The economic footprint of acute care surgery in the United States: Implications for systems development

Lisa M. Knowlton, MD, Joseph Minei, MD, Lakshika Tennakoon, MD, Kimberly A. Davis, MD, Jay Doucet, MD, Andrew Bernard, MD, Adil Haider, MD, L.R. Tres Scherer, III, MD, David A. Spain, MD, *and* **Kristan L. Staudenmayer, MD**, *Stanford, California*

AAST Continuing Medical Education Article

Accreditation Statement

This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education through the joint providership of the American College of Surgeons and the American Association for the Surgery of Trauma. The American College Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

AMA PRA Category 1 Credits™

The American College of Surgeons designates this journal-based CME activity for a maximum of 1 *AMA PRA Category 1 Credit*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Of the *AMA PRA Category 1 Credit*™ listed above, a maximum of 1 credit meets the requirements for self-assessment.

Credits can only be claimed online

AMERICAN COLLEGE OF SURGEONS
Inspiring Quality:
Highest Standards, Better Outcomes

100+*years*

Objectives

After reading the featured articles published in the *Journal of Trauma and Acute Care Surgery*, participants should be able to demonstrate increased understanding of the material specific to the article. Objectives for each article are featured at the beginning of each article and online. Test questions are at the end of the article, with a critique and specific location in the article referencing the question topic.

Claiming Credit

To claim credit, please visit the AAST website at http://www.aast.org/ and click on the "e-Learning/MOC" tab. You must read the article, successfully complete the post-test and evaluation. Your CME certificate will be available immediately upon receiving a passing score of 75% or higher on the post-test. Post-tests receiving a score of below 75% will require a retake of the test to receive credit.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, the American College of Surgeons, as the accredited provider of this journal activity, must ensure that anyone in a position to control the content of *J Trauma Acute Care Surg* articles selected for CME credit has disclosed all relevant financial relationships with any commercial interest. Disclosure forms are completed by the editorial staff, associate editors, reviewers, and all authors. The ACCME defines a `commercial interest' as "any entity producing, marketing, re-selling, or distributing health care goods or services consumed by, or used on, patients." "Relevant" financial relationships are those (in any amount) that may create a conflict of interest and occur within the 12'months preceding and during the time that the individual is engaged in writing the article. All reported conflicts are thoroughly managed in order to ensure any potential bias within the content is eliminated. However, if you'perceive a bias within the article, please report the circumstances on the evaluation form.

Please note we have advised the authors that it is their responsibility to disclose within the article if they are describing the use of a device, product, or drug that is not FDA approved or the off-label use of an approved device, product, or drug or unapproved usage.

Disclosures of Significant Relationships with Relevant Commercial Companies/Organizations by the Editorial Staff

Ernest E. Moore, Editor: PI, research support and shared U.S. patents Haemonetics; PI, research support, Instrumentation Laboratory, Inc.; Co-founder, Thrombo Therapeutics. Associate Editors David Hoyt, Ronald V. Maier and Steven Shackford have nothing to disclose. Editorial staff and Angela Sauaia have nothing to disclose.

Author Disclosures

The authors have nothing to disclose.

Reviewer Disclosures

The reviewers have nothing to disclose.

Cost

For AAST members and *Journal of Trauma and Acute Care Surgery* subscribers there is no charge to participate in this activity. For those who are not a member or subscriber, the cost for each credit is $25.

System Requirements

The system requirements are as follows: Adobe® Reader 7.0 or above installed; Internet Explorer® 7 and above; Firefox® 3.0 and above, Chrome® 8.0 and above, or Safari™ 4.0 and above.

Questions

If you have any questions, please contact AAST at 800-789-4006. Paper test and evaluations will not be accepted.

BACKGROUND: Acute care surgery (ACS) comprises trauma, surgical critical care, and emergency general surgery (EGS), encompassing both operative and nonoperative conditions. While the burden of EGS and trauma has been separately considered, the global footprint of ACS has not been fully characterized. We sought to characterize the costs and scope of influence of ACS-related conditions. We hypothesized that ACS patients comprise a substantial portion of the US inpatient population. We further hypothesized that ACS patients differ from other surgical and non-surgical patients across patient characteristics.

METHODS: We queried the National Inpatient Sample 2014, a nationally representative database for inpatient hospitalizations. To capture all adult ACS patients, we included adult admissions with any International Classification of Diseases—9th Rev.—Clinical Modification diagnosis of trauma or an International Classification of Diseases—9th Rev.—Clinical Modification diagnosis for one of the 16 AAST-defined EGS conditions. Weighted patient data were presented to provide national estimates.

RESULTS: Of the 29.2 million adult patients admitted to US hospitals, approximately 5.9 million (20%) patients had an ACS diagnosis. ACS patients accounted for US $85.8 billion, or 25% of total US inpatient costs (US $341 billion). When comparing ACS to non-ACS inpatient populations, ACS patients had higher rates of health care utilization with longer lengths of stay (5.9 days vs. 4.5 days, $p < 0.001$), and higher mean costs (US $14,466 vs. US $10,951, $p < 0.001$. Of all inpatients undergoing an operative procedure, 27% were patients with an ACS diagnosis. Overall, 3,186 (70%) of US hospitals cared for both trauma and EGS patients.

