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Current national practice patterns for inpatient management of ventral abdominal wall hernia in the United States

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Abstract
Background The health-care burden related to ventral hernia management is substantial, with more than 3 billion dollars in expenditures annually in the US. Previous studies have suggested that the utilization of laparoscopic repair remains relatively low although national volume estimates have not been reported. We sought to estimate the inpatient national volume of elective ventral hernia surgery and characterize the proportion of laparoscopic versus open operations.
Methods We analyzed data from the Nationwide Inpatient Sample to identify adults with a diagnosis of an umbilical, incisional, or ventral hernia who underwent an elective inpatient repair between 2009 and 2010. Cases that involved other major abdominal or pelvic operations were excluded. Covariates included patient demographics, surgical approach, and use of mesh. National surgical volume estimates were generated and length of stay and total hospital charges were compared for laparoscopic versus open repairs.
Results A total of 112,070 ventral hernia repairs were included in the analysis: 72.1 % ($n = 80{,}793$) were incisional hernia repairs, while umbilical hernia repairs comprised only 6.9 % ($n = 7{,}788$). Laparoscopy was utilized in 26.6 % ($n = 29{,}870$) of cases. Mesh was placed in 85.8 % ($n = 96{,}265$) of cases, including 49.3 % ($n = 3{,}841$) of umbilical hernia repairs and 90.1 % ($n = 72{,}973$) of incisional hernia repairs. Length of stay and total hospital charges were significantly lower for laparoscopic umbilical, incisional, and "other" ventral hernia repairs (p values all <0.001). Total hospital charges during this 2-year period approached 4 billion dollars ($746 million for laparoscopic repair; $3 billion for open repair).
Conclusions Utilization of laparoscopy for elective abdominal wall hernia repair remains relatively low in the US despite its excellent outcomes. Given the substantial financial burden associated with these hernias, future research focused on preventing the development and optimizing the surgical treatment of ventral abdominal wall hernias is warranted.

Keywords Abdominal wall hernia · Minimally invasive surgery · Laparoscopic ventral hernia repair · Nationwide inpatient sample · National surgical trends

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More than three billion dollars is spent on abdominal wall ventral hernia repairs in the United States each year. In 2006, this equated to nearly 350,000 operations [1]. Prior to the early 1990s, all repairs were performed in an open fashion. With the introduction of laparoscopic ventral hernia repair, which was first reported in 1993 [2], there has been a significant shift in the surgical approach to ventral hernia repair.

Over the past 15 years, numerous studies have compared laparoscopic ventral hernia repair to open repair. From the earliest publications to the most recent meta-analyses and a Cochrane report, a laparoscopic approach

has consistently been shown to have shorter lengths of stay, lower complication rates, decreased costs, and equivalent, if not lower, hernia recurrence rates [3–9]. Given these results, one might expect that the adoption of laparoscopic ventral hernia repair would be widespread in the US. However, the only published report examining national practice patterns related to laparoscopic ventral hernia repair throughout the US found that a laparoscopic approach was used less than a third of the time [10]. No studies have attempted to estimate the volume of laparoscopic ventral hernia repair in the US, partly because ICD-9 procedure codes for laparoscopic hernia repair have been available only since 2008.

We sought to characterize the annual volume of elective, inpatient ventral hernia repairs performed in the US, with and without mesh prostheses, over a 2-year period. Umbilical, incisional, and other ventral hernia repairs were included in the analysis. Additionally, we examined patient and hospital factors that were predictive of a laparoscopic approach and analyzed length of stay (LOS) and hospital charges associated with each approach.

Methods

Data sources

We utilized Nationwide Inpatient Sample (NIS) data from 2009 and 2010 to generate our patient cohort. The NIS is managed by the Healthcare Cost and Utilization Project (HCUP) and sponsored by the Agency for Healthcare Research and Quality. It contains all-payer data on inpatient hospitalizations from participating states representing >95 % of the US population. Each year, the NIS uses data from approximately 1,000 hospitals and 8 million hospitalizations to generate a 20 % stratified sample of US hospitals. Five hospital characteristics are used to generate each stratum: ownership/control, bed size, teaching status, urban versus rural location, and US region. Post-stratification weights provided by HCUP are then used to generate national estimates for all nonfederal hospitals in the US [11].

