Journal of Trauma and Acute Care Surgery

Barriers to Improving Health Care Value in Emergency General Surgery: A Nationwide Analysis

--Manuscript Draft--

Manuscript Number:	JT-D-19-09964R2
Full Title:	Barriers to Improving Health Care Value in Emergency General Surgery: A Nationwide Analysis
Article Type:	AAST 2019 Podium
Section/Category:	2019 AAST Podium
Keywords:	Emergency General Surgery; Health Care Value; Health Care Quality; complications; Readmission
Corresponding Author:	Bellal Joseph, MD The University of Arizona Tucson, Arizona UNITED STATES
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	The University of Arizona
Corresponding Author's Secondary Institution:	
First Author:	Kamil Hanna, MD
First Author Secondary Information:	
Order of Authors:	Kamil Hanna, MD
	Zaid Haddadin, MD
	Joseph Sakran, MD
	Muhammad Zeeshan, MD
	Samer Asmar, MD
	Narong Kulvatunyou, MD
	Andrew Tang, MD
	Ashley Northcutt, MD
	Bellal Joseph, MD
Order of Authors Secondary Information:	
Manuscript Region of Origin:	UNITED STATES

THE UNIVERSITY OF ARIZONA
College of Medicine

College of Medicine
Department of Surgery
Section of Trauma, Critical Care &
Emergency Surgery

1501 N. Campbell Ave., Rm. 5411
P.O. Box 245063
Tucson, AZ 85724-5063
Phone: 520-626-6608
Fax: 520-626-5016

March 13th, 2019

Ernest E. Moore, MD,
Editor-in-Chief, *the Journal of Trauma and Acute Care Surgery*.

Subject: Letter of Transmittal for the revised original AAST manuscript entitled "Barriers to Improving Health Care Value in Emergency General Surgery: A Nationwide Analysis".

Dear Dr. Moore,
It is a pleasure to send you our revised original AAST manuscript entitled "Barriers to Improving Health Care Value in Emergency General Surgery: A Nationwide Analysis" for consideration in your journal. We thank you for giving us the opportunity to submit our manuscript.

This work was conducted by myself and the following co-authors who all had substantial contributions to study for doing an extensive literature search, drafting and revising the article for critical content, and final approval of the manuscript: Kamil Hanna, MD[1], Zaid Haddadin, MD[1], Joseph Sakran, MD[2], Muhammad Zeeshan, MD[1], Samer Asmar, MD[1], Narong Kulvatunyou, MD[1], Andrew Tang, MD[1], Ashley Northcutt, MD[1], and Bellal Joseph, MD[1]

Presentation: Oral Presentation at the 78th Annual Meeting of the American Association for the Surgery of Trauma (AAST); September 18th- 21th, 2018, Dallas, Texas

Our institutional affiliations are:

[1]Division of Trauma, Critical Care, Emergency Surgery, and Burns, Department of Surgery, College of Medicine, University of Arizona, Tucson, Arizona.
[2]Division of Acute Care Surgery, Johns Hopkins University, Baltimore, Maryland.

This manuscript has not been previously published and is not under consideration elsewhere.
None of the authors have any financial disclosures.
I am sending this letter as a word document; please accept my name below as an electronic signature.

Sincerely,
Bellal Joseph, MD
College of Medicine
Department of Surgery
Section of Trauma, Critical Care & Emergency Surgery
1501 N. Campbell Ave., Rm. 5411
P.O. Box 245063, Tucson, AZ 85724-5063
Phone: 520-626-6608
Fax: 520-626-5016

Reviewer Comments:
Reviewer's Responses to Questions

Level of Evidence

Is the assessment of the Level of Evidence correct? (n.b. levels of evidence are not applicable to some studies, such as in vitro work, animal models, cadaver studies, etc)

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Abstract

Is the abstract concise, informative, accurate, and structured as requested by the Journal?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Introduction

Is there a clearly identified knowledge gap of interest to our readership with current references documenting that gap in knowledge? Is the topic relevant to the Journal's scope?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Is there an explicitly stated hypothesis or objective?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Methods

Is the design of the study explicitly stated? For interventional or in vitro studies, is a timeline provided?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Are the criteria for inclusion and exclusion of study subjects explicitly stated? Does the manuscript include a flow diagram that identifies both excluded patients and those who were ultimately included in the analysis?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

If a hypothesis is being tested, was a power analysis performed? Most especially if the results were negative?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: None

Are the primary and secondary outcomes explicitly defined? Are potential confounders (if appropriate) included in the analysis?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Is the statistical method appropriate for the study design?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

<u>Results</u>

Are the results presented in a systematic and logical fashion relative to either the hypothesis or the objective(s)?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Are tables and figures additive (not redundant) to the text and are they correctly labeled and understandable?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Discussion

Are the results interpreted rationally and compared to the extant recent literature? Does the discussion delve into the potential relevance going forward and contribution of the data to our understanding (not merely a rehash presentation of the results)?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: Yes

Are the pertinent limitations of the work recognized and explicitly stated?

Reviewer #2: Yes

Reviewer #3: None

Reviewer #4: No: There are other limitations that are not highlighted. For example, there measures of "quality" are measures of patient safety rather than quality. Additionally, the composite measure of quality as presented assumes that all components carry equal weight. That a readmission and a death (FTR) are of equal importance. From the patient/family perspective and even from the provider perspective, this is not likely.

Response: We thank the reviewer for the above comment. Quality is a metaphysical concept that is difficult to define and quantitate [1]. Stakeholders who have embraced the study of health care quality and medical outcomes recognize the difficulty in establishing a standardized definition and recommended using quality metrics that capture pertinent attributes of care, including efficacy, effectiveness, efficiency, optimality, and acceptability [2]. Consistently reported quality metrics throughout the surgical literature that are surrogates of such attributes include readmission, reoperation, major complications, and FTR [1-14]. Because these metrics are not patient reported and are not from the patient's perspective we have expanded the limitations section of the manuscript to highlight the shortcomings of the utilized measures. Due to the lack of data regarding the optimal weights to be assigned to each quality metric we utilized an exploratory formula that is based on the direct contribution of each quality metric to the sum without weights. We have expanded the limitations section of the manuscript to highlight the important point raised by the reviewer.

1. Ghaferi AA, Birkmeyer JD, Dimick JB. Variation in hospital mortality associated with inpatient surgery. New England Journal of Medicine. 2009 Oct 1;361(14):1368-75.
2. Bosco III JA, Sachdev R, Shapiro LA, Stein SM, Zuckerman JD. Measuring quality in orthopaedic surgery: the use of metrics in quality management. Instructional course lectures. 2014 Jan 1;63:473-86.
3. Hoyt DB, Ko CY, Jones RS. Optimal Resources for Surgical Quality and Safety: American College of Surgeons; 2017.
4. de Mestral C, Salata K, Hussain M, Kayssi A, Al-Omran M, Roche-Nagle G. Evaluating quality metrics and cost after discharge: a population-based cohort study of value in health care following elective major vascular surgery. Annals of Surgery. 2018 Apr 1.
5. Hirji S, McGurk S, Kiehm S, Ejiofor J, Ramirez-Del Val F, Kolkailah AA, Berry N, Sobieszczyk P, Pelletier M, Shah P, O'Gara P. Utility of 90-day mortality vs 30-day mortality as a quality metric for transcatheter and surgical aortic valve replacement outcomes. JAMA cardiology. 2020 Feb 1;5(2):156-65.
6. Mullen MG, Michaels AD, Mehaffey JH, Guidry CA, Turrentine FE, Hedrick TL, Friel CM. Risk associated with complications and mortality after urgent surgery vs elective and emergency surgery: implications for defining "quality" and reporting outcomes for urgent surgery. JAMA surgery. 2017 Aug 1;152(8):768-74.
7. Varghese TK. Failure to rescue metric in lung surgery: a needed breath of fresh air. JAMA surgery. 2015 Nov 1;150(11):1040-1.
8. Smith T, Li X, Nylander W, Gunnar W. Thirty-day postoperative mortality risk estimates and 1-year survival in Veterans Health Administration surgery patients. JAMA surgery. 2016 May 1;151(5):417-22.
9. Mason MC, Chang GJ, Petersen LA, Sada YH, Cao HS, Chai C, Berger DH, Massarweh NN. National quality forum colon cancer quality metric performance: how are hospitals measuring up?. Annals of surgery. 2017 Dec 1;266(6):1013-20.
10. Mise Y, Vauthey JN, Zimmitti G, Parker NH, Conrad C, Aloia TA, Lee JE, Fleming JB, Katz MH. 90-day postoperative mortality is a legitimate measure of hepatopancreatobiliary surgical quality. Annals of surgery. 2015 Dec;262(6):1071.
11. Keller DS, Chien HL, Hashemi L, Senagore AJ, Delaney CP. The HARM score: a novel, easy measure to evaluate quality and outcomes in colorectal surgery. Annals of surgery. 2014 Jun 1;259(6):1119-25.
12. Bilimoria KY, Sohn MW, Chung JW, Minami CA, Oh EH, Pavey ES, Holl JL, Black BS, Mello MM, Bentrem DJ. Association between state medical malpractice environment and surgical quality and cost in the United States. Annals of surgery. 2016 Jun 1;263(6):1126-32.
13. Chaudhary MA, Jiang W, Lipsitz S, Hashmi ZG, Koehlmoos TP, Learn P, Haider AH, Schoenfeld AJ. The transition to data-driven quality metrics: determining the optimal surveillance period for complications after surgery. journal of surgical research. 2018 Dec 1;232:332-7.
14. Rosenfeld EH, Zhang W, Johnson B, Shah SR, Vogel AM, Naik-Mathuria B. The value of failure to rescue in determining hospital quality for pediatric trauma. Journal of Trauma and Acute Care Surgery. 2019 Oct 1;87(4):794-9.

Manuscript (Discussion)

Quality is a metaphysical concept that is difficult to define and quantitate. There are limitations associated with utilizing surrogate quality metrics such as FTR, readmission, reoperation, and complications. We lack ideal measures of quality that are patient reported and take into consideration the patient's experience

Manuscript (Limitations)

The notion that quality is a composite measure with equal weights given to readmissions, complications, and FTR also contributes to the limitations of the utilized definition of quality. There is a lack of data regarding the optimal weights to be assigned to each quality metric we utilized an exploratory formula that is based on the direct contribution of each quality metric to the sum without weights

---

Additional Comments to Author(s):

Reviewer #2: **Comments to the Author(s) on how to improve the manuscript. Please explain your concerns and provide thoughtful input on additional data that may improve the manuscript. Help the author as you would a colleague.**

The authors have provided additional clarity around their methodology. However, this does not alleviate the concerns raised by this reviewer.

I fear that the authors have put together a formula and run statistical analyses, but that fundamentally the formula is overly simplistic and ultimately an unverified assumption that cannot be verified by the dataset used. Separating "value" of the care delivered from patient complexity is difficult with administrative data. The fact that their trend tracked with an aging and increasingly sicker population suggests that the metric reflects population dynamics and not the "value" of care delivered.

Response: We thank the reviewer for the above comment. Quality is a metaphysical concept that is difficult to define and quantitate. Methods for measuring value remain elusive. In this study, we describe how existing quality metrics and cost accounting data can be used to measure value based on our conceptual understanding of what health care value is. We believe this approach is practical and scalable and can establish the foundation for future work in this area. As described by Lee et al. in their study on developing a measure of value in health care, the numerator (Quality) would be a composite measure composed of multiple qualities metrics. This was the rationale behind the formula utilized. This approach needs to be validated against a gold standard measure of health care value. Unfortunately, there is no gold standard measure of health care value. The limitations section of the manuscript discuss the imperfections of this approach. From a system wide perspective, the value of care eventually depends on the outcomes observed (ie. The incidence of FTR, readmission, re-operation, and major complications). The discussion section of the manuscript elaborates on the fact that elderly patients are predisposed to worse outcomes due to their age and comorbidities and high value care is difficult to achieve in this age group especially in emergency settings when there is limited time for patient optimization (unmodifiable risk factors). Population dynamics therefore play an important role in dictating the value of care.

Reviewer #3: **Comments to the Author(s) on how to improve the manuscript. Please explain your concerns and provide thoughtful input on additional data that may improve the manuscript. Help the author as you would a colleague.**

Reviewer #4: The manuscript is much improved from the earlier version, but there are some remaining areas that can be addressed:

1. The authors should state that these really are measures of patient safety and not quality. We lack ideal measures of quality that take into consideration the patient's perspective and experience, which are relevant.

Response: We thank the reviewer for the above comment. Quality is a metaphysical concept that is difficult to define and quantitate [1]. Stakeholders who have embraced the study of health care quality and medical outcomes recognize the difficulty in establishing a standardized definition and recommended using quality metrics that capture pertinent attributes of care, including efficacy, effectiveness, efficiency, optimality, and acceptability [2]. Consistently reported quality metrics throughout the surgical literature that are surrogates of such attributes include readmission, reoperation, major complications, and FTR [1-14]. Because these metrics are not patient reported and are not from the patient's perspective we have expanded the limitations section of the manuscript to highlight the shortcomings of the utilized measures.

1. Ghaferi AA, Birkmeyer JD, Dimick JB. Variation in hospital mortality associated with inpatient surgery. New England Journal of Medicine. 2009 Oct 1;361(14):1368-75.
2. Bosco III JA, Sachdev R, Shapiro LA, Stein SM, Zuckerman JD. Measuring quality in orthopaedic surgery: the use of metrics in quality management. Instructional course lectures. 2014 Jan 1;63:473-86.
3. Hoyt DB, Ko CY, Jones RS. Optimal Resources for Surgical Quality and Safety: American College of Surgeons; 2017.
4. de Mestral C, Salata K, Hussain M, Kayssi A, Al-Omran M, Roche-Nagle G. Evaluating quality metrics and cost after discharge: a population-based cohort study of value in health care following elective major vascular surgery. Annals of Surgery. 2018 Apr 1.
5. Hirji S, McGurk S, Kiehm S, Ejiofor J, Ramirez-Del Val F, Kolkailah AA, Berry N, Sobieszczyk P, Pelletier M, Shah P, O'Gara P. Utility of 90-day mortality vs 30-day mortality as a quality metric for transcatheter and surgical aortic valve replacement outcomes. JAMA cardiology. 2020 Feb 1;5(2):156-65.
6. Mullen MG, Michaels AD, Mehaffey JH, Guidry CA, Turrentine FE, Hedrick TL, Friel CM. Risk associated with complications and mortality after urgent surgery vs elective and emergency surgery: implications for defining "quality" and reporting outcomes for urgent surgery. JAMA surgery. 2017 Aug 1;152(8):768-74.
7. Varghese TK. Failure to rescue metric in lung surgery: a needed breath of fresh air. JAMA surgery. 2015 Nov 1;150(11):1040-1.

