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Twelve years of component separation technique in abdominal wall reconstruction

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ABSTRACT

Background: Component separation technique involves incision of abdominal muscle and its aponeurosis, which generates a myofascial advancement flap to assist with fascial closure in abdominal wall reconstructions. This tissue mobilization allows for musculo-fascial approximation of much larger abdominal wall defects than would otherwise be possible. With extensive tissue mobilization, however, there is concern for significant wound and systemic complications.

Methods: A prospective, single institution hernia database was queried for patients undergoing component separation from January 2006 to May 2018. Emergency operations were excluded. Anterior component separation (external oblique release with posterior rectus sheath release) and posterior component separation (transversus abdominus release and posterior rectus sheath release) were examined.

Results: Of the 775 component separation, 33.4% included anterior component separation and 66.6% posterior component separation. Mean age was 58.8 ± 11.5 years, mean body mass index was 33.6 ± 7.1 (kg/m^2), and 27.9% of patients were diabetic. Hernias were large (280.0 ± 220.9 cm^2) and often complex (recurrent: 62.6%, incarcerated: 41.5%, concomitant panniculectomy: 39.1%, and contaminated: 37.0%). Defect size was larger in anterior component separation group compared with posterior component separation (379.5 ± 265.2 vs 230.0 ± 175.0 cm^2, $P < .001$). There was a 35.1% wound complication rate with 32 recurrences (4.1%) during a mean follow-up of 23.3 ± 25.1 months. Complete fascial closure and lack of wound complications significantly improved outcomes ($P < .01$). Patients undergoing anterior component separation demonstrated more wound complications (42.9% vs 31.2%, $P < .001$) and recurrences (7.0% vs 2.7%, $P = .005$). In multivariate analysis, anterior component separation was associated with increased risk of wound complications (odds ratio 1.660; confidence interval, 1.125–2.450), but not recurrence (odds ratio 2.95; confidence interval, 0.72–12.19). Since 2013, prehabilitation and perforator sparing techniques reduced anterior component separation wound complications to 19.6% ($P = .008$).

Conclusion: Both anterior component separation and posterior component separation are associated with low recurrence rates, but anterior component separation is associated with higher wound complications. Prehabilitation and operative techniques improve outcomes of component separation.

Introduction

With >350,000 procedures per year, ventral hernia repair (VHR) remains one of the most common surgical procedures performed annually in the United States.[1] Facial reapproximation with mesh, as compared to bridging mesh repairs, has been shown to significantly reduce hernia recurrence and mesh infection rates[2] while simultaneously creating a more functional abdominal wall.[3–10] In large defects, component separation techniques (CSTs) can be utilized to release and medialize the fascia and achieve midline

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reapproximation. The first attempt to gain abdominal wall laxity was described by Gibson in 1920 when he performed relaxing incisions of the lateral anterior rectus sheath.[11] The first operation that mimicked what we now consider a CST was performed in Argentina by Albanese in 1951 when he incised the external oblique to help repair a large eventration.[12] This surgery was somewhat repeated by Young when he described tension relieving fascial incisions where he separated the anterior and posterior rectus sheath and then incised the lateral border of the anterior rectus fascia to repair epigastric hernias.[13] The term CST was coined and the techniques truly popularized by Ramirez et al with the report of the external oblique release (EOR) in 1990.[14,15] It allowed for expanded primary myofascial closure of the abdomen to decrease the need for transposition of remote myocutaneous flaps or free-tissue transfers.[14] Given the sundry and varied approaches to incise musculofascial layers of the abdominal wall to effect primary midline closure, Ramirez's description of combining a vertical incision of the external oblique aponeurosis along with the posterior rectus sheath (PRSR) is often now termed an anterior (A)CST.

Although very useful in providing the end result of a functional abdominal wall that appears cosmetically normal in the short term, an ACST was found to still require mesh reinforcement for more optimal long-term, recurrence-free outcomes.[16] In addition, access to the external oblique aponeurosis typically required significant undermining of skin and subcutaneous tissue. The development of these large subcutaneous flaps markedly increased wound related complications in ACST, which can reach >60%.[16] In response to this inherent problem, numerous variations of CSTs have been described, including epigastric-perforator vessel sparing ACST,[17] endoscopic ACST,[18] and various posterior (P)CSTs, including the rectus sheath release (PRSR) alone or in combination with the transversus abdominis release (TAR).[19] As well, the use of botulinum toxin injection into the oblique muscles has become a more accepted technique to perform a temporary components relaxation.[20] Given the known complications with ACST, these techniques were created in order to limit the skin flap dissection, allow for use with minimally invasive techniques, eliminate the need for CST altogether, and provide either a retrorectus or preperitoneal position for mesh placement. With the variability in the application of CSTs, including the use of mesh reinforcement, location, fixation, choice of mesh, wound management, postoperative quality of life, and many others, CST is a subject of ongoing research.

The purpose of this study was to examine outcomes of abdominal wall reconstructions (AWR) performed with component separation at a tertiary hernia referral center. The applicability of technique to defect size, previous hernia repair, level of wound contamination, associated mesh selection, and their impact on the long-term outcomes of complication and recurrence were studied and are reported herein.

Methods

Study population

All CST were performed at the Carolinas Medical Center in Charlotte, North Carolina. The majority of the patients were referred from other centers, frequently with recurrent hernias and added complexity related to patient co-morbidities. All open CST performed at the institution were studied, including incisional, ventral, flank, and lumbar hernias.

Surgical technique: anterior component separation

EOR involved incising the external oblique aponeurosis approximately 2 cm lateral from the border of the rectus sheath. The external oblique muscle was then separated from the underlying internal oblique from the costal margin to as far as the inguinal ligament as was needed according to surgeon judgement. It was extended above the costal margin for hernias involving the subxiphoid region. The ACST usually involved a panniculectomy or development of large subcutaneous flaps until 2015 when a perforator vessel-sparing technique was adopted as often as could be applied. The ACST included a PRSR in most cases. In this series, the authors nearly always performed a preperitoneal dissection in conjunction with the ACST to allow for the placement of an extremely large mesh. In most cases the mesh extended laterally beyond the area of the external oblique release.

