Risk factors for 30-day readmission in patients undergoing ventral hernia repair

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Background. *Ventral hernia repair (VHR), an increasingly common procedure, may have a greater impact on health care costs than is currently appreciated. Readmissions have the potential to further increase these costs and negatively impact patient outcomes. New national registry data allows for an in-depth look at the predictors and rates of readmission after VHR.*

Methods. *The American College of Surgeon's National Surgical Quality Improvement Program database was queried for all patients who underwent only an incisional or VHR in 2011. Patients who had any concomitant procedure were excluded. Using readmission as the dependent variable, a multivariate logistic regression model was created to identify independent predictors of readmission.*

Results. *VHR had a 4.9% 30-day readmission rate in 2011. Deep/incisional (12.6%) and superficial site infections (10.5%) were the most common wound complications seen in readmitted patients (both* $P < .001$*), whereas sepsis/septic shock (10.14%;* $P < .001$*) was the most common systemic complication. Higher class body mass index is not associated with readmission (*$P = .320$*). Smoking and chronic obstructive pulmonary disease function as predictors of readmission independently from their association with complications (odds ratio [OR], 1.3; 95% confidence interval [CI], 1.1–1.6; and OR, 1.6, 95% CI, 1.1–2.3, respectively). Operative factors such as the use of mesh (OR, 1.3; 95% CI, 0.995–1.7) or laparoscopy (OR, 1.2; 95% CI, 0.96–1.6) do not increase likelihood of readmission.*

Conclusion. *There is room for improvement in VHR readmission rates. Although complications are the main driver of readmission, surgeons must be aware of comorbidities that independently increase the odds of readmission, even when a complication does not occur. (Surgery 2014;155:702-10.)*

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VENTRAL HERNIA REPAIR (VHR) is among the most common operative procedures performed by plastic and general surgeons in the United States. According to the 2001–2006 Healthcare Cost and Utilization Project Nationwide Inpatient Sample[1] and the 2006 Center for Disease Control National Survey of Ambulatory Surgery,[2] an estimated 348,000 repairs were performed in 2006, including 154,278 inpatient and 193,543 outpatient procedures.[3] Additionally, the total estimated aggregate cost for this procedure in 2006 was $3.2 billion, a number that continues to grow owing to increasing interest in abdominal wall reconstruction and the introduction of novel repair techniques and materials.[3] Given the prevalence of this particular operative procedure in the United States, it is clear that factors that influence outcomes after VHR will have a large impact on health care expenditures and patient morbidity.

VHR is generally considered to be a well-tolerated and cost-effective procedure,[3] but recent studies have indicated that it has a greater impact on health care costs than previously appreciated. Several recent papers have demonstrated that VHR is plagued by high rates of recurrence and readmission, both of which have the potential to increase patient morbidity and associated costs.[4-6] In particular, rates of unplanned readmission after this procedure are unacceptably high, with Kassin et al[7] reporting a single-center readmission rate of 11% after VHR, and a recent Danish study reporting a similar rate of 13.3%.[8] As the US health care system attempts to reduce expenditures while improving efficiency, these types of hospital readmission rates will serve as a key parameter for

Accepted for publication December 18, 2013.

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0039-6060/$ - see front matter

http://dx.doi.org/10.1016/j.surg.2013.12.021

measuring health care quality.[9] In 2007, the Medicare Payment Advisory Commission reported that hospital readmissions cost up to $15 billion a year,[10] a number that will only increase until effective measures for controlling readmissions are implemented. Therefore, a formal analysis of the preventable factors leading to readmission after VHR is essential, not only to control costs, but also to improve patient outcomes.

Although outcomes after VHR are generally well documented,[11-16] and there are reports from single institutions that have analyzed readmission rates after VHR,[17] the capacity for performing a nationwide, multicenter analysis of readmissions after VHR has not previously been possible. Fortunately, the inclusion of a new "readmission" variable in the American College of Surgeons' National Surgical Quality Improvement Program Database (ACS-NSQIP) has made this type of analysis possible for the first time. The ACS-NSQIP was established to quantify and improve surgical outcomes among hospitals in the United States. The comprehensive nature of the database has been validated multiple times,[18-20] proving to be a prime resource for elucidating national trends in surgery. Given that this resource has not been previously accessible, our goal was to use the ACS-NSQIP to (1) establish a readmission benchmark for surgeons performing VHR and (2) determine nationwide demographic factors, comorbidities, and postoperative complications that most strongly predict readmission after ventral and incisional hernia repair.

