



To close or not to close: morphologic changes associated with closure of the posterior rectus sheath after posterior component separation

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Abstract

Introduction This study aims to evaluate morphologic changes of the rectus muscles after closure of the posterior rectus sheath (PRS) following component separation. There is no consensus on whether to close the PRS, and limited data exists on how closure affects the morphology and potential function of the abdominal wall musculature.

Methods Retrospective review of all patients between 1/1/2016 and 12/31/2022 who underwent PRS release for ventral hernia repair performed by a single surgeon. During this period, some patients had reconstitution of the PRS while others had the posterior layer buttressed with peritoneum. Subjects were included if preoperative and postoperative cross-sectional imaging was available for review and excluded with: transversus abdominis muscle release, external oblique muscle release, open surgery, or complication of hematoma or seroma. Measurements of rectus muscle width and distance between semilunar lines were obtained at the level of the umbilicus, upper, middle, and lower abdomen. Statistical analysis performed using Student's t-test analysis on continuous variables. Significance defined as $p = .050$.

Results Results include 90 patients divided into two arms: PRS buttressed versus PRS closed. Closed PRS was associated with significantly decreased percent difference in distance between semilunar lines in the middle (4% vs -5%, $p = .001$), umbilical (2% vs -4%, $p = .031$), and lower abdomen (2% vs -3%, $p = .018$) and rectus muscle width in the middle (Right: 20% vs 11%, $p = .009$; Left: 20% vs 6%, $p \leq .001$), umbilical (Right: 20% vs 9%, $p = .001$; Left: 21% vs 10%, $p = .002$), and lower abdomen (Right: 8% vs 0%, $p = .006$; Left: 8% vs -1%, $p = .006$).

Conclusions Release and decoupling of PRS results in increased width of rectus abdominis muscle in both cohorts although significantly larger change observed in PRS bridged. Reloading of the PRS brings the semilunar lines closer together as compared to preop measurements, the opposite is observed when leaving the PRS bridged with peritoneum.

Keywords Ventral hernia · Abdominal wall reconstruction · Posterior rectus sheath release · Posterior rectus sheath closure · Rectus morphology · Hernia surgery

Understanding of retrorectus repair has evolved significantly, with a key step being the release and decoupling of the posterior rectus sheath (PRS). In this approach, the PRS is dissected away from the underside of the rectus abdominis muscle, creating a space where mesh is placed [1, 2]. Decoupling the PRS from its medial contributions allows

for advancement of the anterior myofascial flap, increasing rectus width and facilitating the closure of complex defects over mesh.

Management of the decoupled PRS remains a topic of controversy. While Rives originally described bridging the posterior layer with peritoneum or omentum in his initial publication [3], newer retrorectus techniques such as mini- or less-open sublay (MILOS) and extended totally extraperitoneal (eTEP) access surgery have led to increased adoption of peritoneal bridging over the past decade [4, 5]. However, whether to close the PRS or leave it open with peritoneal buttressing remains an area of debate in abdominal wall reconstruction. The subject sparks lively discussion in hernia-related circles but lacks objective data in the literature to strongly support either position [6]. Some advocate for

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closure to restore native abdominal wall mechanics, while others argue that leaving the PRS bridged with peritoneum reduces tension and minimizes the risk of posterior layer breakdown [7–9].

The rectus abdominis plays a central role in core stability and intra-abdominal pressure regulation [10]. Even subtle changes in its morphology may influence functional or cosmetic outcomes. This study aims to objectively measure these changes following PRS closure to help guide decision-making in abdominal wall reconstruction.

Methods

This study was deemed exempt by the institutional review board. A retrospective review of all patients between 1/1/2016 and 12/31/2022 who underwent minimally invasive PRS release by a single, fellowship trained minimally invasive abdominal wall reconstruction surgeon at a single institution was performed. Patients were included with pre-operative and post-operative cross-sectional CT imaging from xyphoid to pubis. Patients undergoing transversus abdominis muscle release (TAR), external oblique muscle release (EOR), open PRS release, or cases complicated by postoperative seromas/hematomas were excluded.

A manual review of the electronic medical record was performed. Patient demographics and comorbidities, hernia characteristics, and surgical details were recorded. During this time, our surgeon changed practice to start reloading the posterior rectus sheath in all cases. Operative notes were reviewed to determine whether the PRS was left bridged with peritoneum versus closed and reloaded. The post-operative imaging was chosen to be the furthest out from surgery but before any other unrelated abdominal operations. Measurements on pre-op and post-op imaging were taken of the rectus muscle width, height, and distance between the semilunar lines. These were taken at 4 levels; the midpoint between xyphoid and pubis, the upper quartile, lower quartile, and at the umbilicus.

Operative technique

The term “reloading” refers to the active re-approximation of the medial edges of the posterior rectus sheath, with the goal of restoring its native tension-bearing role. In contrast, peritoneal bridging leaves the posterior sheath open and uses preserved peritoneum as a barrier layer. Closure was performed under reduced insufflation pressure of 5 to 7 mmHg to minimize tension during suture placement.

