HHS Public Access

Author manuscript

Ann Surg. Author manuscript; available in PMC 2024 August 01.

Published in final edited form as:

Ann Surg. 2023 August 01; 278(2): 274–279. doi:10.1097/SLA.0000000000005654.

Trends in Surgical Technique and Outcomes of Ventral Hernia Repair in the United States

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Abstract

Objective: To describe national trends in surgical technique and rates of reoperation for recurrence for patients undergoing ventral hernia repair (VHR) in the United States.

Summary Background Data: Surgical options for VHR, including minimally invasive approaches, mesh implantation, and myofascial release, have expanded considerably over the past two decades. Their dissemination and impact on population-level outcomes is not well characterized.

Methods: We conducted a retrospective cohort study of Medicare beneficiaries undergoing elective, inpatient umbilical, ventral, or incisional hernia repair between 2007 and 2015. Cox proportional hazards models were used to estimate the adjusted proportion of patients who remained free from reoperation for hernia recurrence up to 5 years after surgery.

Results: 141,261 patients underwent VHR during the study period. Between 2007 and 2018, the use of minimally invasive surgery increased from 2.1% to 22.2%, mesh use increased from 63.2% to 72.5%, and myofascial release increased from 1.8% to 16.3%. Overall, the 5-year incidence of reoperation for recurrence was 14.1% (95% CI 14.0%–14.1%). Over time, patients were more likely to remain free from reoperation for hernia recurrence 5 years after surgery (2007–2009 reoperation-free survival: 84.9% [95% CI 84.8%-84.9%]; 2010–2012 reoperation-free survival: 85.7% [95% CI 85.6%-85.7%]; 2013–2015 reoperation-free survival: 87.8% [95% CI 87.7%-87.9%]).

Conclusions: The surgical treatment of ventral and incisional hernias has evolved in recent decades, with more patients undergoing minimally invasive repair, receiving mesh, and undergoing myofascial release. Although our analysis does not address causality, rates of reoperation for hernia recurrence improved slightly contemporaneous with changes in surgical technique.

Mini-Abstract

In this observational study of 141,261 patients undergoing elective VHR, the use of minimally invasive repair, mesh placement, and myofascial release increased from 2007–2015.

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Simultaneously, 5-year reoperation for recurrence-free survival increased from 84.9% in patients undergoing VHR from 2007–2009 to 87.8% in patients undergoing VHR from 2013–2015.

Introduction

Umbilical, ventral, and incisional hernias are extremely common and often prompt surgical repair.[1] Over 350,000 such procedures are performed each year in the United States alone.[2] In addition to its short-term risks and morbidity, ventral hernia repair (VHR) is also associated with hernia recurrence, which can occur years after surgery and is associated with poor quality of life, functional limitations, chronic pain, and life-threatening complications.[3–8] In a population-level study of long-term hernia recurrence in patients undergoing VHR between 1987–1999, over 12% of patients required reoperation for recurrence within 5 years of their initial repair.[9] More recently, we found that the incidence of reoperation for recurrence had improved only marginally among patients undergoing VHR in the last decade.[10]

The extent to which changes in hernia recurrence mirrors changes in surgical management of ventral hernias is currently unclear. Surgical techniques and technology related to hernia repair have changed considerably over the past two decades. More patients are undergoing laparoscopic and other minimally invasive approaches.[11] Moreover, the use of synthetic mesh and myofascial release is also increasing.[12–14] To date, however, studies investigating the dissemination of new surgical techniques and their potential effects on patient outcomes have been mostly limited to single-center case series with disparate results, and European studies with uncertain generalizability.[15–24]

A more current understanding of surgical techniques and late recurrence would help clinicians counsel patients on their surgical options and risks. In this context, we conducted a population-based study of the US Medicare population to assess how surgical technique and hernia recurrence rates have changed over the past two decades.

