Complications of appendectomy and cholecystectomy in acute care surgery: A systematic review and meta-analysis

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INTRODUCTION: Acute care surgery (ACS) was initiated two decades ago to address timeliness and quality in emergency general surgery. We hypothesized that ACS has improved the management of acute appendicitis and biliary disease.

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 ACS implementation, were performed.

RESULTS: Of 1,704 studies, 27 were selected for analysis (appendicitis, 16; biliary pathology, 7; both, 4). Following ACS introduction, the complication rate was significantly reduced in both appendectomy and cholecystectomy (risk ratios, 0.70; 95% confidence interval [CI], 0.57–0.85; I^2 = 9.2% and relative risk, 0.62; 95% CI, 0.41–0.94; I^2 = 63.5%) respectively. 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; −2.51 hours: 95% CI, −4.44 to −0.58) in the appendectomy cohort. Time to operation was shorter in the cholecystectomy group (−6.46 hours; 95% CI, −9.54 to −3.4). Length of hospital stay was reduced in both groups (appendectomy, −0.9 day; cholecystectomy, −1.09 day). There was a reduction in overall cost in cholecystectomy group (−US $854.37; 95% CI, –1,554.1 to −154.05). No statistical significance was detected for wound infection, abscess, conversion of laparoscopy to open technique, rate of negative appendectomy, after hours, readmission, and cost.

CONCLUSION: The implementation of ACS models in general surgery emergency care has significantly improved system and patient outcomes for appendicitis and biliary pathology. (*J Trauma Acute Care Surg.* 2020;89: 576–584. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Systematic review and meta-analysis of a retrospective study, level III.

KEY WORDS: Appendectomy; cholecystectomy; general surgery; emergencies; emergency service, hospital.

Emergency general surgery represents both a significant hospital caseload and burden of disease. Patients undergoing emergency general surgery are at substantial risk of both major morbidity and mortality. Appendectomy and cholecystectomy are the two most commonly performed procedures within an acute care surgery (ACS) service.[1]

Previous studies have shown that emergency general surgery procedures are associated with a mortality rate approximating 12.5.[2] Furthermore, 33% of emergency general surgery patients have postoperative complications, and 15% require readmission.[2–4]

Acute care surgery is defined as a dedicated service responsible for the urgent assessment and management of general surgical emergencies.[5] Acute care surgery models were introduced in the mid-2000s to address issues regarding access and quality of emergency surgical assessment and management.

The structure of an ACS service varies between institutes and jurisdictions. Acute care surgery is usually interpreted as urgent assessment and management of surgical emergencies in adults excluding trauma cases. In some jurisdictions, however, including some US hospitals, trauma care is incorporated into the service with general surgical emergencies.[5,6] Acute care surgery often 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 or conflicting clinical duties. Potential benefits include creating predictable scheduling for surgeons, the absence of overlapping elective and emergency duties, improved distribution of operating theaters, and, most importantly, superior quality of both patient care and follow-up.[5]

The implementation of ACS has been studied primarily in multiple single-center studies across the world; however, the full impact of this delivery model has not been fully defined. This is in part because ACS is within its first decade of implementation, and the model continues to further evolve.[7,8] This study will assess the impact of adopting an ACS service.

As a result, the primary objective of this study was to provide an analysis of the complications of appendectomy and cholecystectomy before and after implementation of the ACS model. The secondary objective was to provide data about the efficacy of ACS in reducing hospital stay, time to operation, and cost.

PATIENTS AND METHODS

Inclusion and Exclusion Criteria

Studies comparing patient outcomes following appendectomy and cholecystectomy before and after ACS implementation with a defined implementation date were included. Studies reporting elective or scheduled cholecystectomy or appendectomy, nonhuman subjects, case series, case reports, meta-analyses, systematic reviews, letters, or conference abstracts were excluded.

Outcomes

The primary outcome measures were mortality (cholecystectomy), overall complication rates, time from emergency presentation to admission, time from admission to operating theater, cost of hospitalization, and hospital length of stay (LOS).

Search Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-analyses guideline was followed for this systematic review.[9] The literature search process was conducted in three stages to ensure that all relevant studies were included. The primary search was conducted in one database, followed by

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refinement of search words and Medical Subject Headings (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 articles. The searches were conducted in the following databases: Ovid Medline, Embase, Cochrane Central Register of Controlled Trials, and Google Scholar. The databases were searched from inception to December 2017.

