SURGEON VOLUME AND OPERATIVE MORTALITY

FOR EMERGENCY GENERAL SURGERY OPERATIONS

BY

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DEDICATION

To My Parents

and

To My Wife

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LIST OF ABBREVIATIONS

AHRQ	Agency for Healthcare Research and Quality
AAST	American Association for the Surgery of Trauma
ACS	American College of Surgeons
ASA	American Society of Anesthesiologists
CDC	Centers for Disease Control and Prevention
$\chi 2$	Chi-squared analysis
CI	Confidence Interval
CABG	Coronary Artery Bypass Graft
CPT	Current Procedural Terminology
ED	Emergency Department
EGS	Emergency General Surgery
ESC	Emergency Surgical Care
HCUP	Healthcare Cost and Utilization Project
HVH	High-Volume Hospital
IOM	Institute of Medicine
IRB	Institutional Review Board
ICU	Intensive Care Unit
JAMA	Journal of the American Medical Association
LOS	Length of Stay
LVH	Low-Volume Hospital
NSQIP	National Surgical Quality Improvement Project
NIS	Nationwide Inpatient Sample
NEJM	New England Journal of Medicine
NC	North Carolina

OPA	Operation Patient Access
OR	Odds Ratio; Operating Room
PPACA	Patient Protection and Affordable Care Act
PAS	Professional Activities Study
RSSE	Regional System for Surgical Emergencies
SAS	Statistical Analysis System
SD	Standard Deviation
SEER	Surveillance, Epidemiology, and End Results
SIRS	Systemic Inflammatory Response Syndrome
TURP	Transurethral Resection of the Prostate
USA	United States of America

ABSTRACT

The relationship between surgeon-volume to operative mortality is well established for elective surgical procedures in the United States. However, the importance of this relationship in emergency operations is not understood. Using a primary dataset looking at emergent colon resections over a three year period at one tertiary medical center, we examined the relationship between surgeon volume and operative mortality for emergent colorectal surgical procedures.

CHAPTER 1: REVIEW OF THE LITERATURE

Multiple surgical and medical organizations in the United States, including the American College of Surgeons (ACS), the Centers for Disease Control and Prevention (CDC), the American Association for the Surgery of Trauma (AAST), and the Institute of Medicine (IOM), have all expressed grave concern over what has been termed a "crisis" in the access to emergency surgical care.[1–3] This crisis is defined as the inadequate and/or delayed access to definitive operative care for surgical emergencies which require operative intervention as the primary treatment.[1] It is occurring in emergency departments (ED) and trauma centers throughout the United States (USA), and is causing long waits for patients to be seen, ambulance diversions away from facilities lacking surgical coverage, and postponed – and even missed – operations.[4,5] This lack of definitive surgical treatment, also known as the "access-crisis" and the "emergency surgical care crisis," is compromising patient care and patient safety; due to its pervasiveness, it has reached crisis levels – and is only getting worse.[2,3]

In 2006, the ACS Division of Advocacy and Health Policy published an article entitled "A Growing Crisis in Patient Access to Emergency Surgical Care."[1] The report's aim was to document the underlying causes of the access-crisis by review of surveys and questionnaires given to surgeons, various studies on the topic, and interviews with national surgical leaders.

The report outlined many factors contributing to the access-crisis. These included ED overcrowding; an aging surgical workforce; a growing trend among surgical residents toward subspecialization; inadequate emergency call coverage, especially in smaller hospitals; declining reimbursements and increasingly uncompensated surgical care; surgeons narrowing their scopes of practice to focus almost exclusively on scheduled, elective cases; and surgeons eliminating risky or less profitable cases from the services they offer. These issues have profoundly affected patient safety and quality of care in elemental ways, and all have played a part in the access-crisis.

The ACS report clearly states that there was one underlying factor which they concluded was driving the access problem: “a growing shortage of surgical specialists available to cover our nation’s emergency departments.”[1] This is partly due to a restructuring of surgical training for certain specialities to a “integrated residency” model, where general surgery training is shortened and combined with such sub-specialities as vascular, plastic, or cardiothoracic surgery. Additionally, part of this is also due to the plateau in the number of general surgeons trained per year in the USA: roughly 1000 per year, which has been the case since the 1980s.[1,2] Therefore, in the twenty year period from 1980 to 2000, while the USA population grew from 227 million people to 281 million people,[6] an increase of nearly 24%, the total number of general surgeons remained relatively stable. This has influenced and helped create the access-crisis that exists today.

Furthermore, for the 1000 general surgery trainees who graduate from residency programs each year, “about half... go on to pursue fellowships and subspecialization.”[1] This migration of surgeons away from general surgery has had two drastic consequences, both of which contribute to the access-crisis: first, there are fewer general surgeons available to cover emergency surgical operations; second, subspecialization has translated into more surgeons feeling unqualified to manage the broad range of emergent surgical problems that their predecessors felt prepared to handle – these surgeons therefore opt out of ED coverage.

The findings in the 2006 ACS report were corroborated and expanded upon by the Acute Care Congress, a one-day summit held on August 7, 2008 under the leadership of the AAST, the CDC, and thirteen other member organizations. The aim of the Congress was to identify and discuss the problems facing access to ESC in the United States, and to propose an action plan for addressing them. The final consensus document produced by the Congress was entitled “Acute Care Congress on the Future of Emergency Surgical Care in the United States.”[4]

The Acute Care Congress articulated and identified multiple areas potentially contributing to the crisis in emergency surgical care. Under the heading of “Access to Care,” the Congress discussed multiple issues, including workforce shortages (general surgeon shortage is estimated to number 1300 nationally), uncompensated care, overcrowding, and surgeon subspecialization. Additionally, “Workforce Issues” were considered, including the problem of centralization of care (including the growing problem of tertiary care hospitals receiving a disproportionate share of uninsured emergency patients) and community call shortages. The last major area discussed was “Trauma Systems,” and the lessons that the trauma systems model can provide for emergency surgical care. In the end, recommendations were made for improving the future of ESC, with two major areas of focus: 1) the potential regionalization of non-trauma emergency surgical care; and 2) improving research into emergency surgical services.

In response to the crisis and the issues impacting access to quality surgical care in the USA, the ACS established Operation Patient Access (OPA) in 2008.[7] OPA “is a campaign representing the surgical community, surgical patients, and providers, that aims to work collaboratively with U.S. policymakers to address the urgent issues facing access to quality surgical care.”[7] The recent overhaul of the health care system in the USA, including the Patient Protection and Affordable Care Act (PPACA) signed into law in March 2010,[8] includes numerous health-related provisions which will impact surgical care, surgical quality, and ESC in the USA for years to come. Therefore, OPA’s work of improving the quality of surgical care in the USA remains salient.

Within the broad field of General Surgery, with its multiple specialties, including Pediatric Surgery, Colorectal Surgery, Minimally Invasive Surgery, and Surgical Oncology, to name a few, the discipline under which "non-trauma emergency surgical care" falls is called Acute Care Surgery (though in some areas of the country the Surgical Hospitalist model is more pervasive[9]). Acute Care Surgery is a nascent surgical specialty, which has gradually evolved as the specialty of Trauma Surgery redefined itself over the past 10 years.[10–13] Acute Care Surgery encompasses three major areas under one specialty: Trauma Surgery, Surgical Critical Care, and Emergency General Surgery (EGS).[14]

The thought-leaders of the Acute Care Surgery movement were trained as trauma surgeons. Concomitantly, because of the success in the past 30 years of the regionalization of trauma care,[15–22] this same leadership is now calling for the regionalization of emergency surgical care – as evidenced by the recommendations of the Acute Care Congress.

Regionalization for emergency surgical care "is defined as creating a system of care, within a defined geographic area, to ensure optimal care for every patient with a life-threatening surgical illness. Regionalization is *not* meant to be centralization. Centralization would imply that all acutely ill surgical patients be triaged and transported directly to 'designated acute care surgery centers.' The centralization of most surgical emergencies will not be necessary because most can be appropriately treated at the local community hospital."[23]

This excerpt was taken from a chapter entitled "Development of a Regional System for Surgical Emergencies (RSSE)" in the first comprehensive textbook on Acute Care Surgery, first published in 2006.[23] The authors of the chapter – Eastman, Hoyt, and Meredith, who echo the recommendations of the Acute Care Congress – stress the importance of making the decision to regionalize ESC on empiric foundations. To date, however, there have been few studies done to support regionalization of Acute Care Surgery.

The concept of regionalization of *elective* general surgery services (as opposed to *emergency* surgical services) is not new, and was first proposed back in the late 1970s. Since then, over three decades of research on this topic has not yielded a regionalized system. As the current calls to regionalize emergency surgical care increase, it is worth reviewing the research history of elective surgical care in the context of what led to calls for its regionalization, and what the field of Acute Care Surgery should establish as research priorities to support the potential regionalization of non-trauma emergency surgical care.

The concept of regionalizing elective surgical services first gained widespread recognition with a 1979 *New England Journal of Medicine (NEJM)* paper entitled "Should Operations be Regionalized?" by Luft and colleagues.[24] Luft wanted to explore the relationship between a hospital's surgical volume and its surgical outcomes. He had four hypotheses: 1) there was an inverse relationship between a hospital's surgical volume and its surgical mortality; 2) the quality of care improves with the experience of those providing it; 3) surgical mortality should be lower in hospitals performing higher volumes of a given procedure; and 4) the experience-effect should be more pronounced with more complex procedures, parallel to the experience or learning curve seen in industrial economics.