Methods

Data Source and Study Population

This study used 100% fee-for-service Medicare claims (Part A and Part B) to identify adult (≥18 years) patients undergoing inpatient umbilical, ventral, and incisional hernia repair over an 11-year period from January 1, 2007 to December 31, 2015. Eligible patients were identified using appropriate *Current Procedural Terminology* (CPT) codes and *International Classification of Diseases 9th and 10th Edition* (ICD-9/10) procedure codes with corresponding ICD-9/10 diagnosis codes for umbilical, ventral, or incisional hernia (Supplemental Table 1). Only elective operations were included. Patients were excluded if they had a prior hernia repair in the two years leading up to their index operation or if their index operation was associated with a CPT or ICD-9/10 procedure code for recurrent hernia repair.

Outcome Measures and Explanatory Variables

The primary outcomes in this study were surgical technique and reoperation for hernia recurrence. Surgical technique included surgical approach, mesh implantation, and myofascial release. Surgical approach was identified using appropriate ICD-9/10 and CPT codes and categorized as open or minimally invasive (i.e., laparoscopic, robotic). Mesh placement was identified using CPT code 49568 for open VHR and presumed for minimally invasive repair since use of mesh is included and implied in CPT codes for laparoscopic and robotic hernia repair. Finally, myofascial release was identified using CPT code 15734. Reoperation for hernia recurrence was identified using the same CPT and ICD-9/10 codes used to identify index VHR as well as CPT codes specific to repair of recurrent hernia (49565, 49566, 49656, 49657).

Demographic information included patient age, sex, and White vs. non-White race. Clinical patient characteristics included individual Elixhauser comorbidities.[25,26] Procedural characteristics included surgical approach, mesh implantation, and myofascial release as described.

Statistical Analysis

Descriptive statistics were calculated for all demographic, clinical, and procedural characteristics. Rates of minimally invasive repair, mesh use, and myofascial release were calculated for each year of the study period. Mesh use was also calculated among the subset of patients who underwent ventral/incisional hernia repair after excluding umbilical hernia repair. Univariate comparisons were performed using Chi-squared test or analysis of variance (ANOVA) as appropriate. A multivariable logistic regression model was then used to estimate the risk-adjusted association of individual covariates with reoperation. Estimates from a Cox proportional hazards model were used to estimate the proportion of patients who remained free of reoperation for hernia recurrence up to 5 years after hernia repair.[27] Testing of Schoenfeld residuals revealed that several variables violated the proportional hazards assumption, which states that the hazard ratio remains constant over time.[28] Therefore, an interaction term with time was included for the covariates in the model that violated this assumption.[29] In order to investigate changes in outcomes over time, we separated patients into three time periods based on the date of index hernia repair (2007–2009, 2010–2012, or 2013–2015). All Cox models adjusted for patient age, sex, race, and comorbidities. Robust standard errors were used to adjust for clustering at the hospital level for all models.

All tests of statistical significance were 2-sided with an alpha of 0.05. Statistical analysis was performed using SAS version 9.4 (SAS Institute Inc., Cary, North Carolina) and Stata version 15.1 (StataCorp Inc., College Station, Texas). This secondary analysis of deidentified data was deemed exempt from regulation by the University of Michigan Institutional Review Board and the requirement for informed consent was waived.

Results

A total of 141,261 patients underwent ventral hernia repair during the study period, of whom 130,660 (92.5%) underwent ventral/incisional hernia repair and 10,601 (7.5%) underwent

umbilical hernia repair. 48,606 (34.4%) patients underwent surgery between 2007–2009, 51,615 (36.5%) patients underwent surgery between 2010–2012, and 41,040 (29.1%) patients underwent surgery between 2013–2015 (Table 1). Mean (SD) age was 69.0 (11.2) years, 55,004 (38.9%) patients were male, and 123,701 (87.6%) patients were of White race. Median time to follow up was 5.0 (IQR 0.13) years. The most common comorbidities were hypertension in 89,549 (63.4%) patients, diabetes in 34,085 (24.1%) patients, chronic pulmonary disease in 32,223 (22.8%) patients, and obesity in 25,902 (18.3%) patients.