8. Smith T, Li X, Nylander W, Gunnar W. Thirty-day postoperative mortality risk estimates and 1-year survival in Veterans Health Administration surgery patients. JAMA surgery. 2016 May 1;151(5):417-22.
9. Mason MC, Chang GJ, Petersen LA, Sada YH, Cao HS, Chai C, Berger DH, Massarweh NN. National quality forum colon cancer quality metric performance: how are hospitals measuring up?. Annals of surgery. 2017 Dec 1;266(6):1013-20.
10. Mise Y, Vauthey JN, Zimmitti G, Parker NH, Conrad C, Aloia TA, Lee JE, Fleming JB, Katz MH. 90-day postoperative mortality is a legitimate measure of hepatopancreatobiliary surgical quality. Annals of surgery. 2015 Dec;262(6):1071.
11. Keller DS, Chien HL, Hashemi L, Senagore AJ, Delaney CP. The HARM score: a novel, easy measure to evaluate quality and outcomes in colorectal surgery. Annals of surgery. 2014 Jun 1;259(6):1119-25.
12. Bilimoria KY, Sohn MW, Chung JW, Minami CA, Oh EH, Pavey ES, Holl JL, Black BS, Mello MM, Bentrem DJ. Association between state medical malpractice environment and surgical quality and cost in the United States. Annals of surgery. 2016 Jun 1;263(6):1126-32.
13. Chaudhary MA, Jiang W, Lipsitz S, Hashmi ZG, Koehlmoos TP, Learn P, Haider AH, Schoenfeld AJ. The transition to data-driven quality metrics: determining the optimal surveillance period for complications after surgery. journal of surgical research. 2018 Dec 1;232:332-7.
14. Rosenfeld EH, Zhang W, Johnson B, Shah SR, Vogel AM, Naik-Mathuria B. The value of failure to rescue in determining hospital quality for pediatric trauma. Journal of Trauma and Acute Care Surgery. 2019 Oct 1;87(4):794-9.

Manuscript (Discussion)

Quality is a metaphysical concept that is difficult to define and quantitate. There are limitations associated with utilizing surrogate quality metrics such as FTR, readmission, reoperation, and complications. We lack ideal measures of quality that are patient reported and take into consideration the patient's experience

2. The notion that quality is a composite measure with equal weights given to readmissions, complications, FTR, etc is probably not correct. There isn't much better out there right now, but as presented, a death (FTR) is of equal weight to a readmission. I think this limitation should be highlighted.

Response: We thank the reviewer for the above comment. Due to the lack of data regarding the optimal weights to be assigned to each quality metric we utilized an exploratory formula that is based on the direct contribution of each quality metric to the sum without weights. We have expanded the limitations section of the manuscript to highlight the important point raised by the reviewer.

Manuscript (Limitations)

The notion that quality is a composite measure with equal weights given to readmissions, complications, and FTR also contributes to the limitations of the utilized definition of quality. There is a lack of data regarding the optimal weights to be assigned to each quality metric we utilized an exploratory formula that is based on the direct contribution of each quality metric to the sum without weights

3. Why adjust for hospital ownership, teaching status and size? If teaching hospitals (or private hospitals) provide lower value care, don't we want to know this and improve? By adjusting away the effects we lose this information. The authors used a prediction model approach rather than an adjustment for confounders (which would be better given the goal was to evaluate changes over time), but the point remains.

Response: We thank the reviewer for the above comment. Risk adjustment would be incomplete if the entire spectrum of patient-related and center-related variables were not included in the model. According to the existing body of literature, center-parameters are pertinent predictors of outcomes and variations between center-parameters could confound the results and therefore need to be included in the model. Upon including these variables in the model were able to tease out the independent effect of these parameters on health care value. Table 4 of the manuscript lists the center related parameters that were significant predictors of higher or lower health care value. Admission to metropolitan teaching hospitals is associated with an increase in health care value (β= +0.034 [0.026-0.044]; $p<0.01$). Similarly, admissions to high (β= +0.004 [0.003-0.005]; $p<0.01$) and medium volume (β= +0.001 [0.00017-0.0018]; $p<0.01$) were also associated with an independent increase in health care value. However, admission to low volume centers (β= -0.927 [-1.126-(-0.682)]; $p<0.01$) lowered healthcare value. While adjusting for these parameters the model can still tell us what are the factors we need to focus on to improve as mentioned by the reviewer.

4. The authors state "Examining the between hospital variation in health care value, we noticed a wide variation across EGS centers with 2,018 centers performing below the median health care value-- Figure 2." By design, about half the centers should fall below the median. I'm not certain this is a high value statement.

Response: We thank the reviewer for the above comment. This sentence was removed.

Manuscript (Results)

Examining the between hospital variation in health care value, we noticed a wide variation across EGS centers --**Figure 2**. If centers performing below the median health care value were to improve their performance to the median overall adjusted health care value, we estimated a total reduction in EGS cost of $28.9 billion.

5. Discussion - a little long. It can be condensed. As an example, the paragraph about rehab when this isn't covered to any extent in the paper is probably excessive.

Response: We thank the reviewer for the above comment. The entire discussion was condensed and the paragraph about rehab was shortened.

Manuscript (Discussion)

Using a sample of EGS patients from multiple centers across the nation, our study indicates that there is a gross increase in the rates of major complications, FTR, 6-months readmission, and 6-months re-operation. This coincides with a marked rise in health care costs and an apparent decrease in health care value. The study demonstrates the feasibility of EGS quality assessment using commonly reported quality metrics, while addressing the economic implications of these outcomes. From a value-based perspective, we can see that the health care system is in an apparent suboptimal state when it comes to the outcomes obtained per dollar spent. Furthermore, not all EGS centers are delivering an increase in value at the pace at which health care costs are rising.

The wide spectrum of patient- and hospital-level characteristics that influence the trend in health care value over time allow us to identify barriers to high value care in EGS. These findings can have wide implications on practice considering that many predictors of decreased health care value in EGS are potentially modifiable. Solutions to identify and reduce low-value care remain complex and require targeted interventions on multiple frontiers, such as reducing fragmentation of care, promoting regionalization, patient optimization, and improving health care coverage.

Despite palpable support towards a value based health care system (4), practical methods for measuring value remain elusive (18). In this study, we describe how existing quality metrics and cost accounting data can be used to measure value based on our conceptual understanding of what health care value is (30). We believe this approach is practical, valid, and scalable and can establish the foundation for future work in this area. As described by Lee et al. in their study on developing a measure of value in health care, the numerator (Quality) would be a composite measure composed of multiple qualities metrics (18). Although most of these quality measures are easily captured with the available data, the methods to combine them into a single index score remain elusive and underdeveloped (18). Metrics are usually validated against a gold standard measure of health care value. Unfortunately, there is no gold standard measure of health care value to use for this purpose. There are challenges related to the lack of the infrastructure needed to collect standardized outcome data. Furthermore, current surveillance for patient outcomes and costs of care is not feasible, scalable, or sustainable. Although researchers should work toward the ideal value measure, we need to measure value now with the currently available data and improve over time (18). In addition, calculating the national median health care value provides a benchmark for comparison and performance evaluation.

One of the factors contributing to a decrease in the health care value is the nationwide change in the age distribution of the EGS population. Older adults bring about a unique set of challenges to their surgical course attributed to their comorbidities, geriatric specific syndromes, frailty, and reduced physiological reserves (31-33). This will translate to a longer period of hospitalization, increased costs, and subsequently decreased health care value. Ingraham et al. reviewed the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) exploring the variation in the quality of care after EGS procedures in older adults. They concluded that elderly patients are inherently at a greater risk of adverse events. They also reported substantial variability in the quality of care provided (34).

Along with aging, the overall prevalence of comorbidities also increased throughout the study period. Salim et al. conducted a retrospective cohort analysis of 66,665 EGS patients aiming to quantify the excess burden of morbidity and mortality associated with EGS, and they reported that much of this increased morbidity and mortality can be attributed to the patient's baseline risk profile at the time of surgery (3). Their findings are in agreement with our study as we also noted an upward trend in the rates of complications, readmission, reoperation, and FTR, which paralleled the increase in the comorbidities burden in the EGS population across the study period that, in turn, contributed to an overall decrease in health care value. This might indicate that EGS patients remain a challenge when it comes to obtaining optimal outcomes while maintaining cost effectiveness. The acuity of the disease process imposes time constraints that prevent adequate patient optimization prior to surgical intervention.

Other important predictors of low health care value include insurance status. Schwartz et al. reviewed claims for a large number of Medicare beneficiaries examining low-value services that provide minimal clinical benefit (35). They inferred that low-value care spending constituted a substantial proportion of overall spending influencing around one in two Medicare beneficiaries. Another important admission characteristic is admission on a weekend. Shah et al. compared outcomes among EGS patients admitted on weekday versus those admitted on a weekend. They reported that the adjusted mortality rate was significantly higher in subgroups of EGS patients admitted on a weekend in comparison to those admitted on a weekday (36). This was further verified by Salim et al. who reported that admission on a weekend was an independent predictor of serious adverse events, FTR, and in-hospital mortality (37). Hospital resources may be scarce on weekends and multidisciplinary care teams may be incomplete (38, 39). Our finding that weekend admission was an independent predictor for low health care value may be explained by higher rates of FTR, which is on par with what was described previously. Post-operative rehabilitation was found to increase health care value despite the added services. Despite the lack of high-grade evidence, the literature on rehabilitation concluded that this intervention might be beneficial at reducing adverse events and might be cost effective (40).

Non-index readmission or fragmentation of care was found to have a major contribution to low health care value. This is in agreement with the existing body of literature on the hazards of care discontinuity. Havens et al. reported that one in five readmitted EGS patients will seek care at a non-index hospital and that care discontinuity is an independent predictor of mortality (41). Our findings expand the current understanding of the consequences of care discontinuity by highlighting its economic disadvantage. Not surprisingly, index-hospital volume played an important role in determining health care value. Multiple studies have demonstrated a reliable volume-outcome relationship in EGS. Hospital volume is a surrogate measure of hospital experience and, potentially, surgeon experience. Accumulating experience allows health care systems to minimize errors in management. At the same time, high volume hospitals tend to have a wider spectrum of clinical services offered which will facilitate the timely recognition and handling of post-operative complications that will improve FTR rates (42). Considering the apparently deleterious effects of care fragmentation and admission to low-volume centers, the regionalization of EGS care has been proposed as a solution to these challenges (43). With multiple implications on practice, the regionalization of EGS care has become a subject of debate with no consensus whether the benefits will outweigh the unintended consequences of such an approach. The results of our study support of regionalization by highlighting preventable morbidity, mortality, and cost effectiveness (43). Despite these diverse factors, we noticed from the multivariable linear regression that the downward trend in health care value persisted even after adjusting for the annual EGS case mix. There are possible unmeasured confounding factors that we cannot account for using the database. Other possible reasons include the overuse of diagnostic tests, patient overtreatment, wasted health care expenditure, and medical errors.

Our study is not without limitations. There are limitations attributed to the retrospective nature of the analysis, the contribution of unmeasured confounding factors, and erroneous database entries. The entire spectrum of factors contributing to the decline in health care value were not captured in the utilized database. Using this study design, we can only establish associations rather than a causal relationship. There are also limitations attributed to the lack of a gold standard measure of health care value. Quality is a metaphysical concept that is difficult to define and quantitate. There are limitations associated with utilizing surrogate quality metrics such as FTR, readmission, reoperation, and complications. We lack ideal measures of quality that are patient reported and take into consideration the patient's experience. The notion that quality is a composite measure with equal weights given to readmissions, complications, and FTR also contributes to the limitations of the utilized definition of quality. There is a lack of data regarding the optimal weights to be assigned to each quality metric we utilized an exploratory formula that is based on the direct contribution of each quality metric to the sum without weights. HCUP costs which are based on hospital charges may not completely capture the entire spectrum of health care costs sustained and may not reflect true clinical costs (physician fees, additional services, costs unrelated to patient care, administrative costs, payer costs, and government costs). These variables remain the only information on cost available in the NRD database. Hospital costs may have been underestimated in our analysis due to scope of the utilized database. In addition, the utilized database can only track patients upon readmission within the same state. Patients were missed if they were not readmitted or only followed up on an outpatient basis, or readmitted to a different state. It is possible that we have underestimated the cost and complications incurred by EGS patients. However, this study fills a gap in the literature on the performance of our EGS infrastructure from a value-based model (which had not been previously well described), ascertains the factors contributing to this trend in performance, identifies areas of improvement, and adds to the existing body of literature describing the advantages of a value-based model.

This study highlights several areas for future investigation. Compiling data that are more granular could identify further factors contributing to a decrease in health care value. The entire spectrum of hospital costs are difficult to comprehensively and accurately estimate, nationwide databases can still provide important information on the overall burden. The study may also highlight the need to improve our data infrastructure to better capture health care costs moving forward. This study may also facilitate the shift from a fee-for-service model to a fee-for-value model. Finally, our findings contribute to the growing literature aimed at improving the efficiency of the EGS health care system. Examining the trend in health care value over time for non-operative EGS patients is also an interesting area to explore given that a large proportion of EGS patients are non-operatively managed.

Abstract

Introduction: There is a growing need to improve the quality of care while decreasing health care costs in Emergency General Surgery (EGS). Health care value includes costs and quality and is a targeted metric by improvement programs. The aim of our study was to evaluate the trend of health care value in EGS over time and to identify barriers to high value surgical care.