Nomenclature describing 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, ACS service, surgeon of the week, emergency surgical unit, and emergency general (Supplemental Digital Content 1, Supplementary Table 1, https://links.lww.com/TA/B740). This was combined with different terminologies used to describe the two procedures studied (appendicitis/appendectomy and cholecystitis/gallbladder disease/cholecystectomy). Boolean operator (*and* and *or*) was used. MeSH terms and text words were used to include all possible studies. A detailed study strategy is included in Supplemental Digital Content 2 (Supplementary Tables 3 and 4, http://links.lww.com/TA/B741).

After removing all duplicates, the two data analysts (O.A.B. and S.L.) independently screened all titles and abstracts. Studies with raw data comparing post-ACS with the traditional on-call model (pre-ACS) and a defined transition date, and discussing either acute appendectomy or cholecystectomy were included regardless of the specific year of ACS adoption. We excluded all elective or scheduled cholecystectomy or appendectomy studies, as well as publications involving nonhuman 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, articles that used representative or selected samples, such as the American College of Surgeon's National Surgical Quality Improvement Program, 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 (J.B.K.). κ Coefficient was calculated for interrater reliability. Newcastle Ottawa score was used to assess the quality of studies. Citations from all databases were managed by Endnote X7 (Clarivate, Philadelphia, Pennsylvania).

Data Extraction

Following the abstract review, the full article reviews along with data extraction was carried out. A standardized extraction data sheet was used to record 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 the study was conducted, 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 article, specifically the name of the services and if the study managed trauma and ACS patients.

A literature review identified the most commonly encountered complications in surgical practice.[7,8,11,17] These were the following: pneumonia, respiratory failure, effusion, myocardial infarction, ileus, deep vein thrombosis, pulmonary embolism, 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 abstracted: estimated blood loss, rate of conversion from laparoscopic to open, hospital LOS, and mortality.

Operating time, the time from emergency to admission, and the time from admission to operating theater were collected. Cost of hospital stay was standardized to US dollars (at December 2017 rate) given that most articles were 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, the data were excluded from analysis.

For those articles that discussed more than one procedure, we restricted data collection to the procedure of interest (appendectomy and cholecystectomy). For articles that analyzed more than one era of ACS with traditional on-call, we used the first duration to standardize its inclusion with other publications given that the ACS service was fully implemented.

Study Quality Assessment

According to latest systematic review, there are more than 194 tools available to assess the risk of bias in nonrandomized studies.[37] Cochrane collaboration recommended two main systems of assessment. These are the Down and Black instrument and the Newcastle-Ottawa Scale (NOS).[38] The NOS was selected because it is the most commonly used in the literature and has the ability to account for nonrandomized studies. The three domains of NOS are selection, comparability, and outcome. Rating was performed by two researchers independently (O.A.B. and S.L.). 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 relative risk (RR) and weighted mean difference (MD) 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 (StataCorp LLC, College Station, TX) 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), and the Cochrane Central Register of Controlled Trials databases and through bibliographic reference searching. Of these records, 218 were found to be duplicates. After screening these records, a total of 50 articles were found to be eligible for full article review (interrater κ, 0.9139). Among these, 23 articles were excluded. Exclusions were for the following reasons: eight were conference abstracts, four were either letters or brief reports that lacked vital information, three did not compare pre-ACS and post-ACS, four lacked major information about the specific procedure studies in our article, and four did not use hospital data but rather used representative sample that covers more than one hospital with different ACS service theme or timing. A total of 27 articles were included for qualitative analysis (interrater κ, 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 (Fig. 1).

Study Characteristics

Tables 1 and 2[10–36] provide characteristics of the 27 studies identified for the systematic review. A total of 16 articles (59.3%) reported specifically on appendectomy, 7 articles (25.9%) reported on cholecystectomy, and 4 articles (14.8%) reported on both outcomes. The identified articles were distributed as follows: 9 articles from the United States, 11 from Australia, 3 from Canada, 1 from Singapore, and 1 from China, New Zealand, and United Kingdom, respectively. A total of eight studies (30.7%) identified that ACS incorporated trauma into its services. These articles were mainly completed in the United States and Australia. Table 2 provides extended characteristics of the included studies.

Study Quality Assessment (Risk of Bias in Individual Studies)

The application of a modified NOS on the 27 articles demonstrated that all studies were of good quality (Supplemental Digital Content 3, Supplementary Table 2, http://links.lww.com/TA/B742).

