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Acute Care Surgery Outcomes

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by

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A THESIS

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Abstract

Introduction: The acute care surgery (ACS) model was initiated two decades ago to address issues of availability, timeliness and quality in emergency general surgery care. Previous publications were retrospective, single centered and lacked specific information about morbidity and mortality rates of common ACS procedures. Given that ACS is an evolving model and that the full impact of its implementation is not yet fully understood, we studied the effect of ACS implementation on morbidity and mortality.

Methods: Part I, a systematic review and meta-analysis of outcome studies of appendectomies and cholecystectomies before and after the implementation of ACS. Part II, a prospective analysis of ACS post-operative morbidities and mortality in 8 high volume centres (excluding trauma) was performed. The evaluation was conducted over a 30-day period.

Results: In *part I*, of 1704 studies, 27 studies were selected for analysis. Following ACS introduction, the overall complication rate was significantly reduced in both appendectomy and cholecystectomy (Risk ratios = 0.7; 95% CI 0.57 to 0.85 and RR=0.6; 95% CI 0.40 to 0.94) respectively. Length of stay and time to operate were significantly reduced in both groups. In *part II*, there were a total of 601 post-operative patients who were followed for up to a period of 30 days. Of those, 66% of the procedures were laparoscopic. The overall complication rate was 34% and mortality was 2%. In open procedures, the morbidity rate was 73%.

Conclusions: The implementation of the ACS model was associated with a significant reduction in morbidity and mortality in patients' with appendicitis and cholecystitis. ACS patients continue to represent a high-risk population. Appropriate hospital and system resources are essential for successful implementation of the ACS model.

Keywords: *Acute care surgery, ACS, appendectomy, cholecystectomy. Morbidity.*

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I would like to thank Crystal Wilson for her valuable contribution in thesis language review.

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List of Symbols, Abbreviations and Nomenclature

Symbol	**Definition**
ACS	Acute care surgery
CI	Confidence interval
RR	Risk ratio
EGS	Emergency general surgery
US	United States
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
MI	Myocardial infarction
DVT	Deep vein thrombosis
PE	Pulmonary embolism
TTO	Time to operate
LOS	Length of stay
NOS	Newcastle-Ottawa Scale
CDC	Centers for Disease Control
MeSH	Medical subject headings
NSQIP	National Surgical Quality Improvement Program
MD	Mean difference
ED	Emergency Department
OR	Operating theater
UO	Urine output

I. Chapter one:

Introduction

Surgical emergencies encompass a major burden worldwide. According to the National Inpatient Sample database, there are approximately 4 million related visits to emergency departments annually. Among these, 2.3 million require hospital admission.(1) The nature of these admissions varies on a daily basis, but the vast majority are related to acute appendicitis, biliary disease, pancreatitis, diverticulitis and bowel obstruction.(2) These patients require urgent assessment and implementation of a management plan. Unfortunately, multiple citations report inadequate access to emergency surgical care. Delays in surgical intervention increase disease related morbidity and contribute significantly to the number of emergency visits. This is in-part related to the scarcity of on-call surgeons. (3, 4) Other surveys note, 37% of emergency directors report inadequate emergency general surgery (EGS) coverage in hospital where trauma and EGS are covered by the same team.(5) Lack of depth of coverage also contributed to delays in surgical intervention.

Historically, EGS was managed by a staff person who was expected to cover 24 continuous hours of on-call duty. Irrespective of the surgeons' state of rest, he or she may have been expected to have full elective clinical duties the next day. Such a system may create conflict with clinical duties and potentially effect multiple aspects of patient care. This potentially contributed to an increase in morbidity. Traditional EGS systems also may extend length of stay, delay time to operate, increase cost and increase mortality. These issues led many to revisit the structure of care delivery in the mid 2000s. The goal was to improve access and quality of care for EGS patients. Acute care surgery (ACS) models which combined the EGS with or without trauma and surgical critical care were introduced.(6) The implementation of these systems took time and lacked consistency among different centers around the world. In a survey of 2811 hospitals who provided EGS care in US as of 2015, 16.1% reported implementation of an ACS system while 72.5% reported an ad hoc system. Using results from a national survey, Khubchandani et al, demonstrated an increase in ACS implementation from 2.1% in 2001 to 15.3% in 2015.(7)

The challenges of implementing ACS have been many. Traditional models of compensation needed to be addressed. Surgical work force planning needed to account for dedicated rotations on ACS. Increasing sub-specialization in general surgery led to challenges in identifying which surgeons should rotate on the ACS service. Competition for scheduled and emergency case prioritization inevitably occurred. Demonstration of improvements in quality and overall value were required. These challenges were generally met. In Canada, the majority of centres adopted universal participation in ACS by general surgeons regardless of sub-specialty.(8)

While ACS as a model of surgical care was studied previously, most of those studies are single center and retrospective in nature. Moreover, given a decade old system, the full impact of this model is not yet fully understood and it is potentially evolving. This thesis is objectively and systematically investigating the effect of introducing such a system in different aspects of patient care as well as its economic impact.

Despite the cost reduction described for certain surgical procedures like cholecystectomy, appendectomy and laparotomy post ACS implementation in previous reports,(9, 10) implementing of ACS services requires a significant initial financial investment. This may include monetary compensation for surgical teams, dedicated resources (e.g. OR time) and investments in quality monitoring and improvement. Enhanced efficiency delivered by ACS services may deliver value. For e.g., *Anantha* demonstrated the cost reduction associated with a greater proportion of day vs. night operations despite the increase in the total operations performed.(10) Other potential examples of value would include an overall reduction of in length of stay, reduced morbidity and reduced return visits to the emergency department.

After an extensive literature search to understand the landscape and state of knowledge, this work began with a proposed systematic review. This was subsequently modified to a meta-analysis of the outcomes of ACS in acute appendicitis and biliary diseases. The rationale behind selecting these diagnoses is because they represent the majority of surgical emergency visits. Ovid Medline, Embase, Cochrane Library and google scholar were systematically searched using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.(11) Our search was centered around reports of ACS outcomes when compared with the Pre-ACS era. We excluded elective or scheduled cholecystectomy or appendectomy, studies involving non-human subjects, case-series, case reports, meta-analyses, systematic reviews, letters or conference abstracts. We examined a collective set of complications including pneumonia, respiratory failure, effusion, myocardial infarction (MI), ileus, deep vein thrombosis (DVT), pulmonary embolism (PE), surgical site hemorrhage, wound infection, seroma, hematoma and deep collections. These represent the most commonly reported complications in this field as per our literature review. In addition, we reported procedure specific complications including bile leak, bile duct injury and rate of negative appendectomy in pathology reports. Lastly, quality measures like estimated blood loss and rate of conversion from laparoscopic to open, time to operate (TTO), hospital length of stay (LOS), cost and mortality were also studied. The Newcastle-Ottawa Scale (NOS) was used to assess the quality of the selected studies. Most of these studies were retrospective but of good quality. Amongst 1486 studies, 50 were selected for full text review and 27 were included for qualitative and quantitative synthesis.

For the appendectomy group, there was a significant reduction in the overall complication rate in the ACS group when compared with Pre-ACS. In the ACS group, there was a significant reduction in the mean-time from emergency arrival to admission, mean time from admission to operation, and hospital LOS. For the cholecystectomy group, the results demonstrated a significant reduction in overall complications in the ACS group. There was also a significant reduction in the time to operate and hospital stay.

The meta-analysis led to the understanding that the implementation of ACS contributed significantly to better patient outcomes compared to Pre-ACS. The meta-analysis should be interpreted in light of the limitations of the studies included. This then led to the next step, which was to investigate comprehensively the morbidity and mortality rates following ACS surgeries in a prospective study. In this study, we audited all adults, >/= 16 years of age who were admitted to hospital and underwent surgery in an ACS system. The data collection was performed on a daily basis at eight high volume ACS centers across Canada. Preoperative, intraoperative and postoperative variables were collected using a standardized sheet. To ensure that complications were recorded in a standard fashion, we used CDC definitions for the recorded variables. Amongst all of the admitted patients, cholecystitis compromised the majority (29%), followed by appendicitis (20%), bowel obstruction (18%), incarcerated hernia (12%), gastrointestinal bleeding (9%), soft tissue infections (7%) and other (9%). This study also demonstrated that up to 34% of ACS patients who required urgent or emergent surgical intervention suffered a complication. This rate was significantly higher in open cases (73%). Among these complications, prolonged ileus was the most common morbidity followed by surgical site infection. The evidence suggests superior outcomes of the ACS module compared to Pre-ACS.

Contributors

The majority of work in both research projects was done by Omar Al Busaidi. In the first paper (Complications of Appendectomy and Cholecystectomy in Acute Care Surgery: A Systematic Review and Meta-Analysis), Al Busaidi performed the literature review and authored the research proposal. The protocol was developed with the assistance and advice of the supervisory committee. The primary search, screening and review of the selected manuscripts was performed independently by Al-Buisaidi and a second researcher (Seungwon Lee). The statistical analysis was completed mainly by Al-Busaidi with help from Lee. The manuscript was written by Dr. Al-Busaidi and reviewed by Lee with feedback from the supervisory committee. This paper was presented as a poster at the Canadian surgery Forum on August 2018 and the Abstract was published in the Canadian journal of surgery, Vol. 61 (4 Suppl 2) August 2018. The manuscript is being submitted for publication.

The second manuscript was entitled A 30-day prospective audit of all acute care surgery (non-trauma) inpatient postoperative complications: How well do we really perform? It required greater collaboration with multiple centers across Canada. Dr. Al Busaidi performed the initial literature review and drafted the first manuscript protocol as well as the standardized data collection sheet. Dr. Al Busaidi's work informed the final manuscript which was written collectively by the research team. The initial Ethical proposal was initiated by Dr. Al Busaidi at the University of Calgary and used to facilitate the ethical approval in the other participating institutions. For the data collection, the following centres and researchers supervised and collected information over a defined 30-day period:

- Foothills Medical Center (Calgary), (Mathew Patterson, Chad ball, John Kortbeek, Anthony Maclean).
- Rockyview General Hospital (Calgary), Omar Al Busaidi
- London Health Sciences Center (London), (Patrick Murphy).
- Vancouver General Hospital (Vancouver), (S. Morad Hameed).
- University of Alberta Hospital (Edmonton), (Kevin Verhoeff, Sandy Widder).
- Montreal General Hospital (Montreal), (Kosar Khwaja).
- Hamilton General Hospital and St. Joseph's Healthcare (Hamilton), (Paul T. Engels, Timothy Rice, Rahima Nenshi).
- Queen Elizabeth II Health Sciences (Halifax), (Samuel Minor)

Once all the data was collected, analysis was done by a statistician. Paper writing was done mainly by Al Busaidi and Dr. Ball with feedback from the supervisory committee. This paper was presented at the American College of Surgeons Clinical Congress in Boston, Massachusetts, on October 22, 2018 and it was submitted to the Canadian journal of Surgery on October 25th 2018 for publication. Currently it is under review.

II. Chapter Two

Title: Complications of Appendectomy and Cholecystectomy in Acute Care Surgery: A Systematic Review and Meta-Analysis

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Author Disclosure Statement

The authors, individually and collectively, have no financial, personal or ethical conflicts of interest to report.

Abstract

Introduction: The acute care surgery (ACS) model was initiated two decades ago to address issues of availability, timeliness and quality in emergency general surgery care. This study hypothesizes that the ACS model has significantly improved the management of acute appendicitis and biliary disease. These diseases represent the two most common indications for emergency operations in general surgery.

Methods: A comprehensive systematic review and meta-analysis of outcome studies for emergent appendectomy and cholecystectomy from 1966 to 2017, comparing studies prior to and following the implementation of ACS.

Results: Of 1704 studies, 27 retrospective but good quality studies were selected for analysis (appendicitis = 16, biliary pathology= 7, both = 4). Our analysis demonstrated that following ACS introduction, the overall complication rate was significantly reduced in both appendectomy and cholecystectomy (Risk ratios = 0.7; 95% CI 0.57 to 0.85; I^2 9.2% and RR= 0.6; 95% CI 0.4 to 0.94; I^2 63.5%) respectively. In addition, there was a significant reduction in the time from arrival in emergency until admission and from admission to operation (-1.37 hours: 95% CI -1.93 to -0.80 and -2.51 hours: 95% CI -4.44 to -0.58) in the appendectomy cohort. Time to operation was significantly shorter in cholecystectomy group (-6.46 hours; 95% CI -9.54 to -3.4). Length of hospital stay was significantly reduced in both groups (appendectomy = -0.9 day, cholecystectomy = -1.09 day). Finally, there was a significant reduction in overall cost in cholecystectomy group (-$854.37 USD; 95% CI –1554.1 to -154.05).

