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The Effect of Resident Training in the Operating Room

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by

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Abstract

Medical students wanting to be surgeons have a long road of training that only grows with advancing technology and an expanding range of diseases. Faced with duty hour restrictions, today's residents are experiencing a shift from the traditional training paradigm—instead of learning all basic skills in the operating room (OR), some are being developed with simulation training outside the OR. In order to create a curriculum with an effective blend between operating duties and simulation, it's important that there's an understanding of the effect of resident involvement in the OR. Then, a more accurate simulation/education curriculum can be created that will maximize quality and efficiency of training and begin to reduce adverse effects of intraoperative resident involvement (complications, time, and cost). In an effort to determine these effects at the Mayo Clinic, 324 laparoscopic cholecystectomy (gallbladder removal) cases from 2010-2013 were retrospectively reviewed. All cases were performed by one general surgeon with or without a post-graduate year three surgery resident. There were 174 cases with resident involvement and 150 without. Overall, OR time was significantly greater with a resident (88 ± 30 min versus 57 ± 22 min by surgeon only ($t_{(311)}$=10.33, p<0.0001); however, there were no differences in complications (χ^2=0.026; p=0.436). Excluding high-risk patients, there were 117 cases with resident involvement and 89 without. Again, operative duration was longer with a resident (88 ± 23 min versus 54 ± 22 min surgeon only ($t_{(192)}$=8.97, p<0.0001); but, no differences in complications were seen (χ^2=0.102, p=0.370). While a longer operative duration with resident involvement translates into larger costs, no statistically significant difference in complications is quite encouraging. Educators can now modify their simulation/education curriculum to include more laparoscopic fundamentals—potentially reducing the amount of time spent in the OR learning the basics of laparoscopy—as well as adding sessions that include common GS procedures (like LC and laparoscopic appendectomy). The addition of laparoscopic stations in assessments would also be beneficial to ensure residents are meeting competency standards before they can operate. The ultimate goal of these modifications is to create surgeons who are both efficient and effective in the OR: reducing operative duration without risking patient safety.

"Probably in the not far distant future we will crawl out of our old methods of education, as a snake sheds its skin, and reorganize a new plan." – Dr. Charlie Mayo

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Chapter 1: Introduction

Medical students training to be surgeons have a long road to achieve their goals. With advancing technology, the ever-expanding range of diseases, and the implementation of duty hour restrictions, surgical residents are forced to learn a tremendous amount of information in an extremely limited amount of time.[1] Currently, more emphasis is being placed on the efficiency of the surgical training process. To avoid spending valuable operating room (OR) time teaching and learning basic technical skills, the development of new and novel approaches to training and surgical education has become increasingly important; [2-4] the shift from the majority of resident learning occurring in the OR to simulation labs, laparoscopic task trainers, and cadaver/pig labs is becoming a monumental movement throughout surgery training programs across the country. [1,5-14]

Historically, surgical residents worked seemingly every day, all day; millennial trainees might call it the "walked up hill both ways to school" mantra. Duty hour restrictions, implemented in 2003 by the Accreditation Council for Graduate Medical Education (ACGME) and refined in 2011, forever changed general surgery (GS) residency.[15] Created to provide a safer working environment and improve patient care,[16] the ACGME restricted GS trainees to an 80-hour work week among other limitations, such as one day in seven free of patient duties and a required rest period.[15] While intuitively duty hour restrictions may seem beneficial for everyone involved—surgical residents aren't working long hours, and are therefore more rested and consequently patient care *must* be better—the literature suggests no improvement in patient experience or patient care/safety.[17-19] In addition to a lack of difference for the patient, the amount of time GS residents have to get hands-on experience in the OR has declined. [20,21]

Because residents get less experience in the OR, other modalities of education have become more prominent—most notably, simulation. The International Meeting on Simulation in Healthcare by the Society for Simulation in Healthcare and other simulation societies and conferences have been popping up across the country with the growth of institutional simulation centers and the widespread acceptance of simulation. Importantly, simulation has been shown to be positively correlated to patient-related outcomes;[22-24] in other words, simulation works and is an effective way to help trainees get more experience outside of the OR.

Ideally, a national standardized, surgical simulation curriculum would be a gold-standard, and efforts are under way to begin to develop such education.[1] In this curricula, residents would be allowed to participate in surgical procedures in the OR only after they meet pre-set criteria in the laboratory (simulation setting).[1] In addition, resident advancement would be due to competence, rather than time served.[1] Surgeons and educators at Mayo Clinic Rochester have created several low-cost, low-fidelity bench models, as well as both formal simulation curriculum and biannual objective simulation assessments for all surgical trainees.[5-7,10,11,25-27] However, Mayo Clinic seems to be unique; at the present time, few institutions nationwide have developed any sort of simulation curriculum for surgical residents.