Study population

Ten International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9) procedure codes were used to identify hospitalizations in which an umbilical hernia repair (53.41, 53.42, 53.43, 53.49), incisional hernia repair (53.51, 53.61, 53.62), or "other" abdominal wall hernia repair (53.59, 53.63, 53.69) was performed. "Other" abdominal wall hernia repairs included epigastric, hypogastric, spigelian, and ventral hernias per the ICD-9 coding scheme. These ICD-9 procedure codes were then categorized further into open, laparoscopic, mesh, or non-mesh repairs. Patients who were admitted on an urgent or emergent basis were excluded as were patients under the age of 18. Since the intent of our analysis was to focus on hernia management rather than hernia management in the setting of other major abdominal surgery, we excluded patients who underwent concomitant esophageal, gastric, small bowel, colorectal, pancreatic, splenic, adrenal, urologic, or gynecologic procedures. This involved 263 procedure codes. Of note, those who underwent a small bowel resection (ICD-9 codes 45.61, 45.62, 45.63), lysis of adhesions (54.5, 54.51, 54.59), or experienced an enterotomy (45.01, 45.02) were included in our cohort because these were considered part of the hernia repair itself.

Study variables

Patient demographic variables included age, gender, race, comorbidity status, payment type (private vs. Medicare vs. Medicaid vs. other), and income level (low vs. lower-middle vs. upper-middle vs. high). Comorbidity status was characterized by calculating Charlson scores for each patient on the basis of ICD-9 diagnosis codes. The Charlson score represents a weighted composite measure of overall comorbid status and has been validated for use with administrative data [12]. Hospital characteristics included urban versus rural, teaching status, and region (Northeast vs. Midwest vs. South vs. West). LOS and total hospital charges were also analyzed.

Statistical analyses

Rao–Scott χ^2 tests were used to compare the operations, patient demographics, hospital characteristics, and outcomes by year [13]. Clustering was accounted for at the hospital level in these tests. Multivariate logistic regression modeling was used to characterize the relationship between patient and hospital factors and the likelihood of undergoing a laparoscopic procedure. Age, gender, Charlson score, payment type, income quartile, location, teaching status, and region were included in the multivariate analysis. Generalized estimating equations were used to account for clustering of patients by hospital [14]. All p values were two-sided and were considered statistically significant if the $p < 0.05$. All analyses were performed with SAS ver. 9.3 (SAS Institute, Cary, NC).

Results

Patient cohort selection and annual surgical volume

A total of 218,949 patients underwent an elective, abdominal wall, ventral hernia repair during 2009 and