Conclusion: The implementation of ACS models in general surgery emergency care has significantly improved system and patient outcomes for appendicitis and biliary pathology.

Introduction

Emergency general surgery represents both a significant hospital caseload and burden of disease. These patients are at risk of major morbidity and mortality. The volume and distribution of surgical emergencies may vary on a daily basis, but usually encompasses a spectrum of acute appendicitis, acute cholecystitis, symptomatic biliary disease, gall stone pancreatitis, ascending cholangitis, a small or large bowel obstruction and diverticulitis Appendicitis and cholecystitis represent the two most common conditions.(2)

Previous studies have shown that emergency general surgery (EGS) services have a mortality rate of 12.5% as compared to 2.66% in elective general surgery procedures.(12) Approximately 33% of EGS patients had post-operative complications and 15% required re-admission.(12) Amongst different emergent procedures, colorectal surgeries carried the highest morbidity rates.(13, 14)

Acute care surgery is defined as a dedicated service responsible for the urgent assessment and management of general surgical emergencies.(8) Prior to the introduction of acute care surgery as a model of care, surgical emergencies were managed by staff surgeons assigned to a daily call roster or by direct referral. Ongoing care would be provided by, and be the responsibility of, the admitting surgeon. This occurred irrespective of the surgeon's state of rest, or potentially conflicting demands of scheduled surgery or clinics. Acute Care Surgery models were introduced in the mid 2000s to address issues regarding access and quality of emergency surgical assessment and management.

The ACS service varies between institutes and jurisdictions. In Canada, with some exceptions, ACS is usually interpreted as urgent assessment and management of surgical emergencies in adults excluding trauma cases. This is in contrast to other jurisdictions, including some US hospitals, where trauma was incorporated into a service with general surgical emergencies.(8) The merging of trauma and surgical services occurred in part due to the increasing prevalence of non-operative management in blunt trauma.(6) In Canada, ACS usually involves 7 consecutive days on service by the attending surgeon, managing acute surgical emergencies. The surgeon is typically dedicated to the service and is not burdened by additional scheduled clinical duties. This system was anticipated to provide many benefits. These included, but were not limited to, creating predictable scheduling for surgeons, the absence of overlapping elective and emergency duties, better distribution of operating theaters and importantly, better quality of patient care and follow-up. In the Canadian model, the majority of general surgeons in a division, irrespective of subspecialty, rotate on the ACS during the year.(8)

The implementation of ACS has been studied in multiple single center studies across the world, however, the full impact of this delivery model is not fully understood because it is in the first decade of implementation and the model continues to evolve. There were two meta-analysis published on this topic (Nagaraja et al(15) and Murphy et al(16)) which reported on the general benefit of the ACS model. This study will explore these benefits in greater depth and will include up-to-date studies.

The primary objective of this study is to provide a comprehensive analysis of the common complications of appendectomy and cholecystectomy in the paradigm of ACS model.

Our secondary objective is to provide data about the efficacy of ACS in reducing hospital stay, time to operate, after-hours operations and cost.

Methods

Search strategy

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guideline was followed for this systematic review.(11) The literature search process was conducted in three stages to ensure all relevant studies were included. The primary search was conducted in one database, followed by refinement of search words and MeSH terms in collaboration with a librarian. The developed search strategy was then repeated in the other databases. Lastly, additional literature was identified through checking the reference lists of the included papers. The searches were conducted in the following databases: Ovid Medline, Embase, Cochrane Central Register of Controlled Trials and Google Scholar. The study included all possible papers from inception of databases until December, 2017. Nomenclature describing Acute Care Surgery (ACS), varies around the world. Therefore, the following terms describing different forms of ACS were included in our search: acute surgical unit, acute surgical model, acute care surgery service, surgeon of the week, emergency surgical unit and emergency general surgery. This was combined with different terminologies used to describe the two procedures studied (appendicitis/appendectomy and cholecystitis/gallbladder disease/cholecystectomy). Boolean operator (AND & OR) was used. MeSH terms as well as text words were used in order to include all possible studies. Detailed study strategy is included in the appendix. Table VI.3 &4

After removing all duplicates, the two researchers (Al Busaidi and Lee) independently screened the titles and abstracts. Studies with raw data comparing ACS with the traditional on-call model (pre-ACS) and discussing either acute appendectomy or cholecystectomy were included. We excluded all elective or scheduled cholecystectomy or appendectomy, as well as studies involving non-human subjects, case-series, case reports, meta-analyses, systematic reviews, letters or conference abstracts. Given the difference in the overall study designs and potentially high heterogeneity, papers that used representative or selected samples, such as The American College of Surgeon's National Surgical Quality Improvement Program (NSQIP), National Inpatient Sample and Maryland's Health Services Cost Review commission databases, were also excluded. Disagreement was resolved by consensus between the two researchers or by a third researcher (Kortbeek). Kappa coefficient was calculated for inter-rater reliability. Newcastle Ottawa score was used to assess the quality of studies. Citations from all data bases managed by Endnote X7.

Data Extraction

Following the abstract review, the full article reviews along with data extraction was carried out. A standardized extraction sheet was generated. This was used to extract data from the selected studies by the two independent researchers. General information such as author name, country of origin, year of publication, type of study design, year at which the study was conducted on, sample size, mean age of the population and how many procedures were included in each study were collected. We also charted the information about ACS services in each paper, specifically the name of the services and if the study managed trauma as well as ACS patients.

A literature review identified the most commonly encountered complications in surgical practice.(15-18) These were included in the standardized sheet and are: pneumonia, respiratory failure, effusion, myocardial infarction (MI), ileus, deep vein thrombosis (DVT), pulmonary embolism (PE), surgical site hemorrhage, wound infection, seroma, hematoma and deep collections. Also included were procedure specific complications: bile leak, bile duct injury and rate of negative appendectomy in pathology report. The following quality measures were studied: estimated blood loss, rate of conversion from laparoscopic to open, hospital length of stay (LOS) and mortality.

Operating time, the time from emergency to admission and the time from admission to operating theatre were collected. Cost of hospital stay was standardized to US dollars given that most papers reported in this currency. When the incidence rate of certain complications was not reported directly, the incidence was calculated manually using the sample size and the number of outcomes. In cases where the incidence was aggregated with other events of interest, we excluded that event from charting.

For those papers that discussed more than one procedure, we collected data about the procedure of interest: appendectomy and biliary disease. For papers that analyzed more than one era of ACS with traditional on-call, we used the first duration in order to standardize it with other papers given that the ACS service was implemented fully.

Study Quality Assessment

According to latest systematic review, there are more than 194 tools available to assess the risk of bias in non-randomized studies. (19) Cochrane collaboration recommended two main systems of assessment. These are the Down and Black instrument and the Newcastle-Ottawa Scale (NOS).(20) The NOS was selected as it is the most commonly used in the literature as well as the simplest to apply. The three domains of NOS are selection, comparability, and outcome. Rating was performed by two researchers independently (Al Busaidi and Lee). Using the three domains of NOS, a quality rating was given to each of the selected studies.

Data Synthesis and Statistical Analysis

Descriptive statistics on the extracted data were summarized. A random effects meta-analysis model was used to synthesize the pooled weighted RR and weighted mean difference estimates. Pooled estimates within study and between studies were used to further assess observed heterogeneity. Heterogeneity was assessed through the I^2 statistics. Stratification by selection, comparability, and outcome was conducted to investigate the impact of study quality on the reported outcomes. Forest plots were generated to present significant findings. STATA 14.2 was used for statistical analysis. The study protocol was registered in PROSPERO (CRD42018095759).

Results

Study Selection

The initial search identified a total of 1,704 abstracts from the MEDLINE (Ovid, 1946 - 2017), EMBASE (Ovid, 1974-2017), the Cochrane Central Register of Controlled Trials databases, and through bibliographic reference searching. Of these records, 217 were found to be duplicates. After screening these records, a total of 50 articles were found to be eligible for full article review (inter-rater kappa = 0.9139). Among these, 23 papers were excluded. Exclusions were for the following reasons: 7 were conference abstracts, 4 were either letters or brief reports that lack vital information, 2 did not compare pre and post ACS, 4 lacked major information about the specific procedure studies in our paper and 4 did not use hospital data rather used representative sample that covers more than one hospital with different ACS service theme or timing. A total of twenty-seven articles were included for qualitative analysis (inter-rater kappa = 0.7679) and contained information on the outcomes (e.g. complications, operating time, cost, and others) which allowed for a meta-analysis on the outcomes. (figure II.1)

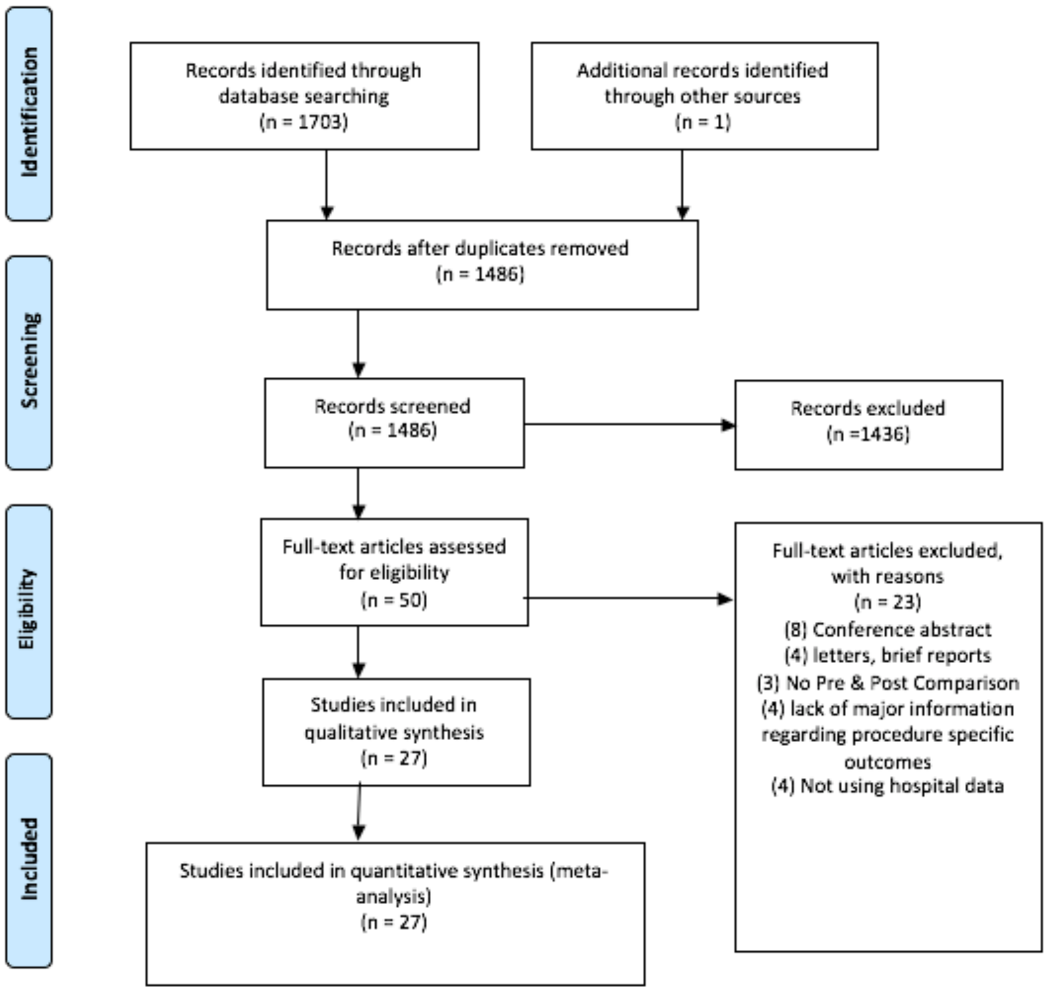

Figure II.1: PRISMA flowchart of the studies included in the study.

Study Characteristics

Table II.1 provides characteristics of the 27 studies utilized in the meta-analysis. A total of 16 (59.3%) papers reported specifically on appendicitis, 7 (25.9%) papers reported on cholecystitis, and 4 (14.8%) papers reported on both outcomes. The identified papers were distributed as following: 9 articles from the United States, 11 from Australia, 3 from Canada, 1 from Singapore, 1 from China, New Zealand, and United Kingdom, respectively. A total of 8 (30.7%) studies identified that ACS incorporated trauma into its services. These papers were mainly completed in the United States and Australia. Tables II.2 provide extended characteristics of the included studies.