Some research has debated resident involvement in the OR suggesting residents may influence both quality and efficiency by morbidity, mortality, and/or operating time.[28-30] However, medical literature is lacking in the area of quantifying the time spent training residents for specific procedures and the associated cost.[31,32] Because of this, it has been hard to justify the amount of time that should go into all educational aspects of surgical residency training, especially in simulation and the OR. Once there's a better understanding of the effect of resident training on OR performance, surgical educators can more accurately create a simulation/education curriculum that will maximize quality and efficiency and begin to reduce adverse effects (complications, time, and cost).

The adoption of laparoscopy in the general surgery profession has forever changed the training process; it has added difficulty and expanded the need for a specific skill set, all which must be learned during the brief course of surgical residency.[33]Laparosopic cholecystectomy, the surgical removal of the gallbladder via laparoscopy—a minimally invasive procedure—is one of the most common laparoscopic procedures performed by general surgeons[34];and therefore, a procedure that every trainee graduating from residency should be able to perform independently.

The purpose of this study was to retrospectively review charts of patients who have undergone laparoscopic cholecystectomy by one surgeon at Mayo Clinic Health Systems in La Crosse, Wisconsin, and analyze the effects of intraoperative resident involvement. The results of this study will help to inform program directors and educators on the specific outcomes of resident involvement, which they can use to improve their curriculum implementation.

Chapter 2: Review of Literature

This review of literature addresses the following topics: General surgical (GS) profession as a whole; medical model for resident education which will include the history of resident training, resident training in the 21st century, and GS resident training at Mayo Clinic; changing roles of GS residents with the introduction of laparoscopy; and the difference in outcomes with residents involved, specifically the complications, including morbidity and mortality, operating time, and cost.

General Surgery Profession

The surgical profession plays a vital role in the medical community. Surgeons "have made magnificent contributions in education, clinical care, and science."[35] Successful surgeons often possess specific qualities, such as humility, good judgment, curiosity, courage, skill, intelligence, etc.[36] However, it takes an immense amount of time and practice to become a general surgeon. It requires at least five years of GS residency training plus an added one year or more for the roughly 70% of trainees who go on to pursue a surgical fellowship.[37] On top of this, GS trainees may step out of residency for a year or more for research in an effort to "beef up" their curricula vitae and increase their chances in getting into a competitive fellowship. Additionally, with the need for continuing medical education courses, recertification, and the continuous inventions of new instrumentation and discoveries of new diseases and treatments, it could be argued that a surgeon's training never truly ends.[38]

General surgeons are specialized in nine primary components of surgery, including: (1) Alimentary tract, (2) Abdomen and its contents, (3) Breast, skin, and soft tissue, (4) Head and neck, (5) Vascular system, (6) Endocrine system, (7) Surgical oncology, (8) Comprehensive management of trauma, and (9) Complete care of critically ill patients with underlying surgical conditions.[39]

Medical Model for Resident Education

History of resident training. William Halsted, at John Hopkins, originally conceived the structure of the medical model in regards to surgical residency in 1889.[40] His idea, then, was to "have a system that, through apprenticeship, would allow a new graduate from medical school to acquire the knowledge and skills necessary to manage safely the patients who required surgical treatment."[41]

Halsted's model was aimed at "…producing one outstanding individual, making 'professors of surgery'".[40] Only eight residents were admitted the first year at John's Hopkins; four of these were one-year positions, three were not guaranteed staff surgeon positions, while one became a house surgeon.[40] The core principles of this triangular model was that the trainee, with skilled surgeon supervision, would get repetitive and intense patient opportunities, increase their knowledge of the science of surgical diseases, develop skills in patient management and technical abilities, and be responsible and independent with an increase in the complexity of patients and cases.[1]

At the height of the Halstedian training era, many national surgery organizations were created, including the American College of Surgeons (ACS), American Medical Association (AMA), and American Board of Surgery (ABS).[1] Since their births, ACS, AMA, and ABS have all been instrumental in graduate medical education (GME).