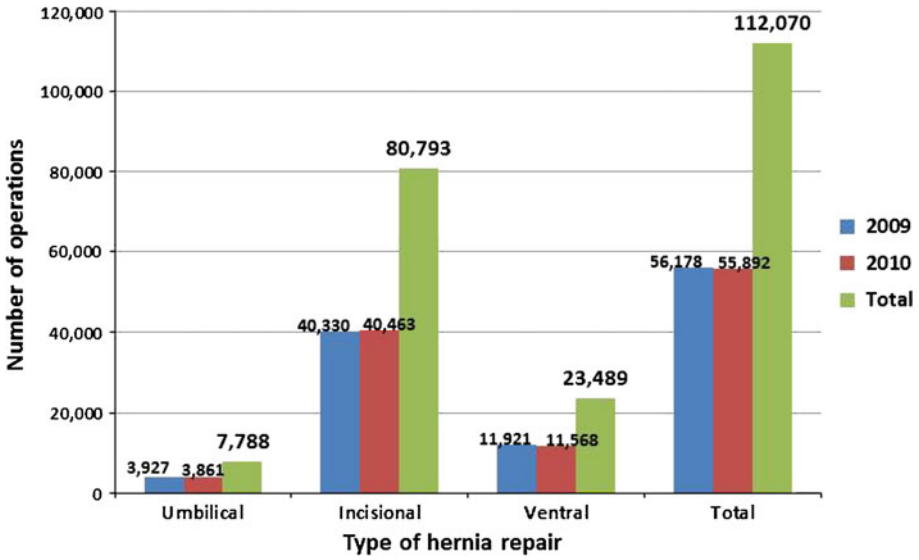

Fig. 1 National volume estimates of elective, inpatient abdominal wall ventral hernia repairs in the US (2009–2010)

2010. Of these patients, 106,699 underwent a concomitant major abdominal or pelvic operation and were excluded from the study. A total of 112,070 hernia repairs were included in our analysis. The number of annual inpatient, elective abdominal wall ventral hernia repairs was approximately 56,000 (Fig. 1). Within this cohort, 25,499 patients underwent either a concomitant lysis of adhesions (22.7 %) or small bowel resection (1.9 %) or experienced an enterotomy (0.1 %).

Type of surgery and technique

A total of 7,788 (6.9 %) of the hernia repairs were umbilical, 80,793 (72.1 %) were incisional, and 23,489 (20.9 %) were ventral (Fig. 1). Laparoscopic hernia repairs were performed in 26.6 % of all cases ($n = 29{,}870$) (Fig. 2A). This included 20.6 % ($n = 1{,}607$) of umbilical hernia repairs and 26.5 % of incisional hernia cases ($n = 21{,}434$) (Table 1). Mesh was used in 85.8 % of cases ($n = 96{,}265$) (Fig. 2B). This included 90.1 % of incisional hernia cases ($n = 72{,}973$) but only 49.3 % of umbilical hernia repairs ($n = 3{,}841$). There were no significant differences between years (Fig. 2 and Table 1).

Patient and hospital characteristics

On univariate analysis, patients who underwent a laparoscopic versus open umbilical hernia repair were older (age 57.2 vs. 55.0; $p = 0.002$) and more likely to be male (25.7 vs. 15.4 %; $p < 0.001$) (Table 2). Laparoscopic incisional hernia repairs were performed more often on white patients (26.6 vs. 24.1 %; $p = 0.04$) who were healthier (26.9, 26.8, and 22.0 % with a Charlson score of 0, 1–2, and >2, respectively; $p = 0.005$). With respect to laparoscopic ventral hernia repair, patients were more likely to be male