Table II.1: Characteristics of the included studies.

Author name	year	country	diagnosis	Sample size PRE	Sample size POST
Cubas et al [21]	2012	United States	Acute appendicitis	82	92
			Biliary disease	51	62
Mathur et al [17]	2017	Singapore	Acute appendicitis	176	188
			Biliary disease	41	28
O,Mara et al [22]	2013	Australia	Acute appendicitis	196	201
			Biliary disease	178	231
Poh et al [23]	2013	Australia	Appendicitis	256	283
Suen et al [24]	2014	Australia	Appendicitis	276	399
Fu et al [25]	2013	China	Appendicitis	146	159
Lancashiro et al[26]	2014	Australia	Appendicitis	247	301
Earley et al [18]	2006	United States	Appendicitis	127	167
Pillai et al [27]	2013	New Zealand	Appendicitis	875	982
Schaetzl et al [28]	2016	United States	Appendicitis	440	505
Qureshi et al [29]	2011	Canada	Appendicitis	169	136
Ekeh et al[30]	2008	United States	Appendicitis	273	279
Brockman et al[31]	2013	Australia	Appendicitis	351	357
Beardsley et al [32]	2013	Australia	Appendicitis	84	66
Wright et al [33]	2013	United States	Appendicitis	526	345
Gandy et al [34]	2010	Australia	Appendicitis	176	226

Noppakunsomboon et al[35]	2017	Thailand	Appendicitis	344	347
Lim et al[36]	2013	Canada	Acute cholecystitis	72	172
Britt et al[37]	2010	United States	Biliary disease	54	132
Lau et al [38]	2011	United States	Acute cholecystitis	81	71
Davis et al[39]	2015	United States	Acute cholecystitis	88	84
Suhardja et al [40]	2015	Australia	Biliary disease	179	163
Shakerian et al [41]	2015	Australia	Biliary disease	254	312
Bokhari et al [42]	2016	UK	Acute cholecystitis	33	68
Michailidou et al [43]	2013	United States	Acute cholecystitis	94	234
Lehan et al [44]	2010	Australia	Acute cholecystitis	87	115
Pepingco et al [45]	2012	Australia	Acute cholecystitis	114	157

These studies reported staff-lead process, however, had variation in when the services started, how long these services lasted, who was covering the nights, the weekends, and whether a day-time operating theatre was available. The variety in ACS services is beyond the scope of this meta-analysis. It also demonstrated that the model of ACS was implemented in many different countries around the world. We also noted a different nomenclature used to describe the service across countries. Table VI.1 provides a summary of ACS names.

Table II.2 Extended characteristics of the included studies

		Using laparoscopy		Mean age		
Author name	diagnosis	PRE	POST	PRE	POST	Mode of service
Cubas et al [21]	Acute appendicitis	-	-	35 + 17	34+17	ACS
	Biliary disease	-	-	38+17	40+19	ACS
Mathur et al [17]	Acute appendicitis	-	-	50 +19	51 +19	ACS & Trauma
	Biliary disease			50+19.5	51+19	ACS & Trauma
O,Mara et al [22]	Acute appendicitis	85	82	-	-	ACS
	Biliary disease	99	99	-	-	ACS
Poh et al [23]	Appendicitis	97.6	96.1	31.5+0.8	31.8 +0.89	ACS
Suen et al [24]	Appendicitis	-	-	30.6 + 13.8	31.4 +14.3	ACS
Fu et al [25]	Appendicitis	-	-	41.3 +16.9	43.8+29	ACS & Trauma
Lancashiro et al[26]	Appendicitis	96.8	98.3	29.5 + 14.8	28.5 + 13.93	ACS
Earley et al [18]	Appendicitis	10	6.5	37 +15	30 + 12	ACS & Trauma
Pillai et al [27]	Appendicitis	79	87.9	28.7 (15-100)	27.9(14.7-88.1)	ACS
Schaetzl et al [28]	Appendicitis	98	99	-	-	ACS
Qureshi et al [29]	Appendicitis	-	-	57 +21	57 +21	ACS
Ekeh et al[30]	Appendicitis	66.6	84.6	36.8 +16.5	35.8 +16.5	ACS & Trauma
Brockman et al[31]	Appendicitis	75	78	25.6	26	ACS
Beardsley et al [32]	Appendicitis	NC	NC	30 (16-72)	29 (16-97)	ACS
Wright et al [33]	Appendicitis	322	286	38.2 +17	36.0+15.3	ACS & Trauma
Gandy et al [34]	Appendicitis	11	40	33.6	32.8	ACS
Noppakunsomboon et al[35]	Appendicitis	-	-	40 +20	39 +19	ACS
Lim et al[36]	Acute cholecystitis	80.6	78.8	49.7	51.2	ACS

Britt et al[37]	Biliary disease	76	80	50.2	44.4	ACS
Lau et al [38]	Acute cholecystitis	-	-	46.7	45.7	ACS
Davis et al(39)	Acute cholecystitis	49	55	54+32	60+22	ACS
Suhardja et al [40]	Biliary disease	-	-	53.1 (18-101)	54.5 (16-95)	ACS
Shakerian et al [41]	Biliary disease	-	-	64 (17-96)	52.5 (17-91)	ACS & Trauma
Bokhari et al [42]	Acute cholecystitis	100	100	49 (16-87)	53 (22-82)	ACS
Michailidou et al [43]	Acute cholecystitis	-	-	39.5 +15	38.1+16	ACS
Lehan et al [44]	Acute cholecystitis	81.6	91.3	50+19.5	47+17	ACS
Pepingco et al [45]	Acute cholecystitis	-	-	44.4 M	45.1 M	ACS & Trauma

Study Quality Assessment (Risk of Bias in Individual Studies)

The application of a modified Newcastle Ottawa Scale (NOS) on these 27 papers demonstrated that all studies are of good quality. Table VI.2 in the appendix showing detailed NOS assessment of the selected studies.

Quantitative Synthesis of Results

The primary outcome of interest was the overall number and type of complications after having undergone appendectomy or cholecystectomy. Relevant secondary complications were also accounted for. The secondary outcome measures were related to health services and included information on factors such as cost.

Outcome measures

Among patients who underwent appendectomy under the ACS model, the pooled relative risk of developing complications in those receiving appendectomy under ACS is 0.7 times the risk of developing complications in those receiving the same procedure under the Pre-ACS model. This is a 30% risk reduction in overall complications (RR=0.7; 95% CI 0.57 to 0.85, I^2=9.2%, P=0.359). (Figure II.2) This result is statistically significant.

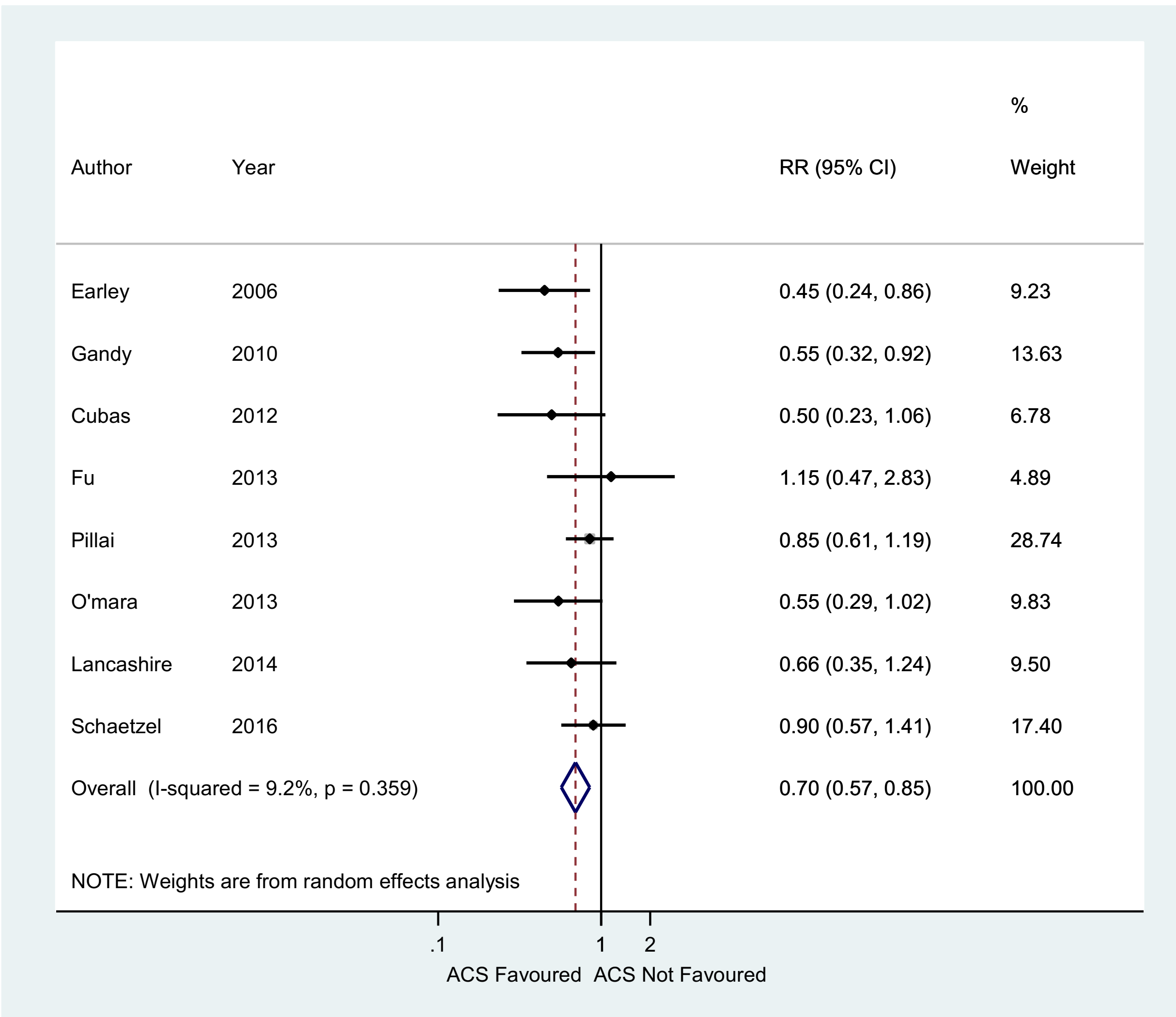

Figure II.2: Forest plot and pooled risk ratios of the overall complications of appendectomy in ACS when compared to Pre-ACS. ACS, acute care surgery

According to our analysis, there is a statistical significance in the timeliness from emergency arrival towards surgical ward admission. This difference favors ACS model with a mean difference of -1.37 hours (MD -1.37; 95% CI -1.93 to -0.80, I^2= 90.5, P=<0.001). (Figure II.3) Significant heterogeneity was observed.

