Surgery xxx (2021) 1–7

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

Nationwide increase in component separation without concomitant rise in readmissions: A nationwide readmissions database analysis

Sullivan A. Ayuso, MD[a], Paul D. Colavita, MD[a], Vedra A. Augenstein, MD[a], Bola G. Aladegbami, MD[a], Raageswari B. Nayak, MS[a], Bradley R. Davis, MD[a], Jeffrey E. Janis, MD[b], John P. Fischer, MD, MPH[c], B. Todd Heniford, MD[a,*]

[a] *Division of Gastrointestinal and Minimally Invasive Surgery, Department of Surgery, Carolinas Medical Center, Charlotte, NC*
[b] *Department of Plastic and Reconstructive Surgery, Ohio State University Wexner Medical Center, Columbus, OH*
[c] *Division of Plastic Surgery, Department of Surgery, Perelman School of Medicine, Philadelphia, PA*

ARTICLE INFO

Article history:
Accepted 13 September 2021
Available online xxx

ABSTRACT

Background: The use of component separation technique (CST) in complex abdominal wall reconstruction (AWR) increases the rate of primary musculofascial closure but can be associated with increased wound complications, which may require readmission. This study examines 3-year trends in readmissions for patients undergoing AWR with or without CST.
Methods: The Nationwide Readmissions Database was queried for patients undergoing elective AWR from 2016–2018. CST, demographic characteristics, and 90-day complications and readmissions were determined. CST versus non-CST readmissions were compared, including matched subgroups. Standard statistics and logistic regression were used.
Results: Over the 3-year period, 94,784 patients underwent AWR. There was an annual increase in the prevalence of CST: 4.0% in 2016; 6.1% in 2017; 6.7% in 2018 ($P < .01$), which is a 67.5% upsurge during that time. Most cases (82.3%) occurred at urban teaching hospitals, which had more comorbid patients ($P < .01$). The yearly 90-day readmission rate did not change: 16.0%, 18.2%, and 16.9% ($P = .26$). Readmissions were higher for CST patients than non-CST patients (17.1% vs 15.7%), but not in the matched subgroup (17.0% vs 16.4%; $P = .41$). Most commonly, readmissions were for infection (28.3%); 14.3% of readmitted patients underwent reoperation. Smoking, morbid obesity, diabetes, chronic lung disease, urban-teaching hospital status, and increased length of stay increased the chance of readmission (all $P < .05$).
Conclusion: From 2016 to 2018, the use of CST increased 67.5% nationwide without an increase in readmissions. As we look toward clinical targets to reduce risk of readmission, modifiable health conditions, such as smoking, morbid obesity, and diabetes should be targeted during the prehabilitation process.

Introduction

Incisional hernia repair (IHR) is 1 of the 5 most common operations performed by General Surgeons.[1] Of the approximately 2 million laparotomies performed in the United States, nearly one third of these incisions will subsequently develop a hernia in long-term follow-up.[2,3] Incisional hernias include a markedly heterogeneous group of abdominal wall defects. They may range from just a few centimeters in width to a massive opening with associated loss of domain that requires a complex abdominal wall reconstruction (AWR). AWR is a challenging field of surgery, as patients often present with high rates of co-morbidities, have often had multiple prior abdominal operations, and frequently require adjunctive techniques involving placement of mesh, complex skin/soft tissue management, and muscle flaps to effect repair.[4–6] The combination of these factors result in high rates of postoperative complications, especially wound complications, that increase the risk of hernia recurrence and need for subsequent re-operation.[7]

One of the main goals of AWR is to provide a primary musculofascial closure, which significantly improves the chances of

* Reprint requests: B. Todd Heniford, MD, FACS, Gastrointestinal and Minimally Invasive Surgery, Department of Surgery, 1025 Morehead Medical Drive, Suite 300, Charlotte, NC 28204.
E-mail address: todd.heniford@gmail.com (B.T. Heniford);
Twitter: @Theniford

https://doi.org/10.1016/j.surg.2021.09.012
0039-6060/

a durable repair and minimizes postoperative complications.[8,9] However, in patients who have wide hernia defects and those with a significant loss of domain, this is not always possible. In these scenarios, surgeons rely primarily on the use of component separation techniques (CST) to create myofascial advancement flaps to achieve fascial closure.[9] CST typically refers to either a rectus abdominus/external oblique release ("anterior CST") or transversus abdominis release ("posterior CST").[10,11] Both techniques provide a myofascial release of the lateral abdominal wall muscles that can lead to an additional 10 to 12 cm of fascial medialization.[9,12,13] Importantly, the use of CST minimizes the need for "bridging" mesh in which mesh is secured to the fascia, but the fascia itself is not directly reapproximated.[14] Bridging mesh is associated with double the overall complication rate and a significant increase in the long-term hernia recurrence rate.[8,9,15–17]

Although CST has become one of the most important advances in AWR, it comes with known risks. Notably, CST is generally associated with increased wound morbidity, which is particularly apparent in cases where large subcutaneous flaps are developed during anterior CST.[9,18] Laceration of one of the lateral abdominal wall muscles can also significantly weaken these muscles and result in a "rounded" abdominal wall or a frank lateral herniation.[19] An additional consideration is that CST can affect the re-operative approach to herniorrhaphy should a recurrence develop.[20] Since the introduction of anterior CST by Ramirez in 1990 and then posterior CST by Novitsky in the mid-2000s, there has been relatively little data examining the frequency of its use as well as any downstream complications related specifically to readmission.[9,21] The aim of this study is to address this gap in the literature by analyzing recent trends in open AWR with and without CST and its impact on readmissions. The authors hypothesize that there has been an increase in the relative amount of CST that is being performed, which will lead to an increase in the rate of short-term readmission.

