoperative complications than others. For example, some patients are more prone to neurovascular postsurgical complications than others. Careful consideration of these patients' medical history will enable better recovery management.
6. Pain management and monitoring – unusual levels of pain after a surgical procedure are a red flag, and should be monitored and managed. This is true whether the reasons for increased pain are known or unknown.
7. Co-morbid disease – much attention is given to the patients' co-morbid diseases, as they are an important predictor of their recovery as well as their post-operative care. One example is the management of patients with a history of cardiac conditions. Cardiac patients are kept for closer monitoring regardless of the type of procedure, as well as or for transition care (e.g., restarting some medications held for surgery, such as anticoagulation or some insulin regimens in patients who may not be able to resume normal diet day of surgery).
8. Distance to patient's home – long travel is generally not recommended on the day of the surgery. Patients who have to travel long distances immediately after the surgery may be advised to spend the night at the hospital, particularly if it is already late in the day.
9. Independent living - patients may stay longer until they are able to resume self-care, in case they live alone.

3.4 RPPR General Statistics at MGH

RPPR category amounted for approximately 10% of all surgical patients during 2010-2014. Specifically, in 2014, 4,600 surgical cases were booked as RPPR, making it 12.52% of the overall 36,740 surgical cases.

Figure 1 shows the distribution of booking categories of all the surgical patients at MGH during those years. The existing booking categories are as follows.

1. *Same Day Admit* – patient arrives from home on the day of the surgery, and will be spending at least one night at the hospital after the surgery.
2. *Inpatient* – patient is already admitted to the hospital and will be transferred to the operating room for surgery after which the patient will be transferred back to the appropriate inpatient floor.
3. *Ambulatory* – patient arrives to the hospital from home, and expected to be discharged from the hospital several hours after they wake up from anesthesia without spending a night at the hospital.
4. *RPPR* –patient is anticipated to be discharged within 24 hours of surgery completion.

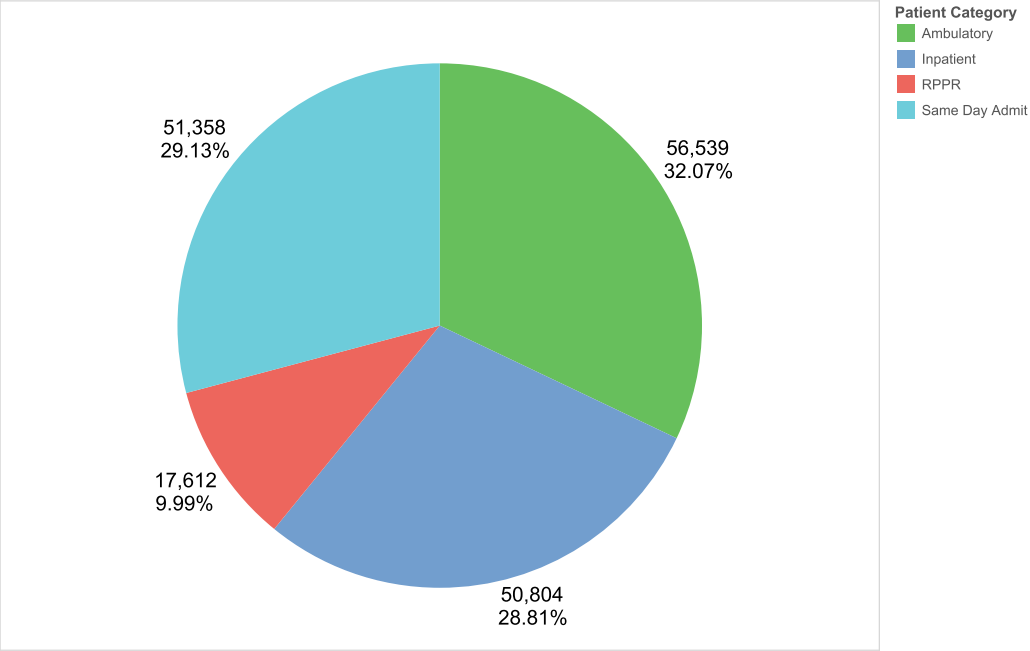

Figure 1: Booking category distribution (2010-2014)

Figure 2 presents the number of RPPR patients per year compared to all surgical patients. There is an observable increase both in fraction and the absolute number of surgical RPPR patients in recent years. One common explanation attributes the increase in RPPR (and *ambulatory*) patients versus *Same Day Admits* (SDA) and *inpatients* to new clinical practices and technologies (e.g., minimally invasive technologies decrease the need for post-surgery admittance) that allow to convert surgical procedures that have required several days of hospitalization into an ambulatory or RPPR cases.

Figure 3 presents the distribution of RPPR patients between 2010-2014, broken by the day of the week, and shows that there is high variability in the daily number of RPPR patients.

Figure 2: Annual number of surgical cases, distributed by booking category (2010-2014)

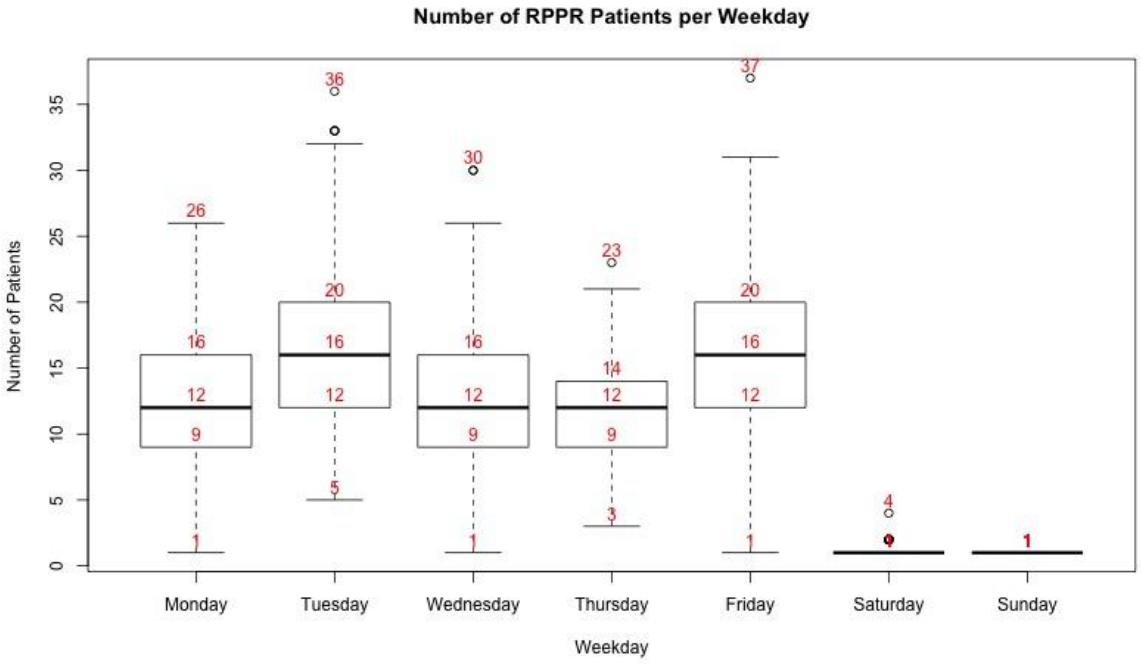

Figure 3: Number of RPPR patients per weekday (2010-2014)

3.5 RPPR Surgical Patient Flow at MGH

Surgical RPPR patients are by definition *elective* surgical patients. Elective surgical patients have scheduled the surgery some time prior to their arrival to MGH and arrive at the hospital prepared for it. Non-elective surgeries include urgent and emergent surgeries and they usually arrive via the Emergency Department.

Generally, RPPR elective surgical patients go through the stages described below. Relevant stages will be discussed in detail later in this section.

1. **Pre-surgery**: Schedule the surgery through their surgeon's office. This is when patients are classified as RPPR.
2. **Day of surgery**:
    a. Check-in to the Center for Perioperative Services (CPC).
    b. Transfer to an operating room and undergo surgery.
    c. Recover in the Post Anesthesia Care Unit (PACU). In the rare case of a clinical emergency patients would be transferred to recovery in the Intensive Care Unit (ICU).
3. **Discharge from the recovery unit**: RPPR patients who are not discharged home the day of the surgery can either stay in the PACU or be transferred to a general hospital floor. The decision process of the appropriate location for recovery in case there is a need for an overnight stay is not clearly-defined, and will be discussed in length in following chapters.

Figure 4 illustrates the surgical RPPR patient flow on a high level. From the PACU, an RPPR patient can be transferred to a floor bed or be discharged home.

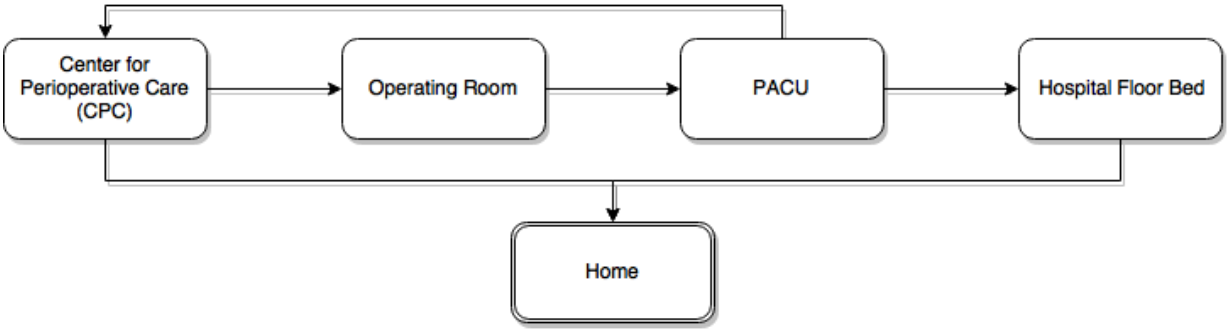

Figure 4: RPPR surgical patient flow

3.5.1.1 Post-Surgical Location Flow

In the post-procedure recovery process at MGH, patients can be transferred to a number of different locations. With the exception of a small number of unusual cases, patients begin the process in the PACU. According to their recovery pace, and other parameters that will be addressed later in this chapter, patients can either spend the first night post-surgery at home, in a general floor bed, or in the PACU. During the second day they can be discharged home, or stay for another night, either at the PACU or in a general floor bed. In rare cases, patients will be transferred to a floor bed, and discharge home at the same day. The different possible location flows are described in the chart below.

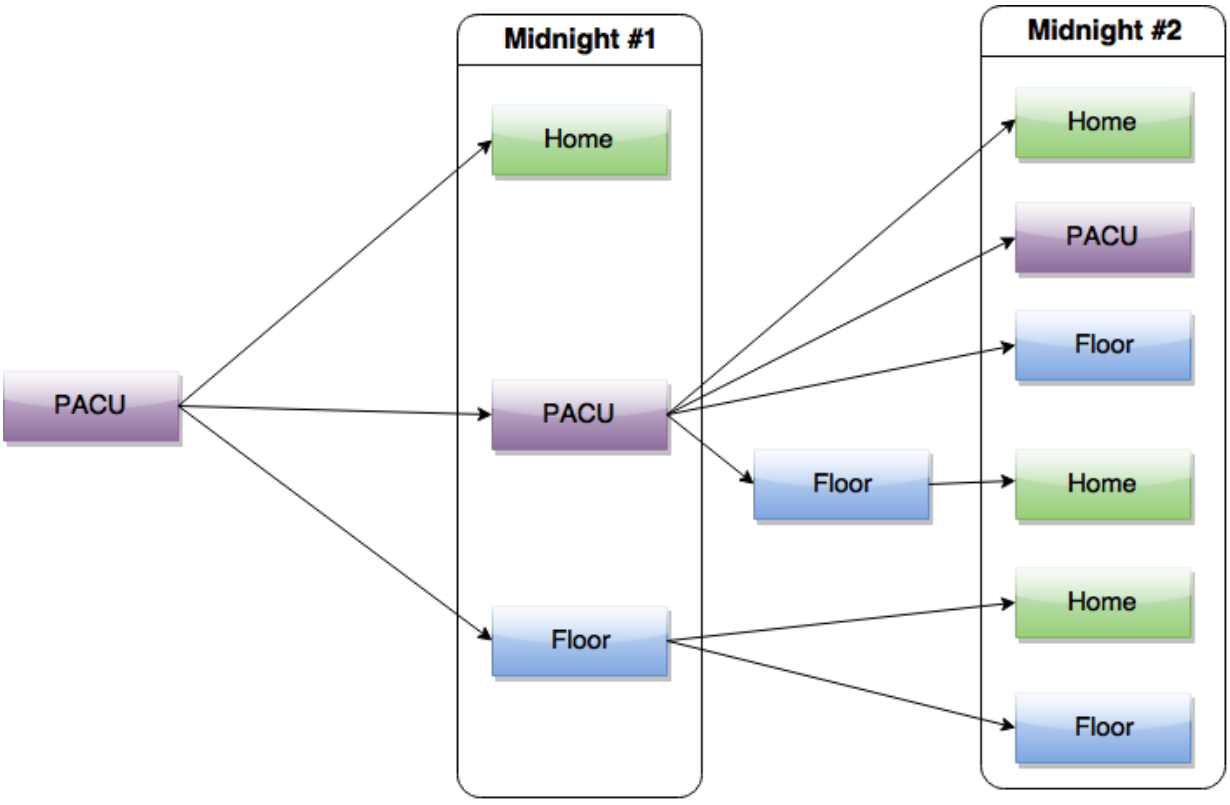

Figure 5: Post-surgical location flow

3.5.1.2 Clinical recovery process

Using data gathered from interviews and IT systems (especially CAS and EPIC), we mapped the recovery process of patients at MGH from a clinical perspective. These processes often vary between different procedures and attending surgeons, however they all begin with the Phase 1: Post-Anesthesia Recovery Process. Throughout the first phase, patients are monitored and treated in recovery units according to a nationally recognized score called "Aldrete Score" – a standard nurse-assessment report which includes metrics and measurements of different clinical parameters of the patient.

Phase 1 - Post-Anesthesia Recovery Process protocol is as follows.

1. When the patient arrives from the OR, the PACU receives a report from Anesthesia, which covers issues related to the course of the surgery (e.g., any irregular complications or progress). This report informs the assessment of the patient's current state and prediction of their course of recovery.
2. Upon a patient's arrival to the PACU, nurses evaluate the patient's status every 15 minutes using the *Aldrete* evaluation. They will continue doing so until the patient reaches a certain *Aldrete* Score which indicates a certain level of recovery.
3. At this point, nurses continue to examine and evaluate the patient's recovery progress using *Aldrete* Score every 30 minutes.
4. When the patient reaches a certain *Aldrete* Score, their condition no longer requires a PACU level of care, and they can be discharged from the PACU.

Some time may pass between the time a patient is deemed out of PACU-level of care and until they are officially signed as such. The decision to remove a patient from PACU-level of care is made strictly by a Nurse Practitioner (NP) or an Anesthesiologist. When a NP is available it takes approximately 10 minutes to get one to review the patient. When a NP is not available (in the weekends for example) it can take up to an hour until an Anesthesiologist is free to sign.

At this point, the patient has completed Phase 1 of recovery and will continue to Phase 2. According to the PACU nurses we interviewed, there are no significant difference in the second-phase recovery process between the PACU and the floor, and no significant difference in the patients' motivation to be discharged. One slight noted difference is in the availability of nurses, which is higher in the PACU. Hence, the differences in Length of Stay between the floors and the PACU (which will be discussed in chapter 3.7.5.1PACU LOS vs Floor LOS Comparison), must come from other operational aspects.

3.5.2 RPPR Booking Practices

Surgeons book patients as RPPR for a number of different reasons, regardless of the official RPPR definition. These include:

- **Type of procedure**: some procedures are defined by payers as *outpatient* procedures although most of the patients' clinical postoperative status usually requires longer recovery time. A surgeon will choose to book these patients as RPPR in order to signal the hospital that these patients will probably stay the night.

