PREDICTING COMPLIANCE, BARRIERS, AND OUTCOMES TO SURGICAL CARE GUIDELINES

by

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ABSTRACT

ALLYSON ROSE COCHRAN. Predicting Compliance, Barriers, and Outcomes to Surgical Care Guidelines

(Under the direction of DR. GEORGE SHAW JR.)

Clinical care guidelines optimize patient care, including Enhanced Recovery after Surgery (ERAS®) guidelines specific to surgery. However, despite their efficacy, compliance to guidelines by providers remains a challenge. Understanding ways to predict, and thus prevent, non-compliance can aid in not only improving uptake by providers but improving post-surgical recovery for patients.

Four approaches were taken to understand and assess these issues. A novel method was developed, coined Vertical Compliance, for measure ERAS compliance with the aim to predict and prevent adverse surgical outcomes before they occur by modifying compliance in real-time. Next, a multi-institutional, multi-surgical specialty retrospective data analysis revealed specific ERAS recommendations that - if not performed - predicted adverse patient outcomes such as increased length of stay (LOS) and clinically-relevant complications. However, understanding barriers to compliance in the first place can potentially improve their uptake via targeted mitigation strategies. A meta-analysis was conducted for the overall medical literature and regression models developed to understand which barriers predict non-compliance to guidelines. Finally, to understand barriers to compliance specific to surgery and ERAS, a survey was developed and analyzed using a mixed-methods approach to understand which barriers to compliance predicted reduces feelings of compliance assurance amongst ERAS professionals.

While conceptually different, vertical compliance and the multi-institutional data analysis revealed similarities in which specific recommendations predict adverse outcomes, including oral carbohydrate loading, early removal of Foley catheter, and limited use of nasogastric tubes.

The two studies examining barriers to compliance found concordance in which barriers most impact compliance, specifically presence of external barriers and familiarity with the guidelines. In the ERAS-specific barriers study, lack of motivation and agreement were also found to drive compliance.

Taken both individually and collectively, these four studies reveal why predicting adverse surgical outcomes due to non-compliance to evidence-based care is important, yet, predicting barriers may prove a critical element to preventing that non-compliance before it occurs.

ACKNOWLEDGEMENTS

They say luck is what happens when preparation meets opportunity. I have been very lucky to have been given so many opportunities which I suppose, if the quote is correct, means I was also prepared to rise to those opportunities when they occurred. I have many people to thank for that preparation.

I firstly want to thank Dionisios Vrochides, who not only has been a mentor in leadership and academic pursuit but has given me every opportunity to prove that I was in fact prepared to meet any challenge. And I was certainly challenged. I was put outside my comfort zone - from public speaking to leadership roles to developing a future thinking mindset - and was only the better for having done so each and every time. I simply cannot thank you more.

I have been fortunate to have other mentors who have set me on the path I find myself on today. Bill Gross, my supervisor and champion at Gaston County Health Department, also challenged me to aim high. Without his mentorship I would not have developed confidence in speaking, writing, leadership, and developing non-traditional solutions to problems in public health. And finally, Andrew Harver opened the proverbial door just enough so my foot could fit in; the beginning of my journey in data and academics despite mispronouncing his name during an elevator speech about how I should be in his program, in a literal elevator.

This doctoral work would not have been what it was without a little help from my friends. Keith Murphy has been an invaluable classmate, doctoral companion, but most importantly a steadfast friend. I am wishing him all the luck on his own journey! And last, but absolutely not least, Jessica Drummond has been more helpful than she likely knows. She could always sense when I was too deep in the dissertation work or feeling overwhelmed, and simply

call and ask if I wanted to take a break. It was those small, serendipitous, uncanny moments that kept me going.

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LIST OF ABBREVIATIONS

ERAS	Enhanced Recovery after Surgery
LOS	length of stay
APP	Advanced practice provider
EIAS	ERAS® Interactive Audit System
EMR	electronic medical record
CDSS	clinical decision support systems
OR	odds ratio
MDT	multidisciplinary team
BMI	body mass index
AIC	Akaike's information criterion
PPML	Poisson pseudo maximum likelihood
REDCap	Research Electronic Data Capture
ANOVA	analysis of variance
PONV	prevention of nausea and vomiting

CHAPTER 1: INTRODUCTION

Introduction

As we will come to see, practitioners of medicine have been using guidelines to optimize care for their patients for many years. The field of surgery is ideal for developing guidelines as the practice itself is tangibly experienced by a primary person and yet reliant on multidisciplinary team efforts, thus conducive to improvements in efficiencies in individual technique as well as efficiencies in team communication and care delivery. Perhaps this is why care guidelines – or protocols – as we know them today were first popularized by surgical societies. To date, a multitude of surgical guidelines have been developed by many groups, however the most robust evidence of improved patient, process, and administrative outcomes has been published by the Enhanced Recovery After Surgery (ERAS®) Society. ERAS® guidelines have a long history of showing improvement in outcomes, and so this work will focus on the guidelines developed by this group.

If following guidelines improves outcomes, then measurement of compliance to these guidelines is imperative. There are a few ways to measure and report on compliance; traditionally involving overall percentages of the guidelines adhered to for a cohort of patients, or overall percentage of compliance for an individual guideline item. These metrics are helpful and necessary to provide continuous feedback on the status of an ERAS program, however they are by nature retrospective and after the fact. Perhaps if providers could predict non-compliance before it happens, then it could be prevented and thus increase the likelihood of improved outcomes for individual patients. This particular concept, coined vertical compliance, is discussed in Chapter Two, though overall application of predictive modelling in surgery is a common theme in this work.

Just because guidelines exist does not necessarily mean providers will use them. Indeed, barriers to compliance is a well-studied topic, having tracked in the literature at the same rate as the publication of the guidelines themselves. It is known that the more guideline items in a protocol one performs, the better chance for significant improvement in patient outcomes, yet low compliance continues to remain an issue. In an effort to describe and collate reasons for this problem, Cabana and colleagues published what would become a foundational framework of barriers to compliance.[1] Cited over 7,600 times, this framework will be utilized in all Chapters in this work, though specifically in Chapter Three to develop a model to predict barriers to guidelines compliance based on data derived from the broader guideline compliance literature.

Developing ways to predict barriers based on the broader literature is an important step to developing ways to predict ERAS-specific barriers. To date, no studies have developed ways to predict non-compliance in the setting of ERAS®. To begin to address this gap, Chapter Four will utilize an ERAS® data registry to use compliance data to predict adverse surgical outcomes in two high-volume ERAS® certified institutions and Chapter Five will survey the multidisciplinary members of the USA Chapter of the ERAS® Society to determine their perceived barriers to compliance to the core ERAS® guideline items, as organized by the Cabana framework. Information and insights derived from these studies will perhaps lay the groundwork for future work on developing ways to mitigate ERAS® specific barriers.

Clinical Guidelines

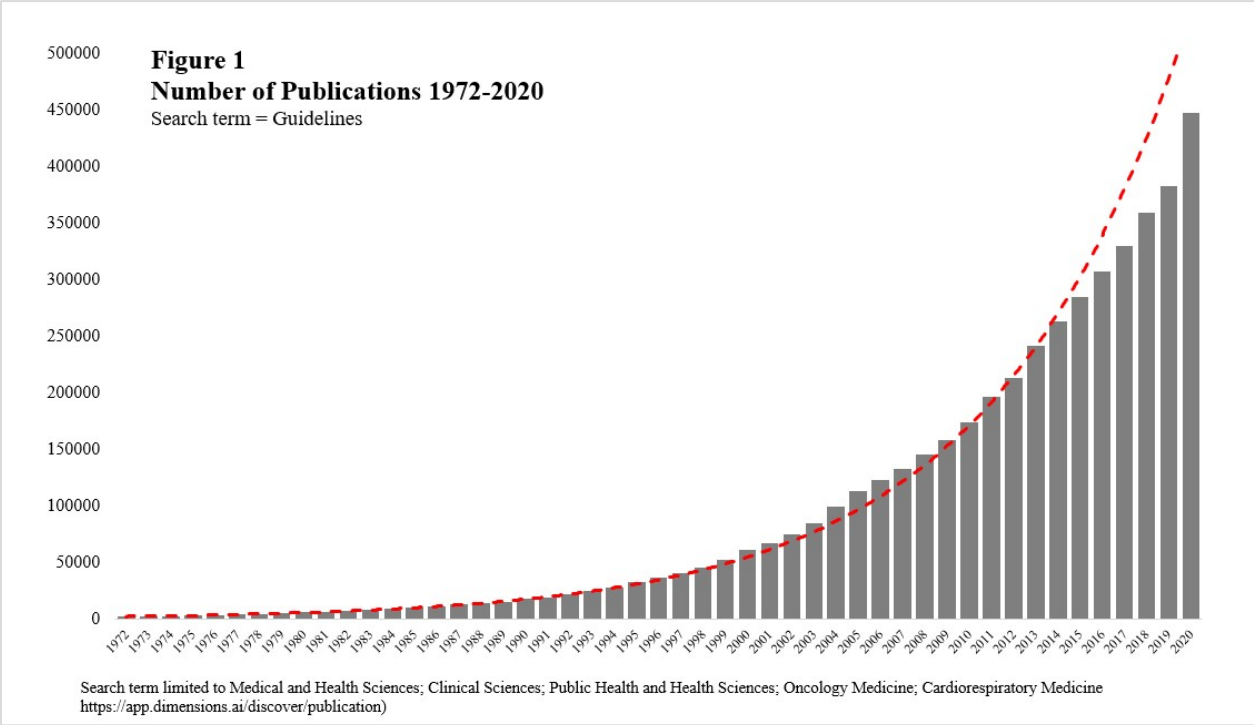
"Clinical guidelines are statements that include recommendations intended to optimize patient care that are informed by a systematic review of evidence and an assessment of the benefits and harms of alternative care options"[2]. Clinical guidelines are generally developed by academic, medical, or professional societies or consortiums with the aim to improve patient care

and efficiency by reducing variation in practice, and delivering evidence-based practice recommendations, standards, and benchmarks.[3]

A Brief History of Guidelines

Medicine has long held that practitioners meet some level of minimal standards to practice, from local medieval regulations to licensure requirements in the late 19th century. Professionally created guidelines, as we understand them today, are an American phenomenon, developed by the American College of Surgeons in 1931 which emphasized standardization of delivery of care in cancer services.[4] However only since the 1970's has medicine world-wide fully embraced the development and application of formal guidelines. The United States was still leading in their development, ultimately culminating in the creation of the Agency for Healthcare Research and Quality (AHRQ) in 1989.[4,5] The emergence of guidelines also coincided with the rise of evidence-based medicine which lead to the expectation of integrating literature-based evidence levels into guidelines development.[4,6] By 2010, the Institute of Medicine (now known as the National Academy of Medicine) had identified clinical guidelines as one of the main ways to translate scientific research into real-world practice and issued detailed standards on their definition, development, quality, and updating.[2]

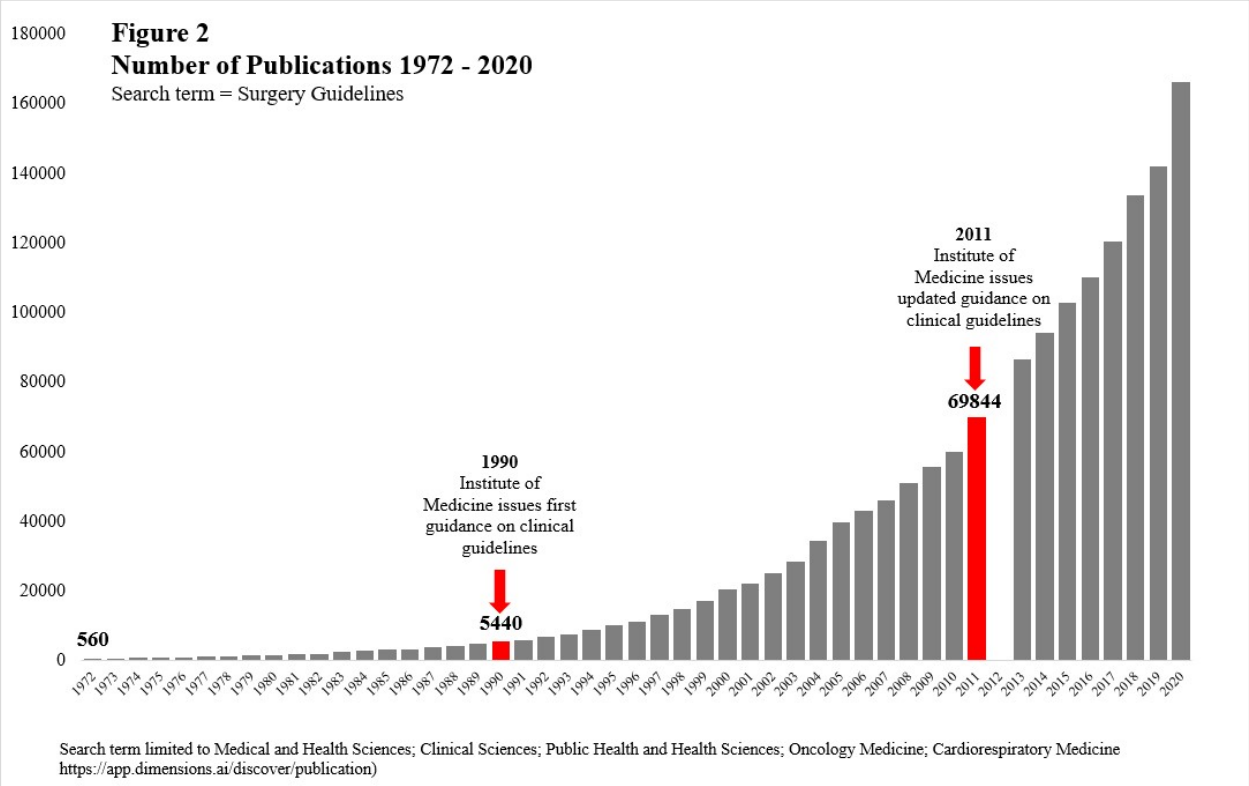
Academic output related to guidelines has dramatically increased (Figure 1). This building of historical momentum, and the ability of well-developed guidelines to eliminate care variation, improve patient outcomes and reduce healthcare costs may explain their current prevalence.



A Brief History of Surgical Guidelines

As previously mentioned, clinical guidelines as we understand them today were developed by the field of surgery in the early twentieth century. This occurred at a time of professional introspection, where some leaders in surgery strongly advocated for tracking post-operative outcomes and results, which at the time was a radical idea. With this shift in thinking, in 1931 the American College of Surgeons produced two sets of guidelines, which ultimately paved the way for the expansion of guidelines-use to general medicine and public health.[7] While publication of surgery guidelines was generally quiescent afterwards, widespread publication and

commentary once again rose at a time when non-surgical interest also increased, and appears to correspond with each year the Institute of Medicine issued formal guidance and commentary on clinical guidelines (Figure 2).



A Brief History of Enhanced Recovery After Surgery (ERAS®)

While clinical guidelines were historically more popular in the United States, academic societies and other medical groups in Western Europe also produced their own versions, perhaps as a response to differences in structure of their respective health care systems.[4]

One such group was the Enhanced Recovery After Surgery (ERAS®) Society which began in the early 2000's as a group of surgeons from Northern Europe who aimed to improve surgical patient recovery and outcomes using a multi-modal approach.[8] This group would

publish case reports to highlight to European surgeons that they were not delivering best practice care according to the literature. In a grassroots effort, the group aggregated and standardized best practice, developed guidelines, and promoted their use amongst colleagues and any medical centers who wanted to participate. This initial group grew into a collection of multi-country collaborations until, in 2010, the ERAS® Society was officially granted status as an official non-profit medical society.[8] To date, the ERAS® Society has developed 18 official guidelines according to the Institute of Medicine's standards,[2] published two books, held eight annual Congress's, developed an international data registry, and has centers of excellence on every continent except Africa.[9]

ERAS® Society guidelines are widely adopted, and official ERAS® continues to be implemented in centers around the world, with fast growth currently in the United States and South America. The USA Chapter of the ERAS® Society was formed not long ago in 2016 and has since held five Annual Congresses. Interestingly, the ubiquity of ERAS® has led to its genericization – or having become a proprietary eponym – in that when people use the word "ERAS" they can be referring to any number of surgical guidelines in the literature (or individually developed) but are not produced by the ERAS® Society.

I have been a member of the ERAS® Society since 2015, served on the Executive Board since 2018, published eight ERAS-related manuscripts, and spoken nationally and internationally on the subject; allowing me to be an up-close witness to the growth of ERAS® as it has spread from Europe to the United States. The impact of having been involved in the grassroots efforts in the United States – similar to when ERAS® was initially developed years ago in Europe – guides this dissertation work. For example, Chapter Two will discuss the development of a novel method to predict ERAS compliance and outcomes, while Chapter Three will lay the

groundwork for future efforts to predict barriers to ERAS compliance utilizing synthesized analysis of existing barriers literature. Chapter Four will describe the development of predictive models from ERAS® registry data to understand which recommendations contribute most to surgical outcomes. And finally, Chapter Five will describe the development of a survey to ask the multidisciplinary ERAS® USA membership their perceptions on barriers to ERAS® guidelines.

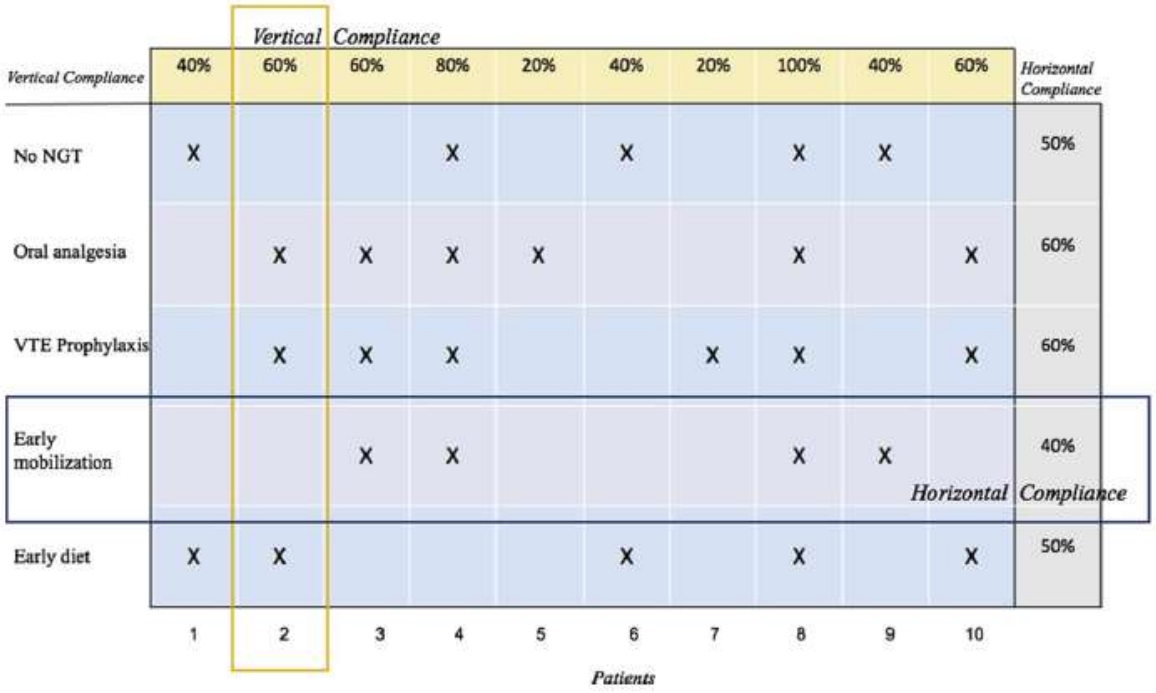
Compliance to Clinical Guidelines and Outcomes

What is Compliance?

To preface this section, it's important to note that depending on the field of study or context, compliance has a different definition than adherence. When one is speaking about patient behavior, such as taking prescribed medication, adherence is the preferred word as it removes the pejorative "paternalistic conceptualization of medication-taking behaviour, which disregards patients' perceptions on medication-taking".[10] However, the terms adherence and compliance appear to be interchangeable in the clinical guidelines literature and given the ERAS® Society and related consortium groups often use 'compliance', this author will aim to primarily use this term.

Compliance to guidelines can be roughly defined as whether or not a component (or item) of the overall guideline has been performed. For example, an item in the overall ERAS® guidelines for colorectal surgery is early removal of the Foley catheter. If this was performed,

Figure 3
Visual Representation of Horizontal and Vertical Compliance



Baimas-George M, Cochran A, Watson M, et al. Vertical Compliance: A novel method of reporting patient specific ERAS compliance for real-time risk assessment. *Int J Med Inform.* 2020;141:104194. doi:https://doi.org/10.1016/j.ijmedinf.2020.104194

compliance was achieved.[11] In terms of measurement, broadly speaking when compliance to an item in an overall guideline set is measured for all patients, this is known as horizontal compliance. When compliance to all the items in a guideline is measured for one patient it can be thought of as vertical compliance (Figure 3).[12]

Vertical Compliance

Chapter Two will describe the concept of vertical compliance, detailing a novel method for utilizing the concept to predict and affect patient care in real time. Briefly, horizontal

compliance tracks the longitudinal adherence to items as measured in aggregate, whereas vertical compliance is an individual patient's experience as they encounter each item along their surgical pathway / journey. As they encounter each item in real time, having experienced it – or not – either increases or decreases their likelihood of having an adverse outcome in the future. Chapter Two will describe the concept and implications, as well as quantify how individual items impact the likelihood of adverse outcomes more than others.

Relationship Between Compliance and Outcomes

Although Americans receive about half of the health care services recommended by evidence-based guidelines,[13] the relationship between compliance and outcomes is clear. While guidelines vary on levels of evidence, even when strong evidence-based guidelines are available, compliance to their recommendations remains low. Unfortunately, lack of compliance to clinical guidelines results in preventable adverse outcomes and inefficiencies such as mortality, inappropriate medical procedures and care variation.[13,14]

For generic enhanced recovery programs (ERPs), compliance can reduce LOS, complications, and postoperative emergency room visits.[15] A Bayesian meta-analysis of randomized control trials of ERPs demonstrated a significant reduction in LOS by 2.5 days and a 50% reduction in morbidity without increasing readmission rates.[16] Another systematic review of ERPs in randomized controlled trials showed concordant results; 1.6 day reduction in LOS and 54% reduction in morbidity.[17]

Specific to ERAS®, many studies have shown the compliance to the entire protocol confers the highest likelihood of a successful recovery for the surgical patient, and the higher the compliance the more likely the improvement of outcomes.[18–25] The reverse has also been demonstrated, where reduced overall compliance was identified as predictive of increased LOS,

morbidity and readmission.[25] That said, there are specific items that seem to contribute more to improved recovery. These individual items include: nasogastric tube avoidance, minimally invasive approach, drain avoidance, preoperative education, [12,20,21,23,24] carbohydrate loading,[12,20] mobilization,[12,21,25] and nausea and vomiting prophylaxis.[24]

Clinical Roles and Compliance

ERAS® guidelines are multidisciplinary, in that they require coordination and participation from different clinical roles throughout the perioperative course (preoperative, intraoperative, postoperative phases) to achieve overall compliance and best outcomes (Table 1). These roles include nurses and APPs, anesthesiologists, surgeons, and other clinical professions such as nutrition, physical therapists, and pharmacy.

Nurses and APPs play a critical role in ensuring ERAS® guidelines are followed with fidelity and reliability. In fact, they are often referred to as the "boots on the ground" whose buy-in can make or break an institution's ERAS® program.[26] Of the standard 20 compliance items, nurses are directly responsible for about nine. Thus, if these do not occur, 45% of the protocol is non-compliant. Further, of these items, preoperative education, carbohydrate loading, and mobilization are highly predictive of patient recovery. Beyond just performing compliance items, nurses – and in particular the role of the ERAS Nurse – model expectations of care, deliver patient education, often perform audit data collection, identify areas of non-compliance, support patient-related engagement, and generally champion the ERAS® guidelines.[27,28] APPs are also critical because, as leaders, they can strengthen any encouragement and expectations of compliance to the guidelines, while providing advanced levels of clinical support to surgeons and anesthesiologists.