To test these hypotheses, he examined the mortality rates for 12 surgical procedures of varying complexity in nearly 1500 hospitals throughout the United States during the years 1974 and 1975. A total of 857,685 patients were included in the analysis, which used data from the Professional Activities Study (PAS) data system. Patients were each categorized by three traits: age (five groups: 0 to 19 years old, 20 to 34 years old, 35 to 49, 50 to 64, and > or = 65), sex (male or female), and number of diagnoses (two groups: one diagnosis or more than one). For each of the 12 operations, 20 mortality rates where then calculated, one for each of the 20 possible cells of the three category groupings (ie: there were twenty age-sex-diagnoses groupings). Hospitals were categorized by the number of times that a designated procedure was performed per year (eight groups: 1 procedure, 2 to 4 procedures, 5 to 10, 11 to 20, 21 to 50, 51 to 100, 101 to 200, and >200). Actual and expected death rates where then compared for each volume level of hospital and for each operation, to define the relationship between surgical volume and mortality.

Luft found that hospitals which performed certain complex surgical procedures (open-heart surgery; vascular surgery; transurethral resection of the prostate – TURP; and coronary artery bypass grafts – CABG) more than 200 times per year had consistently lower death rates than those that didn’t, ranging from 25 to 41% lower. This decreased mortality rate, adjusted for case mix, continued to show an inverse relationship as more and more operations were done. In other words, Luft never saw that the relationship reached an asymptote, where the benefits of higher surgical volume plateaued, indicating ever-increasing economies of scale.

For six other intermediate-complexity procedures, the mortality curve flattened once a certain surgical volume was reached (i.e., plateaued upon reaching an inflection point). This was different from the complex surgical group, which showed no inflection point as mortality rates continually decreased with surgical volume. An example in the intermediate-complexity group was total hip replacements. Luft determined that the inflection-volume number was 50 operations per year at a hospital. Accordingly, if all total hip replacements were performed at hospitals doing 50 or more procedures per year, Luft’s analysis showed that 32% of all in-hospital deaths of patients with that procedure could be avoided.

Certain less-complex surgical procedures, including elective cholecystectomy, showed no relationship between volume and mortality, meaning that there was no significant relationship between a hospital's procedure-specific surgical volume and its in-hospital mortality rates. Furthermore, the influence of additional independent variables was assessed to determine their impact on the volume-outcome relationship. These included hospital size, total aggregate surgical volume, geographic region/location of the hospital, expenses, and teaching status of hospital. When examined with multiple regression analysis, none of them was found to significantly impact mortality or to alter the hospital surgical volume-mortality relationship.

Luft concluded that certain complex elective surgical procedures should be regionalized to high volume centers for better patient outcomes. He also rationalized that optimal quality and cost savings could be achieved by creating economies of scale from the regionalization of surgical care.

The surgical volume-outcome relationship has been substantially expanded upon in the general surgery literature over the 30 years since Luft's original 1979 paper. During this time, databases have become increasingly specialized and statistical techniques more advanced, making analyses more internally and externally valid. Multiple studies have confirmed that, in comparison to higher-volume centers, low-volume hospitals have higher rates of perioperative mortality for certain procedures.[25–30] The data indicate that improved outcomes could be realized for certain elective surgical procedures when the operations were done at high-volume medical centers.

In 1984, Flood et al looked at the volume-outcome relationship by accounting for the risk level of the patient and the difficulty of the procedure, to assess for confounding or mediating effects – and found none.[25] Teaching status and expenditures where also looked at by Flood for potential confounding or mediating effects – and again none was seen.[28] In each analysis, the volume-outcome relationship was statistically significant with no lessening of the impact by these variables.

The next evolution in the analysis, by Hannan et al in 1989, was to look at the combined relationship of hospital surgical-volume and physician-volume, for a particular procedure, to in-hospital mortality.[29] Such studies began to break the volume aspect of the volume-mortality relationship into its component parts: one part being hospital-volume and the other part being surgeon-volume. Threshold volumes began to be defined for particular surgical procedures, which clearly and optimally discriminated between high-volume (HVH) and low-volume (LVH) hospitals and high- and low-volume surgeons.

In the late 1990s, with statistical improvements in accounting for case-mix adjustment, the volume-outcome relationship was again supported, using specialized databases such as the national Medicare claims database (Begg et al 1998[26] and Birkmeyer et al 1999[31]), state-specific hospital discharge data-sets (Dudley et al 2000[30]), and complex meta-analyses (Halm et al 2002[32]). These studies, like few before them, also began to quantify the number of lives which could be potentially saved each year with proper referral patterns to HVHs.

In a March 2000 article by Dudely et al[30] in the *Journal of the American Medical Association (JAMA)* entitled “Selective Referral to High-Volume Hospitals: Estimating Potentially Avoidable Deaths,” nearly 58,000 patients who underwent one of ten surgical operations (each with evidence of a volume-mortality relationship) at LVHs were analyzed; the analysis was based on the 1997 California database of hospital discharges. They estimated 602 potentially avoidable deaths in the LVH group, had they been referred to and treated at a HVH. Dudley concluded that facilitating referral to HVHs (or to low case-mix-adjusted mortality hospitals) could potentially reduce overall hospital mortality for certain surgical conditions.

By the early 2000s, the validity of the volume-outcomes relationship was being questioned.[33,34] Certain studies validated this doubt, by demonstrating no significant relationship between hospital volume and mortality for both high and intermediate complexity operations.[35,36] At the time, studies also questioned the relative importance of volume-outcomes relationship in the face of improved surgical techniques and declining mortality rates.[37,38]

One article reestablished the clinical relevance, applicability, and generalizability of the volume-outcome relationship by confirming that a predictive volume-outcome relationship held true, even with the innovations and technological-advancements that had taken place in surgery over the 20 years prior: a 2002 article in the *NEJM* by Birkmeyer et al entitled “Hospital Volume and Surgical Mortality in the United States.” The article provided clear and significant evidence that the inverse relationship between hospital surgical-volume and mortality held.[27]

Birkmeyer used the Medicare claims database and the NIS to analyze 2.5 million elective surgical procedures over a six year period (6 cardiovascular operations and 8 cancer operations), examining the relationship between hospital volume (total number of procedures performed per year) and mortality (death in-hospital or within 30 days of operation), adjusting for patient characteristics.

Mortality decreased as volume increased for all 14 elective surgical operations, but the relative importance of surgical volume varied markedly according to the complexity of the operation performed. For example, for pancreatic resection, operative mortality ranged from 16.3% at very-low-volume hospitals to 3.8% at very-high-volume hospitals, an absolute difference of over 12%. In contrast, for carotid endarterectomy, the difference was only 0.2%, with operative mortality of 1.7% at very-low-volume hospitals compared to 1.5% at very-high-volume hospitals. Birkmeyer concluded that patients undergoing selected surgical operations could significantly reduce their risk of operative death by selecting a HVH; this was tantamount to Luft's conclusion 25 years prior.

Accordingly, multiple evidence-based studies have confirmed the idea that regionalizing elective surgical care by referring select patients to HVH within a geographic region would have great benefits to patient safety and quality of care. The data indicate that improved outcomes could be realized for certain elective surgical procedures when the operations are done at high-volume medical centers.

The calls for regionalization began when Luft wrote in 1979 "we should not postpone developing policies to encourage the regionalization of those procedures whose outcomes are markedly less satisfactory in low-volume hospitals."[24] Flood in 1984 concluded "our results provide encouragement to those who argue that health care services should be regionalized so that, to the extent possible, patients are treated within facilities and by staff who have ample experience in dealing with similar problems."[28] And Birkmeyer in 1999 wrote "our analysis suggests that Medicare decision makers should consider regionalization as part of broader efforts to improve surgical quality."[31]

However, starting in the early 2000s, research into surgeon-specific procedure volume shifted the debate (as opposed to hospital-specific procedure volume). In 2003 Birkmeyer et al found that surgeon volume was inversely related to postoperative mortality for Medicare patients undergoing eight cardiovascular and oncologic operations, which varied in complexity. For each procedure they studied, patients who were operated on by high-volume surgeons had lower rates of postoperative mortality than those patients operated on by low-volume surgeons. Furthermore, the hospital volume to operative mortality relationship was found to be mediated by surgeon volume for all procedures studied.[39]

A study by Schrag et al in 2003 made slightly different conclusions.[40] Using the Surveillance, Epidemiology, and End Results (SEER)-Medicare linked database to assess patients with primary colon cancer, Schrag and colleagues found that 30-day postoperative mortality was significantly lower in patients who underwent colon cancer resection both at high volume hospitals as well as by high volume surgeons; 2-year survival rates were significantly higher in these groups as well. Interestingly, they found that the association between surgeon volume and mortality was confounded by hospital volume, but not vice versa. This indicates that the surgeon volume to mortality relationship is attributable to hospital specific volume, and therefore that hospital volume may explain more of the variation in mortality outcome after primary cancer resection than surgeon volume.

The relationships of hospital-volume to mortality as well as surgeon-volume to mortality continues to be explored, clarified, and researched today.[41,42] In a review of the literature on surgical volume and specialization on outcomes, Chowdhury et al[41] emphasized the heterogeniety of this body of research, which can lead to conflicting results. Different study designs, specialities, outcomes, patient populations, and conclusions are consistently made, which preclude the ability to conduct a formal meta-analysis. Chowdhury's systematic review showed that 91% of studies of surgical specialization indicated that specialist surgeons had significantly improved outcomes compared to generalists; 74% of studies indicated high-volume operative hospitals had improved outcomes compared to low-volume centers; and 74% of studies showed high-volume surgeons had better outcomes. In the end, Chowdhury concludes that both high surgeon-specific volume and surgeon specialization were consistently and significantly related to improved patient outcomes in both prospective and retrospective studies; the relationship between high hospital operative volume and improved postoperative mortality was less clear, as it only held for retrospective studies.

Overall, what can be concluded from this vast body of literature into the surgical-volume to outcomes relationships is that this research has catalyzed the restructuring of care for certain diagnoses/operations, but has not completely decided the question of total regionalization of elective surgical care. The relative importance of key determinants of quality surgical care and outcomes for elective operations are far from settled. This is because there are myriad influences which help to explain the variation in postoperative morbidity and mortality: hospital volume;[25–30,40] surgeon volume;[39–41] surgeon specialization;[9,41] regionalization;[43,44] institutional systems/processes of care;[2,45–47] validated outcomes monitoring/reporting;[36,48] statewide quality improvement initiatives;[49] teamwork;[50,51] checklists;[52] and many others. All of these, to varying degrees, are key sources of variation in outcomes after an elective operation.