MATERIALS AND METHODS

Data acquisition and inclusion criteria. The present study utilizes data from the ACS-NSQIP database. Deidentified patient information is freely available to all institutional members who comply with the ACS-NSQIP Data Use Agreement. The Data Use Agreement implements the protections afforded by the Health Insurance Portability and Accountability Act of 1996 and the ACS-NSQIP Hospital Participation Agreement. This study conforms with the Helsinki Declaration.

Preoperative variables were prospectively collected, and postoperative variables were tracked for 30 days after the primary operation. Data collection was performed by trained nurses and reviewed by each site's Surgical Clinical Reviewer,[21] providing for reliable and complete data collection that has been validated by multiple studies.[18,20] Additionally, past audits have demonstrated inter-rater reliability in the reporting of outcomes.[19]

All patients who underwent ventral or incisional hernia repair in 2011 were selected from the database based on primary Current Procedural Terminology (CPT) codes and postoperative International Classification of Diseases (ICD)-9 diagnoses. The following primary CPT codes were included: 49560, 49561, 49565, 49566, 49568, 49570, 49572, 49580, 49582, 49585, 49587, 49590, 49652, 49653, 49654, 49655, 49656, 49657, and 49659. Any patient who underwent multiple procedures, identified by the presence of any other CPT code other than 15734 (component separation) or 49568 (use of mesh) was excluded from the sample. Last, the following ICD-9 codes were used to select only those patients whose postoperative diagnosis was a ventral or incisional hernia: 551.2, 551.21, 551.29, 552.2, 552.21, 552.29, 553.2, 553.21, and 553.29. Any patient with an ICD-9 other than those listed was excluded.

Determination of factors associated with readmission. The primary outcome of interest was unplanned readmissions within 30 days of the procedure. Unplanned readmissions included any readmission "likely related to the principal surgical procedure" that was not planned at the time of the initial operation.[21] Univariate analysis was performed to identify factors significantly associated with readmission, using Pearson's Chi-square test for categorical variables (and Fisher's exact test when appropriate) or the Mann–Whitney *U* tests for continuous variables. Demographics, comorbidities, operative characteristics, and postoperative outcomes within 30 days of the procedure were compared between patients who were readmitted and those who were not readmitted. Operative variables included the use of mesh, component separation, use of laparoscopy, emergency operation, repair of recurrent hernia, duration of hospital stay, total operative time, and total work relative value units (RVU). All cases with a reported CPT of 49568 were considered to have used mesh in the repair; similarly, any case with a reported CPT of 15734 was considered to have used component separation techniques. Primary CPTs consisting of 49652, 49653, 49654, 49655, 49656, 49657, or 49659 were listed as laparoscopic procedures. Recurrent hernia repairs were defined as primary CPT codes of 49560, 49566, 49656, or 49657.

Postoperative complications were grouped into wound complications and systemic complications. Wound complications consisted of superficial surgical site infection (SSI), deep/incisional SSI, organ/space SSI, and wound dehiscence. Systemic complications consisted of pneumonia, unplanned intubation, pulmonary embolism, acute

renal failure, urinary tract infection, stroke/cerebrovascular accident, coma, peripheral nerve injury, cardiac arrest, myocardial infarction, blood transfusion within 72 hours of the procedure, graft/prosthesis failure, deep venous thrombosis, and sepsis/septic shock. Patients who had signs of systemic inflammatory response syndrome were counted as having sepsis/septic shock. All adverse outcomes were tracked for 30 days after the procedure and were used as defined in the NSQIP User Guide.[21]

Controlling for confounders. Multivariate logistic regression was utilized to adjust for confounders and generate odds ratios. All factors in Tables I and II, plus all other preoperative variables listed in the NSQIP User Guide,[21] were screened for a significant association with readmission. The total RVU of procedures performed was calculated for each case and used to adjust for operative complexity.[22,23] Preoperative laboratory values were not included owing to a large fraction of missing laboratory data in our sample. Chi-square tests and Mann–Whitney *U* tests were used for categorical and continuous variables as appropriate. Any variable that occurred ≥10 times and was associated with readmission by a significance of $P \leq .05$ was included in the model.[24] A Hosmer-Lemeshow test and C-statistic were computed to assess goodness-of-fit.[25] All statistical analyses were performed using SPSS for Windows (Version 21.0; IBM Corp, Armonk, NY).