Surgical approach was open in 109,686 (77.7%) patients, laparoscopic in 29,131 (20.6%) patients, and robotic in 2,444 (1.7%) patients. Mesh was implanted in 101,182 (71.6%) patients and myofascial release was performed in 11,734 (8.3%) patients. From 2007–2015, minimally invasive repair increased from 2.1% (324 patients) to 22.2% (2,819 patients), mesh implantation increased from 63.2% (9,953 patients) to 72.5% (9,204 patients), and myofascial release increased from 1.8% (281 patients) to 16.3% (2,076 patients) (Figure 1). After excluding patients who underwent umbilical hernia repair, annual rates of mesh use were similar among the 130,660 patients who underwent ventral/incisional hernia repair, increasing from 66.9% (9,891 patients) in 2007 to 74.6% (8,651 patients) in 2015.

A total of 20,404 (14.4%) patients underwent reoperation for hernia recurrence within 5 years of their index operation. Of these patients, 16,521 (81.0%) underwent one reoperation, 3,044 (14.9%) underwent 2 reoperations, and 839 (4.1%) underwent ≥3 reoperations. The corresponding adjusted cumulative incidence of reoperation was 4.0% (95% CI 3.0%−4.0%) at 1 year, 10.8% (95% CI 10.8%−10.8%) at 3 years, and 14.1% (95% CI 14.0%−14.1%) at 5 years after index operation. Older patients and patients with higher comorbidity burden were less likely to undergo reoperation for recurrence (Table 2). Compared to open repair, laparoscopic repair (aOR 0.93 [95% CI 0.88–0.99]) and robotic repair (aOR 0.85 [95% CI 0.75–0.96]) were associated with lower odds of reoperation for recurrence. Mesh use (aOR 0.88 [95% CI 0.85–0.92]) and myofascial flap creation (aOR 0.79 [95% CI 0.74–0.84]) were also associated with lower odds of reoperation for recurrence.

After stratifying patients by whether they underwent surgery in the first, middle, or last 3 years of the study period, the proportion of patients who remained free from reoperation for hernia recurrence increased over time. The adjusted 5-year reoperation-free survival rates were 84.9% (95% CI 84.8%−84.9%) for patients who underwent VHR between 2007–2009, 85.7% (95% CI 85.6%−85.7%) for patients who underwent VHR between 2010–2012, and 87.8% (95% CI 87.7%−87.9%) for patients who underwent VHR between 2013–2015 (Figure 2). Compared to patients who underwent VHR between 2007–2009, this corresponds to adjusted hazard ratios for reoperation of 0.94 (95% CI 0.91–0.97, P<0.001) for patients who underwent VHR between 2010–2012 and 0.92 (95% CI 0.89–0.95, P<0.001) for patients who underwent VHR between 2013–2015.

Discussion

In this large, nationally representative study of patients undergoing elective umbilical, ventral, and incisional hernia repair, three major findings emerged. First, operative technique changed over the course of this 9-year study period, with increasing use of minimally

invasive repair, mesh placement, and myofascial release. Second, patients who underwent hernia repair later in the study period were more likely to remain free from reoperation for hernia recurrence compared to patients who underwent hernia repair earlier in the study period. This finding may be related to the changes in operative technique observed over the course of the study. Finally, even despite this slight improvement, contemporary recurrence rates have only marginally improved over historically reported rates, with 1 in 7 patients undergoing reoperation for recurrence within 5 years of surgery. The burden of recurrence is likely even more dramatic considering that reoperation for recurrence underestimates clinical recurrence by nearly five-fold.[30] Overall, these results suggest that recurrence following VHR remains a common problem despite advances in surgical technique in recent decades.

This study characterized national trends in operative technique for ventral hernia repair. Over a 9-year period, we observed an increase in minimally invasive approach, myofascial flap creation, and a slight increase in mesh use. This is consistent with prior work that has reported increased adoption of these techniques on a smaller scale.[31,32] Independently, each of these techniques was associated with lower likelihood of future reoperation for recurrence, which may underly the lower rate of reoperation for recurrence among patients undergoing hernia repair later in the study period compared to earlier in the study period. This is also consistent evidence from clinical trials demonstrating the efficacy of these techniques.[23,33,34] Nevertheless, reoperative recurrence rates remained significant even among patients in the latter portion of the study period. Additional work is needed to understand why both minimally invasive approaches and mesh use plateaued in the second half of the study period. Both of these techniques have been shown to afford a more durable repair with lower rates of recurrence and complications, yet from 2010 to 2015 there was very little change in their adoption.[35] This trend mirrors other studies that have reported underutilization of best practice for hernia repair, such as a regional analysis of inguinal hernia repair in Michigan which found that 58% of surgeons performed no minimally invasive repair whatsoever, despite strong evidence demonstrating benefits to this approach.[36] The current results, in which the decrease in reoperation for recurrence coincides with the increase of these advanced techniques suggests that their continued adoption may be integral to improving recurrence-related outcomes in the future.