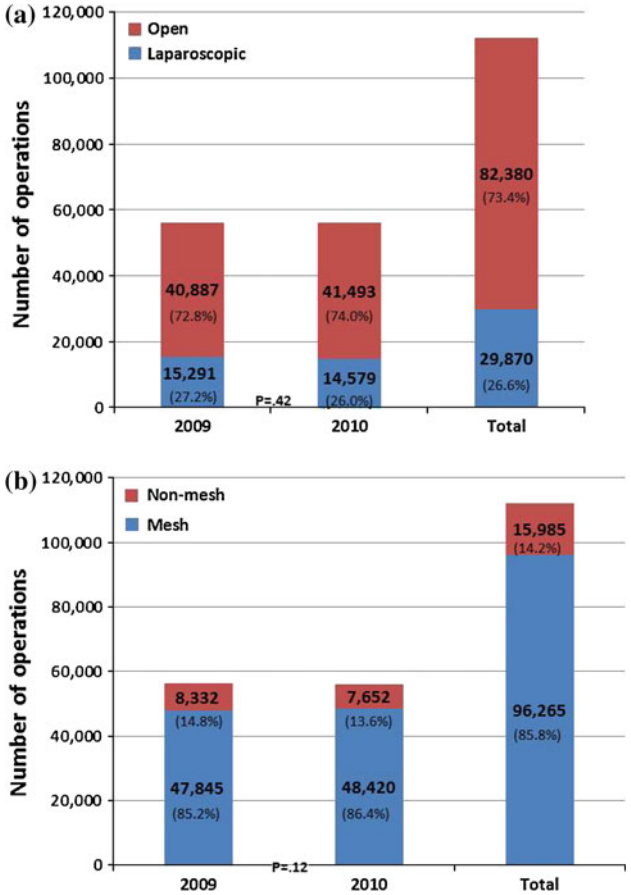

Fig. 2 **A** Open versus laparoscopic hernia repair. **B** Mesh versus nonmesh hernia repair

(31.3 % male vs. 27.9 % female), healthier (30.4, 28.0, and 24.6 % with a Charlson score of 0, 1–2, and >2, respectively; $p = 0.03$), and from the Northeast (36.3 % had surgery in the Northeast vs. 25.2 % in the Midwest;

Table 1 Type of umbilical, incisional, and ventral hernia repairs

	2009	2010	Total
Umbilical			
Laparoscopic	785 (20.0 %)	822 (21.3 %)	1,607 (20.6 %)
Open	3,142 (80.0 %)	3,039 (78.7 %)	6,181 (79.4 %)
	$p = 0.62$		
Mesh	1,820 (46.4 %)	2,020 (52.3 %)	3,841 (49.3 %)
Nonmesh	2,107 (53.6 %)	1,841 (47.7 %)	3,947 (50.7 %)
	$p = 0.06$		
Incisional			
Laparoscopic	10,983 (27.2 %)	10,451 (25.7 %)	21,434 (26.5 %)
Open	29,347 (72.8 %)	30,192 (74.3 %)	59,538 (73.5 %)
	$p = 0.36$		
Mesh	36,108 (89.5 %)	36,866 (90.7 %)	72,973 (90.1 %)
Nonmesh	4,222 (10.5 %)	3,777 (9.3 %)	7,999 (9.9 %)
	$p = 0.10$		
Ventral			
Laparoscopic	3,522 (29.5 %)	3,306 (28.6 %)	6,828 (29.1 %)
Open	8,398 (70.5 %)	8,263 (71.4 %)	16,661 (70.9 %)
	$p = 0.65$		
Mesh	9,917 (83.2 %)	9,534 (82.4 %)	19,451 (82.8 %)
Nonmesh	2,004 (16.8 %)	2,035 (17.6 %)	4,039 (17.2 %)
	$p = 0.57$		

$p = 0.02$). Payment type, income level, location, and hospital teaching status were not significant predictors of a laparoscopic versus an open approach for any of the three hernia types.

Multivariate analysis

On multivariate analysis, gender remained the only significant predictor of undergoing a laparoscopic versus open umbilical hernia repair (odds ratio [OR] 0.6 for females; 95 % CI 0.4–0.7) (Table 3). For incisional hernia patients, a laparoscopic repair was more likely to occur in healthier patients (OR 1.2 for patients with a Charlson score of 0; 95 % CI 1.1–1.5) and less likely for poorer patients (OR 0.7 for patients in the lowest income quartile; 95 % CI 0.6–0.9). Ventral hernia patients were more likely to undergo a laparoscopic repair if they were male (OR 1.3; 95 % CI 1.0–1.4), healthier (OR 1.4 for Charlson score of 0; 95 % CI 1.1–1.8), and from the Northeast (OR 1.8; 95 % CI 1.2–2.8; West region used as reference group). None of the eight covariates in the model were statistically significant across all three types of operations.