Methods: The (2012-2015) National Readmission Database was queried for patients ≥18y who underwent an EGS procedure (according to the AAST definition). Healthcare value (V=quality metrics/cost) was calculated from the rates of freedom from readmission, major complications, reoperation, and failure-to-rescue (FTR) indexed over inflation adjusted hospital costs. Outcomes were the trends in the quality metrics: 6-months readmission, major complications, reoperation, FTR, hospital costs, and healthcare value over the study period. Multivariable linear regression was performed to determine the predictors of lower health care value.

Results: We identified 887,013 patients who underwent EGS. Mean age was 51±20y and 53% were male. The rates of 6-month readmission, major complications, reoperation, and FTR increased significantly over the study period. The median hospital costs also increased over the study period (2012: $9600 to 2015: $13000; p<0.01). However, the healthcare value has decreased over the study period (2012: 0.35, 2013: 0.30, 2014: 0.28, 2015: 0.25; p<0.01). Predictors of decreased health care value in EGS are age≥65 (β=-0.568 [-0.689 - (-0.418)], >3 comorbidities (β=-0.292 [-0.359 - (-0.21)], readmission to a different hospital (β=-0.755 [-0.914 - (-0.558)]), admission to low volume centers (β=-0.927 [-1.126 - (-0.682)]), lack of rehabilitation (β=-0.004[-0.005 – (-0.003)]), and admission on a weekend (β=-0.318 [-0.366 - (-0.254)]).

Conclusion: Health care value in EGS appears to be declining over time. Some of the factors leading to decreased health care value in EGS are potentially modifiable. Health care value could potentially be improved by reducing fragmentation of care, and promoting regionalization.

Level of Evidence: Level III Prognostic

Study Type: Prognostic

Keywords: Emergency General Surgery; Health Care Value; Health Care Quality; Complications; Readmission;

Barriers to Improving Health Care Value in Emergency General Surgery: A Nationwide Analysis

Short Title: "Health Care Value in Emergency General Surgery"

Kamil Hanna, MD[1], Zaid Haddadin, MD[1], Joseph Sakran, MD[2], Muhammad Zeeshan, MD[1], Samer Asmar, MD[1], Narong Kulvatunyou, MD[1], Andrew Tang, MD[1], Ashley Northcutt, MD[1], and Bellal Joseph, MD[1]

[1]Division of Trauma, Critical Care, Emergency Surgery, and Burns, Department of Surgery, College of Medicine, University of Arizona, Tucson, Arizona.
[2]Division of Acute Care Surgery, Johns Hopkins University, Baltimore, Maryland.

Hanna; kamilhanna@surgery.arizona.edu
Haddadin; zaid.haddadin@live.com
Sakran; jsakran1@jhmi.edu
Zeeshan; Muhammad.Zeeshan@wmchealth.org
Asmar; samerasmar94@email.arizona.edu
Kulvatunyou; nkulvatunyou@surgery.arizona.edu
Tang; atang@surgery.arizona.edu
Northcutt;ashleynorthcutt@email.arizona.edu
Joseph; bjoseph@surgery.arizona.edu

Presentation: Oral Presentation at the 78th Annual Meeting of the American Association for the Surgery of Trauma (AAST); September 18th- 21th, 2019, Dallas, Texas.

There are no identifiable conflicts of interests to report.
The authors have no financial or proprietary interest in the subject matter or materials discussed in the manuscript.

Address for correspondence: **Bellal Joseph, MD, FACS**
University of Arizona
Department of Surgery
Division of Trauma, Critical Care,
And Emergency Surgery
1501 N. Campbell Ave, Room 5411
P.O. Box 245063
Tucson, AZ 85724
Email: bjoseph@surgery.arizona.edu
Tel: 520-626-5056
Fax: 520-626-5016

Introduction

Emergency general surgery (EGS) patients represent a large fraction of annual surgical admissions (1). It is estimated that more than 3 million patients are admitted to hospitals in the United States (US) each year for an EGS requiring diagnosis (2). EGS patients represent a unique subgroup. Having a higher disease acuity, they sustain a disproportionately higher burden of complications, mortality, and readmission (3). While the nationwide demand for emergency health care is increasing, availability and access are declining. This is also accompanied by a rise in health care costs (4, 5), declining physician workforce (6), and an alarming surge in emergency department closures (7). Collectively, these trends can create a public health crisis.

Enhancing the quality of EGS health care quality remains a national priority and a key part of improving emergency care in general (8). More specifically, there is also a growing need to improve the quality of care while simultaneously decreasing health care costs (9, 10). The concept of health care value is roughly defined as the health outcomes achieved per dollar of health care costs spent, which simultaneously encompasses the two dimensions of quality and cost containment (11). There is expanding interest in developing a value-based health care system to improve performance with economic sustainability (8).

At present, however, there is a lack of data evaluating the nationwide performance of EGS centers from a value-based health care perspective. Although EGS patients are a heterogeneous group, understanding the temporal trends in EGS quality metrics and costs would be of paramount importance for quality assessment. Policymakers and primary expected payers have embraced quality assessment using such metrics as an effective way to improve patient outcomes through feedback and payment incentives that can promote institutional quality improvement efforts. The aim of our study was to evaluate the trend of health care value in EGS over time and to identify barriers to high value surgical care.

Methods

Data Sources

We performed a 4-year retrospective cohort analysis of the (2012-2015) Health care Cost and Utilization Project (HCUP) Nationwide Readmission Database (NRD). The Agency for Health care Research and Quality maintains the NRD. It records up to 15 million admissions per year and provides longitudinal follow-up data on a nationally representative sample of patients with subsequent readmission(s) throughout a one-year period following their index admission. Sample weights can be applied to obtain national estimates. To track patients upon readmission to an index or a different hospital, the database utilizes a unique identifier. These features make the NRD the largest, most comprehensive, accurate source of US hospital readmission data. Institutional review board approval was exempted because the NRD only contains deidentified data.

Study Population

We queried the database for all adult (≥18years) patients admitted for an EGS procedure as per the definition of the American Association for the Surgery of Trauma (AAST). The AAST Committee on Severity Assessment and Patient Outcomes developed a comprehensive data-driven definition of EGS and identified the International Classification of Diseases 9^{th}Revision (ICD-9) primary diagnostic codes that correspond to the scope of EGS (1). We included all patients who were admitted from January 1 through June 30 for each year. Admissions in the first half of a year ensure a minimum follow-up period of 6 months. Patients discharged from the ED are not included in the database. Survey weights were used for national estimates as per HCUP recommendations.

Patient Stratification

We stratified patients into four groups based on the year of admission for the EGS procedure: 2012, 2013, 2014, and 2015.

Data Points and Definitions:

For each patient, we abstracted the following data points from the database: demographics (age, sex, primary payer, household income, location) and comorbidities (anemia, arthritis, congestive heart failure, diabetes, hypertension, peripheral vascular disease, liver failure, chronic kidney disease, obesity, etc). We also collected data regarding the respective EGS category (eg, appendix, biliary-pancreatic, abdominal wall, upper GI, lower GI, rectosigmoid, perianal, thoracic, peritoneum, genitourinary, etc) and index admission characteristics (weekend admission, length of stay, and discharge disposition). The characteristics of index hospitals performing EGS were also abstracted, including ownership (public, not for profit, investor-owned), bed size, teaching status, and annual EGS volume. Hospital volume was categorized into high (>150 cases per year), medium (50-150 cases per year), and low volume (<50 cases per year) based on the 33^{rd} and the 67^{th} percentile of the annual hospital volume variable. We also reported the urban-rural designation of the EGS center (large metropolitan, small metropolitan, micropolitan, and non-urban).

Data on in-hospital outcomes, along with longitudinal data within 6 months of follow-up, were abstracted regarding the incidence of major complications (defined as the occurrence of pneumonia, myocardial infarction, heart failure, respiratory failure, pulmonary embolism, sepsis, deep surgical site infection, deep vein thrombosis, acute renal failure, abdominal compartment syndrome, cardiac arrest, or cerebrovascular accident). The rates of failure-to-rescue (FTR), 6-

months readmission, 6-months re-operation, number of readmission events, time to readmission, and non-index readmission were also collected, and we examined health care costs.

Failure to Rescue

Failure to rescue (FTR) is typically defined as death following a major complication (12). It is increasingly utilized as a hospital quality metric reflecting the performance of hospitals when addressing postoperative complications (13). This makes it an important benchmark for patient safety (14). Multiple studies reported that there is considerable variation in postoperative outcomes irrespective of patient-related factors potentially due to the hospital's quality of care (15). This makes FTR a targeted metric by quality improvement programs (16). We defined FTR as the occurrence of death and major complications (12-16).

Health Care Value

The operational definition underlying an assessment of the quality of health care requires certain assumptions. Stakeholders who have embraced the study of health care quality and medical outcomes recognize the difficulty in establishing a standardized definition and recommended using quality indicators that capture pertinent attributes of care, including efficacy, effectiveness, efficiency, optimality, and acceptability (9). Commonly reported quality metrics throughout the surgical literature that represent such attributes include readmission, reoperation, major complications, and FTR. However, high quality surgical care faces dynamic challenges related to economic and market forces, limited reimbursement, regulatory measures, and compliance with the Affordable Care Act and Medicare Access. This means that our quality assessment methodology must incorporate health care costs eventually arriving at the concept of health care value (9). The major goal of quality improvement initiatives must be directed towards increasing health care value through decreasing health care costs and reducing utilization. Porter et al. proposed using health care value defined as quality (Q) divided by costs (C) or Value = Q/C (11). In practice, arbitrarily chosen quality indicators must represent Q (9, 17, 18). Quality was calculated as a composite measure utilizing multiple quality metrics commonly utilized in the literature (18): Failure to rescue, readmission, reoperation, and major complications. Because lower rates of all these metrics indicate better quality, quality was calculated using the formula:

$$Q = (1 - P_{Readmission}) + \left(1 - P_{Major\ Complications}\right) + \left(1 - P_{Reoperation}\right) + (1 - P_{FTR})$$

$P_{Readmission}$ = Proportion of patients who were readmitted

$P_{Major\ Complications}$ = Proportion of patients who developed major complications on index admission or upon readmission

$P_{Reoperation}$ = Proportion of patients with reoperation on index admission or upon readmission

P_{FTR} = Proportion of patients with failure to rescue on index admission or upon readmission

The NRD database provides the total hospital charges per admission for each patient (19-21). It also provides a unique and internally validated annual cost-to-charge ratio for each facility. As per HCUP standards and existing literature, hospital charges can be converted to estimated hospital costs using a center specific cost-charge ratio (5, 19, 21-28). This ratio is calculated based on accounting reports collected by CMS (21). Hospital costs were calculated using each patient's hospital total charge (aggregate of index admission and readmissions) multiplied by the corresponding facility cost-to-charge ratio. Hospital costs were adjusted for inflation to have the same dollar value as the year 2015. Using the annual Consumer Price Index, the rate of inflation over the study period was determined to be 3.2% (29).

$$Hospital\ Costs = Hospital\ Charges\ \times Hospital\ Cost\ to\ Charge\ Ratio$$

$$Inflation\ Adjusted\ Hospital\ Costs = Hospital\ Costs + (Hospital\ Costs \times 0.032)$$

Therefore, health care value was calculated using the formula:

$$Healthcare\ Value = \frac{(1 - P_{Readmission}) + (1 - P_{Major\ Complications}) + (1 - P_{Reoperation}) + (1 - P_{FTR})}{Inflation\ Adjusted\ Hospital\ Costs}$$

Outcome Measures:

Our primary outcome measure was the trend in health care value over the study period. Our secondary outcome measures were the trends in the quality metrics over the study period: 6-months readmission, major complications, reoperation, FTR, and health care costs.

Statistical Analysis:

We performed descriptive statistics to outline the baseline characteristics of the study sample and EGS centers based on year of admission. Continuous normally distributed data were summarized using a mean and a standard deviation. Continuous not-normally distributed data were summarized using a median and an interquartile range. Categorical data were summarized using counts and proportions. To compare the baseline characteristics of EGS patients and EGS centers across the duration of the study, we used the Chi-Square test with Bonferroni adjustment for multiple comparisons to compare proportions, the one-way analysis of variance (ANOVA) to compare continuous normally distributed variables with Bonferroni adjustment for multiple comparisons, and the Kruskal-Wallis test to compare continuous not-normally distributed data. The variation in health care value across the study period can be attributed to a wide spectrum of different patient characteristics, distribution of EGS conditions, and hospital-level characteristics.

In order to ascertain the predictors of health care value while adjusting for measurable confounding factors, we performed a hierarchical mixed-effects linear regression model with a random effect for the EGS center. Adjustment was performed for demographics (age, gender, primary payer, income, and location), comorbidities (CCI: Charlson Comorbidities Index), EGS category, index-admission characteristics, hospital ownership, bed size, teaching status, annual EGS volume, and urban-rural designation. This approach takes into account the hierarchical structure of the data among patients from the same EGS center. Because we used multicenter data, the analytic approach needs to account for the intra-cluster effect (patients within the same facility are more correlated than patients from different facilities, thus violating independence assumption) especially that centers differ in their management approach and quality of care. After this model was fit, we calculated the EGS center-specific adjusted health care value from the model's predicted value per EGS center. Based on the distribution of the center-specific adjusted health care value, we calculated the hypothetical estimated reduction in health care costs if centers performing in the lower quartile were to improve their performance in terms of health care value to the median center-specific health care value. We considered a P-value of less than 0.05 ($P < 0.05$) as statistically significant. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 23; SPSS, Inc., Armonk, NY).

Results

A total of 887,013 patients undergoing an EGS procedure at 6,275 hospitals were identified. Stratification of patients by year of admission showed that 236,555 were admitted in 2012, 228,449 in 2013, 198,600 in 2014, and 223,409 in 2015. Overall, the mean age was 51±20 years, and 53% were male. The most common EGS procedure performed involved the appendix (21%), followed by the biliary-pancreatic region (19%) and the abdominal wall (11%). The median length of stay was 3 [2-7] days. Following their inpatient stay, most patients were discharged routinely (76%) --**Table 1**. In terms of the centers performing EGS, most patients (67%) were admitted to hospitals with a high EGS volume --**Table 2**.

