Introduction

The rising cost of healthcare in the United States is a concern for both patients and providers. In 2020, 19.7% of the United States' Gross Domestic Product was comprised of health care spending, and rates only continue to increase [1]. In 2016, the United States spent nearly twice as much per citizen on healthcare as other developed countries [2]. Despite rising costs, US healthcare utilization rates are similar to other nations [2]. Greater healthcare spending in the US may be driven by administrative, pharmaceutical, and labor/goods costs between countries [2].

Many analyses of healthcare cost and finance report charges or payments, rather than actual costs. In a study investigating cost of operating room (OR) time, authors reported difficulty in finding standardized estimates for OR costs, with previous reports only using hospital charges [3]. Macario et al. reported little success in assessing areas of intervention using hospital charges due to various confounding variables. In order to effectively reduce healthcare costs, hospitals and providers must focus more on true costs. As costs become quantifiable, providers and hospitals can execute informed cost reduction strategies.

Acute care surgery (ACS) is a discipline that is well-suited to such a strategy. ACS comprises a large healthcare footprint including emergency general surgery, trauma surgery, and critical care surgery. ACS diagnoses make up 20% of all inpatient admissions and 25% of hospital costs in the U.S. [4] By virtue of their trauma training and practice in trauma centers, acute care surgeons are accustomed to a systems-based approach to care, deploying treatment algorithms consistently and systematically across patient populations. Acute care surgeons are thus positioned to develop and carry out cost reduction measures that could have significant impact on U.S. healthcare. For example, acute care surgeons initially reported that by discharging appendectomy patients directly from the recovery room rather than after a short observation stay, hospitals can reduce costs by over $1000 per case [5].
Extrapolated to the entire United States, one author estimated that nationwide adoption of outpatient appendectomy could result in annual healthcare savings of $921,500,000 [6].

In order to reduce healthcare costs, the US must reduce variation. Using the National Inpatient Sample, Zogg et al., identified wide variation in total hospital costs for appendectomy in the United States [7]. Based on previous evidence from Papanicolas et al., cost differences are likely related to specific high cost “centers” or services within each hospital [1]. Our objective in the current study was to identify variation in total hospital costs specifically for straightforward emergent laparoscopic appendectomy. We chose this population because most patients with straightforward appendicitis can be managed with an outpatient or fast-track pathway, avoiding use of an inpatient bed and associated cost. Furthermore, our goal was to attribute variation to specific cost centers. Cost savings strategies could be more accurately targeted once highly variable groups have been identified.

Methods

Data were obtained from VIZIENT and their use in publication has been approved in writing. The data from this study were de-identified and publicly available to participants by the VIZIENT network. This study does not meet the definition of human subjects research and therefore institutional review board review was not needed. Data were obtained for patients treated from July 1, 2018, to June 30, 2019. No data presented was linkable to any institution or group of institutions. This study examines total hospital costs for patients of all ages with procedure code 44970 (laparoscopy, surgical, appendectomy). Other costs including out of pocket expenses for patients and indirect costs to payers were not a part of this analysis. Total costs were then subdivided into individual cost centers. Relevant centers include OR costs, laboratory, anesthesia, CT imaging, emergency room, pharmacy, routine floor care, and medical/surgical supplies. Medical/surgical supplies are a cost term specific to VIZIENT that encompasses costs not included elsewhere. These costs specifically include items like surgical instruments not included in the category OR costs and pharmaceuticals.

The objective of this analysis was to describe variation in costs for straightforward appendicitis. Only cases with length of stay less than or equal to three days were eligible for analysis to account for variation in post-operative care. Direct costs were extracted from the database for hospitals reporting at least 5 cases or more. Costs were calculated by the area wage index (AWI) provided from the VIZIENT site. These costs were grouped by both age group and diagnosis code. VIZIENT calculates direct costs by multiplying actual charges for a cost center and medical/surgical supplies, maintenance and cleaning, and includes preoperative, holding and recovery room care. These costs have been measured in post-operative care. Direct costs were then subdivided into individual cost centers. Relevant centers include OR costs, laboratory, anesthesia, CT imaging, emergency room, pharmacy, routine floor care, and medical/surgical supplies. Medical/surgical supplies are a cost term specific to VIZIENT that encompasses costs not included elsewhere. These costs specifically include items like surgical instruments not included in the category OR costs and pharmaceuticals.

The next two highest cost centers, medical/surgical supplies and routine floor care, comprise roughly the same percentage of total direct costs.

OR and medical/surgical supplies, also produced the most variability. A strong yet incomplete relationship was apparent between OR costs (median 1198, range 206–3302) and total costs (rho = .68, p < .001, Fig. 3). Proportion of supply costs was significantly lower in low-cost sites versus high cost sites where floor and ED were significantly higher (p < .05, Fig. 4).

Facies included in this analysis were large, reporting an average of 32,824 yearly inpatient discharges (SD = 16,087), with 17% of all admissions requiring ICU. The mean case mix index for all patients at these centers was 2.1. Adult and pediatric patients with appendicitis were included, with the mean of 19.4% pediatric cases (SD = 26.2). A high percentage of appendectomies at 41.9% had localized peritonitis or abscess as indicated by diagnostic code (SD = 17.4%). 65% of centers included Level 1 trauma centers, with a small percentage being Level 2 and Level 3, and 22% of sites being undesignated with respect to trauma.