Outcome Measures

Appendectomy

Among patients who underwent appendectomy within the post-ACS model, the pooled RR of developing complications was 0.7 times the risk of developing complications in those receiving the same procedure under the pre-ACS model (RR, 0.70; 95% confidence interval [CI], 0.57–0.85; I^2 = 9.2%) (Supplemental Digital Content 4, Supplementary Fig. 1, http://links.lww.com/TA/B743).

The analysis identified a statistically significant difference in the time from emergency department arrival to surgical ward admission. This difference favored the ACS model with an MD of −1.37 hours (MD, −1.37; 95% CI, −1.93 to −0.80; I^2 = 90.5; p = <0.001) (Supplemental Digital Content 5, Supplementary Fig. 2, http://links.lww.com/TA/B744). Significant heterogeneity was also observed.

Similar analysis was performed on timeliness between ward admission to operation time. There was a statistical significance in favor of ACS in his analysis, with a mean time difference of −2.51 hours (MD, −2.51; 95% CI, −4.44 to −0.58; I^2 = 91.5%; $p < 0.001$) (Supplemental Digital Content 6, Supplementary Fig. 3, http://links.lww.com/TA/B745).

The ACS model cohort showed a significant reduction in hospital LOS. The MD was 0.9 days less in post-ACS compared with pre-ACS (MD, 0.9; 95% CI, −1.32 to −0.49; I^2 = 72.5%;

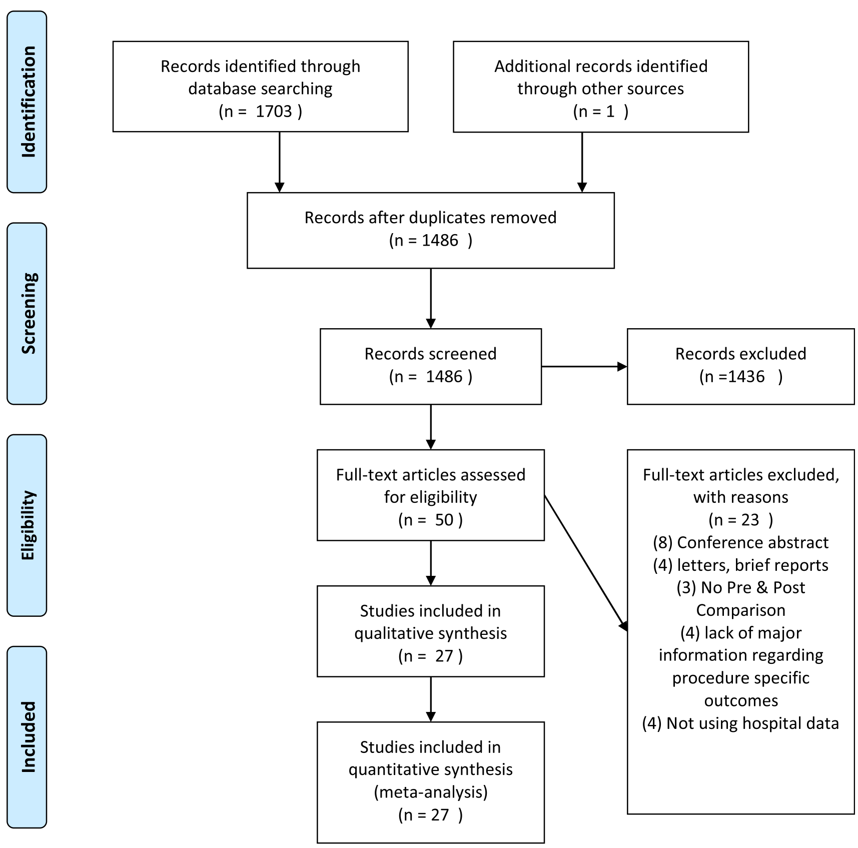

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses flowchart of the studies included in the study.