Surgical technique: posterior component separation

PRSR involved incising the PRS the entire length of the hernia. It was typically performed 1 cm from the linea alba. The fascia was released from the undersurface of the rectus muscle. This usually allowed the anterior sheath to mobilize medially about 2 to 3 cm per side without transecting muscles or raising skin flaps. This technique was also used as part of the transversus abdominis release or a simple release by itself during a preperitoneal hernia repair.[21]

A TAR[19] was initiated by first performing a PRSR, dissecting the posterior rectus sheath to the perforating neuro-vascular bundles feeding the underside of the rectus muscle, and then then making a longitudinal incision into the posterior lamella of the internal oblique. Typically, the transversalis muscle and fascia are transected to enter into the preperitoneal space. This dissection is continued for the length of the hernia and most often included dissection into the space of Retzius and taking down the falciform. Overall this technique allowed for additional medialization of the anterior fascia in comparison to PRSR and generated a large preperitoneal pocket for mesh placement with extensive overlap.

Prehabilitation and wound management

During the study period, significant changes in preoperative standards were instituted. For example active smokers, patients with a HgbA1C of >7.2, and patients with a BMI $\geq$30 were counseled to modify their risk factors prior to surgery.[22,23] Indeed, perioperative data from open ventral hernia repairs performed by the authors was gathered to build the CeDAR app, which has been used to predict postoperative complications and set the standard for patient prehabilitation. Patients with contaminated wounds also were often managed with a technique of VAC-assisted delayed primary closure, as we have previously described,[24] which has reduced wound complication rates in these patients.

Study design

After Institutional Review Board approval, an institution-specific, prospectively maintained, hernia-specific database was queried for all CST between January 2006 and May 2018. Emergency operations were excluded. Data was collected on a prospective basis by dedicated trained abstractors independent from clinical duties and without surgeon review to prevent the introduction of bias. Demographics, operative details, and postoperative information are obtained for each case. Mesh type was categorized into biologic, absorbable synthetic, or permanent synthetic material. CST was divided into anterior and posterior approaches. Anterior approaches were EOR combined with the PRSP (described as ACST throughout the article), whereas PCST included TAR and PRSR. Patients who received more than one type of CST were categorized by the most invasive technique utilized (ie, a patient who underwent a right sided EOR and a left sided TAR was classified as EOR). Hernia grade was based on the definitions set forth by the Ventral Hernia Working Group.[25] The primary outcome of interest was hernia recurrence. The standard for follow-up after a repair is at 2 and 6 weeks, 3 months, 1 year, and then yearly. In addition, patients are consented preoperatively for follow-up phone interviews and mailings for QOL and recurrence data. Patient follow-up is also facilitated by examination from their personal physician and abdominal radiographs. Secondary outcomes included wound complications, mesh infections or other mesh-related complications, duration of stay, readmission (30-day), charges, and mortality. Wound complications were defined as seroma requiring intervention, cellulitis requiring antibiotics, wound breakdown (superficial), wound infection requiring antibiotics, fascial dehiscence, and fistula. Patients that developed multiple wound complications such as a wound infection and fascial dehiscence are counted as one total wound complication.

Statistical analysis

Descriptive statistics are reported as means with corresponding standard deviations for continuous variables and percentages for categorical variables. Additional analyses were performed to examine the rates and factors associated with the incidence of wound complications and hernia recurrences. Categorical variables were evaluated using Pearson χ^2 and Fisher exact test, where appropriate. Continuous and ordinal variables were evaluated using Wilcoxon Mann-Whitney and the Kruskal-Wallis tests. Odds-ratios with corresponding 95% confidence intervals are used to report the results of the logistic regression and Cox proportional hazards regression models. All reported *P* values are 2-tailed. All data were analyzed using Statistical Analysis Software (version 9.4, SAS Institute, Inc., Cary, NC).

Multivariate analysis was performed to evaluate independent association of variables with wound complications and hernia recurrence. The following variables were included in the analysis: BMI, defect size, diabetes, smoking history, synthetic mesh versus biologic mesh, level of contamination, bilateral versus unilateral CST, and fascial closure.

Optimized patient subset analysis

Patient optimization for surgery is often required before complex hernia repair, especially those that are expected to involve CST. Therefore, a subset analysis was performed to examine outcomes for patients that were optimized from a smoking, obesity, diabetes, wound class, and mesh choice standpoint. In this subset, we excluded patients with modifiable characteristics including lightweight mesh (previously found to have higher recurrence rate with similar quality of life),[26] omega-3 fatty acid coated mesh (associated with a higher mesh complication rate),[21] biologic mesh, contaminated cases, bridging, diabetes, smoking, and BMI >35 kg/m^2. Complications such as mesh infection, wound complication, and recurrence were then re-examined in this optimized population.

Results

During the study period there were a total of 775 component separation techniques performed, 259 (33.4%) ACST and 516 (66.6%) PCST. Average age was 58.8 ± 11.5 years with 53.8% of patients being female. The mean BMI was 33.6 ± 7.1. Comorbidities were present in 99.3% of patients with the average number of comorbidities being 4.8 ± 2.5 and 2.4 ± 2.0 previous hernia repairs. Comorbidities included diabetes (27.9%), smoking (17.0%), pulmonary disease (19.0%), history of stroke (4.6%), obstructive sleep apnea (14.7%), and coronary artery disease (11.7%), among others. Nearly 7% took anticoagulants and 60% were classified as American Society of Anesthesiologists score III or IV (Table I).

Table I
Patient characteristics of population undergoing OVHR with CST

	n = 775 (%)
Age (y)	58.8 ± 11.5
Female	417 (53.8)
BMI (kg/m^2)	33.6 ± 7.1
Race	
White	638 (84.8)
Black	54 (7.2)
Other	60 (8.0)
Mean number of comorbidities	4.8 ± 2.5
Mean previous hernia repairs	2.4 ± 2.0
Comorbidity	
Asthma	97 (12.8)
Cirrhosis	19 (2.5)
Congestive heart failure	6 (0.8)
COPD	47 (6.2)
Coronary artery disease	89 (11.7)
Current steroid use	44 (5.8)
Current anticoagulant use	51 (6.7)
Diabetes	214 (27.9)
End stage renal disease	14 (2.0)
History of cancer	175 (23.0)
Hypertension	447 (58.5)
Obstructive sleep apnea	112 (14.7)
Peripheral vascular disease	18 (1.3)
History of smoking	131 (17.0)
Stroke history	35 (4.6)
ASA score	
I	4 (0.5)
II	294 (39.4)
III	420 (56.3)
IV	28 (3.8)
V	0

ASA, American Society of Anesthesiologists score; *COPD*, chronic obstructive pulmonary disease.