- **Patient characteristics**: some patients require longer recovery time due to their medical history, background diseases, age and other characteristics that impact the length of recovery.
- **Individual practice**: we have observed that some of the surgeons' offices book their surgical patients as RPPR due to historical understanding that RPPR is the category preferred by MGH in these cases.

3.5.3 Stakeholders and Decision Process

3.5.3.1 Admitting Department

MGH Admitting Department oversees and allocates licensed floor beds throughout the hospital, making it a key player in the RPPR patient flow.

Prior to the day of the surgery, the Admitting Department receives surgery orders from operating surgeon offices along with the determined booking category for each patient. The booking category will determine whether the Admitting Department will allocate a general floor bed to a patient or not. An important consideration for bed designation is the patient's insurance. The Admitting Department reviews the determined booking category, as it is the primary source of knowledge of the relevant insurance codes, and can update the surgeon's office as to the relevant designation according to the patient's qualification for inpatient care.

When a procedure is determined as RPPR, Admitting Managers assume the patient will need a bed, and in most cases they assign them one. On the day of the surgery, Admitting

Managers often discuss specific cases with PACU nurses, to ensure clear flow throughout the day. According to patient diagnosis, they may decide not to assign a general floor bed for a specific RPPR patient (e.g., that patient will stay overnight at the PACU).

On busy days, the Admitting Department puts extra efforts in prioritizing bed allocations and optimizing the flow of patients to the general floor. Therefore, Admitting Managers work together with the PACU staff to identify RPPR patients who will not require their assigned floor bed. To identify such patients, Admitting Managers revisit RPPR patients' medical charts to reassess their recovery process. Contributing to the efforts, PACU nurses may call Admitting to let them know that a patient will not be needing the assigned bed.

3.5.3.2 Operating Rooms Administration

Operating Rooms (OR) are specialty rooms where surgical procedures take place, and are usually dedicated to specific surgical services. At the MGH main campus there are 70 ORs, 58 of which are used daily. They range from newly built ORs to ORs that have been operating for decades. ORs are located in three buildings, two host legacy ORs and one (Lunder) hosts the newest ones. Uniquely, MGH has two ORs with a designated MRI machine, as well as hybrid\non-hybrid rooms with imaging machines.

In order to learn about OR operations, we spent several days shadowing Operating Rooms Managers. The two physicians shadowed run the ORs once a week each, and are part of the Perioperative Services department. In shadowing at the Operating Rooms, we focused on the OR operations, and especially on scheduling and daily routines that may impact the flow of the RPPR patient.

ORs are one of the most in-demand resources in the hospital. Time slots for waitlist cases are assigned according to the type of case, which is determined according to the urgency of the surgery: emergent (must be operated on within 45-60 minutes), urgent (must be operated on within 4 hours), non-urgent (must be operated on within 24 hours). Elective surgeries are usually pre-assigned to specific ORs.

During these shadowing sessions, we collected important information regarding operational and cultural aspects in addition to gaining specific insights about RPPR patients. Many of those aspects improved and deepened our understanding of RPPR, and are mentioned throughout this thesis. Specific observations regarding OR operations are described below.

The daily routine of the OR managers includes standing meetings which help plan the next day and react to unexpected needs of the day. First, the staff identifies ICU or PACU overnight patients in order to make sure there is room for the first surgical patients of the morning. Later in the day, a bed assignment meeting takes place, after which the Admitting Department prioritize and assign floor beds to patients. Another important meeting (at 11:30) discusses waitlist cases. Somewhat contrary to the robust use of IT in the OR administration, there is limited use of digital systems during those meetings: printed or handwritten papers are used in most of the meetings, patients are often counted manually, and some of the relevant information (e.g. the type of a certain OR) is drawn from memory.

3.5.3.3 Post Anesthesia Care Unit (PACU)

After the surgery is completed, the patient is transferred to the Post Anesthesia Care Unit (PACU). There, the staff makes important decisions regarding the continued care according to the patient's recovery progress and general clinical condition. Therefore, it is one of the key determinants of the RPPR patient flow. Indeed, shadowing the nurses at the PACU provided important insights that were impossible to learn merely from extracting data out of IT systems. Many of the decisions influencing the flow of RPPR patients through the hospital are made throughout the day by PACU nurses in collaboration with the surgeons and the Admitting Department. Decisions are often driven by cultural aspects, which this subsection will discuss.

PACU staff is allocated to patients according to the severity of their condition. At first stages of recovery the ratio of nurse to patient is 1:1, and as the patient recovers and is ready to be discharged from the PACU, the ratio changes and can be 1:4. During the night shift, between 11pm-8am, staff is reduced and the only PACU that remains open is the one in the Ellison building (Ellison 3).

Each PACU can accept patients from any OR, though in practice certain ORs send patients to specific PACUs, unless they are full. Pediatric patients are sent only to Ellison 3 or the CPC, which is divided to adult and Pediatrics.

3.5.3.4 Case Management Department

MGH Case Management (CM) Department consists of Registered Nurses (RNs) who are in charge of managing a patient's progress in the hospital throughout their stay after being

admitted to a hospital floor bed. Each surgical case (i.e. each patient) at MGH is assigned a case manager.

In the case of RPPR patients, Case Management is the department that will ultimately make the case to change a patient's status (from RPPR to *inpatient* for example) if it is clinically appropriate. Because the main concern CM has with RPPR patient flow in the hospital is in case they need a status change, CM treats RPPR as elective outpatients who may need a floor bed. CM uses a decision-support tool, Interqual, to determine whether or not a patient qualifies for inpatient care.

Status change depends strictly on clinical evaluation and not on how long the patient has already stayed in the hospital. To qualify for a status change from RPPR to *inpatient*, there must be some clinical change or abnormal recovery. Every day, CM reviews all the overnight RPPR patients to evaluate who has a clinical justification to stay at the hospital additional days, rendering a status change to *inpatient*. Once CM determines a status change to *inpatient*, the physician can write admitting orders which will satisfy payer requirements.

CM has a monthly report that summarizes all patient status changes, e.g. how many patients were converted from RPPR to *inpatient*. Figure 6 presents a summary of this report, as well as the fraction of conversions out of the total number of RPPR patients admitted to MGH annually.

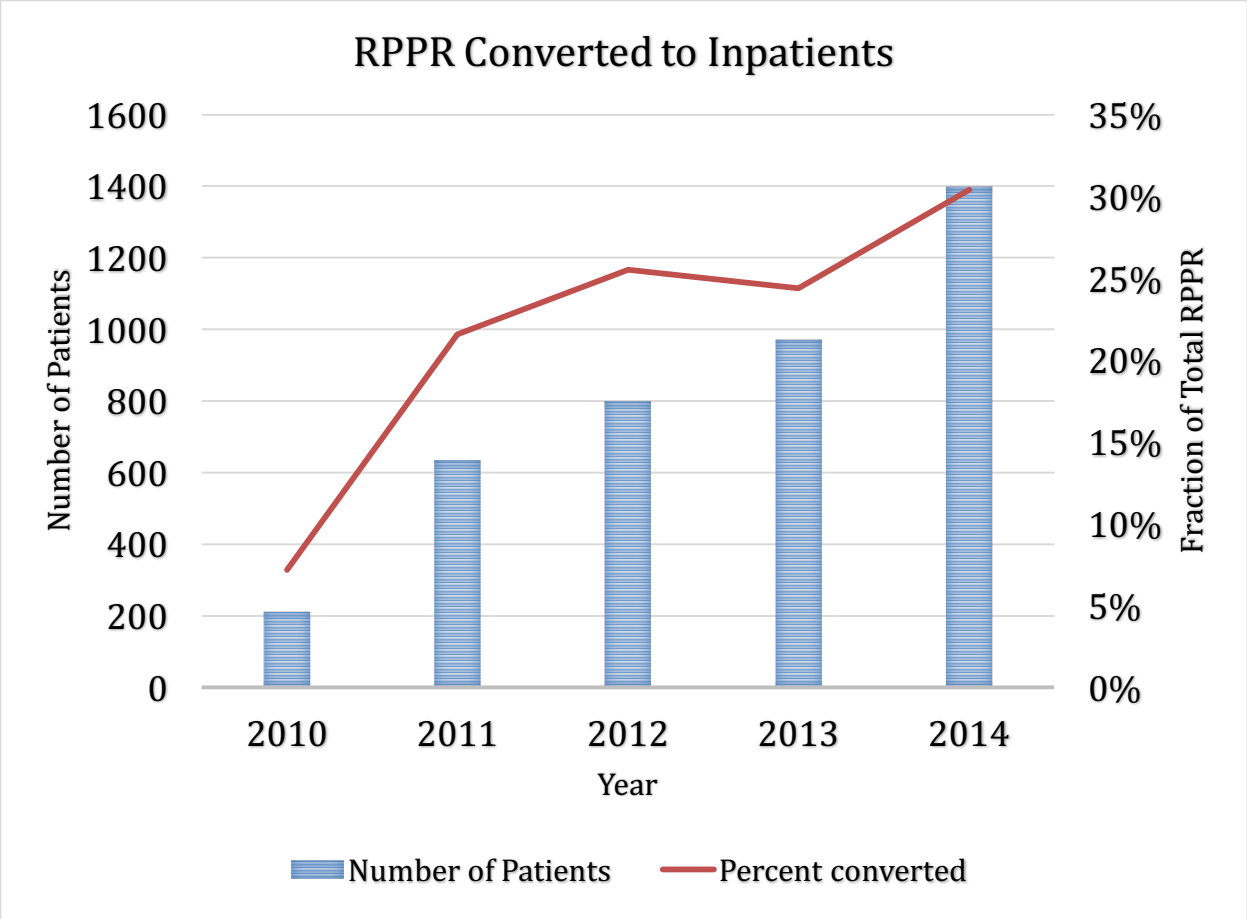

Figure 6: RPPR patients converted into Inpatients[3]

3.5.4 Discharge from the Hospital

In order for a patient to leave the hospital, a surgeon has to sign their discharge order. This protocol often causes delays in discharge since surgeons are not available at all times of the day, and cannot be taken out of surgery to write or sign discharge orders. Surgeons tend to join the morning rounds and then are usually scheduled for surgeries most of the day. Therefore, it often happens that patients who were ready to be discharged after the

[3] Source: Case Management data

morning rounds had to wait an extra day simply because the surgeon was in surgeries all day.

3.5.5 Specific Test Case: Total Thyroidectomy

As a specific test case, we followed the flow of Total Thyroidectomy (Thyroidectomy) patients to learn about the recovery process at MGH. Thyroidectomy patients were chosen because they represent a relatively large population of RPPR patients who regularly stay overnight at the hospital, whether in the PACU or one of the floors. Between 2010-2014 a total of 1,899 Total Thyroidectomy surgeries were performed, to which 938 patients were booked as RPPR. Chapter 5.1 provides additional information about Thyroidectomy surgeries.

This test case demonstrates how the different surgical techniques and practices affect post-surgery recovery paths. Different surgeons have different Total Thyroidectomy techniques, particularly, some practice less invasive techniques than others. While the recovery from anesthesia after a Total Thyroidectomy usually takes only a short time, the surgical technique dictates the rest of the recovery. More invasive procedures require a calcium check 24 hours post-surgery. In order to manage the load on the PACU, the test is usually performed before the morning rounds (sometimes at 3AM) so the surgeon would have all the relevant information during morning rounds and the patient could potentially be discharged that day (and not wait for the next day's rounds).

This is one example that shows how the total postoperative process for Thyroidectomy varies amongst patients, surgeons and type of procedures. Experienced nurses indicate that

they often know early in the process if the patient is going to recover quickly, or is going to need a longer stay.

3.6 Hypotheses

Developing hypotheses and testing them was an important step to inform the recommendations generating process. By testing those hypotheses through the data, we were able to generate a basis to our operational recommendations. Following are the valid hypotheses that we raised in developing the methodology.

1. Booking categories (RPPR vs. Ambulatory) influence the speed of the discharge process.
2. Different operational and clinical practices among surgeons result in different overnight stay patterns even for the same procedure.
3. Time of arrival to the PACU influences the chances of an overnight stay.
4. There are additional patient-specific characteristics that impact length of stay.

3.7 Key Findings

In this section, we will describe the key findings from the current-state analysis we performed using the different data sources (detailed description of the sources is in Appendix 1). It will detail qualitative insights from interviews and shadowing, as well as a quantitative analysis of trends of various metrics, broken down by different factors such as the surgeon, procedure, booking category, time of surgery, recovery location etc.

3.7.1 Key Challenges

Below are the main challenges faced by MGH related to the RPPR booking category. We identified and analyzed these challenges through shadowing, interviews and data-analysis.

In Chapter 5 we will discuss recommendations for possible remediation to some of these challenges.

It should be noted that in past years, some challenges related to RPPR patients were recognized by hospital leadership. Efforts were made to better define RPPR patients and standardize their flow (vs. in\out-patients), as well as understand the financials of the RPPR booking category. This project is a part of these efforts.

1. **Ambiguity of category definition**: RPPR is a booking category that was created internally by MGH for operational purposes. It is assigned to complicated *outpatient* cases that have the potential to- but not necessarily will- become *inpatients* cases. These patients cannot be admitted as *Same Day Admits (SDA)* since payers do not acknowledge the procedure as such. This creates two main issues: first, it is difficult for the surgeon to predict which specific cases qualify as RPPR. Second, most hospital staff is not completely clear on the RPPR definition.

   The fact that the definition of RPPR is not completely clear makes it challenging to determine the right booking category for a specific patient, and leads to its overuse. Booking patients under the inappropriate category creates suboptimal patient flow in the hospital - causing misuse of resources.
2. **Bed assignment challenges**: MGH Admitting Department receives a daily list of all surgical patients and assigns general floor and ICU beds according to the booking category and many other operational and clinical considerations. Today, RPPR patients are often assigned a bed in the respective service floor (the surgical service under

which the patient is booked). Due to the high variability of recovery lengths, it is difficult for the Admitting Department to anticipate whether an RPPR patient will ultimately need a bed. As a result, RPPR patients are often discharged without ever using the beds assigned to them [13]. In many cases, PACU nurses and Admissions Department personnel communicate over the phone in order to update whether a particular RPPR patient needs a bed.

This challenge creates a waste of floor beds by blocking them during the day, which increases wait time for other patients who might need them. Furthermore, it creates a communication burden on both Admissions and the PACU.

3. **Determination of recovery location**: MGH does not have a standard protocol for determining the recovery location of RPPR patients. Generally, patients begin their recovery process in the PACU, and later either stay at the PACU or get transferred to a general floor bed. The decision of whether to keep RPPR patients in the PACU or transfer them to a floor bed is made ad-hoc using inputs from PACU nurses, the Admitting Department and the operating surgeon. In 2014 41.7% of the RPPR patients used floor beds.

   Routing policies of surgical patients throughout their recovery process have changed over the years. The main change in routing-policy was implemented after the opening of the Lunder building in September 2011. The new policy dictates sending patients to the floor as soon as they are clinically ready.

4. **Non-standard clinical recovery process**: In practice, surgeons determine the process of recovery for every patient and procedure. Those processes are given to the PACU

nurses as post-surgery orders attached to the patient file. These non-standard processes create variability in the system, which leads to inefficiencies in of operations.

5. **Financial challenges**: Payers (i.e., insurance companies and government) generally associate patient booking categories with a surgical procedure. RPPR is an internal MGH category which payers are blind to. Per RPPR definition, these patients are acknowledged as *outpatients* by payers and MGH is compensated accordingly. Unless the hospital changes the category of a patient after the surgery for a justified clinical reason, payers do not reimburse for inpatient hospital stay of RPPR patients.