Anesthesiologists are important during the intraoperative phase, as they control fluid balance, sedation, and pain control. Specifically, there are six items related to short acting anesthetics, fluid balance, and prevention of nausea and vomiting. With increased interest in multimodal pain management and its emphasis in the ERAS® guidelines, their participation both in the operating room and beyond is key to ensuring compliance to these elements.

Surgeons are viewed as the leaders of the team, and their strong buy-in and compliance to the guidelines is paramount. Items within the surgeon's locus of control are of course related to the surgery itself, such as performing in a minimally invasive manner if possible. They are specifically responsible for about 7-9 of the items, however they are critical to functioning as the leader of the surgical team and the tone they set regarding compliance is reflected by the team. As such, a strong surgeon champion ensures higher compliance by the multidisciplinary team.[29,30]

While each role has direct responsibility for certain items, it is the overall integration, collaboration, and teamwork of the individuals that facilitates whether the items are successfully executed. For example, while not prescribing opioids is within the prescriber's locus of control, if they aren't compliant to that element then later the nurses won't be able to perform early mobilization and feeding, causing downstream adverse effects to not only compliance but patient care.

Table 1. Twenty "Core" ERAS Items and the Clinical Role Primarily Responsible (Individual institutional experiences will vary)

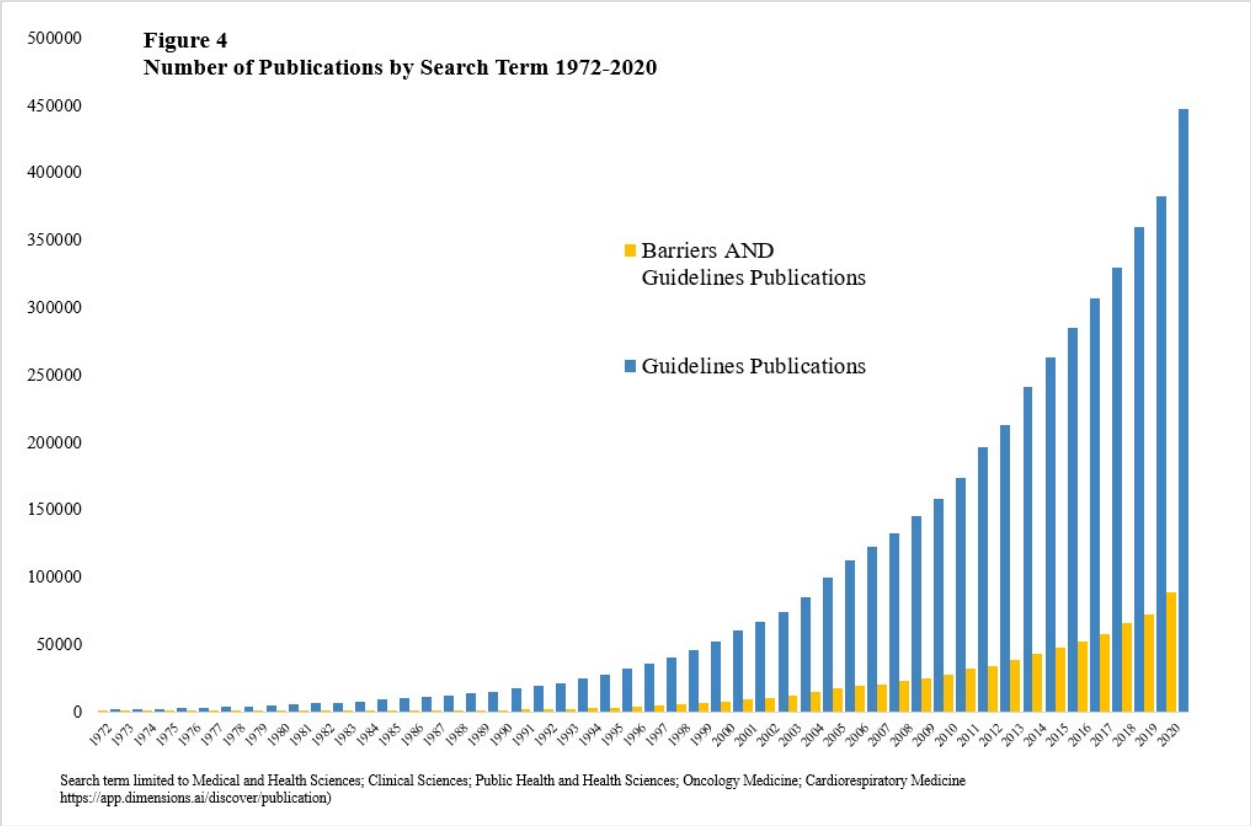
Recommendation	Clinical Role Responsible for Compliance to the Recommendation
Preoperative Phase	
Preadmission counseling	Clinic/Nurse/ERAS Nurse Leader
Carbohydrate loading	Clinic/Nurse/ERAS Nurse Leader
No prolonged fasting	Clinic/Nurse

No/selective bowel prep	Surgeon/Advanced Practice Provider
Antibiotic prophylaxis	Surgeon
Thromboprophylaxis	Surgeon
Intraoperative Phase	
Short acting anesthetics	Anesthesia
No drains	Surgeon
Goal directed fluids	Anesthesia/Surgeon
Normothermia	Anesthesia
Postoperative Phase	
Regional anesthesia/analgesia	Anesthesia/Surgeon
No nasogastric tubes	Surgeon
Prevention of nausea and vomiting	Anesthesia
Goal directed fluids	Anesthesia/ Advanced Practice Provider
Early removal of catheter / avoidance of catheter	Advanced Practice Provider / ERAS Nurse Leader
Early oral nutrition	Advanced Practice Provider / ERAS Nurse Leader
Non opioid oral pain meds (analgesia)	Advanced Practice Provider
Early mobilization	Nurse/ ERAS Nurse Leader
Stimulation of gut motility	Advanced Practice Provider
Audit	ERAS Nurse Leader /Advanced Practice Provider/Nurse

Chapter Four will utilize the EIAS, the international data registry for the ERAS® Society, to identify which individual guideline items contribute most to improved patient outcomes and recovery. Using data from two high-volume, United States-based ERAS® Centers of Excellence, compliance to the protocol and individual items will be used to predict outcomes such as complications, length of stay, and readmission. In addition to contributing to the literature on the impact of each compliance item on outcomes, this study will also hypothesize that items that require more multidisciplinary teamwork will achieve lower compliance; further highlighting the need for improved team collaboration.

Barriers to Compliance

The academic interest in barriers to compliance to clinical guidelines has been rising alongside the guidelines literature itself, suggesting that for as long as there have been guidelines, there have been barriers to their uptake and compliance (Figure 4).



In 1994, Grilli and Lomas evaluated barriers to compliance using three dimensions, as they relate to the guideline recommendation: Complexity, Trialability, and Observability.[31] The authors found that the higher the complexity, the lower the compliance and the higher the trialability, the higher the compliance.

Cabana Framework

There are many models and frameworks that have been developed to understand adoption of guidelines specifically among providers.[1,32–36] Many studies focus on targeting behavioral

change in medical personnel and has been summarized by Grimshaw and colleagues.[37] They note that a reasonable approach to addressing physician-related barriers will target practical considerations while incorporating behavioral theory. Indeed, this multifaceted approach may be most likely to change behavior because it address many barriers to change, not just one.[37]

Building on the work of Grilli and Lomas, Cabana and colleagues developed a physician-centric framework of barriers using a mix of systematic review, surveys, and knowledge-attitude-behavior health education model.[1] The authors also drew upon a previous systematic review focusing on adoption of guidelines,[38] offering a "diagnostic differential" approach which allows for the development of practical and targeted interventions at each potential adoption barrier point. The authors found physician-centric barrier factors included: (lack of) awareness, familiarity, agreement with the guidelines, self-efficacy, expectations of positive outcomes, whether one can overcome the inertia of previous practice, motivation, and external barriers either preventing or facilitating practicing the guidelines. These specific barriers were underpinned and organized by the overall Knowledge, Attitudes, and Behavior domains (Figure 5).

Figure 5. Barriers to Physician Adherence to Practice Guidelines in Relation to Behavior Change

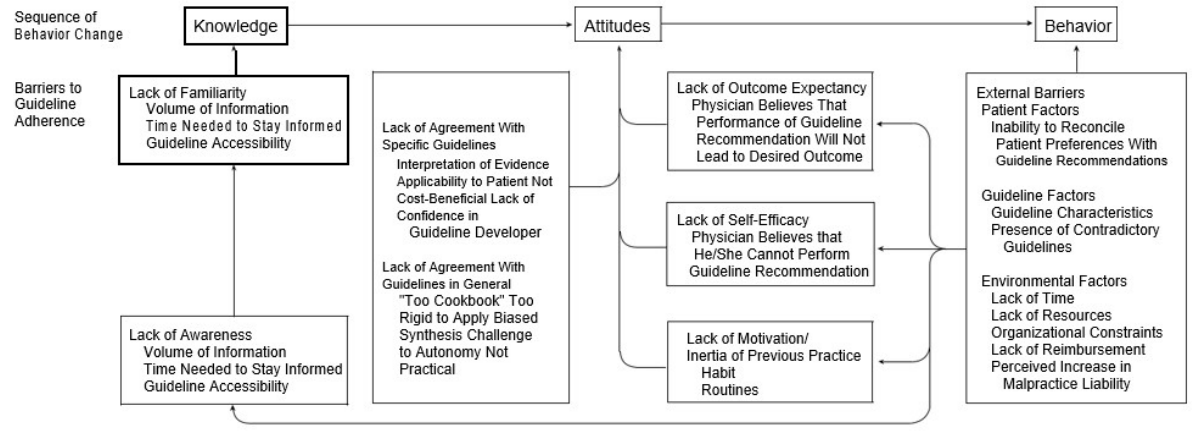


Figure from: Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH, Abboud PA, Rubin HR. Why don't physicians follow clinical practice guidelines? A framework for improvement. JAMA. 1999 Oct 20;282(15):1458-65. doi: 10.1001/jama.282.15.1458.

Since its publication, the Cabana article has been cited over 7,600 times and has provided researchers with a useful and practical structure to study physician-centric barrier to guidelines adoption. In 2016, Fischer and colleagues performed a scoping review and update to the Cabana article.[39] The authors provided updated evidence in support of the Cabana framework, as well as tying literature-based strategies to overcome each barrier type; an important step forward for the practical application of barriers mitigation. A similar scoping review was performed two years prior which assessed barriers to in a European setting.[40]

In the years since publication, many studies have organized their results according to the Cabana framework. In 2009, Lugtenberg et al. conducted focus groups to record perceived barriers to general practice guidelines endorsed by the Dutch government.[41] Of the barriers in the Knowledge domain, lack of familiarity was the most reported. Of the barriers in the Attitude domain, lack of agreement with the guidelines and lack of applicability were most reported. Finally, in the Behavior domain, participants mostly reported environmental factors such as lack of resources, and factors associated with the guidelines themselves. Haagen and colleagues studied physician compliance to fertility guidelines utilizing the Cabana framework. Assessed via mailed survey, the authors found lack of self-efficacy as the primary barrier which was related to inadequate knowledge of several individual guideline items and the external barrier of lack of resources.[42]

Specific to ERAS, Pearsall et al. conducted a qualitative study evaluating barriers to specific recommendations. While not specifically aimed at organizing the results within the Cabana framework, the themes that emerged coincided with specific items were: Oral bowel prep, preoperative fasting, and epidural analgesia were associated with the barrier of overcoming inertia of previous practice; Carbohydrate loading and postoperative nonsteroidal anti-

inflammatory medication was associated with lack of agreement with the guideline or guideline factors; and Early mobilization as associated environmental factors barriers.[43] In the ERAS® Society Manual of Enhanced Recovery Programs for Gastrointestinal Surgery, Pearsall and Okrainec note the common physician-centric barriers to ERAS adoption are resistance to change (overcoming inertia of previous practice) and lack of resources (environmental barriers).[44]

Modifiable vs. Non-Modifiable Barriers

Cabana and colleagues note the barriers they identified are within the physician's locus of control – or modifiable – with the possible exception of environmental-related barriers. Specifically, the acquisition of resources such as equipment, staff, and colleague support, and the perception of increased medical liability and poor reimbursement.[1] However, these Behavior domain barriers may interact with Knowledge or Attitude domain barriers such as self-efficacy and lack of outcome expectancy, most of which are modifiable.

ERAS Barriers, Multidisciplinary

Given the multidisciplinary nature of guidelines, barriers to the guideline items will necessarily be multifactorial and differ based on clinical or professional role. Indeed, the adoption of guidelines is an interplay of those using the guidelines and factors related to the guidelines themselves.[34]

Studies have found nurses thought surgeons didn't adopt ERAS guidelines due to resistance to change and lack of resources.[43,45] Another study notes the need for the education of an entire perioperative team, while necessary for uptake, is itself a barrier.[43] This same study found nurses thought the primary barriers were the perceived lack of resources to carry out items such as patient mobilization and providing comprehensive patient education.

In the United States, APPs (physician assistants and nurse practitioners) are drivers of compliance to guidelines. A 2015 qualitative study performed by Melanie Keiffer, DNP found the major barriers for APPs to be difficulty keeping up with the guideline changes, their being too prescriptive, their being too cumbersome, and too difficult to apply to practice.[34]

Finally, compliance to guidelines doesn't just rest with the individual role but as a relationship between the clinician and the organization. Organizational constraints are often cited as a barrier and so change at the level of the organization is critical to facilitate compliance.[46]

ERAS Barriers, Physician-Centric

A qualitative study from Singapore reported surgeons reported barriers to ERAS were personal preference, not believing a compliance item would benefit the patient, and the guideline is only applicable to certain patients.[45] Pearsall et al. found personal preference as a barrier, and that surgeons don't necessarily think they are resistant to change themselves, but that their colleagues are. Interestingly, anesthesiologists thought their surgeon colleagues would be resistant to change. Both surgeons and anesthesiologists, however, did express some degree of lack of agreement with ERAS analgesia recommendations. This study also found their reported barriers included lack of resources such as nursing staff. Chapter Five will add to these findings via development and distribution of a survey to the multidisciplinary members of the USA Chapter of the ERAS® Society to determine their perceived barriers to compliance to the core ERAS® guideline items, organized by the Cabana framework.

Contiguous Considerations: Informatics, Predictions, and Ethics

The Cabana framework identifies many physician-centric barriers to compliance to guidelines. Of those, lack of familiarity and lack of awareness may be most impacted by informatics-based solutions as they are often due to the volume of new evidence and

recommendations, without the time needed to stay up to date. Leveraging technology such as EMRs to do the remembering for physicians frees their time and makes the "right thing easy to do".[13] Pronovost proposes that an information ecosystem would ensure guidelines are followed. From identifying patients for the whom the guidelines apply, to alerting the providers of the specific recommendations, then ensuring they receive those recommendations, to finally evaluating the outcomes of those guideline recommendations; informatics has a critical role in automating guidelines and providing evidence of their efficacy, reducing preventable harm to patients while addressing many of the Cabana barriers.[14]

Just as Pronovost introduces the idea of an ecosystem, it is important to consider themes that are adjacent to the core topics proposed in this work namely, informatics, analytics, and ethics. These themes will be explored further in the final Chapter.

Role of Electronic Medical Records

While wide-spread use of EMRs didn't occur until the early 2000's, the call for computerizing clinical guidelines began in the 1990's.[47] At that time, members of the relatively new field of medical informatics encouraged EMR developers to create standardized programming approaches, create triggers and reminder systems, and decision support algorithms with the aim to increase compliance to guidelines to ultimately improve patient care.[48] Since, clinical guidelines have become one of the main features of clinical decision support systems which are informatics systems designed to aid decision making by providers during the delivery of care,[49] allowing guidelines to be coded in efforts to remind providers of best practice.[50] Numerous studies have confirmed CDSS improves compliance to clinical guidelines and protocols.[51]

EMRs can play a role in automating guidelines, while collecting and evaluating data on compliance and outcomes. The automation of guidelines using CDSS can address barriers such as lack of knowledge, awareness, and motivation, they also may hinder adoption if the providers fear "cookbook" medicine or environmental barriers such as exhaustion from excessive alerts or triggers known as "alert fatigue".[49] To help address this, the National Academy of Medicine recommends the authors of clinical guidelines think about how the items can be incorporated into systems by utilizing the taxonomy provided by Wright et al. The taxonomy recommends the authors of guidelines include data triggers, specific input data elements, intervention options (ex. notify, get approval, collect free text data, log), and a list of acceptable choices (ex. Write order, defer warning, cancel order, override) in the actual guidelines themselves.[2,49]

Prediction and Analytics

Quantitatively derived scales that stratify risk for acute care patients have been described for decades, though models that predict individual risk for adverse outcomes didn't appear in the literature until later.[52] The ability to predict individual risk based on patient characteristics and modifiable factors is a powerful tool for aiding physician decision making and communicating risk to patients, as well as providing ease of use when programmed as decision support tools in EMRs and other electronic platforms.

Specific to surgery, in 2013 the American College of Surgeons developed a web-based online risk calculator which, at the time, was able to predict eight postoperative outcomes for several surgical procedures.[53] The ACS NSQIP Risk Calculator has undergone several updates and validations studies since its development and now provides 13^{+} personalized risk probabilities, depending on selected procedure.[54] It was around the time of its development, numerous surgery-specific prediction models began appearing in the literature, driving what

Parikh et al. termed the "dawn of precision delivery".[55] Indeed, using predictive and other advanced analytics such as machine and deep learning to optimize patient, financial, and clinical outcomes has "…become the "Holy Grail" of the modern Clinical Precision Medicine era."[56]

Most models in surgery aim to predict post-operative outcomes using patient characteristics such as demographics and clinical indicators. This paradigm also exists in ERAS®-specific context, where predictions are developed using these patient characteristics, though the characteristic of "compliance" is another dimension one can utilize as a predictor.[25] This author previously reported on a single institution experience in incorporating predictive modelling with ERAS® – known as functional ERAS or *f*-ERAS –as a successful way to improve outcomes and increase other efficiencies related to daily laboratory orders.[56] However, to date, multi-institutional studies in the United States have not been developed to evaluate the impact of ERAS® compliance on outcomes. Chapter Four will aim to address this gap by developing multi-institutional models identifying which ERAS® recommendations predict adverse surgical outcomes.

Predictive models can also be used to evaluate the relationship between barriers and compliance (or non-compliance) to guidelines. Several studies exist in the general medicine, and respiratory medicine fields.[31,42,57–60] Some examples include a 2001 study by Cabana and colleagues evaluating this relationship in pediatric asthma guidelines with multivariate regression. They found lack of familiarity and presence of external barriers were significantly associated with non-compliance to the guidelines they evaluated.[61] Similar studies were performed in 2011 and 2012 for COPD guidelines and found agreement with the guidelines, self-efficacy, outcome expectancy, and external barrier of flow predicted compliance[62] and that low self-efficacy and time constraints (environmental barrier) predicted non-compliance.[63] To date,

these studies have been performed in non-surgical fields, thus Chapter Three aims to lay the groundwork for future efforts in surgery to predict barriers to ERAS® compliance by utilizing synthesis analysis of existing barriers literature organized by the Cabana framework.

Ethics

Ethics and Guidelines. On first glance, urging practitioners to follow guidelines appears harmless or even what one should do. Yet intrinsically-based resistance and barriers continue to exist, possibly arising from the discrepancy between a providers desire to provide the best care while maintaining autonomy of clinical decision making. Ethics provides many frameworks for viewing a situation from several angles, and while a thorough study is beyond the scope of this work, Oliver P. Thomas has provided a recent discussion on this topic outlining a framework which may be useful in understanding the ethics of guidelines.[64] Briefly, Thomas explored the deontological and utilitarianism frameworks and found them incomplete in understanding the issue as they disregard autonomy and desire to do good. Finding virtue ethics a better fit, he concludes it is not unethical to not strictly follow guidelines but they do offer a "guide to action" or a way to remind practitioners of how they should act while maintaining the autonomy of "practical wisdom", all the while modelling these virtuous behaviors to junior observers.

Ethics and Predictive Analytics in Healthcare. The use of algorithms to predict future events in healthcare can potentially change the way care is delivered; lowering costs, providing instant strategies for efficiency, preventing adverse outcomes, and so on. However, relying on algorithms presents ethical challenges. Recommendations can conflict with physician decision making, can conflict with the best interest of patients and, if not constructed equitably, can magnify health disparities in already disadvantaged populations.[65] In 2016, Amarasingham and colleagues developed a consensus statement framework that, among other key points, addresses

the ethical considerations by recommending first developing rigorous individual, organizational, and community risk-based analyses, and then clearly communicating these risks to all stakeholders, including patients.[66] Predictive analytics have many points in their development at which flaws can be introduced; from data acquisition, model architecture, validation, communication of results, and application to intended target (patients, processes, etc.). At every point in development, frameworks recommend transparency, equity, and responsibility.

CHAPTER 2: VERTICAL COMPLIANCE: A NOVEL METHOD OF REPORTING PATIENT SPECIFIC ERAS COMPLIANCE FOR REAL-TIME RISK ASSESSMENT

Introduction

In the early 2000s, the Enhanced Recovery After Surgery (ERAS) pathway was created with the formation of the ERAS Study group[1]. The overarching purpose of ERAS development was to identify fundamental surgical outcomes from preadmission through the postoperative period and, using evidence-based protocols focused on quality of recovery, standardize care such that physiological and psychological improvements could be realized. This involves significant multidisciplinary collaboration and commitment between surgical, anesthetic, and nursing teams and depends on the continuous audit of process compliance and patient outcomes to eliminate unnecessary variations or deviations. As the pathways are designed around a framework of over twenty core items, compliance auditing is recommended to occur monthly or bimonthly and allows for frequent changes to be made to improve practice. With these elements in place, ERAS programs have demonstrated significant effectiveness across surgical specialties, consistently reducing hospital lengths of stay (LOS), post-operative complication rates, and costs for both patients and healthcare systems[2,3].

ERAS protocol adherence is measured and reported traditionally as 'items compliance'[4]. Items compliance is defined as the longitudinal adherence of all patients to an ERAS index element, such as early removal of Foley catheter or early mobilization. It is a program-wide metric that can be used to modify cohort behavior as high rates of horizontal compliance are shown to significantly improve post-operative outcomes, reduce LOS, and affect survival[5-9].

Unfortunately, however, compliance reporting solely in this manner can be restrictive and often incapable of affecting patient care in real-time. Therefore, in order to modify behavior effectively and instantaneously, this manuscript aims to introduce the novel concept of "vertical compliance".

Methods

Compliance definitions

The novel concepts of horizontal and vertical compliance were developed and defined by the authors. Horizontal compliance is the traditional 'items compliance' that is currently reported to track longitudinal ERAS protocol adherence of all patients (Figure 6). Vertical compliance is an assessment of an individual's compliance with each ERAS core item along his/her own surgical pathway as he/she encounters each item. Completion of an individual index item generates a specific amount of weight or significance for a patient towards achieving improved outcomes. This study sought to determine the impact of these items through patient-specific models of compliance items to allow for prediction of, and more importantly, real-time alterations in patient care.