Concerning trends in EGS quality metrics over the study period, there is an overall increase in the rates of major complications (2012: 22.4% vs. 2015: 27.2%; p<0.01), FTR (2012: 2.1% vs. 2015: 4%; p<0.01), 6-months readmission (2012: 21% vs. 2015: 23.7%; p<0.01), and 6-months reoperation (2012: 9.3% vs. 2015: 11%; p<0.01). There was also an overall increase in the inflation adjusted hospital costs (2012: $9,600 [$7000-$15000] vs. 2015: $13,000 [$8000-$17000]; p<0.01). The median health care value had a downward trend across the study period (2012: 0.35[0.23-0.49] vs. 2015: 0.25[0.19-0.41]; p<0.01)--**Figure 1**. When examining other quality metrics, there was no significant difference in the number of readmission events among those who were readmitted (2012: 1[1-2] vs. 2015: 1[1-2]; p=0.87). However, the rate of non-index hospital readmission rose significantly over the study period (2012: 22% vs. 2015: 23.8%; p<0.01)--**Table 3.**

On regression analysis, after adjusting for patient and hospital-level baseline characteristics, the downward trend in health care value was persistent on a multivariable level (β=-0.004 [-0.015 – (-0.001)]; p=0.01). At the same time, a number of patient and hospital-level characteristics were significant predictors of lower health care value. The independent predictors of a lower health care value are age group ≥65 years (β=-0.568 [-0.689 - (-0.418)]; p<0.01), low-income quartile (β=-0.368 [-0.455 - (-0.262)]; p<0.01), >3 comorbidities (β=-0.292 [-0.359 - (-0.21)]; p<0.01), weekend admission (β=-0.318 [-0.366 - (-0.254)]; p<0.01), non-index readmission (β=-0.755 [-0.914 - (-0.558)]; p<0.01), and admission to low volume centers (β-0.927 [-1.126 - (-0.682)]; p<0.01).--**Table 4.**

Examining the between hospital variation in health care value, we noticed a wide variation across EGS centers --**Figure 2**. If centers performing below the median health care value were to improve their performance to the median overall adjusted health care value, we estimated a total reduction in EGS cost of $28.9 billion.

Discussion

Using a sample of EGS patients from multiple centers across the nation, our study indicates that there is a gross increase in the rates of major complications, FTR, 6-months readmission, and 6-months re-operation. This coincides with a marked rise in health care costs and an apparent decrease in health care value. The study demonstrates the feasibility of EGS quality assessment using commonly reported quality metrics, while addressing the economic implications of these outcomes. From a value-based perspective, we can see that the health care system is in an apparent suboptimal state when it comes to the outcomes obtained per dollar spent. Furthermore, not all EGS centers are delivering an increase in value at the pace at which health care costs are rising.

The wide spectrum of patient- and hospital-level characteristics that influence the trend in health care value over time allow us to identify barriers to high value care in EGS. These findings can have wide implications on practice considering that many predictors of decreased health care value in EGS are potentially modifiable. Solutions to identify and reduce low-value care remain complex and require targeted interventions on multiple frontiers, such as reducing fragmentation of care, promoting regionalization, patient optimization, and improving health care coverage.

Despite palpable support towards a value based health care system (4), practical methods for measuring value remain elusive (18). In this study, we describe how existing quality metrics and cost accounting data can be used to measure value based on our conceptual understanding of what health care value is (30). We believe this approach is practical, valid, and scalable and can establish the foundation for future work in this area. As described by Lee et al. in their study on developing a measure of value in health care, the numerator (Quality) would be a composite measure composed of multiple qualities metrics (18). Although most of these quality measures are easily captured with the available data, the methods to combine them into a single index score remain elusive and underdeveloped (18). Metrics are usually validated against a gold standard measure of health care value. Unfortunately, there is no gold standard measure of health care value to use for this purpose. There are challenges related to the lack of the infrastructure needed to collect standardized outcome data. Furthermore, current surveillance for patient outcomes and costs of care is not feasible, scalable, or sustainable. Although researchers should work toward the ideal value measure, we need to measure value now with the currently available data and improve over time (18). In addition, calculating the national median health care value provides a benchmark for comparison and performance evaluation.

One of the factors contributing to a decrease in the health care value is the nationwide change in the age distribution of the EGS population. Older adults bring about a unique set of challenges to their surgical course attributed to their comorbidities, geriatric specific syndromes, frailty, and reduced physiological reserves (31-33). This will translate to a longer period of hospitalization, increased costs, and subsequently decreased health care value. Ingraham et al. reviewed the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) exploring the variation in the quality of care after EGS procedures in older adults.

They concluded that elderly patients are inherently at a greater risk of adverse events. They also reported substantial variability in the quality of care provided (34).

Along with aging, the overall prevalence of comorbidities also increased throughout the study period. Salim et al. conducted a retrospective cohort analysis of 66,665 EGS patients aiming to quantify the excess burden of morbidity and mortality associated with EGS, and they reported that much of this increased morbidity and mortality can be attributed to the patient's baseline risk profile at the time of surgery (3). Their findings are in agreement with our study as we also noted an upward trend in the rates of complications, readmission, reoperation, and FTR, which paralleled the increase in the comorbidities burden in the EGS population across the study period that, in turn, contributed to an overall decrease in health care value. This might indicate that EGS patients remain a challenge when it comes to obtaining optimal outcomes while maintaining cost effectiveness. The acuity of the disease process imposes time constraints that prevent adequate patient optimization prior to surgical intervention.

Other important predictors of low health care value include insurance status. Schwartz et al. reviewed claims for a large number of Medicare beneficiaries examining low-value services that provide minimal clinical benefit (35). They inferred that low-value care spending constituted a substantial proportion of overall spending influencing around one in two Medicare beneficiaries. Another important admission characteristic is admission on a weekend. Shah et al. compared outcomes among EGS patients admitted on weekday versus those admitted on a weekend. They reported that the adjusted mortality rate was significantly higher in subgroups of EGS patients admitted on a weekend in comparison to those admitted on a weekday (36). This was further verified by Salim et al. who reported that admission on a weekend was an independent predictor of serious adverse events, FTR, and in-hospital mortality (37). Hospital resources may be scarce on weekends and multidisciplinary care teams may be incomplete (38, 39). Our finding that weekend admission was an independent predictor for low health care value may be explained by higher rates of FTR, which is on par with what was described previously. Post-operative rehabilitation was found to increase health care value despite the added services. Despite the lack of high-grade evidence, the literature on rehabilitation concluded that this intervention might be beneficial at reducing adverse events and might be cost effective (40).

Non-index readmission or fragmentation of care was found to have a major contribution to low health care value. This is in agreement with the existing body of literature on the hazards of care discontinuity. Havens et al. reported that one in five readmitted EGS patients will seek care at a non-index hospital and that care discontinuity is an independent predictor of mortality (41). Our findings expand the current understanding of the consequences of care discontinuity by highlighting its economic disadvantage. Not surprisingly, index-hospital volume played an important role in determining health care value. Multiple studies have demonstrated a reliable volume-outcome relationship in EGS. Hospital volume is a surrogate measure of hospital experience and, potentially, surgeon experience. Accumulating experience allows health care systems to minimize errors in management. At the same time, high volume hospitals tend to have a wider spectrum of clinical services offered which will facilitate the timely recognition and handling of post-operative complications that will improve FTR rates (42). Considering the apparently deleterious effects of care fragmentation and admission to low-volume centers, the regionalization of EGS care has been proposed as a solution to these challenges (43). With multiple implications on practice, the regionalization of EGS care has become a subject of debate with no consensus whether the benefits will outweigh the unintended consequences of such an approach. The results of our study support of regionalization by highlighting preventable morbidity, mortality, and cost effectiveness (43). Despite these diverse factors, we noticed from the multivariable linear regression that the downward trend in health care value persisted even after adjusting for the annual EGS case mix. There are possible unmeasured confounding factors that we cannot account for using the database. Other possible reasons include the overuse of diagnostic tests, patient overtreatment, wasted health care expenditure, and medical errors.

Our study is not without limitations. There are limitations attributed to the retrospective nature of the analysis, the contribution of unmeasured confounding factors, and erroneous database entries. The entire spectrum of factors contributing to the decline in health care value were not captured in the utilized database. Using this study design, we can only establish associations rather than a causal relationship. There are also limitations attributed to the lack of a gold standard measure of health care value. Quality is a metaphysical concept that is difficult to define and quantitate. There are limitations associated with utilizing surrogate quality metrics such as FTR, readmission, reoperation, and complications. We lack ideal measures of quality that are patient reported and take into consideration the patient's experience. The notion that quality is a composite measure with equal weights given to readmissions, complications, and FTR also contributes to the limitations of the utilized definition of quality. There is a lack of data regarding the optimal weights to be assigned to each quality metric we utilized an exploratory formula that is based on the direct contribution of each quality metric to the sum without weights. HCUP costs which are based on hospital charges may not completely capture the entire spectrum of health care costs sustained and may not reflect true clinical costs (physician fees, additional services, costs unrelated to patient care, administrative costs, payer costs, and government costs). These variables remain the only information on cost available in the NRD database. Hospital costs may have been underestimated in our analysis due to scope of the utilized database. In addition, the utilized database can only track patients upon readmission within the same state. Patients were missed if they were not readmitted or only followed up on an outpatient basis, or readmitted to a different state. It is possible that we have underestimated the cost and complications incurred by EGS patients. However, this study fills a gap in the literature on the performance of our EGS infrastructure from a value-based model (which had not been previously well described), ascertains the factors contributing to this trend in performance, identifies areas of improvement, and adds to the existing body of literature describing the advantages of a value-based model.

This study highlights several areas for future investigation. Compiling data that are more granular could identify further factors contributing to a decrease in health care value. The entire spectrum of hospital costs are difficult to comprehensively and accurately estimate, nationwide databases can still provide important information on the overall burden. The study may also highlight the need to improve our data infrastructure to better capture health care costs moving forward. This study may also facilitate the shift from a fee-for-service model to a fee-for-value model. Finally, our findings contribute to the growing literature aimed at improving the efficiency of the EGS health care system. Examining the trend in health care value over time for non-operative EGS patients is also an interesting area to explore given that a large proportion of EGS patients are non-operatively managed.

Conclusion

Health care value in EGS appears to be declining over time. Some of the factors leading to decreased health care value in EGS may be potentially modifiable. Transforming the quality of surgical care requires the adoption of a disruptive model based on health care value. Potentially, this may be implemented through targeted interventions on multiple frontiers. Health care value could potentially be improved by reducing fragmentation of care, and promoting regionalization.

Authors Contributions:

K.H, B.J, Z.H, A.N, N.K, A.T, and S.A designed this study.

K.H, Z.H, B.J, J.S, M.Z searched the literature.

K.H, B.J, Z.H, M.Z, Z.H, N.K and J.S collected the data.

K.H, B.J, Z.H, A.N, A.T and S.A analyzed the data.

All authors participated in data interpretation and manuscript preparation.

Acknowledgements:

None

Conflict of interest:

There are no identifiable conflicts of interests to report

Funding

No funding was provided for this study

References

1. Shafi S, Aboutanos MB, Agarwal Jr S, Brown CVR, Crandall M, Feliciano DV, Guillamondegui O, Haider A, Inaba K, Osler TM. Emergency general surgery: definition and estimated burden of disease. *J Trauma Acute Care Surg*. 2013;74(4):1092-7.

2. Scott JW, Olufajo OA, Brat GA, Rose JA, Zogg CK, Haider AH, Salim A, Havens JM. Use of national burden to define operative emergency general surgery. *JAMA Surg*. 2016;151(6):e160480-e.

3. Havens JM, Peetz AB, Do WS, Cooper Z, Kelly E, Askari R, Reznor G, Salim A. The excess morbidity and mortality of emergency general surgery. *J Trauma Acute Care Surg*. 2015;78(2):306-11.

4. Staudenmayer K, Bernard A, Davis KA, Doucet J, Haider A, Scherer Iii LRT, Minei JP. The current and future economic state of acute care surgery. LWW; 2019.

5. Knowlton LM, Minei J, Tennakoon L, Davis KA, Doucet J, Bernard A, Haider A, Scherer Iii LRT, Spain DA, Staudenmayer KL. The economic footprint of acute care surgery in the United States: Implications for systems development. *J Trauma Acute Care Surg*. 2019;86(4):609-16.

6. Bernard A, Staudenmayer K, Minei JP, Doucet J, Haider A, Scherer T, Davis KA. Macroeconomic trends and practice models impacting acute care surgery. *Trauma Surg Acute Care Open*. 2019;4(1):e000295.

7. Miller PR. Defining burden and severity of disease for emergency general surgery. *Trauma Surg Acute Care Open*. 2017;2(1):e000089.

8. Nix KA, O'Shea JS. Improving Healthcare Quality in the United States: A New Approach. *Southern Med J*. 2015;108(6):359-63.

9. Hoyt DB, Ko CY, Jones RS. Optimal Resources for Surgical Quality and Safety: American College of Surgeons; 2017.

10. 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):444-8.

11. Porter ME. What is value in health care? *N Eng J Med*. 2010;363(26):2477-81.

12. Scarborough JE, Pappas TN, Bennett KM, Lagoo-Deenadayalan S. Failure-to-Pursue Rescue: Explaining Excess Mortality in Elderly Emergency General Surgical Patients with Preexisting “Do-Not-Resuscitate” Orders. *Ann Surg*. 2012;256(3).

13. Shahan CP, Bell T, Paulus E, Zarzaur BL. Emergency general surgery outcomes at safety net hospitals. *J Surg Res*. 2015;196(1):113-7.

14. Sheetz KH, Waits SA, Krell RW, Campbell Jr DA, Englesbe MJ, Ghaferi AA. Improving mortality following emergency surgery in older patients requires focus on complication rescue. *Ann Surg*. 2013;258(4):614.