Recurrence following VHR is widely regarded as the most salient postoperative event for this condition. In a seminal study published 2 decades ago, Flum et al. conducted one of the largest US studies of hernia recurrence and found that roughly 12% of patients underwent reoperation for recurrence in the 5 years after index repair.[9] Large European and US studies in the intervening years corroborate similar long-term recurrence rates ranging from 12–18%.[10,23] The results of the current study suggest that even during a discrete period with increasing utilization of minimally invasive repair, mesh implantation, and myofascial release, long-term hernia recurrence following VHR remains a significant problem, with an overall 5-year reoperation rate of 14.1%.[37] Moreover, in contrast to prior work suggesting that the majority of recurrence occurs in the first two operative years, the current study found an increasing incidence of recurrence throughout all 5 postoperative years.[21] Again, the persistently poor nature of these outcomes becomes even more apparent when considering that reoperation for recurrence underestimates the true incidence of recurrence by up to 5-

fold.[30] Many patients with recurrence are also unable to pursue reoperation due to high-risk comorbidities, as evidenced by the lower odds of reoperation associated with older age and comorbidities in the current study. In short, even contemporary rates of reoperative hernia recurrence leave substantial room for improvement.

Although mesh reduces the risk of subsequent hernia recurrence, it is also associated with its own complications. Some randomized trials have suggested that mesh repair carries a higher risk of postoperative infection compared to suture repair alone.[38,39] Up to 7% of meshes ultimately require removal due to infection.[40] In addition, up to a quarter of patients report chronic pain following ventral hernia repair with mesh.[4] Therefore, it is important to weigh the risks of mesh-related complications with the risk of recurrence in the absence of mesh. López et al.[41] recently performed a meta-analysis to evaluate this balance of mesh-related complications and benefits. Reviewing 10 randomized controlled trials, the authors found that the evidence for mesh prevention of recurrence was robust and consistent across trials, whereas the evidence of mesh-related complications was weaker and more heterogeneous across trials. This suggests that the long-term benefits of mesh do, in fact, outweigh its risks in ventral hernia repair. However, careful attention to how to minimize potential mesh-related complications is essential to ensure that patients can have the best possible outcome given these competing factors.

To that end, future work is critically needed to better understand ways to improve patient selection and operative techniques to improve patient outcomes. An important complement to population-level analyses such as that presented here may be utilization of data from US-based registries that collect detailed, granular details regarding hernia repair and patient outcomes. Currently, two such registries are active – the America Hernia Society Quality Collaborative (AHSQC) and the Michigan Surgical Quality Collaborative Hernia Registry.[42,43] Both registries, which collect detailed data regarding hernia size, mesh use, and operative approach have the potential to improve our understanding of which techniques afford the best outcomes, an area where there is currently very little consensus.[44] In fact, this lack of consensus may underlie the relatively low adherence to current best practices such as mesh use, which was utilized in fewer than half the patients in this study, yet had an association with lower odds of reoperation for recurrence. Moreover, these registries may help inform patient selection for a procedure where there is likely a large proportion of patients who would have better outcomes by deferring or possibly even foregoing surgery altogether. For example, patients with high-risk comorbidities such as smoking and obesity have been shown to have significantly worse outcomes after VHR.[45] Using clinically nuanced data to understand which patients have the highest risk of recurrence and which have the highest risk of nonoperative failure is a critical step to improve outcomes which appear to have remained stagnant in recent decades.

Despite the strengths of this study including its large sample size, long-term follow-up time, and contemporary cohort, it does have important limitations to acknowledge. First, the retrospective nature of this study precludes any determination of the causal relationship between reoperation for hernia recurrence and changes in surgical technique. For example, it may be the case that the observed increase in recurrence-free survival had more to do with improved patient selection than adoption of evidence-based technique.