Given the current crisis in the state of ESC in the USA, this body of 30 years of *elective* surgical research has been generalized to the *emergent* surgical patient. The relationships between hospital operative volume to mortality as well as surgeon-volume to mortality have been theorized to exist for emergent operations, though neither have been formally studied. In fact, some already use these as-of-now-unstudied relationships to argue for regionalization as one solution to the access-crisis for ESC.[4,23]

To an acute care surgeon, this inference makes sense, as they manage emergent trauma and general surgery patients. The success of regionalizing trauma in the USA, facilitated by the creation of trauma systems, has greatly improved the outcomes of trauma patients.[15–22] There are clear parallels between ESC and trauma care: operations are not scheduled ahead of time and are usually done on an emergent basis; because the procedures are unscheduled, there is little opportunity to optimize the status of the patient preoperatively; and patients do not get to choose their surgeon, as they are treated by whichever physician is on-call on a given day/night. Within the field of trauma surgery, studies have shown a clear relationship between hospital volume and outcomes for trauma patients but not a surgeon-volume to mortality relationship.[53–55] This research has helped to validate the creation of regionalized trauma care.

To date, there are no studies showing a volume-outcome relationship in emergent surgical operations in the USA. In fact, very few studies have researched healthcare delivery systems related to emergency surgical care.[56–59] Therefore, the relationships between hospital and/or surgeon volume and EGS outcomes are unknown, and the exact aspects of EGS care that lead to improved outcomes have not been studied. Such evidence will be essential prior to restructuring and regionalizing the entire system of emergency surgical care to improve patient safety, enhance the quality of surgical procedures, and directly address the access-crisis.

Based on the aforementioned research in the field of elective general surgery, it is feasible and essential to address the research-gap in EGS by assessing the surgeon volume to mortality relationship for emergent surgical cases. Our fundamental assumption is that the outcomes of emergent operations are not random or determined by chance, but rather that they are logical, follow persistent patterns, and in some cases are even predictable – meaning that there are patient characteristics and other factors associated with a greater probability of poor outcomes. Because the evidence in the elective surgical literature supports this central hypothesis, our theory is that it is also true for emergency cases.

The main objective of my thesis project will be accomplished by testing the central hypothesis via one specific aim. This will be done through primary dataset review of all patients who underwent an emergent colectomy at Wake Forest University Medical Center over a 36 month period, from

March 1, 2007 to March 1, 2010. I will identify all patients who underwent open, emergent colectomy to pursue the following specific aim:

> ***Specific Aim #1:*** To define the relationship between surgeon volume and post-operative in-hospital mortality for all patients who underwent open, emergent colectomy within 24 hours of their EGS diagnosis at Wake Forest over a three year period.
>
> > ***Hypothesis #1***: This aim tests the hypothesis that an inverse relationship exists between a surgeon's emergent surgical volume and their post-operative in-hospital mortality.

The expected outcomes from the work in specific aim #1 will show that surgeons at Wake Forest perform different numbers of emergent colectomy operations each year, and that those surgeons with higher surgical volumes have lower post-operative mortality.

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CHAPTER 2: MAIN BODY OF TEXT AS JOURNAL ARTICLE

INTRODUCTION:

There is currently a crisis in the access to emergency surgical care in the United States.[1–3] This crisis is defined as the inadequate and/or delayed access to definitive operative care for surgical emergencies which require operative intervention as their primary treatment.[1] It is occurring in emergency departments (ED), trauma centers, and hospitals throughout the USA, and is causing long waits for patients to be seen, ambulance diversions away from facilities lacking surgical coverage, and postponed – and even missed – operations.[4,5]

In response to the crisis and the issues impacting access to quality emergency surgical care (ESC), various solutions have been proposed. Due to the success in the past 30 years of regionalizing trauma care, facilitated by the creation of trauma systems,[6–13] one of those potential solutions is the restructuring of ESC into a regionalized system of care. This makes sense, as there are clear parallels between ESC and trauma care: operations are not scheduled ahead of time and are usually done on an emergent basis; because the procedures are unscheduled, there is little opportunity to optimize the medical condition of the patient preoperatively; and patients do not get to choose their surgeon, as they are treated by whichever physician is on-call on a given day/night.

However, the experience in the creation of trauma systems on both a state and national level has shown that such intricate, complex, and multilayered systems of care take time, planning, and years of research to build.[14] And unlike the surgical specialty of trauma, very few studies have researched ESC in the USA, let alone healthcare delivery systems related to ESC.[15–18]

One body of research that helped to validate the creation of regionalized trauma systems was establishing that there is a clear relationship between the volume of trauma patients a hospital treats and its outcomes for those patients.[19–21] To date, however, there are no similar studies showing a volume-to-outcomes relationship in emergent surgical operations. Establishing this relationship could lead to improved survival for ESC, and help build data-driven support for the restructuring and regionalization of the entire system of ESC.

Volume-outcome relationships have been studied extensively in *elective* patients having scheduled operations. This research in elective cases has shown that increased hospital operative-volume[22–28] as well as increased individual surgeon-volume[28–30] leads to better outcomes. These relationships have been generalized to exist for *emergent* operations. However, this generalization may not be valid, as it is well-established that the emergency general surgery (EGS) patient-population is vastly different from its elective counterpart.[31,32]

The current study aims to define and quantify the risks of mortality associated with differences in individual surgeon-volume in patients requiring emergent colorectal surgery. Our aim is to assess the association between surgeon volume and operative mortality for emergent colorectal operations. Our hypothesis is that increased surgeon volume is associated with decreased mortality.

METHODS:

Dataset & Variables:

This is a retrospective review of all patients who underwent an emergent colectomy at one tertiary medical center over a 36 month period, from March 1, 2007 to March 1, 2010; this 3 year period was chosen as it provided a uniform comparison of operations during which surgical techniques were not greatly changing. Variables were collected through electronic chart review. Data collected included patient demographics, illness characteristics, chronic health conditions, intra-operative metrics, hospital and intensive care unit (ICU) length of stay (LOS), total mechanical ventilator days, postoperative complications, and in-hospital mortality.

Patient Selection:

For the current analyses, only inpatients undergoing open, emergent, colorectal operations by a general surgery service were included. The colorectal patient-population was chosen based on their high degree of postoperative morbidity and mortality, and thus the increased power of the analyses.[32–34] Appropriate Current Procedural Terminology (CPT) codes were used to identify patients who had undergone one of 14 types of open colectomy (Table I). Certain patients were excluded from the study: elective colorectal operations; pediatric patients under the age of 18; patients with an American Society of Anesthesiologists (ASA) score of 6 (brain dead); and all trauma and transplant cases. These criteria were congruous with inclusion and exclusion criteria for the ACS National Surgical Quality Improvement Project (NSQIP).[35]

Table I: CPT codes & descriptions used to identify colorectal procedures	
44140	COLECTOMY, PARTIAL, WITH ANASTOMOSIS
44141	COLECTOMY, PARTIAL, WITH SKIN LEVEL CECOSTOMY OR COLOSTOMY
44143	COLECTOMY, PARTIAL, WITH END COLOSTOMY AND CLOSURE OF DISTAL SEGMENT (HARTMANN TYPE PROCEDURE)
44144	COLECTOMY, PARTIAL, WITH RESECTION, WITH COLOSTOMY OR ILEOSTOMY AND CREATION OF MUCOFISTULA
44145	COLECTOMY, PARTIAL, WITH COLOPROCTOSTOMY (LOW PELVIC ANASTOMOSIS)
44146	COLECTOMY, PARTIAL, WITH COLOPROCTOSTOMY (LOW PELVIC ANASTOMOSIS), WITH COLOSTOMY
44147	COLECTOMY, PARTIAL, ABDOMINAL AND TRANSANAL APPROACH
44150	COLECTOMY, TOTAL, ABDOMINAL, WITHOUT PROCTECTOMY, WITH ILEOSTOMY OR ILEOPROCTOSTOMY
44151	COLECTOMY, TOTAL, ABDOMINAL, WITHOUT PROCTECTOMY, WITH CONTINENT ILEOSTOMY
44155	COLECTOMY, TOTAL, ABDOMINAL, WITH PROCTECTOMY, WITH ILEOSTOMY
44156	COLECTOMY, TOTAL, ABDOMINAL, WITH PROCTECTOMY, WITH CONTINENT ILEOSTOMY
44157	COLECTOMY, TOTAL, ABDOMINAL, WITH PROCTECTOMY, WITH ILEOANAL ANASTOMOSIS, INCLUDES LOOP ILEOSTOMY, AND RECTAL MUCOSECTOMY
44158	COLECTOMY, TOTAL, ABDOMINAL, WITH PROCTECTOMY, WITH ILEOANAL ANASTOMOSIS, CREATION OF ILEAL RESERVOIR (S OR J), INCLUDES LOOP ILEOSTOMY
44160	COLECTOMY, PARTIAL, WITH REMOVAL OF TERMINAL ILEUM WITH ILEOCOLOSTOMY

CPT, Current Procedural Terminology

An emergency operation was defined as one performed as soon as possible and no later than 24 hours after the patient was admitted to the hospital or after the onset of related preoperative symptomatology. Additionally, both primary surgeon and anesthesiologist must have reported the case as emergent, as recorded in the anesthesia case record. The name of the primary operating attending-level surgeon was recorded, and later de-identified using a unique provider identification number.