CONCLUSION: Acute care surgery patients comprise 20% of the inpatient population, but 25% of total inpatient costs in the United States. In addition to being costly, they overall have higher health care utilization and worse outcomes. This suggests that there is an opportunity to improve clinical trajectory for ACS patients that in turn, can affect the overall US health care costs. (*J Trauma Acute Care Surg.* 2019;86: 609–616. Copyright © 2018 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Epidemiologic, level III.
KEY WORDS: Acute care surgery; emergency general surgery; trauma; trauma systems; health care utilization.

Within the United States, patients with emergency general surgical (EGS) conditions have their care provided through a broad range of practice models.[1–4] More recently, "acute care surgery" (ACS) has evolved as a practice model that incorporates trauma, EGS, and surgical critical care. Whether EGS is provided by surgical hospitalists, surgeons on call, or an ACS service, the combined universe of ACS conditions covers a large number of patients hospitalized in the United States and also likely comprise a large "footprint" of inpatient health care utilization and costs.

Previous studies focusing only on trauma or EGS have found that the costs of each are substantial; however, studies vary in their methodology making the creation of a complete picture of ACS-related costs difficult. Traumatic injuries have been estimated to have annual health care costs at over US $400 billion when considering index and subsequent hospitalizations, and over US $670 billion when considering total cost of care and lost productivity.[5] For those with a primary diagnosis of an EGS condition, total inpatient costs for their index admission have been estimated to be approximately US $28.2 billion, with a projected increase of nearly 50% between 2010 and 2060.[6,7] It stands to reason that a conservative estimate of the combined inpatient costs of these two services alone (e.g., excluding critical care) may be significant when compared with the whole.

With health care expenditures in the United States on the rise, there is increasing pressure to better understand cost distribution and allocation of resources. An important part of this process involves identifying patient populations with the greatest impact on utilization and expenditures so that the relevant stakeholders can appropriately target interventions. This has yet to be done for the combined trauma and EGS population. Furthermore, providers caring for patients with ACS conditions should have a substantial voice in shaping the national dialogue on health care reform.

In the current study, we sought to characterize the economic burden of ACS-related conditions. We hypothesized that ACS patients comprise a substantial portion of the US inpatient population as well as health care utilization and costs. We also hypothesize that these patients differ substantially from non-ACS surgical patients. Finally, we postulated that there would be regional variation and differences in characteristics among the US hospitals providing ACS services.

METHODS

The 2014 National Inpatient Sample (NIS) from the Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality was used. While 2015 data are available, the methodology for reporting diagnosis codes changed mid-year from International Classification of Diseases—9th Rev.—Clinical Modification (ICD-9-CM) to ICD-10-CM codes, which limited the ability to calculate total costing for acute care surgery conditions for the calendar year. For this reason, the year 2014 was used. The NIS is a nationally representative, all-payer, all-hospital database capturing inpatient hospitalizations and contains data for approximately 35 million weighted discharges from US hospitals annually. Throughout this article, weighted data are presented to provide nationally representative estimates.

From the Section of Trauma, Surgical Critical Care and Acute Care Surgery, Department of Surgery (L.M.K., L.T., D.A.S., K.L.S.), Stanford University School of Medicine, Stanford, California; Section of Burn, Trauma and Surgical Critical Care, Department of Surgery (J.M.), UT Southwestern Medical Center, Dallas, Texas; Section of General Surgery, Trauma, Surgical Critical Care, Department of Surgery (K.A.D.), Yale School of Medicine, New Haven, Connecticut; Section of Trauma, Surgical Critical Care, Burns and Acute Care Surgery, Department of Surgery (J.D.), University of California, San Diego, California; Section of Trauma and Acute Care Surgery, Department of Surgery (A.B.), University of Kentucky College of Medicine, Lexington, Kentucky; Section of Trauma and Acute Care Surgery, Department of Surgery (A.H.), Harvard Medical School, Boston, Massachusetts; and Section of Pediatric Surgery, Department of Surgery (L.R.T.S.), Indiana University Purdue University, Indianapolis, Indiana.
Address for reprints: Lisa Marie Knowlton, MD, Section of Trauma, Surgical Critical Care and Acute Care Surgery Stanford University, 300 Pasteur Drive, H3634 Stanford, CA 94305; email: drlmk@stanford.edu.
This article will be presented as a podium oral presentation at the 77th Annual Meeting of the American Association for the Surgery of Trauma; September 26–29, 2018 in San Diego, CA.

DOI: 10.1097/TA.0000000000002181

TABLE 1. ACS (Trauma and EGS) Patient and Healthcare Utilization Characteristics, 2014