TABLE 1. Characteristics of the Included Studies

Author Name	Year	Country	Diagnosis	Sample Size	
				Pre	Post
Cubas et al.[10]	2012	United States	Acute appendicitis	82	92
			Biliary disease	51	62
Mathur et al.[11]	2017	Singapore	Acute appendicitis	176	188
			Biliary disease	41	28
O'Mara et al.[12]	2013	Australia	Acute appendicitis	196	201
			Biliary disease	178	231
Poh et al.[13]	2013	Australia	Appendicitis	256	283
Suen et al.[14]	2014	Australia	Appendicitis	276	399
Fu et al.[15]	2013	China	Appendicitis	146	159
Lancashiro et al.[16]	2014	Australia	Appendicitis	247	301
Earley et al.[17]	2006	United States	Appendicitis	127	167
Pillai et al.[18]	2013	New Zealand	Appendicitis	875	982
Schaetzl et al.[19]	2016	United States	Appendicitis	440	505
Qureshi et al.[20]	2011	Canada	Appendicitis	169	136
Ekeh et al.[21]	2008	United States	Appendicitis	273	279
Brockman et al.[22]	2013	Australia	Appendicitis	351	357
Beardsley et al.[23]	2013	Australia	Appendicitis	84	66
Wright et al.[24]	2013	United States	Appendicitis	526	345
Gandy et al.[25]	2010	Australia	Appendicitis	176	226
Noppakunsomboon et al.[26]	2017	Thailand	Appendicitis	344	347
Lim et al.[27]	2013	Canada	Acute cholecystitis	72	172
Britt et al.[28]	2010	United States	Biliary disease	54	132
Lau and DiFronzo[29]	2011	United States	Acute cholecystitis	81	71
Davis et al.[30]	2015	United States	Acute cholecystitis	88	84
Suhardja et al.[31]	2015	Australia	Biliary disease	179	163
Shakerian et al.[32]	2015	Australia	Biliary disease	254	312
Bokhari et al.[33]	2016	United Kingdom	Acute cholecystitis	33	68
Michailidou et al.[34]	2013	United States	Acute cholecystitis	94	234
Lehan et al.[35]	2010	Australia	Acute cholecystitis	87	115
Pepingco et al.[36]	2012	Australia	Acute cholecystitis	114	157

$p < 0.006$) (Supplemental Digital Content 7, Supplementary Fig. 4, http://links.lww.com/TA/B746; Table 3). There were insufficient data for cost analysis for appendectomy.

Cholecystectomy

The analysis demonstrated that the pooled RR of developing complications among those receiving cholecystectomy within the ACS model is 0.62 times the risk of developing complications in those receiving the same procedure under the pre-ACS model. This translated into a 38% risk reduction in overall risk of complications under the ACS model (RR, 0.62; 95% CI, 0.41–0.94) (Supplemental Digital Content 8, Supplementary Fig. 5, http://links.lww.com/TA/B747).

The time to operation was reduced by 6.46 hours in the post-ACS group (MD, −6.46; 95% CI, −9.54 to −3.4; $I^2 = 0.8\%$; $p = 0.365$) (Supplemental Digital Content 9, Supplementary Fig. 6, http://links.lww.com/TA/B748). Mean hospital LOS in days was significantly reduced by 1.09 days in post-ACS cohort (mean days, −1.09; 95% CI, −1.51 to −0.68; $I^2 = 0.0\%$; $p = 0.422$) (Supplemental Digital Content 10, Supplementary Fig. 7, http://links.lww.com/TA/B749). The cost analysis showed a significant reduction in the cost by a mean of US $854.37 (MD, −854.37; 95% CI, −1,554.1 to −154.05; $I^2 = 0$; $p = 0.678$) (Supplemental Digital Content 11, Supplementary Fig. 8, http://links.lww.com/TA/B751).

The ACS group had a 51% reduction in mortality postoperatively when compared with pre-ACS, but this was not statistically significant (RR, 0.49; 95% CI, 0.11–2.16; $I^2 = 0\%$; $p = 0.494$) (Supplemental Digital Content 12, Supplementary Fig. 9, http://links.lww.com/TA/B750). Similarly, readmission rate was reduced by 27% in ACS when compared with pre-ACS, but this was not significant (RR, 0.73; 95% CI, 0.44–1.21).

Other outcome measures such as bile leak, bile duct injury, pancreatitis, conversion to open, and readmission were also assessed. These analyses showed no statistically significant differences between pre-ACS and post-ACS models (Table 4).

DISCUSSION

This study demonstrated a significant difference in overall complications, mean time to operate, mean time to admission, and hospital LOS for those receiving appendectomy and cholecystectomy within the post-ACS model. No statistical significance was detected for wound infection, abscess formation, conversion of laparoscopy to open techniques, rate of negative appendectomy, after-hours time frame, readmissions, and cost.