Of the 775 repairs, 485 were performed in recurrent ventral hernias (62.6%; Table II) with one patient having had 21 previous repairs. The majority of the cases were ventral (96.6%) and were hernia grade 2 (46.3%) based on the Ventral Hernia Working Group grading system.[25] The mean defect area was 280.0 ± 220.9 cm^2. Of the 98.1% of cases receiving mesh, 541 cases received a synthetic mesh (74.1%) with a large mean mesh size of 905.0 ± 394.6 cm^2. Most AWRs required a bilateral CST (81.4%). Concomitant panniculectomy was performed in 303 (39.1%) of cases. Overall hernia recurrence rate for the study population is 4.1% with a mean follow-up of 23.3 ± 25.1 months and average time to recurrence was 23.0 ± 14.7 months (Table III). Wound complications were observed in 272 cases (35.1%), and 14 patients in developed synthetic mesh infections (2.6%). Thirty-day readmission rate was 12.4%.

A primary end point of this study was to examine the differences seen in outcomes after ACST versus PCST. The patient populations receiving these versions of AWR are different (Table IV). The data demonstrated that patients receiving ACST were more likely to have diabetes, a history of smoking, and have had a higher number of previous hernia repairs (all $P < .02$). ACST cases had higher rates of bilateral CST, panniculectomy, a larger defect size, and were more likely to receive a biologic mesh. ACST was associated with longer operative times ($P < .001$). ACST was most often combined with a large preperitoneal dissection and a very large mesh which extended out beyond the cut edges of the external oblique to the pubis and above the xiphoid. ACST was associated with a significantly higher recurrence rate (7.0% vs 2.7%, $P = .005$) and a higher

Table II
Operative characteristics of patients undergoing OVHR with CST

	n = 775 (%)
Recurrent hernia	485 (62.6)
Incarcerated	320 (41.5)
Type of hernia repaired	
Ventral/incisional	656 (96.6)
Lumbar	2 (0.3)
Flank	18 (2.3)
Hernia grade	
1	83 (10.7)
2	359 (46.3)
3	271 (35.0)
4	62 (8.0)
Enterotomy made	28 (3.6)
Bilateral components separation	631 (81.4)
Panniculectomy	303 (39.1)
Average hernia defect size (cm^2)	280.0 ± 220.9
Average mesh size (cm^2)	905.0 ± 394.6
Total operative time (min)	218.6 ± 75.1
Estimated blood loss (mL)	149 ± 122

Table III
Postoperative outcomes of patients undergoing OVHR with CST

	n = 775 (%)
Length of stay (days)	7.8 ± 5.4
In-hospital complications	209 (27.0)
Acute kidney injury	40 (6.8)
Deep vein thrombosis	13 (1.7)
Pneumonia	19 (2.5)
Pulmonary embolism	21 (2.8)
Respiratory failure	21 (2.7)
Wound complications	272 (35.1)
Seroma requiring intervention	103 (13.3)
Superficial wound breakdown	123 (15.9)
Cellulitis	71 (9.4)
Wound infection	102 (13.2)
Intra-abdominal abscess	41 (5.4)
Mesh infection	14 (2.6)
Readmission (30 days)	94 (12.4)
Operative charges (USD)	16,534.3 ± 10,324.8
Total hospital charges (USD)	84,215.1 ± 6,4711.1
Hernia recurrence	32 (4.1)
Average follow-up (mo)	23.3 ± 25.1
Mortality	7 (0.9)

wound complication rate (42.9% vs 31.2%, $P < .001$). Those undergoing an ACST had a 2.1 day longer mean hospital stay than the PCST patients. A multivariate analysis was performed to control for potential confounding factors including BMI, defect size, diabetes, smoking history, synthetic versus biologic mesh, level of contamination (CDC class), and fascial closure. After multivariate analysis controlling for multiple confounding factors, ACST remained independently associated with a higher risk of wound complications (odds ratio [OR] 1.653; 95% confidence interval [CI], 1.118–2.444) but not hernia recurrence (OR 1.662; 95% CI 0.521–5.305). With the strong changes in prehabilitation beginning after development of the CeDAR app, there were significant improvements in wound complications in both the ACST and PCST patients. The difference between ACST and PCST became less significant (29.3% vs 35.5%; $P < .05$). The addition of perforator sparing techniques to prehabilitation[27] in 2015 further reduced the incidence of ACST wound complications significantly to 19.6% ($P = .008$).

There were 32 hernia recurrences (4.1%) in the study population (Table V). Factors associated with recurrence included higher BMI (36.9 ± 12.6 vs 33.5 ± 7.1 kg/m^2), biologic mesh reinforcement (versus permanent synthetic; 7.4% vs 1.9%, $P < .001$), ACST (versus posterior; 7.0% vs 2.7%, $P < .001$), wound complication during the original surgery (8.8% vs 1.6%, $P < .001$), and incidental enterotomy (14.3% vs 3.3%, $P = .017$). Out of 775 repairs, 15 patients did not receive mesh reinforcement (1.9%) and of these 2 had recurrences (13.3%) during 31.7 ± 32.7 months of follow-up. In multivariate analysis, the only variable independently associated with hernia recurrence was the hernia defect size (OR 1.001 per cm^2, 95% CI, 1.000–1.003).