3.7.2 Determination of Booking Category

There is uncertainty amongst most nurses about the reasons some patients are categorized as RPPR or what the insurance implications are. Their impression is that there is no real correlation between the PACU Length of Stay (LOS) and the category (RPPR vs other categories), even though RPPR patients are officially defined as *outpatients* who are expected to stay up to 24 hours in the PACU.

3.7.2.1 Booking Category Distribution

Booking categories vary even for the same surgical procedure. The relative fractions of the different booking categories with respect to a given surgical procedure are generally determined by different factors. Some factors are well-defined (such as insurance guidelines), and some are quite vague and ad hoc (such as the practice of the surgeon office). In our analysis, we discovered that the patient booking category often dictates aspects of the patient care and therefore has a strong influence on the hospital operations.

An analysis of booking category distributions for different procedures often reveals inconsistent and unnecessary usage of the RPPR category. In addition, as shown in Chapter 5, by comparing booking category distributions of different surgeons, for a specific procedure, we can detect abnormal practices of individual surgeons. Detecting such abnormal practices often helped us promote best booking practices for a given procedure.

3.7.3 Bed Assignment

Challenges related to bed assignment throughout the hospital were mainly revealed to us during interviews with the Admitting Department who is in charge of bed allocation. The two main points we observed were long hospital stay for non-clinical reasons and operational challenges on unusually busy days at the PACU and ORs.

Sometimes patients stay in the PACU for non-clinical reasons with the approval of the respective surgeon, even though they were approved as beyond PACU-level of care. Some examples of non-clinical extended stays include patients who did not have a ride home or to ensure patient satisfaction (signaling to patients that MGH will make extra efforts to meet their needs).

Another Admitting pain point is the unusual load on general floor beds during busy days at the ORs. On such busy days, the PACU staff push to transfer patients to the general floors in an increased pace, regardless of the current load on the floors. This practice indeed relieves the load from the PACU but it creates further unexpected load on the general floors.
When asked what could be useful for the department in making more accurate decisions, Admitting mentioned that it would be helpful to have a tool that would identify specific

RPPR patients who are not likely to need a bed. Such a tool would be useful even if without 100% accuracy. Another possible remediation would be the implementation of the Just-In-Time project recommendations by McNichols (2009) - another MIT-MGH collaboration team project. If implemented, less RPPR patients who will most probably not need a bed, will be assigned one in the first place.

3.7.4 Extended Stay

Patient flow seems to be a concern for PACU nurses, and RPPR patients are not necessarily different from other patient populations in that sense. Nurses explain that they have a good sense of whether a patient will stay overnight according to the patient age and medical history, the type and course of the procedure, as well as the specific operating surgeon. Before discharge, they would refer to the surgeon's notes to understand if the patient has recovered sufficiently and is ready to go home. Eventually the surgeon is also involved in the decision to discharge, and must approve it.

PACU nurses typically send patients to the hospital floor as soon as possible. Patients who need to stay for the night can be transferred to the floor only when the specific bed assigned to them is ready. When the relevant IT system indicates that an assigned floor bed is ready for use, the nurse will call the floor before sending the patient. The manual communication is necessary because sometimes the bed deemed free in the system is actually not ready.

In getting a bed, there is a priority for patients that already stayed overnight in the PACU. The PACU and Admitting Department will communicate by phone about specific patients that need or do not need a bed. In addition, transfer of patients from PACU to floors

depends on the outcome of the daily bed assignment meeting. Hence, PACU nurses do not always know if a certain patient will end up getting a general floor bed until late in the day. Another challenge is presented when a PACU patient is ready to be discharged home, but the CPC is not ready to accept them. We have not further researched this as it came up as a secondary issue and not a main concern.

We asked PACU nurses specifically about delays in the recovery or discharge process. They mentioned that sometimes the PACU cannot find the surgeon for discharge approval and other administration matters. Furthermore, voiding and special teaching (e.g., injection) are significant recovery steps in many cases and can cause delays in discharge until completed.

A significant pain point that we identified during the interviews with the Admitting Department is a cultural tendency to keep patients overnight for non-clinical reasons. Patient expectations contribute to this culture, as surgeons are mainly concerned with providing optimal patient care. A part of providing excellent care is ensuring the patient's sense of trust in the hospital, the surgeon and the procedure. Therefore, surgeons would be willing to keep the patient overnight to meet their expectations even if it is not operationally optimal. Patients expect to stay overnight for different reasons such as to insure they are being monitored, to eliminate post-surgery concerns of wellbeing or simply because they feel uncomfortable to go home. Moreover, prior to the elective procedure, patients are told to pack an overnight bag. This creates an expectation to stay in the hospital even when they are clinically ready to be discharged home. There are

psychological effects of such expectations on recovery, as well as implications on patient satisfaction from overall care.

3.7.5 Recovery Location

3.7.5.1 PACU LOS vs Floor LOS Comparison

After surgery, RPPR patients are transferred to the PACU. Some will be admitted to the Intensive Care Unit (ICU), if something highly unpredictable occurred. In 2014, 1% of the patients were transferred to the ICU instead of the PACU. In all cases, the first stage of recovery is always in the PACU or ICU. After the first stage, the recovery process varies between procedures and surgeons. At MGH, the location of the second recovery phase is not well defined for RPPR patients - some are transferred to the floors and some stay in the PACU.

We tested the differences in LOS and chances to stay overnight, based on the choice of recovery location. Generally, the LOS of patients who were transferred to a floor bed is longer than the LOS of patients who were discharged home directly from the PACU. The results are summarized in Figures 7 and 8 below.

The differences in LOS could be biased by the way PACU nurses choose which patients to move to the floors. Patients who are deemed more likely to stay longer are more likely to be selected by the nurses to be transferred to the floors, while patients who are likely to be discharged soon might be kept in the PACU until they are ready to be discharged home. We were able to test this hypothesis by comparing two routing policies used by the hospital in

separate periods. Further discussion on this comparison is presented in the following section (3.7.5.2).

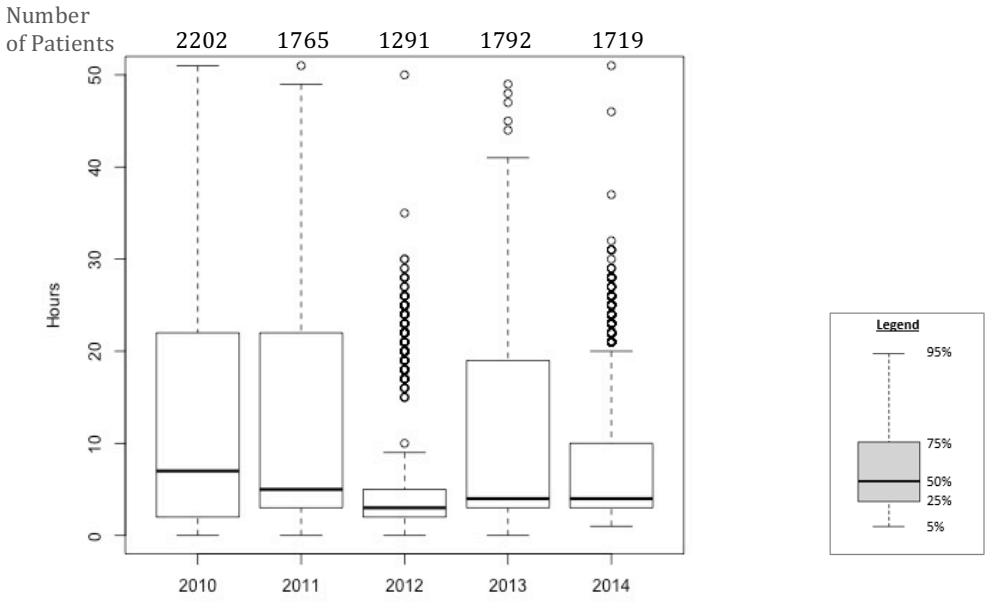

Figure 7: LOS after surgery of RPPR patients who were discharged home form the PACU (2010-2014)

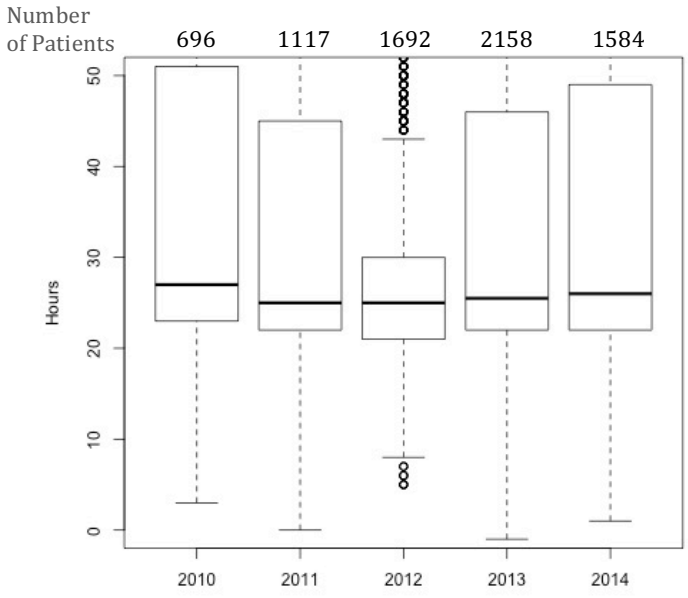

Figure 8: LOS after surgery of RPPR patients who were moved to the floors (2010-2014)

3.7.5.2 Before\after Lunder

Routing policies of surgical patients throughout the recovery process have changed over the years. These policies are treated as best-practices, rather than rules that should be followed in every case. The main change in routing-policy was implemented due to the opening of the large Lunder building in MGH:

1. Before September 2011: The policy was to keep patients in the PACU as much as possible.
2. After September 2011: The Lunder building was opened and the policy was then changed to send patients to the floor as soon as they are clinically ready.

The figures below show the Post-Procedure Hospital LOS of RPPR patients before and after the Lunder building was opened. Figure 9 shows the patients who were transferred to a floor bed; Figure 10 shows the patients who were discharged straight home from the PACU. Both graphs count patients who stayed up to 3 days in the hospital.

Interviewing PACU nurses, we learned that when prioritizing RPPR patients to send to the floors, they try to send the patients who are more likely to have a longer stay. From the graphs below, we see that after September 2011 RPPR patients who go home from the PACU have a shorter LOS, while RPPR patients who are transferred to the floors have roughly the same LOS. Therefore, a possible conclusion from the differences is that PACU nurses are - to some extent - able to predict the recovery time required for individual RPPR patients, and choose to transfer (to the floors) patients that are less likely to be discharged home soon.

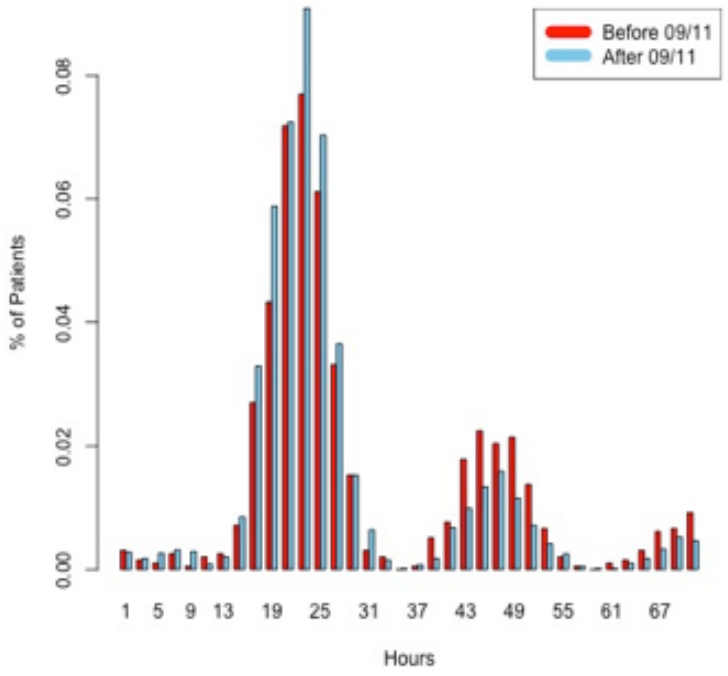

Figure 9: Histogram of post-procedure hospital LOS of patients who were transferred to a floor bed (2010-2014)

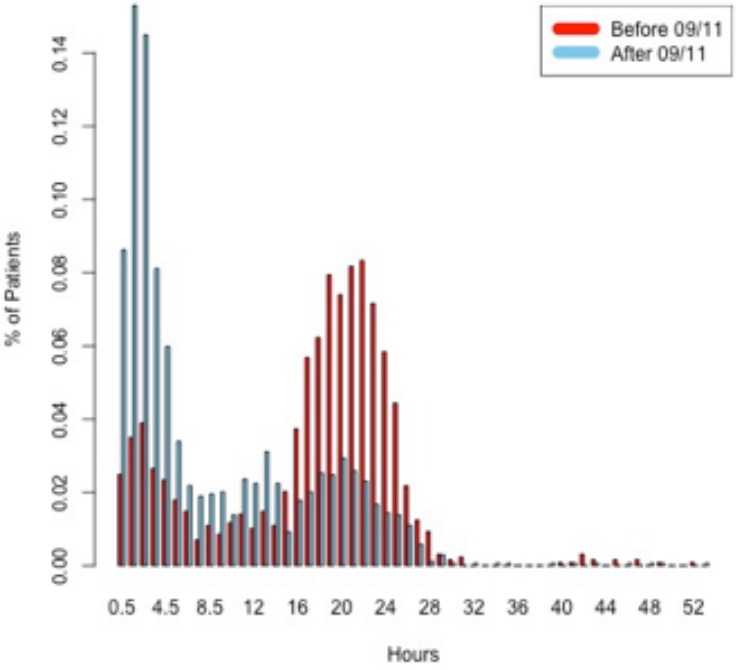

Figure 10: Histogram of post-procedure hospital LOS of patients who were discharged straight home from the PACU (2010-2014)

4 Solution Approach and Results

Data presented in Chapter 3 reveals challenges and deficiencies in the postoperative process of management of RPPR patients. In order to improve the system and address these challenges, we developed actionable operational recommendations. The nature of the recommendations is such that most of them are procedure-specific, and often surgeon-specific. The process of constructing the recommendations began by defining the key operational questions, followed by developing our hypotheses. We then analyzed each hypothesis using the data and findings from interviews and shadowing. Finally, we developed an analysis method to evaluate each case, in a way that will address the key operational and clinical issues. In this chapter we will present the process of constructing the recommendations. In chapter 5 we will present the implementation of the methodology on a few relevant procedures.

This project and its methodology aim to answer the following questions:

1. **How to choose a booking category?** When booking a patient for an elective surgical procedure, the surgeons (or their office) must choose the correct booking category. The surgeon can choose between different categories: *Same Day Admit*, *Ambulatory*, *RPPR* or *Inpatient*, (*Inpatient* category requires that the patient be admitted to the hospital prior to the surgery). Ultimately, we aimed to provide surgeons with clear and transparent booking guidelines.
2. **At what time of the day should surgeries be scheduled?** Operating Rooms scheduling is done by allocating general time blocks to the surgical services, and each service schedules specific procedures within the block. We examined cases

where the time of surgery may affect operational outcomes such as the patient LOS, to see if the services will be able to schedule procedures in a more efficient way.

3. **How to choose the recovery location?** After the initial phase of recovery in the PACU, patients might stay in the PACU until they are discharged home, or be transferred to a floor bed. This decision is made by Admitting Department, PACU nurses, and to some degree the attending surgeon. In order to inform the decision regarding recovery location for RPPR patients on the system level rather than case by case, we simulated a scenario where all RPPR patients are being kept in the PACU. Chapter 4.3 presents the results of this simulation.