Outcomes

Length of stay was shorter for all types of laparoscopic versus open repairs (Table 4). Laparoscopic ventral hernia repair patients averaged 1.2 fewer days in the hospital (mean LOS = 2.8 vs. 4.0 days; $p < 0.001$) while incisional hernia repair patients experienced nearly the same decrease (2.9 vs. 3.9 days; $p < 0.001$). Mean hospital charges were lower for all types of laparoscopic versus open repairs. Hospitals charged an average of $9,265 more for open umbilical ($40,649 vs. $31,384 for laparoscopic; $p < 0.001$), $4,499 more for open incisional ($36,857 vs. $32,358; $p < 0.001$), and $6,702 more for open ventral hernia repair ($38,013 vs. $31,311; $p < 0.001$). The total amount of charges due to laparoscopic hernia repair was $745.9 million dollars while the total amount for open repair was $3.037 billion dollars. The total amount for the entire cohort was 3.782 billion dollars over the 2-year period.

Discussion

Our findings indicate that of the 56,000 inpatient, elective abdominal wall hernia repairs performed in the US each year, the vast majority continue to be performed in an open fashion. Less than one-third of patients underwent a laparoscopic approach in 2009 and 2010. Mesh was placed in more than 90 % of all incisional hernia repairs, but in less than half of the umbilical hernia repairs. No patient or hospital characteristics available in the data set were consistently associated with a higher likelihood of undergoing a laparoscopic approach across all three types of repairs

Table 2 Patient and hospital characteristics of laparoscopic and open hernia repairs

	Umbilical			Incisional			Ventral		
	Lap	Open	*p*	Lap	Open	*p*	Lap	Open	*p*
Patient characteristics									
Age[a]	57.2	55.0	**0.002**	58.9	58.6	0.16	58.2	57.7	0.37
Gender									
Female	15.4 %	84.6 %	**<0.001**	26.9 %	73.1 %	0.14	27.9 %	72.1 %	**0.02**
Male	25.7 %	74.2 %		25.8 %	74.1 %		31.3 %	68.7 %	
Race									
Nonwhite	22.6 %	77.3 %	0.20	24.1 %	75.9 %	**0.04**	28.4 %	71.6 %	0.66
White	18.9 %	81.1 %		26.6 %	73.4 %		29.5 %	70.5 %	
Charlson score									
0	20.0 %	80.0 %	0.70	26.9 %	73.1 %	**0.005**	30.4 %	69.6 %	**0.03**
1–2	21.7 %	78.2 %		26.8 %	73.2 %		28.0 %	72.0 %	
>2	19.7 %	80.3 %		22.0 %	78.0 %		24.6 %	75.4 %	
Payment type									
Medicare	21.9 %	78.1 %	0.20	26.7 %	73.3 %	0.40	28.6 %	71.4 %	0.62
Medicaid	13.8 %	86.2 %		24.2 %	75.8 %		27.2 %	72.8 %	
Private	21.2 %	78.8 %		26.5 %	73.5 %		29.6 %	70.3 %	
Other	20.5 %	79.5 %		27.7 %	72.3 %		31.4 %	68.6 %	
Income quartile									
Low	20.7 %	79.3 %	0.51	24.4 %	75.5 %	0.18	27.5 %	72.5 %	0.71
Lower-middle	21.2 %	78.8 %		26.1 %	73.9 %		29.9 %	70.1 %	
Upper-middle	22.5 %	77.5 %		26.7 %	73.2 %		29.6 %	70.4 %	
High	17.8 %	82.2 %		28.8 %	71.2 %		28.5 %	71.5 %	
Hospital characteristics									
Location									
Urban	19.9 %	80.1 %	0.35	25.8 %	74.2 %	0.47	29.1 %	70.9 %	0.59
Rural	24.4 %	75.6 %		29.1 %	70.9 %		27.4 %	72.6 %	
Teaching status									
Teaching	18.6 %	81.4 %	0.19	24.5 %	75.5 %	0.11	27.4 %	72.6 %	0.26
Nonteaching	22.3 %	77.7 %		27.9 %	72.1 %		30.3 %	69.7 %	
Region									
Northeast	21.5 %	78.5 %	0.27	25.8 %	74.2 %	0.75	36.3 %	63.7 %	**0.02**
Midwest	18.0 %	82.0 %		25.8 %	74.2 %		25.2 %	74.8 %	
South	24.2 %	75.8 %		28.1 %	71.9 %		30.1 %	69.8 %	
West	17.9 %	82.1 %		25.0 %	75.0 %		25.5 %	74.5 %	

p values < 0.05 are highlighted in bold

(umbilical, incisional, and ventral). Lengths of stay and total hospital charges were significantly lower when the laparoscopic approach was used. Hospital charges approached 4 billion dollars over the 2-year period.