15. Ozdemir BA, Sinha S, Karthikesalingam A, Poloniecki JD, Pearse RM, Grocott MPW, Thompson MM, Holt PJE. Mortality of emergency general surgical patients and associations with hospital structures and processes. *Br J Anaesth*. 2015;116(1):54-62.

16. Kozower BD. Failure-to-rescue: an evolving quality metric. *J Thoracic Cardiovasc Surg*. 2015;149(5):1247-8.

17. Wegner SE. Measuring Value in Health Care: The Times, They Are A Changin'. *N C Med J*. 2016;77(4):276-8.

18. Lee KHK, Austin JM, Pronovost PJ. Developing a measure of value in health care. *Value Health*. 2016;19(4):323-5.

19. Rattan R, Parreco J, Namias N, Pust GD, Yeh DD, Zakrison TL. Hidden costs of hospitalization after firearm injury: national analysis of different hospital readmission. *Ann Surg*. 2018;267(5):810-5.

20. Parreco J, Buicko J, Cortolillo N, Namias N, Rattan R. Risk factors and costs associated with nationwide nonelective readmission after trauma. *J Trauma Acute Care Surg*. 2017;83(1):126-34.

21. Healthcare C, Utilization P. Cost-to-charge ratio files. Available: www hcup-us ahrq gov/db/state/costtocharge jsp [accessed 20 June 2010]. 2011.

22. Khorgami Z, Aminian A, Shoar S, Andalib A, Saber AA, Schauer PR, Brethauer SA, Sclabas GM. Cost of bariatric surgery and factors associated with increased cost: an analysis of national inpatient sample. *Surg Obes Relat Dis*. 2017;13(8):1284-9.

23. Faraoni D, Nasr VG, DiNardo JA. Overall hospital cost estimates in children with congenital heart disease: analysis of the 2012 kid's inpatient database. *Ped Cardiol*. 2016;37(1):37-43.

24. Stey AM, Brook RH, Needleman J, Hall BL, Zingmond DS, Lawson EH, Ko CY. Hospital costs by cost center of inpatient hospitalization for medicare patients undergoing major abdominal surgery. *J Am Coll Surg*. 2015;220(2):207-17.

25. Arefian H, Heublein S, Scherag A, Brunkhorst FM, Younis MZ, Moerer O, Fischer D, Hartmann M. Hospital-related cost of sepsis: a systematic review. *J Infection*. 2017;74(2):107-17.

26. Spector WD, Limcangco R, Owens PL, Steiner CA. Marginal hospital cost of surgery-related hospital-acquired pressure ulcers. *Med Care*. 2016;54(9):845-51.

27. Guy GP, Berkowitz Z, Watson M. Estimated cost of sunburn-associated visits to US hospital emergency departments. *JAMA Derm*. 2017;153(1):90-2.

28. Wakeam E, Molina G, Shah N, Lipsitz SR, Chang DC, Gawande AA, Haynes AB. Variation in the cost of 5 common operations in the United States. *Surgery*. 2017;162(3):592-604.

29. Calculator CPII. CPI Inflation Calculator. 2015.

30. Owens DK, Qaseem A, Chou R, Shekelle P. High-value, cost-conscious health care: concepts for clinicians to evaluate the benefits, harms, and costs of medical interventions. *Ann Int Med*. 2011;154(3):174-80.

31. Balentine CJ, Naik AD, Berger DH, Chen H, Anaya DA, Kennedy GD. Postacute care after major abdominal surgery in elderly patients: intersection of age, functional status, and postoperative complications. *JAMA Surg*. 2016;151(8):759-66.

32. Joseph B, Zangbar B, Pandit V, Fain M, Mohler MJ, Kulvatunyou N, Jokar TO, O'Keeffe T, Friese RS, Rhee P. Emergency general surgery in the elderly: too old or too frail? *J Am Coll Surg*. 2016;222(5):805-13.

33. Jokar TO, Ibraheem K, Rhee P, Kulavatunyou N, Haider A, Phelan HA, Fain M, Mohler MJ, Joseph B. Emergency general surgery specific frailty index: a validation study. *J Trauma Acute Care Surg*. 2016;81(2):254-60.

34. Ingraham AM, Cohen ME, Raval MV, Ko CY, Nathens AB. Variation in quality of care after emergency general surgery procedures in the elderly. *J Am Coll Surg*. 2011;212(6):1039-48.

35. Schwartz AL, Landon BE, Elshaug AG, Chernew ME, McWilliams JM. Measuring low-value care in Medicare. *JAMA Int Med*. 2014;174(7):1067-76.

36. Hoehn RS, Go DE, Dhar VK, Kim Y, Hanseman DJ, Wima K, Shah SA. Understanding the “weekend effect” for emergency general surgery. *J Gastrointest Surg*. 2018;22(2):321-8.

37. Metcalfe D, Castillo-Angeles M, Rios-Diaz AJ, Havens JM, Haider A, Salim A. Is there a “weekend effect” in emergency general surgery? *J Surg Res.* 2018;222:219-24.

38. Freemantle N, Ray D, McNulty D, Rosser D, Bennett S, Keogh BE, Pagano D. Increased mortality associated with weekend hospital admission: a case for expanded seven day services? *BMJ*. 2015;351:h4596.

39. Palmer WL, Bottle A, Davie C, Vincent CA, Aylin P. Dying for the weekend: a retrospective cohort study on the association between day of hospital presentation and the quality and safety of stroke care. *Arch Neurol*. 2012;69(10):1296-302.

40. Basse L, Thorbøl JE, Løssl K, Kehlet H. Colonic surgery with accelerated rehabilitation or conventional care. *Dis Colon Rectum*. 2004;47(3):271-8.

41. Havens JM, Olufajo OA, Tsai TC, Jiang W, Nitzschke SL, Cooper Z, Salim A. Hospital factors associated with care discontinuity following emergency general surgery. *JAMA Surg*. 2017;152(3):242-9.

42. Morche J, Mathes T, Pieper D. Relationship between surgeon volume and outcomes: a systematic review of systematic reviews. *Syst Rev*. 2016;5(1):204.

43. Santry H, Kao LS, Shafi S, Lottenberg L, Crandall M. Pro-con debate on regionalization of emergency general surgery: controversy or common sense? *Trauma Surg Acute Care Open.* 2019;4(1):e000319.

Figure Legends

Figure 1: Trends in Health Care Value and Costs

Figure 2: EGS Centers Adjusted Health Care Value

Introduction

Emergency general surgery (EGS) patients represent a large fraction of annual surgical admissions (1). It is estimated that more than 3 million patients are admitted to hospitals in the United States (US) each year for an EGS requiring diagnosis (2). EGS patients represent a unique subgroup. Having a higher disease acuity, they sustain a disproportionately higher burden of complications, mortality, and readmission (3). While the nationwide demand for emergency health care is increasing, availability and access are declining. This is also accompanied by a rise in health care costs (4, 5), declining physician workforce (6), and an alarming surge in emergency department closures (7). Collectively, these trends can create a public health crisis.

Enhancing the quality of EGS health care quality remains a national priority and a key part of improving emergency care in general (8). More specifically, there is also a growing need to improve the quality of care while simultaneously decreasing health care costs (9, 10). The concept of health care value is roughly defined as the health outcomes achieved per dollar of health care costs spent, which simultaneously encompasses the two dimensions of quality and cost containment (11). There is expanding interest in developing a value-based health care system to improve performance with economic sustainability (8).

At present, however, there is a lack of data evaluating the nationwide performance of EGS centers from a value-based health care perspective. Although EGS patients are a heterogeneous group, understanding the temporal trends in EGS quality metrics and costs would be of paramount importance for quality assessment. Policymakers and primary expected payers have embraced quality assessment using such metrics as an effective way to improve patient outcomes through feedback and payment incentives that can promote institutional quality improvement efforts. The aim of our study was to evaluate the trend of health care value in EGS over time and to identify barriers to high value surgical care.

Methods

Data Sources

We performed a 4-year retrospective cohort analysis of the (2012-2015) Health care Cost and Utilization Project (HCUP) Nationwide Readmission Database (NRD). The Agency for Health care Research and Quality maintains the NRD. It records up to 15 million admissions per year and provides longitudinal follow-up data on a nationally representative sample of patients with subsequent readmission(s) throughout a one-year period following their index admission. Sample weights can be applied to obtain national estimates. To track patients upon readmission to an index or a different hospital, the database utilizes a unique identifier. These features make the NRD the largest, most comprehensive, accurate source of US hospital readmission data. Institutional review board approval was exempted because the NRD only contains deidentified data.

Study Population

We queried the database for all adult (≥18years) patients admitted for an EGS procedure as per the definition of the American Association for the Surgery of Trauma (AAST). The AAST Committee on Severity Assessment and Patient Outcomes developed a comprehensive data-driven definition of EGS and identified the International Classification of Diseases 9thRevision (ICD-9) primary diagnostic codes that correspond to the scope of EGS (1). We included all patients who were admitted from January 1 through June 30 for each year. Admissions in the first half of a year ensure a minimum follow-up period of 6 months. Patients discharged from the ED are not included in the database. Survey weights were used for national estimates as per HCUP recommendations.

Patient Stratification

We stratified patients into four groups based on the year of admission for the EGS procedure: 2012, 2013, 2014, and 2015.

Data Points and Definitions:

For each patient, we abstracted the following data points from the database: demographics (age, sex, primary payer, household income, location) and comorbidities (anemia, arthritis, congestive heart failure, diabetes, hypertension, peripheral vascular disease, liver failure, chronic kidney disease, obesity, etc). We also collected data regarding the respective EGS category (eg, appendix, biliary-pancreatic, abdominal wall, upper GI, lower GI, rectosigmoid, perianal, thoracic, peritoneum, genitourinary, etc) and index admission characteristics (weekend admission, length of stay, and discharge disposition). The characteristics of index hospitals performing EGS were also abstracted, including ownership (public, not for profit, investor-owned), bed size, teaching status, and annual EGS volume. Hospital volume was categorized into high (>150 cases per year), medium (50-150 cases per year), and low volume (<50 cases per year) based on the 33rd and the 67th percentile of the annual hospital volume variable. We also reported the urban-rural designation of the EGS center (large metropolitan, small metropolitan, micropolitan, and non-urban).

Data on in-hospital outcomes, along with longitudinal data within 6 months of follow-up, were abstracted regarding the incidence of major complications (defined as the occurrence of pneumonia, myocardial infarction, heart failure, respiratory failure, pulmonary embolism, sepsis, deep surgical site infection, deep vein thrombosis, acute renal failure, abdominal compartment syndrome, cardiac arrest, or cerebrovascular accident). The rates of failure-to-rescue (FTR), 6-

months readmission, 6-months re-operation, number of readmission events, time to readmission, and non-index readmission were also collected, and we examined health care costs.

Failure to Rescue

Failure to rescue (FTR) is typically defined as death following a major complication (12). It is increasingly utilized as a hospital quality metric reflecting the performance of hospitals when addressing postoperative complications (13). This makes it an important benchmark for patient safety (14). Multiple studies reported that there is considerable variation in postoperative outcomes irrespective of patient-related factors potentially due to the hospital's quality of care (15). This makes FTR a targeted metric by quality improvement programs (16). We defined FTR as the occurrence of death and major complications (12-16).

Health Care Value

The operational definition underlying an assessment of the quality of health care requires certain assumptions. Stakeholders who have embraced the study of health care quality and medical outcomes recognize the difficulty in establishing a standardized definition and recommended using quality indicators that capture pertinent attributes of care, including efficacy, effectiveness, efficiency, optimality, and acceptability (9). Commonly reported quality metrics throughout the surgical literature that represent such attributes include readmission, reoperation, major complications, and FTR. However, high quality surgical care faces dynamic challenges related to economic and market forces, limited reimbursement, regulatory measures, and compliance with the Affordable Care Act and Medicare Access. This means that our quality assessment methodology must incorporate health care costs eventually arriving at the concept of health care value (9). The major goal of quality improvement initiatives must be directed towards increasing health care value through decreasing health care costs and reducing utilization. Porter et al. proposed using health care value defined as quality (Q) divided by costs (C) or Value = Q/C (11). In practice, arbitrarily chosen quality indicators must represent Q (9, 17, 18). Quality was calculated as a composite measure utilizing multiple quality metrics commonly utilized in the literature (18): Failure to rescue, readmission, reoperation, and major complications. Because lower rates of all these metrics indicate better quality, quality was calculated using the formula:

$$Q = (1 - P_{Readmission}) + \left(1 - P_{Major\ Complications}\right) + \left(1 - P_{Reoperation}\right) + (1 - P_{FTR})$$

$P_{Readmission}$ = Proportion of patients who were readmitted

$P_{Major\ Complications}$ = Proportion of patients who developed major complications on index admission or upon readmission

$P_{Reoperation}$ = Proportion of patients with reoperation on index admission or upon readmission

P_{FTR} = Proportion of patients with failure to rescue on index admission or upon readmission

The NRD database provides the total hospital charges per admission for each patient (19-21). It also provides a unique and internally validated annual cost-to-charge ratio for each facility. As per HCUP standards and existing literature, hospital charges can be converted to estimated hospital costs using a center specific cost-charge ratio (5, 19, 21-28). This ratio is calculated based on accounting reports collected by CMS (21). Hospital costs were calculated using each patient’s hospital total charge (aggregate of index admission and readmissions) multiplied by the corresponding facility cost-to-charge ratio. Hospital costs were adjusted for inflation to have the same dollar value as the year 2015. Using the annual Consumer Price Index, the rate of inflation over the study period was determined to be 3.2% (29).

$$Hospital\ Costs = Hospital\ Charges\ \times Hospital\ Cost\ to\ Charge\ Ratio$$

$$Inflation\ Adjusted\ Hospital\ Costs = Hospital\ Costs + (Hospital\ Costs \times 0.032)$$

Therefore, health care value was calculated using the formula:

$$Healthcare\ Value = \frac{(1 - P_{Readmission}) + (1 - P_{Major\ Complications}) + (1 - P_{Reoperation}) + (1 - P_{FTR})}{Inflation\ Adjusted\ Hospital\ Costs}$$

Outcome Measures:

Our primary outcome measure was the trend in health care value over the study period. Our secondary outcome measures were the trends in the quality metrics over the study period: 6-months readmission, major complications, reoperation, FTR, and health care costs.