Nevertheless, as mentioned, prior randomized controlled trials and smaller prospective studies have demonstrated that mesh use, minimally invasive approach, and myofascial release confer a lower risk of hernia recurrence compared to open suture repair without myofascial release.[23,33,34] The use of Medicare claims may limit the generalizability of this study, however the current results are in line with previously reported rates of ventral hernia recurrence, and understanding outcomes in this large population of patients is critically important. Another important limitation of this study is that it almost certainly underestimates the true incidence of hernia recurrence. For example, a study of 256 patients who underwent incisional hernia repair found that while 37% reported recurrence after 4 years, only 8% of patients underwent reoperation.[30] Despite this underestimation, reoperation for recurrence is nevertheless one of the most relevant recurrence-related outcomes for both patients and healthcare systems, and it may be precisely in relation to this outcome (as opposed to recurrence which goes untreated) that improvement efforts are most urgently needed.

Conclusion

Recurrence continues to be a common complication following elective ventral hernia repair. Importantly, increasing use of minimally invasive approach, mesh use, and myofascial release observed during the study period coincided with a slight increase in reoperation-for-recurrence-free survival. These results suggest that adopting evidence-based techniques may play a role in further improving outcomes after ventral hernia repair.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Research Support and Acknowledgments:

RH receives unrelated funding from the Blue Cross Blue Shield of Michigan Foundation and the National Institute of Diabetes and Digestive and Kidney Diseases (5T32DK108740-05). JT and AE have no disclosures. ME receives unrelated funding from the Michigan Department of Health and Human Services, the National Institute on Drug Abuse, and salary support from Blue Cross Blue Shield of Michigan. JD receives grant funding from the NIH, ARGQ, Blue Cross Blue Shield of Michigan Foundation, and is a cofounder of ArborMetrix, Inc. DT receives funding from AHRQ K08HS025778-01A1 and receives consulting fees from Medtronic. The content of this study is solely the responsibility of the authors and does not necessarily reflect the official views of Blue Cross Blue Shield of Michigan. No funder or sponsor had any role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication. RH had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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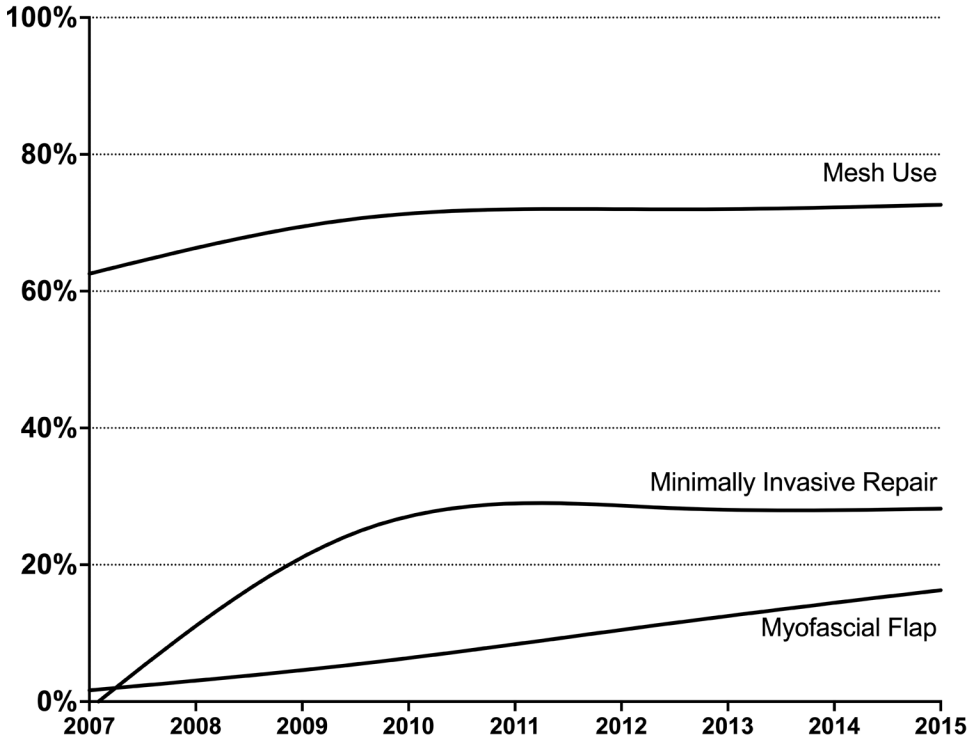

Figure 1:
Annual prevalence of minimally invasive repair, mesh use, and myofascial release from 2007–2015.