Edward Churchill, of Massachusetts General Hospital, criticized two parts of Halsted's model: (1) He felt the model did not result in properly trained surgeons and (2) the model was dependent on one individual.[40] And he wasn't the only one; objections by other surgeons were common—they wanted a defined, shorter duration of training and had a strong disdain for his pyramidal structure.[42] Churchill proposed a new model with a “rectangular structure”.[40] In this new model, only six residents were admitted; four obtained four years of training and the remaining two were kept for six years.[40] This new structure was not dependent on one outstanding individual, but rather a “group of masters”.[40] This was established as an accreditation mandate by the 1960’s; and while Churchill’s “rectangular structure” remained the core model of surgical residency training in the United States until the 21st century, it still had its flaws. It assumed that all trainees in the same class had the same intelligence, skill, and competence.[42]

Resident training in the 21st century. In the late 20th century, the “rectangular” model became stressed by technological advancements, especially the introduction and widespread use of laparoscopy and other forms of minimally invasive surgery.[1,14,40,43,44] In addition, specialties were being created to treat single diseases as the medical community was becoming more disease-oriented.[14,40,43,44] In 1982, the Accreditation Council for Graduate Medical Education (ACGME) was established.[1] The ACGME has introduced very important changes since its founding. The ACGME defined six core competencies that residents were mandated to achieve and master during their training, including medical knowledge, patient care, interpersonal and communication skills, professionalism, practice-based learning and improvement, and systems-based practice.[1,42] The focus of training started to shift to the objective evaluation of outcomes, which still holds true today.[1,45] Additionally, the ACGME mandated the organization of surgery training; for example, GS trainees must rotate through a variety of specialties including transplant, gynecology, and vascular surgery.[42]

With all of these significant changes in GS education, a national standardized curriculum was needed.[1] The Surgical Council on Resident Education (SCORE) was developed to be responsible for monitoring and improving resident education and training in surgery.[1]

Perhaps the biggest and still most talked about change in GS training came in 2003 (and further modified in 2011) when the ACGME regulated resident work hours.[1,14,40,43] Up until this point, surgical trainees were able to work as long and as frequently as needed with no requirements for time off. These new regulations caused a severe restructuring of surgery training programs.[1] With the continuation of advancing technology and the expanding range of diseases, surgical residents began to be forced into learning a tremendous amount of information in a limited amount of time.[1,37,42,46] The duty-hour restrictions caused a need for improvement in the efficiency of the surgical training process; because of this mandated decrease in time at the hospital and clinic, seeing patients, and operating, the opportunity for residents to learn must come from elsewhere. Time in the OR would be much better served learning and practicing higher-level, complex tasks rather than acquiring basic skills.[1,14] Other modalities of training needed to be created or used to aid residents in learning fundamentals, so they would be better prepared to gain the most out of OR experiences.

The ACGME requirements for surgery programs state that all should include some simulation or skills labs, although rigorous simulation education curriculums and assessments are still rare. [1,14,47] While still in its infancy, there is a push towards simulation labs, cadaver labs, laparoscopic task trainers, and low-cost bench models in surgery education. [1,5-14] Simulation provides a safe and controlled environment in which residents can make mistakes while acquiring both knowledge and skills without harming patients.[23,43,48,49] Of note, simulation has proven its effectiveness; the transfer of skills and knowledge from the simulation lab to the OR and clinic has been shown to positively affect patient outcomes.[22-24,50] A systematic review from 2013 focusing only on training in health professionals in laparoscopic surgery, authors identified 219 studies enrolling over 7,000 trainees.[50] Results showed that trainee laparoscopic skills time was faster when utilizing simulation versus no intervention or non-simulation instruction.[50] Another systematic review and meta-analysis of simulation and patient-related outcomes from 2015 analyzed 33 studies with over 1,200 participants (physicians, residents, medical students, dentists, nurses); seven of these reported a correlation with time between simulation and OR performance, which resulted in a medium pooled correlation.[23] While no specific studies have looked at simulated LC and correlation with OR performance, researchers at Mayo Clinic have found that a simulation based curriculum for totally extraperitoneal inguinal hernia repair (general surgery procedure) resulted in a 14 minute decrease in operative time.[9]

To keep all residency programs up-to-date with training, national efforts are under way to develop a standardized curriculum in which residents can only participate in surgical procedures in the OR after they meet pre-set competency standards in the lab.[1,51,52]

General surgery resident training at Mayo Clinic. Mayo Clinic in Rochester has 8-10 positions open each year for their accredited, categorical GS residency;[53] included in these 10 are three integrated tracks (thoracic surgery, community/rural surgery, and vascular surgery). In addition to the categorical residents, the program hires 10-15 preliminary GS residents. While a categorical resident is given a five-year training commitment, preliminary residents are only offered a one-year position.