Statistical Analysis:

We performed descriptive statistics to outline the baseline characteristics of the study sample and EGS centers based on year of admission. Continuous normally distributed data were summarized using a mean and a standard deviation. Continuous not-normally distributed data were summarized using a median and an interquartile range. Categorical data were summarized using counts and proportions. To compare the baseline characteristics of EGS patients and EGS centers across the duration of the study, we used the Chi-Square test with Bonferroni adjustment for multiple comparisons to compare proportions, the one-way analysis of variance (ANOVA) to compare continuous normally distributed variables with Bonferroni adjustment for multiple comparisons, and the Kruskal-Wallis test to compare continuous not-normally distributed data. The variation in health care value across the study period can be attributed to a wide spectrum of different patient characteristics, distribution of EGS conditions, and hospital-level characteristics.

In order to ascertain the predictors of health care value while adjusting for measurable confounding factors, we performed a hierarchical mixed-effects linear regression model with a random effect for the EGS center. Adjustment was performed for demographics (age, gender, primary payer, income, and location), comorbidities (CCI: Charlson Comorbidities Index), EGS category, index-admission characteristics, hospital ownership, bed size, teaching status, annual EGS volume, and urban-rural designation. This approach takes into account the hierarchical structure of the data among patients from the same EGS center. Because we used multicenter data, the analytic approach needs to account for the intra-cluster effect (patients within the same facility are more correlated than patients from different facilities, thus violating independence assumption) especially that centers differ in their management approach and quality of care. After this model was fit, we calculated the EGS center-specific adjusted health care value from the model's predicted value per EGS center. Based on the distribution of the center-specific adjusted health care value, we calculated the hypothetical estimated reduction in health care costs if centers performing in the lower quartile were to improve their performance in terms of health care value to the median center-specific health care value. We considered a P-value of less than 0.05 ($P < 0.05$) as statistically significant. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 23; SPSS, Inc., Armonk, NY).

Results

A total of 887,013 patients undergoing an EGS procedure at 6,275 hospitals were identified. Stratification of patients by year of admission showed that 236,555 were admitted in 2012, 228,449 in 2013, 198,600 in 2014, and 223,409 in 2015. Overall, the mean age was 51±20 years, and 53% were male. The most common EGS procedure performed involved the appendix (21%), followed by the biliary-pancreatic region (19%) and the abdominal wall (11%). The median length of stay was 3 [2-7] days. Following their inpatient stay, most patients were discharged routinely (76%) --**Table 1**. In terms of the centers performing EGS, most patients (67%) were admitted to hospitals with a high EGS volume --**Table 2**.

Concerning trends in EGS quality metrics over the study period, there is an overall increase in the rates of major complications (2012: 22.4% vs. 2015: 27.2%; $p<0.01$), FTR (2012: 2.1% vs. 2015: 4%; $p<0.01$), 6-months readmission (2012: 21% vs. 2015: 23.7%; $p<0.01$), and 6-months reoperation (2012: 9.3% vs. 2015: 11%; $p<0.01$). There was also an overall increase in the inflation adjusted hospital costs (2012: $9,600 [$7000-$15000] vs. 2015: $13,000 [$8000-$17000]; $p<0.01$). The median health care value had a downward trend across the study period (2012: 0.35[0.23-0.49] vs. 2015: 0.25[0.19-0.41]; $p<0.01$)--**Figure 1**. When examining other quality metrics, there was no significant difference in the number of readmission events among those who were readmitted (2012: 1[1-2] vs. 2015: 1[1-2]; $p=0.87$). However, the rate of non-index hospital readmission rose significantly over the study period (2012: 22% vs. 2015: 23.8%; $p<0.01$)--**Table 3.**

On regression analysis, after adjusting for patient and hospital-level baseline characteristics, the downward trend in health care value was persistent on a multivariable level ($\beta=-0.004$ [-0.015 – (-0.001)]; $p=0.01$). At the same time, a number of patient and hospital-level characteristics were significant predictors of lower health care value. The independent predictors of a lower health care value are age group ≥65 years ($\beta=-0.568$ [-0.689 - (-0.418)]; $p<0.01$), low-income quartile ($\beta=-0.368$ [-0.455 - (-0.262)]; $p<0.01$), >3 comorbidities ($\beta=-0.292$ [-0.359 - (-0.21)]; $p<0.01$), weekend admission ($\beta=-0.318$ [-0.366 - (-0.254)]; $p<0.01$), non-index readmission ($\beta=-0.755$ [-0.914 - (-0.558)]; $p<0.01$), and admission to low volume centers (β-0.927 [-1.126 - (-0.682)]; $p<0.01$).--**Table 4.**

Examining the between hospital variation in health care value, we noticed a wide variation across EGS centers --**Figure 2**. If centers performing below the median health care value were to improve their performance to the median overall adjusted health care value, we estimated a total reduction in EGS cost of $28.9 billion.

Discussion

Using a sample of EGS patients from multiple centers across the nation, our study indicates that there is a gross increase in the rates of major complications, FTR, 6-months readmission, and 6-months re-operation. This coincides with a marked rise in health care costs and an apparent decrease in health care value. The study demonstrates the feasibility of EGS quality assessment using commonly reported quality metrics, while addressing the economic implications of these outcomes. From a value-based perspective, we can see that the health care system is in an apparent suboptimal state when it comes to the outcomes obtained per dollar spent. Furthermore, not all EGS centers are delivering an increase in value at the pace at which health care costs are rising.

The wide spectrum of patient- and hospital-level characteristics that influence the trend in health care value over time allow us to identify barriers to high value care in EGS. These findings can have wide implications on practice considering that many predictors of decreased health care value in EGS are potentially modifiable. Solutions to identify and reduce low-value care remain complex and require targeted interventions on multiple frontiers, such as reducing fragmentation of care, promoting regionalization, patient optimization, and improving health care coverage.

Despite palpable support towards a value based health care system (4), practical methods for measuring value remain elusive (18). In this study, we describe how existing quality metrics and cost accounting data can be used to measure value based on our conceptual understanding of what health care value is (30). We believe this approach is practical, valid, and scalable and can establish the foundation for future work in this area. As described by Lee et al. in their study on developing a measure of value in health care, the numerator (Quality) would be a composite measure composed of multiple qualities metrics (18). Although most of these quality measures are easily captured with the available data, the methods to combine them into a single index score remain elusive and underdeveloped (18). Metrics are usually validated against a gold standard measure of health care value. Unfortunately, there is no gold standard measure of health care value to use for this purpose. There are challenges related to the lack of the infrastructure needed to collect standardized outcome data. Furthermore, current surveillance for patient outcomes and costs of care is not feasible, scalable, or sustainable. Although researchers should work toward the ideal value measure, we need to measure value now with the currently available data and improve over time (18). In addition, calculating the national median health care value provides a benchmark for comparison and performance evaluation.

One of the factors contributing to a decrease in the health care value is the nationwide change in the age distribution of the EGS population. Older adults bring about a unique set of challenges to their surgical course attributed to their comorbidities, geriatric specific syndromes, frailty, and reduced physiological reserves (31-33). This will translate to a longer period of hospitalization, increased costs, and subsequently decreased health care value. Ingraham et al. reviewed the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) exploring the variation in the quality of care after EGS procedures in older adults.

They concluded that elderly patients are inherently at a greater risk of adverse events. They also reported substantial variability in the quality of care provided (34).

Along with aging, the overall prevalence of comorbidities also increased throughout the study period. Salim et al. conducted a retrospective cohort analysis of 66,665 EGS patients aiming to quantify the excess burden of morbidity and mortality associated with EGS, and they reported that much of this increased morbidity and mortality can be attributed to the patient's baseline risk profile at the time of surgery (3). Their findings are in agreement with our study as we also noted an upward trend in the rates of complications, readmission, reoperation, and FTR, which paralleled the increase in the comorbidities burden in the EGS population across the study period that, in turn, contributed to an overall decrease in health care value. This might indicate that EGS patients remain a challenge when it comes to obtaining optimal outcomes while maintaining cost effectiveness. The acuity of the disease process imposes time constraints that prevent adequate patient optimization prior to surgical intervention.

Other important predictors of low health care value include insurance status. Schwartz et al. reviewed claims for a large number of Medicare beneficiaries examining low-value services that provide minimal clinical benefit (35). They inferred that low-value care spending constituted a substantial proportion of overall spending influencing around one in two Medicare beneficiaries. Another important admission characteristic is admission on a weekend. Shah et al. compared outcomes among EGS patients admitted on weekday versus those admitted on a weekend. They reported that the adjusted mortality rate was significantly higher in subgroups of EGS patients admitted on a weekend in comparison to those admitted on a weekday (36). This was further verified by Salim et al. who reported that admission on a weekend was an independent predictor of serious adverse events, FTR, and in-hospital mortality (37). Hospital resources may be scarce on weekends and multidisciplinary care teams may be incomplete (38, 39). Our finding that weekend admission was an independent predictor for low health care value may be explained by higher rates of FTR, which is on par with what was described previously. Post-operative rehabilitation was found to increase health care value despite the added services. Despite the lack of high-grade evidence, the literature on rehabilitation concluded that this intervention might be beneficial at reducing adverse events and might be cost effective (40).

Non-index readmission or fragmentation of care was found to have a major contribution to low health care value. This is in agreement with the existing body of literature on the hazards of care discontinuity. Havens et al. reported that one in five readmitted EGS patients will seek care at a non-index hospital and that care discontinuity is an independent predictor of mortality (41). Our findings expand the current understanding of the consequences of care discontinuity by highlighting its economic disadvantage. Not surprisingly, index-hospital volume played an important role in determining health care value. Multiple studies have demonstrated a reliable volume-outcome relationship in EGS. Hospital volume is a surrogate measure of hospital experience and, potentially, surgeon experience. Accumulating experience allows health care systems to minimize errors in management. At the same time, high volume hospitals tend to have a wider spectrum of clinical services offered which will facilitate the timely recognition and handling of post-operative complications that will improve FTR rates (42). Considering the apparently deleterious effects of care fragmentation and admission to low-volume centers, the regionalization of EGS care has been proposed as a solution to these challenges (43). With multiple implications on practice, the regionalization of EGS care has become a subject of debate with no consensus whether the benefits will outweigh the unintended consequences of such an approach. The results of our study support of regionalization by highlighting preventable morbidity, mortality, and cost effectiveness (43). Despite these diverse factors, we noticed from the multivariable linear regression that the downward trend in health care value persisted even after adjusting for the annual EGS case mix. There are possible unmeasured confounding factors that we cannot account for using the database. Other possible reasons include the overuse of diagnostic tests, patient overtreatment, wasted health care expenditure, and medical errors.

Our study is not without limitations. There are limitations attributed to the retrospective nature of the analysis, the contribution of unmeasured confounding factors, and erroneous database entries. The entire spectrum of factors contributing to the decline in health care value were not captured in the utilized database. Using this study design, we can only establish associations rather than a causal relationship. There are also limitations attributed to the lack of a gold standard measure of health care value. Quality is a metaphysical concept that is difficult to define and quantitate. There are limitations associated with utilizing surrogate quality metrics such as FTR, readmission, reoperation, and complications. We lack ideal measures of quality that are patient reported and take into consideration the patient's experience. The notion that quality is a composite measure with equal weights given to readmissions, complications, and FTR also contributes to the limitations of the utilized definition of quality. There is a lack of data regarding the optimal weights to be assigned to each quality metric we utilized an exploratory formula that is based on the direct contribution of each quality metric to the sum without weights. HCUP costs which are based on hospital charges may not completely capture the entire spectrum of health care costs sustained and may not reflect true clinical costs (physician fees, additional services, costs unrelated to patient care, administrative costs, payer costs, and government costs). These variables remain the only information on cost available in the NRD database. Hospital costs may have been underestimated in our analysis due to scope of the utilized database. In addition, the utilized database can only track patients upon readmission within the same state. Patients were missed if they were not readmitted or only followed up on an outpatient basis, or readmitted to a different state. It is possible that we have underestimated the cost and complications incurred by EGS patients. However, this study fills a gap in the literature on the performance of our EGS infrastructure from a value-based model (which had not been previously well described), ascertains the factors contributing to this trend in performance, identifies areas of improvement, and adds to the existing body of literature describing the advantages of a value-based model.

This study highlights several areas for future investigation. Compiling data that are more granular could identify further factors contributing to a decrease in health care value. The entire spectrum of hospital costs are difficult to comprehensively and accurately estimate, nationwide databases can still provide important information on the overall burden. The study may also highlight the need to improve our data infrastructure to better capture health care costs moving forward. This study may also facilitate the shift from a fee-for-service model to a fee-for-value model. Finally, our findings contribute to the growing literature aimed at improving the efficiency of the EGS health care system. Examining the trend in health care value over time for non-operative EGS patients is also an interesting area to explore given that a large proportion of EGS patients are non-operatively managed.

Conclusion

Health care value in EGS appears to be declining over time. Some of the factors leading to decreased health care value in EGS may be potentially modifiable. Transforming the quality of surgical care requires the adoption of a disruptive model based on health care value. Potentially, this may be implemented through targeted interventions on multiple frontiers. Health care value could potentially be improved by reducing fragmentation of care, and promoting regionalization.

Authors Contributions:

K.H, B.J, Z.H, A.N, N.K, A.T, and S.A designed this study.

K.H, Z.H, B.J, J.S, M.Z searched the literature.

K.H, B.J, Z.H, M.Z, Z.H, N.K and J.S collected the data.

K.H, B.J, Z.H, A.N, A.T and S.A analyzed the data.

All authors participated in data interpretation and manuscript preparation.