	ACS Patients, 5,928,865 (20.0%)	Non-ACS Patients, 23,262,985 (80.0%)	*p*
Patient characteristics			
Age in 2014, mean (SD), y	56.3 (0.1)	61 (0.1)	<0.001
Age by category, n (%)			
18–24 y	236,454 (4.0)	1,698,966 (7.3)	<0.001
25–34 y	475,827 (8.0)	3,386,255 (14.6)	
35–44 y	560,484 (9.5)	2,189,389 (9.4)	
45–54 y	872,836 (14.7)	2,828,690 (12.2)	
55–64 y	1,047,987 (17.7)	3,803,698 (16.4)	
65–74 y	1,045,068 (17.6)	4,005,122 (17.2)	
75–84 y	960,412 (16.2)	3,292,841 (14.2)	
85 y and older	732,715 (12.4)	2,055,106 (8.8)	
Sex, n (%)			
Male	2,793,660 (47.1)	9,215,867 (39.6)	<0.001
Female	3,135,205 (52.9)	14,047,118 (60.4)	
Race and ethnicity, n (%)			
White	4,355,424 (73.5)	15,690,619 (67.4)	<0.001
Black	683,089 (11.5)	3,611,032 (15.5)	
Hispanic	601,352 (10.1)	2,475,469 (10.6)	
Other	309,434 (5.2)	1,468,350 (6.3)	
Payer status, n (%)			
Medicare	3,006,761 (50.7)	10,535,339 (45.3)	<0.001
Medicaid	840,725 (14.2)	4,416,727 (19.0)	
Private insurance	1,512,138 (25.5)	6,638,227 (28.5)	
Self-pay/other	566,321 (9.5)	1,675,612 (7.2)	
Zip income quartile, n (%)			
0–25th Percentile	1,687,289 (28.5)	6,813,378 (29.3)	<0.001
25–50th Percentile	1,625,986 (27.4)	6,302,520 (27.1)	
50–75th Percentile	1,336,987 (22.6)	5,190,311 (22.3)	
75–100th Percentile	1,144,321 (19.3)	4,425,484 (19.0)	
Chronic conditions, n (%)			
None	669,962 (11.3%)	3,396,396 (14.6%)	<0.001
1	1,731,228 (29.2%)	7,606,996 (32.7%)	
2+	3,527,675 (59.5%)	12,259,593 (52.7%)	
Health care utilization			
Major procedure, n (%)	2,265,288 (38.2)	6,267,490 (26.9)	<0.001
LOS, mean (SD), d	5.87 (0.03)	4.47 (0.02)	<0.001
LOS if discharge home	4.29 (0.02)	3.57 (0.02)	<0.001
LOS if discharge to rehabilitation	8.63 (0.06)	7.31 (0.05)	<0.001
Discharge destination, n (%)			
Routine home	3,371,659 (56.9)	15,614,721 (67.1)	<0.001
Discharged with home health	820,291 (13.8)	2,968,811 (12.8)	
Transfer to rehabilitation/SNF	1,386,613 (23.4)	3,418,366 (14.7)	
Transfer to other acute hospital	131,363 (2.2)	461,231 (2.0)	
Died	143,040 (2.4)	496,261 (2.1)	
Mean costs of hospitalization (SD), US $	14,466 (146)	10,951 (104)	<0.001

LOS, length of stay; SNF, skilled nursing facility.

We captured all adult patients with any trauma or an EGS diagnosis, regardless of whether or not they underwent operative management. The rationale for using any diagnosis vs. primary diagnosis is that patients admitted for another reason who are found to have an ACS diagnosis were likely to require attention to these conditions. Trauma diagnoses were based on ICD-9-CM codes (ICD-9-CM 800.0 to 959.0, excluding 905 to 924), and EGS conditions were based upon one of 16 AAST-defined and graded EGS conditions.[8] We excluded patients under the age of 18, and those with missing cost data. Injury Severity Score was calculated for each patient using the International Classification of Diseases Program for Injury Categorization version 3.0 within Stata/SE version 14.2 (StataCorp, College Station, TX). Non-ACS patients were defined as all other adult inpatients within our database, including both elective and emergency admissions to hospital.

The primary outcome of interest was the cost of hospitalization. Cost data were obtained by converting charges to cost using conversion ratios provided by HCUP.[9] Patient demographic, outcome, and utilization variables were analyzed. The NIS codes for race and ethnicity into a single variable. Subanalysis was performed based upon whether or not patients underwent operative intervention, as defined by HCUP coding for major procedures.[10] We also conducted sensitivity analyses on patients who had a primary diagnosis of trauma versus EGS.

Hospital level analysis was also performed in order to determine which hospitals provide ACS services (inpatient care to both trauma and EGS patients). We analyzed the differentiating characteristics of these ACS hospitals, as compared to others in the NIS database. Hospitals within the NIS were categorized by region, teaching status, and as private for-profit, nonprofit, and government-owned. Although the region and division location of the hospital were identifiable through the NIS, data was not available at the state or county level. The NIS provides a quartile classification of the estimated median household income of residents in the patients' ZIP code, but this was not granular enough to provide data on socioeconomic status at the local patient or hospital level.

Finally, to identify predictors associated with differences in costs of an ACS admission, we used a random intercept mixed effects multivariate linear regression model, with a significance set at $p < 0.05$. This controlled for potential confounders at both the patient (including demographic, injury specific and clinical) and hospital level (including urban/rural status, ownership, and region). We tested and verified that the assumptions of the model were satisfied.