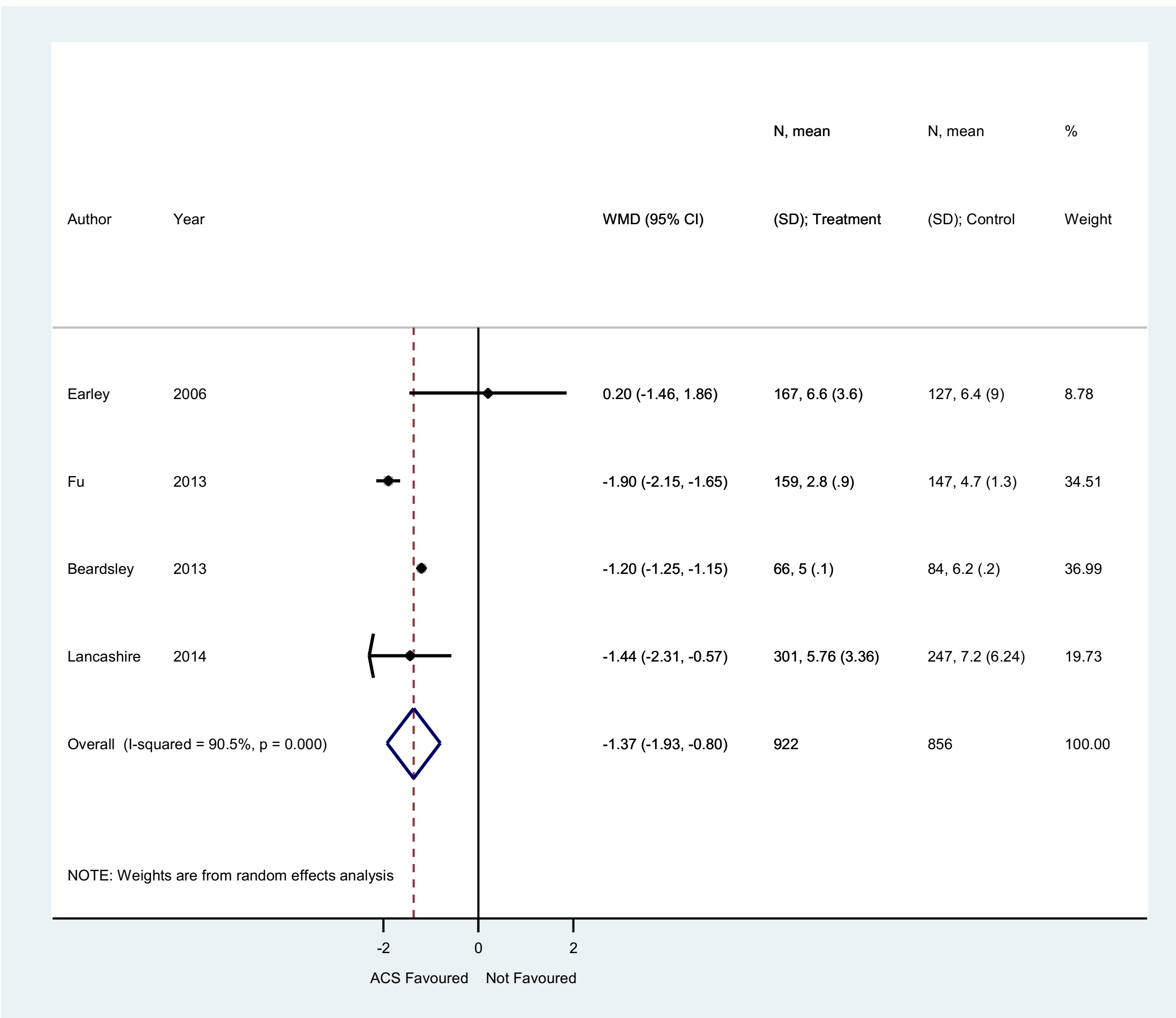

Figure II.3 Forest plot and pooled mean difference in the timing of ED arrival to admission for appendicitis in ACS when compared to the Pre-ACS. ACS, acute care surgery; ED, emergency department

Similar analysis was performed on timeliness between ward admissions to operation time. Results showed a statistical significance in favor of ACS in this analysis, with mean time difference of -2.51 hours (MD -2.51; 95% CI -4.44 to -0.58, I^2= 91.5%, P<0.001). (FigureII.4)

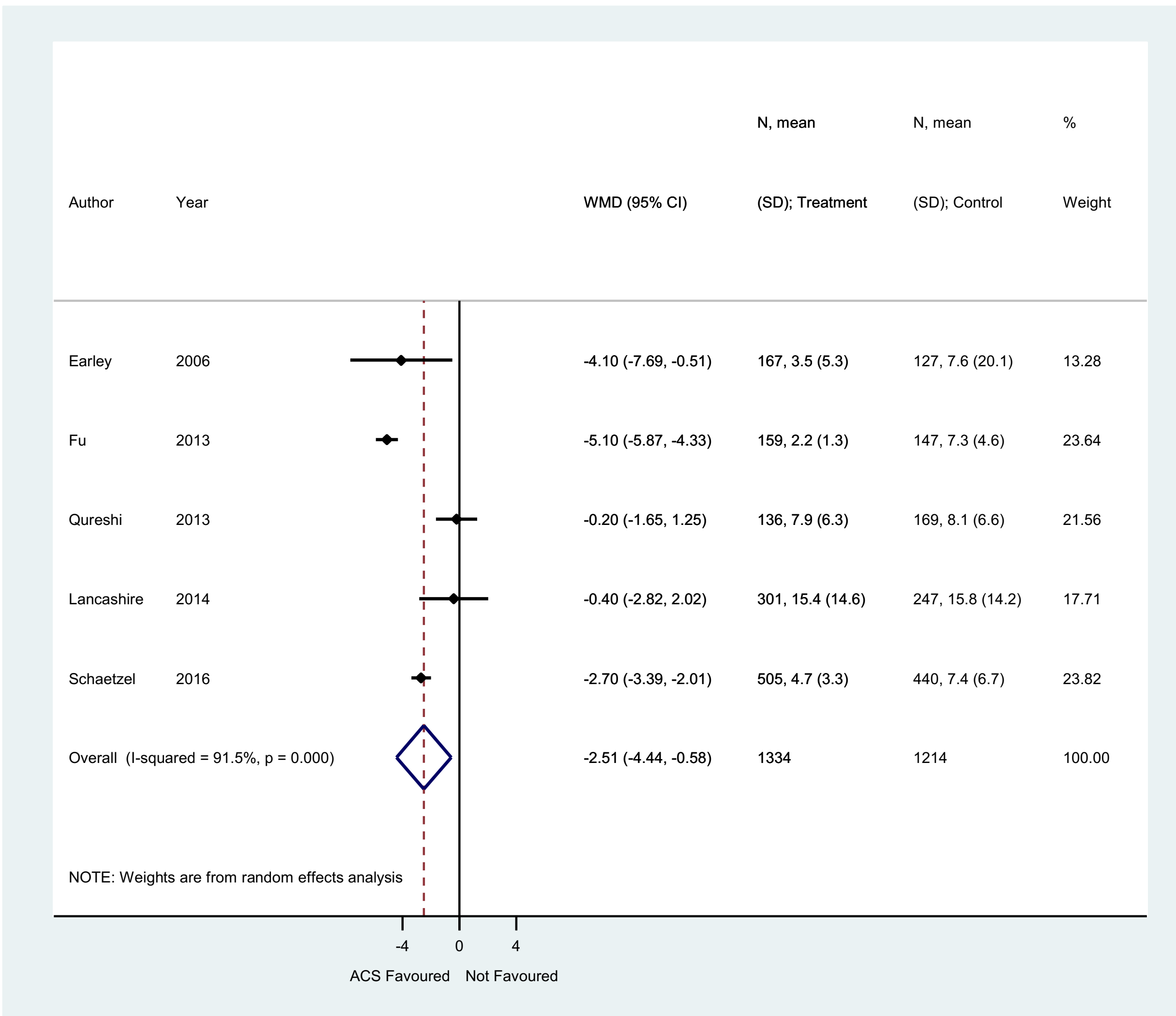

Figure II.4: Forest plot and pooled mean difference in the timing of admission to operation of appendicitis in ACS when compared to the Pre-ACS. ACS, acute care surgery

The ACS model cohort showed significant reduction in hospital length of stay. The mean difference was 0.9 days less in ACS compared to Pre-ACS (MD 0.9; 95% CI -1.32 to -0.49, I^2= 72.5%, P<0.006) (Figure II.5)

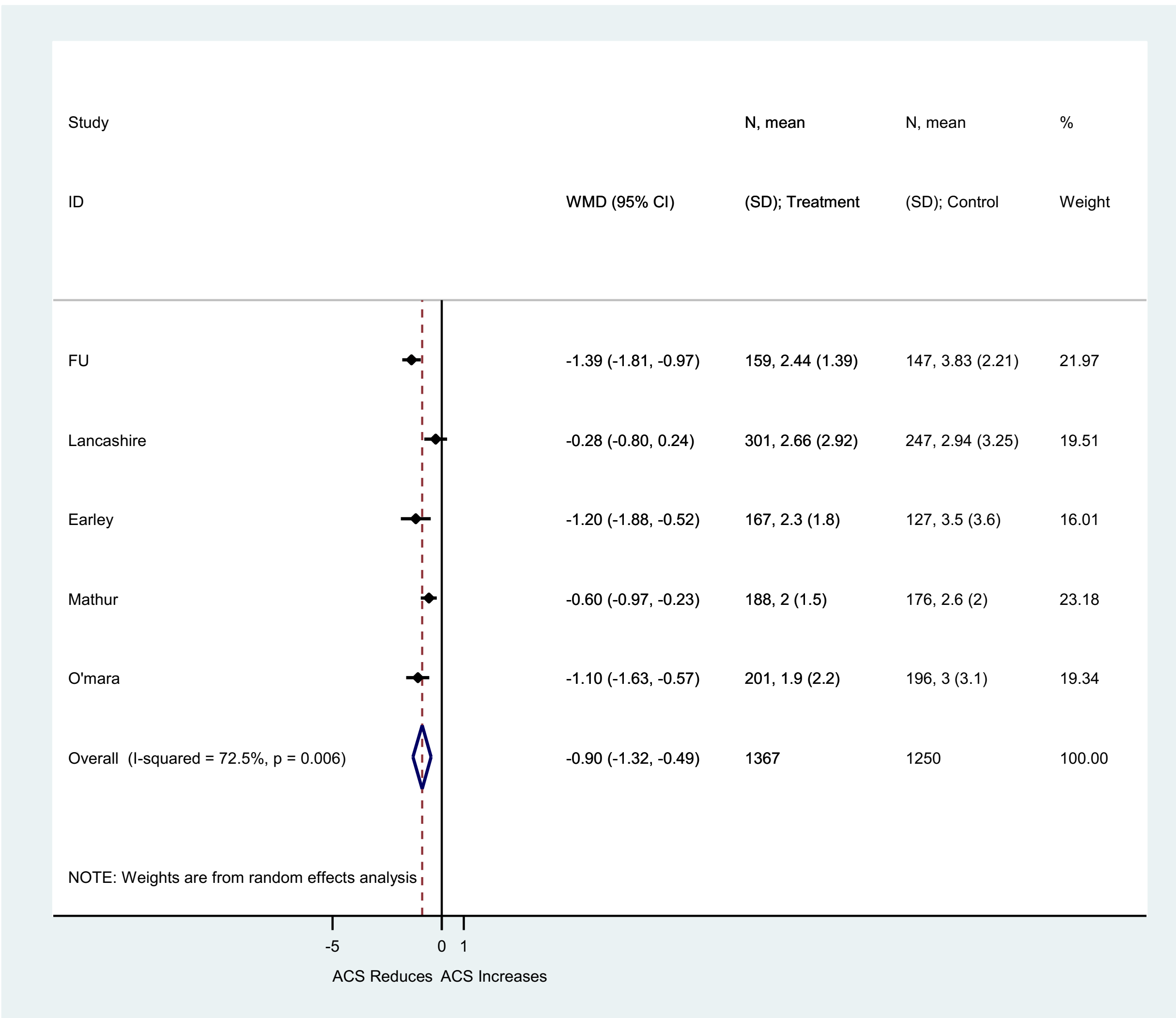

Figure II.5: Forest plot and pooled hospital length of stay of appendicitis in ACS when compared to the Pre-ACS. ACS, acute care surgery

The analysis demostrated no statistical difference in wound infection rates (RR=0.7; 95% CI 0.49 to 1.0), deep abscess (RR=1.13; 95% CI 0.76 to 1.7), conversion - laparoscopic to open (RR=0.98; 95% CI 0.46 to 2.09), rate of negative appendectomy (RR=1.01; 95% CI 0.81 to 1.25), after hours surgery (RR=0.94; 95% CI 0.79 to 1.12), readmission rate (RR=1.16; 95% CI 0.86 to 1.56) and overall cost (MD=350; 95% CI -706 to 6.7). Table II.3 summarize these results.

Table II.3: Summary of risk ratios and mean differences of multiple measures of interest post appendectomy in ACS when compared to Pre-ACS. MD, mean difference; RR, relative risk; ACS, acute care surgery.