Statistical Analyses & Outcome Measures:

The data were stratified into three patient groups by creating categorical variables for volume by ranking surgeons in order of increasing total operative volume (low-, medium-, and high-volume surgeons). We selected cut-off points to most clearly sort patients into three evenly sized groups of patients, defined by surgeon volume: low-volume surgeons, medium-volume surgeons, and high-volume surgeons. In this manner, while the number of patients in each group was roughly equal, the number of surgeons in each group was not. This methodology for analysis of surgeon-volume has been previously used and described.[30]

Patient characteristics, operative data, and outcome metrics between the three groups were first compared using univariate techniques. Chi-squared analysis ($\chi 2$) or Fisher's exact test were used to compare differences in proportions of categorical variables; such data were summarized by percentages. Univariate linear regression (one-way analysis of variance) was used to compare normally distributed continuous variables; such data were summarized by mean values with standard deviations (±SD). Kruskal-Wallis tests were used to compare non-normally distributed continuous variables; such data were summarized by median values with interquartile ranges. A p-value of <0.05 was defined as significant.

The primary outcome measure was in-hospital mortality, used as the dependent variable for all regression analyses. We employed logistic regression to examine the relationship between surgeon-volume and mortality. Parameter estimates for the logistic models were obtained using general estimation equations to account for the unknown correlation of the outcomes within surgeons. Both univariate (unadjusted) as well as risk-adjusted multivariable models were tested to predict in-hospital mortality; odds ratios defined the effects of surgeon-volume on survival. The individual patient responses provided the observations for the analysis, and the surgeon was entered in the model as a repeated factor. In these models, surgeons are assumed to be independent and responses within surgeons are assumed to be correlated. Based on previously demonstrated associations with clinical significance,[32] the following covariates were included in multivariable: age, race, gender, comorbid conditions, and ASA score.

All statistical analyses were conducting using SAS 9.2 (SAS Institute Inc., Cary, NC). This retrospective study was approved by the Institutional Review Board (IRB) at Wake Forest University School of Medicine (IRB #00018702).

RESULTS:

Eighteen surgeons performed 215 open, emergent colorectal operations on 215 unique patients over the three year period: 10 surgeons in the low-volume surgeons group, 5 in the medium-volume surgeons group, and 3 in the high-volume surgeons group (Table II). There were 6.1 cases on average in the low-volume surgeons group, 14.2 cases in the medium-volume group, and 27.7 cases in the high-volume group.

Patient characteristics are summarized in Table III. The majority (81%) of the patients were non-Hispanic White; 15% were Black, and 4% were Hispanic; there were not significant variations by race among the three groups (p=0.5642). Overall, 57% percent of the patients were males, and each of the three groups had an equal proportion of men and women. The mean age was 57 years in the low-volume group, 63 in the medium-volume group, and 64 in the high-volume group, which were significantly different (p=.0394). The mean numbers of comorbidities were 1.7, 2.6, and 1.7 in the low, medium, and high-groups, respectively; this was also significant (p=.0337).There were no significant differences in preoperative ASA class.

Operative and hospitalization characteristics were similar for the three groups (Table IV). In terms of hospitalization characteristics, total hospital LOS, ICU LOS, time on a mechanical ventilator, and the proportion of patients discharged home were all similar across the three groups. Only operative time was significantly different, with the high-volume surgeons spending significantly longer time in the OR than their lower volume counterparts (p=0.0494).

Table II: Surgeon characteristics by surgeon volume			
Variable	**Low-volume surgeons**	**Medium-volume surgeons**	**High-volume surgeons**
Total number surgeons	10	5	3
Average cases per surgeon	6.1	14.2	27.7
Range in number of operations	1 to 11	12 to 18	20 to 38

Table III: Patient characteristics by surgeon volume				
Variable[a]	Low-volume surgeons	Medium-volume surgeons	High-volume surgeons	p-value[b]
Total number patients	61	71	83	--
Female gender	28 (45.9%)	24 (33.8%)	40 (48.2%)	0.1675
Race & Ethnicity:	--	--	--	0.5642
White	48 (78.7%)	57 (80.3%)	69 (83.1%)	--
Black	9 (14.8%)	11 (15.5%)	13 (15.7%)	--
Hispanic	4 (6.6%)	3 (4.2%)	1 (1.2%)	--
Age, years	57 (14)	63 (16)	64 (17)	0.0394
Comorbidities:	--	--	--	--
Number comorbidities, average	1.7 (2.2)	2.6 (2.7)	1.7 (2.0)	0.0337
> or = 1 Comorbidity	32 (52.5%)	48 (67.6%)	41 (49.4%)	0.0590
> or = 2 Comorbidities	25 (41.1%)	40 (56.3%)	35 (42.2%)	0.1266
> or = 3 Comorbidities	18 (29.5%)	33 (46.5%)	28 (33.7%)	0.1006
ASA class:	--	--	--	--
ASA class, average	4 (1)	3 (1)	4 (1)	0.3355
1 - 3 (no disturbanc, mild, severe)	30 (49.2%)	37 (52.1%)	29 (35.0%)	0.0716
4 - 5 (life-threatening, moribund)	31 (50.8%)	34 (47.9%)	54 (65.1%)	0.0716

ASA, American Society of Anesthesiologists

[a]Categorical variables are presented as number (%); continuous data are presented as mean (± standard deviation); and non-normally distributed continuous variables as median (interquartile range)

[b]P-values for overall tests of differences among the three groups from χ2 or Fisher exact test for categorical variables and one-way analysis of variance or Kruskal-Wallis test for continuous variables

Table IV: Operative, hospitalization, and outcome characteristics by surgeon volume				
Variable[a]	**Low-volume surgeons (n=61 patients)**	**Medium-volume surgeons (n=71 patients)**	**High-volume surgeons (n=83 patients)**	**p-value**[b]
Operative Characteristics:	--	--	--	--
Length of operation, minutes	229 (65)	209 (69)	238 (82)	0.0494
Hospitalization Characteristics:	--	--	--	--
Length of total hospital stay, days	22 (34)	21 (24)	21 (34)	0.9594
Length of total ICU stay, days	9 (18)	9 (13)	8 (12)	0.9834
Length of time on ventilator, days	6 (12)	9 (17)	10 (27)	0.5992
Discharged home	36 (59.0%)	36 (50.7%)	38 (45.8%)	0.2904
Morbidity (mortality excluded):	--	--	--	--
Number of complications, average	1.4 (2.0)	1.6 (1.9)	1.6 (2.0)	0.8729
> or = 1 Complication	31 (50.8%)	41 (57.8%)	46 (55.4%)	0.7220
> or = 2 Complications	22 (36.1%)	28 (39.4%)	33 (39.8%)	0.8899
> or = 3 Complications	13 (21.3%)	20 (28.2%)	21 (25.3%)	0.6627
Examples of Complications:	--	--	--	--
Wound disruption	4 (6.7%)	9 (12.9%)	5 (6.0%)	0.2763
Surgical site infection	6 (9.8%)	12 (16.9%)	11 (13.3%)	0.4941
Renal failure	12 (19.7%)	11 (15.5%)	17 (20.5%)	0.7071
Pneumonia	8 (13.1%)	15 (21.1%)	16 (19.3%)	0.4639
Mortality:	--	--	--	--
Death, during hospitalization	14 (23.0%)	18 (25.4%)	25 (30.1%)	0.6063

ICU, Intensive Care Unit

[a]Categorical variables are presented as number (%); continuous data are presented as mean (± standard deviation); and non-normally distributed continuous variables as median (interquartile range)

[b]P-values for overall tests of differences among the three groups from χ2 for categorical variables and one-way analysis of variance or Kruskal-Wallis test for continuous variables

Outcomes were also similar for the three groups, with equal numbers of wound disruptions, surgical site infections, renal failure, and pneumonia in each group. Furthermore, total in-hospital mortality was not significantly lower in the high-volume group compared to the other lower volume categories: 30.1% mortality in the high volume group, 25.4% in the medium group, and 23.0% in the low volume group (p=0.6063).

Logistic regression models quantified the risk of in-hospital mortality (Table V). In the unadjusted analyses, compared to patients in the low-volume surgeon group, the odds of survival were not improved if a patient was operated on by a medium-volume surgeon (OR 1.14; 95% CI: 0.51-2.53; p=0.7536) or high-volume surgeon (OR 1.47; 95% CI: 0.61-3.55; p=0.3930). Variables which univariately predicted mortality were age ≥70 (OR 2.89; 95% CI: 1.73-4.82; p=<0.0001), female gender (OR: 0.58; 95% CI: 0.38-0.89; p=0.0125), and ASA score of 4 or 5 (OR 11.5; 95% CI: 4.75-28.01; p<0.0001).

The adjusted multivariable model demonstrated that surgeon volume is not a key predictor of in-hospital mortality in this cohort of emergent colorectal operations (Table V). The multivariable analysis shows that the odds of survival were not independently improved if a patient was operated on by a medium-volume (OR 0.86; 95% CI: 0.33-2.24; p=0.0.7505) or high-volume surgeon (OR 0.96; 95% CI: 0.30-3.05; p=0.9419). There were, however, three other independent covariates which were significantly predictive of increased risk of death from an emergent colorectal operation: age ≥70 years (OR 3.12; 95%CI: 1.62-5.97; p=0.0006), male gender (OR 2.17; 95% CI: 1.35-3.45; p=0.0012), and ASA score of 4 or 5 (OR 11.6; 95% CI: 5.25-25.47; p<0.0001).