All analyses were conducted using StataSE v14.2. The study was exempt from review by the Stanford IRB as data were

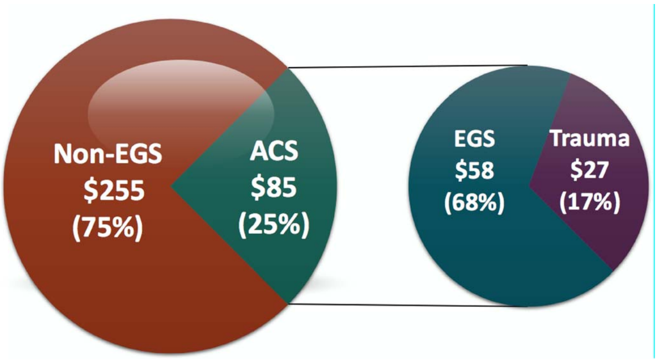

Figure 1. ACS burden and total costs, in billions of dollars, 2014.

TABLE 2. Linear Random Mixed Effects Regression to Predict Cost, Based on Any ACS Diagnosis

	Coefficient, US $	p	95% CI Low, US $	95% CI High, US $
Base cost, US $	3,374			
Age category				
18–24 y			Reference	
25–34 y	261	0.03	20	502
35–44 y	875	<0.001	640	1,110
45–54 y	2,623	<0.001	2,399	2,846
55–64 y	4,170	<0.001	3,948	4,391
65–74 y	3,995	<0.001	3,755	4,235
75–84 y	3,247	<0.001	3,001	3,491
85 y and older	1,876	<0.001	1,622	2,129
Payer status				
Medicare			Reference	
Medicaid	1,146	<0.001	994	1,298
Private insurance	−1,710	<0.001	−1,835	−1,585
Self-pay	−2,460	<0.001	−2,658	−2,261
Race and ethnicity				
White			Reference	
Black	1,981	<0.001	1,852	2,109
Hispanic	967	<0.001	832	1,383
Zip income quartile				
0–25th percentile			Reference	
25–50th percentile	251	<0.001	145	357
50–75th percentile	1,039	<0.001	927	1,152
75–100th percentile	1,869	<0.001	1,750	1,988
Had major OR procedure	12,284	<0.001	12,201	12,368
Type of ACS diagnosis				
Any diagnosis of trauma			Reference	
Any diagnosis of EGS	−1,976	<0.001	−2,085	−1,867
Hospital location				
Rural			Reference	
Urban	1,856	<0.001	1,658	1,923
Hospital region				
Northeast			Reference	
Midwest	1,045	0.07	986	1,265
South	865	0.19	756	988
West	1,118	0.06	1,045	1,256

95% CI, 95% confidence interval.

provided by HCUP in a de-identified format. Use of the NIS followed regulations within the data use agreement as defined by Agency for Healthcare Research and Quality.

RESULTS

Of the weighted 29.2 million adult patients admitted to US hospitals in 2014, approximately 5.9 million (20.3%) inpatients had an ACS diagnosis (Table 1). The majority of ACS patients had an EGS diagnosis (4.3 million, 72.0%), whereas 1.7 million (28.0%) had a diagnosis of trauma.

The ACS patients differed from non-ACS patients across most measures (Table 1). For example, ACS patients were older compared with non-ACS patients (mean age, 60.8 years vs. 56.3 years, respectively, $p < 0.001$). ACS vs. non-ACS patients were more often male (47.1% vs. 39.6%, respectively, $p < 0.001$), white (73.5% vs. 67.4%, respectively, $p < 0.001$), and had a higher mean number of comorbidities (2+ comorbidities: 59.5% vs. 52.7%, respectively, $p < 0.001$).

Overall outcomes were worse for ACS patients. ACS patients had higher rates of mortality compared to non-ACS patients (2.4% vs. 2.1%, respectively, $p < 0.001$). The ACS patients also had longer lengths of stay vs. non-ACS patients (5.9 vs. 4.5 days, respectively, $p < 0.001$) and higher rates of discharge to rehabilitation (23.4% vs. 14.7%, respectively, $p < 0.001$).

Together, ACS patients accounted for US $85.8 billion or 25.2% of total adult US inpatient costs for 2014 (US $341 billion) (Fig. 1). Of ACS patients, EGS diagnoses accounted for US $56.8 billion (66.2%), whereas US $29.0 billion (33.8%) were associated with trauma. Mean costs for ACS patients were overall higher (US $14,466) than for non-ACS inpatients (US $10,951, $p < 0.001$). Patient factors associated with higher costs in regression for ACS patients included increasing age and increasing income (Table 2). When controlling for known confounders, EGS patients were less expensive than trauma patients by approximately US $2,000. Average costs and frequency of EGS conditions are described in Table 3.

Of all adult inpatients, approximately 8.5 million (29.2%) underwent an operative procedure. Approximately 27% of these were patients who had an ACS diagnosis. When considering the rate of operative procedures for ACS vs. non-ACS conditions, there was a significant difference. Approximately 38.2% (2.3 million) ACS patients underwent an operative procedure, compared to 26.9% of non-ACS patients (6.3 million, $p < 0.001$). There were notable differences between ACS and non-ACS patients who underwent surgery. Findings paralleled those that were observed for the overall ACS and non-ACS populations. ACS surgical patients versus non-ACS surgical patients were older (59.0 years vs. 54.8 years, respectively $p < 0.001$), more often male (46.6% vs. 38.3%, respectively, $p < 0.001$), and had a greater number of pre-existing comorbidities (2+ comorbidities: 63.4% vs. 56.9%, respectively, $p < 0.001$). Operative patients with