Methods

Study population

The Nationwide Readmissions Database (NRD) is a national database that is maintained as part of the Healthcare Cost and Utilization Project. The NRD was designed for large-scale readmissions analysis, and it accounts for data from 28 states that represent nearly 60% of the total United States population.[22] Using International Classification of Disease Tenth Revision Procedure Coding System (ICD-10-PCS) codes, patients were retrospectively identified from the NRD who underwent open AWR with and without CST from 2016 to 2018. This time frame was selected to coincide with the 2016 transition from ICD-9 to ICD-10. Previous NRD studies have evaluated patients undergoing AWR using ICD-9 codes, and codes from these studies were converted to ICD-10-PCS codes to help identify the appropriate AWR patients.[23,24] Non-CST patients were identified with the codes 0WQF0ZZ, 0WUF07Z, 0WUF0JZ, and 0WUF0KZ. CST patients were identified with the aforementioned codes plus one or more of the additional codes: 0JR80JZ, 0JR80KZ, 0H87XZZ, 0HX6XZZ, 0KNK0ZZ, and 0KNL0ZZ. The NRD weighting strategy was used to generate national estimates for patients undergoing open AWR.[22] Outpatient surgeries and patients who were placed in observation were excluded from analysis, as were patients undergoing umbilical hernia repair. Patients who died during their initial admission were excluded for the readmission analysis.

Outcomes

There were 2 primary outcomes—the percentage of patients receiving CST over time and the CST 90-day readmission rate over time, which was compared to non-CST patients. These data were from elective operations. To ensure that the readmission comparison was similar between CST and non-CST patients, readmission rates from a propensity-matched subgroup were also examined. The propensity-score match was done in a 1:1 fashion and was performed based on age, gender, morbid obesity, diabetes, chronic lung disease, teaching hospital status, payer type, and income quartile.[23]

The secondary outcomes included the reason for readmission, whether there was a need for reintervention, and the cost associated with readmission. Readmissions were also evaluated specifically for patients with high-risk comorbidities, which included smoking, diabetes, and morbid obesity (body mass index [BMI] $\geq$40 kg/m^2).[25] The reason for readmission and the need for reintervention were identified by using ICD-10 Clinical Modification (ICD-10-CM) and ICD-10-PCS codes. Specifically, the authors evaluated the top 5 ICD-10-CM codes as the reasons for readmission for each patient and the top 10 ICD-10-PCS codes determining the procedures performed once readmitted. If appropriate, diagnoses or procedures were combined if they indicated a similar outcome. In addition, demographics, hospital type and location, payer type, postoperative complications, and outcomes were evaluated. Patient comorbidities were assessed using the Charlson comorbidity Iindex (CCI), which is a weighted scoring system that uses 17 comorbidities to calculate mortality risk.[26] The CCI was determined for each patient using the method of Quan.[27]

Statistical analysis

All statistical analyses were performed by a statistician using Statistical Analysis Software, version 9.4 (SAS Institute, Inc., Cary, NC). Categorical variables were reported as percentages, and continuous variables were reported as means with corresponding standard deviations. A univariate analysis was performed to compare CST readmissions over time, readmissions between CST and non-CST patients, and for the propensity-matched subgroup. A χ^2 or Fisher exact test were used for evaluation of categorical variables, and continuous variables were evaluated with a Kruskal-Wallis or Wilcoxin-Mann-Whitney test when appropriate. Logistic regression was performed to assess factors that were predictive of readmission. Logistic regression was performed using the same confounding variables that were used for the propensity match as well as operation type and length of stay. A P value <.05, which was 2-sided, was used to determine statistical significance.

Results

From 2016 to 2018, there were a total of 94,784 AWR cases identified. The number of cases by year were 34,831 in 2016, 31,085 in 2017, and 28,868 in 2018. There were 5,231 patients who received CST and 89,553 who were repaired without CST. The number and percentage of patients who underwent CST increased annually (Fig 1): 1,403 (4.0%); 1,893 (6.1%); and 1,935 (6.7%) (P < .01). From 2016 to 2018, there was a 67.5% increase in the relative number of CST performed and a 37.9% in the absolute amount of CST performed.