Table V: Logistic regression analyses predicting in-hospital mortality based on surgeon volume				
Predictor	Unadjusted model[a]		Adjusted multivariable model[b]	
	OR (95% CI)	p-value[c]	OR (95% CI)	p-value[c]
Surgeon volume:				
Low-volume surgeons	1.0	--	1.0	--
Medium-volume surgeons	1.14 (0.51-2.53)	0.7536	0.86 (0.33-2.24)	0.7505
High-volume surgeons	1.47 (0.61-3.55)	0.3930	0.96 (0.30-3.05)	0.9419
Candidate Covariates:				
Age > or = 70 years	2.89 (1.73-4.82)	<0.0001	3.12 (1.62-5.97)	0.0006
Female gender	0.58 (0.38-0.89)	0.0125	0.46 (0.29-0.74)	0.0012
White	1.15 (0.63-2.11)	0.6497	1.07 (0.50-2.29)	0.8614
> or = 3 Comorbidities	1.11 (0.68-1.82)	0.6661	0.86 (0.44-1.68)	0.6662
ASA score 4 or 5	11.5 (4.75-28.01)	<0.0001	11.6 (5.25-25.47)	<0.0001

OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists

[a]Unadjusted univariate analyses were used to test an independent variables's predictive ability on in-hospital mortality

[b]Model covariates for mortality were chosen by full selection;general estimation equations were used to account for unknown correlation within individual surgeons to mortality

[c]P-value of <0.05 significant

DISCUSSION:

Patients treated by high-volume surgeons had similar outcomes to patients treated by lower-volume surgeons for all emergent, open, colorectal procedures over the three year study. The high-volume group did, on average, four times as many operations over the three years as the low-volume group (27.7 cases vs 6.1 cases), but this increase in operative volume did not translate into improved outcomes for the three surgeons in the high-volume surgeons group. Accordingly, contrary to our primary hypothesis, surgeon volume was not a good predictor of outcome.

This finding is somewhat surprising, especially given the relative importance of surgeon volume to the outcomes of *elective* operations. In certain complex elective general surgery procedures, a patient can cut their adjusted operative mortality risk by 50 to 75% by seeing a high-volume surgeon.[30] Yet this same type of survival benefit is not realized for emergency colorectal cases.

In the 215 patients analyzed, outcome was primarily determined by preoperative characteristics (age, gender, and ASA score) rather than by the operative volume of the individual surgeon. In the high-volume surgeons group there was a slight increase in the average age (64 years vs 57 years old in the low-volume group) and percentage of patients with ASA 4 or 5 (65.1% vs 50.8% in the low-volume group). This therefore may have contributed to offsetting any potential benefit from higher operative volume, as the high-volume surgeons may simply have been operating on sicker patients. After adjusting for these variables in the multivariable analyses, the adjusted odds ratios for the higher-volume groups went from >1 (meaning higher volume harmful) to <1 (meaning higher volume protective), though these ORs were still nonsignificant.

One of the reasons why surgeon-volume may not matter as much to the outcomes of emergent cases as it does for elective cases relates to the physiologic derangements which exist when an emergent operative patient enters the operating room. In the emergency surgical patient the systemic derangements caused by inflammation are a direct manifestation of their surgical disease, and thus can take hold preoperatively. In one national analysis of all emergency operations, 44% of EGS patients fit the criteria for the Systemic Inflammatory Response Syndrome (SIRS) preoperatively compared to only 7% of the elective patients; of those undergoing colon resection, the emergent patients had a mortality rate of 14% versus a mortality rate of 2% for non-emergent cases.[31,32] As such, emergency patients often enter the operating room with physiologic derangements, and this upregulation of the inflammatory response can greatly increase the risk of mortality. As we have shown in the current study, this mortality is independent of the volume of the surgeon who operates.

Our results represent confirmation that elective and emergent surgical patients represent two unique patient-populations. These findings also signify a major paradigm shift in the way we think of emergent operations: the experience of the surgeon does not matter to the outcome as much as the severity of the patient's illness at presentation. To that end, the trajectory of outcomes in EGS patients may be more defined preoperatively than intraoperatively.

This last point may help to show that emergency general surgery patients are more closely comparable to trauma patients than they are to elective general surgery patients. In elective operations there is a clear relationship between surgeon volume and operative mortality; the same is not true for individual trauma surgeons. Studies have shown that within the field of trauma surgery, individual trauma surgeon-volume is not related to patient mortality; there is, however, a clear relationship between hospital volume and outcomes for trauma patients.[19–21] This body of research has helped to validate the creation of regionalized trauma care, within set trauma systems.

The negative finding in our analysis also confirms that perhaps systems of care matter more than individual surgeons in emergency surgical situations, whether they be general surgery emergencies or trauma emergencies. This would make sense, since in both EGS as well as trauma, operations are done on an emergent basis and are performed by the on-call surgeon with no ability to preoperatively choose your surgeon.

This highlights a fundamental difference with non-emergent, elective cases: there is no ability to control for and/or optimize preoperative status (nutritionally, functionally, medically, etc) with emergent/urgent operations. Accordingly, the institutional management of a given patient would be essential to capture in any future analyses. Concomitantly, using hospital surgical volume may be preferential to surgeon volume.

These data provide evidence to suggest that there are other factors driving postoperative outcomes for emergency colorectal surgery patients. From the study of elective operations, we know that there are myriad influences which help to explain the variation in postoperative morbidity and mortality: hospital volume;[22–28] surgeon volume;[28–30] surgeon specialization;[29,36] regionalization;[37,38] institutional systems/processes of care;[2,39–41] validated outcomes monitoring/reporting;[35,42] statewide quality improvement initiatives;[43] teamwork;[44,45] checklists;[46] and many others. To that end, in order to uncover clinically meaningful outcome-benefits for emergency surgical patients, other independent variables need to be studied.

The current study has limitations. First, our conclusions are drawn from retrospective data, and are thus constrained by the limitations and biases therein. This includes selection bias, as this is a single hospital's experience and patients were chosen to undergo operations based on individual surgeon assessment. These biases could potentially be avoided with a large scale multicentered retrospective study, as well as with a prospective analysis with objective criteria for operative selection.

Second, the definition of an emergency patient is a construct of the study, as well as the individual assessments of the attending surgeon and anesthesiologist. Therefore, generalizing to all emergency surgical patients may not be valid, as definitions of "emergency patient" are not standardized.[47] Thirdly, the data are from one institution, which is a tertiary medical center and large academic hospital; this may not be representative of a national sample from which to make conclusions.

A fourth limitation is that the ability to risk-adjust the data was limited to the variables within the dataset. Specifically, physiologic parameters were not recorded; therefore, our risk-adjustment model is based completely on comorbid conditions and other basic patient characteristics. We were not able to fully risk-adjust the data for acute physiologic abnormalities at presentation, which we know play a key role in the outcomes of EGS patients (note that ASA score indirectly accounts for physiologic derangements based on a patient's presentation, but ASA does not include objective physiologic criteria for its score). However, while it would be ideal to be able to make such an adjustment, studies have in fact validated the risk-adjustment of data with comorbid factors alone (such as the Charlson Comorbidity Index). As such, there may be other preoperative risk factors not identified here which more accurately predict morbidity and mortality in emergency patients.

A fifth limitation is that we did not account for the overall procedural complexity of each of the 14 colorectal operations. This is potentially concerning, as the relative importance of surgical volume to outcomes can vary markedly according to the complexity of the operation performed.[48,24,30] While some inferences can be made (CPT 44140 partial colectomy with anastamosis is less complex than CPT 44158 colectomy with proctectomy with reconstruction), the numbers of individual types of colon resections in the present study are so low as to limit such as analysis.

Sixth, our conclusions are drawn from a small sample size of 215 patients operated on by 18 surgeons. Therefore, we lack the necessary power to show potentially significant differences between the surgeon-volume groups. This is supported in the elective literature, as certain complex surgical procedures need to be done more than 200 times per year to see a real difference between high- and low-volume categories.[48] Along those same lines, we do not have enough patients to stratify the data for subanalyses. With a more robust dataset, we could stratify the data in many ways (for example, by the least complex operations or by the healthiest patients). We may further conclude that the relationship reaches an asymptote for certain cases, where the benefits of higher surgical volume plateaus; this has been shown previously for some elective cases, where higher operative volume is only beneficial up to a certain number of cases, beyond which the death rate flattens out.[48]

A seventh limitation is that we were unable to adjust the data for characteristics of the individual surgeons outside of average case volume. Because of this, our results may be explained by other factors intrinsic to the individual surgeons, such as years of experience, as opposed to purely their case volume (note that we used case volume as a proxy for experience, which is consistent with previous studies[30]). For example, surgeons with more years of operative experience may select better patients on which to operate, and therefore have better outcomes independent of volume (this contributes to selection bias). In short, because the decision to operate on an emergent patient is often multifactorial (including both objective and subjective components), we cannot account for how individual surgeons choose to operate on emergent cases.

Eighth, the study of an individual surgeon's outcomes for emergent cases may not be externally valid (i.e. generalizable) in the field of ESC for a number of key reasons (though as we have seen, it is externally valid for elective cases). As aforementioned, emergency patients do not choose their surgeon for emergent operations; rather, they are seen by the on-call surgeon who is covering that day. This is akin to being seen in an emergency department, where patients have little to no choice in which ED physician takes care of them. When a patient presents to the hospital with a surgical emergency, they are treated by the on-call surgeon, not the surgeon they'd elect to see if the case were scheduled. Because of this, the global institutional experience is extremely important with ESC care: patients are cared for not solely by surgeons, but by a whole host of people who greatly contribute to the outcome of individual patients: nurses, nursing assistants, transport techs, operating room teams, anesthesiologists, radiology techs, consulting services, and so forth. This is likely better represented by hospital surgical volume as opposed to specific surgeon volume; the former implies an institutional experience, the latter an individual's experience.

A ninth and final limitation, similar to but unique from the eighth limitation, is that it is very difficult to truly isolate the effect of an individual surgeon's volume on operative outcomes. There may be interactions between surgeon-volume and other independent variables which can potentially lead to problems estimating a surgeon's overall impact on a patient's mortality. One good example is hospital-volume; if surgeon-volume is strongly correlated to hospital-volume, collinearity between these two variables limits the assessment of any one variable. The goal of the present study was to isolate the effect of surgeon volume on mortality at one hospital, making collinearity with hospital volume a minor issue; when multiple institutions are analyzed, this interaction must be accounted for.[24,29,30]

In conclusion, these results indicate that increased surgeon volume is not a key predictor of mortality in emergency colorectal surgical patients. To the contrary, it seems that the primary determinants of outcome in emergent cases exist preoperatively (age, gender, ASA score), and are not determined intraoperatively. These results represent the first study to look at surgeon volume to mortality outcome in emergency surgical care; prior to the restructuring and regionalization of the entire system of ESC, more data-driven research must be conducted to elucidate the major determinants of outcomes in these difficult surgical patients.