TABLE 3. Common Inpatient EGS Conditions and Mean Costs, 2014

EGS Condition	Frequency, n (%)	Mean Costs (SD), US $
Skin and soft tissue infection	539,149 (24%)	7,299 (28)
Intestinal obstruction	272,886 (12%)	11,335 (67)
Pancreatitis	268,029 (12%)	9,434 (68)
Diverticulitis	214,600 (10%)	10,264 (118)
Cholecystitis	210,626 (10%)	12,272 (45)
Hernia	165,365 (7%)	14,400 (86)
Appendicitis	137,768 (6%)	10,451 (45)
Surgical site infection	136,001 (6%)	13,354 (121)
Infectious colitis	102,884 (5%)	9,293 (73)
Intestinal ischemia	47,247 (2%)	13,830 (209)
Esophageal perforation	26,715 (1%)	11,449 (239)
Pelvic inflammatory disease	26,710 (1%)	8,276 (196)
Perirectal abscess	21,637 (1%)	8,064 (145)
Perforated ulcer	13,688 (1%)	22,997 (439)
Breast infection	13,468 (1%)	6,014 (111)
Pleural space infection	11,039 (1%)	26,700 (500)

an ACS diagnosis also had worse outcomes than non-ACS surgical patients. They had higher mortality (2.1% vs. 1.1%, respectively, $p < 0.001$), longer mean LOS (7.1 vs. 4.5 days, respectively, $p < 0.001$), fewer routine discharges home (53.7% vs. 68.4%, respectively, $p < 0.001$). Mean costs for ACS patients undergoing surgery were also higher than for non-ACS surgical patients (US \$22,094 vs. US \$18,673, $p < 0.001$). Multivariate linear regression controlling for patient factors revealed that ACS patients undergoing an operative procedure cost approximately US \$12,285 more compared to their non-surgical ACS counterparts (95% confidence interval, US \$12,201–12,368, $p < 0.001$).

We compared the EGS population to the trauma population. EGS patients were on average younger than trauma patients (59.5 years vs. 64.3 years, respectively, $p < 0.001$), but had a greater number of comorbidities (2+ comorbidities: 65.3% vs. 57.6%, respectively, $p < 0.001$). Health care utilization was lower for EGS patients, with shorter lengths of stay compared to trauma patients (5.4 days vs. 6.1 days, $p < 0.001$) and EGS patients were more routinely discharged home (63.5% vs. 39.9%, respectively $p < 0.001$). EGS patients also underwent operative intervention less frequently than their trauma counterparts (34.7% vs. 47.1%, $p < 0.001$).

Finally, we determined the mix of hospitals caring for ACS patients throughout the United States. Overall, 3,186 (69.6%) of US hospitals treated patients with both EGS and trauma diagnoses. To determine the ACS burden for hospitals, we compared the proportion of ACS patients in each hospital to its total population. The median percent of ACS to all inpatients within these centers was 21% with an interquartile range of 18% to 24%. ACS-treating hospitals were compared with hospitals that did not treat any ACS patients. Their health care utilization differed significantly, with longer mean LOS in ACS-treating hospitals (vs. non-ACS hospitals: 5.3 days vs. 4.4 days, $p < 0.001$) and higher rates of non-routine discharge (42.1% vs. 39.3%, $p < 0.001$). ACS-treating hospitals were more frequently located in the East North Central states of Wisconsin, Michigan, Illinois, Indiana, and Ohio (16.2% vs. 8.2%, $p < 0.001$) as well as the South Atlantic states including Maryland, District of Columbia, Virginia, and the Carolinas (37.8% vs. 32.0%, $p < 0.001$) compared with hospitals that did not treat ACS patients. They were also more often situated within urban environments at teaching facilities (37.4% vs. 11.8%, $p < 0.001$) and were of large bed size (vs. other hospitals: 32.2% vs. 6.6%).

DISCUSSION

Of the 29.2 million adult hospitalized patients in 2014, patients with an ACS diagnosis comprised 20%. Costs associated with ACS diagnoses are even larger, at US \$85.8 billion, or 25% of annual US inpatient costs. Furthermore, these estimates are likely an underestimate because we could not ascertain surgical critical care costs in this database. These numbers are comparable to those for conditions that receive substantial attention. In 2015, approximately 7.5 million patients were estimated to have a diagnosis of stroke, with costs of care estimated to be approximately US \$34 billion.[11] Similarly, roughly US \$87.8 billion was spent in 2014 on cancer-related health care. The cost and burden of ACS diseases confirm our initial hypothesis that ACS conditions comprise a significant proportion of US health care utilization and costs. These findings highlight both the critical importance of the specialty as well as an opportunity for ACS providers to have substantial impact on US health care costs. An extension of this concept is the ability of surgeons to influence the national discussion on health care policy and funding.

Not surprisingly to those who care for these patients, ACS patients are sicker when compared with non-ACS hospitalized patients. ACS patients, on average, present with a greater number of comorbidities, are older, and experience higher rates of inpatient mortality. These findings are consistent with Gale et. al. who found that EGS patients are medically complex, with a mean age around 60 years and with multiple comorbidities.[7] The result of the higher acuity and more frequent comorbid conditions result in higher average costs for ACS patients. Therefore, in addition to the large "footprint" for admissions and costs, ACS patients may provide opportunities for cost reduction. Cost reduction efforts might occur not only through efficiencies in care but also potentially through the prevention of emergent surgical presentations.