This relatively low rate of laparoscopy use is remarkably similar to that in the only other study which reported national rates of laparoscopic hernia repair in the US. Using NIS data from 2009, Colavita et al. [10] found that only 27.6 % of inpatients who underwent ventral hernia repair with mesh (excluding umbilical hernias) had a laparoscopic operation. Our results are also very similar to those from the only other country that has reported national practice patterns for ventral hernia management. In their 2010 publication that included 5,629 elective inpatient and outpatient ventral hernia repairs in the comprehensive Danish Ventral Hernia Database, Helgstrand et al. [15] reported that 27 % of ventral hernia repair patients in Denmark underwent a laparoscopic ventral repair in 2007 and 2008.

Though the US data set and the Danish national registry have some notable differences, i.e., the Danish registry includes outpatient cases and thus a higher proportion of

Table 3 Multivariate analysis of the likelihood of undergoing a laparoscopic versus an open hernia repair

	Umbilical hernia	Incisional hernia	Ventral hernia
Age	1.01 [1.00–1.02]	1.00 [1.00–1.01]	1.01 [1.00–1.01]
Female	**0.6 [0.4–0.7]**	1.1 [1.0–1.1]	**0.8 [0.7–1.0]**
Charlson score			
0	1.1 [0.7–1.7]	**1.2 [1.1–1.5]**	**1.4 [1.1–1.8]**
1–2	1.1 [0.7–1.7]	**1.2 [1.0–1.5]**	1.2 [0.9–1.6]
>2	Ref	Ref	Ref
Payment type			
Medicaid	0.7 [0.4–1.2]	0.9 [0.8–1.1]	0.9 [0.7–1.2]
Medicare	0.9 [0.6–1.2]	1.0 [0.9–1.1]	0.9 [0.7–1.1]
Other	1.0 [0.6–1.6]	1.1 [0.9–1.3]	1.1 [0.9–1.5]
Private	Ref	Ref	Ref
Income quartile			
Low	1.0 [0.6–1.5]	**0.7 [0.6–0.9]**	1.0 [0.8–1.4]
Lower-middle	1.1 [0.7–1.7]	**0.8 [0.7–1.0]**	1.1 [0.9–1.5]
Upper-middle	1.2 [0.8–1.8]	0.9 [0.8–1.0]	1.1 [0.9–1.5]
High	Ref	Ref	Ref
Urban location	0.8 [0.5–1.5]	0.8 [0.5–1.3]	1.1 [0.8–1.6]
Teaching hospital	0.9 [0.6–1.2]	0.9 [0.7–1.1]	**0.8 [0.6–1.0]**
Region			
Northeast	1.4 [0.8–2.4]	1.1 [0.8–1.5]	**1.8 [1.2–2.8]**
Midwest	0.9 [0.5–1.5]	1.0 [0.7–1.5]	1.0 [0.7–1.5]
South	1.5 [0.9–2.5]	1.3 [0.9–1.7]	1.3 [0.9–1.9]
West	Ref	Ref	Ref

Values are odds ratio and 95 % CI in brackets; p values < 0.05 are highlighted in bold. Multivariate models include each of the variables in the table

Ref reference

Table 4 Length of stay and total charges for umbilical, incisional, and ventral hernias