Acknowledgements:

None

Conflict of interest:

There are no identifiable conflicts of interests to report

Funding

No funding was provided for this study

References

1. Shafi S, Aboutanos MB, Agarwal Jr S, Brown CVR, Crandall M, Feliciano DV, Guillamondegui O, Haider A, Inaba K, Osler TM. Emergency general surgery: definition and estimated burden of disease. *J Trauma Acute Care Surg*. 2013;74(4):1092-7.
2. Scott JW, Olufajo OA, Brat GA, Rose JA, Zogg CK, Haider AH, Salim A, Havens JM. Use of national burden to define operative emergency general surgery. *JAMA Surg*. 2016;151(6):e160480-e.
3. Havens JM, Peetz AB, Do WS, Cooper Z, Kelly E, Askari R, Reznor G, Salim A. The excess morbidity and mortality of emergency general surgery. *J Trauma Acute Care Surg*. 2015;78(2):306-11.
4. Staudenmayer K, Bernard A, Davis KA, Doucet J, Haider A, Scherer Iii LRT, Minei JP. The current and future economic state of acute care surgery. LWW; 2019.
5. Knowlton LM, Minei J, Tennakoon L, Davis KA, Doucet J, Bernard A, Haider A, Scherer Iii LRT, Spain DA, Staudenmayer KL. The economic footprint of acute care surgery in the United States: Implications for systems development. *J Trauma Acute Care Surg*. 2019;86(4):609-16.
6. Bernard A, Staudenmayer K, Minei JP, Doucet J, Haider A, Scherer T, Davis KA. Macroeconomic trends and practice models impacting acute care surgery. *Trauma Surg Acute Care Open*. 2019;4(1):e000295.
7. Miller PR. Defining burden and severity of disease for emergency general surgery. *Trauma Surg Acute Care Open*. 2017;2(1):e000089.
8. Nix KA, O'Shea JS. Improving Healthcare Quality in the United States: A New Approach. *Southern Med J*. 2015;108(6):359-63.

9. Hoyt DB, Ko CY, Jones RS. Optimal Resources for Surgical Quality and Safety: American College of Surgeons; 2017.

10. 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):444-8.

11. Porter ME. What is value in health care? *N Eng J Med*. 2010;363(26):2477-81.

12. Scarborough JE, Pappas TN, Bennett KM, Lagoo-Deenadayalan S. Failure-to-Pursue Rescue: Explaining Excess Mortality in Elderly Emergency General Surgical Patients with Preexisting “Do-Not-Resuscitate” Orders. *Ann Surg*. 2012;256(3).

13. Shahan CP, Bell T, Paulus E, Zarzaur BL. Emergency general surgery outcomes at safety net hospitals. *J Surg Res*. 2015;196(1):113-7.

14. Sheetz KH, Waits SA, Krell RW, Campbell Jr DA, Englesbe MJ, Ghaferi AA. Improving mortality following emergency surgery in older patients requires focus on complication rescue. *Ann Surg*. 2013;258(4):614.

15. Ozdemir BA, Sinha S, Karthikesalingam A, Poloniecki JD, Pearse RM, Grocott MPW, Thompson MM, Holt PJE. Mortality of emergency general surgical patients and associations with hospital structures and processes. *Br J Anaesth*. 2015;116(1):54-62.

16. Kozower BD. Failure-to-rescue: an evolving quality metric. *J Thoracic Cardiovasc Surg*. 2015;149(5):1247-8.

17. Wegner SE. Measuring Value in Health Care: The Times, They Are A Changin'. *N C Med J*. 2016;77(4):276-8.

18. Lee KHK, Austin JM, Pronovost PJ. Developing a measure of value in health care. *Value Health*. 2016;19(4):323-5.

19. Rattan R, Parreco J, Namias N, Pust GD, Yeh DD, Zakrison TL. Hidden costs of hospitalization after firearm injury: national analysis of different hospital readmission. *Ann Surg*. 2018;267(5):810-5.

20. Parreco J, Buicko J, Cortolillo N, Namias N, Rattan R. Risk factors and costs associated with nationwide nonelective readmission after trauma. *J Trauma Acute Care Surg*. 2017;83(1):126-34.

21. Healthcare C, Utilization P. Cost-to-charge ratio files. Available: www hcup-us ahrq gov/db/state/costtocharge jsp [accessed 20 June 2010]. 2011.

22. Khorgami Z, Aminian A, Shoar S, Andalib A, Saber AA, Schauer PR, Brethauer SA, Sclabas GM. Cost of bariatric surgery and factors associated with increased cost: an analysis of national inpatient sample. *Surg Obes Relat Dis*. 2017;13(8):1284-9.

23. Faraoni D, Nasr VG, DiNardo JA. Overall hospital cost estimates in children with congenital heart disease: analysis of the 2012 kid's inpatient database. *Ped Cardiol*. 2016;37(1):37-43.

24. Stey AM, Brook RH, Needleman J, Hall BL, Zingmond DS, Lawson EH, Ko CY. Hospital costs by cost center of inpatient hospitalization for medicare patients undergoing major abdominal surgery. *J Am Coll Surg*. 2015;220(2):207-17.

25. Arefian H, Heublein S, Scherag A, Brunkhorst FM, Younis MZ, Moerer O, Fischer D, Hartmann M. Hospital-related cost of sepsis: a systematic review. *J Infection*. 2017;74(2):107-17.

26. Spector WD, Limcangco R, Owens PL, Steiner CA. Marginal hospital cost of surgery-related hospital-acquired pressure ulcers. *Med Care*. 2016;54(9):845-51.

27. Guy GP, Berkowitz Z, Watson M. Estimated cost of sunburn-associated visits to US hospital emergency departments. *JAMA Derm*. 2017;153(1):90-2.

28. Wakeam E, Molina G, Shah N, Lipsitz SR, Chang DC, Gawande AA, Haynes AB. Variation in the cost of 5 common operations in the United States. *Surgery*. 2017;162(3):592-604.

29. Calculator CPII. CPI Inflation Calculator. 2015.

30. Owens DK, Qaseem A, Chou R, Shekelle P. High-value, cost-conscious health care: concepts for clinicians to evaluate the benefits, harms, and costs of medical interventions. *Ann Int Med*. 2011;154(3):174-80.

31. Balentine CJ, Naik AD, Berger DH, Chen H, Anaya DA, Kennedy GD. Postacute care after major abdominal surgery in elderly patients: intersection of age, functional status, and postoperative complications. *JAMA Surg*. 2016;151(8):759-66.

32. Joseph B, Zangbar B, Pandit V, Fain M, Mohler MJ, Kulvatunyou N, Jokar TO, O'Keeffe T, Friese RS, Rhee P. Emergency general surgery in the elderly: too old or too frail? *J Am Coll Surg*. 2016;222(5):805-13.

33. Jokar TO, Ibraheem K, Rhee P, Kulavatunyou N, Haider A, Phelan HA, Fain M, Mohler MJ, Joseph B. Emergency general surgery specific frailty index: a validation study. *J Trauma Acute Care Surg*. 2016;81(2):254-60.

34. Ingraham AM, Cohen ME, Raval MV, Ko CY, Nathens AB. Variation in quality of care after emergency general surgery procedures in the elderly. *J Am Coll Surg*. 2011;212(6):1039-48.

35. Schwartz AL, Landon BE, Elshaug AG, Chernew ME, McWilliams JM. Measuring low-value care in Medicare. *JAMA Int Med*. 2014;174(7):1067-76.

36. Hoehn RS, Go DE, Dhar VK, Kim Y, Hanseman DJ, Wima K, Shah SA. Understanding the "weekend effect" for emergency general surgery. *J Gastrointest Surg*. 2018;22(2):321-8.

37. Metcalfe D, Castillo-Angeles M, Rios-Diaz AJ, Havens JM, Haider A, Salim A. Is there a "weekend effect" in emergency general surgery? *J Surg Res*. 2018;222:219-24.

38. Freemantle N, Ray D, McNulty D, Rosser D, Bennett S, Keogh BE, Pagano D. Increased mortality associated with weekend hospital admission: a case for expanded seven day services? *BMJ*. 2015;351:h4596.

39. Palmer WL, Bottle A, Davie C, Vincent CA, Aylin P. Dying for the weekend: a retrospective cohort study on the association between day of hospital presentation and the quality and safety of stroke care. *Arch Neurol*. 2012;69(10):1296-302.

40. Basse L, Thorbøl JE, Løssl K, Kehlet H. Colonic surgery with accelerated rehabilitation or conventional care. *Dis Colon Rectum*. 2004;47(3):271-8.

41. Havens JM, Olufajo OA, Tsai TC, Jiang W, Nitzschke SL, Cooper Z, Salim A. Hospital factors associated with care discontinuity following emergency general surgery. *JAMA Surg*. 2017;152(3):242-9.

42. Morche J, Mathes T, Pieper D. Relationship between surgeon volume and outcomes: a systematic review of systematic reviews. *Syst Rev*. 2016;5(1):204.

43. Santry H, Kao LS, Shafi S, Lottenberg L, Crandall M. Pro-con debate on regionalization of emergency general surgery: controversy or common sense? *Trauma Surg Acute Care Open.* 2019;4(1):e000319.

Figure Legends

Figure 1: Trends in Health Care Value and Costs

Figure 2: EGS Centers Adjusted Health Care Value

Table 1: Baseline Characteristics of the Study Sample

Variable	2012 (N=236,555)	2013 (N=228,449)	2014 (N=198,600)	2015 (N=223,409)	P-Value
Demographics					
Male, n (%)	125611 (53.1)	119707 (52.4)	101882 (51.3)	118183 (52.9)	<0.01
Age, years, n (%)					
18-44	92730 (39.2)	84298 (36.9)	70503 (35.5)	84449 (37.8)	<0.01
45-64	78773 (33.3)	77673 (34)	68517 (34.5)	76853 (34.4)	<0.01
≥65	65053 (27.5)	66250 (29)	59580 (30)	64342 (28.8)	<0.01
Primary Payer, n (%)					
Medicare	73332 (31)	74931 (32.8)	68120 (34.3)	72608 (32.5)	<0.01
Medicaid	34064 (14.4)	32440 (14.2)	33961 (17.1)	33511 (15)	<0.01
Private insurance	90837 (38.4)	84755 (37.1)	71893 (36.2)	82438 (36.9)	<0.01
Self-pay	23892 (10.1)	22388 (9.8)	15491 (7.8)	22341 (10)	<0.01
Other	14430 (6.1)	13935 (6.1)	9136 (4.6)	11394 (5.1)	<0.01
Household Income, n (%)					
$1-$37,999	70730 (29.9)	63280 (27.7)	55012 (27.7)	62778 (28.1)	<0.01
$38,000–$47,999	56773 (24)	60996 (26.7)	53622 (27)	59203 (26.5)	<0.01
$48,000–$63,999	55590 (23.5)	53914 (23.6)	45678 (23)	54288 (24.3)	<0.01
≥$64,000	49440 (20.9)	46604 (20.4)	41309 (20.8)	45799 (20.5)	<0.01
Patient Location, n (%)					
Central Counties	62687 (26.5)	62367 (27.3)	54416 (27.4)	59427 (26.6)	<0.01
Fringe Counties	65053 (27.5)	58026 (25.4)	53026 (26.7)	59203 (26.5)	<0.01
Other	108815 (46)	108056 (47.3)	91157 (45.9)	105672 (47.3)	<0.01
Comorbidities, n (%)					
CCI>0	173868 (73.5)	172707 (75.6)	153518 (77.3)	168450 (75.4)	<0.01
Alcohol Abuse	5204 (2.2)	5711 (2.5)	5759 (2.9)	7819 (3.5)	<0.01
Drug Abuse	5914 (2.5)	6625 (2.9)	6752 (3.4)	7819 (3.5)	<0.01
Anemia	24365 (10.3)	24901 (10.9)	23236 (11.7)	23681 (10.6)	<0.01
Arthritis	4258 (1.8)	4341 (1.9)	3972 (2)	5809 (2.6)	<0.01
CHF	9462 (4)	10052 (4.4)	9533 (4.8)	8936 (4)	<0.01
COPD	30279 (12.8)	30384 (13.3)	27605 (13.9)	28820 (12.9)	<0.01
DM	30752 (13)	30612 (13.4)	27208 (13.7)	29267 (13.1)	<0.01
HTN	90837 (38.4)	91608 (40.1)	82419 (41.5)	89364 (40)	<0.01
Hypothyroidism	17742 (7.5)	18047 (7.9)	16484 (8.3)	19660 (8.8)	<0.01
Liver Failure	6150 (2.6)	6625 (2.9)	6554 (3.3)	8266 (3.7)	<0.01
CKD	13011 (5.5)	14621 (6.4)	13902 (7)	13405 (6)	<0.01
Neurological	9462 (4)	9823 (4.3)	8937 (4.5)	8713 (3.9)	<0.01
Obesity	30279 (12.8)	32897 (14.4)	30982 (15.6)	31054 (13.9)	<0.01
PVD	11828 (5)	12793 (5.6)	12909 (6.5)	12734 (5.7)	<0.01
Malignancy	2839 (1.2)	2970 (1.3)	2979 (1.5)	4692 (2.1)	<0.01

EGS Category					
Appendix	56773 (24)	48431 (21.2)	37933 (19.1)	47139 (21.1)	<0.01
Biliary-Pancreatic	45182 (19.1)	43862 (19.2)	37734 (19)	42671 (19.1)	<0.01
Abdominal wall	28387 (12)	25358 (11.1)	21647 (10.9)	25245 (11.3)	<0.01
Upper GI	5204 (2.2)	5026 (2.2)	4369 (2.2)	4245 (1.9)	<0.01
Lower GI	14193 (6)	16677 (7.3)	15491 (7.8)	14745 (6.6)	<0.01
Rectosigmoid	4258 (1.8)	4112 (1.8)	3575 (1.8)	2904 (1.3)	0.78
Perianal	2839 (1.2)	2741 (1.2)	2185 (1.1)	2011 (0.9)	0.21
Thoracic	5441 (2.3)	5254 (2.3)	4766 (2.4)	4692 (2.1)	<0.01
Peritoneum	18924 (8)	20789 (9.1)	18470 (9.3)	19437 (8.7)	<0.01
Genitourinary	5441 (2.3)	5254 (2.3)	4568 (2.3)	4915 (2.2)	0.78
Musculoskeletal	17978 (7.6)	18047 (7.9)	17477 (8.8)	19660 (8.8)	<0.01
Integument	17269 (7.3)	16905 (7.4)	15491 (7.8)	17873 (8)	<0.01
Other	14666 (6.2)	15991 (7)	14895 (7.5)	17426 (7.8)	<0.01
Weekend Admission, n (%)	54644 (23.1)	53229 (23.3)	47465 (23.9)	52054 (23.3)	<0.01
Length of Stay, d, median [IQR]	3 [2-6]	4 [2-7]	4 [2-7]	4 [2-6]	<0.01
Rehabilitation, n (%)	8043 (3.4)	6397 (2.8)	3376 (1.7)	5809 (2.6)	<0.01
Discharge Disposition, n (%)					
Routine	183803 (77.7)	174307 (76.3)	148156 (74.6)	169121 (75.7)	<0.01
Skilled Nursing Facility	21527 (9.1)	22388 (9.8)	21052 (10.6)	21000 (9.4)	<0.01
Home Health Care	26494 (11.2)	26957 (11.8)	24825 (12.5)	27703 (12.4)	<0.01
Against Medical Advice	946 (0.4)	914 (0.4)	993 (0.5)	2904 (1.3)	<0.01

CCI=Charlson Comorbidity Index; CHF=Congestive Heart Failure; COPD=Chronic Obstructive Pulmonary Disease; DM=Diabetes Mellitus; HTN=Hypertension; CKD=Chronic Kidney Disease; PVD=Peripheral Vascular Disease; GI=Gastrointestinal; IQR=Interquartile Range; d=Days.