RESULTS

Comorbidities, preoperative, and demographic factors. A total of 17,211 patients who underwent ventral or incisional hernia repair were identified from the NSQIP database. Out of this initial sample, 4,538 patients who underwent any concurrent procedure other than insertion of mesh (CPT code 49568) or component separation (CPT code 15734) were excluded. Out of the final sample, 612 were readmitted within 30 days of the procedure, for an overall unplanned readmission rate of 4.9%. Differences in demographic values, comorbidities, and operative characteristics between patients who were readmitted and those that were not readmitted are shown in Table I. Gender, race, body mass index (BMI), prior operation within 30 days, previous cardiac surgery, and previous stroke were the only factors not associated with readmission. Readmitted patients had much higher rates of smoking (26.09% vs 19.61%; $P < .001$), hypertension (58.62% vs 48.45%; $P < .001$), chronic obstructive pulmonary disease (COPD; 10.31% vs 4.39%; $P < .001$), and diabetes (20.13% vs 15.42%; $P = .002$). The majority of readmitted patients also had longer operation times (87 minutes [interquartile range, 57.5–128.0] vs 65 minutes [interquartile range, 40–103]; $P < .001$). Readmitted patients were mostly classified as ASA Class 3 (53.95%; $P < .001$), whereas a majority of patients who were not readmitted were classified ASA Class 2 (51.47%; $P < .001$).

Postoperative complications. Rates of postoperative outcomes for all patients are displayed in Table II. Wound infections and systemic infections accounted for the majority of complications in all patients, though readmitted patients had significantly higher rates of every type of adverse outcome. The most common complications were deep incisional SSI (12.56% vs 0.37%; $P < .001$), superficial SSI (10.47% vs 1.32%; $P < .001$), sepsis/septic shock (10.14% vs 0.37%), and urinary tract infection (4.19% vs 0.74%; $P < .001$). Neurologic complications were the least likely to occur overall—the only neurologic complication reported was stroke/cerebrovascular accident (0.48% readmitted vs 0.02% not readmitted; $P = .001$).

Predictors of readmission. The results of the multivariate logistic model used to control for potential confounders can be found in Table III. The calculated concordance statistic for our model was 0.768, indicative of high predictive capacity. Predictors of readmission consisted of various comorbidities, operative complications, and operative characteristics. No demographic variable, including BMI, was found to be independently associated with a greater likelihood of readmission. Comorbidities that independently increased readmissions included smoking (odds ratio [OR], 1.303; 95% confidence interval [CI], 1.047–1.623), COPD (OR, 1.575; 95% CI, 1.114–2.227), ascites (OR, 3.578; 95% CI, 1.636–7.823), renal disease requiring active dialysis (OR, 3.460; 95% CI, 1.746–6.856), and ASA class >1 (class 2: OR, 2.188; 95% CI, 1.186–4.036; class 3: OR, 2.565; 95% CI, 1.368–4.809; class 4: OR, 2.495; 95% CI, 1.132–5.500).

Postoperative complications predicted readmission more strongly than any preoperative factor. After controlling for confounders, unplanned intubation and blood transfusions were the only complications that did not significantly change the odds of readmission. In contrast, patients who experienced a deep/incisional SSI, organ/space SSI, pulmonary embolism, or myocardial infarction were ≥10 times as likely to be readmitted. The occurrence of a deep/incisional SSI increased odds of readmission the most (OR, 27.563; 95% CI, 17.840–42.585), whereas wound dehiscence