Bridged posterior rectus sheath

The retrorectus space is dissected either transabdominally or via an eTEP approach at 15 mmHg (5). The posterior rectus sheath (PRS) is released along its medial aspect from the perixiphoid region down to the arcuate line. It is then fully decoupled and dissected away from the underside of the rectus abdominis muscle. The entire retrorectus space is carefully dissected, ensuring that neurovascular bundles are identified, preserved, and left uninjured. Hernia contents are reduced with meticulous attention to prevent trauma to surrounding structures.

Care is taken to preserve the peritoneal bridge between the cut edges of the PRS, composed of the falciform and umbilical ligaments. Any defects in the PRS or peritoneum are closed using 3–0 or 2–0 braided or barbed absorbable sutures to maintain an intact posterior layer, serving as a barrier between the mesh and intra-abdominal contents.

The anterior rectus sheath and linea alba are then reconstructed using a 0 non-absorbable barbed suture. Mesh is placed in the retrorectus space, ensuring proper positioning. A retromuscular drain is placed for 3 to 6 days, and the space is desufflated under direct vision.

Reconstituted posterior rectus sheath

Dissection is performed in a similar manner to the previously described approach. The medial edges of the posterior rectus sheath (PRS) are then re-approximated using a running 2–0 barbed absorbable suture in a horizontal mattress fashion. Care is taken to ensure even distribution of tension across the entire PRS. Insufflation is decreased to 5–7 mmHg during this step to facilitate precise closure.

A 2–0 Prolene suture on an SH needle is then used to reinforce the posterior suture line in a whipstitch fashion. Once the PRS is reloaded, the anterior rectus sheath and linea alba are reconstructed with a 0 non-absorbable barbed suture. Mesh is placed in the retrorectus space, a drain is inserted, and the space is desufflated to ensure proper approximation and positioning.

Statistical analysis

Data was collected and stored in the Research Electronic Data Capture (REDCap), a secure research database application. Patients were stratified based on whether the Posterior Rectus Sheath was reconstituted or not. Descriptive statistics were performed on demographic and perioperative data. Continuous variables are reported as mean \pm standard deviation and dichotomous variables as count \pm frequency. The anatomical measurements for preoperative and most recent postoperative CT scans were

recorded for Right/Left Rectus Width/Height and Width between Semilunaris at the Epigastric, Middle, Umbilical, Suprapubic levels. The Middle point was defined as the halfway point between xyphoid and pubis. The Epigastric point was the halfway point between the Middle and xyphoid. The Suprapubic point was the halfway point between the Middle and pubis. The Umbilical measurement was the point where the stalk met the fascia. The percent difference in change from preoperative to postoperative CT was recorded. Student's t-test and Chi square analysis were performed as indicated based on variable type. Linear regression analysis was performed on anatomical measurement and postoperative outcomes. Statistical significance was defined as $p \leq 0.050$. All statistical analysis was performed using MathWorks MATLAB 2021b.

Results

Demographics

In total, 90 patients were included in this study, 63 patients in the bridged PRS (bPRS) group and 27 in the closed PRS (cPRS) group (Table 1). There were 613 charts reviewed for hernia repairs, 247 had other component releases leaving 366 patients who had PRS release alone. 167 patient's pre-op imaging was not available, and 197 patients did not have post-op imaging or imaging was unavailable. There were 99 patients who had PRS release and both imaging available, 4 patients excluded for seromas, 3 excluded for hematomas, and 2 excluded for open repair. The average patient age was 58.2 ± 13.0 years and BMI was 33.8 ± 7.3 kg/m². These were not significantly different between the two groups. There was no significant difference among patient-reported race or American Society of Anesthesiologists (ASA) class. There was a greater percentage of males in the closed PRS group (bPRS 44%/56%; cPRS 74%/26%; $p = 0.009$) (Male%/Female%). The most common comorbidities were hypertension, diabetes, and obstructive sleep apnea. Ten percent of patients were active smokers. Sixty-four percent of patients had incisional hernias compared to primary ventral. Thirty-six percent of patients had prior hernia repairs.