Table 2: Characteristics of Index Hospitals by EGS Admission Year					
Variable	**2012 (N=236,555)**	**2013 (N=228,449)**	**2014 (N=198,600)**	**2015 (N=223,409)**	**P-Value**
Ownership, n (%)					
Public	31462 (13.3)	27642 (12.1)	24229 (12.2)	29713 (13.3)	<0.01
Not-for-profit	164879 (69.7)	162427 (71.1)	143389 (72.2)	157727 (70.6)	<0.01
Investor-owned	40214 (17)	38379 (16.8)	30982 (15.6)	36192 (16.2)	<0.01
Bed Size, n (%)					
Small	25311 (10.7)	23987 (10.5)	28797 (14.5)	27703 (12.4)	<0.01
Medium	52988 (22.4)	52315 (22.9)	56005 (28.2)	56746 (25.4)	<0.01
Large	158255 (66.9)	151919 (66.5)	113798 (57.3)	141865 (63.5)	<0.01
Teaching Status, n (%)					
Metropolitan non-teaching	97461 (41.2)	91380 (40)	56998 (28.7)	81097 (36.3)	<0.01
Metropolitan teaching	114729 (48.5)	113996 (49.9)	125118 (63)	119971 (53.7)	<0.01
Non-metropolitan	24365 (10.3)	22845 (10)	16484 (8.3)	23011 (10.3)	<0.01
EGS Volume, n (%)					
Low	4495 (1.9)	4797 (2.1)	5759 (2.9)	7372 (3.3)	<0.01
Medium	59375 (25.1)	68306 (29.9)	72290 (36.4)	70150 (31.4)	<0.01
High	172922 (73.1)	155117 (67.9)	120352 (60.6)	151248 (67.7)	<0.01
Urban-Rural Designation, n (%)					
Large Metropolitan Areas	132707 (56.1)	125875 (55.1)	111017 (55.9)	124439 (55.7)	<0.01
Small Metropolitan Areas	79482 (33.6)	79729 (34.9)	71099 (35.8)	76853 (34.4)	<0.01
Micropolitan Areas	19634 (8.3)	18733 (8.2)	12512 (6.3)	18766 (8.4)	<0.01
Non-Urban	4731 (2)	4112 (1.8)	3972 (2)	3575 (1.6)	<0.01

EGS=Emergency General Surgery;

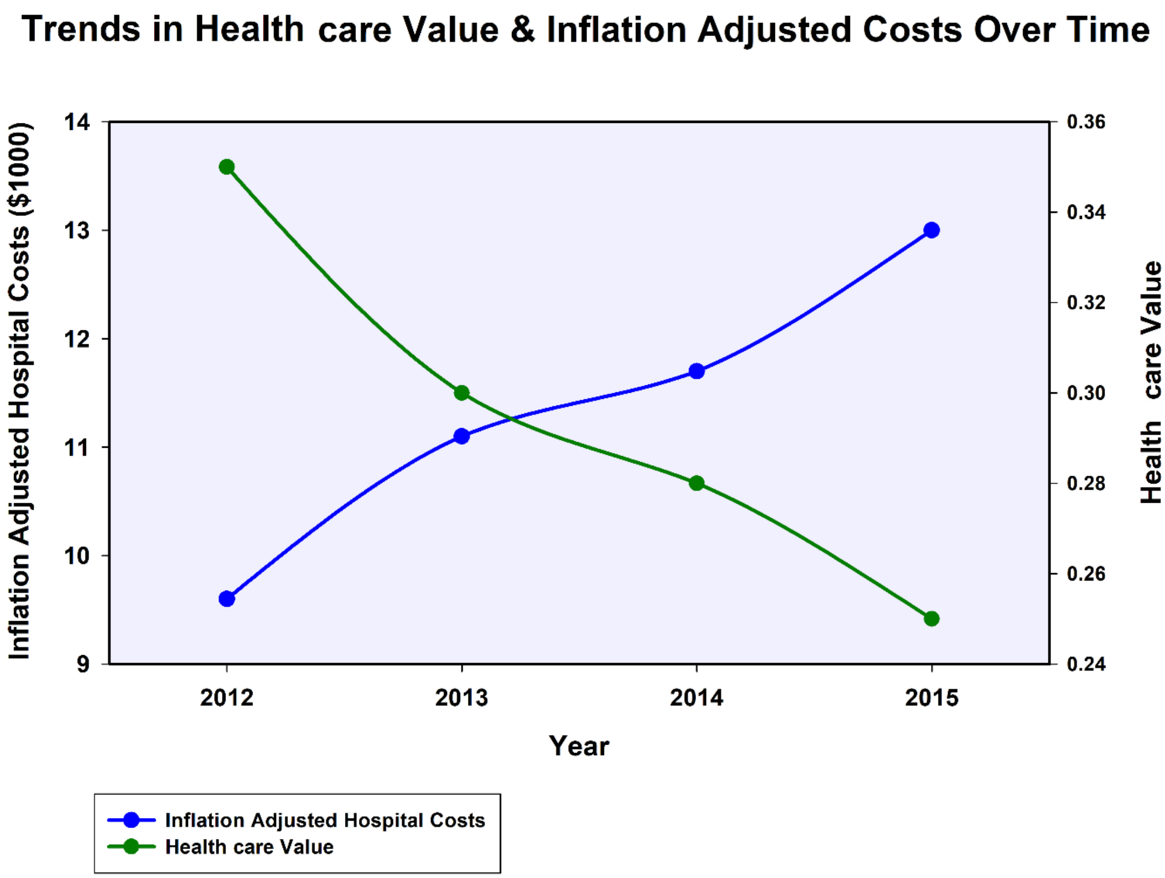
Table 3: Trends in EGS Quality Metrics					
Variable	**2012 (N=236,555)**	**2013 (N=228,449)**	**2014 (N=198,600)**	**2015 (N=223,409)**	**P-Value**
Primary Outcomes					
Major Complications, n (%)	52988 (22.4)	55742 (24.4)	53225 (26.8)	60767 (27.2)	<0.01
Failure-to-Rescue, n (%)	4968 (2.1)	5940 (2.6)	5958 (3)	8936 (4)	<0.01
6-Mon Readmission, n (%)	49677 (21)	51858 (22.7)	46671 (23.5)	52948 (23.7)	<0.01
6-Mon Re-operation, n (%)	22000 (9.3)	22160 (9.7)	20654 (10.4)	24575 (11)	<0.01
Hospital Charges, $1000, median [IQR]	35 [22-58]	38 [24-63]	39 [25-67]	45 [26-71]	<0.01
Cost to charge ratio, median [IQR]	0.29 [0.23-0.38]	0.29 [0.23-0.37]	0.28 [0.22-0.36]	0.29 [0.21-0.36]	0.12
Hospital Costs, $1000, median [IQR]	9.3 [7-15]	10.8 [7-15]	11.3 [7-16]	13 [8-17]	<0.01
Inflation Adjusted Costs, $1000, median [IQR]	9.6 [7-15]	11.1 [7-15]	11.7 [7-17]	13 [8-17]	<0.01
Healthcare Value, median [IQR]	0.35 [0.23-0.49]	0.30 [0.22-0.48]	0.28 [0.22-0.48]	0.25 [0.19-0.41]	<0.01
Other Quality Metrics					
Number of readmissions, median [IQR]	1 [1-2]	1 [1-2]	1 [1-2]	1 [1-2]	0.87
Time to readmission, d, median [IQR]	18 [11-36]	18 [11-36]	19 [11-37]	18 [11-35]	<0.01
Non-index readmission*, n (%)	10882 (22)	11194 (21.5)	10327 (22.1)	53171 (23.8)	<0.01

Mon=Month; IQR=Interquartile range; d=days; *: calculated as a proportion of the number of patients who were readmitted.

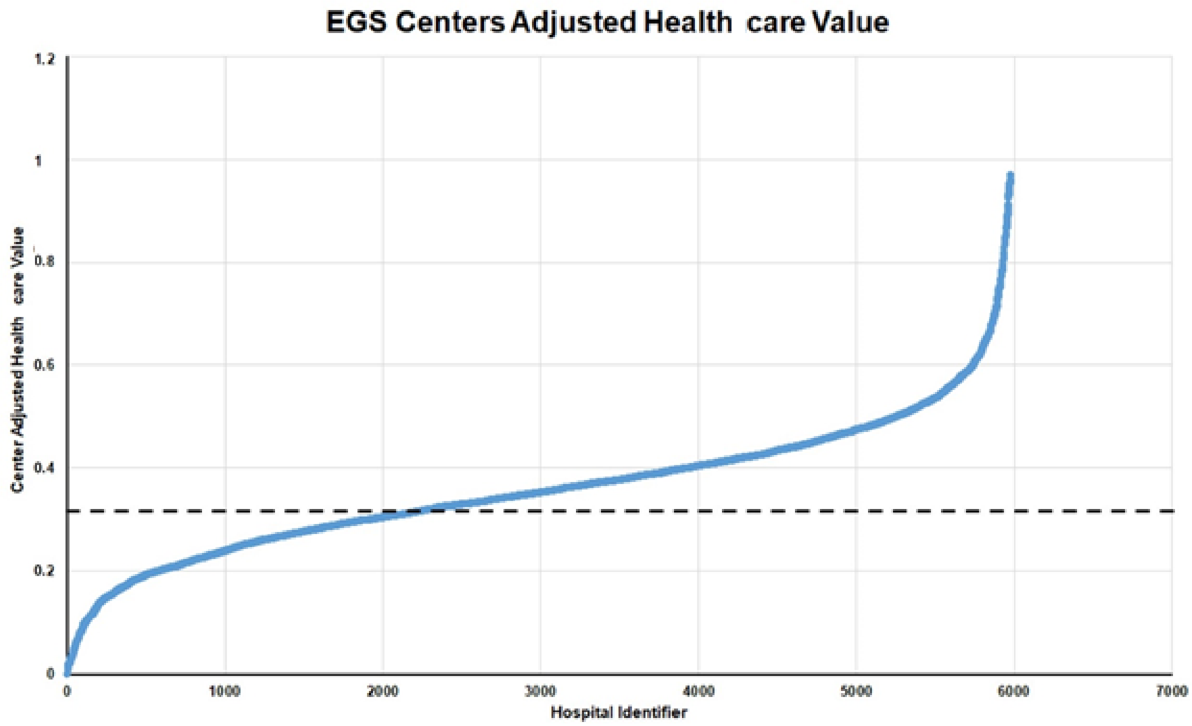
Table 4: Mixed Effects Linear Regression Analysis With a Random Hospital Effect			
Covariates	**β Coefficient**	**95% CI**	**P-Value**
Year	-0.004	-0.015 – (-0.001)	0.01
Male	-0.934	-1.149 - (-0.672)	0.65
Age Group			
0-17	0.003	0.002 - 0.004	<0.01
18-44	0.002	0.002 - 0.002	<0.01
45-64	0.003	0.002 - 0.004	<0.01
≥65	-0.568	-0.689 - (-0.418)	<0.01
Primary Payer			
Medicare	-0.571	-0.696 - (-0.418)	<0.01
Medicaid	-0.457	-0.563 - (-0.328)	<0.01
Private insurance	-0.188	-0.231 - (-0.135)	<0.01
Self-pay	-0.847	-0.98 - (-0.671)	<0.01
Household Income			
≤ $47,999	-0.368	-0.455 - (-0.262)	<0.01
>3 Comorbidities	-0.292	-0.359 - (-0.21)	<0.01
Weekend Admission	-0.318	-0.366 - (-0.254)	<0.01
Rehabilitation	0.004	0.003 - 0.005	<0.01
Non-index Readmission	-0.755	-0.914 - (-0.558)	<0.01
Metropolitan teaching Hospital	0.034	0.026 - 0.044	<0.01
Index Hospital Volume			
Low	-0.927	-1.126 - (-0.682)	<0.01
Medium	0.001	0.001 - 0.001	<0.01
High	0.004	0.003 - 0.005	<0.01

CI=Confidence Interval

Figures 1


Trends in Health care Value & Inflation Adjusted Costs Over Time
Inflation Adjusted Hospital Costs ($1000)
14
13
12
11
10
9
0.36
0.34
0.32
0.30
0.28
0.26
0.24
Health care Value
2012
2013
2014
2015
Year
Inflation Adjusted Hospital Costs
Health care Value

Figures 2



EGS Centers Adjusted Health care Value
Center Adjusted Health care Value
1.2
1
0.8
0.6
0.4
0.2
0
0
1000
2000
3000
4000
5000
6000
7000
Hospital Identifier