TABLE 2. Extended Characteristics of the Included Studies

Author Name	Diagnosis	Using Laparoscopy		Mean ± SD Age		Mode of Service
		Pre	Post	Pre	Post	
Cubas et al.[10]	Acute appendicitis	—	—	35 ± 17	34 ± 17	ACS
	Biliary disease	—	—	38 ± 17	40 ± 19	ACS
Mathur et al.[11]	Acute appendicitis	—	—	50 ± 19	51 ± 19	ACS and trauma
	Biliary disease			50 ± 19.5	51 ± 19	ACS and trauma
O'Mara et al.[12]	Acute appendicitis	85	82	—	—	ACS
	Biliary disease	99	99	—	—	ACS
Poh et al.[13]	Appendicitis	97.6	96.1	31.5 ± 0.8	31.8 ± 0.89	ACS
Suen et al.[14]	Appendicitis	—	—	30.6 ± 13.8	31.4 ± 14.3	ACS
Fu et al.[15]	Appendicitis	—	—	41.3 ± 16.9	43.8 ± 29	ACS and trauma
Lancashiro et al.[16]	Appendicitis	96.8	98.3	29.5 ± 14.8	28.5 ± 13.93	ACS
Earley et al.[17]	Appendicitis	10	6.5	37 ± 15	30 ± 12	ACS and trauma
Pillai et al.[18]	Appendicitis	79	87.9	28.7 (15–100)	27.9 (14.7–88.1)	ACS
Schaetzl et al.[19]	Appendicitis	98	99	—	—	ACS
Qureshi et al.[20]	Appendicitis	—	—	57 ± 21	57 ± 21	ACS
Ekeh et al.[21]	Appendicitis	66.6	84.6	36.8 ± 16.5	35.8 ± 16.5	ACS and trauma
Brockman et al.[22]	Appendicitis	75	78	25.6	26	ACS
Beardsley et al.[23]	Appendicitis	NA	NA	30 (16–72)	29 (16–97)	ACS
Wright et al.[24]	Appendicitis	322	286	38.2 ± 17	36.0 ± 15.3	ACS and trauma
Gandy et al.[25]	Appendicitis	11	40	33.6	32.8	ACS
Noppakunsomboon et al.[26]	Appendicitis	—	—	40 ± 20	39 ± 19	ACS
Lim et al.[27]	Acute cholecystitis	80.6	78.8	49.7	51.2	ACS
Britt et al.[28]	Biliary disease	76	80	50.2	44.4	ACS
Lau and DiFronzo[29]	Acute cholecystitis	—	—	46.7	45.7	ACS
Davis et al.[30]	Acute cholecystitis	49	55	54 ± 32	60 ± 22	ACS
Suhardja et al.[31]	Biliary disease	—	—	53.1 (18–101)	54.5 (16–95)	ACS
Shakerian et al.[32]	Biliary disease	—	—	64 (17–96)	52.5 (17–91)	ACS and trauma
Bokhari et al.[33]	Acute cholecystitis	100	100	49 (16–87)	53 (22–82)	ACS
Michailidou et al.[34]	Acute cholecystitis	—	—	39.5 ± 15	38.1 ± 16	ACS
Lehan et al.[35]	Acute cholecystitis	81.6	91.3	50 ± 19.5	47 ± 17	ACS
Pepingco et al.[36]	Acute cholecystitis	—	—	44.4 M	45.1 M	ACS and trauma

M = Median.

A subgroup analysis was attempted on ACS services with dedicated emergency operating room availability and on ACS services that were inclusive of trauma care.

Acute care surgery was introduced in the mid-2000s to improve access to surgery and the quality of care for general surgical emergencies. This diversification created by surgical

TABLE 3. Summary of Risk Ratios and MDs of Multiple Measures of Interest Postappendectomy in ACS When Compared With Pre-ACS

Measure of Interest	No. Studies	RR or MD	95% CI	Statistically Significant? ($p < 0.05$)	I^2	Favoring
Overall complication	8	RR, 0.70	0.57 to 0.85	Yes	9.2%	ACS
Timing of ED arrival to admission, h	4	MD, −1.37	−1.93 to −0.80	Yes	90.5%	ACS
Timing of admission to operation, h	5	MD, −2.51	−4.44 to −0.58	Yes	91.5%	ACS
Hospital LOS, d	5	MD, −0.90	−1.32 to −0.49	Yes	72.5%	ACS
Wound infection	7	RR, 0.70	0.49–1.00	No	0.0%	ACS
Abscess	6	RR, 1.13	0.76–1.70	No	16.2%	Pre-ACS
Laparoscopic to open	6	RR, 0.98	0.46–2.09	No	50.5%	—
Negative appendectomy	10	RR, 1.01	0.81–1.25	No	60.1%	—
After hours surgery	8	RR, 0.94	0.79–1.12	No	89.3%	—
Readmission	6	RR, 1.16	0.86–1.56	No	0.0%	Pre-ACS
Cost	3	MD, −350.07	−706.85 to 6.70	No	60.8%	ACS

ED, emergency department.