Mayo Clinic GS residents rotate on different services and specialties throughout each level of training, having at least three months of general surgery each training year. During their third year of training, they spend six weeks at a rural hospital (Mayo Clinic Health Systems-La Crosse, WI) or children's hospital (Children's St. Paul Pediatric Hospital, St. Paul MN).

Every resident in each training level is required to participate in bi-annual objective structured clinical examination (OSCE) style simulation assessment events.[5-7,10,11,25-27] Residents are also mandated to go through a simulation curriculum, held once a week, for their entire first year of training. This training consists of a weekly GS topic. Residents rotate through a variety of stations, where they work one-on-one with a bench model, operate on a simulated patient performing abbreviated portions of surgical procedures, and engage in interactive didactic-based teaching sessions.[5-7,10,11,25-27] Two of these sessions focus on basic laparoscopic skills and procedures; residents perform fundamental tasks (like laparoscopic cutting and tying knots), as well as laparoscopic cholecystectomy and appendectomy. However, due to logistical difficulties (short time allotted, lack of instructors), trainees are not required to test out of any of these laparoscopic skills. Moreover, no studies have been done linking the very brief (six hour maximum) simulation training sessions with operative performance, leaving Mayo educators to only speculate on session effectiveness.

Changes in roles of general surgery residents with new surgical procedures. When the first surgeries were performed, surgeons could only operate during hours when there was sufficient daylight to see in their operating rooms. Before the days of real sterilization, visitors from other institutions were allowed in the ORs, which had mirrors above the table to provide a good view to those watching from the sidelines. Surgeons, trainees, and spectators were able to look into large incisions to get a good visualization of anatomy and disease.[54]

Fast forward to the increase of technological advancements in the late 20th century to early 21st century, residents are required to learn new skills to master less-invasive surgery; especially for GS residents, laparoscopy has become an integral part of training.

Laparoscopy. The broad and rapid embracement of laparoscopy brought the challenge of integrating new procedures safely and efficiently into surgical resident training.[55] Laparoscopy (often called minimally invasive surgery or MIS) offers unique challenges; surgeons need to learn how to operate with a limited view of the field, reduced motion and maneuvering of the tools, lack of haptic feedback, loss of depth perception, not to mention misaligned eye-hand-target axis, degraded image quality, and magnified hand tremor.[12,56] On top of these, ergonomic challenges stemming from the close proximity of instruments can't be forgotten.[57] MIS requires more experience, and with the current paradigm of surgical training, that requires more time observing, assisting/performing while under supervision, and much more practice via simulation.[58]

A simulation program was developed to aid in the practice of laparoscopy, called the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills, MISTELS.[59] The simulator was a laparoscopic trainer box in which residents/surgeons were able to complete a number of tasks ranging from basic to advanced laparoscopic skills.[59-61] To begin, each resident or surgeon reviewed a video tutorial of each task to be completed; after the video, the tasks were attempted.[59] Performance was scored for precision and speed by an instructor. The tasks completed were: peg transfer, circle cut, clip application, placement of ligating loop, mesh placement over a defect, intracorporeal and extracorporeal knot tying.[59,60] These tasks are linked to MIS procedures like hernia repair (mesh placement), vascular surgery (ligating loop), cholecystectomy (clip application); additionally, they are generalizable for many laparoscopic procedures (i.e. ability to move an object from hand to hand like peg transfer, ability to tie a knot in the cavity, etc.).

Training on the validated MISTELS simulator has been correlated with an increase in objective laparoscopic skills scores (Global Operative Assessment of Laparoscopic Skills) in the OR when assessed by the attending surgeon.[61,62] Simulator training also was found to be associated with improvements in bimanual dexterity, tissue handling, and depth perception.[60,61,63,64] Additionally, when a fundamentals of laparoscopic surgery proficiency-based curriculum was implemented, trainees scored significantly higher on both a simulator, as well as in the OR while performing a laparoscopic cholecystectomy.[60]

MISTELS became a component of the Fundamentals of Laparoscopic Surgery (FLS) program that was developed by the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) and the ACS.[60,65] Surgeons must be FLS certified to perform laparoscopic surgeries.[64]

Difference in Outcomes with Surgical Residents Involved

Understanding the consequences of resident involvement in the OR is crucial in order to determine and justify the amount of time that should go into all educational aspects of surgical residency training—both in the OR and simulation labs, didactics, etc.—as well as to create an effective curriculum to reduce the consequences for complications, operating time, and cost.