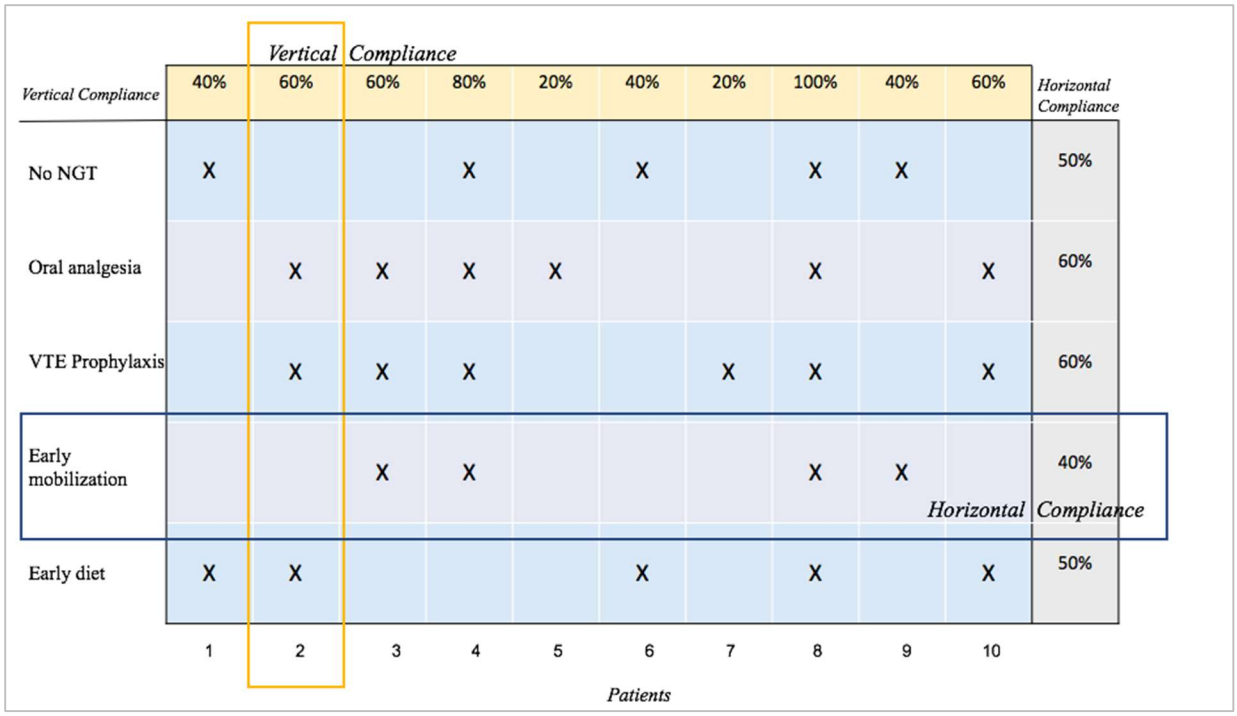


Figure 6. Visual representation of the concepts of vertical and horizontal compliance.

Study Design

An official ERAS program was implemented at Carolinas Medical Center, a tertiary care center in Charlotte, NC in September of 2015 by the hepatobiliary surgical division. All patients enrolled in an ERAS pathway had compliance data prospectively entered into the ERAS Interactive Audit System (EIAS) database. EIAS is a secure online data registry provided by ERAS Society for standardization of outcome tracking, reporting, and analysis[10]. Populated by trained personnel or clinicians with de-identified data, this audit system acts to track perioperative patient compliance and outcome data, allowing for quality improvement. There are 46 ERAS index pathway items identified for which compliance is recorded.

A retrospective review of all patients from Carolinas Medical Center who underwent a pancreatic resection, either pancreaticoduodenectomy or left pancreatectomy, or hepatic

resection were queried. Inclusion criteria included adult patients (age ≥ 18 years old), enrollment in an ERAS pathway, and complete data records.

Compliance models

Individual linear regression models were generated for each of the 46 compliance items as an independent variable against the dependent variable of LOS for 1) pancreatic procedures (pancreaticoduodenectomy, left pancreatectomy) and 2) hepatic resections. A p-value of < 0.05 was considered significant and thus, any compliance items with $p < 0.05$ were retained. Multivariable linear regression models were generated in an additive fashion. The first model demonstrated LOS against the first retained compliance item. The second model demonstrated LOS against the first and second retained compliance items. This pattern continued until all retained compliance items were included to comprise a final predictive model. Each compliance item had a unique coefficient that both predicted its effect on LOS and controlled for the effect of the other compliance items in the model. Each coefficient was added to the model β-coefficient, to arrive at a predicted LOS if that compliance item was positive for a patient (Figure 7). Each logical iteration of compliance events was linearly mapped out. This process was repeated for each additive model until the final model contained all compliance items. All statistical analyses were performed using STATA statistical software (Statcorp, College Station, Tx, Version 15).

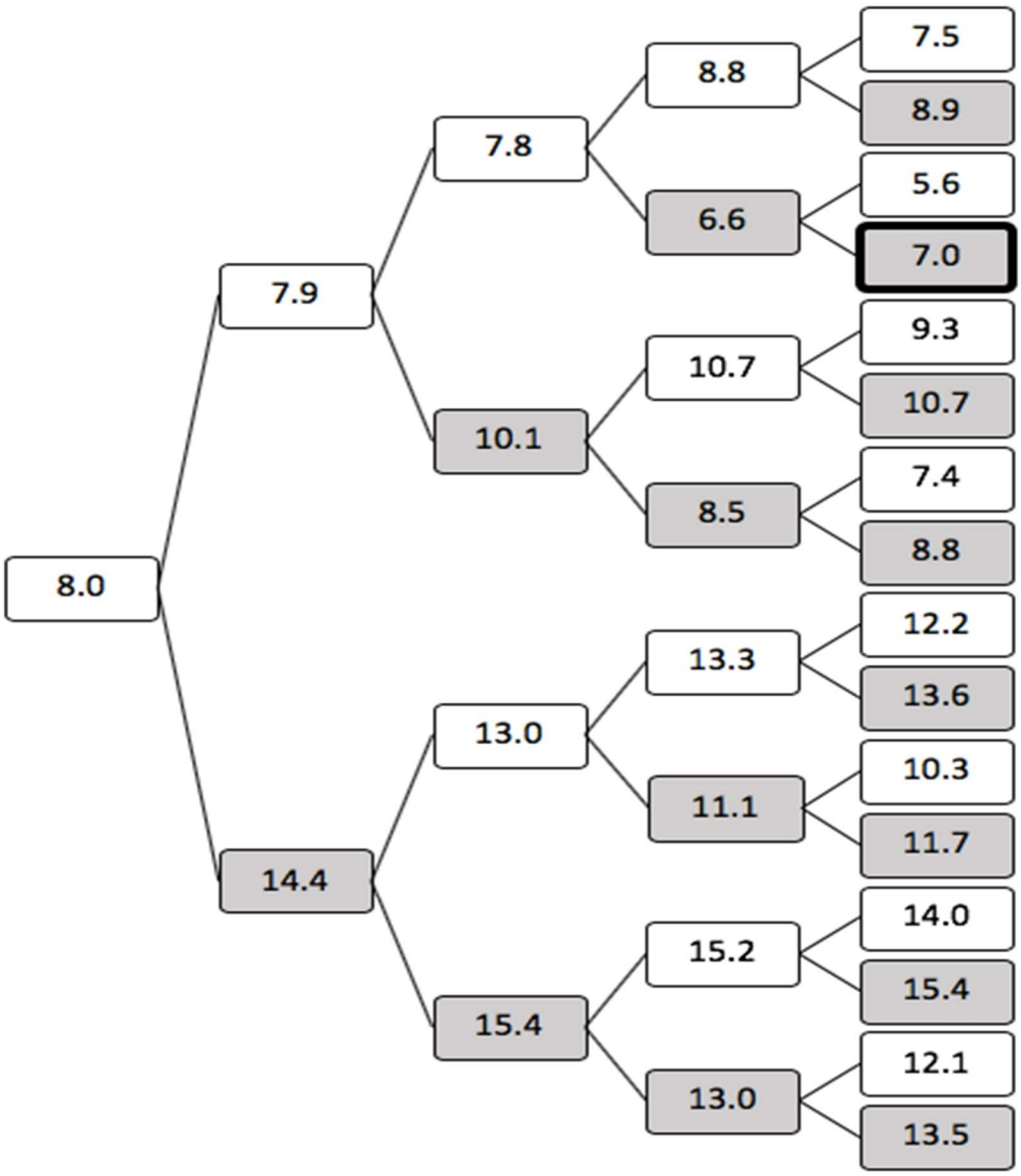


Figure 7. Interpretation of model calculations; light gray shaded boxes represent non-compliance. Values in boxes represent effect on LOS. Values have been calculated through Model 5. Ie) Bolded box calculation example: The compliance is: item 1: yes, item 2: yes, item 3: yes, item 4: no, item 5: no. To calculate LOS, use Table X and add the coefficients of the compliant items (yes items) to the constant coefficient (15.0 + (-1.5) + (-4.7) + (-1.8) = 7.0).

Results

There were 483 patients identified retrospectively who underwent a pancreatic procedure and 292 patients who underwent a hepatic resection who met inclusion criteria.

Hepatic resections

Linear regression models of all 46 compliance items after hepatic resection found six items to be significant (Table 2). These retained compliance items were as follows: 1) compliance to not using a preoperative bowel preparation; 2) compliance to not placing a surgical drain; 3) compliance to avoidance of IV opioids; 4) compliance to near-zero fluid balance with balanced crystalloid fluid; 5) compliance to removal of nasogastric tubes (NGT) immediately following completion of operation; and 6) compliance to early and scheduled mobilization. The first model demonstrates the impact on LOS with compliance of not using an oral bowel preparation (Figure 8). With compliance, LOS was 4.4 days versus 14.5 days without. The second model adds compliance to not placing a surgical drain which can impact mobilization. If the patient is not compliant to both items, LOS is 15.4 days. If the patient is compliant to both items, LOS is 3.6 days. The third model adds compliance to avoidance of IV opioids and reviews the difference in LOS with compliance of each of the items which ranges from 3.4 days to 18.6 days (Figure 8). The final three models follow the same pattern and the effect on LOS with the remaining compliance items is listed in Table 3 and an example of how to calculate compliance depending on model is demonstrated in Figure 7.

Table 2. Recommendations for the retained compliance items, through linear regression modelling, for patients undergoing pancreatic or hepatic resections.

	Retained Compliance Item	Recommendation
Hepatic Resection	Oral bowel preparation	There is no proven benefit of oral bowel preparation in hepatic procedures. It should not be used.
	Resection site drainage	Routine drainage is discouraged as it may impair mobilization.
	Avoidance of IV opioid analgesics	Use of IV opioids analgesics only after failure of non-opioid multimodal therapy.
	Prophylactic nasogastric intubation	Pre-emptive use of nasogastric tubes does not improve outcomes. Removal at the end of the case is recommended.
	Fluid balance	Near-zero fluid balance, avoiding overload of salt and water, results in improved outcomes. Balanced crystalloids should be preferred to 0.9% saline.
	Early and scheduled mobilization	Patients should be mobilized actively within 24h from surgery and encouraged to meet daily targets for mobilization.
Pancreatic Resection	Preoperative fasting and preoperative carbohydrates load.	Preoperative fasting does not need to exceed 6 h for solids and 2 h for liquids. Carbohydrate loading is recommended the evening before liver surgery and 2 h before induction of anesthesia.
	Avoidance of pre-anesthetic medication	Long-acting anxiolytic drugs should be avoided. Short-acting anxiolytics may be used to perform regional analgesia prior to the induction of anesthesia.
	Postoperative nausea and vomiting (PONV) prophylaxis	Multimodal approach to PONV should be used. Patients should receive PONV prophylaxis with 2 anti-emetic drugs
	Regional anesthesia	Recommend use of regional anesthesia in the form of epidural (for open cases), tap block or spinal.
	Prophylactic nasogastric intubation	Pre-emptive use of nasogastric tubes does not improve outcomes. Removal at the end of the case is recommended.
	Early and scheduled mobilization	Patients should be mobilized actively from the morning of the first postoperative day and encouraged to meet daily targets for mobilization.
	Foley catheter	Foley catheters should be removed on postoperative day 2.

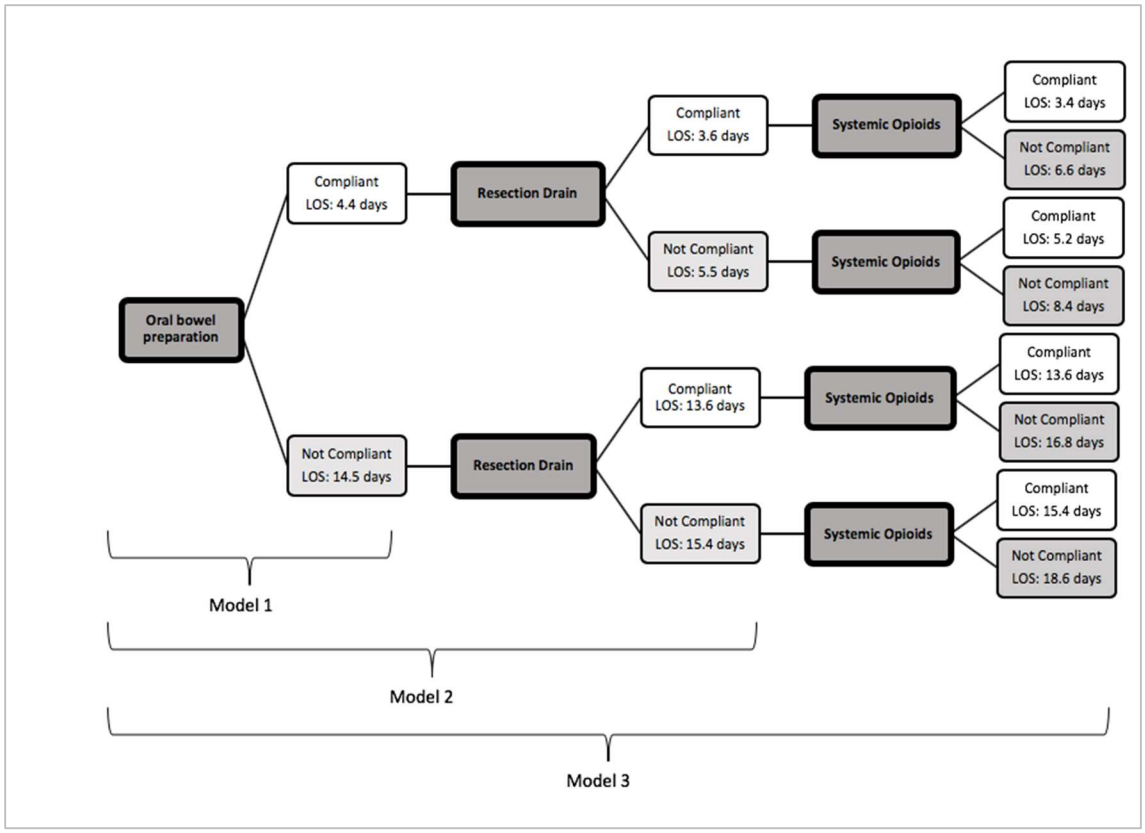


Figure 8. Vertical compliance model demonstrating the effect on length of stay with and without compliance of the first 3 retained items for patients undergoing hepatic resections. Light gray shaded boxes represent non-compliance.

Table 3. Vertical Compliance models predicting length of stay for Hepatic Resections

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Oral bowel prep (1)	-10.01	-9.96	-10.18	-10.33	-9.04	-9.37
Resection drainage (2)		-1.81	-1.79	-1.67	-1.27	-1.10
IV opioids (3)			-3.22	-3.25	-3.43	-3.34
Fluid balance (4)				-1.11	-0.96	-0.95
NGT (5)					-3.27	-2.98
Mobilization (6)						-1.41
Model constant	14.50	15.40	18.61	19.69	21.16	21.53

Pancreatic resections

Linear regression models of all 46 compliance items after pancreatic resection found seven items to be significant (Table 2). These retained compliance items were as follows: 1) compliance to preoperative fasting and carbohydrate load; 2) compliance to avoidance of preanesthetic sedative medication; 3) compliance to prophylactic multimodal approach to preventing postoperative nausea and vomiting (PONV); 4) compliance to regional anesthesia; 5) compliance to removal of NGT immediately following completion of operation; 6) compliance to early and scheduled mobilization; and 7) compliance to early removal of Foley catheter. The first model demonstrates the effect of the first compliance item: preoperative fasting and oral carbohydrate loading (Figure 9). If compliant, LOS is estimated to 8.0 days versus 9.6 if it is not. The second model adds compliance to preanesthetic medications (Figure 9). If the patient is not compliant to both items, LOS is 15.9 days. If the patient is compliant to both items, LOS is 7.9 days. The third model adds compliance to prophylactic PONV with multimodal therapy systemic opioids which effects the LOS with a range from 7.8 days to 16.8 days. The final three models follow the same pattern and the effect on LOS with the remaining compliance items is listed in Table 4. An example of how to calculate compliance depending on model is demonstrated in Figure 7.

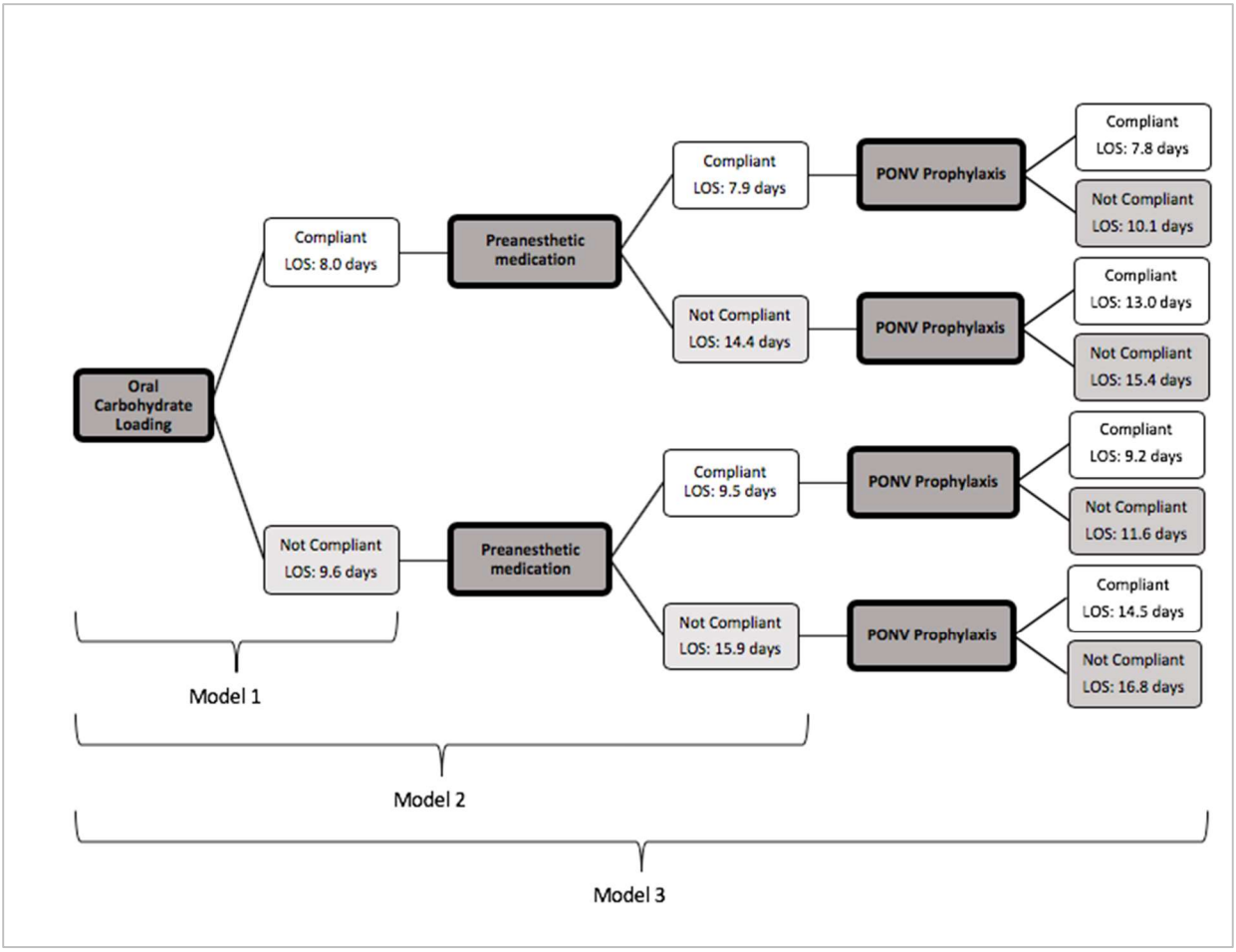


Figure 9. Vertical compliance model demonstrating the effect on length of stay with and without compliance of the first 3 retained items for patients undergoing pancreatic resections. Light gray shaded boxes represent non-compliance.

Table 4. Vertical Compliance models predicting length of stay for Pancreatic Resections

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Preop carb loading (1)	-1.55	-1.53	-1.46	-1.49	-1.50	-1.57	-1.58
Pre-anesthetic meds (2)		-6.43	-5.25	-4.50	-4.66	-4.62	-4.61
PONV ppx (3)			-2.34	-1.94	-1.76	-1.85	-1.66
Regional anesthesia (4)				2.18	1.89	1.91	1.70

NGT (5)					-1.44	-1.34	-1.62
Mobilization (6)						-1.22	-0.88
Foley catheter (7)							-0.0004
Model constant	9.57	15.92	16.81	14.49	15.02	15.52	24.46

Discussion

A prospective diagnostic and prognostic prediction metric based on routinely collected ERAS compliance data was established and validated. Vertical compliance, a novel metric defined in this study, can provide significant and accurate patient-specific risk prediction to impact care in real-time. Our analysis demonstrates, through evaluation of compliance items that effect an outcome (ie: LOS), that it is possible to harness real-time data tracking to provide tailored risk predictions based on individual ERAS pathway adherence. This allows for the creation of a variable echelon such that pathway items are ranked by importance to illustrate effect on select clinical outcomes.

Horizontal compliance has, logically, been demonstrated to be effective on patient care improvement throughout surgical and medical literature. For instance, compliance with surgical site infection prevention pathways significantly decreases post-operative morbidity[11]. Whereas the reverse also holds true; poor compliance and adherence to guidelines or patient pathways can negatively impact clinical outcomes[12,13]. With the implementation of ERAS, compliance of patients, nursing teams, and physicians has become more stringently documented and audited; with feasibility demonstrated across traditionally more problematic populations[14]. Due to the maintenance of these data registries, there has been a plethora of research across surgical

disciplines that consistently demonstrate a significant and often independent association between protocol compliance and important clinical outcomes such as survival, complications, and LOS[8,15-19]. Nomograms have even been developed to help predict successful postoperative outcomes after ERAS using patient and operative characteristics[20]. These promising results encourage further expansion of ERAS to new disciplines and patient populations, even pediatric units, in hopes of further outcome improvements[21-23].

Even with such promise, there is always room for improvement and there continues to be a distinctly obvious shortcoming in the analysis of ERAS compliance. Horizontal compliance, the method by which protocol compliance is currently measured, evaluates, retrospectively, the longitudinal adherence of a patient cohort to a specific ERAS index element. The results of auditing on this metric can modify cohort behavior to subsequently improve future patients' outcomes and survival[5-8]. The use of vertical compliance may help fill a gap in care and help to provide a prospective and valid, continuous measure of patient outcomes in real-time. It allows for ongoing assessments, providing early recognition and thus opportunity to reinforce or alter contributing factors. This type of prospective monitoring is uncommon in healthcare but when utilized, does improve outcomes[24,25]. The impact of the variable coefficient can suggest to providers the extent an ERAS element will impact an outcome. For instance, in Model 6 for patients undergoing hepatic resections, the effect of avoiding IV opioids is more significant on LOS then postoperative mobilization. In difficult patients who are requiring more pain medicines to mobilize, decreasing mobilization goals in order to avoid IV opioid use can be considered. Thus, providers can use vertical compliance information to harness resources and prioritize ERAS elements that produce a greater effect on clinical outcomes. Being able to

enforce the importance of certain elements over others can help patients and nursing rank and choose appropriate battles.

This analysis focused on LOS as the outcome of interest. The linear regression models supplying the retained compliance items were thus evaluated by their effect on LOS. The same algorithm can be used to investigate effect on other outcomes such as complication rates or cost. Study limitations include a diverse patient population with different disease biology and baseline health. Although each patient underwent the same ERAS pathway, accounting for demographics, intraoperative, and postoperative outcomes into the analysis would allow for more accurate prediction. Additionally, selection bias is unavoidable as some of the ERAS compliance items, such as preoperative bowel regimen, may vary based on severity of patient disease and subsequent resection.

As this is an introduction to vertical compliance, there is no prior data to validate or compare our findings to. We are currently working to validate our data prospectively and we hope other centers will calculate their own vertical compliance metrics, using these methods, for comparison.