Discussion

The median total direct hospital cost of laparoscopic appendectomy in this analysis was $4609 but varied widely with a greater than three-fold difference between the lowest and highest vigintiles. Standard deviation within vigintiles was relatively low, but at the extremes the variability was larger. Only appendicitis cases that underwent surgery were used for this analysis, all the procedures were laparoscopic, and we excluded cases that exceeded three days. These exclusion criteria were intended to create a relatively homogeneous population of relatively straightforward appendicitis cases generally treated in the same way.

OR costs had the largest single contribution to total direct costs of the individual centers included in this study. OR costs are comprised of salaries, supplies, maintenance and cleaning, and includes preoperative, holding and recovery room care. These costs have been measured and reported previously as a per-minute cost. In a study from California conducted using data from public and private hospitals, authors reported an average cost per minute of OR time as $37.45 [8]. Cost of OR staff alone may be at least $10 per minute [9]. Median OR cost in the present study is consistent with those previously reported. Some contributors to OR cost are not modifiable. Collins et al. reported that appendicitis severity correlated with operative duration and total cost [10]. Training environments are also likely to be associated with greater operative times [11]. One opportunity to significantly reduce operative costs is instrument choice and supplies such as gloves, sutures and other equipment [8]. For example, the use of reusable instruments can significantly reduce costs without increasing operative duration [12].

The next two highest cost centers, medical/surgical supplies and routine floor care, were significantly lower in low-cost sites versus high cost sites where floor and ED were significantly higher (p < .05, Fig. 4).
costs. The authors acknowledge that the category “medical/surgical supplies” is specific to VIZIENT and costs included here may be attributed to other categories in other studies or analyses. Large variation in supply costs have been reported in multiple studies. Malholtra et al. reported a supply cost range of $650 to $1067 per case, without reported differences in operative duration [13]. Medical/surgical supply costs will also vary according to contract pricing and utilization between centers. In our study, medical/surgical supplies as a percentage of total costs were considerably lower in low-cost hospitals vs high-cost hospitals. Hospitals with low costs in this category may need to focus on length of stay and bed cost, or other supplies as additional opportunities. Routine floor care costs are largely attributed to use of the hospital bed and nursing staff. Significant cost savings of $1000 per case can be realized by discharging patients from post-anesthesia care [5].

Pharmacy costs are relatively low compared to other cost centers analyzed but are not insignificant. At approximately $398 per case, cost saving strategies related to pharmaceuticals could include contract pricing, minimal acceptable duration of therapy, and least expensive acceptable alternative. Through rigorous scientific investigation and systems-based care, surgeons can clearly reduce therapy duration. For example, in complex acute appendicitis with intra-abdominal infection, the current recommended treatment duration has been decreased to four days of broad-spectrum antimicrobials [14]. Currently a Dutch trial is investigating whether two days of broad-spectrum antimicrobials result in similar outcomes to five days of the same regimen [15]. In our study of straightforward appendicitis, antimicrobial therapy is not indicated post-operatively in most patients. Another source of modifiable pharmacy cost is analgesics, particularly IV opioids. Approximately half of appendectomy patients can be managed without any opioids at all including IV opioids [16]. Emergency department, anesthesia and laboratory cost variation was relatively low across the 128 medical centers in this analysis.

The current study examined only total direct costs as they pertain to laparoscopic appendectomy. Indirect costs including facilities maintenance and other non-revenue centers are largely outside the realm of control of clinicians. These are not likely to change based on clinician efficiency, variable supply utilization or operating time and thus are not high value targets for cost-reduction efforts.

This study has several limitations. Costs in this study are calculated by use of a cost-to-charge ratio. Greater precision in measuring and reporting cost data will be necessary for surgeons to implement the most effective cost-reduction measures. Data were obtained from a consortium of various types of centers but is not necessarily reflective of
every hospital. Centers were grouped into vigintiles for the purpose of an anonymization which slightly limits detail in the graphical representation. Large variability exists in the number of appendectomies performed at each facility, with a minimum of 6 cases ranging to a maximum of 254 cases per site. Cost variation may be related in part to sample size. Low sample size may be attributed to how VIZIENT categorizes cases. Sample cases provided might have been those technically characterized as inpatients. Nonetheless, cost data should be accurate and relative differences are still relevant. Though the cost centers provide greater specificity than just total costs, they are still broad categories and specific line items will be needed to track cost reduction precisely. This study did not distinguish pediatric and adult populations. Though this is a limitation with respect to determining in which population cost variation lies, the analysis was intended to be broadly applicable and pragmatic.

Benchmarked financial performance as reported in this study permits high outlying centers to initiate cost reduction strategies and low outlying centers to share their expertise. Though total costs are informative, analyzing specific cost centers permits focused quality improvement. Evidence shown here suggests that a multi-pronged approach at cost-reduction may be warranted in laparoscopic appendectomy focusing on costs inside and outside the OR.

**CRediT authorship contribution statement**

Elise Rogers designed the study, collected the data, analyzed the data, and wrote the article. Daniel Davenport designed the study, analyzed the data, and edited the article.

Julie Parrish designed the study, collected the data, and analyzed the article.

Andrew Bernard designed the study, analyzed the data, edited the article, and supervised the project.

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None.

**Ethics approval**

This study does not meet the definition of human subject research; and therefore institutional review board review was not required.

**Declaration of competing interest**

None.
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