A total of 272 cases resulted in a wound complication (35.1%). Patients with wound complications had higher rates of diabetes and higher BMIs than those without wound complications. They were more likely to have an incidental enterotomy, a wound class of 3 or 4, concomitant panniculectomy, use of biologic mesh, and a larger defect size (Table VI). Factors including Ventral Hernia Working group grade, American Society of Anesthesiologists score, and history of smoking did not have association with wound complications (all P values >.05). Aggressive management of smoking and increasing wound class, which had been associated with wound complications in prior work, with strict smoking cessation for 4 weeks prior to surgery and using VAC-assisted delayed primary closure for the more contaminated cases have improved these factors to the point that they no longer drive higher rates of complications.[22,24] Patients that developed a wound infection had a longer length of stay (8.3 ± 5.7 vs 7.6 ± 5.3 days, $P = .012$). They also were more likely to have a 30-day readmission and a >5 times likelihood of recurrence (8.8% vs 1.6%, $P < .001$). Patients receiving permanent synthetic mesh that developed wound complications were more likely to have a mesh infection as well (8.2% vs 0%, $P < .001$). In multivariate analysis, factors independently associated with wound complication included higher BMI (OR 1.066 per 1 kg/m^2; 95% CI, 1.038–1.094), diabetes (OR 1.623; 95% CI, 1.102–2.391), and ACST (OR 1.653; 95% CI, 1.118–2.444).

The goal of CST is to approximate the fascia in the midline for closure of the hernia defect. Overall 89% of cases had complete fascial closure. Hernia recurrence was significantly higher in the group without full fascial closure (16.1% vs 2.5%, $P < .001$), even when excluding biologic mesh (12.9% vs 1.2%, $P = .001$). When examining wound complications, those with fascial closure had a 16% less chance of developing a wound complication (49.4% vs 33.1%, $P = .003$) and had a synthetic mesh infection rate that was 2.7 times higher (6.5% vs 2.4%, $P = .048$).

Patients that had CST in an ideal situation (BMI <35, not diabetic or HbgA1C of less than 7.2, nonsmoker, the use of a synthetic mesh [without use of lightweight mesh or omega-3 fatty acid coated mesh],[21] primary fascial closure, and a noncontaminated field) were examined. One hundred and sixty-eight operations fell into this ideal category (Table VII). These patients had a high rate of previous hernia repairs (51.8%), high rate of concomitant panniculectomy, and large defects (249.8 ± 168.9 cm^2) with a large mesh used in the repair (880.7 ± 250.9 cm^2). Forty-eight patients received an ACST repair (28.6%). The wound complication rate was 21.4% in this group and there was 1 recurrence (0.6%). There were 4 mesh infections in this group (2.5%). Mean follow-up was 23.1 ± 24.1 months.

Outcomes have been routinely examined temporally to uncover potential improvements within the hernia center. Cases performed by year included 195 from 2006 to 2012, 184 from 2012 to 2013, 203 from 2014 to 2015, and 193 from 2016 to May 2018. Recurrence rate was different between the eras, 2006 to 2012: 5.6%, 2012-2013: 7.1%, 2014 to 2015: 3.5%, and 2016 to 2018: 0.5% ($P = .008$), but when controlling for follow-up length, the trend is no longer significant (OR vs 2006–2012, 2012–2013: OR 1.312, 95% CI 0.551–3.124, 2014–2015: OR 0.914, 95% CI 0.299–2.797, 2016–2018: OR 0.157, 95% CI, 0.018–1.408). There was, however, a significant improvement the rate of wound

Table IV
Anterior versus posterior CST in OVHR

	CST type		
	Anterior n = 259 (%)	Posterior n = 516 (%)	*P* value
Age (y)	59.3 ± 11.1	58.5 ± 11.7	.45
BMI (kg/m^2)	33.2 ± 6.8	33.8 ± 7.2	.33
Comorbidity			
Current steroid use	17 (6.8)	27 (5.3)	.419
Diabetes	87 (34.3)	127 (24.8)	.006
Peripheral vascular disease	7 (2.8)	8 (1.6)	.253
Smoking history	56 (22.1)	75 (14.6)	.009
Prior infection present	39 (15.1)	42 (8.2)	<.001
Recurrent hernia	166 (64.1)	319 (61.8)	.538
Mean previous hernia repairs	2.8 ± 2.5	2.2 ± 1.6	.017
Incarcerated	88 (34.1)	232 (45.1)	.003
Hernia grade			
1	19 (7.3)	64 (12.4)	.089
2	116 (44.8)	243 (47.1)	
3	101 (39.0)	170 (33.0)	
4	23 (8.9)	39 (7.6)	
Enterotomy made	15 (6.1)	13 (2.5)	.016
Bilateral CST	229 (88.4)	402 (77.9)	.001
Panniculectomy	134 (51.7)	169 (32.8)	<.001
Average hernia defect size (cm^2)	379.5 ± 265.2	230.0 ± 175.0	<.001
Average mesh size (cm^2)	954.3 ± 444.5	879.9 ± 364.5	.377
Biologic mesh	85 (32.8)	108 (20.9)	.001
Absorbable synthetic mesh	1 (0.4)	9 (1.8)	<.001
Total operative time (min)	253.5 ± 90.5	201.9 ± 59.8	<.001
Length of stay (days)	9.2 ± 7.1	7.1 ± 4.2	<.001
Readmission (30 days)	32 (13.0)	62 (12.1)	.732
Operative charges (USD)	18,400.3 ± 12,504.7	15,592.2 ± 8,896.4	.036
Total hospital charges (USD)	100,851.4 ± 84,623.0	75,674.3 ± 49,586.5	<.001
Wound complication	111 (42.9)	161 (31.2)	.001
Seroma requiring intervention	34 (13.1)	69 (13.5)	.272
Superficial wound breakdown	60 (23.1)	63 (12.2)	<.001
Cellulitis	28 (10.8)	43 (8.3)	.193
Wound infection	42 (16.2)	60 (11.6)	.572
Hernia recurrence	18 (7.0)	14 (2.7)	.005