Table I. Patient preoperative variables stratified by readmission

Demographics	*Not readmitted* (n = *12,052*)		*Readmitted* (n = *621*)		P *value*
Age (y)*,†	56	(45–66)	58	(47–69)	<.001
BMI (kg/m^2)					.320
Underweight (≤18.5)	86	0.71%	8	1.29%	
Normal (>18.5–25)	1,780	14.77%	84	13.53%	
Overweight (>25–30)	3,334	27.66%	166	26.73%	
Obese (>30–35)	3,042	25.24%	149	23.99%	
Severely obese (>35–40)	1,893	15.71%	98	15.78%	
Very severely obese (>40)	1,801	14.94%	107	17.23%	
Gender					
Male	5,123	42.51%	278	44.77%	.252
Female	6,909	57.33%	341	54.91%	
Race					
White	9,542	79.17%	496	79.87%	.866
Black	1,270	10.54%	69	11.11%	
Asian	112	0.93%	4	0.64%	
Other	107	0.89%	5	0.81%	
Comorbidities					
Diabetes*	1,859	15.42%	125	20.13%	.002
Current smoker*	2,363	19.61%	162	26.09%	<.001
Steroid use*	319	2.65%	28	4.51%	.006
Prior operation <30 days	43	0.36%	5	0.81%	.085
Dyspnea*	862	7.15%	69	11.11%	<.001
Hypertension*	5,839	48.45%	364	58.62%	<.001
COPD*	529	4.39%	64	10.31%	<.001
Bleeding disorders*	320	2.66%	32	5.15%	<.001
Previous PCI*	229	1.90%	21	3.38%	.010
Previous cardiac surgery	263	2.18%	18	2.90%	.237
Previous stroke	137	1.14%	12	1.93%	.073
Previous TIA*	99	0.82%	11	1.77%	.013
Systemic sepsis*	165	1.37%	18	2.90%	.002
Ascites*	46	0.38%	10	1.61%	<.001
On dialysis*	70	0.58%	12	1.93%	<.001
Functional status					
Not independent*	122	1.01%	17	2.74%	<.001
ASA classification*					<.001
1	862	7.15%	13	2.09%	
2	6,203	51.47%	243	39.13%	
3	4,706	39.05%	335	53.95%	
4	262	2.17%	29	4.67%	
Operative characteristics					
Mesh*	4,950	41.07%	304	48.95%	<.001
Component*	274	2.27%	32	5.15%	<.001
Lap*	3,767	31.26%	165	26.57%	.014
Recurrent hernia*	2,033	16.87%	133	21.42%	.003
Emergency case*	563	4.67%	43	6.92%	.010
Preoperative stay >24 h*	580	4.81%	65	10.47%	<.001
Total operation time (min)*,†	65	(40–102)	87	(57.5–128)	<.001
Total work RVU*,†	16.21	(12.88–17.25)	16.8	(12.90–17.25)	.002

*$P \leq .05$.

†Continuous variables listed as median with associated interquartile range.

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease; *PCI*, percutaneous coronary intervention; *RVU*, relative value units; *TIA*, transient ischemic attack.

increased odds of readmission the least (OR, 3.909; 95% CI, 1.611–9.487). Total work RVU for each case was included in the regression models in an attempt to adjust for procedural differences (eg, strangulated open hernia repair with mesh placement vs a simple laparoscopic repair), but

Table II. Postoperative outcomes stratified by readmission status*

Outcome	*Not readmitted* (n = *12,052*)		*Readmitted* (n = *621*)		P *value*
Any complication (≥1)	491	4.07%	271	43.64%	<.001
Wound complication (≥1)	244	2.02%	169	27.21%	<.001
Superficial SSI	159	1.32%	65	10.47%	<.001
Deep incisional SSI	45	0.37%	78	12.56%	<.001
Organ/space SSI	20	0.17%	18	2.90%	<.001
Wound dehiscence	30	0.25%	15	2.42%	<.001
Systemic complication (≥1)	285	2.36%	154	24.80%	<.001
Pneumonia	57	0.47%	23	3.70%	<.001
Unplanned intubation	44	0.37%	22	3.54%	<.001
Pulmonary embolism	10	0.08%	13	2.09%	<.001
Ventilator for >48 h	37	0.31%	12	1.93%	<.001
Progressive renal insufficiency	9	0.07%	10	1.61%	<.001
Acute renal failure	8	0.07%	4	0.64%	.002
UTI	89	0.74%	26	4.19%	<.001
Stroke/CVA	2	0.02%	3	0.48%	.001
Coma	0	0.00%	0	0.00%	—
Peripheral nerve injury	0	0.00%	0	0.00%	—
Cardiac arrest	10	0.08%	4	0.64%	.004
Myocardial infarction	10	0.08%	11	1.77%	<.001
Blood transfusion	63	0.52%	11	1.77%	.001
Graft/prosthesis failure	0	0.00%	0	0.00%	—
DVT	20	0.17%	17	2.74%	<.001
Sepsis/septic shock	44	0.37%	63	10.14%	<.001
Days from operation to discharge†	1	(0–2)	2	(0–4)	<.001

*$P \leq .05$.
†Continuous variables listed as median with associated interquartile range.
CVA, Cerebrovascular accident; *DVT*, deep venous thrombosis; *SSI*, surgical site infection; *UTI*, urinary tract infection.

cases with increased RVU did not predict a higher likelihood of readmission (OR, 0.977; 95% CI, 0.948–1.906).