Since the operating room is a large driver for costs, we compared ACS surgical patients to non-ACS surgical patients. ACS surgical patients comprise nearly 30% of all adult surgical inpatients within the United States. Similar to costs for the general ACS population, ACS patients undergoing surgery have high costs of care when compared with ACS nonsurgical patients (US \$22,094 vs. US \$18,673, $p < 0.001$). This is consistent with the findings of Ogola et. al. that major operative procedures are an important predictor of many high-cost hospitalizations.[12] The ACS patients who underwent surgery stay in the hospital for 2.6 days longer. In addition to patient factors and severity of illness, other drivers for increased length of stay may include lack of dedicated operating theater time for ACS cases, as compared with elective cases. A recent study by Wang et. al.[13] demonstrated that prolonged time to operation was a significant driver of cost and LOS in their acute surgical unit, whereby patients on average spent almost half of their hospitalization waiting for surgery. These delays add significantly to costs, utilization and ultimately place our sickest surgical patients at risk for further deterioration due to prolonged surgical wait-times. It is possible that one opportunity to impact these costs may, therefore, be to address delays that are unevenly experienced by the ACS population. For example, 24-hour access to dedicated emergency operating rooms, as well as readily available acute care surgeons has been associated with cost reductions and improved outcomes in multiple studies reviewing ACS practices.[2,14–17] To ensure the success of these efforts, appropriate funding, resources and hospital cultural acceptance need to be channeled into streamlining the efficiency of ACS services.

Another finding from our study is that there is variability in the "footprint" of ACS in different hospitals across the country. Hospitals treating ACS patients likely experience greater health care utilization given that they treat overall sicker surgical populations, in large hospitals and in urban locations (including both teaching or nonteaching). Although there were certain areas where the percent of ACS hospitals was higher than that of non-ACS hospitals, it is unlikely that the burden of ACS diseases is truly confined by geographic regions. Our findings suggest that access to ACS services were present throughout the United States, albeit somewhat more limited in certain areas of the country. Given the significant and growing burden of ACS-related diseases, efforts to continue to expand the presence of hospital and providers delivering ACS specialized services will further streamline care for these sick patients.

There are several limitations to this study. The analysis is constrained by the fact it is a retrospective nationally representative administrative database. While NIS provides a valuable overview of the demographic characteristics, and health care utilization patterns of ACS patients, NIS does not provide granular clinical data nor trauma-specific information, such as trauma center status or mechanism of injury. National Inpatient Sample also lacks provider-level information, and therefore we were unable to ascertain the specialty of surgeons providing care and whether they were acute care surgery trained. All trauma-related information (injuries and injury severity) was derived from ICD-9-CM codes, converted using the International Classification of Diseases Program for Injury Categorization tool. Furthermore, while more than 16 EGS diagnoses exist, we chose to limit our sample to those for which a standardized classification and grading system by the AAST exists, to more accurately clarify the EGS burden. There are likely other populations for which ACS-practicing surgeons provide care. Again, this would result in an underestimate. Similarly, we did not include costs associated with the provision of surgical critical care services by ACS surgeons. This is due to the fact that critical care services are a subset of the study population already, and that critical care services provided for other patient populations but cared for by critical care-boarded surgeons would be hard to identify (e.g., an ACS surgeon caring for a liver transplant patient in the ICU). Finally, the NIS uniquely captures data associated with inpatient hospitalizations. Consequently, we were not able to extrapolate upon outpatient costs of ACS care, the burden of long-term disability, nor the out-of-hospital mortality rate (i.e., for patients who never survived to be admitted to hospital, or those who later died after discharge). We also suspect that many patients presenting with certain EGS conditions, such as appendicitis and cholecystitis, were likely operated upon and discharged within the same day, thereby not being counted within our inpatient sample. Given the variety of practice models covering EGS and trauma patients, our findings simply provide a national snapshot of the scope of ACS care. We hope that the findings from this study spur follow-up analyses with more robust clinical data are required from trauma registries and possibly nascent EGS registries to help delineate the ACS burden in more detail.

CONCLUSION

Acute care surgery patients comprise 20% of the inpatient population, but 25% of total inpatient costs in the United States. In addition to being costly, they overall have higher health care utilization and worse outcomes. This suggests that there is an opportunity to improve clinical trajectory for ACS patients that, in turn, can affect the overall US health care costs. Because EGS comprises 70% to 80% of ACS activities and 70% of ACS costs, the greatest impact may lie in improvements in care for the EGS population.

AUTHORSHIP

L.K. participated in the study design, data analysis and article preparation. J.M. participated in the study design, data interpretation and article revisions. L.T. participated in the data collection and management. K.A.D. participated in the data interpretation and article revisions. J.D. participated in the data interpretation and article revisions. A.B. participated in the data interpretation and article revisions. A.H. participated in the data interpretation and article revisions. L.R.T.S. participated in the data interpretation and manuscript revisions. D.S. participated in the data analysis and article revisions. K.S. participated in the study design, data analysis, and article preparation.

DISCLOSURE

K.S. is currently receiving a grant (1K08AG04442801A1) from the National Institute of Health. The other authors declare no conflict of interest.