Complications. Complications patients experience are expressed as morbidity and mortality. The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) defines morbidity as the presence of at least one of the following complications within 30 days of an operation: superficial surgical site infection, deep surgical site infection, organ space surgical site infection, wound dehiscence, neurologic event (stroke or cerebrovascular accident, coma lasting more than 24 hours, or peripheral neurologic deficit), cardiac arrest, myocardial infarction, bleeding requiring transfusion, deep vein thrombosis, pulmonary embolism, pneumonia, unplanned intubation, ventilator dependence more than 48 hours, urinary tract infection, progressive or acute renal insufficiency, and sepsis or septic shock.[66] Mortality is defined as the death of the patient.

Raval et al. included 607,683 cases (234 hospitals) from 2006-2009 with resident intraoperative involvement.[66] Residents were associated with slightly increased morbidity (10.89% without resident and 11.50% with) and slightly decreased mortality (11.89% without resident and 10.99%) with in both general and vascular surgery cases. Similarly, Tseng et al. studied seven common general surgery procedures from 2005-2007, and Hwang et al. studied 2,293 patients from 2003-2006; the findings in both studies were analogous with Raval's analysis.[67,68] Tseng et al. found a 2% increase in morbidity and 0.02% decrease in mortality with resident involvement; Hwang et al. found no significant difference in morbidity (3.78% versus 5.07%) with resident involvement, but a lower mortality (1% versus 2.87%).[67,68] The morbidity may be slightly increased due to intraoperative technical complications that are more common with resident involvement, unmeasured case-mix differences, and/or increased vigilance toward identifying and recording postoperative complications by residents.[66] The slight decrease in mortality could potentially be due to a better postoperative care for patients when a resident is involved.[68]

Davis et al. argued that there was no difference in morbidity, mortality, and operative time between residents of different levels.[69] Advani et al. completed a study from 2005-2008 on resident involvement in laparoscopic appendectomies and found that complication rates were similar between residents of postgraduate years one through five, consistent with the findings of Davis.[70] Kazaure et al. studied cases involving residents with and without a scrubbed attending surgeon present in the OR.[71] It was found that the occasions in which residents were operating with minimal presence of a scrubbed attending surgeon were not associated with an increased risk of complications.[71]

In a more recent review of nearly 70,000 basic laparoscopic procedures (appendectomy and cholecystectomy), resident involvement was not significantly associated with mortality or morbidity.[72]

Operating time. The difference in operating time is an important factor to analyze when comparing resident involvement with no resident involvement. Time is money; the longer the operation takes, the higher its cost.

Davis et al. (2013) found that in nearly 80,000 cases, operative times with residents were roughly 20-47% longer; the biggest difference (47.7%) was for laparoscopic cholecystectomy procedures.[69] In addition, resident involvement in laparoscopic cholecystectomy has been associated with an increase of operating time of up to 49% of that with an attending surgeon alone.[73]

Surgical times for laparoscopic appendectomy, another basic procedure, with resident involvement were found to be 38-64 minutes, while the attending surgeons' times were 27-46 minutes.[70] When seven cases of nonemergency operations, including laparoscopic cholecystectomy, were studied from 2005-2007 the mean operating time for cases with surgical resident involvement were significantly longer (24 minutes, on average) than those without.[68]

It's agreeable in medical literature that resident participation creates additional time in the OR (although the amount differs based off of the institution being studied), but it's also important to note the difference, or lack thereof, in OR times for residents of different training levels. Wang et al. (2001) collected data from laparoscopic cholecystectomies completed under the supervision of one attending surgeon, junior residents, and senior residents; there were no significant differences in operating times among the residents of different seniorities.[74] Papandria et al. (2012) and Davis et al. (2013) concluded their study similarly; there was no significant difference between the junior and senior residents' operating times.[69,75] Other studies suggest with increasing seniority of training, operative time increases.[69,76] It could be speculated that as residents progress through their training, they become increasingly more involved in the procedures or are being exposed to more difficult or challenging cases.

Cost. Other than OR time, very few researchers have tried to quantify the cost to the hospital of resident involvement. In many studies, the cost of resident involvement is noted as lacking data; resulting in only speculative ideas about how expensive residents are to a hospital.[77] The cost of one minute of operating time is somewhat nebulous and often confidential information.