Table I shows the demographic characteristics of the CST patients. Most of the patients included underwent bilateral CST (84.1%) as compared with unilateral CST (15.9%). The mean age of CST patients was 58.9 ± 12.5 years; 11.3% were smokers, 22.0% were

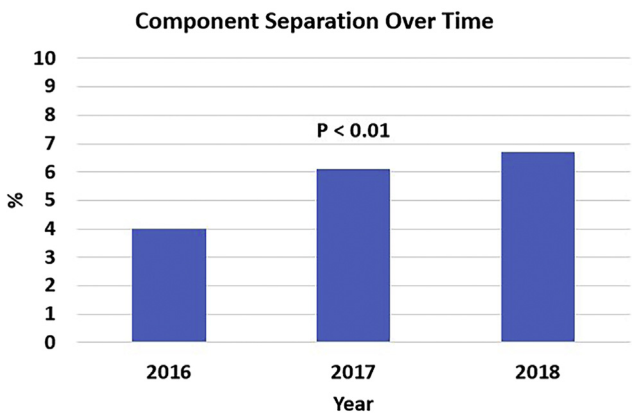

Fig 1. Percentage of AWR patients receiving component separation significantly increased each year over the course of the 3 years included in this study.

diabetic, and 13.3% were morbidly obese. The mean weighted CCI was 1.1 ± 1.7 (range 0–12). Urban-teaching hospitals accounted for 82.3% of CST cases performed, and these academic hospitals saw the largest absolute increase in CST performed over time, with an absolute increase of 47.1% over the 3-year period ($P < .01$). The total amount of CST performed at urban non-teaching hospitals decreased by 10.3% ($P < .01$). Patients at urban-teaching hospitals had higher mean CCIs compared with those at urban non-teaching and rural hospitals (1.6 ± 2.2 vs 1.2 ± 1.8 vs 1.1 ± 1.7; $P < .01$). For all CST patients, the mean length of stay (LOS) was 6.3 ± 8.8 days and in-hospital mortalities were low overall (1.0%).

Readmissions

The 90-day readmission rate remained stable over the 3-year period. The overall readmission rate for CST patients was 17.1%, and by year, it was 16.0% in 2016, 18.2% in 2017, and 16.9% in 2018 ($P = .26$). Of the readmitted patients, 15.4% of patients were readmitted to a different hospital. For the CST patients who had 1 (31.2%) or 2 (7.1%) high-risk comorbidities, the readmission rate was 19.2% and 24.6%, respectively. Both of these rates of readmission were significantly higher than the rate of readmission of non-comorbid patients (16.1%). The CST readmission rate was higher for CST patients (Fig 2) than non-CST patients (17.1 vs 15.7 %; $P < .01$). Notably, patients who underwent repair with biologic mesh had a higher rate of readmission than those who underwent repair with synthetic mesh (25.8% vs 16.1%, $P < .01$). In the propensity-matched analysis with 5,142 matched pairs (Table II), the readmission rate was similar between CST and non-CST patients (17.0% vs 16.4%, $P = .41$). Readmission was similar between the 2 groups despite there being a greater number of patients with biologic mesh in the CST matched group (7.6% vs 4.3%, $P < .01$).

The most common reasons for CST readmissions included unspecified postoperative infection (28.3%), abscess of the abdominal wall (7.0%), and wound breakdown (4.6%). Of those patients readmitted, 14.3% required reoperation, and 13.1% required drain placement (9.5% in the abdominal wall, and 2.6% in the peritoneal cavity). There were 3.9% of readmitted patients who required removal of a synthetic mesh following AWR, and of these 46.7% had at least 1 high-risk comorbidity. No patients required biologic mesh removal. A more complete list of diagnoses and procedures for readmission can be found in Table III. The mean charge of the original hospitalization was $96,109 ± $124,655, and the mean charge per readmission was $49,265 ± $62,122 for all patients (Table IV). However, the costs when patients had reoperation

Table I
Demographics and hospital characteristics for component separation patients: Primary hospitalization

	CST patients (N = 5,231)
Age, y	58.9 ± 12.5
Female	56.7%
CCI	1.1 ± 1.7
Diabetes	22.0%
Smoking	11.3%
Morbid obesity	13.3%
Chronic lung disease	21.5%
Chronic kidney disease	7.8%
Mesh type	
Biologic	92.5%
Synthetic	7.5%
Bilateral	84.1%
Unilateral	15.9%
Hospital type	
Urban teaching	82.3%
Urban non-teaching	13.7%
Rural	3.5%
Payer type	
Medicare	44.8%
Medicaid	12.8%
Private insurance	38.2%
Other	4.2%
Income quartile	
1	24.1%
2	26.6%
3	26.8%
4	22.5%
Length of stay, days	6.3 ± 8.8
Mortality	0.8%

CST, component separation techinique; *CCI,* Charlson comorbidity index.