REFERENCES

1. Mok JM, Martinez M, Smith HE, Sciubba DM, Passias PG, Schoenfeld A, Isaacs RE, Vaccaro AR, Radcliff KE. Assoication for Collaborative Spine Research Investigators. Impact of a bundled payment system on resource utilization during spine surgery. *Int J Spine Surg*. 2016;10:19.
2. Chana P, Burns EM, Arora S, Darzi AW, Faiz OD. A systematic review of the impact of dedicated emergency surgical services on patient outcomes. *Ann Surg*. 2016;263(1):20–27.
3. Sorelli PG, El-Masry NS, Dawson PM, Theodorou NA. The dedicated emergency surgeon: towards consultant-based acute surgical admissions. *Ann R Coll Surg Engl*. 2008;90(2):104–108.
4. Tisherman SA, Kaplan L, Gracias VH, Beilman GJ, Toevs C, Byrnes MC, Coopersmith CM. Surgery Section, Society of Critical Care Medicin. Providing care for critically ill surgical patients: challenges and recommendations. *JAMA Surg*. 2013;148(7):669–674.
5. Olufajo OA, Cooper Z, Yorkgitis BK, Najjar PA, Metcalfe D, Havens JM, Askari R, Brat GA, Haider AH, Salim A. The truth about trauma readmissions. *Am J Surg*. 2016;211(4):649–655.
6. Ogola GO, Gale SC, Haider A, Shafi S. The financial burden of emergency general surgery: national estimates 2010 to 2060. *J Trauma Acute Care Surg*. 2015;79(3):444–448.
7. Gale SC, Shafi S, Dombrovskiy VY, Arumugam D, Crystal JS. The public health burden of emergency general surgery in the United States: a 10-year analysis of the Nationwide inpatient sample—2001 to 2010. *J Trauma Acute Care Surg*. 2014;77(2):202–208.
8. Utter GH, Miller PR, Mowery NT, Tominaga GT, Gunter O, Osler TM, Ciesla DJ, Agarwal SK Jr., Inaba K, Aboutanos MB, Brown CV, Ross SE, Crandall ML, Shafi S. ICD-9-CM and ICD-10-CM mapping of the AAST emergency general surgery disease severity grading systems: conceptual approach, limitations, and recommendations for the future. *J Trauma Acute Care Surg*. 2015;78(5):1059–1065.
9. Healthcare Cost and Utilization Project. Cost-to-charge ratio files. https://www.hcup-us.ahrq.gov/db/state/costtocharge.jsp. Accessed August 12, 2018.
10. Healthcare Cost and Utilization Project. Major operating room ICD-9-CM procedure indicator. 2014; https://www.hcup-us.ahrq.gov/db/vars/sedddistnote.jsp?var=orproc. Accessed August 10, 2018.
11. Center for Disease Control. Stroke Facts. 2017; https://www.cdc.gov/stroke/facts.htm. Accessed August 22, 2018.
12. Ogola GO, Shafi S. Cost of specific emergency general surgery diseases and factors associated with high-cost patients. *J Trauma Acute Care Surg*. 2016; 80(2):265–271.
13. Wang E, Jootun R, Foster A. Management of acute appendicitis in an acute surgical unit: a cost analysis. *ANZ J Surg*. 2018.
14. Dultz LA, Pachter HL, Simon R. In-house trauma attendings: a new financial benefit for hospitals. *J Trauma*. 2010;68(5):1032–1037.
15. Williams TE Jr., Satiani B, Thomas A, Ellison EC. The impending shortage and the estimated cost of training the future surgical workforce. *Ann Surg*. 2009;250(4):590–597.
16. Hutter MM. Specialization: the answer or the problem? *Ann Surg*. 2009; 249(5):717–718.
17. Borman KR, Vick LR, Biester TW, Mitchell ME. Changing demographics of residents choosing fellowships: long term data from the American Board of Surgery. *J Am Coll Surg*. 2008;206(5):782–788; discussion 788–789.

DISCUSSION

DAVID B. HOYT, M.D. (Chicago, Illinois): Good morning. Dr. Reed, Dr. Miller, members and guests, thank you for the opportunity to discuss Dr. Knowlton's excellent study.

Advocating for our patients in the future will require us to speak with accurate knowledge if we want to have credibility with system administrations, payers, and government.

The authors' hypothesis is that ACS, as they defined it, is a significant part of our National disease burden. ACS has often historically been dismissed as less important, or primarily the responsibility of safety net hospitals. This paper shows that ACS accounts for 20 percent of our use of hospitals and 25 percent of our costs.

As health care goes to more providers able to do with less hospital infrastructure the responsibility to maintain hospital infrastructure will increasingly be the burden of fewer diseases. This is a looming crisis. The ability to offset costs will be more challenging.

Specialties that can move to the ambulatory setting readily will not advocate for ACS resources needed at a hospital. We've already seen that. Historically those that can, have moved out of the hospital and no longer see the hospital with the same concern.

A true resource crisis is looming if we don't look at the message this data and the authors have made regarding the importance of ACS on hospital use.

Just to put this in perspective, there are about 20 million operations done a year in this country, and that's been pretty stable over the last decade.