Bridges and Diamond led one of the few studies that quantified financial cost associated with resident involvement. They found that the non-supply cost per graduating resident was nearly $50,000 for operative training in the hospital alone.[32] After extrapolation to include all 1,014 GS residents in 1997, the annual cost of OR training for GS residents was $53 million.[32] Most of the hospital costs, approximately 60% of the total,[78] are acquired while the patient is in the OR.[73]

Some specialty surgery training programs have reported anywhere from $275 to over $2100 per case as an additional cost of teaching a resident while in the OR.[79,80] In a more recent analysis completed in 2016 at a teaching hospital in South Carolina, an extra minute spent in the OR cost the hospital $9.57, leading to an extra $500,000 in costs per year due to resident involvement.[29] Minimizing the amount of teaching/training that happens in the OR would be extremely beneficial, financially for teaching hospitals.

Summary

The structure of the surgical residency has drastically changed since the Halstedian era; the adoption of laparoscopy along with advancement of operative technology, diseases, and surgical training requirements have revolutionized surgical care and created a need for better, more efficient education. With this added difficulty and need for a specific skill set, residents need to become confident, capable surgeons in a shorter amount of time now more than ever. [33] However, there’s no real consensus on exactly what the effects of intraoperative resident involvement are, much less how to combat these issues using simulation or other forms of education outside of the OR. By looking at resident involvement during laparoscopic cholecystectomy, one of the most common laparoscopic procedures performed by general surgeons [34]—and therefore one that every graduating trainee should be able to independently perform—there will be a better understanding of the effect of resident training on OR performance. Surgical educators can then more accurately create a simulation/education curriculum that could maximize quality and efficiency and begin to reduce adverse effects (complications, time, and cost).

Chapter 3: Study Design

Methods

Resident involvement in the OR may influence both quality and efficiency by morbidity, mortality, and/or operating time. However, there have not been many attempts at defining the precise amount of time associated with training a particular level resident on a particular procedure.[31]

Laparoscopic cholecystectomy (LC), the removal of the gallbladder, could be viewed as an ideal procedure to analyze for the effect of resident involvement because (1) it's one of the most common, routine procedures performed by general surgeons, [34,81] and (2) the teaching model at Mayo Clinic-La Crosse creates an environment in which the resident performs the operation as the operating surgeon, while the attending physician (educator) acts as an assistant. This means that the outcomes of the surgery relative to time and complications will be directly correlated to the surgical abilities of the resident rather than attending physician. This study was accepted by the Institutional Review Board at Mayo Clinic.

Purpose

The purpose of this study was to determine whether or not resident involvement in the OR affected the outcomes of laparoscopic cholecystectomies. Specifically, the outcomes for this study are operating time and complications during and after surgery. By analyzing the effect of resident involvement, the GS program director and other surgery educators at Mayo Clinic can optimize their surgical simulation/education curriculum to create a more efficient and effective model of training.

Hypotheses

The following research hypotheses were tested in this investigation:

1. There will be an increase in operating time when residents are involved in LC procedures which translates into an increase in cost for both the patient and the hospital.
2. There will be more complications when residents are involved in LC procedures.

Limitations of the Study

1. The amount of resident involvement in each procedure is subject to change on a case-by-case basis and was not quantified or recorded.
2. Because this study is specific to one laparoscopic procedure, the results may not be applicable to other, more involved, procedures.
3. Because this study is specific to one institution's training program, the results may not be applicable to other institutions or training programs.

Assumptions

When residents are involved, they act as the operating surgeon under supervision of the attending surgeon (who acts as an assistant). This assumption is based on interviews with the attending surgeon, who has completed all the cases in this study, and his residents.

Subjects

All patients that have undergone a LC performed by Dr. Michael Roskos (MCR) at Mayo Clinic Health Systems (MCHS) in La Crosse, WI, from January 1, 2010 to December 31, 2013 were included in this investigation. MCR has been a general surgeon at MCHS-La Crosse (formerly Franciscan Skemp Healthcare) since July 1999; he began training residents in January 2009. The residents involved are postgraduate year three (PGY-3) completing their GS residencies through the Mayo Clinic School of Graduate Medical Education based out of Rochester, MN; they have had some experience with laparoscopy prior to their rotations with the

GS department at the La Crosse campus. Laparoscopic experience for the residents includes two simulation sessions and two to three years of rotations on general and specialty services. Specific operative experience is variable between residents based on things such as services rotated on and at which time of the year (usually schedules are more full towards the end of the calendar year), attending physicians (some have preference and ability for teaching, while others do not), support staff (other more junior/senior residents or medical students on the same service), and patients (some very unique cases, others very routine).

Instruments

Chart review for data collection was completed using the Electronic Medical Record (EMR) and Power Chart for MCHS. A coding research analyst at MCHS-La Crosse provided a list of the patients included in this study.