Conclusion

Vertical compliance is a novel metric that may be used to not only monitor outcomes but identify and address patients who are on a path to poor results. This metric needs to be further assessed and validated with additional studies and centers to accurately determine clinical significance.

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CHAPTER 3: THE RELATIONSHIP BETWEEN BARRIERS OF THE CABANA THEORETICAL FRAMEWORK AND COMPLIANCE TO CLINICAL CARE GUIDELINES: AN ANALYSIS OF THE EXTANT LITERATURE

Introduction

Evidence-based clinical guidelines are recommendations of how care should be delivered by physicians and providers that have been developed based on scientific literature.[1] In surgery, ERAS® guidelines are a global, widely accepted set of evidence-based recommendations developed by the ERAS® Society, organized by specific surgical procedures.[2,3]

It is known that higher adoption of these guidelines by providers improves patient outcomes[4–8] and can help to simplify clinical decision making to support providers as they navigate complex medical scenarios.[9] Studies show the higher the compliance to both the individual recommendations and to the entire ERAS protocol improves surgical patient outcomes and predicts successful recovery.[4,6,8,10–14]

However, just because guidelines exist does not mean providers will adopt them. In 2009, Proctor et al. defined a conceptual model for implementation research which included the concept of adoption, defined as the uptake of an evidence-based practice.[15,16] Said another way, adoption is a provider's intention or commitment to actually changing their practice based on the proposed guideline(s).[17] However, many providers do not adopt guidelines to change practice and reduce care variation, despite their impact on improved patient outcomes.[18] For these reasons, it is important to understand the barriers to guideline adoption in order to design interventions to increase provider uptake and compliance.

Barriers

Many models and frameworks have been developed to understand adoption of guidelines among providers. Building off of previous work evaluating barriers to compliance,[17,19] in 1999 Cabana et al. developed a physician-centric framework of barriers using a mix of systematic review, surveys, and knowledge-attitude-behavior health education model.[18] They found physician-centric barrier factors included (lack of): awareness, familiarity, agreement with the guidelines, self-efficacy, expectations of positive outcomes, whether one can overcome the inertia of previous practice, motivation, and external barriers either preventing or facilitating practicing the guidelines. These factors represent significant impediments to successful implementation of guidelines, as intention alone does not predict compliance.[20] Their effort to create a "diagnostic differential" approach allowed for the development of practical and targeted interventions at each potential barrier. Since its publication, many studies in the medical literature have organized their study design and findings around the Cabana barriers framework.[21] Specific to the ERAS, Pearsall et al. found themes coinciding with the Cabana framework were associated with the barrier of overcoming inertia of previous practice, lack of agreement with the guideline or guideline factors; and external barriers.[22] Pearsall and Okrainec later note the common physician-centric barriers to ERAS adoption are overcoming inertia of previous practice and external barriers such as lack of resources.[23]

Predicting Compliance and Barriers

Modeling in surgery generally aims to predict post-operative outcomes using patient characteristics such as demographics and clinical indicators. This paradigm also exists in ERAS®-specific context, where predictions are developed using these patient characteristics, though the characteristic of "compliance" is another dimension one can utilize as a predictor.[14]

While modelling is widely used in surgery to predict post-operative outcomes or the impact of compliance on outcomes, predictive models to evaluate the relationship between barriers and compliance to guidelines have not been reported. Several studies exist in the general medicine and respiratory medicine fields; including COPD, and pediatric asthma[19,20,24–27] and provide rich data on the relationship between compliance to guidelines and barriers as organized by the Cabana framework, however to date, studies like these have not been performed in surgery.

The aim of this study is to review the existing literature in all areas of medicine to assess and analyze the effects of Cabana framework barriers on compliance with guidelines in physicians. Secondary aims are to develop and assess meta-regression models describing the relationship between barriers to compliance, and to lay the groundwork for future efforts in surgery to predict barriers to ERAS compliance organized by the Cabana framework.

Methods

Search Strategy and Approach

A realist approach to create a knowledge-support synthesis was utilized. Here, in addition to traditional systematic review approaches, the reviewer also assesses quality and relevance holistically; seeking evidence from the totality of existing studies and utilizing evidences within studies that perhaps originally did not have the same explanatory question of the synthesis.[28] A knowledge-support synthesis aims to describe the evidence as background information for decision-making.[29,30]

Publications were considered for inclusion if they occurred in a medical context, utilized barriers as described by Cabana et al., provided metrics for compliance to guidelines, and the study population was comprised of physicians. No date range was imposed on inclusion, nor

whether the study occurred in the United States. Exclusions included non-English language studies, and studies that did not report a statistical effect size between barriers as an independent variable and guidelines compliance as a dependent variable.

Key word and citation searches of PubMed and databases available to University of North Carolina J. Murrey Atkins Library (database n=483) were performed. Secondary search sources included reviewing Google Scholar for related or cited articles and reference lists of relevant articles and reviews. Search terms are available in Table 3. Studies were selected if they included statistics of association between a Cabana barrier type (independent variable) and compliance to any clinical guideline (dependent variable), and a description of the statistical methodology.

Table 3. Search Terms for Article Discovery

barriers knowledge attitudes beliefs
cabana barriers to guidelines and adherence regression
cabana barriers to guidelines and adherence regression surgeons
barriers to guidelines and compliance regression
barriers to guidelines and compliance regression surgery
barriers to clinical guidelines regression
barriers to clinical guidelines regression surgery
association of barriers and adherence clinical guidelines cabana
association of barriers and adherence clinical guidelines surgery cabana
association of barriers and compliance to clinical guidelines cabana
association of barriers and compliance to clinical guidelines surgery cabana
association of barriers and adherence guidelines
association of barriers and adherence guidelines surgery
association of barriers and adherence clinical guidelines
barriers to guidelines regression

Data collection included study characteristics such as year of publication, sample size, clinical guideline or recommendation, guideline source, area of medicine, and physician type.

Odds ratios, confidence intervals, beta (β) coefficients and compliance percentages were also collected.

Barriers and Compliance Relationship

Barrier types were not reported in a uniform manner across studies. Thus to standardize the concept of each barrier, barriers were collapsed and coded to create six categories, termed "Factors": External Barriers, Self-Efficacy, Agreement, Familiarity, Motivation/Inertia, and Outcome Expectancy.

Studies measured the association between barriers and compliance differently, where some were measured as inverted relationships and others as linear. A study could have reported that a *lack* of agreement with a guideline predicted non-compliance, whereas another could report that agreement with a guidelines predicted compliance and while both are directionally linear, are not reversible. For example, the presence of external barriers may predict compliance (inverted, an OR < 1 would be expected) in one study and in another, lack of external barriers would predict compliance (linear, an OR > 1 would be expected). As such, a categorical variable was created to denote each association type, termed "Prediction Group" (Table 4).

Table 4. Prediction Groups Characteristics and Interpretation

Prediction Group	Compliance type	Factor type	Expected Effect Size Interpretation	Example interpretation of Compliance and Factor
1	Compliance (+)	Presence of factor (+)	If Agreement is present, the odds of compliance increase (OR>1)	A physician's agreement with a guideline predicted compliance

2	Non-compliance (-)	Presence of factor (+)	If External Factors are present, the odds of non-compliance increase (OR>1)	A physician's agreement with a guideline predicted non-compliance Or, Presence of external factors predicts non-compliance
3	Compliance (+)	Absence of factor (-)	If lack of Agreement is present, the odds of compliance decrease (OR<1)	A physician's lack of agreement with a guideline predicted compliance
4	Non-compliance (-)	Absence of factor (-)	If lack of Agreement is present, the odds of non-compliance increase (OR>1)	A physician's lack of agreement with a guideline predicted non-compliance

Synthesis and Analysis

Studies retained for analysis reported odds ratios and confidence intervals. Normality was assessed, and OR and CI data were log-transformed. Effect size was thus evaluated as log-odds and standard error was developed as log of the standard error (upper CI – lower CI)*3.92 as described by Higgins et al.[31] All eligible study data was included in analysis, regardless of the statistical significance in its original study.

Meta-regression

Effect sizes violated the assumption of independence as multiple observations contributed from each study, creating correlation within studies that traditional univariate meta-analysis does not accommodate.[32] Univariate meta-regression was also not appropriate given the inter-dependence of the data. The contribution of multiple effect sizes from one study serves to create a multilevel structure, as such a hierarchal meta-analysis approach was taken utilizing the metafor rma.mv function R package.[33] The multilevel – or nested – structure was as follows: 76

individual study effect sizes nested within six studies which are then nested within four Prediction Groups, creating a four-level hierarchical meta-analysis structure.

Each effect size in the dataset was given a unique identifier, and each study was grouped and identified by a study identifier, where multiple effects could exist within a given study. This represents a three-level model. To account for the different methods each study measured the relationship between barriers and outcomes, models were created only within a Prediction Group type (PGs 1-4). This aimed to make results more interpretable, given the differences in how the barrier-compliance relationship was reported in each study.

An initial random effects, nested model without moderators (Factors) was created ("Nested model"), comprising the effect size, and study groups, while utilizing data from within each PG. Subsequent models were then created using the Nested model as a base and included a Factor as a moderator, allowing to control of the multiple effect sizes within studies, while testing the effect of a specific Factor type within a given PG. Model coefficients, standard errors, and p-values were reported for each Factor-specific moderated model.

Next, to account for other variations of the dataset such as different study participant types, survey methods, and other unknown complexities, correlated and hierarchical effects (CHE) models were developed for each Factor type, within each PG.[34] To account for dependent effect sizes and small sample sizes of the dataset, Sandwich robust variance estimation and CR2 method was applied to each CHE model using the clubSandwich R package.[35,36] Robust model coefficients, standard errors, and p-values were reported for each Factor-specific moderated model. Each model type (Nested model vs. CHE model) was then compared using Akaike information criterion (AIC). R version 4.2.1 was utilized for statistical computation and significance was set at $p \leq .05$.

Results

Nine studies were initially included for data analysis, however three were eventually removed due to the underlying analysis being linear regression-based and not reporting error or variability measures. All retained studies (n=6) reported odds ratios and confidence intervals. Included publications and their details in Appendix A.

Of the seven main Cabana-derived Factors (Familiarity, Awareness, Agreement, Outcome Expectancy, Self-Efficacy, Motivation, and External Barriers), five were identified and analyzed from the literature. These included Familiarity, Agreement, Outcome Expectancy, Self-Efficacy, and External Factors. Most effect sizes (observations) were from the Agreement Factor (25.0%) and fewest from Outcome Expectancy (14.5%), though there was a reasonable distribution among the Factors. Of the four Prediction Groups, most observations (36.8%) were from Prediction Group 1 (Compliance+ / Presence of factor+) followed by Prediction Group 4 (30.3%) (Non-Compliance- / Absence of factor-). (Table 5)

Table 5. Number of Observations by Barrier Type and Prediction Group
Row and Column Percentages

	Adherence and presence of factor (a=1, p=1) Group 1	Non-adherence and presence of factor (a=0, p=1) Group 2	Adherence and factor not present (a=1, p=0) Group 3	Non-adherence and factor not present (a=0, p=0) Group 4	Total
External Barriers	**12** 75.0% 42.9%	**4** 25.0% 40.0%	**0**	**0**	16 21.1%
Self-efficacy	**5** 29.4% 17.9%	**0**	**4** 23.5% 26.7%	**8** 47.1% 34.8%	17 22.4%
Agreement	**5** 26.3% 17.9%	**6** 31.6% 60.0%	**3** 15.8% 20.0%	**5** 26.3% 21.7%	19 25.0%
Familiarity	**3**	**0**	**4**	**6**	13

	23.1% 10.7%		30.8% 26.7%	46.2% 26.1%	17.1%
Outcome expectancy	**3** 27.3% 10.7%	**0**	**4** 36.4% 26.7%	**4** 36.4% 17.4%	11 14.5%
Total	28 36.8%	10 13.2%	15 19.7%	23 30.3%	76 100%

Models

Given their majority representation in the study data, and the complexity of interpretation of results for PGs 2 and 3, models were developed for PG 1 and 4 only. For PG 1, there were 28 effect sizes from three study identifiers. PG 4 consisted of 23 effect sizes from two study identifiers.

Table 6 reports the results of PG 1 models, where the presence of a factor predicts compliance. The presence of external barriers significantly decreased the log odds of compliance in both the Nested and the CHE model types. For the Nested model, the log odds of compliance decreased by 0.74 units if external barriers were present (β=-0.74, p=.05). For the CHE model, the log odds of compliance decreased by 0.97 units if external barriers were reported (β=-0.97, p=.04). While not significant in the Nested models, CHE model results show a significant relationship between physician familiarity with guidelines and compliance, where the presence of familiarity increased the log odds of compliance by 0.66 (p=.05). Finally, while not significant at the $p \leq .05$ level, presence of agreement predicted a 0.40 increase in the log odds of compliance in the CHE model (p=.06). For PG 4, where the lack of a factor predicts non-compliance, no models were statistically significant (Table 7).

Table 6. Impact of Each Barrier, by Model Type. Prediction Group 1				
Prediction group 1	Nested Meta-regression Model	*p*-value	CHE Model	*p*-value
Factor 1 External Barriers				
Model Intercept β (SE)	0.08 (0.17)	0.61	-0.19 (0.16)	0.45
Factor β (SE)	-0.74 (0.37)	0.05**	-0.97 (0.09)	0.04**
Factor 2 Self-efficacy				
Model Intercept β (SE)	-0.09 (0.15)	0.54	-0.39 (0.06)	0.08
Factor β (SE)	0.32 (0.51)	0.53	0.21 (0.32)	0.63
Factor 3 Agreement				
Model Intercept β (SE)	-0.10 (0.15)	0.50	-0.37 (0.07)	0.09
Factor β (SE)	0.63 (0.61)	0.31	0.40 (0.04)	0.06*
Factor 4 Familiarity				
Model Intercept β (SE)	-0.18 (0.21)	0.42	-0.93 (0.10)	0.04
Factor β (SE)	0.21 (0.30)	0.49	0.66 (0.08)	0.05**
Factor 5 Outcome expectancy				
Model Intercept β (SE)	-0.07 (0.16)	0.66	-0.41 (0.06)	0.07
Factor β (SE)	0.04 (0.46)	0.94	0.07 (0.02)	0.13

* indicates statistical significance at $p < .10$
** indicates statistical significance at $p \leq .05$

Table 7. Impact of Each Barrier, by Model Type. Prediction Group 4				
Prediction group 4	Nested Meta-regression Model	*p*-value	CHE Model	*p*-value
Factor 2 Self-efficacy				
Model Intercept β (SE)	0.82 (0.41)	0.06	0.02 (0.38)	0.97
Factor β (SE)	-0.05 (0.68)	0.94	-0.02 (0.04)	0.67
Factor 3 Agreement				
Model Intercept β (SE)	0.77 (0.36)	0.04	0.01 (0.40)	0.98
Factor β (SE)	0.24 (0.92)	0.79	0.04 (0.25)	0.89
Factor 4 Familiarity				

Model Intercept β (SE)	0.77 (0.39)	0.06	-0.05 (0.34)	0.91
Factor β (SE)	0.12 (0.73)	0.87	0.13 (0.14)	0.53
Factor 5 Outcome expectancy				
Model Intercept β (SE)	0.86 (0.37)	0.03	0.05 (0.39)	0.91
Factor β (SE)	-0.28 (0.83)	0.74	-0.17 (0.16)	0.46

When AIC values were compared between the two types of models (Nested vs. CHE), CHE models – which include robust variance estimators and adjustments for small sample sizes – were universally shown to fit the data better than the nested models without these adjustments (Table 8).

Table 8. Comparison of Model Types by Prediction Group	
Prediction Group 1	Akaike information criterion (AIC)
Factor 1 External Barriers	
Nested Meta-regression Model	67.2
CHE Model	52.9
Factor 2 Self-efficacy	
Nested Meta-regression Model	70.7
CHE Model	62.1
Factor 3 Agreement	
Nested Meta-regression Model	69.7
CHE Model	61.3
Factor 4 Familiarity	
Nested Meta-regression Model	72.2
CHE Model	59.8
Factor 5 Outcome expectancy	
Nested Meta-regression Model	71.8
CHE Model	62.9
Prediction Group 4	Akaike information criterion (AIC)
Factor 2 Self-efficacy	
Nested Meta-regression Model	70.1
CHE Model	55.8
Factor 3 Agreement	
Nested Meta-regression Model	69.7
CHE Model	55.4

Factor 4 Familiarity	
Nested Meta-regression Model	70.1
CHE Model	55.7
Factor 5 Outcome expectancy	
Nested Meta-regression Model	70.0
CHE Model	55.7

Discussion

After review of the existing literature that provides statistical data on the relationship between barriers and compliance to clinical guidelines, results show presence of external barriers significantly negatively impacts compliance to guidelines, and familiarity significantly predicts increased compliance. Agreement with guidelines, while not significant at the $p \leq .05$ level, was a promising factor of interest.

To account for the complexities of the underlying data structure, specifically dependent effect sizes and differing compliance-barrier measurement approaches, two types of nested meta-analysis models were created. Of the two approaches explored, the correlated and hierarchical effects models using robust variance estimators and small sample correction techniques were shown to fit the data better as compared to models that did not utilize these corrections.

Many iterations of search terms were performed to capture literature describing barriers to compliance as organized by the Cabana framework. Out of nine studies initially considered for inclusion in the dataset, three were dropped due to incomplete statistical information. Of the six remaining, the date range spanned 16 years (2000-2016) and about a third of the effect sizes were from studies authored by Dr. Michael Cabana, of the Cabana framework. Of the 76 effect sizes included from the six studies under review, only 32 (42%) were statistically significant in their studies of origin, further reducing the impact on the overall literature of data describing the

barrier-compliance association. However, while this review appears to have found few studies conducted to quantitatively assess the barrier-compliance relationship within the Cabana framework, many studies have described robust survey and qualitative approaches, contributing to the larger and richer discussion on this topic.[21,37,38]

Methods for measuring the barrier-compliance relationship varied across studies. To account for these differing measurement methods, groups needed to be created to categorize - and control for – the different directionalities of assessment. The approach taken was to build a composite profile of whether a barrier (Factor) was present or not, and whether the outcome measured was compliance, or lack of compliance; the combination potentials resulting in four Prediction Groups. The two Prediction Groups ultimately used in analysis was due to their coherence (PG 1: the presence of a factor predicts compliance and PG 4: the lack of a factor predicts non-compliance) as each represented about a third of the group types, perhaps speaking to their salience, ease of measurement and study design, or both.

In this study, the external barriers factor was associated with impacting compliance in both model types. This factor comprised 21% of the barrier types reported in this study, whereas others have reported up to a 42% prevalence of this particular barrier preventing adherence.[21] Social psychology provides us with models to explain why one may attribute success intrinsically and failure extrinsically, serving as a way of an individual to explain their surroundings or behaviors.[39] Organized around internal or external, controllability, and stability factors, attribution of a behavior is ultimately about perception.[40] Using this framework, Borkowski and Allen assert the low adoption of clinical guidelines by physicians stem from external forces such as reimbursement environment, threat of penalty, and skepticism of motivation of guideline developers.[41] Interestingly, they recommend increasing communication

with providers who are reluctant to adopt a given set of guidelines, and thus increase familiarity, supporting this study's findings of the impact of familiarity on improved compliance.

Given the low sample size of studies and interdependence of the effect sizes, the use of advanced meta-analytic techniques which, while necessary, introduced complexity and could potentially have masked associations. It is also true that while a thorough review was performed, not all studies in the literature may have been identified which could contribute to an underpowered meta-analysis. Next, the data from each original study were not collected or reported in exactly the same manner. This lack of standardization across studies necessitated the creation of a categorization variable, Prediction Groups, which may contribute to loss of overall association, and introduce bias and inconsistency. These factors – low sample size and the non-standardized assessment of the barrier to compliance relationship – highlight the need for more formalized study designs and research surrounding these issues.

The studies identified for inclusion were primarily from the respiratory medicine literature and caution should be taken when generalizing results to other clinical areas. However, given the subject matter under study is social in nature – not biomedical - it is reasonable to consider the value of studying effects within differing contexts to develop external validity and support decision making.[42] Indeed, others have asserted that quality appraisal of social studies following a traditional biomedical paradigm may not account for the complexity of real-world structures and may disregard relevant contributions.[28,42]

Future studies in this area should aim to standardize the data collection and reporting of the barrier-compliance relationship. The two paradigms that make the most intuitive sense (Prediction Groups 1 and 4) appear to be reasonable starting points for future study design considerations. For example, in the first scenario a researcher would collect individual-level data

on objective compliance with a guideline recommendation as a binary yes-no, and whether a factor was present (e.g. the physician indicated Agreement with the recommendation). These data could then be reported as statistical effect sizes and add to – or be supported by - the limited existing literature.

The area of surgery has long developed and utilized predictive modeling; ranging from nomograms, to institution-specific and national-level prediction calculators, to advanced artificial intelligence techniques. While it has gotten close to applying predictions in the area of guidelines compliance, these efforts remain aimed at predicting clinical outcomes.[8,14,43] Surgery may well benefit from applying principles of prediction modelling to barriers to guideline compliance, such as the ability to predict the likelihood of compliance to guidelines before an implementation program begins. This potential to create an implementation risk calculator where specific 'high-risk' barriers are known beforehand and targeted for mitigation could improve implementation processes and save time and resources.

Conclusion

This study analyzes the effects of the Cabana barriers on compliance in studies that reported statistical associations explaining the relationship between barriers and compliance to clinical guidelines. The presence of external barriers was significantly associated with decreased compliance, and familiarity improved compliance. Future studies should standardize how the barrier-compliance relationship is captured and reported and aim towards joining the established acceptance in surgery of prediction modelling with improving compliance to guidelines.