TABLE 4. Summary of Risk Ratios and MD of Multiple Measures of Interest Postcholecystectomy in ACS When Compared With Pre-ACS

Measure of Interest	No. Studies	RR or MD	95% CI	Statistically Significant? ($p < 0.05$)	I^2	Favoring
Overall cholecystectomy complication	9	RR, 0.62	0.41–0.94	Yes	63.5%	ACS
Timing of admission to operation, h,	3	−6.46	−9.54 to −3.40	Yes	0.8%	ACS
Hospital LOS, d	6	−1.094	−1.51 to −0.68	Yes	0.0%	ACS
Cost, US $	2	−854.37	−1,554.1 to −154.05	Yes	0.0%	ACS
Bile leak	8	RR, 0.81	0.44–1.49	No	0.0%	—
Bile duct injury	7	RR, 1.07	0.28–4.19	No	0.0%	—
pancreatitis	4	RR, 1.30	0.35–4.83	No	0.0%	Pre-ACS
Laparoscopic to open	12	RR, 0.74	0.51–1.08	No	52.5%	ACS
Readmission	4	RR, 0.73	0.44–1.21	No	3.5%	ACS
Mortality	6	RR, 0.49	0.11–2.16	No	0.0%	ACS

subspecialization led to changes in priorities and preferences among practicing surgeons. Some subspecialized surgeons also became less comfortable with general surgical emergencies.[39,40] Appendectomy and cholecystectomy represent the two most common general surgical emergency procedures performed in the United States.[41] This analysis systematically reviewed and meta-analyzed the effect of the ACS delivery model on patient outcomes for appendectomy and cholecystectomy.

The present study is unique in providing a detailed search strategy and outlining inclusion/exclusion criteria (excluding articles with limited information such as abstracts and short articles). As a collective, these publications often lacked vital methodologic information, which in turn made quality assessment challenging. Subgroup outcomes of interest were explored and analyzed. For example, the analysis on cost, mortality, bile duct injury, and bile leak are unique to this meta-analysis. Risk ratio was deemed a more appropriate metric when compared with odds ratios used in previous meta-analysis (i.e., because included studies are before-and-after cohort constructions comparing traditional delivery models to ACS delivery structures [ratio of two cohorts]). Patients receiving appendectomy within the ACS format displayed a statistically significant 0.7 times the risk of developing complications (30% reduction) when compared with pre-ACS.

Complication rates are a standard measure of quality in surgical specialties. These were not described in detail among many of the included studies. Of note, there were only a few studies that accurately defined complications within their methodology. Almost all articles reported an overall retrospective complication rate, which was an aggregate and not necessarily well defined. In addition, studies varied in identifying complications because of the lack of standardized definitions. Respecting these limitations, ACS patients receiving cholecystectomy displayed a 0.62 times risk of developing complications (38% reduction) compared with the pre-ACS model. This observation was statistically significant. Generally speaking, complications can be directly impacted by the age of the patient, comorbidity status, and type of procedure performed[42] but also indirectly by other measures such as deficiency of surgical skills, inadequate access to emergency theater, and the presence of a dedicated emergency team.[43]

There are several components that could explain the observed reduction in both groups. These include the organizational structure addressing patient flow from emergency registrations to ward admission, and subsequently to operation. Variation in defining time of arrival to the emergency department and time of admission may limit comparison between studies. Acute care surgery adoption has been accompanied by the development and implementation of standardized surgical techniques and care pathways (e.g., enhanced recovery after surgery), which may expedite care processes and improve outcomes. One recent study demonstrated an increase in the rate of computed axial tomography scans (CTs) performed to diagnose appendicitis in less than 2 hours from 3% to 42% after adoption of a standard care pathway within and ACS.[44]

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 dedication in managing these cases.