4.1 Metrics

4.1.1 Overnight Stay

An important metric we analyzed is the percentages of patients who stayed in the hospital overnight. For overnight stay, we looked at different patterns in terms of location, i.e., how many nights in the PACU and how many in a floor bed. Chapter 3 details the reasons for RPPR patients to stay overnight. A key point in regard to overnight stay is that when patients spend the night in the PACU they might block a bed for early morning patient admissions and disrupt the morning surgical schedule.

4.1.2 Length of Stay

Some of the most important metrics related to RPPR patients are the time they spend in different parts of the surgical flow in the hospital. We used two different Length-of-Stay (LOS) metrics:

- PACU LOS - Time between the patient's arrival to the PACU (after surgery) and the discharge from the PACU (discharged home, transferred to a floor bed, etc.).
- Hospital LOS (Post-Procedure) - Time between the patient's arrival to the PACU (after surgery) and the discharge home, regardless of the final location in the hospital. Therefore, Hospital LOS includes PACU LOS.

4.1.3 Time of surgery

In some cases, the procedure end-time (i.e. when the patient arrives to the PACU) influences the length of stay and the chances that the patient will stay overnight. The influence of time of surgery varies between procedures and surgeons. From an operations perspective, patients whose surgeries are early in the day, are the most challenging to keep for a long period of time in the PACU since they create a load in the PACU for the rest of the day. In that sense, surgeries performed later in the day are less problematic for extended stays that day, but the chance of an overnight stay increases as well, which might interfere with the morning operations.

4.1.4 Variability by Surgeon

For each surgical procedure, we analyzed and compared the LOS of patients by the surgeon who performed the surgery. We found that in many cases the same procedures performed by different surgeons yield significantly different LOS values. Those differences are likely rooted in different causes, including the individual's surgeon mix of patients, the booking practices of surgeons, the surgeon's surgical technique and the post-procedure orders. Chapter 4.2 describes the methods we have used to evaluate the root causes and potential remediation for the LOS differences between surgeons.

4.2 Analysis Method

We developed a three phase analysis for each case as follows:

Procedure level:

1. Bucket procedures into clinically similar groups.
2. Classify into booking category.
3. Analyze influence of time-of-arrival.

Surgeon level:

1. Analyze variability in surgeons' booking practice.
2. Analyze variability in surgeons' clinical practice.

Patient level:

1. Patients' surgical groups.
2. Patient specific.

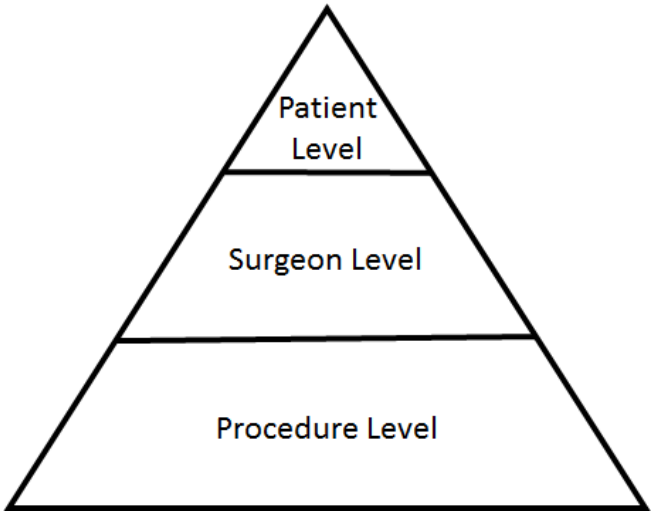

Figure 11: Three levels of analysis

4.2.1 Procedure Level Analysis

A procedure-level approach is the first part of the analysis methodology. In light of the current state of RPPR patients at MGH, we realized that some of the issues related to RPPR patients can be best analyzed and solved at the procedure-level. For example, there are certain procedures (e.g., Internal Pulse Generators replacement) where patients are always categorized as RPPR although they can be booked as *ambulatory* or *Same Day Admits (SDA)*. Because a bed is held for many RPPR patients, modifying these cases may provide clarity to the stakeholders and reduce the time in which beds are unoccupied during the day.

4.2.1.1 Procedure Grouping

As a first step of the procedure level analysis, we divided the procedures that involve RPPR patients into groups, or buckets. A bucket included procedures with a similar clinical recovery process. This way, we were able to analyze a smaller set of procedures with similar characteristics. The process of bucketing the procedures was made possible with much support from physicians, and especially the head of Perioperative Services, Dr. Peter Dunn.

Procedure grouping allowed us to simultaneously address all stakeholders of a certain procedure group when presenting the operational recommendations (chapter 5).

The groups/buckets are as follow:

Table 1: RPPR surgical procedure groups

#	Group Title	Number of Patients (2010-2014)	Number of RPPR Patients (2010-2014)	Number of Distinct Procedures
1	Head / Neck / Endo	4,289	2,549	8
2	Breast	2,865	976	13
3	Lap Chole	3,493	668	3
4	TURP / Cysto	5,586	953	12
5	Laryngoplasty / Airway	4,569	556	12
6	Hysterectomy / Gyn	2,874	888	12
7	PEDI - GI	3,283	404	11
8	Extremity ortho	5,547	337	15
9	Hernia / Abdominal Wall	3,971	674	10
10	Dental	398	317	5
11	Neuro pulse gen	502	172	4
12	Angio / Vascular	3,183	480	6
13	Mandible	740	291	9
14	Spine	1,629	162	6
15	Complex lapar.	394	91	3
16	Shoulder / Upper Extremes	1,753	265	10
17	Thoracoscopy	932	33	2
18	Maxillary	686	392	6
19	Foot and ankle	2,279	538	12
20	Plastic / Soft tissue	3,545	761	15
21	Burns / Skin	1,317	148	4

4.2.1.2 Booking Category Classification

The second step of the procedure-level analysis was classifying each procedure in the procedure-bucket into its recommended booking category. We examined each procedure and tried to assess the appropriate category in which patients should be booked. To do so, we analyzed the current distribution of booking categories, considered the percentages of patients staying overnight, and matched a booking category that fit the majority of the cases. At this stage of the analysis, surgeons that significantly deviated from current

practices were not assigned a group. A specific analysis of these cases was performed in the next stage (surgeon-level).

The recommended booking category was determined as follows. If most RPPR patients typically go home at the same day, then the recommendation is that procedure can be booked as Ambulatory. If most of the RPPR patients stay overnight, the hospital would prefer to have the procedure booked as SDA. Many times, the reason that procedures are not booked as SDA is that payers do not recognize them as such. If this is the case, MGH can either negotiate with payers to change their policy, or check internally with the surgeons if their practice dictates overnight stay while the common practice elsewhere does not. Regardless, until any changes can be made, such procedures should be booked as RPPR when a surgeon anticipates that a patient will stay overnight, in order to signal that to the hospital that a bed is likely needed. In analyzing each procedure with high percentages of overnight stay, we initiated conversations with some of the relevant surgeons, as well as reviewed post-procedure orders with the help of anesthesiologists and PACU nurses, in order to understand whether the root cause is a clinical or operational (as discussed in the hypotheses).

4.2.1.3 Time-of-Arrival Analysis

Another key factor we studied was the influence of the time in which the patient arrived at the PACU post-surgery. In some cases, we found correlation between time of arrival to LOS and to chances for overnight stay. In other cases, we found a cutting-hour, after which a significantly higher number of patients end up staying overnight. In those cases, we recommended that if possible, the procedure should be booked earlier in the day.

It is worth mentioning that this is essentially a scheduling optimization problem. For each surgical practice, we would need to check what procedures are performed within a scheduling block, and optimize the scheduling. This problem is out of the scope of our project, since it is rare that schedule blocks contain only RPPR patients. Therefore, instead of optimizing the schedule, we used a heuristic approach to provide recommendations with regard to RPPR patients.

The heuristic specifies required cutoff time by procedure and surgeon. Patients arriving at the PACU before the cutoff time are likely to be discharged home the same day, and those arriving after the cutoff time are likely to stay overnight at the hospital.

While the full optimization problem is out of scope, we have defined it in general terms (as presented below), to provide a starting point for future projects.

Objective: for every permutation of procedures in a given block, what is the best order for a minimum of overnight stays? The optimization objectives can vary. Examples are: minimize overnight stay, minimize LOS etc.

Inputs: distribution of %overnight by Time Of Arrival for each procedure and surgeon.

Make sure the procedures are done within the same block.

Considerations: When scheduling, consider staggering strategies as well; Also consider to average “mistakes”, meaning if for two procedures, done by the same surgeon or in the same room, the chances for a patient to stay are 20% and 80% respectively, try to book them at the same day.

4.2.2 Surgeon Level Analysis

The second step of the analysis methodology was to look at variability related to different surgeons within a certain procedure group. Using the data, we identified different

outcomes between surgeons in terms of one or more of the metrics we used, including LOS, overnight stay, and booking category distribution. In addition, we identified surgeons that were outliers with respect to one or more of these metrics. When we found such variability in the data, we interviewed surgeons and PACU nurses, as well as reviewed patient files, in order to understand the root cause. Often we found that surgeons vary in one or more factors, including: surgical practice, post-surgery practice and booking practice. While surgical practice, or the method in which the surgeon performs the surgery, is sometimes interesting in terms of understanding the factors contributing to lower or higher LOS, it is generally outside of the scope of our operational recommendations. Differences in booking practice and postoperative practice will be discussed in the sub chapters below.

4.2.2.1 Surgeon Booking Variability

As a first step in the surgeon-level analysis, we looked at the different booking practices of different surgeons. We searched for significant differences between surgeons, as well as for suspicious booking practices. We realized that surgeons do not have a well-defined booking strategy, and they either just book in one category as they were told to, or leave it in the hands of their administrative staff altogether.

Booking behaviors that required further investigation included, for example, surgeons who booked a significant number of their patients as RPPR and a significant number as Ambulatory. We observed two possible reasons for this booking pattern. One is that the surgeon is either making a distinction between patients who might need extended recovery and others who might not. A second possible reason is that the surgeon office books with no guidelines, and perhaps changes practice from time to time. We used both the data and interviews with the surgeons in order to find the cause for an inconsistent booking

strategy. For example, if patients have only slightly different average LOS between RPPR and Ambulatory, it is unlikely that the surgeon is making a correct distinction when booking the patient.

4.2.2.2 Surgeon postoperative practice variability

In some cases, we found that there are significant differences between surgeons in terms of patients' LOS in the same procedure, and the same booking category. In such cases, we interviewed surgeons and nurses, as well as reviewed postoperative orders in patients' files, in order to find the root cause. According to our hypotheses, such differences may result from the postoperative practices, from time of surgery (in case different surgeons operate in certain times consistently), or from patient-specific issues (for example, if one surgeon is mostly dealing with one kind of patients, e.g. pediatrics). In discussing the findings from the data with clinical personnel, we were able to distinct between the three options mentioned. When we found that there is a certain practice causing the difference in patient stay patterns, we often presented it to the surgeons and offered them to consider changes in practice, as they see clinically fit.

4.2.3 Patient Level Analysis

The final part of the analysis methodology was to consider patient-level factors that may influence some of the metrics we used. We divided patient-level analysis into two categories: surgical groups and individual patient factors, both will be explained below.

4.2.3.1 Surgical Groups

The first category deals with groups of patients with a distinct characteristic, for example pediatric or transplants patients. In many cases, certain surgeons focus their clinical

practice on specific groups of patients. For example, some surgeons mostly deal with bariatric patients. In those cases, we divided the surgeons into groups within a specific procedure, and analyzed the various metrics separately for each group. In some cases, for example, an extended LOS is reasonable because the type of patients requires more recovery time.

4.2.3.2 Individual Patient Factors

Talking to surgeons, we learned that the best ways to look for patient variability are by patient age and comorbidities. Other variables include: 1) Length of surgery; 2) ASA level[4]; 3) Discharge type (whether the patient got admitted or not). This kind of analysis is generally out of scope for this thesis, and should be considered as a continuation project.

4.3 Simulated PACU Utilization

In order to inform the decision about the optimal location for RPPR patients to recover, we simulated a scenario where all RPPR patients remain at the PACU for their entire recovery period. This simulation allowed us to evaluate an optional policy considered by the hospital – to keep RPPR patients in the PACU and not admit them to inpatient floors (unless it is required due to clinical complications).

One upside of this policy is the potential to free inpatient beds that will no longer be occupied by (or reserved for) RPPR patients. Another advantage is the likelihood that the overall LOS will be lower on average for RPPR patients (details to support this hypothesis are discussed in Chapter 3). The main downside of this policy is the potential disruption to

[4] *ASA physical status classification system* is a six-category system used for assessing the fitness of patients before surgery.

the PACU and to the Operating Rooms schedule. If more RPPR patients will stay in the PACU for the full durations of their recovery process, the PACU might run out of available beds for patients coming out of surgery.

Figure 12 below presents that distribution of number of RPPR patients in the PACU, by hour of the day, assuming no RPPR patients were transferred out of the PACU. The data used is between January-June 2014.

It should be noted that in generating the simulation, we assumed that the LOS remains the same if patients remain in the PACU during their entire post-surgery hospital stay, or is transferred to a floor. That is a stringent assumption, as there is a high probability that patients would be discharged earlier (thus, shortening their LOS) if they were to stay only at the PACU (see discussion in Chapter 3).

Results suggest that if all RPPR patients were kept in the PACU and never sent to floor beds, the burden on the PACU will be significant throughout the day. For example, around 8am when the first surgical patients typically get to the PACU, there will be an average of 15 occupied beds.

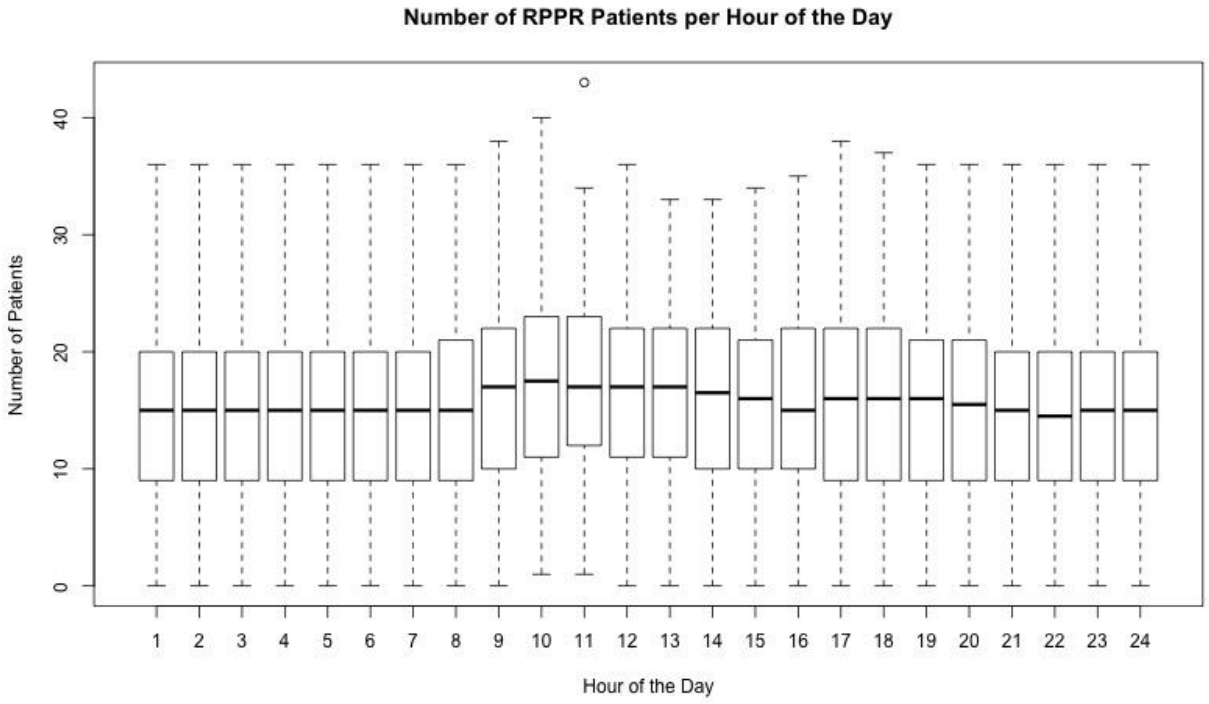

Figure 12: Simulated PACU capacity (January-June 2014)

5 Operational Recommendations

After establishing the current state of operations related to RPPR patients, we applied the methodology described in Chapter 4 to generate operational recommendations for MGH. This chapter will describe the recommendations, as well as their anticipated impact on key metrics such as patient Length of Stay (LOS).