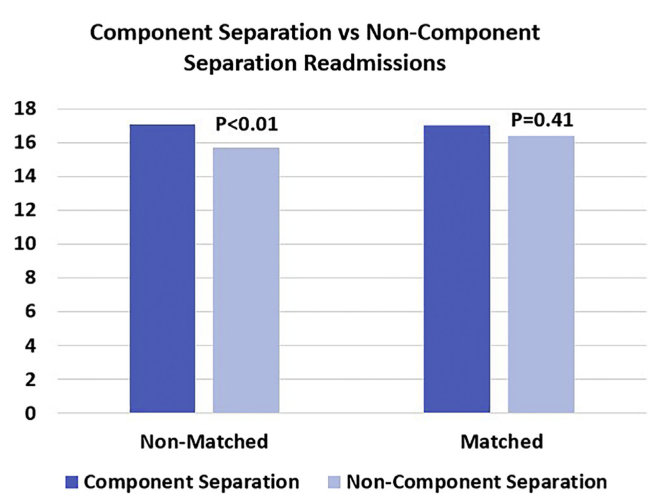

Fig 2. When evaluating the propensity-matched subgroup, 90-day rates of readmission were comparable between the component separation and non-component separation patients (however, in the non-matched group readmissions were higher).

($94,764 ± $179,373) a drain placed ($67,963 ± $113,006) had significantly higher charges associated with readmission ($P < .05$). Patients who were reoperated on and had removal of synthetic mesh had the highest readmission charges ($131,784 ± $112,099).

Logistic regression

The factors that were included in the regression analysis that were not predictive of readmission included age, gender, and income quartile (each $P < .05$) (Table V). However, there were

Table II
Propensity-matched groups for readmissions analysis

	CST patients (N = 5,142)	Non-CST patients (N = 5,142)	*P* value
Age, y	59.0 ± 12.5	59.0 ± 12.89	.98
Female	56.8%	56.8%	.95
Morbid obesity	13.3%	13.1%	.79
Smoking	11.3%	11.1%	.76
Diabetes	22.2%	22.1%	.74
Chronic lung disease	21.3%	21.6%	.71
Biologic mesh	7.6%	4.3%	<.01
Hospital type			0.70
Urban teaching	82.9%	83.0%	
Urban non-teaching	13.7%	13.8%	
Rural	3.5%	3.2%	
Payer type			0.93
Medicare	44.9%	44.8%	
Medicaid	12.8%	12.8%	
Private insurance	38.6%	38.3%	
Other	3.7%	4.1%	
Income quartile			0.97
1	24.0%	24.1%	
2	27.0%	26.6%	
3	26.7%	26.8%	
4	22.3%	22.5%	
Length of stay, days	6.2 ± 7.4	5.9 ± 7.7	0.11
90-day readmissions	17.0%	16.4%	0.41

CST, component separation techinique.

Table III
Common readmission diagnoses and procedures for component separation patients

Diagnoses	Procedures
Unspecified infection following initial encounter (28.3%)	Reoperation (14.3%)
Abscess of abdominal wall (7.0%)	Placement of central line (11.3%)
Wound breakdown (4.6%)	Drain placed in abdominal wall (9.5%)
Acute kidney injury (4.4%)	Blood transfusion (5.8%)
Sepsis (3.9%)	Drainage of stomach (2.9%)
Dehydration (3.9%)	Drain place in peritoneal cavity 2.6%)

several factors that did positively correlate with readmission. The variable that was most strongly predictive of readmission was smoking (OR 1.44; 95% confidence interval [CI] 1.15–1.79). Other variables that were predictive of readmission were morbid obesity (OR 1.30; 95% CI 1.06–1.51), diabetes (OR 1.27; 95% CI 1.07–1.51), chronic lung disease (OR 1.22; 95% CI 1.03–1.45), urban-teaching hospital status (OR 1.38; 95% CI 1.09–1.74), and increased length of stay during the index hospitalization (OR 1.04; 95% CI 1.03–1.05).

Discussion

In complex abdominal wall reconstruction, CSTs are valuable techniques utilized to achieve primary musculofascial closure (often mesh-reinforced). CST has, however, been reported to increase wound morbidity for AWR patients with anterior CST having the highest chance for wound complications.[9,28] These complications can oftentimes lead to readmission, increased costs, and additional operations and procedures.[4] The current study used the NRD to examine operative and readmission trends over a 3-year period (2016–2018). In this study, there was a 67.5% increase in the relative use of CST, but with no increase in 90-day readmissions in a propensity-matched subgroup analysis, refuting our original hypothesis that increased use of CST would be associated with increased readmission rates. Rather, increased readmission rates were statistically significantly associated with smoking, morbid obesity, diabetes, chronic lung disease, urban-teaching hospital status, and increased length of stay. These data support that patient health conditions are the primary drivers for complications and readmissions in complex AWR rather than surgical technique.[28]

This is likely a result of improved perforator-sparing CST techniques (both anterior and posterior), greater knowledge and skill associated with skin/soft tissue management, and possibly due to regionalization of complex AWR, which is supported in this report with the rise in the percentage of CST case numbers in urban teaching hospitals and a decrease at non-teaching hospitals.