DISCUSSION

Postoperative readmissions vary according to the procedure and are fundamentally different from readmissions owing to chronic medical illness. Multiple variables affect patient readmission after a surgical procedure, including patient comorbidities, procedural complications, and operative variables (Fig). This complexity has made the analysis of these factors very difficult using existing models, most of which have been formulated to study nonoperative diagnoses identified by the Hospital Readmissions Reduction Program.[7,26-31] However, the recent inclusion of readmission data into the validated ACS-NSQIP database allows a nationwide, in-depth look at patterns in VHR surgery, facilitating analysis of both patient and procedural factors that might influence unplanned readmission.

Recent studies have demonstrated that VHR continues to be hampered by high rates of recurrence and unplanned readmission,[7,8,17] both of which contribute to rising costs and patient morbidity. To reduce readmission after VHR and simultaneously improve health care quality, predicting which patients are most likely to be readmitted is fundamental to tailoring preoperative and postoperative therapies. The objective of this study was to use the ACS-NSQIP database to more clearly define the expected rate of unplanned readmission after VHR, and to identify the factors most commonly associated with these readmissions. Ultimately, we believe that a more comprehensive understanding of the problem posed by unplanned readmissions will serve as the basis for practice changes designed to reduce patient morbidity and health care costs associated with this commonly performed procedure.

Any attempt at quality improvement requires that the target problem be accurately defined with a benchmark. In the case of unplanned hospital readmission after VHR, our analysis of 12,673 cases yielded a 30-day readmission rate of 4.9%. This is significantly lower than the readmission rates previously reported. Kassin et al[7] reported a single-center readmission rate of 11.0% after VHR, and

Table III. Multivariate logistic regression of predictors of unplanned readmission

Predictor	Odds ratio	95% confidence interval		P value
		Lower	Upper	
Age	1.004	0.997	1.012	.241
Comorbidities				
Diabetes	0.996	0.784	1.267	.977
Smoker*	1.303	1.047	1.623	.018
Steroid use	1.425	0.912	2.224	.119
Dyspnea	1.184	0.872	1.607	.279
COPD*	1.575	1.114	2.227	.010
Previous PCI	1.378	0.816	2.326	.231
Hypertension	1.074	0.876	1.317	.494
Previous stroke	0.756	0.370	1.548	.445
Ascites*	3.578	1.636	7.823	.001
On dialysis*	3.460	1.746	6.856	<.001
Functional status				
Not independent	1.729	0.940	3.181	.078
ASA class				
1				
2*	2.188	1.186	4.036	.012
3*	2.565	1.368	4.809	.003
4*	2.495	1.132	5.500	.023
Postoperative outcomes				
Superficial SSI*	8.214	5.814	11.605	<.001
Deep/incisional SSI*	27.563	17.840	42.585	<.001
Organ/space SSI*	10.163	4.303	24.006	<.001
Wound dehiscence*	3.909	1.611	9.487	.003
Pneumonia*	4.586	2.267	9.275	<.001
Unplanned intubation	1.927	0.854	4.346	.114
Pulmonary embolism*	19.650	7.209	53.563	<.001
UTI*	4.135	2.396	7.136	<.001
Myocardial infarction*	15.905	5.903	42.860	<.001
Blood transfusion	2.005	0.903	4.453	.088
DVT*	9.141	4.159	20.094	<.001
Sepsis/shock*	7.330	4.102	13.100	<.001
Operative characteristics				
Use of mesh	1.316	0.995	1.740	.054
Component separation	2.039	0.821	5.064	.125
Lap	1.242	0.956	1.614	.105
Emergency case	1.111	0.747	1.654	.603
Recurrent hernia	1.043	0.826	1.318	.721
Days to discharge	0.973	0.94	1.007	.118
Total work RVU	0.977	0.947	1.009	.161
Preoperative stay >24 h	1.344	0.948	1.906	.097

*$P \leq .05$.