Measure of interest	Number of Studies	Relative risk (RR) or mean difference (MD)	95% Confidence interval	Statistically significant? (P<0.05)	I^2	Favoring
Overall Complication	8	RR 0.7	0.57 to 0.85	Yes	9.2%	ACS
Timing of ED arrival to admission (hours)	4	MD -1.37	-1.93 to -0.80	Yes	90.5%	ACS
Timing of admission to operation (hours)	5	MD-2.51	-4.44 to -0.58	Yes	91.5%	ACS

Hospital Length of Stay (days)	5	MD -0.9	-1.32 to -0.49	Yes	72.5%	ACS
Wound infection	7	RR 0.7	0.49 to 1.00	No	0.0%	ACS
Abscess	6	RR 1.13	0.76 to 1.70	No	16.2%	Pre-ACS
Laparoscopic to open	6	RR 0.98	0.46 to 2.09	No	50.5%	-
Negative appendectomy	10	RR 1.01	0.81 to 1.25	No	60.1%	-
After hours surgery	8	RR 0.94	0.79 to 1.12	No	89.3%	-
Readmission	6	RR 1.16	0.86 to 1.56	No	0.0%	Pre-ACS
Cost	3	MD -350.07	-706.85 to 6.70	No	60.8%	ACS

Cholecystectomy

Among patients receiving cholecystectomy, the analysis demonstrated that the pooled relative risk of developing complications in those receiving cholecystectomy under the ACS is 0.62 times the risk of developing complications in those receiving the same procedure under the non-ACS model. This would translate into 38% risk reduction in overall risk of complications under the ACS model (RR=0.62; 95% CI 0.41 to 0.94). (*Figure II.6)*

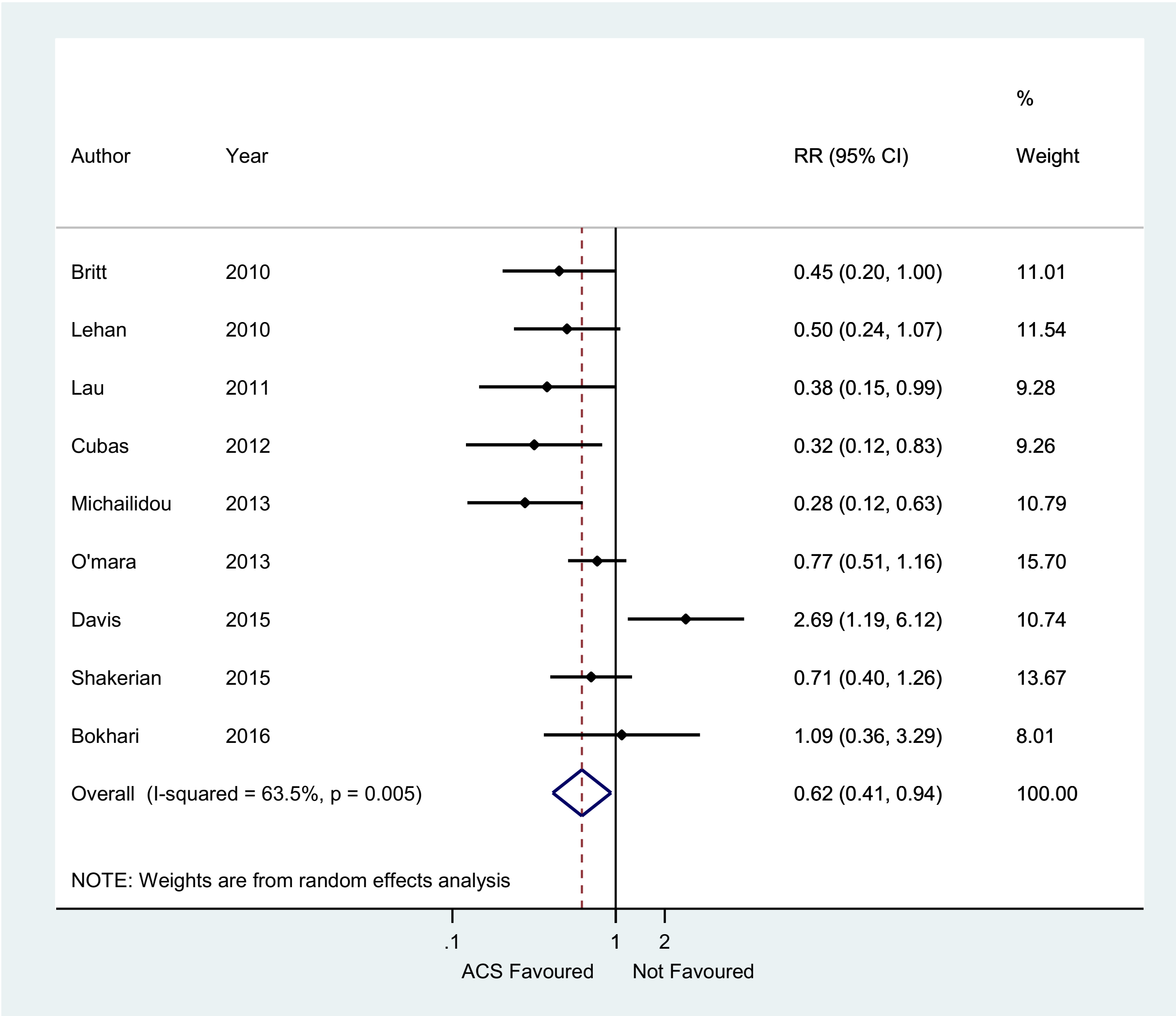

Figure II.6: Forest plot and pooled risk ratios of the overall cholecystectomy complication in ACS when compared to the Pre-ACS. ACS, acute care surgery

The time to operate was reduced by 6.46 hours in the ACS group (MD -6.46; 95% C.I -9.54 to -3.4, I^2=0.8%, P=0.365). (*Figure II.7) Mean* hospital length of stay in days, was significantly reduced by 1.094 days in ACS cohort (mean days=-1.094; 95% C.I -1.51 to -0.68, I^2=0.0%, P=0.422). (Figure II.8) The cost analysis showed a significant reduction in the cost by a mean of 854.37 US $ (MD -854.37; 95% C.I -1554.1 to -154.05, I^2=0, P=0.678). (Figure II.9)

The ACS group had a 51% reduction in mortality post-operatively when compared to Pre-ACS, but this was not statistically significant (RR = 0.49; 95% CI 0.11 to 2.16, I^2= 0%, P=0.494) (Figure II.10) Similarly, readmission rate was reduced by 27% in ACS when compared to Pre-ACS but this was not significant as well (RR 0.73; 95% CI: 0.44 to 1.21).

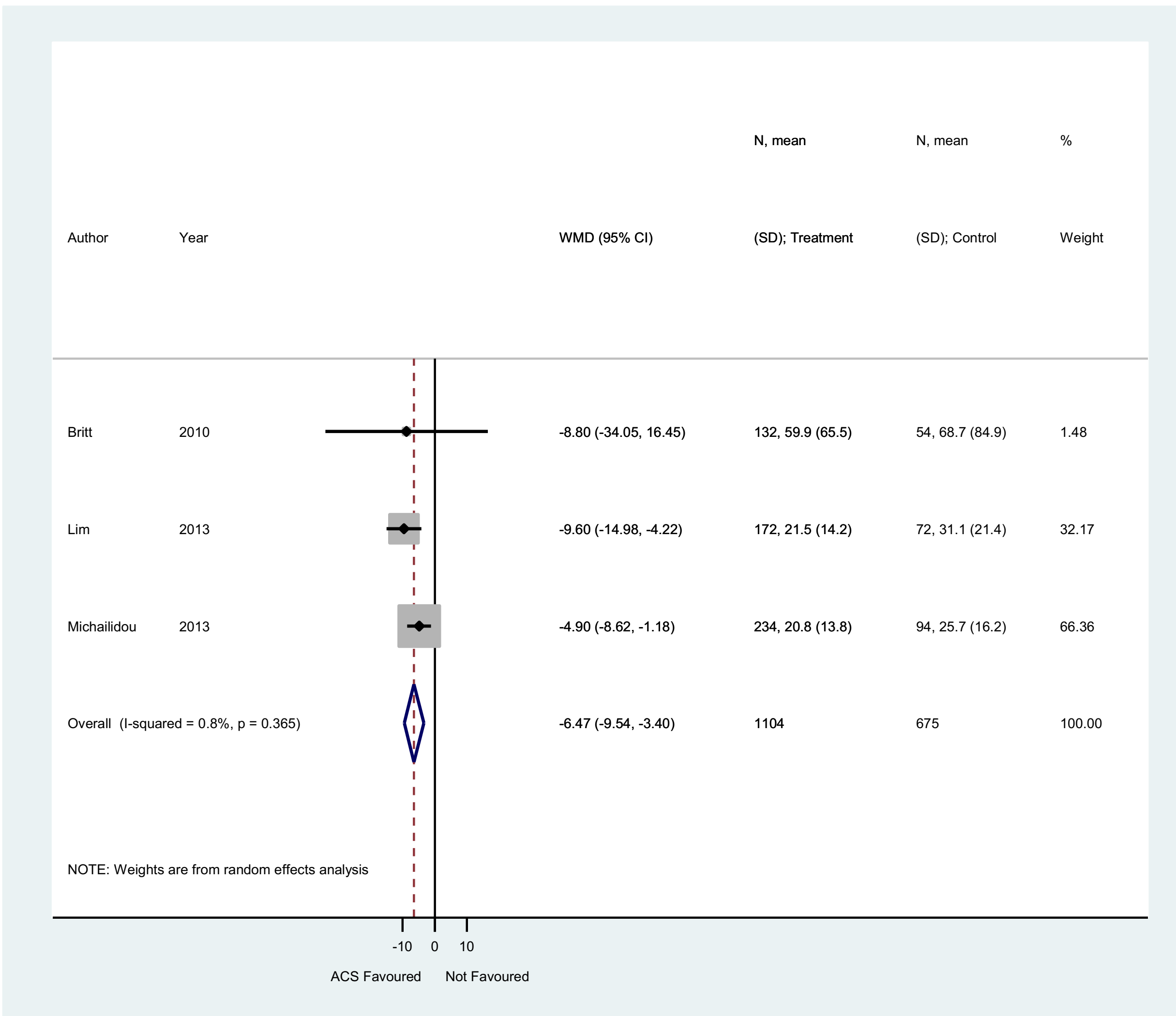

Figure II.7 Forest plot and pooled mean difference of the timing of admission to operation in cholecystectomy in ACS when compared the Pre-ACS model. ACS, acute care surgery

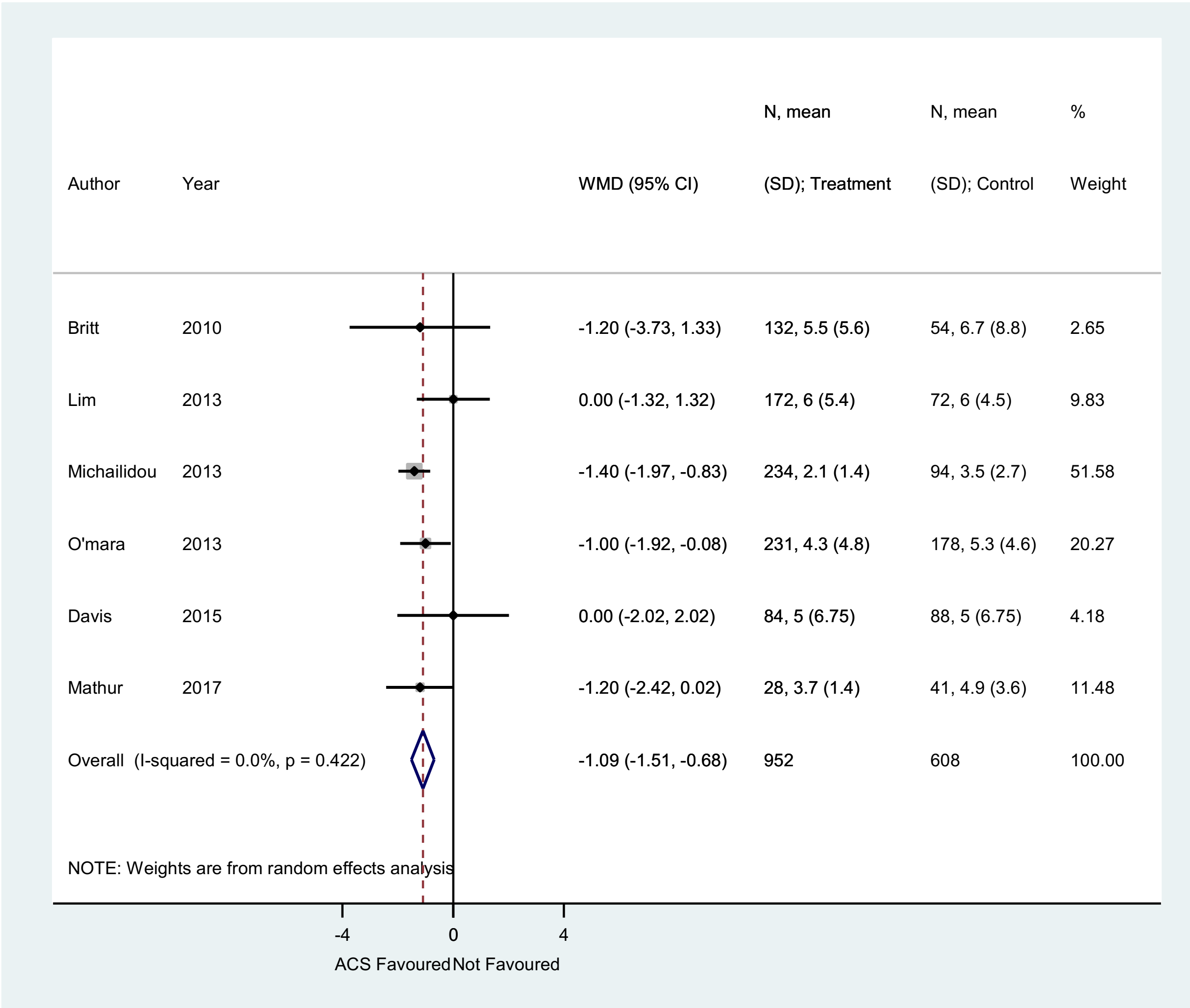

Figure II.8: Forest plot and pooled mean difference in LOS post cholecystectomy in ACS when compared to the Pre-ACS model. ACS, acute care surgery; LOS, length of stay.