A previous study that adds support to these concepts was conducted by Arnold et al. using data from the National Surgical Quality Improvement Database Program (NSQIP).[21] In that study, the volume of CST increased five-fold from 2005 to 2014, and during that time, the number of major complications and wound complications decreased from 25.6% to 12.8% and 18.0% to 10.2%, respectively, suggesting a possible volume-outcome relationship. Arnold's work, along with the current report, supports the concept of regionalization, where complex operations are clustered and performed in high-volume institutions, which may lead to improved outcomes over time.[6,9,24] Supporting this concept, Maloney et al (2019) showed that in a tertiary hernia center CST and non-CST patients, who were matched on body mass index (BMI), hernia defect size, and gender did not display a difference in 30-day readmissions, major postoperative complications, or quality of life.[29] Those findings, again, emphasize that patient complexity (eg, BMI, smoking status, diabetes, etc) has perhaps become the most markedly influential factor(s) in determining outcomes rather than purely the addition of CST. Although wound class was unavailable, it may be inferred that patients with biologic mesh were more likely to have contaminated or dirty wounds. Even despite an increased proportion of biologic mesh in the matched CST group, readmissions were comparable.

Table IV
Readmission charges for component separation patients

Patient type	Charges (US dollars)
All CST patients	\$48,265 ± \$62,122
Patients with excision of mesh	\$131,784 ± \$112,099
Patients requireing reoperation	\$94,764 ± \$179,373
Patients requiring drain placement	\$67,963 ± \$113,006

CST, component separation techinique.

Table V
Logistic regression: Identifying factors predictive of readmissions

Category	95% Confidence interval (CI)	P value
Age group, years*		
2 vs 1	0.65–1.19	.26
3 vs 1	0.59–1.04	.92
4 vs 1	0.54–1.00	.37
5 vs 1	0.55–1.09	.88
6 vs 1	0.36–1.02	.17
Female sex	0.96–1.28	.13
Morbid obesity	1.03–1.31	**.01**
Diabetes	1.07–1.51	**<.01**
Chronic lung disease	1.03–1.45	**.02**
Hospital type		
Urban teaching vs urban non-teaching	1.07–1.71	**<.01**
Rural vs urban non- teaching	0.78–1.93	.78
Income quartile		
2 vs 1	0.81–1.24	.55
3 vs 1	0.80–1.21	.90
4 vs 1	0.77–1.21	.74
Payer type		
Medicare vs Medicaid	0.77–1.25	.55
Private vs Medicaid	0.55–0.82	.06
Other vs Medicaid	0.52–2.01	.74
Smoking	1.15–1.79	**.01**
Length of stay	1.03–1.05	**<.01**

* Age group 1: ≤40 years; group 2: 41–50 years; group 3: 51–60 years; group 4: 61–70 years; group 5: 71–80 years; group 6: ≥80 years.

A benefit of using the NRD to compare CST and non-CST patients is that the NRD utilizes data from multiple centers in many states and allows researchers to eliminate patients who undergo outpatient surgeries or were only kept for overnight observation and, therefore, allows exclusion of patients who have smaller and simpler hernias that would be less apt for comparison, which is what was done in the current study. An earlier and somewhat contrary report was authored by Feimester et al (2020), who were the first to compare the readmission rates between CST and non-CST patients using the NRD (2013–2014).[23] That study compared CST and non-CST patients and concluded that CST patients were more prone to readmission when compared with their non-CST counterparts (OR 1.35; 95% CI 1.22–1.60). However, in that study, the authors chose to include umbilical hernias, which would markedly alter the comparison between CST and non-CST patients. The factors in that paper that were predictive of readmission included payer status, hospital teaching status, and income quartile and were used in the present study to perform the propensity-match to compare CST and non-CST patient readmissions.

The improvement in wound morbidity despite increasing use of CST has certainly been grounded in improved techniques whereby blood flow to the skin is preserved. With the increasing utilization of both the minimally invasive anterior components separation as well as the posterior CST, there are fewer wound complications, which impacts readmission rates.[9] For example, the perforator sparing anterior CST, which was first described by Butler et al (2011), spares the deep inferior epigastric subcutaneous perforators during the subcutaneous dissection.[30,31] Recently, a large study with prospectively gathered data demonstrated equal complication rates when a perforator sparing anterior CST was compared with posterior CST using matched patients.[31] Endoscopic anterior CST is another novel technique, though not necessarily captured by this data set, that has been associated with decreased wound complications and length of stay.[32]

As expected, readmissions were due predominantly to infectious causes, and approximately 15% readmitted patients required reoperation.[23,24,33] When reoperation was required, it doubled the charges associated with readmission and when excision of mesh was required, this figure nearly tripled, suggesting longer hospital stays and more complicated postoperative courses. The findings in this study support those by Plymale et al (2020) who demonstrate double the hospital cost for patients requiring an operation for mesh removal.[34] However, the costs associated with complications for AWR patients reach far beyond the cost of hospitalization. Augenstein et al (2015) showed that the mean follow-up cost associated with a wound infection or mesh infection were approximately \$20,000 and \$60,000, respectively.[35] The incidence of complications and hernia recurrence subsequently increase with each failed hernia repair, the so-called "vicious cycle" of hernia surgery as described by Holihan et al (2015) that can lead to downstream costs that are significantly greater than that captured in this data set.[7] Ensuring that the index AWR operation is performed well and that patients are healthy and optimized for their procedure can reduce some of these deleterious financial effects.