HL: 0.083. C-stat: 0.768.

ASA, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease; *DVT*, deep venous thrombosis; *PCI*, percutaneous coronary intervention; *RVU*, relative value units; *SSI*, surgical site infection; *UTI*, urinary tract infection; HL, Hosmer-Lemeshow.

a nationwide study in Demark[8] found the unplanned readmission rate to be 13.3%. The lower readmission rate derived from our analysis is likely explained by the exclusion of concomitant operative procedures and the inclusion of VHRs performed in the outpatient setting. Intuitively, patients with additional disease that require concomitant operative procedures are at higher risk for readmission.[7,8,13] Likewise, the inclusion of outpatient VHRs likely increased the proportion of our sample composed of relatively healthy patients with less extensive hernias. These patient selection criteria were established with the intent of defining the procedure-specific readmission rate for VHR alone, without confounding factors derived from other procedures.

The results of our nationwide analysis support previous findings indicating that procedural complications are the main driver of unplanned readmission after VHR.[7,8,17,32] Postoperative complications increased the likelihood of readmission much more dramatically than any other factor. In accordance with past studies emphasizing wound infections as the most common reasons for early readmissions after VHR,[7,8,17,33] we found that wound infections, urinary tract infections, and sepsis are present in a large proportion of readmitted patients. Although systemic complications are less common than wound infections, certain adverse outcomes (eg, myocardial infarction and pulmonary embolism) increase the likelihood of readmission more than any type of wound infection, apart from a deep/incisional SSI. Therefore, although perioperative wound and systemic infections are much more common in readmitted patients, serious systemic complications almost guarantee readmission, a fact well-known by many surgeons.

The novel finding of our analysis was that certain patient comorbidities predict unplanned readmission independent of any operative complication traditionally associated with that comorbidity. Other large-scale studies have not been able to differentiate the roles of patient comorbidities and operative complications on readmission rates after VHR,[8] a knowledge gap that we believe the present study may begin to fill. Although patients who were readmitted had greater rates of almost every comorbidity, only 4 comorbidities demonstrated an independent effect on unplanned readmission in the multivariate analysis. Smoking, COPD, ascites, and chronic renal failure requiring dialysis were all predictors of readmission independent from any complications they may have caused. Dialysis, COPD exacerbations, and ascites have been

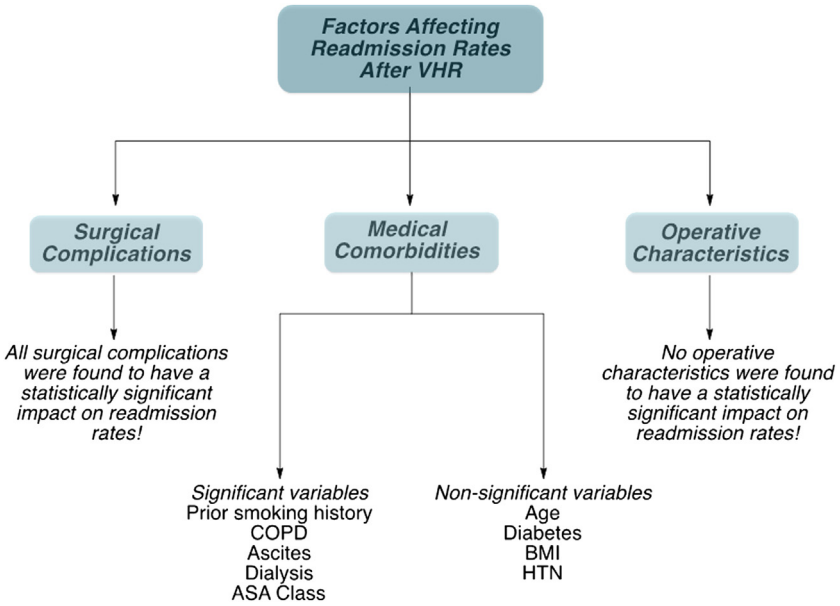

Fig. Factors affecting admission rates after ventral hernia repair (VHR) include operative complications, medical comorbidities, and operative characteristics. *ASA*, American Society of Anesthesiologists; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease; *HTN*, hypertension.

implicated as strong predictive factors for readmission to internal medicine wards in the past.[26] Thus, our analysis demonstrates that these medical factors can independently increase readmission after an operation as well. On the other hand, smoking has been assumed to increase rates of readmission through its association with poor healing and wound infections.[34] However, our study was able to show that even after controlling for the postoperative complications associated with smoking, this variable still increased the likelihood of readmission. This finding quantifies how readmission after VHR is not simply based on operative complications or patient comorbidities, but rather on the complex interactions between the stress of surgery and patient factors. Surgeons operating on smokers must be aware that the likelihood of readmission is greater regardless of whether the patient develops a specific postoperative complication.