Table V
Recurrences after CST in OVHR

	Recurrence		
	No n = 743 (%)	Yes n = 32 (%)	*P* value
Age (y)	59.0 ± 11.4	55.0 ± 12.6	.075
BMI (kg/m^2)	33.5 ± 7.1	36.9 ± 7.0	.005
Comorbidity			
Current steroid use	43 (5.9)	1 (3.2)	.532
Diabetes	204 (27.8)	10 (32.3)	.584
Peripheral vascular disease	15 (2.1)	0 (0)	1
Smoking history	122 (16.5)	9 (30.0)	.054
Prior infection present	74 (10.0)	7 (21.9)	.149
Recurrent hernia	464 (62.5)	21 (65.6)	.716
Mean previous hernia repairs	2.4 ± 1.9	3.2 ± 2.4	.054
Incarcerated	309 (41.8)	11 (34.4)	.407
CDC Class 3 and 4	93 (12.5)	11 (36.7)	<.001
Enterotomy made	24 (3.3)	4 (14.3)	.017
Anterior CST	241 (32.4)	18 (56.3)	<.001
Fascial closure	668 (90.2)	17 (54.8)	<.001
Panniculectomy	288 (38.8)	15 (46.9)	.357
Average hernia defect size (cm^2)	276.0 ± 207.4	386.5 ± 444.7	.357
Average MESH SIZE (cm^2)	906.7 ± 393.1	861.4 ± 436.8	.17
Biologic mesh	179 (24.1)	14 (43.8)	.001
Absorbable synthetic mesh	10 (1.3)	0 (0)	<.001
Total operative time (min)	215.5 ± 70.7	289.6 ± 125.7	<.001
Duration of stay (days)	7.6 ± 5.0	12.4 ± 11.2	<.001
Readmission (30 days)	91 (12.5)	3 (10.7)	.231
Wound complication	24 (33.4)	24 (75.0)	<.001

Table VI
Wound complication after CST in OVHR

	Wound complication		
	No n = 503 (%)	Yes n = 272 (%)	*P* value
Age (y)	59.2 ± 11.6	58.0 ± 11.4	.135
BMI (kg/m^2)	32.5 ± 6.6	35.7 ± 7.5	<.001
Comorbidity			
Current steroid use	30 (6.1)	14 (5.3)	.644
Diabetes	120 (24.1)	94 (35.2)	.001
Peripheral vascular disease	12 (2.4)	3 (1.1)	.225
Smoking history	79 (15.8)	52 (19.4)	.201
Recurrent hernia	308 (61.2)	177 (65.1)	.292
Mean previous hernia repairs	2.4 ± 2.0	2.5 ± 2.0	.415
Incarcerated	210 (41.8)	110 (40.7)	.769
CDC class 3 and 4	54 (10.8)	50 (18.4)	.003
Enterotomy made	9 (1.8)	19 (7.2)	<.001
Anterior CST	148 (29.4)	111 (40.8)	.001
Fascial closure	458 (91.2)	227 (84.1)	.003
Panniculectomy	168 (33.4)	135 (49.6)	<.001
Average hernia defect size (cm^2)	267.7 ± 227.6	301.9 ± 207.2	.005
Average mesh size (cm^2)	910.1 ± 378.2	895.3 ± 424.6	.533
Biologic mesh	111 (22.1)	82 (30.1)	.006
Total operative time (min)	207.9 ± 69.1	238.4 ± 81.6	<.001
Length of stay (days)	7.6 ± 5.3	8.3 ± 5.7	.012
Readmission (30 days)	23 (4.7)	71 (27.0)	<.001
Operative charges (USD)	16,055.9 ± 10,054.3	17,385.4 ± 10,760.0	.171
Total hospital charges (USD)	80,132.8 ± 58,115.1	91,418.1 ± 74,544.2	.028
Hernia recurrence	8 (1.6)	24 (8.8)	<.001

Table VII
Outcomes of ideal CST cases

	n = 168 (%)
Age	60.1 ± 13.3
Female	82 (48.8)
BMI	29.2 ± 3.6
Recurrent hernia	87 (51.8)
Component separation	
Bilateral	138 (82.1)
Anterior	48 (28.6)
Panniculectomy	47 (28.0)
Average hernia defect size (cm^2)	249.8 ± 168.9
Average mesh size (cm^2)	979.1 ± 270.7
Recurrence	1 (0.6)
Wound complication	36 (21.4)

Ideal case defined as patients with BMI <35, not diabetic, no smoking history, synthetic mesh used (no lightweight or omega-3 fatty acid coated), fascia closed, noncontaminated field.

complications (41.0%, 42.9%, 30.5%, 26.4%, P = .001) despite an increase in the number of contaminated cases (P < .001). During this time period there was a significant decrease in the use of ACST (52.3%, 35.3%, 20.2%, 9.5%, P < .001) despite a significant increase in defect size (342.4 ± 326.1, 389.9 ± 249.3, 410.6 ± 206.9, 410.1 ± 190.0 cm^2, P = .015). There has been marked increase in botulinum toxin use (83 cases in the past 3 years) in a planned effort to reduce ACST use. During the past 5 years there has also been a change to a perforator vessel sparing ACST. This, and perhaps it combined with strict prehabilitation goals, significantly decreased wound complications within the ACST group (45.1%, 61.5%, 24.4%, 29.4%, P < .001). Given the Hernia Center's periodic outcome reviews of the patient care elements (prehabilitation, technique, wound management, mesh, etc) and dissemination and adoption by its member surgeons, surgical outcomes according to the attending surgeon were also compared. There was no difference in wound complications or recurrence per surgeon when factors in the MVA were controlled.

Discussion

Component separation technique is a technically challenging procedure when performing abdominal wall reconstruction for complex abdominal hernias. There have been multiple adaptations to the original description of the ACST, including vessel-sparing techniques, tunneled procedures performed via lateral incisions, endoscopic variations, and posterior approaches, among others.[27–34] In this study, a review of 12 years of prospectively collected CST data was performed at a tertiary hernia center detailing outcomes with the progression of prehabilitation, technique changes, and wound management. This combination of factors, including preoperative smoking cessation, reduction in HgbA1C to less than 7.2, weight loss in obese patients, reduction in ACST by using a PCST or adaption of minimally invasive, perforator vessel-sparing ACSTs, or the use of botulinum toxin, resulted in a substantial reduction in complications despite increasing hernia complexity over time. The data reported reinforces the real need to reduce wound complications owing to the short and long-term deleterious effects that result.[35,36] Indeed, patients that developed a wound infection had a significantly longer duration of stay, higher 30-day readmission rate, dramatically increased mesh infection rate, and a 5-times increased likelihood of recurrence (8.8% vs 1.6%, P < .001).