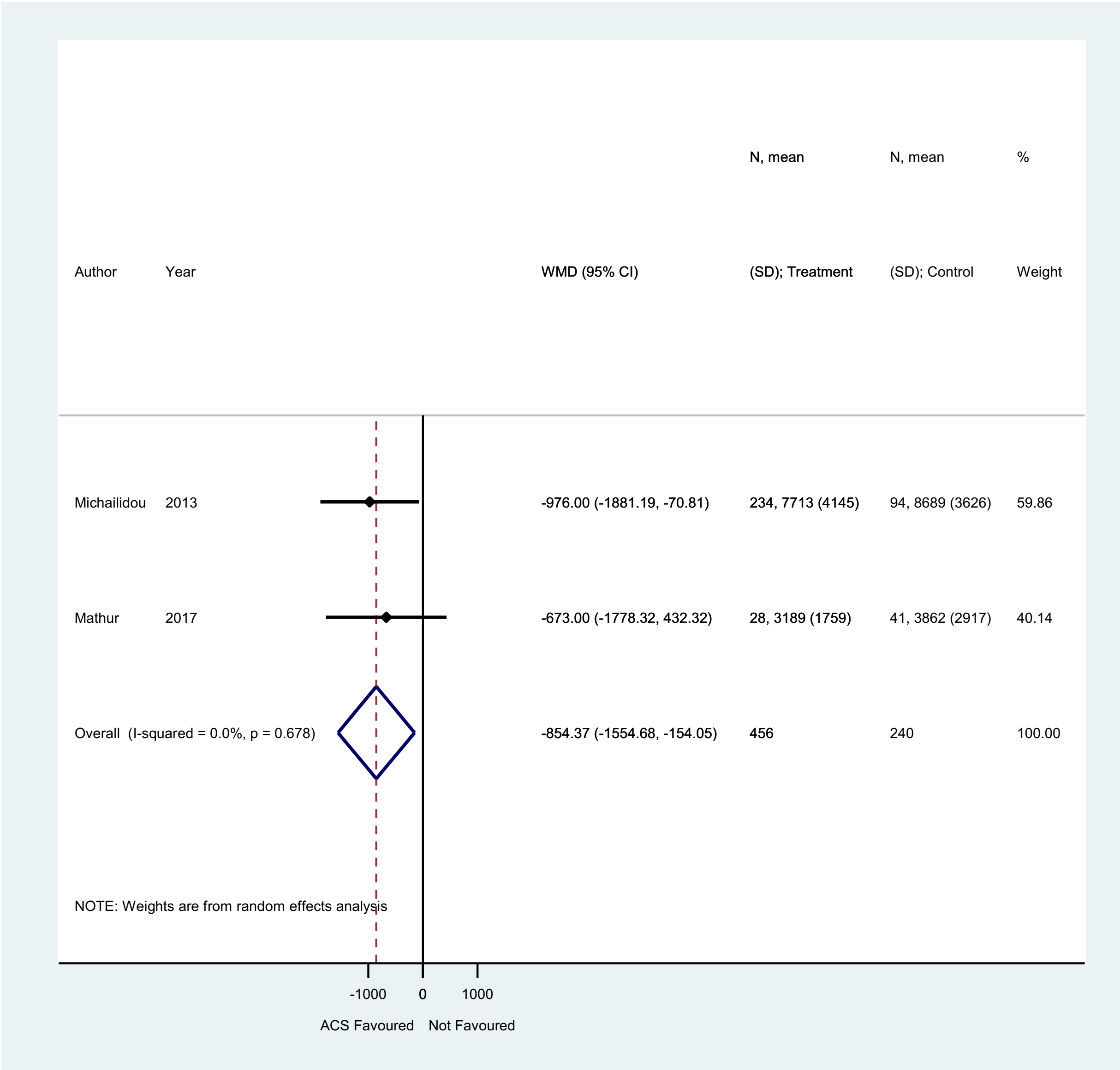

Figure II.9: Forest plot and pooled mean difference of cholecystectomy cost in ACS when compared to the Pre-ACS model. ACS, acute care surgery

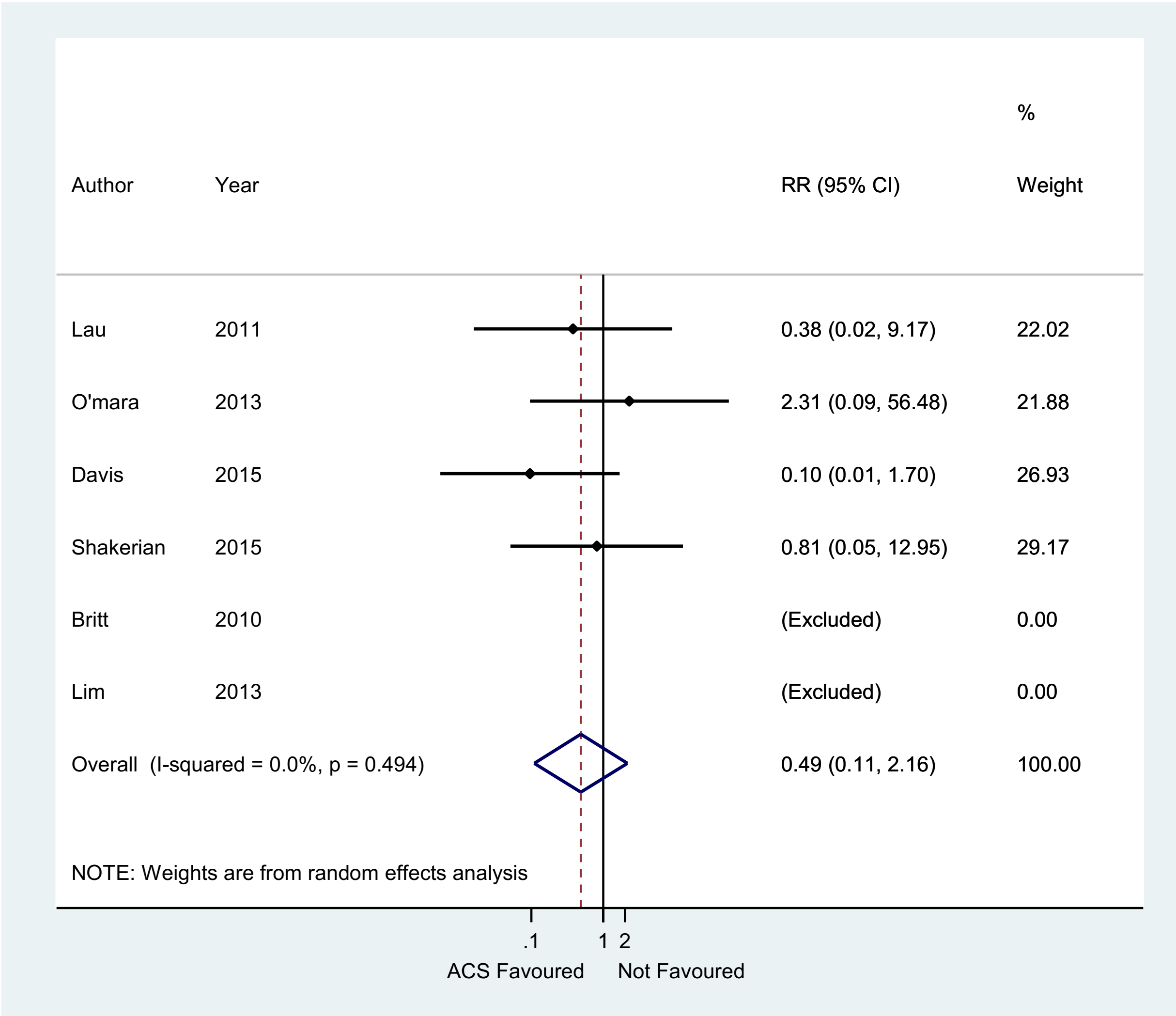

Figure II.10: Forest plot and pooled mean difference of cholecystectomy mortality in ACS when compared to the Pre-ACS model. ACS, acute care surgery.

Other measures like bile leak, bile duct injury, developing pancreatitis, conversion to open and readmission were also assessed. These analyses showed no statistical significant differences between Pre-and post-ACS models. Table II.4 summarizes these results.

Table II.4: Summary of risk ratios and mean difference of multiple measures of interest post cholecystectomy in ACS when compared to Pre-ACS. MD,mean difference; RR, relative risk; ACS, acute care surgery.

Measure of interest	Number of studies	Relative risk (RR) or mean difference (MD)	95% Confidence interval	Statistically significant? (P<0.05)	I^2	Favoring
Overall cholecystectomy complication	9	RR=0.62	0.41 to 0.94	Yes	63.5%	ACS
Timing of admission to operation (hours)	3	-6.46	-9.54 to -3.40	Yes	0.8%	ACS
Hospital Length of Stay (days)	6	-1.094	-1.51 to -0.68	Yes	0.0%	ACS
Cost (US $)	2	-854.37	-1554.1 to -154.05	Yes	0.0%	ACS
Bile leak	8	RR= 0.81	0.44 to 1.49	No	0.0%	-
Bile duct injury	7	RR= 1.07	0.28 to 4.19	No	0.0%	-
pancreatitis	4	RR= 1.30	0.35 to 4.83	No	0.0%	Pre-ACS
Laparoscopic to open	12	RR= 0.74	0.51 to 1.08	No	52.5%	ACS
Readmission	4	RR= 0.73	0.44 to 1.21	No	3.5%	ACS
Mortality	6	RR= 0.49	0.11 to 2.16	No	0.0%	ACS

Discussion

Acute care surgery was introduced in the mid-2000s to improve surgery access and quality of care for general surgical emergencies. The diversification created by surgical sub-specialization led to changes in priorities and preferences amongst practicing surgeons. Some sub-specialized surgeons became less comfortable in dealing with general surgical emergencies.(46, 47) Appendectomy and cholecystectomy are the two most common general surgical emergency procedures performed in the United States.(48) This paper systematically reviewed and meta-analyzed the effect of the ACS delivery model on appendectomy and cholecystectomy outcomes.

The present study is unique in providing a detailed search strategy and outlining inclusion/exclusion criteria and excluding papers with limited information such as abstracts and short papers. These papers were found to lack vitals methodologic information which in turn made quality assessment very challenging. Subgroup outcomes of interest were explored and analyzed. For example, the analysis on cost, mortality, bile duct injury and bile leak are to date unique to this meta-analysis. Risk ratio were deemed a more appropriate metric to report compared to odds ratios used in previous meta-analysis, simply due to the fact that included studies are before-and-after cohorts comparing traditional delivery models to ACS delivery models (ratio of two cohorts).

This study demonstrated a significant difference in overall complications, mean time to operate, mean time to admit and hospital length of stay for those receiving appendectomy and cholecystectomy under the ACS model. No statistical significance was detected for wound infection, abscess, conversion of laparoscopy to open, rate of negative appendectomy, after-hours, readmission and cost. A subgroup analysis was attempted on ACS services with dedicated emergency operating room and on ACS services that were run in conjunction with trauma.