In contrast, another novel finding was that certain factors associated with complications were not independent predictors of readmission. BMI and diabetes are both factors associated with adverse outcomes after hernia repair.[35-38] However, there was no significant difference in BMI between the patients who were readmitted and those who were not.[36,38] Similarly, despite a greater rate of diabetes among readmitted patients, diabetes was not found to be an independent predictor of readmission after controlling for resultant complications.[35,37] Age, steroid use, and bleeding disorders were other risk factors that failed to predict readmission despite their known association with complications. In contrast with smoking, we conclude that factors such as age, BMI, and diabetes must increase readmission rates by increasing postoperative complications.

Specific details about operative procedures are not tracked in the ACS-NSQIP database, but we were still able to account for the impact of a few operative factors on the rates of readmission in our study. Although more readmitted patients underwent an open procedure, emergency procedure, repair for a recurrent hernia, component separation, mesh placement, or had a preoperative stay of >24 hours, multivariate analysis showed that none of those factors independently predicted readmission. Therefore, the increased rates of these factors in the readmitted cohort can be explained by their association with adverse outcomes alone.[8,12,14,16] Last, we attempted to capture differences in procedures through a calculation of the total RVU of each case, but this was not found to change readmission. This stands in contrast with previous studies in which case complexity affected readmission rates.[8,17]

Our nationwide, multicenter sample provided sufficient power to uncover independent predictors of readmission after VHR that have not been previously identified. Despite these advantages, the study has several limitations. First, the ACS-NSQIP does not track variables specific to VHR (ie, defect

size, type of incision, mesh class, or mesh position).[8,17,32,33] Furthermore, outcomes such as seroma or hernia recurrence are not available through ACS-NSQIP, which limits the analysis that can be performed regarding these postoperative complications. Second, when determining inclusion criteria, it was necessary to decide between excluding all patients with any concurrent operative procedure and excluding only those that had concurrent procedures that would not significantly change readmission risk. Given controversies in the literature regarding outcomes after VHR combined with other operative procedures,[11,39,40] we decided that a more conservative approach would allow us to better isolate the predictors of readmission related VHR alone. Third, previous research has shown that predicting readmission accurately requires the inclusion of factors related to the patient's cultural and socioeconomic environment,[41,42] which are not available in the ACS-NSQIP database. Fourth, ACS-NSQIP data are deidentified, and we could not know with certainty the reason for readmission. Despite this limitation, the trends identified in this study corroborate findings in other studies that were able to identify specific reasons for readmission,[7,8,17] giving us confidence that most of the postoperative complications identified were indeed the cause of readmissions for those patients. Last, the analytic techniques used in this paper are subject to inherent problems such as the lack of validation and possibility of multiple comparisons. However, the reliability of NSQIP data as a secondary data source has been externally validated multiple times.[18,20]

In conclusion, VHR is a common operative procedure that has the potential to significantly increase health care costs and patient morbidity, especially if readmissions are not properly controlled. New mandates linking readmission rates with health care quality have given impetus to further research on the predictors of readmission, especially because surgical readmissions are inherently distinct from readmissions owing to medical illness. In addition to establishing a benchmark readmission rate for surgeons performing VHR, we have confirmed the finding that postoperative complications are the main driver of readmissions after VHR. Last, our use of the nationwide ACS-NSQIP database has allowed us to identify several other comorbidities that predict readmission independent of their influence on operative complications. Going forward, surgeons performing VHR will not only have a standard readmission rate against which to compare their own practice, but also be aware of what factors must be controlled to lower readmissions. With this deeper understanding of how operative complications, operative details, and patient comorbidities interact to affect readmission rates, we hope that methods through which these factors may be managed will be the subject of further research.

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

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