CHAPTER 3 REFERENCES

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APPENDIX A

Study Name	Barrier	Prediction Group	Sample size	Area of medicine	Effect Size: Odds Ratio	CI low	CI upper
Cabana et al (2001)			456	Pediatric asthma			
	Lack of self efficacy	4			1.41	0.88	2.25
	Lack of self efficacy	4			3.36	1.85	6.1
	Lack of self efficacy	4			3.81	1.7	6.1
	Lack of self efficacy	4			1.4	0.85	2.3
	Lack of self efficacy	4			2.81	1.34	5.89
	Lack of self efficacy	4			1.44	0.89	2.32
	Lack of agreement	4			6.79	3.2	14.4
	Lack of agreement	4			6.46	0.74	56.3
	Lack of agreement	4			2.77	0.22	34.8
	Lack of agreement	4			1.22	0.1	5.45
	Lack of familiarity	4			2.29	1.42	3.67
	Lack of familiarity	4			2.51	1.55	4.07
	Lack of familiarity	4			1.64	1.04	2.58
	Lack of familiarity	4			2.02	1.29	3.49
	Lack of outcome expectancy	4			4.48	0.45	43.3
	Lack of outcome expectancy	4			4.67	2.46	8.86
	Lack of outcome expectancy	4			1.41	0.88	2.27
	Lack of outcome expectancy	4			1.12	0.72	1.75
	External barriers	2			1.65	1.01	2.69
	External barriers	2			1.9	1.17	3.09
	External barriers	2			1.71	1.01	2.98
	External barriers	2			1.78	1.06	2.92
Perez et al (2012)			154	COPD guidelines			

	Lack of agreement	3		0.99	0.09	6.19
	Lack of agreement	3		0.28	0.02	2.46
	Lack of agreement	3		0.44	0.11	1.54
	Lack of familiarity	3		0.92	0.25	3.15
	Lack of familiarity	3		0.45	0.06	2.43
	Lack of familiarity	3		0.62	0.23	1.71
	Lack of familiarity	3		0.45	0.15	1.33
	Lack of outcome expectancy	3		2.42	0.44	11.98
	Lack of outcome expectancy	3		1.21	0.11	8.12
	Lack of outcome expectancy	3		3.46	0.47	46.84
	Lack of outcome expectancy	3		1.17	0.15	7.17
	External barriers	1		0.31	0.08	0.99
	External barriers	1		0.39	0.08	1.54
	External barriers	1		0.76	0.15	3.96
	External barriers	1		1.26	0.28	5.36
	Lack of self efficacy	3		0.3	0.03	1.59
	Lack of self efficacy	3		0.44	0.05	2.84
	Lack of self efficacy	3		0.28	0.1	0.74
	Lack of self efficacy	3		0.61	0.22	1.7
Salinas et al (2011)			500	COPD guidelines		
	Outcome expectancy	1		1.55	1.16	2.07
	Outcome expectancy	1		0.88	0.69	1.13
	Outcome expectancy	1		0.9	0.73	1.1
	External barriers	1		0.23	0.11	0.46
	External barriers	1		1.42	0.76	2.66
	External barriers	1		1.27	0.54	2.98
	External barriers	1		0.8	0.44	1.45
	External barriers	1		0.96	0.55	1.67
	External barriers	1		0.93	0.52	1.66
	Self efficacy	1		1.34	1.01	1.78

	Self efficacy	1		1.52	1.05	2.2
	Self efficacy	1		0.92	0.69	1.24
	Self efficacy	1		1.03	0.74	1.42
	Lack of agreement	1		3.15	2.03	4.86
	Lack of agreement	1		1.62	1.16	2.27
	agreement	1		1.12	0.82	1.54
	familiarity	1		1.04	0.91	1.18
	familiarity	1		1.16	0.97	1.39
	familiarity	1		0.96	0.81	1.13
Halm et al (2000)			139 Pneumonia			
	Agreement	2		1.1	0.5	2.5
	Agreement	2		0.7	0.3	1.4
	Agreement	2		3.7	0.4	32.8
	Agreement	2		1.6	0.9	2.9
	Agreement	2		1.3	0.7	2.4
	Agreement	2		2.6	1.3	4.8
Garber et al (2008)			528 Cystic Fibrosis			
	Lack of self efficacy	4		3.49	1.72	7.07
	Lack of self efficacy	4		3.9	1.05	14.49
	Lack of agreement	4		2.01	1.08	3.77
	Lack of familiarity	4		2.66	1.7	4.18
	Lack of familiarity	4		8.33	3.38	20.52
Kulczycki et al (2016)			301 HPV vaccination			
	External barriers	1		0.79	0.39	1.61
	External barriers	1		1.55	0.5	4.85
	Self efficacy	1		5.1	2.75	9.45
	Agreement	1		2.39	1.01	5.61
	Agreement	1		1.85	1.03	3.35

CHAPTER 4: ERAS® RECOMMENDATIONS THAT MOST IMPACT CARE: A MULTI-INSTITUTIONAL, MULTI-DISCIPLINE ANALYSIS IN THE UNITED STATES

Introduction

The Enhanced Recovery after Surgery (ERAS®) Society is an international non-profit medical society formed in 2010 to improve surgical patient recovery by eliminating variation and delivering quality surgical care according evidence-based best practice.[1] Founded in 2016, the USA Chapter of the ERAS® Society extends ERAS principles to the United States with a focus on multi-professional and multi-disciplinary collaboration. The ERAS® Society has developed surgical guidelines for approximately 20 procedures, the specifics of which vary significantly depending on the procedure. However, there are several core recommendations that apply to most surgical procedure types, for example oral carbohydrate loading, multimodal pain management, and prevention of nausea and vomiting.[2]

Each multidisciplinary team member, such as surgeons, nurses, anesthesiologists, and APPs, have responsibility for their certain recommendations; however, it is the overall integration and collaboration of these individuals that ensures not only whether each recommendation is performed, but the success of the overall pathway. For example, if a provider prescribes a long-acting anesthetic or opioid, the nurses will not be able to perform early mobilization or early feeding, which can cause a downstream cascade of adverse effects to compliance and patient care. This team effort may play a role in results from studies showing compliance to the entire protocol conferring the highest likelihood of a successful recovery for the surgical patient, where the higher the compliance the more likely the reduction in complications.[3–9] That said, specific items may predict improved recovery more than others, to

include nasogastric tube avoidance, minimally invasive approach, drain avoidance, preoperative education,[5,6,8,9] carbohydrate loading,[5] mobilization,[6] and nausea and vomiting prophylaxis.[9]

While predictive modelling has been widely reported in surgery, with models generally predicting post-operative outcomes using patient characteristics such as demographics and clinical indicators, modelling within an ERAS specific context adds "compliance" as an additional dimension to utilize as an independent variable.[10] The ability to track compliance and assess its impact on patient recovery is foundational to ERAS philosophy; from holding teams accountable and providing programmatic feedback, to utilizing advanced analytics to identify variation with electronic medical record-based adherence monitoring systems.[11] Many studies incorporating modelling with ERAS have been performed,[3–10,12] though they are single center, not based in the United States, or report on only one area of surgery; usually colorectal procedures.

This study aims to develop models to evaluate the impact of ERAS compliance both by perioperative phase and by the individual ERAS recommendations on adverse surgical outcomes in a multi-institutional United States setting across four different surgery types.

Methods

A retrospective chart review study was performed using data from two ERAS® Centers of Excellence in the United States. Data were downloaded from the EIAS which is an online secure platform developed for the ERAS® Society for standardization of outcomes tracking, reporting and data analysis. The EIAS system is populated by trained personnel or clinicians with deidentified data to include limited patient demographics, operative characteristics, ERAS pathway compliance and short-term clinical outcomes. Procedure types were selected based on procedures that overlapped between the two centers; liver (major and minor hepatectomy),

pancreas procedures (Whipple and distal pancreatectomy), urology (radical cystectomy), and head and neck cancer resections. Study outcomes were LOS, 30-day all-cause mortality, 30-day all-cause readmission, and 30-day Clavien-Dindo ≥ 3, a measure of clinically relevant complications.[13] Two types of compliance variables were assessed: binary compliance to the individual recommendations (itemized compliance), and continuous compliance variables by perioperative phase as calculated by the EIAS system. Perioperative phases were pre-admission, pre-operative, intra-operative, post-operative, and total compliance. Limited patient demographics included age, sex, and BMI.

The centers were coded to either 0 or 1 anonymize their respective data. The 30-day Clavien-Dindo ≥ 3 variable was developed as a combination of in-hospital and post-discharge Clavien-Dindo scores, where "30-day Clavien-Dindo ≥ 3" was yes if either the in-hospital and post-discharge variable was ≥3. LOS was the number of nights between surgery and discharge. Sex was coded as male =1, female was referent. Significant missingness in the BMI variable was found for Center 0, so this patient characteristic was not included in the models.

Continuous variables were assessed with Shapiro-Wilk tests of normality. Comparison analysis was performed with Wilcoxon rank-sum tests and Chi-square as appropriate to the data. For continuous variables, means and standard deviations were reported for saliency, though medians and interquartile ranges would be traditional. Categorical variables were reported as counts and percentages.

Regression Models

For the binary outcomes 30-day readmission and 30-day Clavien-Dindo ≥ 3 (30-day clinically significant complications), three different modelling methods were assessed - zero-inflated negative binomial, zero-inflated Poisson, and Poisson regressions - by AIC and negative

binomial overdispersion parameter (α). In both cases, Poisson regression was similar or superior to the zero-inflated Poisson regression, and in no cases was zero-inflated negative binomial superior to Poisson. Therefore Poisson regressions were performed using a stepwise backward procedure where terms were removed if $p \geq .20$ and were added if $p < .10$ and robust variance estimators were utilized.[14] For 30-day mortality, given the very low occurrence of this outcome, specialized PPML regressions were performed that allow for high degrees of dimensionality by identifying and dropping predictor variables that cause the non-existence of estimate.[15] Variables were retained in the final model if $p < .10$, and robust variance estimator was utilized. For the continuous LOS outcome, stepwise backward selection linear regression models were developed, removing terms with $p \geq .20$ and adding those with $p < .10$. To ensure that severity of complications was controlled for, the 30-day Clavien-Dindo ≥ 3 variable was included in all models, except the model for which that variable was the primary outcome of interest.

Models were developed by each surgery type (liver, pancreas, urology, and head & neck resection), and all stepwise models locked in – or forced retained – the variable that designated the center. To assess the different ways to measure compliance, two compliance model types were created for each outcome of interest: Binary compliance to the individual recommendations (itemized compliance), and compliance as measured by the continuous metrics calculated by the EIAS system. Model results were reported as exponentiated estimates (odds ratios) if binary dependent variables, and as beta coefficients for the continuous LOS variable.

Itemized compliance items are different for each surgery type, and while some recommendations overlap across all surgery types, others were specific to each surgery model. Additionally, some recommendations were not available from the EIAS download, or had very

high missingness or not applicable response types. Table 9 lists which specific recommendations were considered for inclusion in each surgery type model.

Table 9. Specific Recommendations for Inclusion in Each Surgery-Specific Model

Liver	**Pancreas**	**Urology**	**Head and Neck**
Patient Education	Patient Education	Patient Education	Patient Education
Oral Carbohydrate Loading	Oral Carbohydrate Loading	Oral Carbohydrate Loading	Oral Carbohydrate Loading
No or Selective Bowel Prep	No or Selective Bowel Prep	No or Selective Bowel Prep	Antibiotic Prophylaxis
Antibiotic Prophylaxis	Antibiotic Prophylaxis	Antibiotic Prophylaxis	Thromboprophylaxis
Thromboprophylaxis	Thromboprophylaxis	Thromboprophylaxis	Use of Short Acting Anesthetics
Use of Short Acting Anesthetics	Limited or No Use of Drains	Use of Short Acting Anesthetics	Normothermia
Limited or No Use of Drains	Normothermia	Normothermia	Prevention of Nausea / Vomiting
Normothermia	Limited or No Nasogastric Tubes	Limited or No Nasogastric Tubes	Postoperative Goal Directed Fluids
Limited or No Nasogastric Tubes	Prevention of Nausea / Vomiting	Prevention of Nausea / Vomiting	Early Removal / Avoidance of Foley Catheter
Prevention of Nausea / Vomiting	Postoperative Goal Directed Fluids	Postoperative Goal Directed Fluids	Early Oral Nutrition / Early Feeding
Early Removal / Avoidance of Foley Catheter	Early Removal / Avoidance of Foley Catheter		

Data were analyzed using Stata statistical software (StataCorp Release 17; College Station, TX) and statistical significance was set at a $p < .05$ level. This study was approved by the Atrium Health IRB Review Board (IRB#02-22-15EX)

Results

After initial data download, 315 records were removed due to not reporting an operative date, leaving an overall sample size of 2,886. Center 0 represented 32.5% and Center 1 represented 67.5% of contributing records (Table 10). During their ERAS programs (while the

centers were actively practicing ERAS), average age and sex were numerically similar between the two centers and most outcomes - while significantly different – were also numerically similar (Table 11). However, the two centers did differ statistically, supporting the use of center designation as a fixed covariate in the regression models.

Table 10. Comparison of Area of Surgery, by Center

Area of Surgery	Center 0 [939]	Center 1 [1947]	p-value
Head and Neck	149 (15.9)	318 (16.3)	.751
Liver	181 (19.3)	447 (23.0)	.025
Pancreatic	267 (28.4)	745 (38.3)	<.000
Urology	342 (36.4)	437 (22.4)	<.000

n (%)
[ ] = sample size

Table 11. Comparison of Demographics, Outcomes, and Calculated Compliance Metrics During an ERAS program, by Center

Variable	Center 0	Center 1	p-value
Age [a]	65.5 (11.8) [936]	63.4 (13.1) [1609]	<.000
Sex, male [b]	547 (58.4) [937]	903 (56.1) [1609]	.268
Outcomes, during ERAS program			
Length of stay (nights in hospital after primary operation) [a]	8.7 (6.4) [935]	8.6 (7.2) [1592]	.018
Thirty-day mortality [b]	6 (0.6) [937]	37 (2.3) [1609]	.002
Thirty-day Clavien-Dindo ≥3 [b]	98 (11.3) [870]	493 (30.9) [1597]	<.000
Thirty-day readmission [b]	150 (17.1) [875]	306 (19.9) [1535]	.092
Calculated Compliance Metrics, during ERAS program			
Preadmission compliance [a]	15.1 (34.1) [937]	71.2 (35.7) [1609]	<.000
Pre-operative compliance [a]	81.3 (16.5) [937]	87.8 (15.6) [1609]	<.000
Intra-operative compliance [a]	71.4 (20.6) [937]	83.3 (17.9) [1609]	<.000
Post-operative compliance [a]	56.5 (22.2) [937]	50.9 (18.3) [1609]	<.000

Total (overall) compliance [a]	63.2 (12.9) [937]	67.7 (11.3) [1609]	<.000
[a] mean (SD) [b] n (%) [ ] = sample size			

Regressions

Full model results for LOS and calculated compliance are in Tables 12-15. Full model results for binary outcomes and calculated compliance are in Tables 16-19. Full model results for LOS and itemized recommendations are in Tables 20-23. Full model results for binary outcomes and itemized recommendations are in Tables 24-27. All models controlled for center designation and clinically relevant complications, with the exception of the models for which the clinically relevant complication variable was the outcome of interest.

Impact of calculated compliance on outcomes

Liver. Total compliance decreased LOS by 0.23 days (β= -0.23, 95% CI: -0.32, -0.14, p=.000). For every unit increase in intraoperative compliance patients had 3% less odds for 30-day readmission (OR=0.97, 95% CI: 0.95, 0.99, p=.025), and post-operative compliance decreased the odds of 30-day mortality by 14% (OR=.086, 95% CI: 0.80, 0.93 p=.000). Total compliance also decreased the odds of clinically relevant complications by 20% (OR=.80, 95% CI: 0.74, 0.86, p=.000).

Pancreas. Compliance to the intra-operative and post-operative phases reduced LOS by 0.05 and 0.03 days respectively. For 30-day mortality, compliance to each peri-operative phase significantly reduced LOS, with post-operative compliance showing the most impact by reducing the odds of mortality by 21% (OR= 0.79, 95% CI: 0.72, 0.87, p=.000). Similarly, for every unit

increase in post-operative compliance, the odds of clinically relevant complications decreased by 2% (OR=0.98, 95% CI: 0.98, 0.99, p=.001).

Urology. Increased compliance to the pre-operative phase decreased LOS by 0.05 days (β= -0.05, 95% CI: -0.10, -0.01, p=.012), similarly increased compliance to the post-operative phase decreased LOS by 0.12 days (β= -0.12, 95% CI: -0.17, -0.07, p=.000). No calculated compliance metrics significantly impacted 30-day readmissions, though intra-operative compliance decreased the odds of 30-day mortality by 3% (OR= 0.96, 95% CI: 0.92, 0.99, p=.027) and post-operative compliance decreased the odds of clinically relevant complications also by 3% (OR= 0.97, 95% CI: 0.95, 0.99, p=.002).

Head and Neck. Increased compliance to the post-operative phase of ERAS significantly reduced LOS by 0.25 days (β= -0.25, 95% CI: -0.48, -0.03, p=.030), and total compliance was shown to decrease the odds of clinically relevant complications by 2% (OR= 0.98, 95% CI: 0.97, 0.99, p=.000).

Impact of itemized compliance recommendations on outcomes

Liver. Early removal of the foley catheter decreased LOS by 3.3 days (β= -3.3, 95% CI: -5.2, -1.4, p=.001). The thromboprophylaxis recommendation significantly increased the odds of 30-day readmission, though the confidence interval was fairly wide for this metric (OR=5.1, 95% CI: 1.2, 20.2, p=.021). No recommendations were significant predictors for 30-day mortality. Finally, compliance to early removal of the foley catheter decreased the odds of clinically relevant complications by 58% (OR= 0.42, 95% CI: 0.29, 0.62, p=.000) and limited or no use of drains decreased the odds of complications by 63% (OR= 0.37, 95% CI: 0.22, 0.62, p=.000).

Pancreas. Limiting the use of nasogastric tubes (β= -2.3, 95% CI: -3.9, -0.73, p=.004), oral carbohydrate loading (β=-2.2, 95% CI: -3.6, -0.79, p=.002), and early removal of the foley catheter (β=-2.3, 95% CI: -3.8, -0.72, p=.004) all significantly reduced LOS. No itemized recommendations were shown to significantly impact 30-day readmissions, however those that received normothermia had fewer odds of 30-day mortality as compared to those who did not (OR= 0.03. 95% CI: 0.001, 0.85, p=.040). Normothermia (OR= 0.37, 95% CI: 0.19, 0.73, p=.004) and early removal of the foley catheter (OR= 0.51, 95% CI: 0.37, 0.71, p=.000) both significantly predicted lower odds of clinically relevant complications, however similar to the findings in liver surgery, thromboprophylaxis increased the odds of clinically relevant complications (OR= 3.5, 95% CI: 1.2, 10.5, p=.023), though a wide CI was observed here as well.

Urology. No individual ERAS recommendations were significant predictors of LOS. Patients receiving thromboprophylaxis decreased the odds of 30-day mortality by 84% as compared to those who did (OR= 0.16, 95% CI: 0.04, 0.65, p=.010) and limited use of nasogastric tubes decreased the odds of clinically relevant complications by 78% (OR= 0.22, 95% CI: 0.08, 0.58, p=.002).

Head and Neck. Early removal of the foley catheter was shown to decrease LOS by almost 4 days as compared to those patients who did not experience this compliance item (OR= -3.6, 95% CI: -5.8, -1.4, p=.002). While no individual recommendations significantly impacted 30-day readmission, those that received patient education had 0.31 times the odds – or 69% fewer odds – of 30-day mortality compared to those who did not (OR= 0.31, 95% CI: 0.09, 0.97, p=.044). Early post-operative oral nutrition decreased the odds of clinically relevant

complications by 45% as compared to those who did not (OR= 0.55, 95% CI: 0.31, 0.97, p=.039).

Table 12. Results of stepwise backward selection linear regression models: Effect of calculated compliance metrics and length of stay, **liver surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-2.3	.56	-3.4	-1.2	.000
Age	.04	.01	.01	.06	.010
Total compliance	-.23	.05	-.32	-.14	.000
Thirty-day Clavien-Dindo ≥3 (1)	6.1	.52	5.0	7.1	.000
Pre-admission compliance	.02	.01	.01	.03	.001
Pre-operative compliance	.09	.02	.06	.13	.000
Post-operative compliance	.09	.02	.04	.13	.000
Intercept	5.9	1.6	2.8	9.0	.000
	F	*df*	n	Adj. R^2	p-value
Overall model	40.9	7, 609	617	0.31	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom

Table 13. Results of stepwise backward selection linear regression models: Effect of calculated compliance metrics and length of stay, **pancreas surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-1.2	.53	-2.2	-.11	.030
Age	.03	.02	-.001	.06	.060
Sex (1)	.73	.40	-.05	1.5	.067
Thirty-day Clavien-Dindo ≥3 (1)	8.7	.45	7.9	9.6	.000
Pre-operative compliance	-.02	.01	-.05	.01	.169
Post-operative compliance	-.03	.01	-.05	-.01	.002
Intra-operative compliance	-.05	.01	-.07	-.02	.000
Intercept	12.7	1.9	9.0	16.4	.000
	F	*df*	n	Adj. R^2	p-value
Overall model	68.5	7, 991	999	0.32	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom

Table 14. Results of stepwise backward selection linear regression models: Effect of calculated compliance metrics and length of stay, **urology surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-2.6	.56	-3.7	-1.5	.000
Age	.06	.02	.02	.10	.005
Total compliance	.16	.05	.06	.26	.002
Thirty-day Clavien-Dindo ≥3 (1)	8.1	.55	7.0	9.2	.000
Pre-operative compliance	-.05	.02	-.10	-.01	.012
Post-operative compliance	-.12	.03	-.17	-.07	.000
Intra-operative compliance	-.03	.01	-.06	.002	.066
Intercept	7.9	1.8	4.5	11.4	.000
	F	*df*	n	Adj. R^2	p-value
Overall model	39.9	7, 700	708	0.28	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom

Table 15. Results of stepwise backward selection linear regression models: Effect of calculated compliance metrics and length of stay, **head and neck surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-2.3	1.1	-4.5	-.10	.040
Post-operative compliance	-.25	.11	-.48	-.03	.030
Total compliance	.23	.17	-.10	.57	.175
Thirty-day Clavien-Dindo ≥3 (1)	7.2	.67	5.9	8.6	.000
Pre-operative compliance	-.04	.03	-.10	.02	.175
Pre-admission compliance	-.03	.02	-.07	.003	.074
Intercept	15.0	1.8	11.5	18.6	.000
	F	*df*	n	Adj. R^2	p-value
Overall model	27.9	6, 458	465	0.26	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom

Table 16. Results of stepwise backward selection Poisson regression models: Effect of calculated compliance metrics and binary outcomes, **liver surgery**

			95% CI		
Readmission Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.81	.27	.42	1.6	.531
Intra-operative compliance	.97	.01	.95	.99	.025
Total compliance	1.1	.05	1.01	1.2	.032

Thirty-day Clavien-Dindo ≥3 (1)	11.2	3.3	6.3	19.9	.000
Pre-operative compliance	.98	.02	.95	1.01	.113
Post-operative compliance	.96	.02	.92	1.002	.063
Intercept	.05	.04	.01	.21	.000
			n	R^2	p-value
Overall model			587	0.21	.000
Thirty-day Mortality Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Age	1.1	0.3	1.03	1.1	.001
Sex (1)	3.6	2.2	1.1	11.7	.033
Post-operative compliance	.86	.03	.80	.93	.000
Total compliance	1.09	.05	.99	1.2	.050
Intercept	.000	.000	.000	.01	.000
			n	R^2	p-value
Overall Model			124	0.33	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	4.0	1.2	2.2	7.2	.000
Total compliance	.80	.03	.74	.86	.000
Sex (1)	.76	.10	.58	.99	.047
Pre-admission compliance	1.01	.003	1.01	1.02	.000
Pre-operative compliance	1.1	.01	1.04	1.1	.000
Intra-operative compliance	1.03	.01	1.01	1.05	.002
Post-operative compliance	1.08	.02	1.03	1.1	.000
Intercept	.75	.31	.33	1.7	.477
			n	R^2	p-value
Overall model			619	0.17	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio
[a] PPML regression

Table 17. Results of stepwise backward selection Poisson regression models: Effect of calculated compliance metrics and binary outcomes, **pancreas surgery**

			95% CI		
Readmission Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.83	.13	.61	1.1	.228
Age	.99	.004	.98	1.0	.079
Total compliance	1.01	.004	1.001	1.01	.032
Thirty-day Clavien-Dindo ≥3 (1)	4.9	.60	3.8	6.2	.000

Sex (1)	1.2	.12	.98	1.5	.070
Intercept	.12	.04	.05	.23	.000
			n	R^2	p-value
Overall model			946	.12	.000
Thirty-day Mortality Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	11.1	8.4	2.5	48.6	.001
Age	1.1	.02	1.02	1.1	.000
Pre-admission compliance	.97	.01	.95	.98	.000
Pre-operative compliance	.88	.03	.83	.94	.000
Intra-operative compliance	.94	.02	.89	.98	.008
Post-operative compliance	.79	.04	.72	.87	.000
Total compliance	1.5	.17	1.2	1.9	.000
Intercept	.000	.001	.000	.02	.000
Overall Model			n	R^2	p-value
			1012	0.25	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	4.3	.84	2.9	6.3	.000
Age	1.01	.004	1.004	1.01	.002
Sex (1)	1.2	.10	.97	1.4	.105
Total compliance	1.02	.01	.99	1.04	.054
Post-operative compliance	.98	.005	.98	.99	.001
Intercept	.03	.02	.01	.08	.000
			n	R^2	p-value
Overall model			1009	0.07	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio
[a] PPML regression

Table 18. Results of stepwise backward selection Poisson regression models: Effect of calculated compliance metrics and binary outcomes, **urology surgery**

			95% CI		
Readmission Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	1.1	.26	.66	1.7	.769
Pre-operative compliance	.98	.01	.97	1.001	.071
Total compliance	1.03	.02	.99	1.1	.102
Thirty-day Clavien-Dindo ≥3 (1)	3.5	.56	2.6	4.8	.000
Post-operative compliance	.98	.01	.96	1.01	.150