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CHAPTER 3: EXPANDED DISCUSSION

FUTURE DIRECTIONS:

The inadequacy in the timely availability of definitive operative interventions for patients with surgical emergencies in the USA has been termed a "crisis" in emergency surgical care ESC.[1] This lack of access to decisive surgical treatment for conditions readily curable by operative intervention has worsened over time; with the growing USA population and the increasing shortage of surgeons to cover emergency operations, access continues to dwindle. Multiple surgical and medical organizations in the USA have expressed the need to find solutions to the ESC crisis, but as of now, no consensus decision has been made.[2,3]

One potential solution is the restructuring of emergency surgical systems of care in the USA, including how and when such emergencies are triaged and where they are managed. Such a drastic departure from our current systems must be evidence-based, but to date there is a lack of data to support or initiate such change. It was exactly such evidence which catalyzed both the restructuring of elective surgical care as well as the regionalization of trauma surgery 30 years ago; both of these surgical systems continue to mature, evolve, and be researched today.[6,29,49,50]

Building on my current thesis project, the long-term goal of my research is to understand the fundamental aspects of emergency surgery systems of care in the USA and play a leading role in its development and improvement. To date, however, there is a significant lack of understanding of ESC in the USA, including little knowledge of what drives outcomes, poor comprehension of the systems through which ESC is delivered, and a dearth of evidence-based solutions to address the crisis facing the field. With data and research, however, the current knowledge-gap in ESC can be reversed, the timely access to and availability of decisive surgical treatment for readily curable conditions can be improved, and the feasibility of restructuring the entire system of ESC can be addressed.

To that end, the objective of my thesis was to define the relationship between a surgeon's operative volume and their postoperative in-hospital mortality for EGS operations at one institution. The central hypothesis of my thesis was that the outcomes of emergent operations are not random or determined by chance, but rather that they are logical, follow persistent patterns, and in some cases are even predictable.

As outlined in the results section above, and discussed at length in Chapter 2's Discussion section, in my thesis I failed to confirm this central hypothesis; the current study is therefore a "negative" study. In our dataset of 215 patients operated on by 18 surgeons, a surgeon's operative volume was not associated with or independently predictive of in-hospital mortality. We did not see logical, persistent, or predictable patterns in regards to outcomes based on surgeon-volume.

The fact remains that the central hypothesis for our research has been formulated on and supported by excellent work in the elective surgical literature, as outlined in the Chapter 1's Literature Review section. The research into volume-outcomes for emergency operations in the USA therefore does not end with the negative conclusion of this thesis project. Rather, the next step is to use a larger dataset which will ensure an adequately powered study. One such dataset which has been widely used for secondary dataset review is the NIS (Nationwide Inpatient Sample).

The NIS is a database of 5 to 8 million all-payer inpatient hospital stays from approximately 1,000 hospitals sampled to approximate a 20-percent stratified sample of USA hospitals. Data are from approximately 40 States participating in the Healthcare Cost and Utilization Project (HCUP); all discharges from sampled hospitals are included in the NIS database.

The unit of measurement in the NIS is a hospital discharge (not an individual patient). The NIS is part of the HCUP, sponsored by the Agency for Healthcare Research and Quality (AHRQ), and is one of the only comprehensive national datasets with the ability to differentiate emergent and nonemergent operations.

The NIS dataset makes conclusions widely generalizable in the USA and the four geographic regions by which we can perform subanalyses (northeast, south, midwest, west). The large size of the database also allows assessment of performance/outcome at very meaningful levels of hospital volume. Additionally, the dataset includes adult patients of all ages, which provides insight into a large portion of patients that would go unstudied if using only medicare data.

The NIS could afford us the opportunity to essentially repeat the current thesis project on a much larger scale. This would address many of the shortcomings of the current study. It should be noted that unlike the current study, however, NIS-based projects would look at hospital-volume as an independent variable, as opposed to surgeon-volume. As outlined throughout this thesis manuscript, that remains a viable study scheme.

The current thesis project looked at mortality as the primary outcome metric. Mortality has historically been the *sine qua non* of trauma and surgical outcomes research, and is the primary outcome measure in our study (though we did include a few hospitalization metrics and non-mortality complication metrics).[51] My focus is not on secondary outcome measures *per se*;

however, in addition to looking at mortality with larger datasets (such as the NIS), a more in depth analysis of secondary outcomes in the future is equally essential because it will add another level of detail and understanding to our knowledge of ESC.[4]

Exploring secondary outcomes is therefore an additional logical and crucial future step, and will be the topic of future studies as we work toward our long-term goal of understanding the fundamental aspects of emergency surgery systems and improving ESC in the USA. Examples of secondary outcome measures include morbidity, postoperative complications/occurrences, return to function, discharge disposition, quality of life, hospital length of stay, need for reoperation, and cost of hospitalization.

Furthermore, by studying secondary outcome measures in the future, we will also be able to conduct higher order analyses with various independent predictor variables to assess their impact on mortality, morbidity, and other outcome metrics. Accordingly, when assessing emergent surgical systems of care, we will be able to risk-adjust, analyze, and/or stratify the data based on:

1) hospital characteristics (geographic region of the hospital, region of the country in which the hospital is located, hospital size, total surgical volume aggregated per year at a hospital, teaching status of hospital, latency time to operating room);
2) patient characteristics (American Society of Anesthesia score, probability of death, cost of hospitalization, length of operation, total intensive care unit days, discharge disposition); and
3) postoperative occurrences (wound infections, respiratory complications, urinary tract complications, cardiac occurrences, vascular complications such as deep venous thrombosis and pulmonary embolism).

Such future studies, using larger datasets, will serve to further elucidate the root causes of mortality as well as various other outcome measures for emergent operations. This current thesis study has provided the initial foundation; with the refinement of future studies, an informed, restructured, and effective ESC system can be developed.

We remain committed to the belief that the outcomes of emergent operations are not random or determined by chance, but rather that they are logical, follow persistent patterns, and in some cases are even predictable. The NIS may be a key to determining if: 1) hospitals in the USA perform vastly different numbers of emergent operations each year; 2) hospitals with higher emergent surgical volumes have lower post-operative mortality rates (an inverse relationship); and 3) the inverse relationship between emergent surgical volume and in-hospital post-operative mortality is more pronounced for more complex procedures and more severely-ill patients.

We were unable to conclude these aims in the current study, but they remain vitally important because they would quantitatively establish for the first time that the delivery of emergency surgical care varies in the USA by hospital, and that this variability contributes significantly to risk-adjusted post-operative mortality. There is currently a void in the understanding of ESC in the USA, including little knowledge of what determines mortality and other outcomes, poor comprehension of the systems through which ESC is delivered, and a lack of evidence-based solutions to address the crisis facing the field. Evidence-based results from the use of a larger, national dataset such as the NIS would help address the void in knowledge by establishing certain fundamental aspects of and predictable relationships within emergency surgery systems of care.

The crisis in ESC represents one of the last areas of surgery that has not been analyzed from a health care delivery standpoint, and a paradigm shift is desperately needed to improve the quality, efficiency, and effectiveness of emergency surgical care in the USA. Future results with larger datasets would represent the second step in a continuum of long-term research (beginning with the current thesis project) that is expected to help address the lack of timely availability to ESC. Over time, the collective results of our research into ESC will provide a foundation to inform decisions to restructure our nation's emergency surgical systems of care.

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EMPLOYMENT:

1997-1998	Commodities Trader Haut Commodities Far Hills, New Jersey & New York, New York
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EDITORIAL CONSULTATION:

2002-2004	*Dartmouth Medicine*, Editorial Board Member
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PANEL MEMBERSHIPS:

January 2011	"Building an Emergency General Surgery Registry: Current Benchmarking and Future Directions." Panel discussant at Eastern Association for the Surgery of Trauma, Annual Scientific Assembly.
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INTERNATIONAL MEDICINE & SURGERY:

Summer 2002	Dar es Salaam, Tanzania Muhumbili Hospital, HIV/TB Research Abbas Medical Center, Outpatient medical and diabetes clinic
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INSTITUTIONAL SERVICE:

2008-2009	General Surgery Journal Club, Co-Chair Wake Forest General Surgery Residency Program
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2004-present	American Medical Association, resident member
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8) Neff LP, Ladd MR, **Becher RD**, Jordanhazy R, Pranikoff T. Computerized Topography Utilization in Children with Appendicitis: Differences in Referring and Children's Hospitals. *The American Surgeon*. August 2011; 77(8): 1061-1065.

9) Neff LP, **Becher RD**, Blackham AU, Banks NA, Mitchell ER, Petty JK. A Novel Anti-Reflux Procedure: Gastroplasty with Restricted Antrum to Control Emesis (GRACE). *Journal of Pediatric Surgery*. January 2012; 47(1): 99-106.

10) **Becher RD**, Meredith JW, Chang MC, Hoth JJ, Beard HR, Miller, PR. Creation and Implementation of an Emergency General Surgery Registry Modeled After the National Trauma Data Bank. *Journal of the American College of Surgeons*. February 2012; 214 (2): 156-163.

11) **Becher RD**, Hoth JJ, Miller PR, Meredith JW, Chang MC. Systemic Inflammation Worsens Outcomes in Emergency Surgical Patients. *Journal of Trauma and Acute Care Surgery*. May 2012; 72(5): 1140-1149.

12) Ladd MR, Neff LP, **Becher RD**, Gallaher JR, Pranikoff T. Computerized Tomography in the Workup of Pediatric Appendicitis: Why Are Children Scanned? *The American Surgeon*. June 2012; 78(6): 716-721.

13) **Becher RD**, Chang MC, Hoth JJ, Kendall JL, Beard HR, Miller, PR. Does Acute Physiology and Chronic Health Evaluation (APACHE) II Provide a Valid Metric To Directly Compare Disease Severity in Trauma versus Surgical Intensive Care Unit Patients? *The American Surgeon*. November 2012; 78(11): 1261-1269.