	Umbilical		Incisional		Ventral	
	Lap	Open	Lap	Open	Lap	Open
Length of stay (mean No. days)	2.6	3.3	2.9	3.9	2.8	4.0
p value	<0.001		<0.001		<0.001	
Hospital charges per hospitalization (mean)	$31,384	$40,649	$32,358	$36,857	$31,311	$38,013
p value	<0.001		<0.001		<0.001	
Total charges	$49,297,019	$248,697,109	$675,420,525	$2,160,637,307	$21,143,782	$627,509,457

Total charges for laparoscopic repair = $745,861,326. Total charges for open repair = $3,036,843,873. Total charges for all repairs = $3,782,705,199

umbilical hernias (45 vs. 6.9 % in our cohort) and a correspondingly lower proportion of incisional hernias (33 vs. 72.1 % in our cohort), the national rate of adoption of laparoscopic ventral hernia repair appears to be fairly slow in both countries despite the publication of numerous studies supporting the superiority of laparoscopic repairs compared to open repairs. As a frame of reference, in 2009, a higher percentage of patients underwent a laparoscopic resection of their colon (35 %) [16] than underwent a laparoscopic repair of their ventral hernia (27 %).

The reasons for the slow rate of adoption are unclear. Urgent and emergent cases were excluded in our analysis. Thus, patient factors that may have discouraged surgeons from performing a laparoscopic repair, such as hemodynamic instability in critically ill patients, bowel obstruction (difficulty with laparoscopic access or bowel injuries), or a contaminated field (concern regarding laparoscopic placement of intraperitoneal mesh), should have been minimized. Although male gender and healthier status were associated with a laparoscopic approach in two of the three hernia types, our analysis did not reveal any consistent patient or hospital characteristics that were predictive of a laparoscopic approach. It seems unlikely that patients would have preferred open surgery given the benefits of

laparoscopy, which include shorter length of stay, lower complication rate, less pain, and lower cost.

Although the NIS does not include provider-specific variables such as training background, specialty, or years in practice, we suspect that surgeon characteristics may have been major factors in determining which technique was used. Laparoscopic ventral hernia repairs have been performed for more than 20 years, but they can be tedious and technically demanding operations with potentially poor outcomes, particularly in the setting of missed enterotomies. We are not aware of any studies that have examined the relationship between surgeon characteristics and type of ventral hernia repair approach. This represents an area for future qualitative analysis, including surveys of surgeons or focus groups. Though all ventral hernias may not be amenable to laparoscopic repair, the ideal rate is almost certainly higher than one in four patients.

Another potential area for quality improvement concerns the large number of incisional hernias. Nearly three in four inpatient ventral hernia repairs were incisional. Hospitals charged more than one billion dollars each year for management of these hernias. Though the literature varies widely, conservative estimates suggest that at least 10 % of patients who undergo a laparotomy and have at least 6 months of follow-up develop an incisional hernia [17]. Incision closure, including the type of suture used and the suturing technique used (i.e., running vs. interrupted), have been shown to have minimal influence on incisional hernia development rates. Though there is a need to decrease our hernia rate after laparotomy, another way to address this issue is to perform more primary operations laparoscopically. This has the potential to save the health-care system hundreds of millions of dollars in incisional hernia management costs.

Relatively little is known about practice patterns related to the surgical care of adult umbilical hernia in the US, specifically regarding the frequency of mesh use and laparoscopy. In our study, of the 4,000 annual elective, inpatient umbilical hernia repairs performed in the US, less than half underwent mesh placement. Given that the only randomized controlled trial of adult umbilical hernia surgery, published over a decade ago, and recent case series have shown that open suture repair techniques have significantly higher recurrence rates than mesh repairs [18, 19], this is somewhat surprising.