Recommendations focused on a number of different aspects of the hospital operations, including:

- How should each group determine the preferred booking category?
- What is the preferred time during the day to perform a specific surgery?
- Should a patient stay in the PACU for recovery or be transferred to a floor bed?

In order to improve the operational metrics, we recommended that physicians benchmark their decisions related to recovery process with each other, when it is applicable. This was key especially in cases where we identified superior practices that consistently led to faster patient discharge, without clear differences in the clinical outcomes.

Recommendations are described in this thesis the way they were delivered to the hospital - bundled to the relevant procedure group (as described in chapter 4). This chapter describes the recommendations for a selected set of procedures that we found to be the most influential on hospital operations if implemented. Most influential are procedures that booked at least 50 RPPR patients annually.

5.1 Group 1 - Head and Neck

All the procedures in this group are performed by the General Surgery Department at MGH. Out of the procedures in the group, we identified three that can benefit from operational changes.

5.1.1 THYROIDECTOMY TOTAL[5]

Total Thyroidectomy is the surgery with the most RPPR patients per year, reaching a total of 344 in 2014 alone, and an average of 6.1 RPPR patients booked per week. Therefore, it was a main focus of our study. Surgeons use different Total Thyroidectomy techniques (that usually vary by level of invasiveness) which impact the length of recovery. More invasive procedures require a calcium check 24 hours post-surgery, which creates the need for an overnight stay. Some less invasive techniques do not require the calcium check and patients can be discharged the day of the surgery, if their clinical status allows it. Observations are presented in the graph below, using number of patients booked under different categories by specific surgeons.

[5] Procedure code: THYROIDT

Figure 13: Percent of Total Thyrodectomy patients stayed overnight by surgeon and booking category (2010-2014)

More than 95% of patients stay overnight at the hospital after Total Thyroidectomy. All surgeons have typical booking practices, and use mostly RPPR or SDA, even though the rates of overnight stay for RPPR patients are 100% for patients of all surgeons other than Surgeon C.

An exception is Surgeon C who is able to identify with some success patients who can potentially be discharged the same day and books them as Ambulatory. Even then, 23% spend the night at the hospital.

Recommendations:

- There is a small number of Total Thyroidectomy patients who can be discharged the day of the surgery, as is shown in Surgeon C's practices. Surgeons should make an effort to identify those patients and book them as *ambulatory*. It could be useful for the surgeons to discuss and put together a list of key traits that would help them better identify those patients with high chances to be discharged the same day.
- After identifying potential *ambulatory* patients, book all other Total Thyroidectomy patients as *SDA*. In case there are insurance or other considerations that do not allow booking as *SDA*, the use of RPPR is appropriate in this case in order to signal the relevant hospital entities that this patient will need a bed.

5.1.2 PARATHYROIDECTOMY[6]

Results are presented in the graph below, indicating the percentage of patients who stayed overnight after the surgery, according to booking category and surgeon.

[6] Procedure code: PARATHY

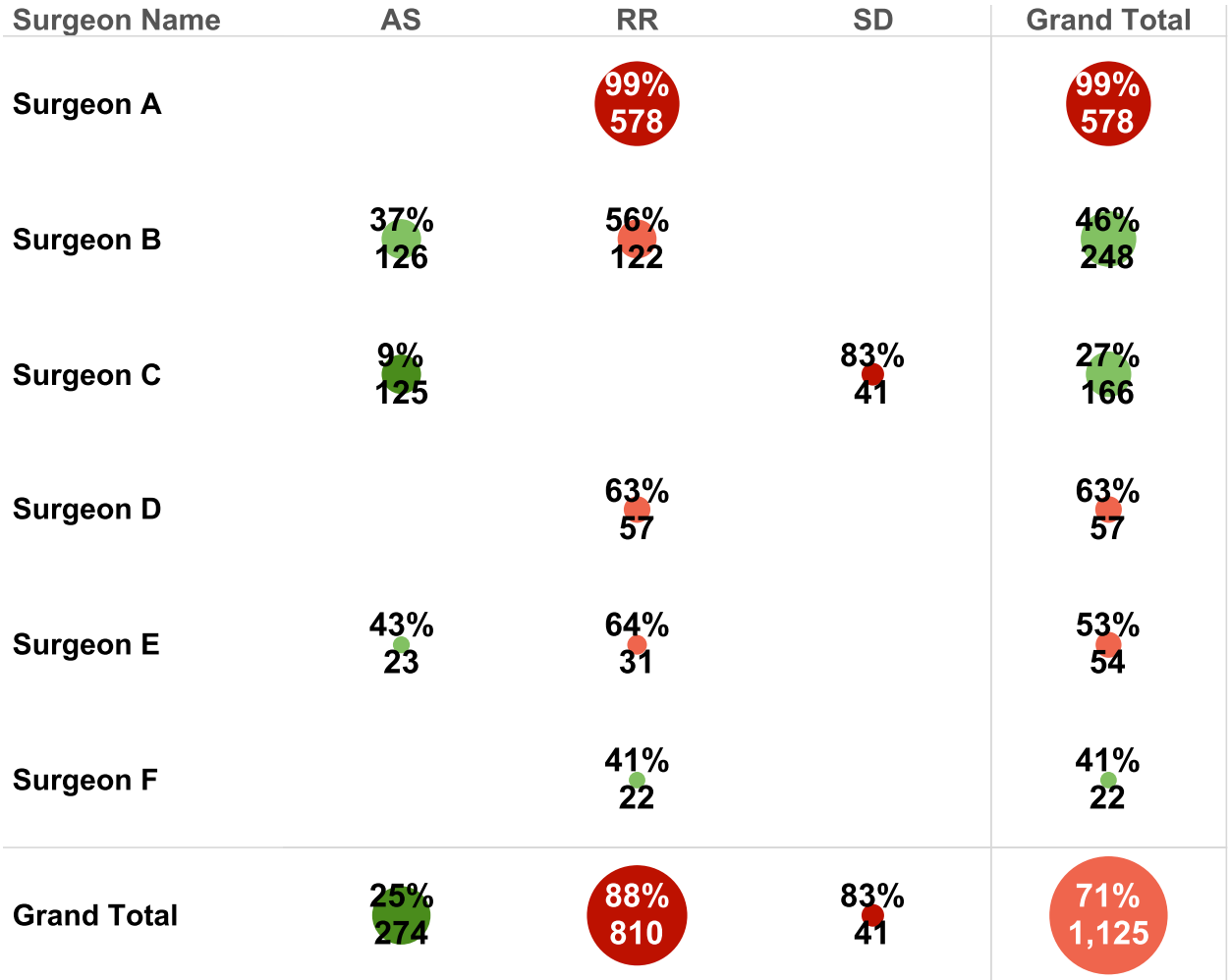

Figure 14: Percent of Parathyroidectomy patients who stayed overnight by booking category and surgeon; only shows 20 patients or more (2010-2014)

In this procedure there is an average of 3.2 patients booked as RPPR per week. There is a high variability in booking categories and a range of booking categories amongst surgeons. Moreover, between 2010-2014, some surgeons booked their patients under different categories for the same surgery.

In addition, patients of specific surgeons are likely to go home the same day, regardless of the booking category. For example, only 41% of the RPPR patients operated on by Surgeon F spent the night in the hospital. Still, Surgeon F books all his Parathyroidectomy patients

under RPPR. An opposite example is Surgeon A - where 99% of the patients stay overnight, and still – they are all booked under RPPR.

Surgeons differ not only by booking strategies and post-procedure recovery orders, but also in clinical and surgical practices (the method in which the surgery on performed). In this case, Surgeon A practices a more invasive technique, which requires longer period of recovery and monitoring. Therefore, it is his practice to keep almost all patients (99%) overnight.

Recommendations:

- When clinically appropriate, book surgical patients for this procedure as Ambulatory, and discharge them home the same day. This will reduce the load on general floor beds assigned to RPPR patients in this procedure group. In previous chapters, we discussed the possibility that the booking category impacts the LOS, therefore it is likely that booking them as Ambulatory will reduce the LOS and chances for overnight stay.
- We recommend that the surgeons compare practices to establish a common best-practice. This aims to reduce the significant differences between the LOS of different surgeons' patients. An example of an appropriate use of booking categories and recovery strategies is in the case of Surgeon C. He books most of his patients as *ambulatory*, and indeed 91% of them are discharged home the same day. 83% of the patients he booked as *SDA* patients indeed stay overnight. 54% of the RPPR patients stay overnight, which could possibly be reduced by implementing our first recommendation.

5.1.3 THYROID LOBECTOMY & HEMITHYROIDECTOMY[7]

An average of 0.8 patients per week were booked as RPPR for this surgery between 2010-2014. As shown in Figure 8 below, there is high variability in booking categories amongst surgeons. Some surgeons (e.g., Surgeon D) book patients mostly as RPPR, while others book more than half as Ambulatory (e.g., Surgeon C). As expected, patients of surgeons who book more RPPR patients (vs. Ambulatory) are more likely to stay overnight in the hospital.

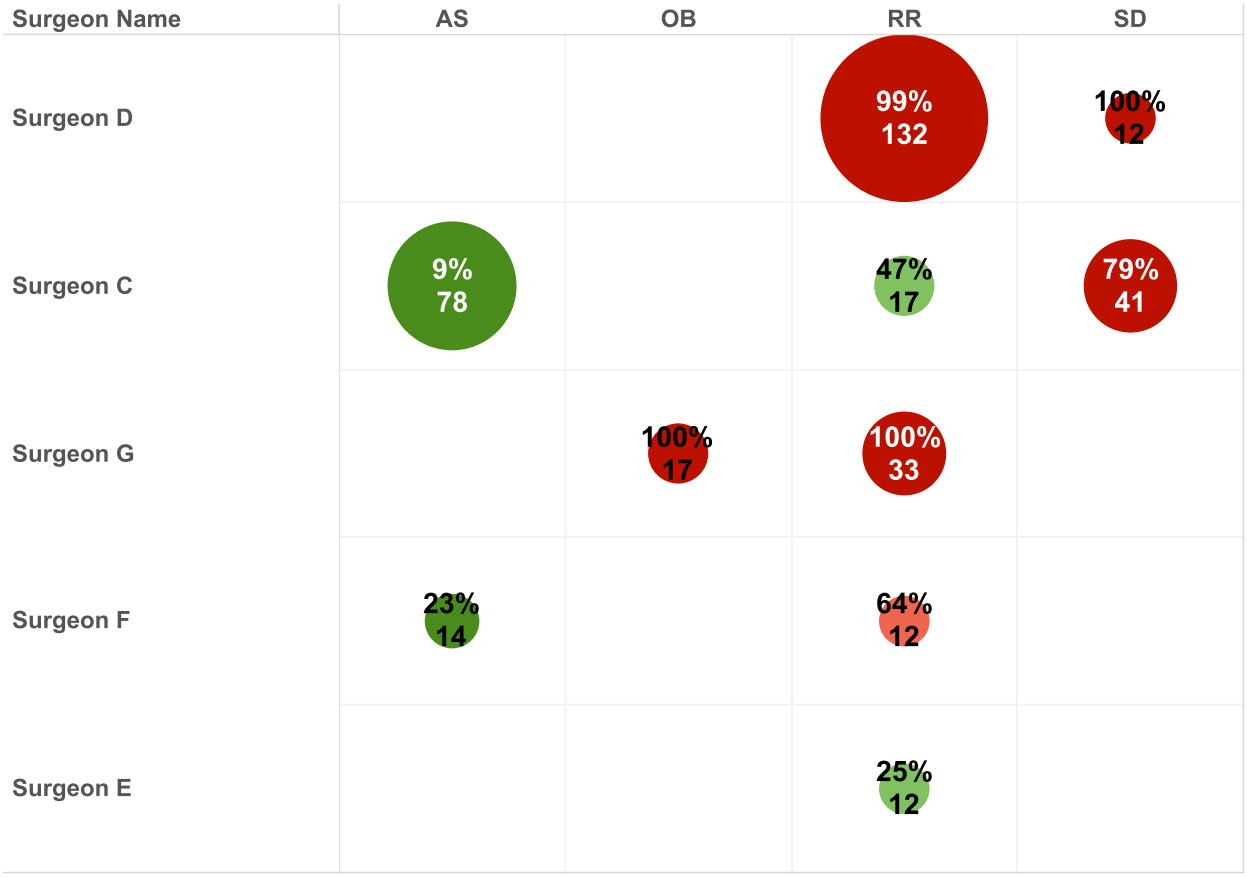

Figure 15: Percent of THYROID LOBECTOMY & HEMITHYROIDECTOMY patients stayed overnight by booking category and surgeon; only shows 10 patients or more (2010-2014)

[7] Procedure codes: THYLOBE and HEMITHYR

Recommendations:

- Compare surgeon practices to establish best practices, that will enable speedy recovery and as fast a discharge as clinically possible. The chart below presents an opportunity for such a comparison between two surgeons. Surgeon A's patients will most probably be discharged home the day of the surgery, while Surgeon B's patients have over 95% probability to stay overnight.

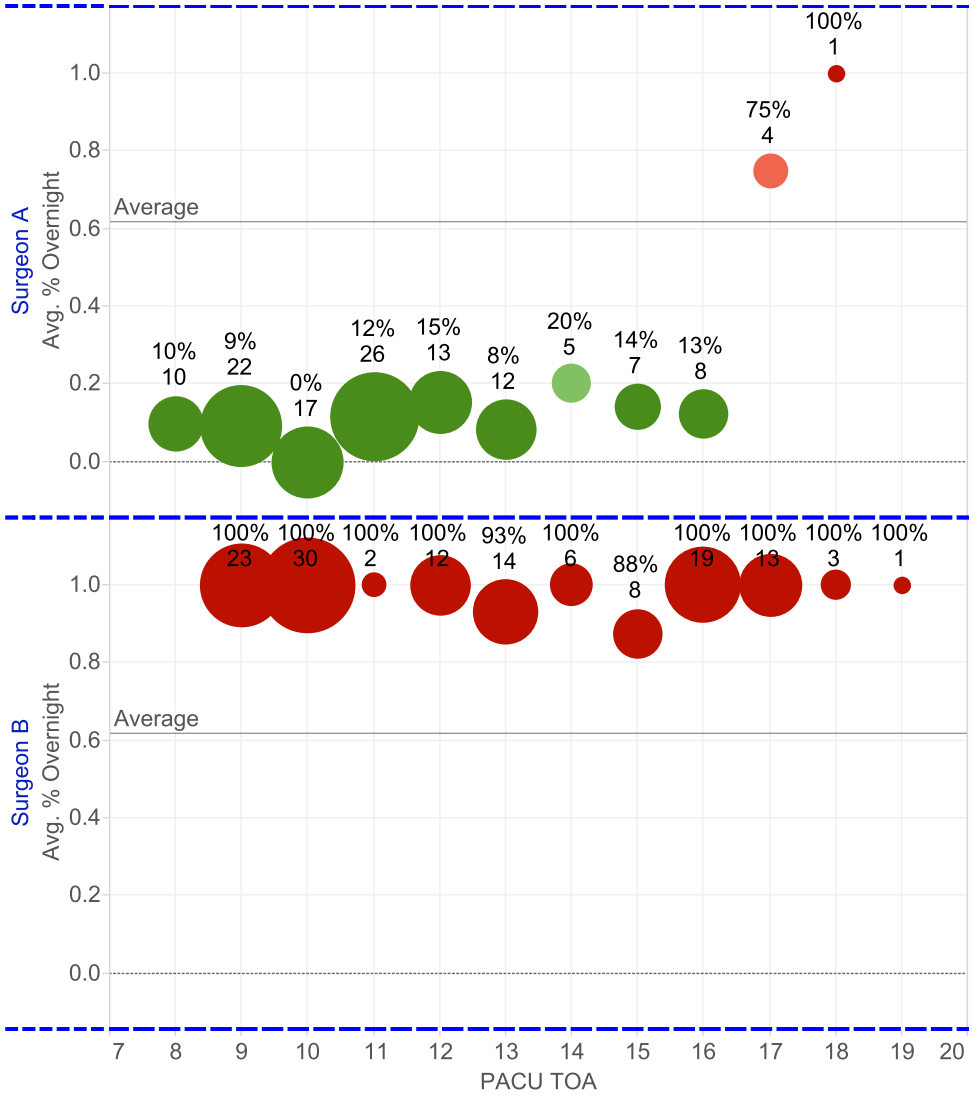

Figure 16: PACU Time-of-Arrival vs. average percent of RPPR & Ambulatory patients stayed overnight (2010-2014)

5.2 Group 2 - Breast

This group of procedures includes breast surgeries, and is performed by the Plastic Surgery Department. In this group, we recommended changes in two procedures: Bilateral Mammoplasty and Breast Lumpectomy with Needle Localization and Sentinel Node Biopsy.