Patients receiving appendectomy under ACS had 0.7 times the risk of developing complications (30% reduction) when compared to Pre-ACS (RR=0.7; 95% C.I 0.57 to 0.85). This result was statistically significant. The complication rate is a general standard measure of quality in surgical specialties and was not necessarily described in detail in the included studies. Of note, there were only a few studies that accurately defined complications in their methodology. Almost all papers reported an overall complication rate which was an aggregate rate and not necessarily defined. These publications were retrospective. In addition, studies varied in identifying complications due to the lack of standardized definitions. Respecting these limitations, ACS patients receiving cholecystectomy had 0.62 times the risk of developing complications (38% reduction) compared to the pre-ACS model (RR=0.62; 95% C.I 0.41 to 0.94). This observation was statistically significant. Generally speaking, complications, specifically gastrointestinal complications can be directly impacted by the age of the patient, co-morbidity status, type of procedure performed (49), but also indirectly by other measures like deficiency of surgical skills, inadequate access to emergency theater as well as the presence of a dedicated emergency team.(50) There is more than one component that could explain this observed reduction in both groups. This includes, for example, the organizational structure addressing patient flow from emergency registrations to ward admission, and subsequently to operation. The progressive increase in the utilization of laparoscopy may have affected these outcomes. It is also possible that the training between ACS staff differed. Surgeons with greater experience and interest in ACS emergencies may have improved judgment in managing these cases.

Multiple previous studies looked at hospital LOS under the ACS model, but reported conflicting opinions. Faryniuk et al(51), Cubas et al(21), and Early et al (18) demonstrated hospital LOS reduction among appendectomy cohort. Gandy et al(34), Ekeh et al(30) and Qureshi et al (29) showed no differences.

This meta-analysis demonstrated that the ACS model was associated with a statistically significant reduction in hospital LOS by a mean of 0.9 days in appendectomy cohort (95% C.I -1.32 to -0.49). This may be partially related to early hospital admission (1.37 hours earlier; 95% CI 1.93-0.80), and early operating time (2.51 hours earlier in ACS; 95% CI 4.44-0.58). A similar reduction was observed in LOS in cholecystectomy cohort by a mean 1.094 days (95% C.I -1.51 to -0.68).

The availability of a dedicated staff member for examining patients, ordering additional investigations, and making real-time clinical decisions significantly affects the patient's flow from emergency to the operating theater. Such findings were demonstrated previously in trauma care. For example, in some institutions, in-house attendings were associated with significant reductions in overall emergency and hospital LOS compared to out of house attendings.(52)

Future studies could explore if the presence of such dedicated teams for general surgery emergencies affected the relationship between emergency physicians and surgeons and whether it enhanced the patient flow in care delivery.

The ACS delivery model was associated with a reduction in cost (mean difference of 706.85 US$, 95% CI -706.58 to 6.7) among appendectomy patients but this was not statistically significant. This result should be interpreted cautiously, given that only three papers provided cost analysis (two favoring ACS(17, 28) and one showing no difference(26)) and may allude to potential publication bias. On the other hand, there was a significant reduction in ACS cholecystectomy cohort cost by a mean of 854.37 US $ (95% C.I -1554.1 to -154.05, I^2=0, P=0.678). We related those reductions to minimizing overall mean length of stay and overall complication rate.

We attempted a further subgroup analysis looking at the presence of dedicated morning operating theaters on complication rates and overall hospital LOS. Unfortunately, only a few papers specifically stated the presence or absence of a dedicated OR. We also attempted to assess whether providing a combined ACS and trauma service would result in outcome differences when compared to services providing ACS only. Such analysis was not possible given the limited number of studies in each subgroup.

Our results correlate well with previous studies, specifically the overall complication rate. This was reported as 14.5% in Pre-ACS and 10.9 % in ACS appendectomy cohort (OR 1.64, 95% CI 0.73 to 3.71). Murphy et al published similar results *(16).* He demonstrated a significant reduction in complication rates in appendectomy OR= 0.65 and cholecystectomy OR=0.5 favoring ACS. The present study also agrees with Murphy et al. in the reduction of LOS in both groups.

This meta-analysis carries several limitations. First, it is limited by the quality of the included content, as is typical of meta-analyses done in this topic. We were also restrained by available study details for data extraction. For instance, only a few studies confirmed the availability or absence of a dedicated emergency OR. If available, this would have been valuable data in the timeliness analysis. Other information that could be useful includes the presence of on-site staff and the training level of the operating staff (e.g. resident vs staff). Secondly, important definitions were missed in the included papers. Specifically, many papers reported “overall complication rates” without categorizing them. Lack of standardization limit the ability to compare papers.

Several complications were identified that were not significantly different when comparing the pre-ACS to the ACS era. These were wound infection, abscess collection, bile duct injury, bile leak and after-hours surgeries. Despite this, there was a significant reduced overall morbidity. Identification of which morbidities are associated with the overall morbidity requires additional study.

Jurisdictional variability in service was noticeable. Trauma is incorporated within the ACS model in the US, whereas ACS is a separate service from trauma in other jurisdictions. This can potentially affect different aspects of patient care such as earlier surgical review, hence intervention in the ACS-only group. Finally, many of the included studies were from a single center. All of these could be reasons for observing significant heterogeneity in our meta-analysis. Careful interpretation is warranted given these limitations.

Conclusion

The implementation of the ACS models in general surgery emergency care has significantly improved system, and patient outcomes for appendectomy and cholecystectomy. Improvements were clearly demonstrated in the overall complication rate, timeliness from ED to admission and to operation.

III. Chapter Three

A 30-day prospective audit of all acute care surgery (non-trauma) inpatient postoperative complications: How well do we really perform?

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Short Running Title: Acute care surgery postoperative complications

Author Disclosure Statement

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Keywords: Complications; postoperative; acute care surgery; emergency general surgery

Abstract

Background: Acute care surgery (ACS) demands timely care and intervention for some of our most challenging patients. These patients are often critically ill and carry both advanced comorbidities and poor physiologic reserve. Despite the explosion of ACS across North America, the true postoperative morbidity rates remain largely unknown.

Methods: Patients at 8 high volume, geographically diverse ACS centers underwent 30-day prospective evaluations following operative intervention whilst inpatients (or during readmissions). Preoperative, intraoperative and postoperative variables were tracked. descriptive statistics were used where applicable. T-test and chi square were utilized. ($p<0.05$=significant).

Results: A total of 601 ACS patients were followed for up to 30 inpatient or readmission days after their index emergent operation. Patients were most commonly female (51%), with a median age of 51 years and frequently significant medical comorbidities (42%) and obesity (15%). The majority of procedures were minimally invasive (66% laparoscopic) with a median length of stay of 3.3 days and an early readmission (< 30 days) rate of 6%. Admission to the critical care suite was 6%, with all-inclusive complication and mortality rates of 34% and 2% respectively. Cholecystitis (31%), appendicitis (21%), bowel obstruction (18%), incarcerated hernia (12%), gastrointestinal hemorrhage (7%) and soft tissue infections (7%) were the most common diagnoses. Open surgical procedures displayed morbidity and mortality rates of 73% and 5% respectively.

Conclusion: Non-trauma ACS operations are associated with a high postoperative morbidity rate. This study will serve as a prospective benchmark for ACS-related postoperative complications and subsequent quality improvement across our nation.

Introduction

It is clear to every acute care (ACS) and emergency general (EGS) surgeon that a significant proportion of our urgently ill patients demand both timely and complex surgical care to achieve optimal outcomes.(2, 8) Not surprisingly, postoperative morbidity and mortality remain a dominant source of both patient and surgeon distress. Although the occurrence of postoperative complications is often expected given the frequently critical nature and advanced comorbid state (i.e. poor physiologic reserve) of these patients, improvements in both patient and system care quality must continue to be a primary goal for any busy acute care surgery service.(53, 54) While precise morbidity and mortality rates are commonly reported for oncologic resections, trauma care,(55) and scheduled elective surgical interventions, much less is known about the true incidence of postoperative complications within the contemporary delivery of service based care for our ACS/EGS patient population.

Not only is a granular understanding of ACS/EGS postoperative complications essential to the realm of quality metrics, but it also critical to the creation and delivery of postoperative care pathways for many of our most common ACS/EGS diagnoses.

Given the absence of either detailed or comprehensive prospective morbidity and mortality data within the literature, the primary goal of this prospective study was to analyze all 30-day inpatient complications following ACS/EGS operative interventions at multiple high-volume centers.

Methods

All adult (≥16 years of age) patients who were admitted to an ACS/EGS service and subsequently underwent an operative intervention were prospectively audited on a daily basis. The total duration of inpatient follow-up was 30 days or until the patient was discharged home (or to a formal rehabilitation facility). Readmissions within a 30-day window were also captured. This 30-day study was carried out at various institutions between January 1, 2018 and July 31, 2018. A standardized comprehensive data capture form was utilized for all sites. Institutional ethics review board approval and formal data sharing agreements were required for each hospital. Participating centers included the Foothills Medical Center (Calgary), Rockyview General Hospital (Calgary), London Health Sciences Center (London), Vancouver General Hospital (Vancouver), University of Alberta Hospital (Edmonton), Montreal General Hospital (Montreal), Hamilton General Hospital and St. Joseph's Healthcare (Hamilton), and Queen Elizabeth II Health Sciences Centre (Halifax). Each of these centers is a large tertiary care, University affiliated, teaching hospital.

All complication definitions were standardized and agreed upon by the authorship group prior to initiation of the study. Specific definitions from the Centers for Disease Control (CDC) were utilized for pneumonia, blood stream infection, urinary tract infection, and surgical site infections (both superficial and deep). Definitions for acute kidney injury (abrupt (<48 hrs) reduction in kidney function (absolute increase in serum creatinine > or equal to 26.4 umol/L, a > 50% increase in serum creatinine or a reduction in UO less than 0.5 ml/kg per hour for more than six hours)), wound disruption (fascial or skin dehiscence), gastrointestinal anastomotic leakage (confirmed on cross-sectional imaging, fistulogram or evidence on re-intervention), deep venous thrombosis/pulmonary embolus (confirmed by imaging), prolonged ileus (lack of clinical bowel activity beyond the expected time frame), gastrointestinal or intraperitoneal hemorrhage, and organ failure were consistent across all study patients. Patient, disease and operative demographics were also evaluated.

Data are presented as means or medians where appropriate using descriptive statistics. Differences in demographic data and secondary measures between patient groups were assessed using a Chi-Squared analysis and student T-tests for categorical and scale data, respectively. An alpha significance level of .05 was set a priori. All statistical testing was performed using Stata/IC version 15.0 (Stata Corp., College Station, TX, U.S.A.).

Results

Amongst 8 centers from across Canada, a total of 601 patients (range: 52 to 96 patients per site) were prospectively audited following an operative intervention. Patient demographics were remarkably consistent across all sites (Table III.1) ($p>0.05$). Only the rate of obesity varied significantly between hospitals (2% to 26%)($p<0.05$). Diagnoses across sites were also similar (Table III.1) ($p>0.05$). Operative techniques were primarily laparoscopic amongst all sites (i.e. laparoscopic cholecystectomy and appendectomy ranging from 14% to 43% ($p<0.05$) and 5% to 28% ($p<0.05$) of total operative cases respectively across hospitals). The remaining laparoscopic cases included: bowel obstruction (lysis or release) (8%), hernia repair (7%), diagnostic endeavors (3%) and common bile duct exploration (1%).

Table III.1: Patient, disease and procedure demographics

Patients characteristics/Outcomes		95% confidence interval
Median age (years)	51 years	NA
Sex (Female)	51%	NA
Mean ASA	2	NA
Morbid obesity	15%	NA
Significant medical comorbidities	42%	NA
Final diagnosis:		
Cholecystitis	31%	(0.26- 0.33)
Appendicitis	21%	(0.17- 0.23)
Bowel obstruction	18%	(0.15- 0.24)
Incarcerated hernia	12%	(0.10- 0.15)
Gastrointestinal hemorrhage	7%	(0.06- 0.09)
Soft tissue infections	7%	(0.06- 0.08)
Other	4%	(0.03- 0.04)
Procedures:		
Laparoscopic technique	66%	(0.47- 0.69)
Laparoscopic cholecystectomy	30%	(0.28- 0.33)
Laparoscopic appendectomy	19%	(0.15- 0.22)
Other laparoscopy	17%	(0.14- 0.18)

Hospital performance across sites for postoperative complications was similar ($p>0.05$). Amongst surgical site infections, superficial (wound) infections comprised 69%. Laparoscopic cases also suffered less postoperative morbidity than open surgical procedures ($p<0.05$). Upon evaluation of only open cases, complication and mortality rates approximated 73% and 5% respectively (204 total open cases) ($p<0.05$).