14) **Becher RD**, Colonna AL, Enniss TM, Weaver AA, Crane DK, Martin RS, Mowery NT, Miller PR, Stitzel JD, Hoth JJ. An Innovative Approach to Predict the Development of ARDS in Blunt Trauma Patients. *Journal of Trauma and Acute Care Surgery*. November 2012; 73(5): 1229-1235.

15) **Becher RD**, Hoth JJ, Kendall JL, Rebo JJ, Miller PR. Locally-Derived versus Guideline-Based Approach to Treatment of Hospital-Acquired Pneumonia in the Trauma Intensive Care Unit. *Surgical Infections*. December 2012; 13(6): 352-359.

16) Ladd MR, Pajewski NM, **Becher RD**, Swanson JM, Gallaher JR, Pranikoff T, Neff LP. Delays in Treatment of Pediatric Appendicitis: A More Accurate Variable for Measuring Pediatric Healthcare Inequalities? Pending publication in *The American Surgeon*. September 2013.

17) Groves LB, Ladd MR, Gallaher JR, Swanson JM, **Becher RD**, Pranikoff T, Neff LP. Comparing the Cost and Outcomes of Laparoscopic Versus Open Appendectomy for Perforated Appendicitis in Children. Pending publication in *The American Surgeon*. September 2013.

ABSTRACTS:

1) Erekson EA, Sung VW, DiSilvestro PA, **Becher RD**, Myers DL. *Urinary Symptoms and Impact on Quality of Life in Women Following Treatment for Endometrial Cancer.* American Urogynecological Society (AUGS) 29th Annual Scientific Meeting, September 2008.

2) **Becher RD**, Corriere MA, Edwards MS, Pettus J, Godshall CJ. *Late Erosion of a Prophylactic IVC Filter into the Aorta, Right Renal Artery, and Duodenal Wall* (Southern Association of Vascular Surgery Annual Meeting, January 2010). Journal of Vascular Surgery. December 2009; 50(6): 1540-1541.

3) **Becher RD**, Shen P, Stewart JH, Russell G, Bradley T, Levine EA. *Splenectomy Ameliorates Hematologic Toxicity of Intraperitoneal Hyperthermic Chemotherapy* (Society of Surgical Oncology Annual Cancer Symposium, March 2010). Annals of Surgical Oncology. February 2010; 17(Suppl.1): S83-S84.

4) **Becher RD**, Hoth JJ, Neff LP, Rebo JJ, Martin RS, Miller PR. *Multidrug-Resistent Pathogens and Initial Empiric Antibiotic Therapy for Pneumonia in the Trauma versus Surgical Intensive Care Unit* (Surgical Infection Society Annual Meeting, April 2010). Surgical Infections. April 2010; 11(2): 230-231.

5) Banks N, Neff LP, **Becher RD**, Blackham AU, Mitchell E, Petty JK. *Gastroplasty with Restrictive Antrum to Control Emesis (GRACE): A Novel Anti-Reflux Procedure.* Wake Forest University Medical Student Research Day, October 2010.

6) Gallaher JR, Ladd MR, Neff LP, **Becher RD**, Pranikoff T. *Comparing the outcomes of laparoscopic versus open appendectomy for perforated appendicitis in pediatric patients.* Wake Forest University Medical Student Research Day, October 2010.

7) Kendall JL, **Becher RD**, Rebo JJ, Hoth JJ, Miller P. *Defining new empiric treatment algorithms for presumed pneumonia in the trauma and surgical intensive care units.* Wake Forest University Medical Student Research Day, October 2010 (won 2nd place out of 48 posters).

8) Neff LP, Ladd MR, Gallaher JR, **Becher RD**, Pranikoff T. *Comparing the Outcomes of Laparoscopic versus Open Appendectomy for Perforated Appendicitis in Pediatric Patients.* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day, November 2010.

9) Neff LP, **Becher RD**, Ladd MR, Gallaher JR, Pranikoff T. *Socioeconomic Factors Predict Perforated Appendicitis in Children.* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day, November 2010.

10) Neff LP, **Becher RD**, Ladd MR, Gallaher JR, Pranikoff T. *Predicting the Use of Computerized Tomography to Diagnose Acute Appendicitis in Children.* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day, November 2010.

11) Neff LP, **Becher RD**, Blackham AU, Banks N, Mitchell E, Petty JK. *A Novel Anti-Reflux Procedure: Gastroplasty with Restricted Antrum for Control of Emesis (GRACE).* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day, November 2010 (won Silver Medal for second place).

12) **Becher RD**, Chang MC, Hoth JJ, Kendall JL, Beard HR, Miller, PR. *Does Apache-II Provide A Valid Metric To Directly Compare Disease Severity In Patients In The Trauma Versus Surgical Intensive Care Unit?* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day, November 2010.

13) **Becher RD**, Hoth JJ, Kendall J, Rebo JJ, Miller PR. *Comparing A Locally-Derived Versus Guideline-Based Approach To Treatment Of Hospital Acquired Pneumonia In The Trauma Intensive Care Unit.* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day, November 2010 (won Gold Medal for first place)

14) **Becher RD**, Chang MC, Hoth JJ, Kendall JL, Beard HR, Miller, PR. *Does APACHE II Provide a Valid Metric to Directly Compare Disease Severity in Patients in the Trauma Versus Surgical Intensive Care Unit?* Eastern Association for the Surgery of Trauma Annual Scientific Assembly, January 2011.

15) **Becher RD**, Meredith JW, Chang MC, Hoth JJ, Beard HR, Miller, PR. *The Future of Tracking Acute Care Surgery Patients: Creating an Emergency General Surgery Registry Modeled After the National Trauma Data Bank.* Eastern Association for the Surgery of Trauma Annual Scientific Assembly, January 2011.

16) **Becher RD**, Hoth JJ, Miller PR, Mowery NT, Chang MC, Meredith JW. *A Critical Look at Outcomes in Emergency versus Non-Emergency General Surgery using the ACS NSQIP Database*. Southeastern Surgical Congress Annual Scientific Meeting, February 2011.

17) **Becher RD**, Hoth JJ, Kendall JL, Rebo JJ, Miller PR. *Comparing A Locally-Derived Versus Guideline-Based Approach To Treatment Of Hospital Acquired Pneumonia In The Trauma Intensive Care Unit* (Surgical Infection Society Annual Meeting, May 2011). Surgical Infections. May 2011; 12(Supplement 1): S-42.

18) Neff LP, **Becher RD**, Blackham AU, Banks N, Mitchell E, Petty JK. *A Novel Anti-Reflux Procedure: Gastroplasty with Restricted Antrum for Control of Emesis (GRACE).* American Pediatric Surgical Association Annual Meeting, May 2011.

19) **Becher RD**, Hoth JJ, Miller PR. *Antibiotic Resistance and the Difficulty of Empiric Coverage for Late Pneumonia in the Surgical Intensive Care Unit: A Plea for Antibiotic Stewardship.* American Association for the Surgery of Trauma Annual Meeting, September 2011.

20) **Becher RD**, Hoth JJ, Miller PR, Meredith JW, Chang MC. *Sepsis Worsens Outcome after Emergency Colon Surgery: What Every General Surgeon Should Know.* American Association for the Surgery of Trauma Annual Meeting, September 2011.

21) **Becher RD**, Hoth JJ, Miller PR. *Antibiotic Resistance and the Difficulty of Empiric Coverage for Late Pneumonia in the Surgical Intensive Care Unit: A Plea for Antibiotic Stewardship.* Wake Forest School of Medicine, Surgical Sciences Residents' Research Day, November 2011.

22) Nunez JM, **Becher RD** (co-first author), Rebo JJ, Farrah JP, Borgerding EM, Miller PR. *Prospective Evaluation of Weight-Based Prophylactic Enoxaparin Dosing in Critically-Ill Trauma Patients: Adequacy of Anti-Xa Levels is Improved.* Forest School of Medicine, Surgical Sciences Residents' Research Day, November 2011.

23) **Becher RD**, Hoth JJ, Miller PR, Meredith JW, Chang MC. *Systemic Inflammation Worsens Outcome in Emergency Surgical Patients.* Wake Forest School of Medicine, Surgical Sciences Residents' Research Day, November 2011.

24) Neff LP, **Becher RD**, Ladd MR, Gallaher JR, Pranikoff T. *Computerized Tomography in the Workup of Pediatric Appendicitis: Why Are Children Scanned?* Southeastern Surgical Congress Annual Scientific Meeting, February 2012.

25) Nunez JM, **Becher RD** (co-first author), Rebo JJ, Farrah JP, Borgerding EM, Miller PR. *Prospective Evaluation of Weight-Based Prophylactic Enoxaparin Dosing in Critically-Ill Trauma Patients: Adequacy of Anti-Xa Levels is Improved.* Western Trauma Association, February 2012.

26) **Becher RD**, Gallaher JR, Meredith JW, Neff LP, Chang MC. *Benchmarking Quality in Acute Care and Elective Surgical Practice: the Need for Separation*. American Association for the Surgery of Trauma Annual Meeting, September 2012.

27) **Becher RD**, Gallaher JR, Sun Y, Miller PR, Chang MC. *The Maturation Of Damage Control: Why Indications For Staged Laparotomy Should Be Different In Emergency General Surgery And Trauma Patients.* Wake Forest School of Medicine, Division of Surgical Sciences Residents' Research Day, November 2012.

28) **Becher RD**, Gallaher JR, Neff LP, Meredith JW, Chang MC. *Improving The Quality Of Care And Reported Outcomes Of Elective General Surgeons Through The Implementation Of An Acute Care Surgery Service.* Wake Forest School of Medicine, Division of Surgical Sciences Residents' Research Day, November 2012.