One of the keys to successful mesh placement is adequate overlap with the fascia, with one recent set of consensus guidelines recommending a 3–5-cm overlap for incisional hernias [20]. Though visualization of the fascial defect is possible in an open procedure, particularly when using mesh tailored for umbilical hernia repair [21], it can be difficult and may require significant abdominal wall dissection. Given these challenges, a laparoscopic repair with mesh may warrant serious consideration as the preferred approach for umbilical hernia repair, particularly for larger hernias that require inpatient admission. Though no studies have directly compared the two approaches, a laparoscopic approach offers a clear view of the fascial defect and allows relatively easy placement of an underlay mesh with wide overlap. Despite these potential advantages, our study found that only 20 % of inpatient umbilical hernia repairs in the US were performed laparoscopically. Likewise, in the Danish Ventral Hernia Registry, which includes both inpatients and outpatients, 14 % underwent laparoscopic repair [15]. These data suggest that laparoscopy may be underutilized for umbilical hernia repair, particularly when considering the potential for cost savings for those who require an inpatient admission.

For all three approaches, hospital charges were significantly lower for patients who underwent a laparoscopic repair. Other single institutional analyses of intraoperative and postoperative costs have also shown substantial cost savings with laparoscopy [22], yet relatively little research has been conducted in this area. Only one study has estimated inpatient and outpatient ventral hernia management costs in the US: 3.2 billion dollars per year [1]. This analysis was performed before laparoscopic hernia ICD-9 procedure codes existed and thus differentiating laparoscopic from open hernia repairs was not possible. In 2008, a Health Technology Assessment identified 37 studies that addressed the issue of cost in ventral hernia management [23]. Of those studies, none represented a full economic evaluation of laparoscopic versus open repair. The authors concluded that "none of the studies primarily aimed to investigate costs or even effectiveness." Given the billions of dollars that are spent annually on ventral hernia management in the US, this is an area where outcomes research could result in significant cost savings to the health-care system.

One way to address the need for more rigorous ventral hernia cost-effectiveness research is to develop a national hernia registry in the US. While registries are more commonly associated with cancer care [24], high-quality hernia registries do exist and have had a favorable impact. The Swedish Hernia Register, which is more than 20 years old, currently records nearly 100 % of all inguinal hernia repairs in Sweden [25]. Inguinal and ventral hernia registries have also been generated in Denmark at a cost of <75,000 USD per year (0.002 % of the annual cost of ventral hernia care in the US) [15, 26]. Financially supported by the government along with smaller contributions from each participating hospital, data from these registries have been used in many studies. One recent study from the Danish Ventral Hernia registry found that the only significant predictors of readmission and recurrence were an open repair and a large hernia defect [9]. Similar efforts could be initiated in the US, particularly given the interest in

comparative effectiveness research that has been generated by recent national health-care reforms.

Our study has important limitations. The NIS is an inpatient database and thus we were not able to analyze outpatient operations, which comprise approximately half of all ventral hernia repairs. Though our findings may not be generalizable to the outpatient setting, a laparoscopic approach would seem ideal for outpatient hernia repairs and may represent another area in which significant cost savings could be achieved. Additionally, relevant intraoperative details such as hernia size and outpatient follow-up data, including complication, recurrence, and reoperation rates, were not available. We used hospital charge data as a proxy for cost and thus did not assess the actual cost to hospitals and patients. Finally, we excluded patients who underwent ventral hernia repair in addition to other concomitant major abdominal surgery. The intent of our analysis was to study how elective ventral hernia repairs were managed rather than how they were managed when a surgeon was already performing another procedure. Consequently, our charge data likely underestimated the true inpatient burden of ventral hernia management in the US.

In conclusion, the majority of ventral hernia repair operations continue to be performed in an open fashion in the US despite numerous studies suggesting that a laparoscopic approach is associated with improved outcomes at a lower cost. An increase in the frequency of laparoscopic ventral hernia repair seems justified as we move forward, but more robust data collection is needed. This includes qualitative research on what determines the type of surgical approach, randomized trials comparing laparoscopic and open approaches, rigorous cost-effectiveness research, and perhaps the establishment of a national hernia registry. This type of comprehensive research strategy would optimize hernia outcomes and likely reduce the large financial burden that ventral hernia management currently places on our health-care system.

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