Table III.2: Patient outcomes following surgical intervention

Patients outcomes		95% confidence interval
Mean intensive care unit admission	6%	NA
Median hospital length of stay (days)	3.3	NA
Early readmission rate (<30 days)	6%	NA
Overall mortality	2%	NA
Overall morbidity	34%	NA
Prolonged ileus	24%	(0.21- 0.29)
Surgical site infections	13%	(0.10- 0.15)
Superficial (Wound)	9%	(0.07- 0.11)
Deep (Organ space)	4%	(0.03- 0.06)
Aspiration (incl. aspiration pneumonia)	8%	(0.05- 0.09)
Hematoma	5%	(0.04- 0.07)
Delirium	4%	(0.02- 0.06)
Gastrointestinal hemorrhage	4%	(0.03- 0.06)
Urinary tract infection	4%	(0.01- 0.05)
Major cardiac events	4%	(0.02- 0.06)
Poor postoperative analgesia	2%	(0.01- 0.02)
Clostridial difficile colits	2%	(0.01- 0.02)
Deep venous thrombosis	2%	(0.01- 0.03)
Pulmonary embolus	1%	(0.01- 0.01)
Other	4%	(0.02- 0.05)

Discussion

Although the postoperative mortality rate amongst patients on ACS/EGS services across high volume centers was only 2%, morbidity was substantial and approximated 34%. This observation confirms retrospective NSQIP data highlighting a 33% postoperative morbidity rate.(12) When evaluating open surgical interventions in isolation (absence of laparoscopic cases), the complication rate increased to 73% (mortality = 5%). Given these observed high complication rates across centers of excellence, hospitals and health care systems that are willing to offer emergency on-call general surgical services must also contemplate both the associated financial costs and resource implications of treating these comorbid and significantly ill patients.

More specifically, ACS/EGS services must be appropriately resourced in all relevant areas to ensure timely and adequate patient care (access to the operating theater in an urgent manner, adequate manpower for clinical care (nurse practitioner(s) and/or resident house staff depending on the site), a dedicated inpatient ward for the bulk of ACS/EGS patients, focused attending surgeon coverage, and an acute pain service compliment). Although they represent the minority of total cases (34%), it is particularly clear amongst patients with non-cholecystitis and non-appendicitis diagnoses who also require an open surgical procedure that resource requirements are even higher.

While resource demands to ensure safe and excellent patient care for the ACS/EGS population are critical, improving quality and overall outcomes in these emergency surgical patients is also essential. In particular, tools such as the National Surgical Quality Improvement Process (NSQIP) are available both within and outside of the United States.[6] Despite their tremendous upfront financial cost, these aids allow both internal and external benchmark comparisons using standardized definitions of diagnoses and subsequent complications. As indicated in a multitude of publications,(16, 56-59) the financial and patient cost of postoperative complications remains substantial and concerning.

It is interesting to note that approximately two-thirds of all cases on busy ACS/EGS services utilized laparoscopy. While the vast majority of these procedures were cholecystectomy and appendectomy, application of this methodology to other instances (bowel obstructions, hernias, diagnosis) was also observed. Despite preceding debate on the role of traditional open appendectomy, it is also clear that nearly all patients with appendicitis amongst the observed centers underwent a laparoscopic approach. Benefits of the minimally invasive methodology are clear and it is encouraging that these rates may be increasing over time compared to preceding national publications.(60-63)

Although an ACS/EGS service within a busy hospital typically displays a wide variance in patient diagnoses and interventions, surgical procedures typically cluster around laparoscopic cholecystectomy, laparoscopic appendectomy, release of bowel obstructions, reduction of incarcerated hernias, arrest of gastrointestinal hemorrhage and drainage/debridement of soft tissue infections. These 'Big 6' areas of focus also represent the greatest opportunities for quality improvement. For example, many patients with acute appendicitis can now be treated and released from hospital in less than 24 hours as long as rapid access to the operating theater and programmatic fast track are available.(64, 65)

The dominant limitations of this project include: First, data was isolated to centres that expressed an interest in participating and therefore similar to preceding studies, (66) the possibility of participation bias cannot be eliminated. Given the relative similarity to large retrospective national database study however,(12) it is probable that these data apply well beyond the 8 participating centers. Second, although this project includes multiple centres from across a large country (Canada), smaller community hospitals may treat a very different case mix in regards to patient illness severity and required surgical procedures. As a result, this could limit the generalizability of these results to more remote areas within Canada who continue to provide emergency general surgical care; and lastly, despite the importance of formal surgical rescue (67) in determining the rate of mortality following patient complications, our national group was unable to reliably capture this data across all centres. We postulate that given the academic tertiary care nature of the participating centres however, that the low reported mortality rate (2%)

indirectly indicates reasonably good surgical rescue efforts for patients with significant postoperative complications.

Conclusion

Up to 34% of patients requiring an emergent surgical procedure within the context of a formal ACS/EGS service will suffer a postoperative complication. Amongst open surgical cases, this rate increases to 73%. Given the significant patient medical comorbidities and severe illness that many of these patients possess, appropriate hospital system resourcing and subsequent structured attempts at quality improvement are essential.

IV. Chapter Four

Conclusion

Acute Care surgery was introduced in the first decade of the twenty-first century to address issues regarding access and quality of emergency surgical assessment and management. Such a system was expected to improve different dimensions in health care. Anticipated benefits were not limited to patient care but also extended to potentially bettering surgeon's scheduling and life style and reducing burn-out. ACS is a new and evolving health care system and hence the full impact of such a service has not been well understood. The literature to date has provided limited information describing the morbidity and mortality associated with an ACS model of care.

This thesis began with a systematic review and meta-analysis of appendectomy and cholecystectomy in the ACS compared to the Pre-ACS era. These represent the most common procedures in emergency general surgery. This study was undertaken to provide a better understanding of ACS morbidity and other quality measures. The investigation began with the question, did the introduction of ACS affect patient outcomes significantly? The ACS model was associated with a significant reduction in the overall complication rate, hospital LOS and timing from admission to operation in appendectomies as well as cholecystectomies. The early assessment and management associated with ACS modules may have led to better outcomes and hence reduced hospital length of stay. ACS permits introduction of standardized care pathways which may lead to improved care. Dealing with the above acute conditions in a dedicated service, with the availability of experienced staff to provide immediate decisions likely has been responsible for the reported benefits. The progressive utilization of laparoscopy, is a confounder however and may have directly and indirectly affected the morbidity and LOS.

Unfortunately, the lack of robust retrospective studies detailing the methodology restricted the subgroup analysis and hence a few questions were not answered. These included the effect of running ACS with trauma and the effect of a dedicated daytime scheduled OR for the ACS.

Knowing that ACS has had a significant impact on the health system, the next question was how good are we? Understanding the precise morbidity and mortality rate is essential for quality improvement in any surgical specialty. To answer the above question, a 30 day multi-centre prospective study in high volume ACS centers (total of 8) across Canada was performed. The analysis was able to demonstrate the six most common diagnoses in ACS. Also, the study was able to provide a list of the most common morbidities associated with ACS procedures. These data will serve as a benchmark for ACS post-operative complications as well as for future quality improvement.

Despite the observed reduction in overall complications, LOS and cost reported in the meta-analysis, the prospective observational study demonstrated a persistent high rate of morbidity associated with laparoscopic (34%) and open (73%) procedures in ACS. These high acuity patients require a tremendous amount of hospital resources. These include, but are not limited to, structure (dedicated services), staffing and financial support. The description of the evolutionary effects of introducing ACS, as well as a robust prospective audit of the morbidity experienced by patients on ACS is an important step in understanding the ACS model. This work will inform future studies which evaluate benchmarking tools for ACS as well as priorities and effects of interventions aimed at improving outcomes in ACS.

V. References

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VI. Appendix

Table VI.1: Acute care surgery nomenclature around the world

Names of services	Country
acute care surgery	US, China, Thailand
emergency general surgery	Australia, Singapore
acute surgical unit	Australia, New Zealand
emergency general surgery	Australia, Singapore
acute care emergency surgical service ACESS	Canada
acute surgical model	Australia
acute care surgical unit	Australia
emergency surgical unit	Australia
acute care surgical model	Australia

Table VI.2: Newcastle Ottawa Scale assessment of the selected studies

Author name	Study type	Selection	Comparator	Outcome	Quality
Cubas et al [21]	Retrospective cohort	****	NA	**	good
Mathur et al [17]	Retrospective cohort	****	NA	**	good
O,Mara et al [22]	Retrospective cohort	****	NA	**	good
Poh et al [(23)]	Retrospective cohort	****	NA	**	good
Suen et al [(24)]	Retrospective cohort	****	NA	**	good
Fu et al [(25)]	Retrospective cohort	****	NA	**	good
Lancashiro et al[(26)]	Retrospective cohort	****	NA	**	good
Earley et al [(18)]	Retrospective cohort	****	NA	**	good
Pillai et al [(27)]	Retrospective cohort	****	NA	**	good
Schaetzl et al [(28)]	Retrospective cohort	****	NA	**	good

Qureshi et al [29]	Retrospective cohort	****	NA	**	good
Ekeh et al[30]	Retrospective cohort	****	NA	**	good
Brockman et al[31]	Retrospective cohort	****	NA	**	good
Beardsley et al [32]	Retrospective cohort	****	NA	**	good
Wright et al [33]	Retrospective cohort	****	NA	**	good
Gandy et al [34]	Retrospective cohort	****	NA	**	good
Noppakunsomboon et al[35]	Retrospective cohort	****	NA	**	good
Lim et al[36]	Retrospective cohort	****	NA	**	good
Britt et al[37]	Retrospective cohort	****	NA	**	good
Lau et al [38]	Retrospective cohort	****	NA	**	good
Davis et al[39]	Retrospective cohort	****	NA	**	good
Suhardja et al [40]	Retrospective cohort	****	NA	**	good
Shakerian et al [41]	Retrospective cohort	****	NA	**	good
Bokhari et al [42]	Retrospective cohort	****	NA	**	good
Michailidou et al [43]	Retrospective cohort	****	NA	**	good
Lehan et al [44]	Retrospective cohort	****	NA	**	good
Pepingco et al [45]	Retrospective cohort	****	NA	**	good

Table VI.3: EMBASE search strategy

1. acute care surger*.mp.
2. acute surgical unit.mp.
3. acute surgical model.mp.
4. acute care surgery.mp.
5. acute surgery unit.mp.
6. emergency surgical unit.mp.
7. emergency surgery unit.mp.
8. ACS model.mp.
9. limit 8 to abstracts
10. acute care surgical service.mp.
11. acute care surgery service.mp.
12. emergency surgical unit.mp.
13. acute care emergency surgical model.mp.
14. acute surgical model.mp.
15. acute surgery model.mp.
16. ASM.mp.
17. limit 16 to abstracts
18. emergency general surgery.mp.
19. EGS.mp.
20. limit 19 to abstracts
21. Acute Surgical Unit Model.mp.
22. Acute Care Emergency Surgical Service.mp.
23. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22
24. exp appendicitis/ or exp acute appendicitis/
25. appendicitis.mp.
26. Appendectomy.mp. or exp appendectomy/
27. Appendectom*.mp.
28. acute appendicitis.mp.
29. exp cholecystitis/
30. exp acute cholecystitis/
31. Cholecystitis.mp.
32. exp cholecystectomy/
33. exp laparoscopic cholecystectomy/
34. Cholecystectomy.mp.
35. 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34
36. 23 and 35

Table VI.3: Medline search strategy

1. acute care surger*.mp.
2. acute surgical unit.mp.
3. acute surgical model.mp.
4. acute surgery unit.mp.
5. emergency surgical unit.mp.
6. emergency surgery unit.mp.
7. (ACS adj model).mp.
8. acute care surgical service.mp.
9. acute care surgery service.mp.
10. emergency surgical unit.mp.
11. acute care emergency surgical model.mp.
12. acute surgical model.mp.
13. acute surgery model.mp.
14. ASM.mp.
15. emergency general surgery.mp.
16. EGS.mp.
17. Acute Surgical Unit Model.mp.
18. Acute Care Emergency Surgical Service.mp.
19. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18
20. exp Cholecystitis/21. exp Cholecystitis, Acute/22. exp Cholecystectomy/
23. exp Cholecystectomy, Laparoscopic/
24. Cholecystectomy.mp.
25. cholecystitis.mp.
26. exp Appendicitis/
27. Appendicitis.mp.
28. exp Appendectomy/
29. Appendectom*.mp.
30. acute appendicitis.mp.
31. gallbladder disease/su
32. 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31
33. 19 and 32