Factors that were predictive of 90-day readmission included ones that are modifiable and targeted in the prehabilitation process of AWR patients. For instance, smoking, morbid obesity, and diabetes increased the risk of readmissions for CST patients. These are the same pre-operative risk factors described in the CeDAR app published several years ago, which demonstrates on demand the extent to which wound complications can be reduced in individual patients with smoking cessation 4 weeks before surgery, weight loss, and with a hemoglobin A1c <7.2.[35,36] Others have emphasized the same.[28,37,38] When these complications do occur, they can predispose patients to markedly poor outcomes, such as reoperation, mesh infection (3.9% required mesh excision in this study, half of which had a high-risk comorbidity), hernia recurrence, which all come with a significant financial cost.[35,36,39] Despite the overwhelming evidence in the literature that supports preoperative optimization, recent data from the Michigan Surgical Quality Collaborative suggests that optimization is not uniformly practiced by surgeons, and there is still significant room for improvement.[25] In that study, up to 50% of patients at some hospitals underwent hernia repair with at least 1 high-risk comorbidity (eg, smoking, obesity).

Patients who underwent CST at urban-teaching hospitals were more likely to be readmitted than those at urban non-teaching hospitals or rural hospitals. However, the mean CCI score at urban-teaching hospitals was higher in comparison to urban non-teaching hospitals and rural hospitals. CCI alone is designed to predict mortality and does not reveal any details regarding the complexity of the hernias or the repairs performed. Other variables, such as hernia size and loss of domain, are known to influence postoperative outcomes, but are unknown in this study.[40] Another factor to consider is trainee involvement the patient's operation; however, there are data to suggest that resident participation has little impact on morbidity for patients undergoing AWR.[41] A distinction should be made between urban-teaching hospital and high-volume center; just because a hospital is a teaching hospital does not necessarily mean that is high-volume for complex AWR. Studies of patients undergoing hernia repair at high-volume centers have generally displayed better outcomes despite having a more complex patient population.[24,42,43]

This study is not without limitations. The study is limited inherently by the use of a large national database to assess CST operative volume and readmissions. It did not allow the authors to evaluate the relative differences between specific CST technique utilized, wound classifications, previous abdominal surgeries, type of mesh, or location of mesh placement. Even with these limitations, the aims of the study were achieved and both operative volume and readmissions over time were adequately determined. Future direction of study should seek to compare outcomes and readmissions with patients undergoing various CST techniques. Most importantly, however, greater efforts should be directed towards resource utilization to ensure that surgeons, primary care physicians, and other stakeholders are incentivized to optimize patients preoperatively.

In conclusion, over a recent 3-year period, there was a relative and absolute increase in the amount of CST that was performed nationwide. Even with an increase in the amount of CST performed, there was no change in the rate of 90-day readmissions. The rate of CST readmissions were comparable to those of non-CST patients in a propensity-matched analysis that accounted for demographic variables and comorbidities that can influence patient outcomes.[23] The results of this study suggest that patient factors and health conditions are a primary driver of outcomes in complex AWR, which are infrequently addressed by surgeons.[25] Modifiable risk factors, such as smoking, diabetes, and obesity, were strongly predictive of CST readmission and should be appropriately optimized in patients prior to AWR.

Funding/Support

This work did not receive any outside funding or financial support and was funded solely by Carolinas Laparoscopic and Advanced Surgical Program and Atrium Health.

Conflict of interest/Disclosures

Drs. Ayuso, Colavita, Aladegbami, and Ms. Nayak have nothing to disclose. Dr. Augenstein receives honoraria for speaking from Medtronic, Allergan, Intuitive, Acelity, and W.L. Gore. Dr. Janis receives royalties from Thieme and Springer Publishing. Dr. Fischer is a consultant for Bard, Integra, and W.L. Gore. Dr. Heniford receives surgical research/education grants as well as honoraria for speaking from Allergan and W.L. Gore.