Although debate exists regarding the optimal AWR technique selection, it is generally accepted that using CST for fascial reapproximation is superior to bridging mesh. In a meta-analysis, one group reported that achieving primary fascial closure through CST resulted in a lower recurrence rate and lower surgical site occurrences in comparison to bridged mesh repairs.[6] The present study demonstrates improved outcomes with fascial closure. Although PCST is demonstrated to have lower complication rates in the present study, not all hernias are amenable to this technique when fascial closure is desired because ACST allows for further medialization than TAR in cadaver models.[37] Given the improved outcomes with fascial closure,[2,5–7] ACST is sometimes necessary. The present study supports this assertion because the cases in which

ACST was utilized had much larger fascial defects on average. As time progressed, ACST demonstrated higher complication rates which led to efforts to reduce rates of ACST or reduce the subcutaneous dissection and preserve the blood supply to the subcutaneous flaps. The use of botulinum toxin is thought to provide enough laxity to avoid ACST in larger defects.[20] This is reflected in the temporal analysis of the present study because PCST rates increased when botulinum toxin was used more frequently, and wound complications rates during ACST decreased over time as the technique improved. This improvement in outcomes was despite the increase in hernia size and the number operations performed in contaminated fields.

The decision to perform CST cannot always be accurately predicted preoperatively. The authors perform adhesiolysis as needed and assess the ability to close the linea alba. If unable to reapproximate the midline, the posterior rectus sheath is incised and released on one or both sides. The fascial medialization is once again assessed. If the fascia is within approximately 3 to 4 cm of closure while under tension and the intestine reduced, the PRSR is expanded to a TAR. If there is >4 cm of fascial separation after the PRSR, an ACST is then performed on one side, and the ability to close the fascia is reassessed. If the fascia cannot be approximated, a bilateral ACST is completed. The mesh is placed in the preperitoneal plane in >95% of cases.

As would be expected, the defects in this report were large. Mesh was used to augment the repair in 98.1% of the operations. Although mesh has decisively been proven to decrease hernia recurrence in the repair of standard ventral hernias, its use may be more important in patients undergoing CST. As one would expect, studies have shown the recurrence of nonmesh reinforced AWR with CST to be quite high, but considering that there are few remaining options if a hernia repaired with a CST fails, the authors refrain from a CST in the majority of cases if mesh was not going not be installed.[3,4,38] Most often the meshes implanted in this study group were very large. Indeed, when an ACST was performed, a preperitoneal dissection typically accompanied it to allow wide buttressing of the abdominal wall well lateral to the site of the external oblique release.[21] We thought that this extensive mesh overlap of the abdominal wall defect results in the low recurrence rates that we report in this article. When we have seen outside referrals with CST failures, our current go-to preference to facilitate abdominal wall closure is to use botulinum toxin to cause temporary components relaxation, as we have previously detailed.[20] We have also performed a repeat surgical CST, especially when the previous release was an ACST. Often a CT scan assessment of the recurrent hernia and abdominal wall demonstrates no or minimal EOB release despite the previous operative note detailing such. In these cases, a formal ACST can yield extensive midline mobilization. In those operations in which an EOB release is identified on CT scan, repeating the ACST can gain additional midline extension of the myofascial complex; this is undoubtedly partly owing to remobilization of the subcutaneous tissues which tethers the fascia in place. We do not perform an ACST on the same side of the abdominal wall as a previously performed PCST, or, likewise, a PCST after an ACST. If both an ACST and a PCST were to be performed on the same side, the EOB fascia and muscle, the posterior fascia of the internal oblique and the transversalis muscle and fascia would be transected which would leave only the anterior internal oblique fascia and muscle. These may lead to an unstable abdominal wall and a lateral, full thickness, musculofascial rupture.

In the present study, the recurrence rate is 4.1% after AWR with CST, whereas recurrence rates in the literature range from 1.5% to 52%.[6,19,28–30,33,39–43] In our patients, and in accordance with other literature, increased BMI was associated with recurrence and complications.[21,44] For every point of BMI >26, there was a 1.066 times increased wound complication rate. Although surgeons sometimes pick a level of BMI for patients over which they will not operate, the authors have not scientifically established a cutoff point. But we will encourage weight loss to all overweight patients before surgery and insist on it in patients who are morbidly obese or overweight and have defects demonstrating loss of domain.

Other factors affecting recurrence included enterotomy occurring during surgery (9.4% versus 2.2% without an enterotomy),[21] wound complications, the use of a bridging biologic mesh versus a synthetic (biologic mesh in contaminated cases), and the use of ACST compared with PCST. In the unadjusted analysis, ACST associated with a higher recurrence rate is similar to a finding from Krpata et al.[43] But, in the present study, we demonstrate that ACST is not independently associated with recurrence when confounding factors, such as defect size and wound complexity, are controlled. When a multivariate regression analysis was performed, the only factor independently associated with recurrence was hernia defect size (OR 1.001 per cm^2, 95% CI, 1.000–1.003).

The pervasive complication of CST is the increase in wound complications. ACST requires creation of large subcutaneous flaps, generating space for fluid to accumulate and potentially devascularization of the skin flaps. In a systematic review by Cornette et al, they found an SSO rate of 33.4%.[45] In a study of anterior versus PCST, there was a significantly higher wound complication rate in the ACST group (48.2% vs 25.5%).[43] Our study also found a higher rate of wound complication with ACST compared with PCST (42.9% vs 31.2%). Multiple factors may have influenced an increased risk of wound complications including higher BMI and diabetes in the ACST group (even though patients were optimized preoperatively). When controlling for potential confounding factors including defect size, mesh type, and comorbidities, ACST still was independently associated with an increased risk for wound complication. However, with the strong changes in prehabilitation beginning after development of the CeDAR app, significant improvements in wound complications in both the ACST and PCST patients was seen. The difference between PCST and ACST became less significant (29.3% vs 35.5%). As well, with the addition of perforator sparing techniques in 2015, as espoused by the Plastic Surgery group from MD Anderson,[27] the incidence of ACST wound complications markedly decreased to 19.6% ($P = .008$).