Intercept	.14	.05	.07	.29	.000
			n	R^2	p-value
Overall model			687	.070	.000
Thirty-day Mortality Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	1.2	1.1	.21	6.8	.842
Age	1.1	.04	1.003	1.2	.040
Thirty-day Clavien-Dindo ≥3 (1)	15.4	13.9	2.6	91.1	.003
Sex (1)	3.3	3.1	.54	20.7	.197
Pre-operative compliance	1.1	.03	1.002	1.1	.042
Intra-operative compliance	.96	.02	.92	.99	.027
Post-operative compliance	.98	.02	.94	1.01	.180
Intercept	.001	.001	.000	.00	.001
Overall Model			n	R^2	p-value
			710	0.31	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	1.03	.29	.59	1.8	.921
Total compliance	1.02	.01	.99	1.05	.103
Post-operative compliance	.97	.01	.95	.99	.002
Intercept	.18	.08	.07	.45	.000
			n	R^2	p-value
Overall model			710	0.04	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio

Table 19. Results of stepwise backward selection Poisson regression models:
Effect of calculated compliance metrics and binary outcomes, **head and neck surgery**

			95% CI		
Readmission Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	1.01	.37	.49	2.1	.975
Total compliance	.97	.02	.93	1.01	.117
Thirty-day Clavien-Dindo ≥3 (1)	6.8	2.2	3.7	12.7	.000
Post-operative compliance	1.04	.02	.99	1.1	.090
Intercept	.03	.02	.01	.15	.000
			n	R^2	p-value
Overall model			448	0.13	.000

Thirty-day Mortality Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	1.9	3.7	.05	79.4	.723
Post-operative compliance	1.1	.02	1.03	1.1	.000
Thirty-day Clavien-Dindo ≥3 (1)	10.5	12.0	1.1	98.9	.040
Intra-operative compliance	1.04	.01	1.01	1.02	.001
Pre-admission compliance	.97	.02	.95	1.004	.093
Intercept	.001	.000	.000	.001	.000
			n	R^2	p-value
Overall Model			467	0.16	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.79	.23	.45	1.4	.432
Intraoperative compliance	1.01	.01	.99	1.01	.174
Total compliance	.98	.005	.97	.99	.000
Pre-admission compliance	1.01	.002	1.001	1.01	.008
Intercept	.50	.20	.22	1.1	.087
			n	R^2	p-value
Overall model			467	0.03	.000
n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio					

Table 20. Results of stepwise backward selection linear regression models:
Effect of itemized compliance recommendations and length of stay, **liver surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-1.2	.77	-2.8	.27	.108
Age	.04	.02	.01	.08	.026
Prevention of Nausea / Vomiting	1.5	.87	-.22	3.2	.087
Thirty-day Clavien-Dindo ≥3 (1)	6.6	.82	4.9	8.2	.000
Patient Education	1.7	.81	.07	3.2	.041
Use of Short Acting Anesthetics	-1.6	.82	-3.2	.01	.051
Early Removal / Avoidance of Foley Catheter	-3.3	.96	-5.2	-1.4	.001
Intercept	4.2	1.9	.48	7.8	.027
	F	*df*	n	Adj. R^2	p-value
Overall model	17.7	7, 224	232	0.34	.000
n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom					

Table 21. Results of stepwise backward selection linear regression models: Effect of itemized compliance recommendations and length of stay, **pancreas surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-1.9	.93	-3.8	-.13	.035
Postoperative Goal Directed Fluids	-1.03	.58	-2.2	.11	.078
Sex (1)	3.7	1.5	.79	6.5	.012
Thirty-day Clavien-Dindo ≥3 (1)	9.1	.68	7.8	10.4	.000
Limited or No Nasogastric Tubes	-2.3	.81	-3.9	-.73	.004
Oral Carbohydrate Loading	-2.2	.72	-3.6	-.79	.002
No or Selective Bowel Prep	-2.8	1.8	-6.4	.71	.118
Antibiotic Prophylaxis	1.4	1.04	-.70	3.4	.197
Early Removal / Avoidance of Foley Catheter	-2.3	.78	-3.8	-.72	.004
Intercept	14.8	2.4	10.1	19.5	.000
	F	*df*	n	Adj. R^2	p-value
Overall model	30.3	9, 363	373	0.41	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom

Table 22. Results of stepwise backward selection linear regression models: Effect of itemized compliance recommendations and length of stay, **urology surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-.56	.76	-2.1	.94	.465
Age	.10	.04	.03	.17	.007
Sex (1)	-1.9	1.1	-4.0	.24	.081
Thirty-day Clavien-Dindo ≥3 (1)	7.9	1.2	5.5	10.2	.000
Prevention of Nausea / Vomiting	-1.8	1.3	-4.4	.79	.173
Oral Carbohydrate Loading	-1.6	.98	-3.6	.32	.101
Intercept	4.1	2.8	-1.5	9.7	.151
	F	*df*	n	Adj. R^2	p-value
Overall model	10.3	6, 162	169	0.25	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom

Table 23. Results of stepwise backward selection linear regression models: Effect of itemized compliance recommendations and length of stay, **head and neck surgery**

			95% CI		
Effects	Estimate (β)	SE	LL	UL	p-value
Center code (1)	-3.1	.97	-5.0	-1.2	.002

Postoperative Goal Directed Fluids	-1.5	.85	-3.2	.17	.077
Sex (1)	-3.0	1.2	-5.4	-.59	.015
Thirty-day Clavien-Dindo ≥3 (1)	4.9	.94	3.0	6.7	.000
Early Oral Nutrition / Early Feeding	-1.4	.92	-3.2	.42	.130
Early Removal / Avoidance of Foley Catheter	-3.6	1.1	-5.8	-1.4	.002
Intercept	15.9	1.3	13.3	18.6	.000
	F	*df*	n	Adj. R^2	p-value
Overall model					
n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit; df =degrees of freedom					

Table 24. Results of stepwise backward selection Poisson regression models: Effect of itemized compliance recommendations and binary outcomes, **liver surgery**

			95% CI		
Readmission Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.65	.24	.32	1.3	.235
Sex (1)	3.8	2.5	1.04	13.7	.043
Thirty-day Clavien-Dindo ≥3 (1)	10.7	4.0	5.1	22.4	.000
Patient Education	1.7	.69	.75	3.8	.207
Thromboprophylaxis	5.1	3.6	1.2	20.2	.021
Prevention of Nausea / Vomiting	.67	.24	.34	1.3	.260
Intercept	.01	.01	.002	.07	.000
			n	R^2	p-value
Overall model			291	0.24	.000
Thirty-day Mortality Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Age	1.1	.02	1.03	1.1	.000
Patient Education	.53	.49	.09	3.2	.492
Oral Carbohydrate Loading	1.3	1.2	.20	8.6	.772
Intercept	.000	.001	.000	.01	.000
			n	R^2	p-value
Overall Model			424	0.07	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	4.2	1.9	1.7	10.4	.002
Use of Short Acting Anesthetics	2.3	1.02	.93	5.5	.073

Early Removal / Avoidance of Foley Catheter	.42	.08	.29	.62	.000
Limited or No Use of Drains	.37	.10	.22	.62	.000
Oral Carbohydrate Loading	.70	.15	.46	1.1	.098
Antibiotic Prophylaxis	.34	.22	.10	1.2	.092
Prevention of Nausea / Vomiting	.73	.15	.49	1.1	.118
Intercept	.52	.51	.08	3.5	.503
			n	R^2	p-value
Overall model			234	0.22	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio
[a] PPML regression

Table 25. Results of stepwise backward selection Poisson regression models:
Effect of itemized compliance recommendations and binary outcomes, **pancreas surgery**

			95% CI		
Readmission Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.68	.18	.41	1.1	.132
Age	.99	.01	.97	1.001	.066
Sex (1)	1.6	.51	.85	2.99	.148
Thirty-day Clavien-Dindo ≥3 (1)	5.1	1.2	3.3	7.9	.000
Early Removal / Avoidance of Foley Catheter	1.5	.41	.89	2.6	.130
Oral Carbohydrate Loading	.69	.15	.46	1.05	.085
Prevention of Nausea / Vomiting	1.6	.54	.80	3.1	.188
Intercept	.21	.13	.06	.70	.011
			n	R^2	p-value
Overall model			360	0.12	.000
Thirty-day Mortality Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Age	1.1	.01	1.01	1.1	.006
Patient Education	.43	.59	.03	6.4	.542
Oral Carbohydrate Loading	1.4	.69	.55	3.7	.458
Antibiotic Prophylaxis	.09	.11	.01	1.04	.054
Thromboprophylaxis	.57	.47	.11	2.9	.497
Normothermia	.03	.06	.001	.85	.040
Prevention of Nausea / Vomiting	.25	.48	.01	10.5	.468
Early Removal / Avoidance of Foley Catheter	.15	.26	.01	4.3	.271
Intercept	.94	3.3	.001	922.4	.986
Overall Model			n	R^2	p-value

			397	0.29	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	3.2	1.1	1.7	6.1	.000
Age	1.01	.01	1.001	1.02	.049
Normothermia	.37	.13	.19	.73	.004
Thromboprophylaxis	3.5	1.9	1.2	10.5	.023
Early Removal / Avoidance of Foley Catheter	.51	.08	.37	.71	.000
Intercept	0.8	.05	.02	.28	.000
			n	R^2	p-value
Overall model			376	0.10	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio
[a] PPML regression

Table 26. Results of stepwise backward selection Poisson regression models:
Effect of itemized compliance recommendations and binary outcomes, **urology surgery**

			95% CI		
Readmission Effects	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	2.3	1.2	.84	6.5	.106
Age	1.04	.02	1.01	1.1	.026
Thirty-day Clavien-Dindo ≥3 (1)	2.3	.76	1.2	4.4	.011
Oral Carbohydrate Loading	5.7	4.8	1.1	29.7	.037
No or Selective Bowel Prep	.49	.24	.19	1.3	.142
Prevention of Nausea / Vomiting	.50	.22	.22	1.2	.108
Postoperative Goal Directed Fluids	.51	.27	.18	1.4	.202
Intercept	.003	.01	.0001	.07	.000
			n	R^2	p-value
Overall model			171	0.14	.000
Thirty-day Mortality Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	1.1	1.3	.11	11.5	.931
Age	1.1	.04	1.003	1.2	.040
Sex (1)	.07	.05	.02	.28	.000
Thirty-day Clavien-Dindo ≥3 (1)	28.3	29.3	3.7	215.8	.001
Oral Carbohydrate Loading	7.9	5.4	2.1	30.0	.002
Thromboprophylaxis	.16	.12	.04	.65	.010
Use of Short Acting Anesthetics	.24	.27	.03	2.1	.201
Limited or No Nasogastric Tubes	2.6	1.6	.81	8.5	.107

Postoperative Goal Directed Fluids	.96	.87	.16	5.7	.967
Intercept	.000	.001	.000	.03	.001
Overall Model			n	R^2	p-value
			524	0.28	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	2.7	1.5	.95	7.8	.063
Limited or No Nasogastric Tubes	.22	.11	.08	.58	.002
Thromboprophylaxis	.34	.26	.08	1.5	.150
No or Selective Bowel Prep	2.3	1.4	.67	7.9	.187
Intercept	.34	.26	.07	1.5	.160
			n	R^2	p-value
Overall model			171	0.09	.000

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio
[a] PPML regression

Table 27. Results of stepwise backward selection Poisson regression models: Effect of itemized compliance recommendations and binary outcomes, **head and neck surgery**

			95% CI		
Readmission Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.78	.42	.27	2.2	.641
Thirty-day Clavien-Dindo ≥3 (1)	5.0	2.9	1.6	15.8	.006
Prevention of Nausea / Vomiting	.43	.22	.16	1.2	.094
Postoperative Goal Directed Fluids	1.9	1.1	.64	5.9	.235
Intercept	.06	.05	.01	.28	.000
			n	R^2	p-value
Overall model			156	0.11	.046
Thirty-day Mortality Effects [a]	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.70	.87	.06	8.0	.775
Age	.99	.03	.93	1.1	.906
Sex (1)	.96	1.1	.11	8.5	.971
Thirty-day Clavien-Dindo ≥3 (1)	3.7	5.4	.22	63.3	.365
Patient Education	.31	.18	.09	.97	.044
Oral Carbohydrate Loading	1.2	.78	.34	4.3	.779
Postoperative Goal Directed Fluids	.69	.90	.05	8.9	.774

Intercept	.01	.03	.000	2.9	.114
			n	R^2	p-value
Overall Model			422	0.07	.000
Clinically Relevant Complications Effects (Thirty-day Clavien-Dindo ≥3)	Estimate OR	Robust SE	LL	UL	p-value
Center code (1)	.61	.28	.25	1.5	.277
Early Removal / Avoidance of Foley Catheter	.63	.21	.33	1.2	.168
Postoperative Goal Directed Fluids	.66	.18	.39	1.1	.127
Early Oral Nutrition / Early Feeding	.55	.16	.31	.97	.039
Use of Short Acting Anesthetics	2.4	1.2	.90	6.3	.080
Thromboprophylaxis	.67	.18	.39	1.1	.128
Intercept	.81	.35	.35	1.9	.620
			n	R^2	p-value
Overall model			128	0.06	.002

n=number of observations; CI = confidence interval; LL = lower limit; UL = upper limit OR=exponentiated regression coefficients, odds ratio
[a] PPML regression

Discussion

Controlling for center and for severity of patient complications, compliance with the post-operative phase of an ERAS protocol significantly decreased adverse surgical outcomes in all areas of surgery in this study. Intra-operative compliance also significantly reduced adverse outcomes in all areas except head and neck procedures. Early removal of the foley catheter was associated with significant reductions in LOS in liver, pancreas, urology, and head and neck procedures, and was associated with reductions in clinically relevant complications in liver and pancreas procedures. Limited use of nasogastric tubes was associated with reductions in LOS in pancreas and clinically relevant complications in urology. Finally, the only areas of surgery where pre-operative compliance items predicted reductions in adverse outcomes were pancreas, where oral carbohydrate loading reduced LOS, and in head and neck procedures where the odds of mortality decreased if patient's received pre-operative education about their upcoming

surgery. There appears to be concordance between the calculated phase compliance and the itemized compliance results, where overall post-operative compliance, a metric calculated by the EIAS database system, was predictive of lowered adverse outcomes in all surgery types which, upon review of the itemized compliance items that occur during this phase, also showed reduced odds of adverse outcomes. A similar pattern was seen for intra-operative calculated phase compliance.

The findings of this multi-institutional study support similar single-center studies that report compliance to oral carbohydrate loading, early removal of the foley catheter, and limited use of nasogastric tubes significantly reduced LOS for pancreas surgery patients.[16] Similarly in liver patients, a previous single-center study found compliance to the overall ERAS pathway significantly reduced LOS and clinically relevant complications,[9] a finding validated in these multi-institutional results.

The post-operative phase of an ERAS protocol requires high levels of multidisciplinary teamwork, including buy-in from the patients.[21] Early mobilization is one such example, where patients must expect and accept that they will be out of bed even on the day of surgery, nurses and technicians must consistently get them out of bed, and orders must be written to instruct the team on the cadence and type of mobilization. All of these tasks are dependent on if compliance to the upstream recommendations was achieved and are facilitated by a culture of acceptance of the importance of early mobilization. Future studies should assess the role of the coordination of MDT post-operative care and why this study, and others, show its significant impacts on surgical outcomes. Thromboprophylaxis was associated with increased odds of readmission and clinically relevant complications in liver and pancreas respectively, however in urology it was associated with lower mortality. While this result remains unexpected until further studies can inspect

confounding and other unknown sources of variation, some studies have shown that critically ill patients undergoing major surgery – including liver surgery - are at higher risk of complications if thromboprophylaxis is administered.[17] Additionally, patient BMI has been shown to be a predictor of thromboprophylaxis failure,[18] a variable the current study was unable to assess.

The only factor that predicted readmission across all surgery types was if the patient experienced clinically relevant complications, a finding that makes intuitive sense and has been previously supported.[19] Identifying factors that predict all-cause 30-day readmission is a challenge that large healthcare and other organizations are investigating and is beyond the scope of this study though there is ongoing debate as to whether readmission rates are too multifactorial, or is an outcome too far removed from its root cause to predict or to be an accurate indicator of quality care delivery.[20]

Finally, the relationship between complications and compliance to an ERAS pathway is more complex than the general cause and effect association of poor compliance causing poor outcomes.[12] The confounding nature of this relationship is disentangling whether poor compliance leads to poor outcomes, or if the poor compliance is a reflection of the patient's complications. Given this relationship, this study adjusted for clinically relevant complications in regression models.

Limitations to this study include low occurrences of the 30-day mortality outcome, contributing to instability and uncertainty in the mortality regression models. Instability was also seen in itemized compliance models which may reflect unknown variance in the data. Multicollinearity in regression models was shown when the models included pre/intra/post compliance and total compliance, since pre/intra/post each contribute to overall total compliance to the pathway. While this is reflective of the reality of the cascading nature of compliance along

the perioperative course, and why ERAS is successful, the unexpected values make interpretation of the results less intuitive, though does not generally affect inferences made about the predictive power of these models.[22] Future studies should investigate the unexpected itemized compliance findings, such as oral carbohydrate loading predicting mortality in urology patients, and examine the influence of covariates this study was unable to assess. Finally, generalizability of the findings may not apply to all institutions that perform ERAS in the surgery areas studied.

This study shows that compliance to ERAS protocols impacts patient recovery and reports individual recommendations, by surgery type, to further contextualize and describe this relationship in a multi-institutional United States setting. Future studies should examine the role of multidisciplinary teamwork participation on compliance - and thus outcomes – as well as explore the impact of individual ERAS recommendations in more detail.

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CHAPTER 5: COMPLIANCE TO ERAS® RECOMMENDATIONS AND PERCEPTIONS OF BARRIERS: A MULTI-METHODS SURVEY ANALYSIS

Introduction

Gaining world-wide acceptance in the 1970's, clinical practice guidelines have become a widely adopted way of reducing variation and optimizing care using evidence-based recommendations.[1] Compliance to practice guidelines has been shown to show improvement in patient outcomes for a wide range of medical practice highlighting the need for consistent and robust uptake of their utilization.[2]

In surgery, singular or institution-specific guidelines exist however the ERAS® guidelines are a widely accepted set of evidence-based recommendations developed by the ERAS® Society, and organized by specific surgical procedures.[3,4] ERAS guidelines generally contain approximately 20 'core' recommendations, though each protocol necessarily has variations specific to the type of surgery performed. Examples of core recommendations include early mobilization, antibiotic prophylaxis, early oral nutrition, and avoidance of opioids. Higher compliance to the individual recommendations has been shown to improve surgical patient outcomes, with compliance to the entire protocol conferring the highest likelihood of a successful recovery for the surgical patient.[5–12]

However, barriers to compliance to all types of clinical guidelines have existed since the development of guidelines themselves. Understanding what these barriers are can aid in developing mitigation strategies to address them[13] with contextual development essential to their efficacy.[14] As such, it is important to organize the barriers themselves in a meaningful, environment-specific manner, here, within a clinical setting. Studies that focus on changing

behaviors in clinical settings have been summarized by Grimshaw and colleagues, who note that addressing physician-related barriers should target practical considerations while incorporating behavioral theory.[15] Given this, as well as building off of previous work evaluating barriers to compliance,[16] Cabana and colleagues developed a physician-centric framework of barriers using a mix of systematic review, surveys, and the knowledge-attitude-behavior health education model.[17] The authors also drew upon a previous systematic review focusing on adoption of guidelines,[18] offering a "diagnostic differential" approach which allows for the development of practical and targeted interventions at each potential adoption barrier point. Since its development in 1999, the Cabana theoretical framework has been cited over 7,600 times and provided researchers with a useful and practical structure to study physician-centric barriers. The framework has been re-visited since, with authors continuing to find evidence to support its ongoing utility.[13,19,20]

ERAS guidelines are multidisciplinary and require coordination and participation from different clinical roles throughout the perioperative course (preoperative, intraoperative, postoperative phases) to achieve overall compliance and best outcomes. These roles include nurses and APPs, anesthesiologists, surgeons, and other clinical professions such as nutrition, physical therapists, and data analysts. Previous studies have shown that multidisciplinary teamwork is key to ensuring successful ERAS implementation, and the robust collaboration predicts success ERAS programs.[21] However, members of the multidisciplinary team perceive barriers to the ERAS recommendations differently. Studies have found nurses thought surgeons didn't adopt ERAS guidelines due to resistance to change and lack of resources,[22,23] that the education of an entire perioperative team, while necessary for uptake, is itself a barrier, and lack of resources to carry out items such as patient mobilization and providing comprehensive patient

education.[22] Major barriers for APPs are reported to be difficulty keeping up with the guideline changes, their being too prescriptive, their being too cumbersome, and being too difficult to apply to practice.[24] Finally, surgeons report not believing a compliance item would benefit the patient, the guideline is only applicable to certain patients,[23] personal preference, lack of resources, and lack of agreement.[22]

To assess barriers to guidelines compliance using the Cabana framework, surveys and qualitative studies have been conducted among providers and multidisciplinary team members which allow for rich contextual data that may be difficult to gather with quantitative methods alone. Mixed methods studies organized around the Cabana barrier types like this exist in the overall medical[13] and intensive care nutrition literature,[25,26] though no studies to date have used this approach in surgery. Specific to ERAS, studies evaluating barriers to *implementation* of an overall ERAS program have been performed,[22,27–29] though these studies do not consider compliance to the individual ERAS® recommendations, and do not organize the barriers as proposed in the Cabana framework. Seow-En et al. surveyed multidisciplinary ERAS team members on perceived issues with compliance to individual guideline recommendations – as well as overall implementation of an ERAS program - though the results were not organized within the Cabana framework.[23] Given the standardized and well-supported nature of the Cabana framework and the differing views of the MDT members on reasons for barriers, it is important to better understand multidisciplinary barriers to compliance to specific ERAS® guideline recommendations organized by this framework.

The primary aim of this study is to quantitatively assess the relationship between the perception of primary barriers to individual ERAS recommendations and one's perceived ability to assure compliance to that recommendation among multidisciplinary role types who deliver

ERAS-based care via survey. Secondary aims are to assess if there is a relationship between a recommendation's frequency of being a part of one's role and ability to assure compliance, and if years of experience predicts assurance to compliance. Finally, this study will incorporate qualitative thematic analysis of participant's insights and experiences with barriers to ERAS compliance.

Methods

A survey was developed using the REDCap electronic data capture tool, a web-based software platform designed to support data capture for research studies, as well as providing extensive survey functionality.[30] Developing the questionnaire items began with a review of the literature for similar, validated surveys. While no surveys were published specific to this study, the work of Cahill et al. served as a model for assessing barriers to guidelines and perceptions specifically utilizing the barriers of the Cabana framework.[26]

Survey Items

Participant characteristics included were job role, number of years worked, and what surgical or professional specialty they spent at least half time or more. Three quantitative survey dimensions were created for each of the core ERAS® recommendations to ascertain:

Dimension 1 (Role). How much the participant felt the recommendation was a part of their self-identified role

Dimension 2 (Assurance). How much they felt they could assure compliance to the recommendation and

Dimension 3 (Barrier). The primary barrier to assuring compliance to that recommendation.

Dimension 1 was measured on a five-point Likert scale ranging from “Not at all” to “Always”, with a sixth option for “Not Applicable or Do not know”. Dimension 2 was a numerical, whole number scale, ranging from 0 (as Definitely Cannot) to 10 (as Definitely Can). Dimension 3 was a single selection drop-down menu of Cabana framework barriers (Table 28). The full survey is available in Appendix B.

Table 28. Drop-down Selection List of Barriers to an ERAS Recommendation	
1	Lack of familiarity
2	Lack of awareness
3	Lack of agreement with this specific recommendation
4	Lack of agreement with using guidelines in general
5	Lack of belief it will lead to the desired outcome
6	Lack of belief it can be done
7	Lack of motivation to change current practice to this recommendation
8	Lack of time to perform this recommendation
9	Lack of resources to perform this recommendation
10	Patient factors prevent this recommendation from being performed
11	There is contradictory evidence to this recommendation
12	Performing this recommendation could increase chances of medical liability

Qualitative data were collected from a large notes field located at the end of the survey inviting participants to provide any additional insights, and any experiential feedback on barriers to ERAS recommendations.