References

1. Decker MR, Dodgion CM, Kwok AC, et al. Specialization and the current practices of general surgeons. *J Am Coll Surg*. 2014;218:8–15.
2. Carney MJ, Weissler JM, Fox JP, Tecce MG, Hsu JY, Fischer JP. Trends in open abdominal surgery in the United States—Observations from 9,950,759 discharges using the 2009–2013 National Inpatient Sample (NIS) datasets. *Am J Surg*. 2017;214:287–292.
3. Fink C, Baumann P, Wente MN, et al. Incisional hernia rate 3 years after midline laparotomy. *Br J Surg*. 2014;101:51–54.
4. Khansa I, Janis JE. The 4 principles of complex abdominal wall reconstruction. *Plast Reconstr Surg Glob Open*. 2019;7:e2549.
5. Khansa I, Janis JE. Complex open abdominal wall reconstruction: management of the skin and subcutaneous tissue. *Plast Reconstr Surg*. 2018;142:125S–132S.
6. Janis JE, Khansa I. Evidence-based abdominal wall reconstruction: the maxi-mini approach. *Plast Reconstr Surg*. 2015;136:1312–1323.
7. Holihan JL, Alawadi Z, Martindale RG, et al. Adverse events after ventral hernia repair: the vicious cycle of complications. *J Am Coll Surg*. 2015;221:478–485.
8. Booth JH, Garvey PB, Baumann DP, et al. Primary fascial closure with mesh reinforcement is superior to bridged mesh repair for abdominal wall reconstruction. *J Am Coll Surg*. 2013;217:999–1009.
9. Maloney SR, Schlosser KA, Prasad T, et al. Twelve years of component separation technique in abdominal wall reconstruction. *Surgery*. 2019;166:435–444.
10. Ramirez OM, Ruas E, Dellon AL. “Components separation” method for closure of abdominal-wall defects: an anatomic and clinical study. *Plast Reconstr Surg*. 1990;86:519–526.
11. Novitsky YW, Elliott HL, Orenstein SB, Rosen MJ. Transversus abdominis muscle release: a novel approach to posterior component separation during complex abdominal wall reconstruction. *Am J Surg*. 2012;204:709–716.
12. Majumder A, Miller HJ, del Campo LM, Soltanian H, Novitsky YW. Assessment of myofascial medialization following posterior component separation via transversus abdominis muscle release in a cadaveric model. *Hernia*. 2018;22:637–644.
13. Majumder A, Martin-del-Campo LA, Miller HJ, Podolsky D, Soltanian H, Novitsky YW. Evaluation of anterior versus posterior component separation for hernia repair in a cadaveric model. *Surg Endosc*. 2020;34:2682–2689.
14. Giordano S, Garvey PB, Baumann DP, Liu J, Butler CE. Primary fascial closure with biologic mesh reinforcement results in lesser complication and recurrence rates than bridged biologic mesh repair for abdominal wall reconstruction: a propensity score analysis. *Surgery*. 2017;161:499–508.
15. De Vries FEE, Hodgkinson JD, Claessen JJM, et al. Long-term outcomes after contaminated complex abdominal wall reconstruction. *Hernia*. 2020;24:459–468.
16. Sosin M, Nahabedian MY, Bhanot P. The perfect plane: a systematic review of mesh location and outcomes, update 2018. *Plast Reconstr Surg*. 2018;142:107S–116S.
17. Holihan JL, Nguyen DH, Nguyen MT, Mo J, Kao LS, Liang MK. Mesh location in open ventral hernia repair: a systematic review and network meta-analysis. *World J Surg*. 2016;40:89–99.
18. Novitsky YW, Fayezizadeh M, Majumder A, Neupane R, Elliott HL, Orenstein SB. Outcomes of posterior component separation with transversus abdominis muscle release and synthetic mesh sublay reinforcement. *Ann Surg*. 2016;264:226–232.
19. Deerenberg EB, Shao JM, Elhage SA, et al. Preoperative botulinum toxin A injection in complex abdominal wall reconstruction– a propensity-scored matched study. *Am J Surg*. 2021;222:638–642.
20. Pauli EM, Wang J, Petro CC, Juza RM, Novitsky YW, Rosen MJ. Posterior component separation with transversus abdominis release successfully addresses recurrent ventral hernias following anterior component separation. *Hernia*. 2015;19:285–291.
21. Arnold MR, Otero J, Schlosser KA, et al. *A decade of components separation technique: an increasing trend in open ventral hernia repair*. Academic Surgical Congress; 2018, 70.10.
22. Agency for Healthcare Research and Quality (AHRQ). Healthcare Cost and Utilization Project. NRD Overview. https://www.hcup-us.ahrq.gov/nrdoverview.jsp. Accessed June 14, 2021.
23. Feimster JW, Ganai S, Scaife S, Mellinger JD. Determinants of 90-day readmission following ventral hernia repair with and without myocutaneous flap reconstruction: a National Readmissions Database analysis. *Surg Endosc*. 2020;34:4662–4668.
24. Rios-Diaz AJ, Cunning JR, Broach RB, et al. One-year health care utilization and recurrence after incisional hernia repair in the United States: a population-based study using the Nationwide Readmission Database. *J Surg Res*. 2020;255:267–276.
25. Howard R, Delaney L, Kilbourne AM, et al. Development and Implementation of preoperative optimization for high-risk patients with abdominal wall hernia. *JAMA Netw Open*. 2021;4:e216836.
26. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic in longitudinal studies : development and validation. *J Chronic Dis*. 1987;40:373–383.
27. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005;43:1130–1139.
28. Maloney SR, Schlosser KA, Prasad T, et al. The impact of component separation technique versus no component separation technique on complications and quality of life in the repair of large ventral hernias. *Surg Endosc*. 2020;34:981–987.
29. Shulkin JM, Mellia JA, Patel V, et al. Characterizing hernia centers in the United States: what defines a hernia center? [epub ahead of print] *Hernia*. 2021 April 19. Available from: https://doi.org/10.1007/s10029-021-02411-x, accessed June 1, 2021.
30. Butler CE, Campbell KT. Minimally invasive component separation with inlay bioprosthetic mesh (MICSIB) for complex abdominal wall reconstruction. *Plast Reconstr Surg*. 2011;128:698–709.
31. Ghali S, Turza KC, Baumann DP, Butler CE. Minimally invasive component separation results in fewer wound-healing complications than open component separation for large ventral hernia repairs. *J Am Coll Surg*. 2012;214:981–989.
32. Elhage SA, Marturano MN, Prasad T, et al. Impact of perforator sparing on anterior component separation outcomes in open abdominal wall reconstruction. *Surg Endosc*. 2021;35:4624–4631.
33. Jensen KK, Henriksen NA, Jorgensen LN. Endoscopic component separation for ventral hernia causes fewer wound complications compared to open components separation: a systematic review and meta-analysis. *Surg Endosc*. 2014;28:3046–3052.