5.2.1 BREAST REDUCTION (MAMMOPLASTY), BILATERAL[8]

An average of 1.5 Breast Reduction patients were booked as RPPR patients per week.

The graph below presents the number of patients booked under different categories, by surgeon.

[8] Procedure code: MAMMORED

Surgeon Name	AS	OB	RR	Grand Total
Surgeon A2	50% 5	80% 5	88% 151	87% 161
Surgeon B2	11% 9	100% 6	50% 122	49% 137
Surgeon C2	90% 10	100% 28	95% 23	96% 61
Surgeon D2	29% 21		54% 13	38% 34
Surgeon E2	50% 5	100% 5	100% 15	92% 25
Surgeon F2			100% 13	100% 13
Grand Total	42% 50	98% 44	74% 337	73% 431

Figure 17: Percent of BREAST REDUCTION (MAMMOPLASTY), BILATERAL patients stayed overnight by booking category, for 6 with highest number of patients; only shows 5 patients or more (2010-2014)

Most surgeons booked the majority of their patients as RPPR, but were able to identify some specific patients with potential to be discharged the same day and booked them as *ambulatory*. An exception is Surgeon D2 who booked most of his patients as *ambulatory*.

The probability to stay the night at the hospital varies amongst surgeons. Some surgeons have a discharge rate of more than 50% of the patients at the same day (such as Surgeon D2 and Surgeon B2), and other have a high rate of overnight stays (such as Surgeon A2).

The chart below presents the RPPR and *ambulatory* patients of Surgeons B2 and D2. It shows the number and average percentage of patients who spend the night at the hospital by the time of arrival to the PACU post-procedure. Surgeons B2 and D2 were chosen as they are the surgeons whose patients are the most likely (more than 50%) to go home at the same day. From this analysis, we infer that there is a higher probability that patients who arrive to the PACU early in the day will be discharged the same day. For example, 74% of patients who arrive to the PACU before noon are discharged from the hospital that same day.

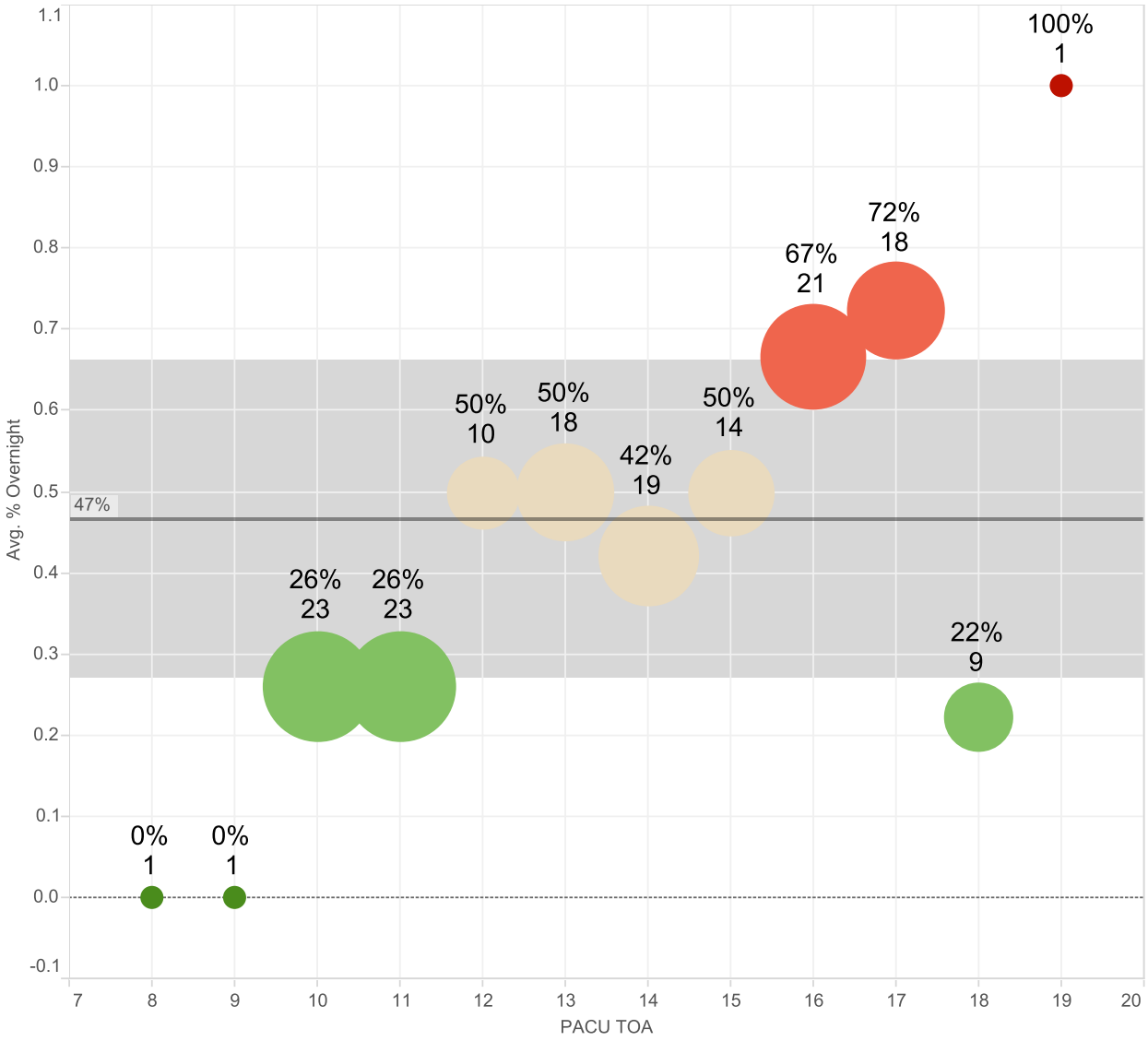

Figure 18: Number and average percentage of RPPR and Ambulatory patients of Surgeons B2 and D2 who spent the night at the hospital, by the time of arrival to the PACU post-procedure (2010-2014)

Recommendations:

- Difference in the probability for a patient to stay overnight amongst surgeons stems from difference in clinical practices. Therefore, the appropriate booking category should be determined according to the specific surgeon. Some surgeons should book their patients as *ambulatory*, unless clinically inappropriate. Such is the case with

Surgeon D2 and Surgeon B2, whose rates of patient overnight stay are 38% and 49% respectively.

- When scheduling surgeries, RPPR patients should be booked early in the day to increase their chances of being discharged home that same day.

5.2.2 BREAST LUMPECTOMY WITH NEEDLE LOCALIZATION & SENTINEL NODE BIOPSY[9]

An average of 0.6 patients are booked as RPPR for this surgery, weekly.

The chart below presents the percentage of patients who stayed overnight out of the total number of patients booked under different categories, by surgeon.

[9] Procedure code: BRLUNLSN

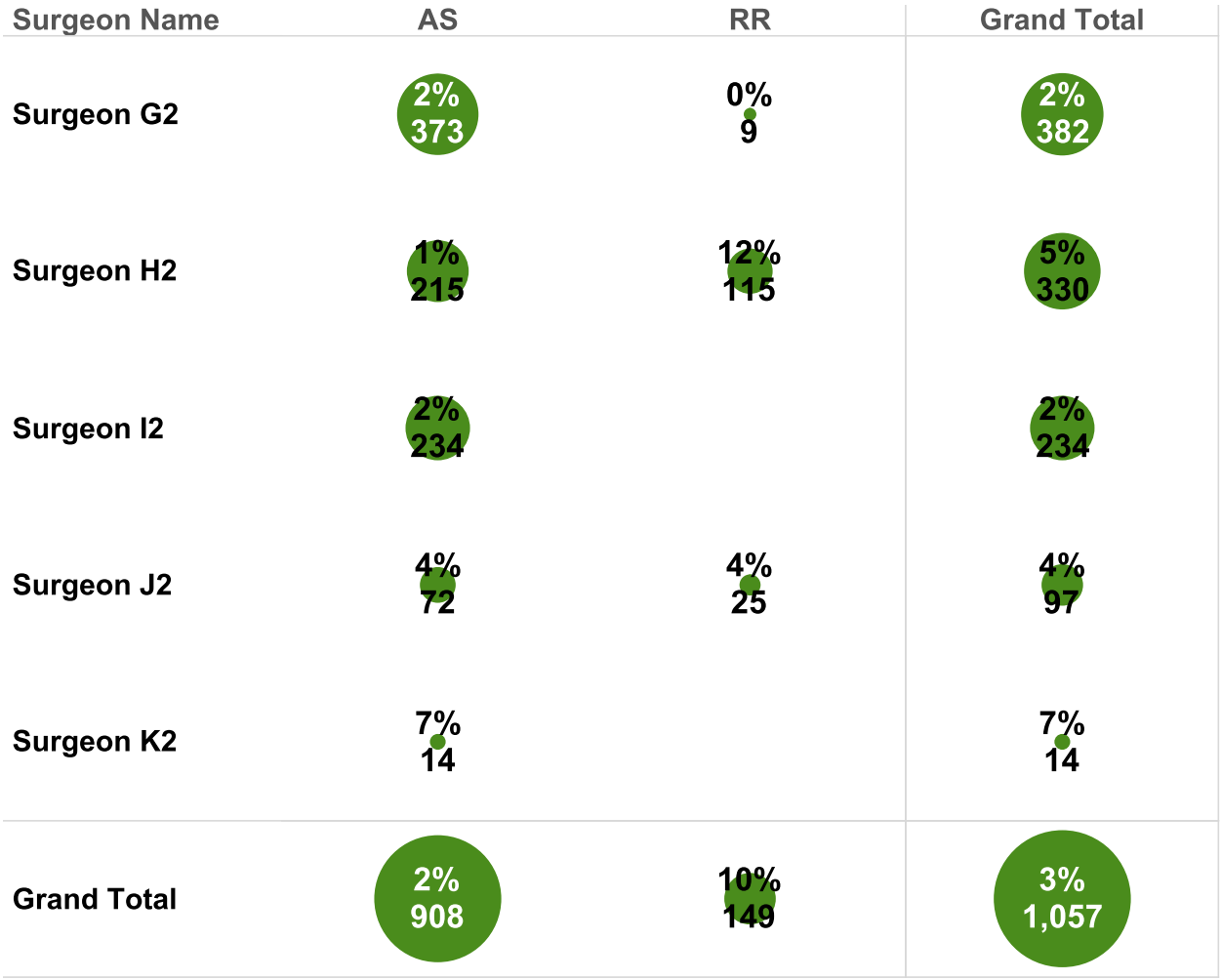

Figure 19: Percent of BREAST LUMPECTOMY WITH NEEDLE LOCALIZATION & SENTINEL NODE BIOPSY patients stayed overnight by surgeon and booking category; only shows 5 patients or more (2010-2014)

The vast majority of the patients are booked as *ambulatory* for this procedure. Out of the patients booked as RPPR, only 10% eventually stay overnight.

It should be noted that in recent years there was a decrease from 65 RPPR patients booked on average per year in 2010-2011 to 11 per year in 2012-2014, with the main driver was an adjustment in Surgeon H2's booking practices.

Recommendations:

- We recommend that patients will be booked as *ambulatory*, unless the surgeon estimates that due to specific patient special needs they will have to stay overnight.

5.3 Group 3 - Laparoscopic Cholecystectomy

There are three different types of procedures related to Laparoscopic Cholecystectomy. These types of procedures differ in patient populations and are performed by different surgeons. In our recommendations, we focused on one of the procedures (LAPAROSCOPIC CHOLECYSTECTOMY), which has the highest number of RPPR patients.

5.3.1 LAPAROSCOPIC CHOLECYSTECTOMY[10]

To generate accurate and relevant recommendations, we divided the surgeons into four groups, according to the types of patients: General, Churchill, Pediatric and Transplants. The recommendations below are applicable to the General group. Patients in other groups tend to have special needs and their recovery process is generally longer and more complex.

An average of 2.3 patients were booked as RPPR per week.

There is high variability amongst surgeons in booking categories and probability of overnight stay. An interesting observation is presented in the charts below, showing the probability of an overnight stay for RPPR and Ambulatory patients of Surgeon A3 (Figure 22) and the rest of the General Surgery team (Figure 21). The probability that a patient will stay overnight is significantly lower for Surgeon A3 (7%) than others (28%).