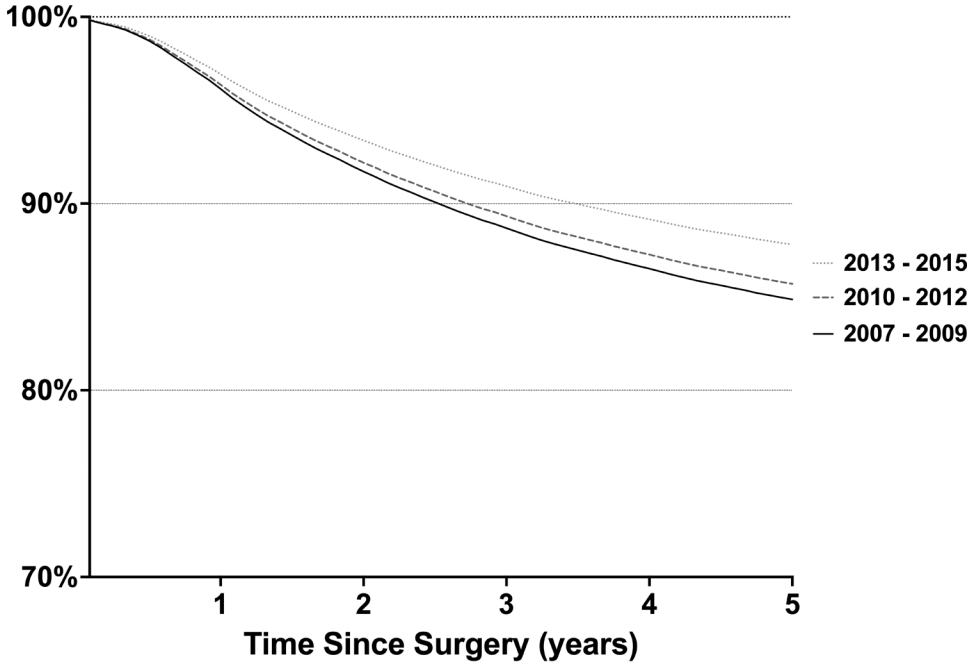

Figure 2:
Adjusted rate of recurrence-free survival stratified by years of index operation.

Table 1 –

Cohort characteristics

All values represented as N (%) unless otherwise indicated. Comorbidities with a prevalence ≥3.0% reported. Mesh use includes any open procedure with a separate billing claim for mesh placement or any minimally invasive procedure (laparoscopic, robotic) as mesh placement is included in the billing claim for these cases.