34. Celio AC, Kasten KR, Pofahl WE, Pories WJ, Spaniolas K. Causes of readmission after laparoscopic and open ventral hernia repair: identifying failed discharges and opportunities for action. *Surgery*. 2016;160:413–417.
35. Plymale MA, Davenport DL, Walsh-Blackmore S, et al. Costs and complications associated with infected mesh for ventral hernia repair. *Surg Infect (Larchmt)*. 2020;21:343–348.
36. Augenstein VA, Colavita PD, Wormer BA, et al. CeDAR: Carolinas Equation for Determining Associated Risks. *J Am Coll Surg*. 2015;221:S65–S66.
37. Heniford BT, Ross SW, Wormer BA, et al. Preperitoneal ventral hernia repair: a decade long prospective observational study with analysis of 1023 patient outcomes. *Ann Surg*. 2020;271:364–374.
38. Cox TC, Blair LJ, Huntington CR, et al. The cost of preventable comorbidities on wound complications in open ventral hernia repair. *J Surg Res*. 2016;206:214–222.
39. Liang MK, Bernardi K, Holihan JL, et al. Modifying risks in ventral hernia patients with prehabilitation: a randomized controlled trial. *Ann Surg*. 2018;268:674–680.
40. Bueno-Lledó J, Torregrosa-Gallud A, Sala-Hernandez A, et al. Predictors of mesh infection and explantation after abdominal wall hernia repair. *Am J Surg*. 2017;213:50–57.
41. Schlosser KA, Maloney SR, Prasad T, Colavita PD, Augenstein VA, Heniford BT. Three-dimensional hernia analysis: the impact of size on surgical outcomes. *Surg Endosc*. 2020;34:1795–1801.
42. Schrand KV, Hussain LR, Dunki-Jacobs EM, Grannan KJ. Outcomes associated with resident involvement in ventral hernia repair: a population based study using the NSQIP database. *Am J Surg*. 2018;216:923–925.
43. Chattha A, Muste J, Patel A. The impact of hospital volume on clinical and economic outcomes in ventral hernia repair: an analysis with national policy implications. *Hernia*. 2018;22:793–799.

Discussion

Dr. Daniel S. Eiferman (Ohio State University): You used the readmission database to see if the CST technique resulted in an increased readmission rate. We can certainly conclude from your paper that the number of component separation techniques is on the rise. We've shown that the known risk factors of smoking, obesity, and diabetes are still rearing their ugly head, and that prehabilitation is important. Let me ask you a couple questions. First of all, whenever we talk about readmission rates, we need to discuss length of stay as well, because those two outcomes seem to be inversely related to each other.

My other two questions: was there a difference between anterior components, which has been around since 1990, and the newer technique of TAR, that became popular in the 2000s? Were you able to look at type of mesh? You talked about mesh explantation. Was there a difference in readmissions between using a synthetic, a hybrid, a biologic mesh?

Dr. Ayuso: Thank you so much, Dr. Eiferman. And very good questions.

I'll start with length of stay. When we looked at length of stay and compared between components separation and non-component separation patients, we found about a half day longer length of stay for the more complex operations. This was true in the propensity matched subanalysis and then overall with the univariate comparison. Our initial idea for the project was to compare TAR and retrorectus repair to make a comparison that was most similar. Unfortunately, the main limitation of this study is that we're using ICD-10 CM and PTS codes to classify the procedures, so we were unable to look at anterior versus posterior components separation specifically. With that said, we know from our own data and from other published data that, given the development of these large subcutaneous flaps with anterior component separation, there is generally a higher rate of complication and readmission. That's definitely true with our data. Mesh type is unfortunately not available.

One thing that was very relevant for us is this continued issue of prehabilitation. I think we all know that these things are important when we see patients in clinic. There is a very good paper that was published by Dan Tollen's group recently in *JAMA* that showed that upwards of 50 percent of patients at some hospitals were still not receiving that rehabilitation counseling at the time of operation. I think part of our paper is just to continue to reinforce that point, that especially in a complex patient population, that it is even more important and can have a very real impact on outcomes. A lot of our work in the next year will be focusing specifically on how we can better locally and then internationally with prehabilitation as well. (Applause)