[10] Procedure code: CHOLAPAS

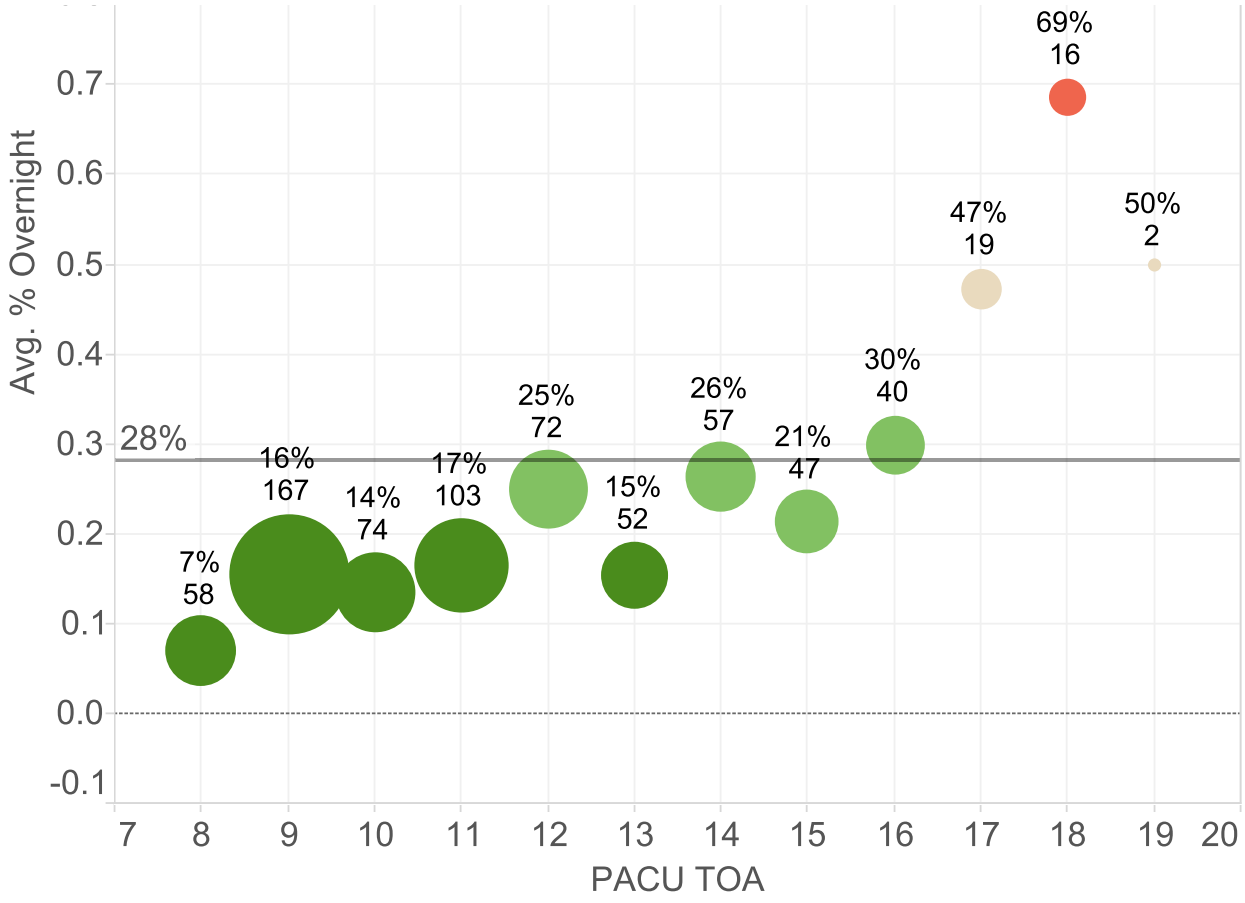

Figure 20: Overnight stay of RPPR and Ambulatory patients of Surgeon A3 who stayed up to one night in the hospital (2010-2014)

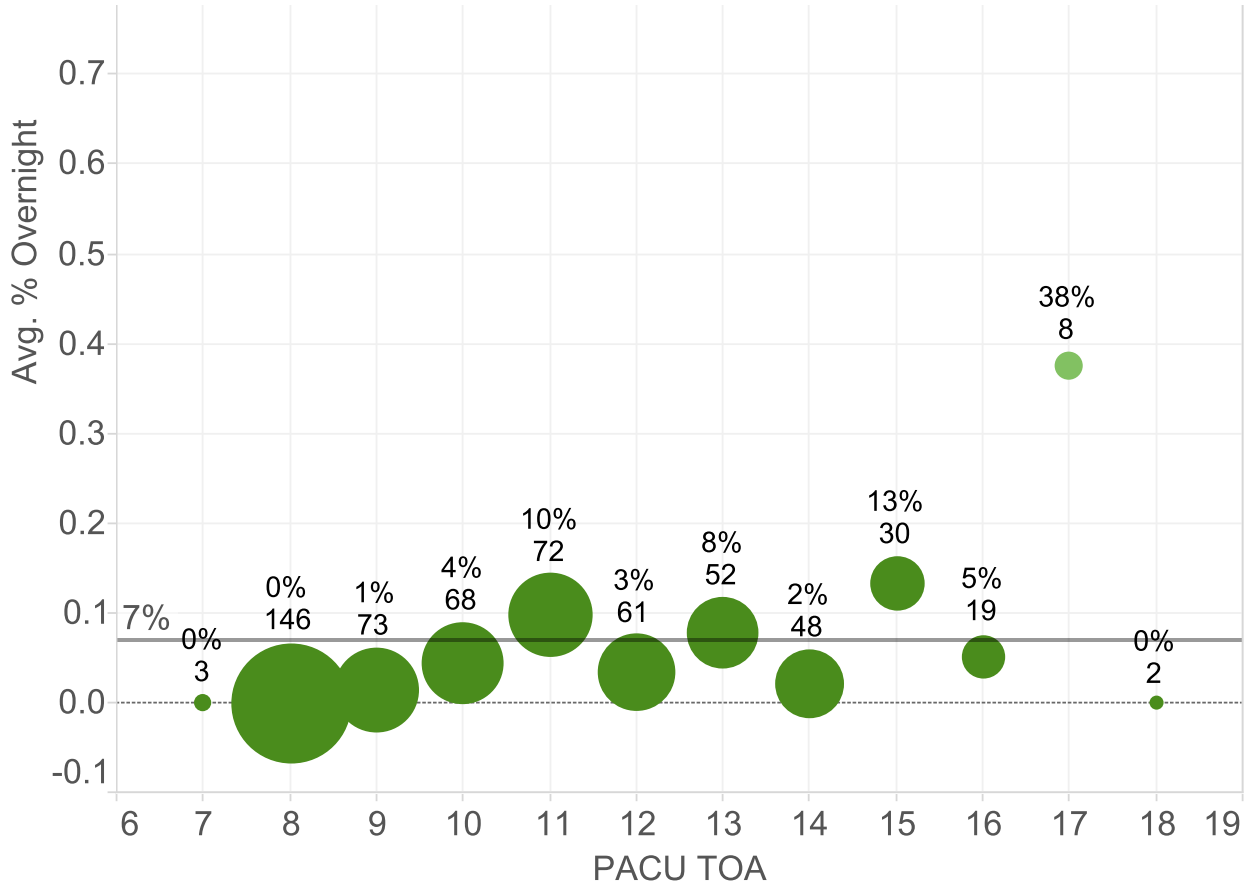

Figure 21: Average overnight stay of RPPR and Ambulatory patients of the General team, without Surgeon A3, who stayed up to one night in the hospital (2010-2014)

The chart below presents the probability of an overnight stay at the hospital by time of arrival to the PACU after the surgery, for RPPR patients of the General surgeons group. It indicates that there is a strong correlation between time-of-arrival to the PACU and probability to stay overnight. For example, RPPR patients who arrive at the PACU before noon have less than 26% probability to stay the night. That is in contrast with patients who arrive after 3pm, who have a probability of 68% and above to stay overnight.

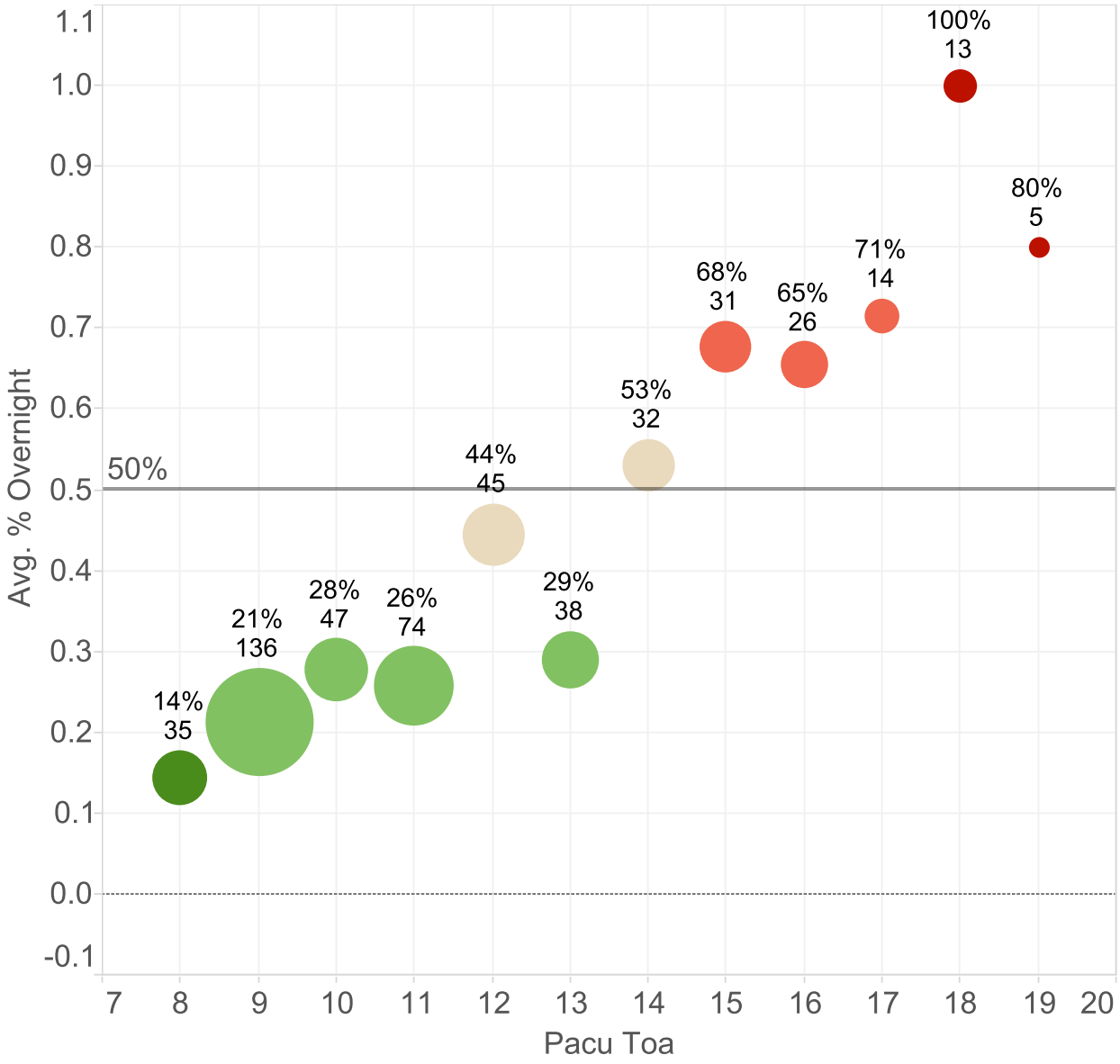

Figure 22: Overnight stay at the hospital by time of arrival to the PACU post-surgery, for RPPR patients of the General surgeons group (2010-2014)

Recommendations:

- Book as *ambulatory* unless clinically inappropriate. Data shows that most patients can be discharged the day of the procedure. Furthermore, efforts can be made to further reduce the probability of an overnight stay, as in the case of Surgeon A3's practice, whose average of overnight patient stay is 7%. A change to that extent would demand

adjustments in clinical practices and should be executed after discussion of best practices.

- Surgeons should make an effort to book Laparoscopic Cholecystectomy early in the day to increase the patient's probability to be discharged that same day. Preferably, the time of arrival at the PACU should be any time before 2pm.

5.4 Group 10 - Neuro Pulse Generator

This group contains four procedures, all different aspects of Internal Pulse Generator (IPG) management. There are two surgeons performing all surgeries in this group, one of them performing the vast majority of surgeries. Due to the similarities between the procedures in the group, the chapter describes recommendations for the four combined.

Procedure names and codes:

- IPG Placement (procedure code: PGBAT)
- IPG Battery Replacement, Bilateral (procedure code: IPGBCB)
- IPG Battery Replacement (procedure code: IPGBTR)
- IPG Replacement (procedure code: IPGREP)

Between 2010-2014, an average of 1.2 patients were booked as RPPR for these surgeries per week.

The chart below presents the number of patients booked for each category, by surgeon and the probability of each for an overnight stay. Data shows that Surgeon A10 generally booked his patients as RPPR, while only 15% of them actually stayed overnight. Surgeon B10 booked most patients as Ambulatory.

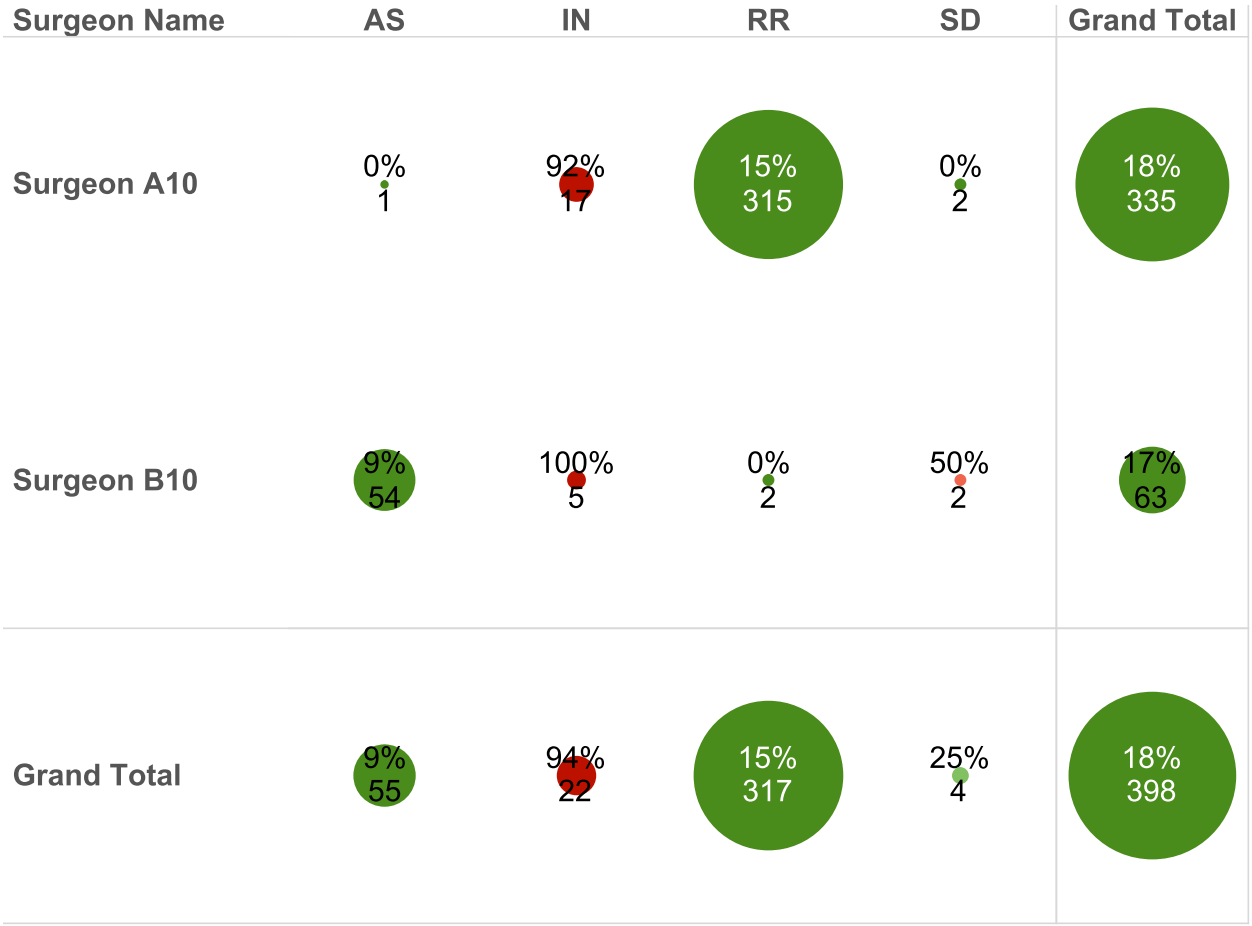

Figure 23: Number of patients booked for each category, by surgeon and the probability of each for an overnight stay (2010-2014)

Data presented in the graph below, shows the probability of an overnight stay by time of arrival at the PACU post-surgery, by procedure, for Surgeon A10's RPPR patients.