Development

Content and face validity was developed in collaboration with subject matter experts in ERAS® principles and barriers (experienced surgeon and APP), and with three researchers with academic expertise in health services, data science, and clinical practice research. Issues with

clarity and conciseness, and design considerations such as font sizing and coloring, were also addressed and refined. Rounds of user-experience and technical functioning testing for the web-based platform were performed with the same group.

Survey Administration

With permission of the ERAS® USA Research Committee and Executive Leadership, an email list of ERAS® USA members (past or present) was obtained and uploaded into the survey management feature of REDCap. Participant Identifier features were not enabled, to ensure survey responses could not be tied to the provided email addresses. An email was sent to each email address which included a contextual message, an invitation to participate, and a unique survey link to prevent duplicate attempts. Three rounds of surveys were sent approximately one month apart from July 2022 – September 2022. Bounce-back and other error email notifications were recorded and categorized.

Analysis

Internal consistency was assessed by dimensions, where "How much the participant felt the recommendation was a part of their self-identified role" = Role dimension, "How much they felt they could assure compliance to the recommendation" = Assurance dimension and "The primary barrier to assuring compliance to that particular recommendation" = Barrier dimension. Cronbach's alpha was performed for the Role and Barrier dimensions, and McDonald's omega was performed for the continuous Assurance dimension.[31]

Total number of potential participants is the number of valid email addresses received on the initial list-serv removing email addresses with a bounce-back or error messages. Response rate was calculated as number of participants who completed any amount of the survey divided by total potential participants. Qualitative completion rate was calculated as number of

participants who completed the qualitative component of the survey divided by number of survey participants.

Quantitative Analysis

Descriptive statistics were performed on all question items and stratified by participant characteristics variables. Missingness and non-response data were also reported.

Missing data patterns for the dependent variable (assurance score variables) was assessed and correlation matrix was generated against participant roles. Twenty datasets from missing data imputations based on chained bootstrap predictive mean matching with ten nearest neighbors were created and stratified by – or imputed within – participant role. Descriptive analysis was reported with non-imputed data, and comparative analyses were reported with imputed datasets.

To assess if variance existed between an ERAS recommendation being a part of a participant's role and their reported ability to assure compliance to that recommendation, one way ANOVA tests were performed. Tukey post-hoc tests were conducted to determine statistically significant differences between the Likert survey responses (Not at all – Always) groups and the compliance assurance scores.

To assess if the years of experience a participant had in their current role predicted their ability to assure compliance to an ERAS recommendation, bivariate multiple imputation linear regression models were performed. Small sample degrees of freedom (Student's t) adjustments and ordinary least squares (OLS) variance estimator was applied.[32] The Years of Experience variable was dichotomized to either > or ≤ to 10 years' experience, where >10 years of experience was the referent group. To assess the impact of each of the 12 primary barriers on

compliance assurance score, multiple imputation linear regressions were performed in a similar way as described above. Barriers were dummy coded, and all were included in an initial ERAS recommendation-specific model. Overall model significance was set at $p < .10$ level, and the significance for individual barrier predictor variables within the models was set at $p < .05$. Barrier predictor variables that were significant at a $p < .05$ level were retained to create a final model describing the impact of perceived barriers on ERAS recommendations. Data were analyzed using Stata statistical software (StataCorp Release 17; College Station, TX).

Qualitative Analysis

Qualitative text data were coded using the Cabana framework barriers and participant self-identified roles according to the methodology proposed by Braun and Clarke.[33] A mind map was then created to visualize and organize themes that emerged from the data. The coded text and mind map themes were synthesized and thematically described. Qualitative data were analyzed using CATMA 6, an open-source program developed for literary and text analysis.[34]

This study was approved as Expedited by the Wake Forest Institutional Review Board (IRB#00084525). Participant answers were confidential and could not be linked to identifiable information, and informed consent and study details verbiage were included.

Results

Of 268 potential participants, 59 (22.0%) completed the survey. Most participants were surgeons (35.6%) and nurses (30.5%) and had more than 10 years of experience in their self-identified role (63.8%). The highest reported specialties were anesthesia (15.8%) and colorectal (15.8), followed by general surgery (12.3%) and hepato-pancreatic biliary (12.3%)(Table 29).

Table 29. Survey Respondent Characteristics	
Role	n=59
APP	5 (8.5)
Allied Health	4 (6.8)
Anesthesiologist	9 (15.3)
Nurse	18 (30.5)
Nutritionist/Dietician	2 (3.4)
Surgeon	21 (35.6)
Years of Experience	n=58
Less than 1	1 (1.7)
1-5	12 (20.7)
6-10	8 (13.8)
11-20	10 (17.2)
20 or more	27 (46.6)
<= 10 years	21 (36.2)
> 10 years	37 (63.8)
What specialty do you spend at least half your time on or more?	n=57
Anesthesia	9 (15.8)
Bariatrics	1 (1.8)
Cardiac or Thoracic	1 (1.8)
Colorectal	9 (15.8)
Data Analysis or Research/Quality Improvement	1 (1.8
Emergency General Surgery	1 (1.8)
General Surgery	7 (12.3)
Head & Neck	1 (1.8)
Hepato-Pancreatic Biliary	7 (12.3)
Leadership or Administration	6 (10.5)
Neurosurgery	1 (1.8)
Nutrition	1 (1.8)
Obstetrics or Gynecology	4 (7.0)
Pediatrics	2 (3.5)
Urology	3 (5.3)
Vascular	1 (1.8)
Other	2 (3.5)
n (%)	

Internal Consistency

Dimensions were created (Role, Barrier, and Assurance) to assess survey scale reliability. As measured by Cronbach's alpha, the Role dimension demonstrated good

consistency (α=0.896) and the Barrier dimension demonstrated acceptable internal consistency (α=0.749). The continuous Assurance dimension demonstrated excellent consistency as measured by McDonald's omega (Ω=0.917).

Missing Data

Missingness of the dependent variable (assurance score variables) was assessed, with most missingness occurring in the goal directed therapy assurance score (18.6%) and short acting anesthetic assurance score (15.3%). Missing data pattern analysis showed 61% of the dataset as complete. A correlation matrix of missing data patterns for assurance score variables against participant roles revealed a correlation between roles with assurance scores.

Quantitative Survey Analysis

Dimension 1: How much participant's felt the recommendation was a part of their self-identified role

Table 30 highlights the percentage of participants who responded "Always" as a recommendation being a part of their role. Overall, surgeons appeared to report that recommendations were always a part of their role more often than other groups, particularly antibiotic prophylaxis (90.4%), and limiting drain use and nasogastric tubes (87.5% each). Surgeons reported the lowest "Always" responses for the use of short acting anesthetics (9.5%), euvolemia (19.0%), and regional anesthesia (28.6%); recommendations that anesthesiologists reported high levels of role participation. APPs also reported high levels of participation in the ERAS recommendations, with 100% of respondents reporting "Always" to prevention of nausea and vomiting, followed by antibiotic prophylaxis and non-opioid medication administration at 80% each. Nurses reported lower rates of recommendations always being a part of their role,

with the exception of delivering patient education (55.6%), and oral carbohydrate loading and data audit at 50% each.

Recommendations that had higher levels of participation across the multidisciplinary roles were antibiotic prophylaxis (60.3%) and prevention of nausea and vomiting (55.9%). Other recommendations that reported higher rates of multidisciplinary participation were non-opioid pain management, data audit, and delivery of patient education.

Table 30. "…recommendation is a part of my role" Frequency of "**Always**", by Multidisciplinary Role

Recommendation	APP	Allied Health	Anesthesia	Nurse	Nutrition	Surgeon	Overall
Patient Education	2/5 40.0%	0/4	0/9	10/18 55.6%	0/2	14/20 70.0%	26/58 44.8%
Oral Carbohydrate Loading	1/5 20.0%	0/4	1/9 11.1%	9/18 50.0%	0/2	8/21 38.1%	19/59 32.2%
No Prolonged Fasting	2/5 40.0%	0/4	3/9 33.3%	8/17 47.1%	0/2	10/21 47.6%	23/58 39.7%
No or Selective Bowel Prep	2/5 40.0%	0/4	0/9	3/17 17.6%	0/2	14/21 66.7%	19/58 32.8%
Antibiotic Prophylaxis	4/5 80.0%	0/4	7/9 77.8%	5/17 29.4%	0/2	19/21 90.4%	35/58 60.3%
Thromboprophylaxis	3/5 60.0%	0/4	1/9 11.1%	7/17 41.2%	0/2	15/20 75.0%	26/57 45.6%
Use of Short Acting Anesthetics	2/5 40.0%	0/4	6/8 75.0%	2/18 11.1%	0/2	2/21 9.5%	12/58 20.7%
Limited or No Use of Drains	1/5 20.0%	0/4	0/9	1/18 5.6%	0/2	18/21 85.7%	20/59 33.9%
Euvolemia	3/5 60.0%	0/4	7/9 77.8%	1/17 5.9%	0/2	4/21 19.0%	15/58 25.9%
Normothermia	3/5 60.0%	0/4	7/8 87.5%	7/18 38.9%	0/2	6/20 30.0%	23/57 40.4%
Regional Anesthesia/Analgesia	0/5 0%	1/4 25.0%	4/9 44.4%	3/17 17.6%	0/2	6/21 28.6%	14/58 24.1%
Limited or No Nasogastric Tubes	2/5 40.0%	0/4	0/8	1/18 5.6%	0/2	18/21 85.7%	21/58 36.2%
Prevention of Nausea / Vomiting	5/5 100.0%	0/4	8/9 88.9%	8/18 44.4%	0/2	12/21 57.1%	33/59 55.9%
Postoperative Goal Directed Fluids	3/5 60.0%	0/4	0/8	4/17 23.5%	0/2	13/20 65.0%	20/56 35.7%
Early Removal / Avoidance of Foley Catheter	2/5 40.0%	0/4	0/8	6/18 33.3%	0/2	17/21 80.9%	25/58 43.1%

Early Oral Nutrition / Early Feeding	2/5 40.0%	0/4	0/9	4/18 22.2%	0/2	16/21 76.2%	22/59 37.3%
Non-Opioid Pain Medication	4/5 80.0%	1/4 25.0%	2/8 25.0%	5/18 27.8%	0/2	16/21 76.2%	28/58 48.3%
Data Audit/Collecting Compliance and Outcomes Data	2/5 40.0%	4/4 100.0%	0/9	9/18 50.0%	0/2	12/21 57.1%	27/59 45.8%
Data reported as numerator and denominator of responses, and percentage							

Dimension 2: How much participant's felt they could assure compliance to the recommendation

Both APPs and surgeons reported high averages of compliance assurance, with each reporting an average assurance score of eight or more in seven ERAS recommendation categories (Table 31). APPs reported the highest levels of compliance assurance in antibiotic prophylaxis (μ=9.5), and postoperative euvolemia and early oral nutrition (μ=9.4 each). Surgeons reported highest levels of compliance assurance in the limited use of nasogastric tubes and non-opioid medication (μ=9.1), and limited use of drains and early oral nutrition (μ=8.9). APPs and surgeons overlapped in high levels of compliance assurance for non-opioid pain medication, early oral nutrition, antibiotic prophylaxis, early foley catheter removal, and thromboprophylaxis. Anesthesiologists felt they could assure compliance to antibiotic prophylaxis (μ=9.7), and prevention of nausea and vomiting (μ=9.6), followed by anesthesia-related recommendations of use of short acting anesthetics and regional anesthesia. Excepting allied health and nutritionists, nurses reported the fewest recommendations to which they felt they had high levels of compliance assurance. Data audit was the highest average compliance assurance among this group (μ=8.2), followed by prevention of nausea and vomiting (μ=8.0).

The lowest average compliance assurance in APPs was reported in the use of short acting anesthetics. Among anesthesiologists, the lowest averages were found in no or selective bowel prep (μ=1.5), followed by early removal of foley catheter and limited use of drains. Nurses only reported very low levels of compliance assurance in one category, limited use of nasogastric tubes, and surgeons reported no low levels of compliance assurance in any category.

Table 31. "I can assure compliance to…" Average Scores by Multidisciplinary Role

Recommendation	**APP** N=5	**Allied Health** N=4	**Anesthesia** N=9	**Nurse** N=18	**Nutrition** N=2	**Surgeon** N=21	**Overall** N=59
Patient Education	7.4 (4.2)	3.3 (3.9)	4.4 (2.9)	7.8 (2.0)	6 (0)	5.8 (3.6)	6.1 (3.3)
Oral Carbohydrate Loading	5.8 (3.3)	5.5 (3.8)	4.6 (3.0)	7 (2.5)	6 (0)	4.7 (3.8)	5.6 (3.3)
No Prolonged Fasting	6 (3.9)	5 (3.5)	6.4 (2.9)	7.1 (2.8)	3 (4.2)	5.5 (3.7)	6.0 (3.3)
No or Selective Bowel Prep	6.4 (4.3)	3.5 (4.1)	1.5 (2.8)	7.5 (3.3)	1.5 (2.1)	6.5 (3.7)	5.6 (4.0)
Antibiotic Prophylaxis	9.5 (1)	6.25 (4.5)	9.7 (0.7)	6.9 (4.1)	0 (0)	8.5 (2.9)	7.8 (3.5)
Thromboprophylaxis	8 (2.7)	2.5 (4.4)	6.2 (3.1)	7.3 (4.1)	0 (0)	8.3 (2.4)	6.9 (3.7)
Use of Short Acting Anesthetics	3.8 (5.2)	4.5 (4.7)	8.8 (1.8)	5.6 (3.6)	0 (0)	4.8 (3.9)	5.4 (4.0)
Limited or No Use of Drains	5.2 (4.1)	2.25 (3.9)	2.3 (3.9)	4.5 (4.4)	0 (0)	8.9 (1.7)	5.5 (4.3)
Euvolemia	6.8 (3.9)	4.3 (4.9)	7.8 (2.6)	4.4 (3.6)	0 (0)	5.7 (3.1)	5.5 (3.6)
Normothermia	5.4 (5.0)	4 (4.7)	8.3 (3.5)	5.6 (3.5)	0 (0)	5 (3.6)	5.5 (3.9)
Regional Anesthesia/Analgesia	5.4 (5.0)	4.8 (4.4)	8.7 (1.2)	5.1 (4.2)	0 (0)	5.9 (3.5)	5.8 (3.9)
Limited or No Nasogastric Tubes	4.4 (3.4)	6 (4.2)	6.5 (2.3)	4 (4.1)	1 (1.4)	9.1 (1.9)	6.3 (3.8)
Prevention of Nausea / Vomiting	9 (2.2)	6.5 (4.4)	9.6 (0.5)	8 (3.5)	2 (.)	7.3 (2.9)	7.9 (3.0)
Postoperative Goal Directed Fluids	9.4 (0.9)	2.3 (3.9)	5.5 (3.0)	5.5 (4.5)	0 (0)	7.1 (3.0)	6.0 (3.8)
Early Removal / Avoidance of Foley Catheter	8.4 (2.1)	6 (4.2)	4.1 (3.6)	7.5 (3.7)	0 (0)	8.5 (2.5)	7.2 (3.6)

Early Oral Nutrition / Early Feeding	9.4 (0.5)	4.8 (3.4)	4.8 (2.9)	6.6 (3.8)	7 (.)	8.9 (1.0)	7.4 (3.0)
Non-Opioid Pain Medication	8.6 (2.1)	6 (4.1)	6.7 (3.1)	6.6 (3.7)	0 (0)	9.1 (1.1)	7.4 (3.2)
Data Audit/Collecting Compliance and Outcomes Data	7.5 (4.4)	8 (2.7)	4.8 (3.5)	8.2 (2.5)	7 (.)	6 (3.8)	6.78 (3.5)
Data reported as mean (SD)							

Dimension 3: The primary barrier to assuring compliance to that recommendation

Of the 12 barriers provided in the survey, the most common reported barriers were patient factors preventing the recommendation from being performed (18.5%), and lack of agreement with this specific recommendation (13.6%). Table 32 reports the two most cited barriers by each ERAS recommendation. For the delivery of patient education, 32.1% cited lack of resources as the primary barrier. For limited use of drains, 33.3% cited lack of agreement with the specific recommendation, and limited use of nasogastric tubes had similar results (31.3%). Participants cited patient factors as the primary barrier to early removal of foley catheter (43.4%), which was a similar finding for early oral nutrition (37.0%) and non-opioid pain medication (30.4%). Finally, the highest reported barrier was found for the data audit recommendation, where 70.0% of survey respondents cited lack of resources as the primary barrier.

Within these specific ERAS recommendations with higher overall levels of agreement on its primary barrier, there was some variation when stratifying by role. While patient education, limited use of drains, and data audit had strong agreement across all the roles for its reported primary barrier, when examining the nasogastric tube recommendation most surgeons reported that patient factors were the primary barrier (31.6%); a divergence from the overall barrier

reported as lack of agreement with the specific recommendation. Similarly, most roles reported patient factors as the primary barrier to early removal of foley catheter, though anesthesiologists reported lack of agreement with the specific recommendation as the top barrier for this particular recommendation (37.5%).

Table 32. "What is the most common barrier to achieving this recommendation" Frequencies by Top Two Reported Barriers

	Overall
Patient Education	n=56
Lack of resources to perform this recommendation	18 (32.1)
Lack of time to perform this recommendation	14 (25.0)
Oral Carbohydrate Loading	n=58
Patient factors prevent this recommendation from being performed	16 (27.6)
Lack of resources to perform this recommendation	12 (20.7)
No Prolonged Fasting	n=53
Patient factors prevent this recommendation from being performed	9 (17.0)
Lack of awareness	8 (15.1)
No or Selective Bowel Prep	n=52
Lack of belief it will lead to desired outcome	10 (19.2)
There is contradictory evidence to this recommendation	10 (19.2)
Lack of agreement with this specific recommendation	9 (17.3)
Antibiotic Prophylaxis	n=44
Patient factors prevent this recommendation from being performed	9 (20.5)
Lack of motivation to change current practice to this recommendation	7 (15.9)
Thromboprophylaxis	n=44
Lack of agreement with this specific recommendation	9 (20.5)
Patient factors prevent this recommendation from being performed	9 (20.5)
Lack of awareness	7 (15.9)
Use of Short Acting Anesthetics	n=50
Lack of agreement with this specific recommendation	13 (26.0)
Lack of motivation to change current practice to this recommendation	8 (16.0)
Limited or No Use of Drains	n=45
Lack of agreement with this specific recommendation	15 (33.3)
Lack of belief it will lead to desired outcome	5 (11.1)
Lack of motivation to change current practice to this recommendation	5 (11.1)
There is contradictory evidence to this recommendation	5 (11.1)
Euvolemia	n=48
Lack of motivation to change current practice to this recommendation	14 (29.2)
Lack of agreement with this specific recommendation	11 (22.9)

Normothermia	n=45
Lack of motivation to change current practice to this recommendation	14 (31.1)
Lack of awareness	9 (20.0)
Regional Anesthesia/Analgesia	n=49
Lack of agreement with this specific recommendation	8 (16.3)
Lack of belief it will lead to desired outcome	8 (16.3)
Patient factors prevent this recommendation from being performed	8 (16.3)
Limited or No Nasogastric Tubes	n=48
Lack of agreement with this specific recommendation	15 (31.3)
Patient factors prevent this recommendation from being performed	10 (20.8)
Prevention of Nausea / Vomiting	n=47
Lack of awareness	12 (25.5)
Lack of motivation to change current practice to this recommendation	9 (19.2)
Postoperative Goal Directed Fluids	n=51
Lack of awareness	10 (19.6)
Lack of motivation to change current practice to this recommendation	9 (17.7)
Early Removal / Avoidance of Foley Catheter	n=53
Patient factors prevent this recommendation from being performed	23 (43.4)
Lack of agreement with this specific recommendation	8 (15.1)
Early Oral Nutrition / Early Feeding	n=54
Patient factors prevent this recommendation from being performed	20 (37.0)
Lack of agreement with this specific recommendation	9 (16.7)
Non-Opioid Pain Medication	n=56
Patient factors prevent this recommendation from being performed	17 (30.4)
Lack of motivation to change current practice to this recommendation	10 (17.9)
Data Audit/Collecting Compliance and Outcomes Data	n=50
Lack of resources to perform this recommendation	35 (70.0)
Lack of time to perform this recommendation	7 (14.0)

Associations to Compliance Assurance

To assess if there was a relationship between an ERAS recommendation being a part of the survey respondent's role and their compliance assurance score with that recommendation, ANOVA tests were performed using both the original and imputed datasets. Results show that in all ERAS recommendations there was significant variance in average compliance assurance score across the Likert responses (Not at all – Always), holding true in both original and imputed

datasets (Table 33). Individual Tukey post-hoc tests show the mean difference in compliance assurance score between those who reported the recommendation was "Not at all" a part of their role and those who reported it was "Always" a part of their role was significantly different in all recommendations at the p <.000 level.

Table 33. Differences Between Compliance Assurance Score by "…recommendation is a part of my role" Responses

	Non-imputed ANOVA	Imputed ANOVA
Patient Education	11.9 (4, 50) <.000	205.5 (5) <.000
Oral Carbohydrate Loading	7.9 (5, 51) <.000	176.0 (5) <.000
No Prolonged Fasting	15.8 (5, 51) <.000	301.4 (5) <.000
No or Selective Bowel Prep	15.7 (5, 48) <.000	303.8 (5) <.000
Antibiotic Prophylaxis	30.2 (5, 50) * <.000	445.7 (5) <.000
Thromboprophylaxis	34.3 (4, 48) * <.000	473.6 (5) <.000
Use of Short Acting Anesthetics	8.9 (5, 43) <.000	152.5 (5) <.000
Limited or No Use of Drains	21.9 (5, 45) <.000	317.5 (5) <.000
Euvolemia	21.2 (4, 42) <.000	202.0 (5) <.000
Normothermia	14.2 (5, 43) <.000	190.1 (5) <.000
Regional Anesthesia/Analgesia	10.8 (5, 46) <.000	162.3 (5) <.000
Limited or No Nasogastric Tubes	10.5 (5, 47) <.000	228.6 (5) <.000
Prevention of Nausea / Vomiting	14.8 (5, 48) <.000	207.7 (5) <.000
Postoperative Goal Directed Fluids	17.3 (5, 46) <.000	323.1 (5) <.000
Early Removal / Avoidance of Foley Catheter	42.8 (5, 49) * <.000	434.1 (5) <.000
Early Oral Nutrition / Early Feeding	16.3 (5, 46) <.000	216.4 (5) <.000
Non-Opioid Pain Medication	26.9 (5, 49) * <.000	432.2 (5) <.000
Data Audit/Collecting Compliance and Outcomes Data	7.5 (5, 47) <.000	142.2 (5) <.000

Analysis of variance (ANOVA)
Values reported as F(df), p-value
* indicates the model (Adjusted R^2) explains >70% of the variance observed

Multiple imputation bivariate linear regressions were performed to assess if years of experience predicted a respondent's compliance assurance score, where each ERAS recommendation was its own bivariate model. No models were statistically significant, i.e. having ≤10 years of experience did not predict the ability of respondents to assure compliance to any ERAS recommendation.

To assess the impact of the primary barriers to compliance assurance for each ERAS recommendation, individual multiple imputation linear regression models were created. Of the 18 ERAS recommendation-specific models developed with all 12 barriers included as predictor variables, three models had an overall p-value of <.10. These were oral carbohydrate loading (p=.067), thromboprophylaxis (p=.011), and post-operative euvolemia (p=.008). Retained predictor variables for the oral carbohydrate loading model were lack of familiarity and lack of motivation to change current practice to this recommendation. Retained predictor variables for thromboprophylaxis were lack of agreement with this specific recommendation, lack of belief it can be done, lack of resources, and patient factors. Finally, the retained variables for post-operative euvolemia were lack of awareness, lack of agreement with this specific recommendation, lack of agreement with using guidelines in general, lack of time to perform this recommendation, and lack of resources. Final model results with retained barrier variables are in Tables 34-36. For oral carbohydrate loading, the lack of familiarity barrier predicted a 6.1 decrease in ability to assure compliance to that recommendation, and lack of motivation predicted a 3.1 decrease in compliance assurance. The other final models (Thromboprophylaxis

and Post-operative euvolemia) barrier variables all predicted an *increase* in compliance assurance score, a somewhat unexpected result.