	Total (N=141,261)	2007–2009 (N=48,606)	2010–2012 (N=51,615)	2013–2015 (N=41,040)
Age (mean (SD))	68.95 (11.2)	69.3 (11.4)	68.8 (11.3)	68.7 (11.0)
Male	55004 (38.9)	18733 (38.5)	19970 (38.7)	16301 (39.7)
White	123701 (87.6)	43094 (88.7)	45158 (87.5)	35449 (86.4)
Comorbidities				
Hypertension	89549 (63.4)	28573 (58.8)	33183 (64.3)	27793 (67.7)
Diabetes w/o chronic complications	34085 (24.1)	10587 (21.8)	12837 (24.9)	10661 (26.0)
Chronic pulmonary disease	32223 (22.8)	10360 (21.3)	11740 (22.7)	10123 (24.7)
Obesity	25902 (18.3)	6011 (12.4)	9868 (19.1)	10023 (24.4)
Hypothyroidism	19227 (13.6)	5490 (11.3)	7088 (13.7)	6649 (16.2)
Fluid and electrolyte disorders	17182 (12.2)	4252 (8.7)	6386 (12.4)	6544 (15.9)
Depression	13913 (9.9)	3189 (6.6)	5228 (10.1)	5496 (13.4)
Renal failure	12673 (9.0)	3189 (6.6)	4663 (9.0)	4821 (11.7)
Deficiency Anemias	12666 (9.0)	2875 (5.9)	4788 (9.3)	5003 (12.2)
Congestive heart failure	9702 (6.9)	3002 (6.2)	3577 (6.9)	3123 (7.6)
Peripheral vascular disease	6706 (4.8)	1932 (4.0)	2511 (4.9)	2263 (5.5)
Valvular disease	6021 (4.3)	1850 (3.8)	2169 (4.2)	2002 (4.9)
Other neurological disorders	5926 (4.2)	1605 (3.3)	2185 (4.2)	2136 (5.2)
Liver disease	4375 (3.1)	1200 (2.5)	1533 (3.0)	1642 (4.0)
Procedure Characteristics				
Open	109686 (77.7)	43071 (88.6)	37150 (72)	29465 (71.8)
Laparoscopic	29131 (20.6)	5390 (11.1)	13758 (26.7)	9983 (24.3)
Robotic	2444 (1.7)	145 (0.3)	707 (1.4)	1592 (3.9)
Mesh use	101182 (71.6)	32290 (66.4)	36978 (71.6)	29696 (72.4)
Myofascial Flap use	11734 (8.3)	1515 (3.1)	4349 (8.4)	5870 (14.3)

Table 2 –

Multivariable logistic regression for reoperation for recurrence.

	No Recurrence (N=120,857)	Recurrence (N=20,404)	aOR (95% CI)	P
Age (mean (SD))	69.38 (11.1)	66.40 (11.5)	0.98 (0.97–0.98)	<.001
Male	47378 (39.2)	7626 (37.4)	0.92 (0.89–0.96)	<.001
White	105724 (87.5)	17977 (88.1)	1.21 (1.15–1.27)	<.001
Comorbidities				
Hypertension	76993 (63.7)	12556 (61.5)	1.03 (1.00–1.06)	0.063
Diabetes w/o chronic complications	29496 (24.4)	4589 (22.5)	0.98 (0.94–1.01)	0.185
Chronic pulmonary disease	27611 (22.9)	4612 (22.6)	0.88 (0.85–0.92)	<.001
Obesity	21973 (18.2)	3929 (19.3)	1.00 (0.96–1.04)	0.845
Hypothyroidism	16537 (13.7)	2690 (13.2)	0.99 (0.94–1.04)	0.724
Fluid and electrolyte disorders	14787 (12.2)	2395 (11.7)	1.05 (1.00–1.10)	0.039
Depression	11734 (9.7)	2179 (10.7)	1.00 (0.95–1.05)	0.877
Renal failure	11105 (9.2)	1568 (7.7)	0.81 (0.77–0.86)	<.001
Deficiency Anemias	10940 (9.1)	1726 (8.5)	1.01 (0.95–1.06)	0.820
Congestive heart failure	8679 (7.2)	1023 (5.0)	0.78 (0.73–0.83)	<.001
Peripheral vascular disease	5847 (4.8)	859 (4.2)	0.96 (0.89–1.04)	0.322
Valvular disease	5300 (4.4)	721 (3.5)	0.81 (0.74–0.88)	<.001
Other neurological disorders	5177 (4.3)	749 (3.7)	0.93 (0.86–1.00)	0.063
Liver disease	3651 (3.0)	724 (3.6)	0.83 (0.75–0.92)	<.001
Procedure Characteristics				
Open	93946 (77.7)	15740 (77.1)	Reference	
Laparoscopic	24789 (20.5)	4342 (21.3)	0.93 (0.88–0.99)	0.018
Robotic	2122 (1.8)	322 (1.6)	0.85 (0.75–0.96)	0.010
Mesh use	86946 (71.9)	14236 (69.8)	0.88 (0.85–0.92)	<.001
Myofascial Flap use	10316 (8.5)	1418 (7.0)	0.79 (0.74–0.84)	<.001