As our population seems to continue to grow increasingly more comorbid, the ability to counsel patients and optimize them for surgery has become a priority for surgeons. Using standardized protocols to improve patient modifiable factors before surgery has been shown to improve wound complications and long-term outcomes.[22] A subset analysis of what might be considered an optimized set of patients or more ideal set of patients was performed. Patients included in this group needed to have a BMI <35 (encouragement of weight loss), no history of smoking (smoking cessation before elective surgery), controlled diabetes (patients should have a HgbA1C <7.2 before surgery), synthetic mesh choice (biologic mesh are most often used in high risk or contaminated fields), noncontaminated cases (careful dissection and prevention of enterotomy), and primary fascial closure. When an AWR using CST was performed in these more ideal settings, the wound complication rate was 21.4%, and there was only 1 recurrence (0.6%) in 168 patients. These findings tend to emphasis the importance of optimization before surgery and a good surgical technique.

A recurring question in surgery for 40 years is the potential improvements in outcomes that regionalization of surgical care or a tertiary, specialized surgical center might provide.[46,47] Regionalization of care assumes that disease-specific knowledge and expertise owing to greater patient density will positively affect outcomes. With the prospective collection of data in 1999 and the establishment of our hernia center in 2004,[48,49] our outcomes in hernia surgery have been repeatedly reviewed, which allowed substantive, data-driven changes in our preoperative management and goals before surgery,[22,50] selection of operative techniques,[21] appropriate mesh choice,[26,51] and postoperative management. With each review and rereview of these changes, the Hernia Center's surgeons have tightened each of these aspects of care to the point that our approach is essentially uniform. With this, although our outcomes have not been compared with outside surgeons or other hernia centers, we have significantly improved our incidence of complications and recurrence in abdominal wall reconstruction operations, which has been noted by other hernia centers.[52,53] The combination of these factors has reduced our incidence of complications by 50%, decreased recurrence by >60%, and saved nearly $4 million over 5 years when all open hernia repairs were examined.[23] These efforts reduced complications by 63% in the present study of patients undergoing CST (41.0% to 26.4%, $P = .001$). Although hernia referral center outcomes have not been robustly compared with individual surgeons, there has been a significant increase in ventral hernias referrals to hospitals with higher volumes.[54]

Abdominal wall reconstruction continues to be a challenge in surgery. The present study demonstrates the outcomes of 12 years of CST in a single tertiary center, but it also highlights the persistently changing practices during that time in patient preparation, operative techniques, and postoperative wound management and how these changes improved outcomes. Although CST in AWR was associated with moderate wound complication rates in this study, the abdominal wall closure afforded by CST, when combined with mesh reinforcement, resulted in low hernia recurrence rates. Demonstration of ACST's association with higher wound complications began the adoption of perforator vessel-sparing techniques and a movement to PCST, both of which have decreased the incidence of wound complications. Additional study in the future may point reliably to other possible options, like botulinum toxin or other agents that may allow temporary relaxation of the abdominal wall musculature to affect a tension-free repair.

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Discussion

Dr Michael Ujiki (Chicago, IL): I would first like to thank the Association for the opportunity to discuss this presentation. Dr Shoup, I also want to congratulate you on your presidency. You put a lot of work into not just this society but many others, so congratulations.

Thank you for the manuscript well in advance. I enjoyed reading it. A lot of what I have to have say and the questions that I have are also in the review for the paper.

Over the years, we have learned a lot about ventral hernia repairs and component separation from the group here at Carolina Medical Center.

In this series of nearly 800 ventral hernia repairs, we learned a lot about the differences between anterior and posterior component separation, and I think we can all learn a lot about when to apply the different techniques and under what situations. I would like to delve a little more deeply into that. Given that, my questions are the following:

You are a regional center and get a lot of very complex hernias from outside of your center. How did you determine your recurrence rate? How did you follow these patients long-term?

I think what could really come out of this study and this paper would be an algorithm that helps us define when to use a posterior component separation technique versus anterior, because there is some advantage with the anterior technique in terms of the amount of release that you get, for bigger defects, for example. If you could tell us, what do you do to determine when to use an anterior component separation technique? How big is the hernia just based on size? Also, when do you use Botox? I know that you mentioned some Botox use in the paper. Is there a certain cut-off or size where you might say Botox would be helpful?

Lastly, morbidly obese patients, what is your cut-off? I think you mentioned 35. An algorithm would be really nice for us to know when anterior, when posterior, when Botox, what BMI.

The other thing the presentation and paper leaves out is how to deal with very complex patients. For example, the mesh infections. So a patient that has a mesh infection that maybe has already been placed in the preperitoneal space, how do you deal with removal of that mesh, and now that that space has been obliterated, how are you treating those patients? How are you treating patients that maybe don't have a mesh infection but have a recurrence and have had mesh placed in the preperitoneal space or have already had a posterior release? How are you dealing with those patients?

You mentioned that bridging has led to high recurrence rate. So what can we do if we can't do any release? Is bridging our only option?

I would like to hear a little bit about robotics. I know people are going to cringe, including me, but there might be a good role for robotics in these cases because, as you mentioned here, the wound infection rate, even in cases that are ideal, it's not low, and I wonder if we get rid of the large incision, if we are able to actually perform a posterior component separation robotically, or an interior, is that maybe a solution to decreasing the wound rate?

Dr Sean R. Maloney: Thank you very much for your discussion and those very interesting questions. Starting with the first one, determining recurrences, because our database is a prospective database, our patients are consented on their first preoperative visit for continued phone follow-up as well as reaching out to their referring provider for follow-up, because if they don't come back to us it would be difficult to determine if they have a recurrence. But we have found good success in bringing patients back if they have a complaint on those phone follow-ups.

In terms of an algorithm, there's a couple of different ways that we think about this. There's the intraoperative algorithm that our surgeons typically follow, which is performing preperitoneal dissection to allow for a large piece of mesh place, and then performing a posterior rectus sheath release, understanding that they are going to get about 90% of their release from that, and they won't get too much more from performing the transversus abdominus release. So as the posterior rectus sheath is released and the fascia is not able to be reapproximated, they will typically go to performing an external oblique release on one side and reevaluating, and then performing it on the other side, if necessary.

In terms of preoperative, this is something that we are currently working on, looking at a variety of different factors including volumetrics within the hernia, the hernial sac, loss of domain in the defect side, and we hope to be able to produce some sort of algorithm that can predict the use of botulinum toxin or different types of posterior or anterior component separations.