Multiple previous studies evaluated hospital LOS within the ACS model. Reports were conflicting however. Faryniuk et al.,[45] Cubas et al.,[10] and Earley et al.[17] demonstrated a reduced hospital LOS within the appendectomy cohort. Gandy et al.,[25] Ekeh et al.,[21] and Qureshi et al.[20] showed no significant 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 for appendectomy cohort. This is likely related to early hospital admission and an earlier operation. A similar reduction was observed in the LOS for the cholecystectomy cohort.

The availability of a dedicated faculty member for examining patients, ordering additional investigations, and making real-time clinical decisions significantly affects the patient's flow from the emergency department to the operating theater. Such findings have been previously demonstrated within trauma care. For example, in some institutions, in-house attendings were associated with significant reductions in overall emergency and hospital LOS.[46] Future studies could explore whether the presence of such dedicated teams for general surgery emergencies affects the relationship between emergency physicians and surgeons, and whether this model would enhance patient flow in care delivery.

The ACS delivery model was associated with a reduction in cost among appendectomies, but this was not statistically significant. This result should be interpreted cautiously, given that only three articles provided a cost analysis, two favoring ACS[11,19] and one showing no difference.[16] Interestingly, there was a significant reduction in the ACS cholecystectomy cohort cost. These reductions reflect minimizing overall mean LOS and complication rates. The costs were not adjusted for inflation over time. Inflation averaged more than 2.5% in high-income countries over the study period. As a result, the magnitude of the cost reduction post-ACS adoption may be greater than reported.

A further subgroup analysis evaluated the impact of dedicated operating theaters on complication rates and overall hospital LOS. Unfortunately, only a few publications specifically stated the presence or absence of a dedicated and available operating theater. An attempt also was made to assess whether providing a combined ACS and trauma service would result in outcome differences when compared with services providing ACS only. This was not statistically possible given the limited number of studies within each subgroup.

The results of this meta-analysis correlate well with previous studies. The overall complication rate was 14.5% in the pre-ACS and 10.9% in ACS appendectomy cohort (odds ratio [OR], 1.64); Murphy et al.[8] published similar results. This group 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.[8] in the reduction of LOS among both groups.

This meta-analysis possesses several limitations. First, it is limited by the quality of the included content. The study was also restrained by available details for data extraction. For instance, only a few studies confirmed the availability of a dedicated emergency operating theater. Adoption of ACS may therefore has been accompanied by dedicated emergency OR time. If the information regarding dedicated OR time was available, this would have been valuable in the timeliness analysis. Other information that would have been extremely useful includes the presence or absence of on-site faculty and the training level of the operating staff (e.g., resident vs. staff).[47] An increased proportion of surgeries in ACS may have been performed by attending surgeons experienced in emergency general surgery. Second, important definitions were omitted within the included publications. Specifically, many articles reported "overall complication rates" without categorizing them in any detail. The reasons for readmission were not consistently defined across studies. Although publications that described scheduled or elective surgery were excluded, the cholecystectomies performed in the ACS studies would have included a spectrum of disease from recurrent biliary colic to severe cholecystitis. Lack of standardization limited our ability to compare publications.

Several complications that were not significantly different when comparing the pre-ACS to post-ACS era were identified. These included superficial surgical site/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 many centers in the United States, whereas ACS is a separate service from trauma in many other jurisdictions. This can potentially affect different aspects of patient care, such as earlier surgical review and intervention in the ACS-only group. Studies varied in the schedule of attending physician coverage from 1-week assignments (with variable nighttime relief) to 24-hour assignments. Variations with two or three faculty surgeons assigned to the week were also described.

Finally, many of the included studies arose from a single center. All of these realities could be etiologies for the significant heterogeneity observed within our meta-analysis.

CONCLUSIONS

The implementation of ACS models within general surgery emergency care has significantly improved system and patient outcomes for both appendectomy and cholecystectomy. Quality improvements were clearly demonstrated within the overall complication rate and timeliness from emergency department to admission and to operation.

AUTHORSHIP

O.A.B. designed the protocol. O.A.B. and S.L. worked on the acquisition and analysis of the data and drafted the article. J.B.K., C.G.B, A.L., H.T. S., and T.C.T provided instruction and oversight to study, helped with the study design and data interpretation, critically revised the article, and guided the study through each step of the process. All authors provided final approval for the publication version.

DISCLOSURE

The authors declare no conflicts of interest.

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