Procedures

The charts of all of the LC patients between January 1, 2010 and December 31, 2013 were reviewed. The following information was recorded: patient gender, patient age, patient BMI, patient comorbidities, pre- and post-operative diagnosis, conversion to open procedure, whether there was a resident involved, operation time (incision to closure), complications during and after surgery (up to 30 days post operation), if patient returned to the OR for a subsequent procedure due to complication(s) from LC, length of stay of patient, use of cholangiogram during operation, gallstone and bile spillage, and whether the procedure was elective or emergent. The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) sets guidelines for the recording of patient comorbidities. For the purpose of this study, patients with comorbidities of diabetes or other immunocompromise diseases, those with a preoperative diagnosis of acute cholecystitis or choledocholithiasis, and those taken to the OR emergently were considered high-risk. Patients 70 years of age or older were also considered high-risk. Patients that did not fall in the high-risk category were considered low-risk.

Cases were categorized as “with resident” (the resident was scrubbed in and acted as operating surgeon while attending surgeon acted as an assistant) or “without resident” (the attending surgeon was the operating surgeon, no resident involvement). Patient demographics, such as gender, age, BMI, and risk (high or low) were compared between the groups. This was important to ensure that residents are involved in LC procedures with a variety of patient types. Next, the operating time was compared between the two groups. Then, the patient outcomes were considered by looking at the complications during and after surgery (up to 30 days post-operation), the length of stay of the patient, and if the patient returned to the OR due to complications from the LC procedure. Patient outcomes with and without resident involvement were compared.

An open cholecystectomy requires more time and increases the risk for complications and infections; thus, it cannot be compared with laparoscopic cholecystectomy or the results would be skewed. Any laparoscopic cholecystectomies converted to open were excluded.

Data Analysis

Two-sample t-tests were used to analyze the difference in time between the residents and attending surgeons (denoted as “without resident”). Chi-square was used to analyze the difference in gender and complications between the two groups. A p-value of <0.05 was considered statistically significant.

Chapter 4: Results and Discussions

Results

The total number of laparoscopic cholecystectomies reviewed was 324; 174 with resident involvement and 150 without. Patient demographics such as age, BMI, and gender did not differ statistically between the two groups ($\chi^2<4.316$, $p>0.34$ for all). The duration of the operation was found to be 88 minutes on average with resident involvement and 57 minutes without ($t_{(311)}=10.33$, $p<0.0001$;). There were 10 complications when residents were involved and eight complications when the attending was operating alone ($\chi^2=0.026$; $p=0.436$).

Using previously mentioned criteria, 118 patients were considered high-risk, leaving 206 categorized as low-risk. Of these 206, 117 LCs were performed with resident involvement, 89 without. Patient demographics such as age, BMI, and gender did not differ statistically between the two groups ($\chi^2<2.082$, $p>0.149$ for all). Operation time was found to be, on average, 88 minutes with resident involvement and 54 without ($t_{(192)}=8.97$, $p<0.0001$). Complications were low; there were five complications when residents were operating and only three when the attending was performing the operation ($\chi^2=0.102$, $p=0.370$).

Discussion

The results of this study show that resident involvement in laparoscopic cholecystectomies at Mayo Clinic Health System in La Crosse, WI, is associated with significantly longer OR time and no statistically significant difference between the numbers of complications.

When looking at cases with resident involvement between the overall patient data and the low-risk cohort, there is not much variability in operation duration; cases without resident involvement follow the same pattern. LCs performed with resident involvement were found to be

88 minutes on average when only low-risk patients were considered and when both low- and high-risk patients were included. Similarly, when the attending physician was operating alone, he averaged operation duration of 54 minutes (low-risk cohort) and 57 minutes (all patients). This leads to the conclusion that time in the OR for an LC isn't influenced by patient risk.

Residents in the present study spent 31 minutes longer in the OR performing LC than the attending physician alone; equating to a 54% increase in operation duration. While this difference may seem intuitive—an experienced surgeon with more than 10 years in practice doing LCs is going to be able to progress more quickly through the procedure than a young trainee in his/her third year of residency—it has never been studied for this institution's training program. Many studies in the medical literature have found similar results regarding the effect of resident involvement on operating time. Davis suggested a 47.7% increase in OR time with residents,[69] Traverso was as high as 49%,[73] and Tseng suggested a 47% increase.[68]

A more clear-cut impact of the 54% longer resident OR time is that it increases cost. In particular, Mayo Clinic's costs (similar to other institutions) are based on physician fees, OR time, supplies, and incidentals. Because Mayo's cost per minute of OR time is confidential, the exact cost for the extra on average 31 minutes due to residents cannot be calculated. However, using a 2016 average cost from a South Carolina hospital[29]—at $9.57/minute—it would cost Mayo Clinic an extra $297 per LC. This number is similar to reported costs ($275-$286) from other institutions.[79,80] However, it's hard to say whether this cost is consequential or not, as institutional budgets for the OR and training are unpublished.