Table 34. Oral Carbohydrate Loading and Significant Barriers, Retained Barriers Only		
Overall Model	F (2, 53.1) = 6.8	p=.002
Barrier	Coefficient (SE)	p-value
Lack of familiarity	-6.1 (2.1)	.005
Lack of motivation to change current practice to this recommendation	-3.1 (1.3)	.017
Multiple imputation linear regression with small sample adjustment 20 imputations		

Table 35. Thromboprophylaxis and Significant Barriers, Retained Barriers Only		
Overall Model	F (4, 37.1) = 3.0	p=.031
Barrier	Coefficient (SE)	p-value
Lack of agreement with this specific recommendation	3.2 (1.3)	.022
Lack of belief it can be done	4.0 (3.4)	.242
Lack of resources to perform this recommendation	3.8 (1.8)	.043
Patient factors prevent this recommendation from being performed	3.5 (1.3)	.012
Multiple imputation linear regression with small sample adjustment 20 imputations		

Table 36. Post-operative Euvolemia and Significant Barriers, Retained Barriers Only		
Overall Model	F (5, 43.1) = 3.5	p=.009
Barrier	Coefficient (SE)	p-value
Lack of awareness	1.4 (1.3)	.039
Lack of agreement with this specific recommendation	5.2 (2.1)	.003
Lack of agreement with using guidelines in general	5.2 (2.1)	.003
Lack of time to perform this recommendation	2.6 (1.5)	.017
Lack of resources to perform this recommendation	4.5 (1.5)	.001
Multiple imputation linear regression with small sample adjustment 20 imputations		

Qualitative Survey Analysis

Text Analysis: Barriers

Text data from the large free-text notes section of the survey were collected and coded for Cabana barrier themes, and other contextual information as relevant. Of the 59 survey respondents, 24 (40.7%) provided free text qualitative feedback. Of these, nine (37.5%) were

nurses, seven (29.2%) were surgeons, three (12.5%) anesthesiologists, three (12.5%) members of allied health professionals, and two (8.3%) APPs. Most reported having over ten years of experience in their current role (58.3%).

Lack of agreement with specific recommendations was the most commonly cited barrier. Respondents mostly cited specific recommendations that other professional colleagues, in their opinion, do not perform. Nurses cited surgeons and anesthesiologists as being non-compliant with certain recommendations which, while mostly as an agreement issue, also was described in close relationship with lack of motivation to change previous practices. It was thought that a surgeon's agreement, or not, with ERAS recommendations drove compliance. A nurse said: "*Overall, the physicians "pick and choose" the recommendations they follow."* An anesthesiologist expressed a similar sentiment: "*Surgeons dictate the pathway so unless there is agreement it is hard to go against the surgeon*."

Surgeons also cited lack of agreement from their colleagues, though did not mention nurses or APPs as a source of this barrier. One also cited lack of agreement as a barrier from their system or institution; noting the organization for which they worked did not agree with the specific bowel prep avoidance recommendation.

Overcoming the inertia of previous practice – or the lack of motivation to change previous practice – was also a noted barrier. All roles cited prolonged fasting, mentioned three times, and the use of opioid pain medications, mentioned four times, as being recommendation-specific issues. Those that specifically cited these recommendations also tied in how patients have expectations surrounding these that are not aligned with ERAS recommendations. One nurse wrote, "*Surgeon's offices are still slow to break away from the culture of prolonged fasting…*" going on to say, "*Educating the patients to think outside of decades of NPO culture is*

a tough thing to break…" One surgeon expressed a similar sentiment saying, *"…patients have accepted surgical dogma as much as surgeons have*." They went on to suggest patient education not only as a barrier itself, but a solution to this issue.

Finally, many respondents cited a lack of resources as being a barrier to many of the ERAS recommendations. Resources related to healthcare staffing were described, as well as recommendation-specific items such as nutritional supplementation and oral carbohydrate beverages. The idea that lack of overall resources drives non-compliance and lack of buy-in was repeated by several respondents. A nurse noted, *"…but they (providers) don't want to take the time to implement all of them (ERAS protocols) because of the lack of resources*." A surgeon expressed a similar idea saying, "*Lack of time and resources are also HUGE…have a negative effect on getting surgeons and others to accept and implement ERAS principles*." Another nurse respondent summarized these frustrations:

"I feel like I'm set up to fail because there are no resources to truly make a meaningful difference. We need to do the right thing, at the right time, for the right reason. That's the whole point of the ERAS pathway."

Text Analysis: Other Themes

In addition to those derived from the Cabana barriers, other themes emerged from the survey responses which included the impact of multidisciplinary teamwork on the success of ERAS. All role types stressed the importance of multidisciplinary teamwork and coordination, to include how it impacts the start of implementation, "*The key is to solicit participation from other specialties to change culture as you move to an ERAS protocol* (Surgeon)" and characteristics of the team, "*You have so many people involved in the success of a program and without a set*

strong team that clearly communicates, it can be a barrier not a help (APP)." The respondents' overall sentiments seemed to indicate that the multidisciplinary nature of a successful ERAS program was both a strength and a challenge; as summed up by one APP: "*The thing that makes ERAS so amazing is that it's multidisciplinary. That also makes the barriers*." While multidisciplinary teamwork as a whole was mentioned often, nurses and APPs were specifically mentioned as main drivers of success; termed the "boots on the ground".

Finally, the role of data audit and informatics was discussed by several respondents. The act of data audit, and its role in providing programmatic feedback and setting expectations was noted by an Allied Health professional: "*The evidence alone wasn't enough to change practice…the lack of making ERAS expectations (a) part of physician and RN onboarding/job descriptions with high turnover, the auditing must be continuous*." As well, EMR-based tools such as order sets, consistent documentation, and data visualization platforms were suggested as drivers of improved compliance.

Mind Map

Given the inter-relatedness of the themes, a thematic mind map was developed to better understand and visualize themes' relationships to ERAS barriers (Figure 10). Generally organized by Cabana barriers, the other themes of the importance of multidisciplinary teamwork and informatics were prominent. Implications from these themes proved practical, for example increased and continuous staffing education and utilizing EMR-based tools were suggested to mitigate ERAS barriers.

Figure 10. Mapped Depiction of Themes (Mind Map) from Free-text Responses

Discussion

This study aimed to understand the relationship between ability to assure compliance to ERAS recommendations and their barriers as described by ERAS professionals and clinicians using a mixed-methods approach. For oral carbohydrate loading, lack of familiarity and lack of motivation to change previous practice were predictors of a participant's decreased feelings of compliance assurance. The thromboprophylaxis and post-operative euvolemia models retained significant barriers such as lack of agreement and lack of resources, though these interestingly predicted increased feelings of compliance assurance among survey respondents. Text analysis revealed rich themes related to barriers including lack of motivation to change previous practice and lack of agreement with specific recommendations. Further themes emerged from the qualitative synthesis including the impact of coordination and education within multidisciplinary teams, and the role of data audit and informatics on improving compliance and sustaining ERAS practice.

Previous studies have described multidisciplinary perceptions to barriers within an ERAS context. Studies have found nurses thought surgeons didn't adopt ERAS guidelines due to resistance to change and lack of resources,[22,23] which agrees with sentiments from nurses revealed in this study. In that same study, nurses stressed that the importance of education of the entire multidisciplinary team, while necessary for uptake, is itself a barrier.[22] Key findings from two ERAS qualitative studies also found education of staff was the primary facilitator to success.[29,35] The present study's findings are concordant to this, and this theme was mentioned often by different role types. The role of multidisciplinary teamwork was shown in quantitative results from the survey as well, where high levels of "Always" responses were seen across many of the ERAS recommendations, specifically PONV and antibiotic prophylaxis. PONV was

specifically mentioned by a nurse in the qualitative text as being dependent on other providers to ensure compliance, an important finding as studies show PONV is predictive of improved patient outcomes.[11]

This study also shows that surgeons feel they are responsible for most of the ERAS recommendations, reporting consistently high levels of recommendations "Always" being a part of their role, and high levels of compliance assurance. Themes emerged from the qualitative text that support this finding, both from nurses and anesthesiologists, and from surgeons themselves, though one surgeon expressed an opposite sentiment from the others asserting that medical doctors are not drivers of compliance, instead it is the boots-on-the-ground providers such as nurses and APPs. This sentiment is supported by the results of APPs stating they are "Always" involved in many of the ERAS recommendations, though conflicts with nurses' lower overall reporting of the recommendations "Always" being a part of their role. This finding, and others that point to designation of role responsibilities and external factors such as resources, may be at least partially explained by perceptions of attribution as originally described by Kelley[36] and later in clinicians by Borkowski and Allen.[37]

Similar studies have found external barriers to be the primary barrier to guideline compliance,[38–40] and ERAS-specific studies have also found lack of resources and time as primary barriers.[29,35,41] This present study found that the overall primary barriers to ERAS recommendations were patient factors and lack of agreement with that specific recommendation however, when stratifying by specific ERAS recommendations, patient education, oral carbohydrate loading, and data audit were primarily impacted by lack of resources, an external barrier type. This quantitative finding was supported in the thematic analysis, particularly data audit and oral carbohydrate loading being specifically mentioned three and seven times

respectively. These two recommendations, most impacted by external barriers such as lack of time and resources, are important to the success of both an individual patient's recovery and to the overall success of an ERAS program. Oral carbohydrate loading is a simple and effective strategy to mitigate the cascading effects of surgical stress which accumulate over the perioperative course,[42,43] yet lack of resources was cited as a primary barrier, and in thematic analysis nurses reported difficulty with obtaining these products. Data audit and feedback also contributes substantially to a successful ERAS program. Generally, data audit and feedback are designed to change clinical practice by comparing providers to benchmarks which can include performance from their colleagues or set targets for certain metrics, usually within a framework of clinical practice guidelines. In quality improvement, it is not only well documented that audit improves professional practice,[44] the body of evidence of its efficacy has reached a saturation limit.[45] It is, however, one of the most resource intensive recommendations in the ERAS protocol, requiring time, personnel, and equipment that does not otherwise go directly to the delivery of patient care.

One major limitation to this study is the inherent issues with survey-based results which include survey design issues such as respondent bias, and a low response rate; decreasing generalizability of the results, though the survey results appear to be concordant with findings from similar studies. Others have reported internet-based surveys of healthcare providers with only slightly higher response rates in pre-pandemic settings,[46] and future studies should consider the impact of post-COVID provider burden on ability or willingness to participate in surveys.[47] Next, this study received limited data from dieticians, an issue noted by others when undertaking evaluations of multidisciplinary perceptions to barriers in ERAS.[21,48] The perceptions of barriers from allied health personnel, such as dieticians, pharmacy, and physiology should be evaluated

in future research. Finally, in two out of three models, barriers were shown to predict increased feelings of compliance assurance. This may be related to something intrinsic about the nature of the question, how the respondent chose to answer the question, or about the respondent themselves. Future directions for this would consider adjusting the models for multidisciplinary role type to assess if the effects were due to something inherent about how the individual role types responded, or potentially drawing on insights from behavioral or psychological fields of study.

Conclusions

Using a standardized and practical framework, such as that described by Cabana et al., for reporting barriers to individual ERAS recommendations may help develop ways to mitigate those barriers, especially in a multidisciplinary context, as well as advance generalizability of barriers to other clinical guideline types. By integrating quantitative and qualitative survey analysis from ERAS professionals, a rich analysis stratified for each ERAS recommendation was performed and revealed key insights into professional's perceptions of barriers and ability to maintain compliance to core ERAS recommendations.

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APPENDIX B

ERAS® Barriers to Guidelines

Your experience is valued!Barriers to adopting ERAS recommendations have existed for as long as the recommendations themselves. We hope you take this survey to help better understand these barriers and optimize guideline implementation. The survey will take approximately 10-15 minutes to complete depending on how much you would like to share.

By completing the survey, you are consenting for your responses to be used as part of a study being conducted with permission from the Research Committee of the USA Chapter of the ERAS® Society, by Allyson Cochran, MSPH a UNC Charlotte Health Services Research Doctoral Candidate. Your responses are confidential and not identifiable.

You will receive no direct benefits from participating in this research study. However, your responses will help us learn more about the multidisciplinary contributions to ERAS® recommendations. There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life.

Your survey answers will be stored initially in the REDCap survey system, and later downloaded and stored on secure servers. Your answers can not be tied to you as an individual, and you may skip any question you do not wish to answer for any reason.

Thank you for your participation!

For additional information, you may contact either the Principal Investigator at Allyson.cochran@atriumhealth.org or responsible faculty person Dr. Andrew Harver arharver@uncc.edu

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What is your role?

- ◯ Allied Health (Data Analyst, Administrator, Coordinator)
- ◯ Advanced Practice Provider (Nurse Practitioner or Physician Assistant)
- ◯ Anesthesiologist
- ◯ Nurse
- ◯ Nurse Anesthetist
- ◯ Nutritionist / Dietician
- ◯ Surgeon
- ◯ Other

Other role:

_____

How many years of experience do you have in this role?

- ◯ Less than one year
- ◯ 1-5 years
- ◯ 6-10 years
- ◯ 11-20 years
- ◯ More than 20 years
- ◯ I don't know

What specialty do you spend at least half your time on or more?

- ◯ Anesthesia
- ◯ Bariatrics
- ◯ Cardiac or Thoracic
- ◯ Colorectal
- ◯ Data Analysis or Research/QI
- ◯ EGS
- ◯ General Surgery
- ◯ Head and Neck
- ◯ Hepato-Pancreatic Biliary
- ◯ Leadership or Administration
- ◯ Neurosurgery
- ◯ Nutrition and Dietetics
- ◯ Obstetrics or Gynecology
- ◯ Orthopedics
- ◯ Pediatrics
- ◯ Pharmacology
- ◯ Plastics or Breast
- ◯ Spine
- ◯ Upper GI
- ◯ Urology
- ◯ Vascular
- ◯ Other

Other specialty: _____

For the questions about assuring compliance to recommendations, use the slider to indicate your ability to assure compliance where: 0 is "I definitely CANNOT assure compliance to this recommendation" 10 is "I definitely CAN assure compliance to this recommendation" You will have the opportunity to provide free text response / feedback at the end of the survey so you can expand on any additional views or insights you may have about barriers to the ERAS guidelines

Preoperative Phase

Patient Education is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Patient Education recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Patient Education recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Oral Carbohydrate Loading is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Oral Carbohydrate Loading recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Oral Carbohydrate Loading recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

No Prolonged Fasting is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the No Prolonged Fasting recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the No Prolonged Fasting recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

No or Selective Bowel Prep is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the No or Selective Bowel Prep recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the No or Selective Bowel Prep recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Antibiotic Prophylaxis is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Antibiotic Prophylaxis recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Antibiotic Prophylaxis recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Thromboprophylaxis is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Thromboprophylaxis recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Thromboprophylaxis recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Use of Short Acting Anesthetics is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Use of Short Acting Anesthetics recommendation

0 Definitely CANNOT 5 10 Definitely CAN

In your opinion, what is the primary barrier for successful compliance to the Use of Short Acting Anesthetics recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Intraoperative Phase

Limited or No Use of Drains is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Limited or No Use of Drains recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Limited or No Use of Drains recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Euvolemia is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Intraoperative Goal Directed Fluids / Euvolemia recommendation

0 Definitely CANNOT 5 10 Definitely CAN

In your opinion, what is the primary barrier for successful compliance to the Euvolemia recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Normothermia is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Normothermia recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Normothermia recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Regional Anesthesia/Analgesia is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Regional Anesthesia/Analgesia recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Regional Anesthesia/Analgesia recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Limited or No Nasogastric Tubes is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Limited or No Nasogastric Tubes recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Limited or No NG Tubes recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Postoperative Phase

Prevention of Nausea / Vomiting is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Prevention of Nausea / Vomiting recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Prevention of N/V recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Postoperative Goal Directed Fluids is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Postoperative Goal Directed Fluids / Euvolemia recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Postoperative Euvolemia recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Early Removal / Avoidance of Foley Catheter is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Early Removal / Avoidance of Foley Catheter recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Early Removal/Avoidance of Foley recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Early Oral Nutrition / Early Feeding is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Early Oral Nutrition / Early Feeding recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Early Oral Nutrition recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Non-Opioid Pain Medication is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Non-Opioid Pain Medication recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Non-Opioid Pain Medication recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

Data Audit/Collecting Compliance and Outcomes Data is a part of my role

- ◯ Not at all
- ◯ Rarely
- ◯ Occasionally / Sometimes
- ◯ Most of the time
- ◯ Always
- ◯ Not applicable or Do not know

I can assure compliance to the Data Audit/Collecting Compliance and Outcomes Data recommendation

0 Definitely CANNOT 5 10 Definitely CAN

(Place a mark on the scale above)

In your opinion, what is the primary barrier for successful compliance to the Data Audit recommendation?

- ◯ Lack of familiarity
- ◯ Lack of awareness
- ◯ Lack of agreement with this specific recommendation
- ◯ Lack of agreement with using guidelines in general
- ◯ Lack of belief it will lead to the desired outcome
- ◯ Lack of belief it can be done
- ◯ Lack of motivation to change current practice to this recommendation
- ◯ Lack of time to perform this recommendation
- ◯ Lack of resources to perform this recommendation
- ◯ Patient factors prevent this recommendation from being performed
- ◯ There is contradictory evidence to this recommendation
- ◯ Performing this recommendation could increase chances of medical liability

In the space below, we invite you to provide additional views and feedback about barriers to ERAS recommendations! Please share any input, observations, and suggestions which we will then develop into a comprehensive thematic analysis of day-to-day experiences

CHAPTER 6: CONCLUSION

Discussion of Results

Surgery is experiencing the "dawn of precision delivery"[55] by using the large quantities of healthcare data, expertise, and innovation to optimize and predict the surgical patient's outcomes. However, optimization best occurs when standardized, such as within surgical care guidelines such as ERAS®, and this dissertation shows that integration of these both high- and low-tech methods can develop insights that are practical and tangible.

Predicting Outcomes with Compliance

Chapter Two utilized data from the same ERAS data registry as Chapter Four, both describing the specific evidence-based recommendations that, if not performed, would predict adverse outcomes for the surgical patient. However, they differ as Chapter Two describes not only the effect of compliance – nor not – on an outcome such as LOS, but also expands the concept to applications for real-time changes in individual patient care that can prevent that outcome before it happens. By integrating this concept of the cascading effects of compliance to each ERAS® recommendation into technologies such as EMRs and decision support systems, providers can effectively change the future of each surgical patient.

The findings in Chapter Four have similar implications, though are conceptually different. The aim of Chapter Four was to identify specific ERAS® recommendations that most impact patient care, and while similar studies have been performed previously, had not been done in a United States, multi-institutional basis using surgical procedures not commonly reported in the literature. So while Chapter Two utilized similar data and methodologies to describe a conceptual approach to prediction modelling, Chapter Four both supplements these

findings and extends them to other specialties. Both studies found overlap in recommendations that if not performed, predicted longer LOS; where in pancreas procedures, compliance to oral carbohydrate loading, early removal of the foley catheter, and limited use of nasogastric tubes significantly reduced LOS for these patients. This appears to validate the efficacy of these specific recommendations in pancreatic procedures. Similarly in liver patients, a previous study found total compliance to the overall ERAS protocol significantly reduced LOS and clinically relevant complications,[24] a finding validated in the multi-institutional results in Chapter Four. Chapter Four also provides results for other not-often reported procedures such as urological, and head and neck resections, highlighting the need for more multi-institutional studies to further support the evidence that evidence-based practices improve patient outcomes in these procedures.

Predicting Compliance with Barriers

Having established that compliance to evidence-based surgical care recommendations improves patient care, it is then important to examine the reasons why these practices are sometimes not performed by providers. These reasons are framed as barriers and exist in a wide variety of contexts and settings making it important when trying to mitigate barriers, to utilize practical frameworks developed from the right population and from the right context. A theoretical framework developed by Cabana and colleagues nearly 25 years ago describes both a conceptual and practical infrastructure, providing a validated and highly utilized roadmap for barriers to clinical practice guidelines among physicians.[1,39] Understanding the impact of these barriers on compliance to clinical guidelines then is important and Chapter Three aimed to collect and analyze data in the literature that quantitatively described this relationship. While no studies were discovered specific to surgery, six were ultimately analyzed and meta-regression

models developed to better understand how barriers predict compliance; finding presence of external barriers, familiarity, and agreement predict compliance to care guidelines in medical settings. That few studies were found in the broader medical literature highlights the need not only for health services researchers to explore this area more generally, but to also focus on barriers specific to surgery and surgical guidelines.

Given this gap, Chapter Five describes a mixed-methods survey approach to understanding what professionals experienced in ERAS and surgical care thought were barriers to compliance to specific ERAS recommendations. The survey was able to quantitatively assess how much a particular recommendation was a part of a respondent's role, how much they felt they could ensure compliance to that recommendation, and finally what they felt was the primary barrier to compliance for that recommendation. The models developed from the interplay between ability to assure compliance to a specific ERAS recommendation and its primary barrier revealed that barriers to oral carbohydrate loading include lack of familiarity and motivation to change practice. The qualitative analysis revealed lack of motivation, lack of agreement, and external barriers such as lack of resources as impeding overall success. The survey findings from Chapter Five are concordant to the meta-regression results in Chapter Three, where familiarity and presence of external barriers predict whether a provider performs a particular clinical care recommendation. While not exactly parallel, in that the meta-regression results are from the broader medical literature assessing observable compliance and the survey results assess feelings of compliance assurance in surgery, the overlap is intriguing and should be explored in future studies. Knowing which barriers predict compliance could contribute to the development of successful implementation programs for any type of set of guidelines and, specifically to ERAS®, can provide evidence-based framework for structured implementation programs.

Applications and Next Steps

As standardization via care guidelines is important to reducing variation in care, standardization of reporting barriers to those care guidelines is as well. The medical literature has robustly utilized the Cabana barrier framework, and some authors in the field of surgery have reported barriers that correspond to some Cabana barriers in their studies, however standardization of reporting barriers in surgical care guidelines should be considered as next steps. Elias et al., in a joint statement by the ERAS® and ERAS® USA Societies, published a checklist to aid and standardize the reporting of ERAS results in the literature[67] and this appears to be a good foundation for developing a similar aid on the reporting of barriers to ERAS® compliance utilizing the Cabana framework. Similarly, as the source of data for the predictive models of barriers and compliance described in Chapter Three was from the medical literature only, next steps would be to develop surgery-specific studies which are modeled after these medical studies so results can be generated that not only speak to the unique experience of surgery but may also validate what the medical literature has described to date.

Before we consider developing high-tech solutions to ensure compliance to evidence-based practices, we need to first understand why providers don't practice them in the first place. The barriers identified in these Chapters are a tangible start, however interdisciplinary research should occur between surgery and the fields of psychology, sociology, organizational studies, and human centered design. Only after the inter- and intra-personal dynamics of the surgical team and environment are better understood, can the next step be the integration of technology with these structures.

However, technological solutions are a natural next step for components of this dissertation's findings, particularly the cascading effects of compliance as described in Chapter

Two and predicting barriers to compliance described in Chapter Three. Integrating vertical compliance prediction modelling into an EMR or other decision support tool has the potential to identify and alert providers of missed ERAS recommendations in real-time, affording the opportunity to correct this moment of non-compliance and preventing future adverse outcomes for that patient. As for predicting barriers, after building more robust literature on the quantitative relationship specifically between Cabana barriers and ERAS compliance, a risk calculator could potentially be developed. This tool could allow administrators or other programmatic professionals to assess the likelihood of a successful ERAS implementation either overall, or to specific guideline items, by assessing barriers and resources unique to their organization.

Final

These Chapters expand the knowledge of why compliance to surgical care pathways is important, and why understanding the barriers to that compliance is as well yet understudied. Retrospective reflection on non-compliance to either the overall protocol or to the individual recommendations, while informative, is too late to prevent potential adverse outcomes, underscoring the need for risk assessment utilizing data-driven analytics. Predicting adverse surgical outcomes due to non-compliance to evidence-based care is important, yet, predicting barriers may prove a critical element to preventing that non-compliance before it occurs.

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