29) Groves LB, Ladd MR, Gallaher JR, Neff LP, Swanson J, **Becher RD**, Pranikoff T. *Comparing the Cost and Outcomes of Laparoscopic Versus Open Appendectomy for Perforated Appendicitis in Pediatric Patients.* Wake Forest School of Medicine, Division of Surgical Sciences Residents' Research Day, November 2012.

30) Neff LP, Ladd MR, Swanson J, **Becher RD**, Gallaher JR, Pranikoff T. *Socioeconomic Factors Associated with Perforated Appendicitis in Children.* Southeastern Surgical Congress Annual Scientific Meeting, February 2011.

31) **Becher RD**, Gallaher JR, Sun Y, Neff LP, Miller PR, Chang MC. *Defining Criteria for the Rapid Source Control Laparotomy in Emergency General Surgical Patients.* American Association for the Surgery of Trauma, Annual Meeting, September 2013.

ORAL RESEARCH/SCIENTIFIC PRESENTATIONS:

January 2010	*Late Erosion of a Prophylactic IVC Filter into the Aorta, Right Renal Artery, and Duodenal Wall.* Southern Association for Vascular Surgery, Annual Meeting.
April 2010	*Multidrug-Resistent Pathogens and Pneumonia in the Trauma versus Surgical Intensive Care Unit.* Surgical Infection Society, Annual Meeting.
July 2010	*Does APACHE-II Provide a Valid Metric to Directly Compare Disease Severity in Patients in the Trauma versus Surgical Intensive Care Unit?* Resident Trauma Paper Competition (won second place), North Carolina chapter, American College of Surgeons Committee on Trauma.
November 2010	*Does APACHE-II Provide a Valid Metric to Directly Compare Disease Severity in Patients in the Trauma versus Surgical Intensive Care Unit?* Resident Trauma Paper Competition (won second place), Region IV, American College of Surgeons Committee on Trauma.
May 2011	*Comparing A Locally-Derived Versus Guideline-Based Approach To Treatment Of Hospital Acquired Pneumonia In The Trauma Intensive Care Unit.* Surgical Infection Society, Annual Meeting.
July 2011	*Sepsis Worsens Outcome after Emergency Colon Surgery: What Every General Surgeon Should Know.* Resident Trauma Paper Competition (won second place), North Carolina chapter, American College of Surgeons Committee on Trauma.
September 2011	*Sepsis Worsens Outcome after Emergency Colon Surgery: What Every General Surgeon Should Know.* American Association for the Surgery of Trauma, Annual Meeting.
November 2011	*Sepsis Worsens Outcome after Emergency Colon Surgery.* Resident Trauma Paper Competition (won second place), Region IV, American College of Surgeons Committee on Trauma.

POSTER RESEARCH/SCIENTIFIC PRESENTATIONS:

February 2009	*Sentinel Lymph Node Mapping for Gastric Adenocarcinoma.* Southeastern Surgical Congress, Annual Scientific Meeting.

November 2009	*Sentinel Lymph Node Mapping for Gastric Adenocarcinoma.* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day.
March 2010	*Splenectomy Ameliorates Hematologic Toxicity of Intraperitoneal Hyperthermic Chemotherapy.* Society of Surgical Oncology, Annual Cancer Symposium.
March 2010	*Multidrug-Resistent Pathogens and Initial Empiric Antibiotic Therapy for Pneumonia in the Trauma versus Surgical Intensive Care Unit.* Wake Forest University Graduate School of Arts & Sciences, Grad Student Research Day.
November 2010	*Does Apache-II Provide A Valid Metric To Directly Compare Disease Severity In Patients In The Trauma Versus Surgical Intensive Care Unit?* Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day.
November 2010	*Comparing A Locally-Derived Versus Guideline-Based Approach To Treatment Of Hospital Acquired Pneumonia In The Trauma Intensive Care Unit.* (won Gold Medal for first place) Wake Forest University School of Medicine, Surgical Sciences Residents' Research Day.
January 2011	*Does APACHE II Provide a Valid Metric to Directly Compare Disease Severity in Patients in the Trauma Versus Surgical Intensive Care Unit?* Eastern Association for the Surgery of Trauma, Annual Scientific Assembly.
January 2011	*The Future of Tracking Acute Care Surgery Patients: Creating an Emergency General Surgery Registry Modeled After the National Trauma Data Bank.* Eastern Association for the Surgery of Trauma, Annual Scientific Assembly.
February 2011	*A Critical Look at Outcomes in Emergency versus Non-Emergency General Surgery using the ACS NSQIP Database.* Southeastern Surgical Congress, Annual Scientific Meeting.
March 2011	*Comparing A Locally-Derived Versus Guideline-Based Approach To Treatment Of Hospital Acquired Pneumonia In The Trauma Intensive Care Unit.* Wake Forest University Graduate School of Arts & Sciences, Grad Student Research Day.
September 2011	*Antibiotic Resistance and the Difficulty of Empiric Coverage for Late Pneumonia in the Surgical Intensive Care Unit: A Plea for Antibiotic Stewardship.* American Association for the Surgery of Trauma, Annual Meeting.
November 2011	*Antibiotic Resistance and the Difficulty of Empiric Coverage for Late Pneumonia in the Surgical Intensive Care Unit: A Plea for*

	Antibiotic Stewardship. Wake Forest School of Medicine, Surgical Sciences Residents' Research Day.
November 2011	*Systemic Inflammation Worsens Outcome in Emergency Surgical Patients.* Wake Forest School of Medicine, Surgical Sciences Residents' Research Day.
September 2012	*Benchmarking Quality in Acute Care and Elective Surgical Practice: the Need for Separation.* American Association for the Surgery of Trauma, Annual Meeting.
November 2012	*The Maturation Of Damage Control: Why Indications For Staged Laparotomy Should Be Different In Emergency General Surgery And Trauma Patients.* Wake Forest School of Medicine, Surgical Sciences Residents' Research Day.
November 2012	*Improving The Quality Of Care And Reported Outcomes Of Elective General Surgeons Through The Implementation Of An Acute Care Surgery Service.* Wake Forest School of Medicine, Surgical Sciences Residents' Research Day.
September 2013	*Defining Criteria for the Rapid Source Control Laparotomy in Emergency General Surgical Patients.* American Association for the Surgery of Trauma, Annual Meeting.

INVITED LECTURES:

April 2009	"Vascular Surgery and War: Advancing Vascular Injury Management." Invited speaker at Grand Rounds, Department of Vascular and Endovascular Surgery, Wake Forest University School of Medicine.
December 2009	"Epidemiology, Surgery, and the International Public Health Agenda." Invited speaker at Wake Forest University Graduate Program in Clinical Population Translational Sciences.
February 2010	"The Global Burden of Surgical Disease: Redefining Global Public Health." Invited speaker at Wake Forest University Chapter of Alpha Epsilon Delta, the pre-medical undergraduate honor society.
May 2010	"Surgery in the Developing World: Why It Matters" Invited speaker at Grand Rounds, Department of General Surgery, Wake Forest University School of Medicine.
June 2010	"Pneumonia in the Trauma and Surgical Intensive Care Units." Invited speaker at Grand Rounds, Department of Pulmonary & Critical Care, Wake Forest University School of Medicine.

October 2010	"Pediatric Trauma: Epidemiology, Outcomes, Research." Invited speaker at the Childress Institute for Pediatric Trauma, Brenner Children's Hospital, Wake Forest University Medical Center.
February 2011	"Lactate and Base Deficit in Trauma: Accurate Predictors of Mortality in the Setting of Negative Blood Alcohol Levels?" Invited discussant at the Southeastern Surgical Congress, Annual Scientific Meeting.
March 2011	"Biostatistics: What Every Surgeon Should Know." Invited speaker at the Department of General Surgery, Wake Forest University School of Medicine.
May 2013	"The Role of Surgery in Global Health." Invited speaker at Grand Rounds, Department of General Surgery, Wake Forest University School of Medicine.

RESEARCH MENTORSHIP TO WAKE FOREST MEDICAL STUDENTS:

Natalie Banks	Class of 2013, Wake Forest University School of Medicine
H. Randall Beard	Class of 2010, Wake Forest University School of Medicine
Mallory Bray	Class of 2012, Wake Forest University School of Medicine
Daniel Crane	Class of 2011, Wake Forest University School of Medicine
Jared R. Gallaher	Class of 2011, Wake Forest University School of Medicine
Jennifer L. Kendall	Class of 2013, Wake Forest University School of Medicine
Mitchell R. Ladd	Class of 2013, Wake Forest University School of Medicine
Brent McNaught	Class of 2011, Wake Forest University School of Medicine
Yankai Sun	Class of 2013, Wake Forest University School of Medicine

COMMUNITY ACTIVITIES AND SERVICE:

UNDERGRADUATE ACTIVITIES:

1994	Colby College Men's Varsity Lacrosse
1994, 1996	Colby College Men's Varsity Golf
1995-1996	University of London Sailing Team

MEDICAL SCHOOL ACTIVITIES:

2001-2004	Dartmouth International Health Group, Co-Chair 2002-2003
2001-2003	Diverse Elderly Council, Chair 2002-2003
2002-2004	Editorial Board Member, *Dartmouth Medicine*
2004-2013	Editorial Board Member, *Brown Medicine*
2003-present	Counselor to Dartmouth Medical School students with Learning Disabilities

2004-present	Counselor to Brown Medical School students with Learning Disabilities

COMMUNITY ACTIVITIES:

1996, 1997	Community Snow Shoveler Waterville, Maine
1997, 1998	Liberty Corner First Aid Squad, EMT Liberty Corner, New Jersey
1998, 1999	Search and Rescue Squad Member / EMT Curry County, Oregon
1999, 2000	Catholic Worker Free Clinic Philadelphia, Pennsylvania
2000, 2001	Habitat for Humanity Providence, Rhode Island
2000, 2001	Rhode Island Food Bank Providence, Rhode Island
2009-2013	Preceptor for premed students Wake Forest University, Winston-Salem, North Carolina
2010-2013	Preceptor for premed students Colby College, Waterville, Maine