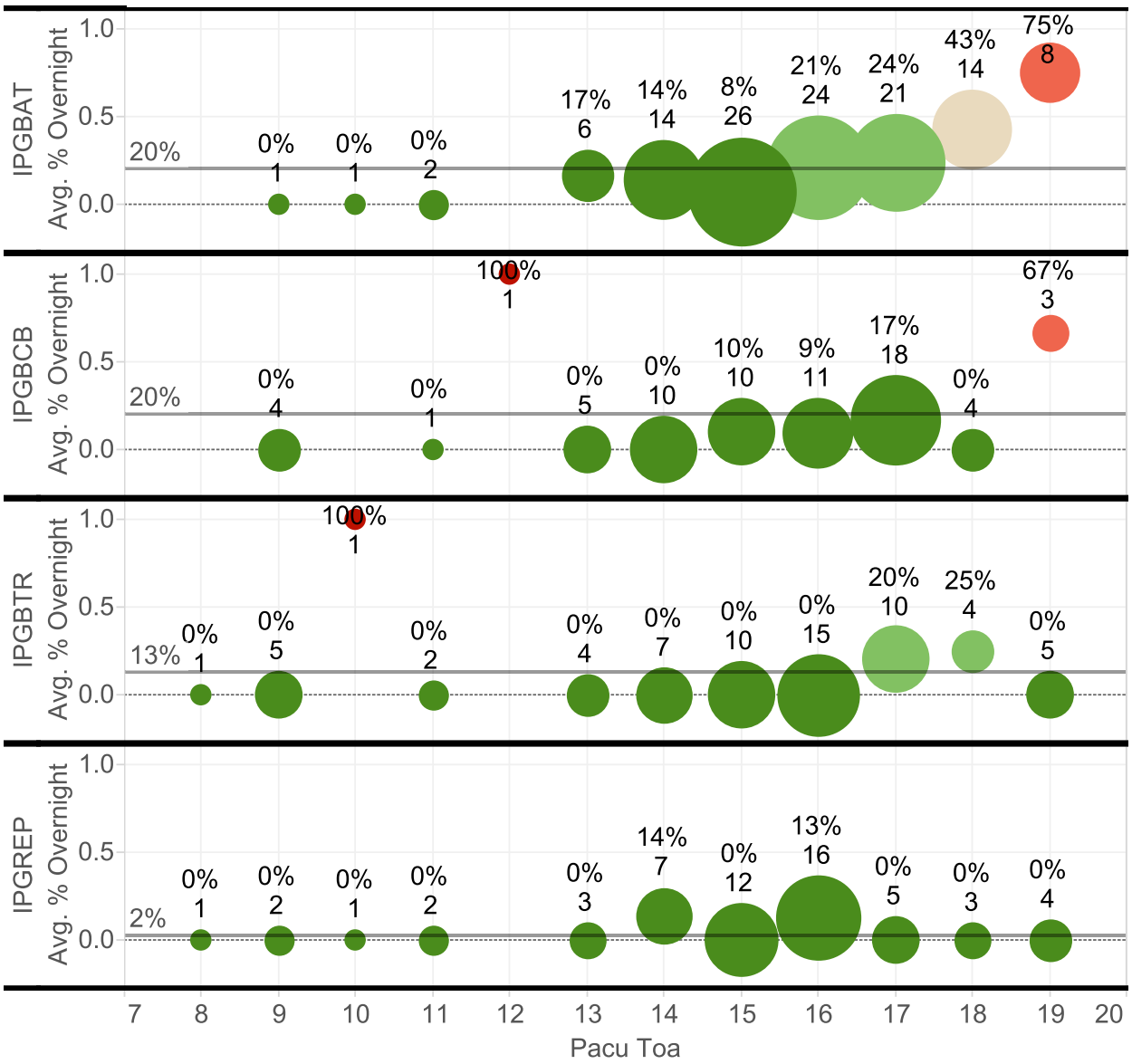

Figure 24: Probability of an overnight stay by time of arrival at the PACU post-surgery, by procedure, for Surgeon A10's RPPR patients (2010-2014)

In each of the 4 procedures, 80%-98% of the patients were discharged home on the day of the surgery. Patients who arrive at the PACU after 6PM have a higher probability to stay overnight. For example, patients undergoing IPG Placement (code: IPGBAT) who arrive at the PACU after 6pm have more than 43% probability to stay the night. However, if they arrive at the PACU any time before 6pm have less than 24% probability to stay.

Recommendations:

- Book all procedures as *ambulatory* unless clinically inappropriate. This is true for all four procedures, as rates of overnight stay are consistently low.
- Schedule procedures early in the day. Surgeons should make an effort and prioritize patients by length of surgery so that most if not all patients arrive at the PACU before 6PM.

5.5 Group 20 - Plastic / Soft Tissue

This group includes all plastic and soft tissue surgeries. From this group, the procedure with most significant amount of RPPR patients (0.9 RPPR patients weekly on average) was Excision of Lesion / Mass / Cyst.

5.5.1 EXCISION OF LESION / MASS / CYST[11]

As presented in the chart below, out of 1303 patients undergoing this procedure in 2010-2014, 243 were booked as RPPR. This comes to an average of 0.9 RPPR patients per week.

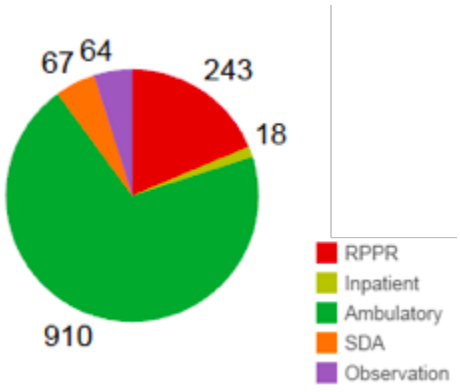

Figure 25: Booking category distribution (2010-2014)

[11] Procedure code: EXCLESIO

The chart below presents the percentages of RPPR, Ambulatory and SDA patients stayed overnight by booking category, for each surgeon with more than 50 such patients between 2010-2014.

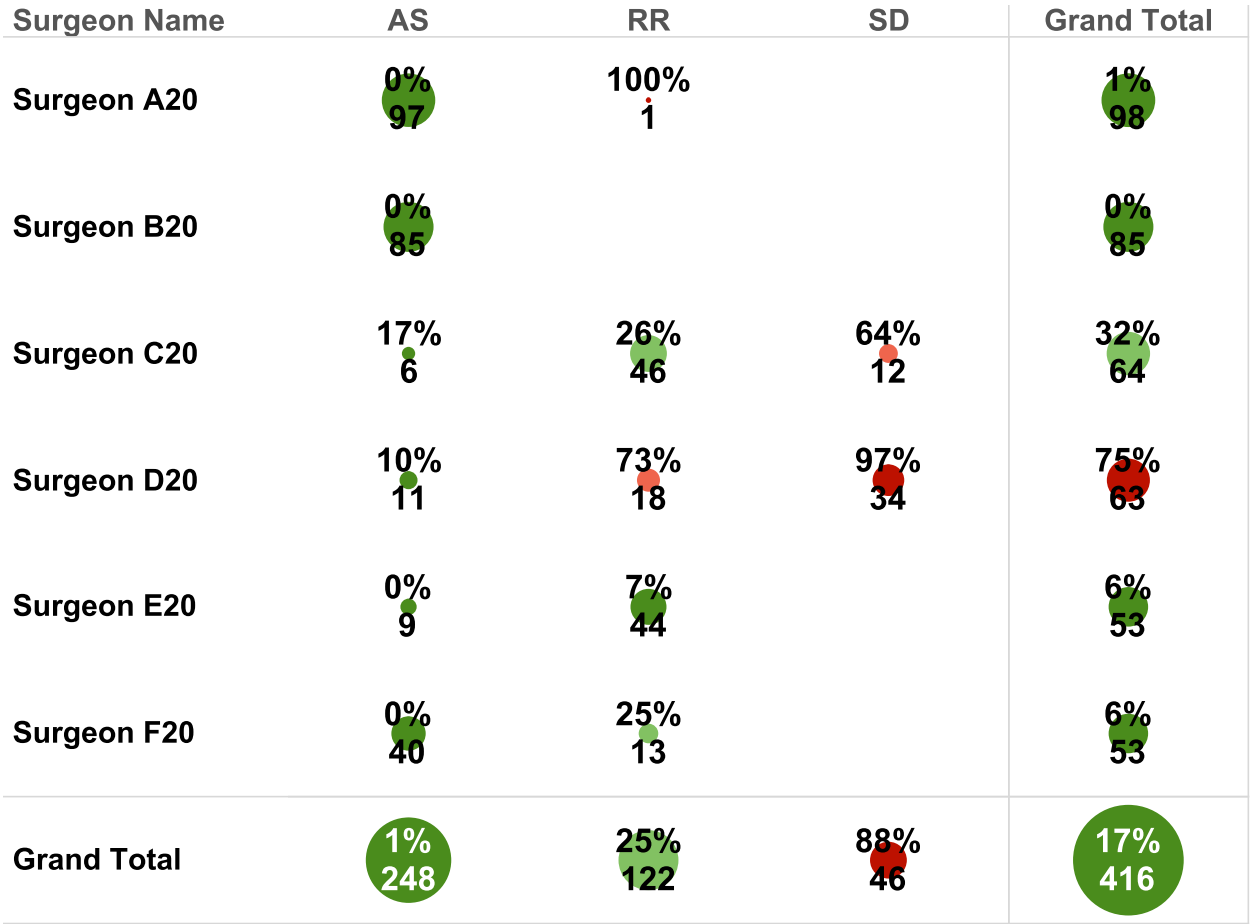

Figure 26: Percentages of RPPR, Ambulatory and SDA patients stayed overnight by booking category, for each surgeon with more than 50 such patients (2010-2014)

Most surgeons book the majority of their patients as Ambulatory. An exception worth mentioning is Surgeon E20 who books most of his patients as RPPR although 94% of them are eventually discharged the same day. Another exception is Surgeon D20, who books most of his patients under *SDA*, and indeed 71% of all his\her patients stay overnight.

On average, only 25% of the RPPR patients stay overnight. In the grand total - only 17% of the RPPR, *ambulatory* and *SDA* patients eventually needed a hospital bed, with the majority of the patients staying overnight being operated on by two of the surgeons.

Recommendations:

- Book all patients as *ambulatory* unless clinically inappropriate.

6 Future Work and Conclusions

6.1 Future Work

In the following subsection we will describe additional work we recommend to be performed, either by MGH or as future research. Such potential next steps include:

1. **Robust simulation of PACU capacity over time**: The decision of whether to keep patients in the PACU overnight or send them to the floors is influenced by PACU capacity. The PACU must be ready to check-in patients after surgical procedures, including the first surgeries of the morning. A simulation of the PACU capacity over time, including all types of patients, will allow MGH to make an informed decision regarding when to keep patients in the PACU overnight, as well as exploring potential future initiatives of creating and expanding recovery areas in the hospital.
2. **Model alternative RPPR location flows**: The implications of redefining the flow of RPPR patients throughout the hospital include reducing patient LOS, reducing the number of hours floor beds are reserved unnecessarily, and reducing expenses for the hospital. In modeling the different alternatives for recovery locations, we can search for the approach that is most efficient in one or more of these aspects. Another reason to create such a model would be to test if a dedicated recovery space for RPPR patients is operationally and financially reasonable.
3. **Analyze wasted bed-time**: Inpatient floor beds are a scarce resource in the hospital, and should be at high utilization. In some cases, inpatient floor beds are assigned and ready for RPPR patients to use, but patients are eventually discharged straight from the PACU, never to use the bed. Currently, rather manual measures are

taken to alleviate this issue, such as trying to estimate whether an RPPR patient will actually use the bed assigned, and to prioritize other patients if necessary. By analyzing the time in which floor beds are waiting for RPPR patients, we can understand the waste created in the system and take steps to reduce it. This is related to work done by Hiltrop [12] and McNichols [13].

4. **Transform surgery scheduling**: Past efforts have been made to improve OR scheduling in the hospital by MGH-MIT collaboration team. Considering some of the links found in this thesis between LOS and time of surgery, we propose a project that will optimize the scheduling of operations within and across surgical blocks. Such project can recommend scheduling guidelines to the different surgical services, or even form the basis for an OR scheduling system.
5. **Create a predictive model for patients' length of stay in the hospital**: A predictive model can be created in order to estimate patient LOS before the time of surgery. Such estimation will help the Admitting Department to accurately designate recovery locations in a way that will optimize the use of hospital and PACU beds. An addition to such a model would be to allow real time updates in different stages of the recovery, e.g. if the surgery had a complication or the patient had an unexpected result to a medication.

6.2 Conclusions

We learned that at MGH, the patient is really the center, and giving the best care possible is truly the main mission. It shows in every day-to-day decision. As a strong hub for clinical expertise and research, MGH views operational efficiency as key to the hospital success in providing excellent patient care.

This project dealt with a patient population that is operationally challenging for the hospital. In doing the research and analysis, we revealed a great deal of previously unknown or undefined insights about this population. We received much help and support from clinical and administrative staff members, who realize that operations around RPPR patients can be improved, and were eager to assist us in doing so.

In addition to the research, the team proposed operational changes in the hospital. We met with surgeons, nurses, and others to present our recommendations for change, and received generally positive responses. Some recommendations were implemented right away, some are being implemented at the time of writing this thesis, and some are expected to be implemented in the future as part of the overall effort to improve the operations related to RPPR patients.

If this project improves the operational efficiency at MGH, and by thus patient care, we are grateful to have had the opportunity to take part in it.

7 Appendices

7.1 Appendix 1: Data Sources

In order to collect the data and information required to generate a comprehensive analysis of the hospital operations related to RPPR patients, we mainly used two approaches: i) Shadowing and interviewing key stakeholders; ii) Extracting and aggregating data from the hospital IT and database systems.

7.1.1 Shadowing and Stakeholder Interviews

Through shadowing and interviewing relevant stakeholders, we were able to uncover some of the key challenges and bottlenecks in operational management of RPPR patients. The main goal was to gather information that cannot be gathered from data maintained in the various hospital IT systems. Shadowing took place in two areas: Operating rooms and one of the PACUs (Ellison 3).

During the day, there is an OR manager who is in charge of the ORs operational aspects. The role is fulfilled by a number of physicians who rotate on a daily basis. We joined several of the physicians on their daily shift.

PACU units and their clinical teams interact with RPPR patients. By spending several days in Ellison 3 PACU, we were able to gather key insights on the clinical, operational, and cultural aspects related RPPR patients.

In addition, we conducted interviews with various stakeholders in MGH, including from the following units:

1. Perioperative Services
2. PACU Nurses

3. Admitting Department
4. Case Management Department
5. Surgeons from a number of services

7.1.2 IT and Databases

In order to quantify different aspects of the hospital operations around RPPR patients, we have obtained and analyzed data elements related to all the surgical patients between calendar years 2010 (CY2010) and 2014 (CY2014). Some of the data was aggregated and analyzed to quantify operational metrics. Other types of data - on the patient level - were used in order to better understand the end-to-end post-surgery recovery paths. Data needed for the analysis is maintained in several different databases. These data sources provide information on patient movements throughout the perioperative care system. This includes admission times, transfer times, and discharge times through the Emergency Department, Preoperative environment, Intensive Care Units, and General Care Units. These data sources also contain basic patient information such as age, sex, admitting diagnosis, medical team, and procedures completed. Each patient has a unique patient Medical Record Number (MRN) that can be used to cross reference patient visits across data sources.

Below is a summary of IT systems and data sources:

- **OR Database**: This database contains surgery data, procedure type, dates and times of various steps in the surgical flow, and patient characteristics. The data is collected within the perioperative environment, including the ORs, the Center for Perioperative Care (CPC) and the PACU.

- **EPIC**: Since July 2014, this centralized IT system hosts the hospital-wide data regarding patient movements, medical teams, bed assignments, patient diagnoses and more. The data housed in EPIC is accessible via different systems, such as EPIC Hyperspace, Electronic Data Warehouse (EDW), and D4Q.
- **PATCOM**: Includes inpatient movements, medical teams, and patient diagnoses, until June 2014. We used this system to gather data about patient discharge dates and times during 2014.
- **CBEDS**: Contains detailed patient movements, along with bed requests and assignment. We used this system for patient discharge dates and times between 2010-2013.

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