In terms of mesh infections, while that's not the specific scope of this paper, a colleague of mine is writing a paper on our experience with mesh infections at this time. Within our institution, we have about a 64% rate of explantation, after utilization of infectious disease consults to try to salvage the mesh as much as possible. Then when we go to repair these patients and they have a recurrence with a mesh infection or need explantation, we have found that performance of a ventral hernia repair with biologic mesh versus a simple suture repair has similar complication rates but a lower recurrence.

In terms of previous component separations and what to do when a patient is seen, preoperatively, CT scan to really identify whether the component separation was complete, especially in patients that are referred to your center. Weight loss is critical in these patients because that is going to help reduce some of the tension on the fascia, and both botulinum toxin is a go-to in these patients. Nearly all of them will get it after they have had a previous component separation. The one rule that we tend to follow is we never perform transversus abdominus release and an external oblique release on the same side. We will utilize them on contralateral sides.

In terms of robotics, I think that this is an area of future research. In looking at some of the studies that are out there, the size of the defects that are being used in the robotic studies tend to be a little bit smaller than what we see on average. However, there are obviously innovators out there who will continue to explore this and see if they can utilize this instead of doing these big open techniques that do cause significant fluid shifts and wound complications.

Dr Vic Velanovich (Tampa, FL): My question has to do with panniculectomy. How do you decide who gets a panniculectomy? Is this something that is decided preoperatively? Is it billed as a separate procedure? And do you have to get prior approval for that? And do you really feel that it reduces the recurrence rates, or are you just doing it for body contour?

Dr Sean R. Maloney: Panniculectomies are performed for a variety of reasons. Thank you for your question. Typically, they are decided on preoperatively and you will see an association with panniculectomy and our anterior component separation for 2 different reasons. Either we need to perform an external oblique release, and thus we perform a panniculectomy at this time, or we are already proceeding to a panniculectomy and the external oblique is there, easy to visualize, so it's easy to perform the component separation.

In talking to some of my attendings, the process behind billing is difficult. Many of the patients do get preoperative approval from the insurance company. And it's usually done because of thin skin, overlying the hernial sac, and not so much for cosmetic appeal at all.

Dr Brian Harbrecht (Louisville, KY): I may have missed it in the your analysis, but did you factor in other associated procedures besides panniculectomy such as intestinal resections or stoma takedowns in terms of their risk of recurrence and/or wound complications?

Dr Sean R. Maloney: We included that utilizing the level of contamination, so those cases even with planned approach into the GI tract were CDC class 2 where we control for that in our multivariate.

Dr R. Matthew Walsh (Cleveland, OH): Quick questions around obesity and wound infection. What do you do with the patient who has a high BMI? Do they have to come down to a certain BMI, or a percent change in their BMI? Are there any downsides to waiting for weight reduction? Those are the ones that seem to come in to the emergency department incarcerated when I am on call.

Regarding your wound infection rates, even in your small ideal group had a high rate. So what is the bacteriology of those wound infections? What have you changed as a result of this finding: change in your antibiotics, dosing, and duration?

Dr Sean R. Maloney: There is a degree of weight loss as well as time that goes into our consideration. We know that even with weight loss that a hernia defect will get bigger over time. That's just the nature of the external oblique's pulling on the abdominal wall. And so currently, as I mentioned, we are trying to generate an algorithm that will help us educate a patient, hey, you need to lose 25 pounds within 3 months or we should do your repair, because one or the other is going to make the repair easier. That is definitely something that we are considering.

We don't see a significant acute incarceration rate in these patients because their defects are so large. So the risk of an emergency operation is typically not on our forefront to this patient population.

In terms of your other question, my wound complication definition includes things like seroma that requires intervention, cellulitis, wound infection. So the majority of those patients in the ideal group had a seroma formation that required a drain either at the bedside or by interventional radiology. So while that may not require antibiotics, it's still something that the patient has morbidity to.

Dr Peter Hallowell (Charlottesville, VA): Two quick questions. First, you are putting the mesh below the posterior fascia? The second question is, you talked about an ideal patient and 2 mesh types that were not ideal. So what is your mesh type that is ideal?

Dr Sean R. Maloney: The preperitoneal plan is the approach that our surgeons typically use, and that is between the peritoneum and the posterior rectus sheath. In terms of an ideal mesh, either medium or heavyweight synthetic mesh.

Dr Fred Luchette (Maywood, IL): Dr Maloney, I too join the other discussants in congratulating you on a very nice study and excellent presentation. As you know, 2 years is a rather brief time for follow-up of patients who have a hernia repaired. Although the majority of recurrences occur in the first year after repair, recurrences can occur up to 5 and even 10 years, particularly with complex repairs as performed in your study. Your study period was 12 years, so why was the follow-up only for 2 years? So if you were to follow your patients out to 5 or 10 years, do you think your recurrence rate is actually higher than you are reporting today?

Dr Sean R. Maloney: I agree, 2 years is an average follow-up for patients undergoing ventral hernia repair. Five years of follow-up, that would definitely be better. When we compare our outcomes based on patients who we operated on ten years ago in this study, those patients, we do have follow-up into the 5-year range. Then we do have a recurrence rate of about 7.5%. However, when we control for follow-up length within all 12 years of our study, our recurrence rate was not significantly different. So we expect there to be continued recurrences as time always tells, but we don't feel like that it's significantly influenced by our follow-up.

Dr Dimitrios Stefanidis (Indianapolis, IN): Thank you very much for a nicely presented study. Having spent at Carolinas the early part of my career, I have a very good appreciation of what hernias you deal with; as challenging as they can get.

I have the following questions:

You published previously that patients who had concomitant panniculectomy have higher wound infection rates. Given that the wound infection rate you reported in this study was higher in the anterior repair group, could this be related to the panniculectomy rather than to the anterior approach to the repair? Could an endoscopic anterior release have decreased the infection rate?

Dr Sean R. Maloney: That was something that we did look at in this study was whether or not panniculectomy influenced our wound infection rates, and it is associated on the univariate but on multivariate analyses controlling for both anterior panniculectomy and other factors, panniculectomy was not an independent risk factor for wound complication.