Overall complications in this study were minimal and not statistically significant. When residents were involved, complications included a ventral hernia, UTI, allergic reaction, pneumonia, septic shock, two patients with a mild umbilical wound infection, two patients with a seroma, and one patient that died due to cardiac arrest. With no resident involvement, complications included an upper GI bleed, sepsis, urinary tract infection, bile leak, pancreatitis, mild wound infection, and two patients with pneumonia. It could be argued that some of these complications are not a direct result from skills of the operating surgeon. For example, one patient had an allergy to oral Colace—a drug used to relieve constipation. However, this still gets recorded in the chart as a complication of surgery. In addition, half of the patients with complications (five) in the "with resident" group were considered high risk, and thus, the complications were more likely due to patient comorbidities than the actual LC. Five of the patients with complications in the "without resident" group were also considered high risk. Similar to findings by Kazaure et al., this study showed no statistical difference in complications.[71] While Raval, Tseng, and Hwang reported an increased morbidity with resident involvement in LC and other laparoscopic procedures, they had much larger, older data sets from multiple institutions.[66-68] The current study uses a single-institution in a community setting, which results in one surgeon drawing from one population. Additionally, the data set was smaller (and may not have been big enough to tease out any differences) and newer (potential for different operating procedural method and/or equipment) which could be the reason for the differences.

While residents training in the OR leads to a greater cost for the hospital, one could argue that resident involvement is actually quite beneficial for both patients and the hospital. Academic teaching hospitals are often large centers for medical research while caring for patients with rare diseases and the most difficult cases.[82] Practicing academic surgeons even argue that by having challenging, inquisitive residents around, it forces them to keep their knowledge up-to-date with current literature and research to be able to offer answers and insight.[82] Additionally, the extra time (and therefore, cost) the attending surgeon spends teaching residents in the OR may very likely be balanced with the time saved from residents completing much of the pre- and postoperative patient care tasks.[31]

While the effects of resident involvement in the OR for LC at Mayo Clinic are now more clear, the battle for medical educators is ongoing. This study identified a gap in the training program—significantly longer operative times with resident surgeons—and now the clinic could consider creating better, more effective, education efforts. The era of “see one, do one, teach one” in the OR doesn’t fit in the new paradigm of training; surgery trainees need to be more prepared before they can operate so that the time difference can tighten (or completely closed).

Although no studies have specifically looked at simulation training of LC and its effect on resident involvement in the OR (at any institution), a previously mentioned study has found a strong positive effect with inguinal hernia repair at Mayo Clinic using Mayo Clinic residents.[9] Specifically, a 14-minute decrease in operative time by participating in a specific simulation curriculum. A comparable curriculum could be crafted for both general laparoscopic skills, as well as LC basics, to expand on the current six hour per year education. This author suspects similar result would be seen, which could significantly decrease the 54% documented longer OR time for GS residents that currently exists for LC procedures. Additionally, as it seems simulation is important and useful, testing residents repetitively during and after simulation sessions, as well as before they enter an OR, could ensure competency will laparoscopic skills and knowledge. By decreasing the OR time with resident involvement for LC, there would be a reduction in cost, an opportunity for the resident to gain additional experiences in a different OR/clinic with the “extra” time, and the resident could spend valuable operating time learning higher-level concepts and complexities instead of basic laparoscopic fundamentals.

Conclusions

Based on the results of this study, the following conclusions can be made:

(1) Residents spend on average 54% more time performing LCs than their attending physician counterpart resulting in a higher cost for the hospital; (2) There are no more complications when residents are involved in LC procedures compared to that of the attending physician.

Recommendations

Based on the results and conclusions of this study the following recommendations for future study are made:

1. Change the current simulation/education curriculum to include more laparoscopic fundamentals. This could reduce the amount of time spent in the OR on learning and practicing the basics of laparoscopy (figuring out how to perceive depth, move instruments in such a confined space with lack of haptic feedback, etc.). The addition of such laparoscopic stations in the assessments could also be beneficial to ensure residents are up to set competency standards.
2. Add basic GS procedures, such as LC and laparoscopic appendectomy, in curriculum to reflect the core operations that graduating residents will likely complete on a daily basis.

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