Eight million of those, as we've just seen, are in the in-hospital patient area; 12 million are now in the out-patient area. The disease burden today of most hospital-based surgical care is provided by ACS surgeons, neurosurgeons, thoracic surgeons, vascular surgeons, transfer and some orthopedics, and elective general surgery.

Much of ophthalmology, ENT, plastics, urology, orthopedic surgery and elective general surgery have moved out of the hospital. Everyone should be thinking about how to preserve the future resources to care for these patients.

I have several questions. 1) Do you have any data as to how many surgeons in these 3,100 hospitals actually cared for these patients? I suspect it's a lot less than we actually think, and it's going to be a very important message, particularly to the AAST.

2) Was there a large variability in the cost and reimbursement of these patients? Or is there a group, if you will, where we could target cost reduction?

3) Is there data regarding the employment status of the surgeon providing care, or their identifiable specialty?

I congratulate the authors. Keep up the good work. This type of analysis will allow you to be physician leaders and catalyze conversations that will look out for our patients' needs and the needs of surgeons to be fairly compensated for their work. Thank you very much.

MICHAEL WALTERS, M.D. (Gainesville, Florida): That was a great presentation. I just have one quick question. How much of the burden of acute care surgery cost is a result of lack of access to elective procedures because of lack of insurance?

I noticed especially that your numbers seem to suggest that, as patients get older – above age 65, eligibility for Medicare – the number of acute procedures actually goes down. Could we potentially be saving money in our system by giving patients greater access to elective services?

WALTER L. BIFFL, M.D. (San Diego, California): It's a really nice study, nice presentation. You know, yesterday morning we heard a paper about the variations in EGS outcomes.

And in that paper, it was from the California Inpatient Database, there were 220 different hospitals represented. So I'm curious, in how many of the hospitals in this sample are both trauma patients and EGS patients cared for? Thanks.

MICHAEL F. ROTONDO, M.D. (Rochester, New York): Congratulations on an incredibly well-presented and well-structured piece of work this morning. My question is really about methodology.

Can you clarify for all of us how we're going to bring better understanding to the concept of cost? You know, when defining cost, the insurance companies have an idea of what their cost is, the hospitals have an idea of what their cost is, the physicians and care providers have an idea of what their cost is.

How are we going to level that and understand that definition better and come to some more universal understanding of really what the cost of care is? Thank you.

R. LAWRENCE REED, M.D. (Indianapolis, Indiana): I have one brief comment. I noticed that you had to exclude patients who were less than 18 years old and those who had missing cost data.

There are two issues from that: Number 1, our information system is inadequate to provide us with all the answers we need; and Number 2, this probably represents a huge underestimate of the impact of acute care surgery, because of those missing variables.

After all, as we know, trauma is the leading cause of death in children in many of those age groups, and yet we're not getting data on those patients.

KRISTAN L. STAUDENMAYER, M.D., M.Sc. (Stanford, California): Thank you, Dr. Hoyt, for your wonderful discussion, and to everyone else for your thoughtful questions.

I will answer Dr. Hoyt's questions first. The first and third questions addressed information about physicians caring for the patients in this study. Unfortunately, we don't have that type of data in this database. But I do agree that understanding roles and impact of surgeons is an important next step that we need to look at.

You also asked is there variability in the cost and reimbursement of these patients. The answer is yes. There is indeed substantial variability across just about every measure when we broke it down. For example, as a patient's estimated income increases, so do their costs. There is a large cost difference between ACS patients in the higher vs. lower income brackets. This observation raises the question of what costs should be. For example, are we potentially giving wealthier patients too much care, or are lower-income patients not getting sufficient care? There is substantial opportunity to dig into this more to determine the efficiency of the care we provide.

Dr. Walters, thank you for your question. As a matter of fact, the Committee was just meeting prior to this presentation and was discussing different causes for high costs, including lack of access to care. While there is still work to be done to prove this, I do agree that there is likely money to be saved by preventing the need for an emergency surgical presentation. This is an entirely other body of work that absolutely needs to be done.

And, Dr. Biffl, thank you for your question. We did not break out in detail complication rates between the EGS and trauma diagnoses nor did we compare that to the breakdown between patient populations by hospital, but certainly we did see a lot of variability there as well. Particularly the EGS population, there's large variability across the different EGS diagnoses.

Dr. Rotondo, thank you for important question you ask regarding methodology and where to go from here. That is to say what philosophic and practical approach should we be employing when we're talking about costs? As you suggest, everyone considers costs from their own perspective, and even some researchers study what hospitals get reimbursed for, rather than the cost that the patient or employer might see.

All I can do is share my personal philosophy which is that we should focus on the cost to society. If we focus on hospital reimbursement or physician reimbursement, we're not going to be able to have a really cogent discussion. This still leaves a large arena in which to define costs. For example, should we include cost burden of lost days at work in our cost analyses? Either way, moving forward we will need to find some standard way of talking about costs as it impacts our population.

And, finally, Dr. Reed, thank you for your comments. You are correct and our numbers do reflect an underestimate based on the limitations you mention. If we were to broaden the analysis to include out-patient care and different age groups, we would likely find that acute care conditions dominate the U.S. economic landscape.

But again, that's going to be the product of future studies. And I look forward to us continuing this line of work and anyone else who also continues the further discussion.

Thank you very much.