Perioperative

Notably, for the bPRS group, 60% of cases were laparoscopic vs 40% robotic compared to the cPRS group which was 100% robotic ($p < 0.001$). The cPRS group had significantly longer operative times of 128 ± 30 min compared to 108 ± 39 ($p = 0.018$) and smaller mesh size 499 ± 113 cm² compared

Table 1 Demographics

	bPRS		cPRS		<i>p</i> -value
Sample size	63		27		
Age (years)	56.7	13.8	61.7	10.3	0.091
Male/female (%)	44%	56%	74%	26%	0.009
BMI	33.6	7.6	34.5	6.4	0.570
Race					0.547
White	50	79%	23	88%	
Black or African American	9	14%	0	0%	
Mixed race	1	2%	0	0%	
Declined to answer	3	5%	2	8%	
Other	0	0%	1	4%	
ASA					0.964
1	2	3%	0	0%	
2	31	50%	13	48%	
3	29	47%	14	52%	
4	1	2%	0	0%	
HTN	39	62%	15	56%	0.578
CAD	1	2%	3	11%	0.047
Diabetes mellitus	13	21%	10	37%	0.104
COPD	3	5%	1	4%	0.826
Asthma	20	32%	1	4%	0.004
OSA	21	33%	7	26%	0.492
Smoker					0.938
Current	6	10%	3	11%	
Former	18	29%	10	37%	
Never	39	62%	14	52%	
Hernia type					0.224
Incisional	37	59%	21	78%	
Ventral	26	41%	6	22%	
Previous hernia repair	23	37%	9	33%	0.776
Other prior abdominal surgery	40	63%	18	67%	0.776

Bold indicates statistical significance at $p < 0.05$

Table 2 Perioperative outcomes

	bPRS		cPRS		<i>p</i> -value
Sample size	63		27		
AWR type					< .001
Laparoscopic	38	60%	0	–	
Robotic	25	40%	27	100%	
Surgery duration (procedure minutes)	108	39	128	30	0.018
Mesh size (cm ²)	638	298	499	113	0.021
Hospital LOS days	0.43	0.67	0.41	0.69	0.892

Bold indicates statistical significance at $p < 0.05$

Table 3 Postoperative outcomes

	bPRS		cPRS		<i>p</i> -value
Sample size	63		27		
Superficial SSI	2	3.2%	0	–	0.355
Deep SSI	0	–	0	–	–
MI	0	–	0	–	–
DVT/PE	1	1.6%	1	3.7%	0.538
Other complication	3	4.8%	3	11.1%	0.274
60 days reoperation	0	–	0	–	–
30 days all cause readmission	2	3.2%	7	25.9%	0.001

Bold indicates statistical significance at $p < 0.05$

to 638 ± 298 ($p = 0.021$). There was no difference in hospital length of stay with overall average 0.42 ± 0.67 days ($p = 0.892$) (Table 2).

Postoperative outcomes

Post-operative outcomes showed significant difference in 30-day readmissions in the cPRS group 25.9% compared to bPRS 3.2% ($p = 0.001$) (Table 3). The bPRS group, readmissions included pulmonary embolism and asthma exacerbation with gastroenteritis. For the cPRS group, readmissions included pulmonary embolism, esophageal food impaction, constipation, two small bowel obstructions managed non-operatively, and two with acute pancreatitis. There was no significant difference between superficial surgical site infection, MI, DVT/PE, and other complications. No patients in this study had 60-day return to the operating room. No patients in the study had postoperative seroma or hematoma as these were excluded.

Abdominal wall measurements

Preoperative and postoperative CT imaging was used to compare the rectus height and width, and width between semilunaris at the levels of the epigastrium, halfway between xiphoid and pubis (middle), at the umbilicus, and suprapubic. Notably, the width between semilunaris was significantly different at the levels of middle, umbilical, and suprapubic. There was a percent increase in the width between semilunaris in bPRS compared to a percent decrease cPRS (middle 4% vs -5%, $p = 0.001$; umbilical 2% vs -4%, $p = 0.031$; 2% vs -3%, $p = 0.018$; bPRS vs cPRS) (Table 4). Additionally, the percent increase from preoperative to postoperative CT imaging in rectus width was significantly different for both the right rectus width (middle 20% vs 11%, $p = 0.009$; umbilical 20% vs 9%, $p = 0.001$; 8% vs 0%, $p = 0.006$; bPRS vs cPRS) and left rectus width (middle 20% vs 6%, $p < 0.001$; umbilical 21% vs 10%, $p = 0.002$; 8% vs -1%, $p = 0.006$;

Table 4 Percent difference in measurements between pre- and post-operative imaging

	bPRS	cPRS	<i>p</i> -value
Sample size	63	27	
Epigastric right rectus width	12%	10%	0.530
Epigastric right rectus height	0%	9%	0.062
Epigastric left rectus width	13%	9%	0.263
Epigastric left rectus height	2%	11%	0.106
Epigastric width between semilunaris	2%	-1%	0.060
Middle right rectus width	20%	11%	0.009
Middle right rectus height	3%	5%	0.614
Middle left rectus width	20%	6%	<0.001
Middle left rectus height	4%	7%	0.512
Middle width between semilunaris	4%	-5%	0.001
Umbilical right rectus width	20%	9%	0.001
Umbilical right rectus height	-2%	3%	0.147
Umbilical left rectus width	21%	10%	0.002
Umbilical left rectus height	-1%	2%	0.583
Umbilical width between semilunaris	2%	-4%	0.031
Suprapubic right rectus width	8%	0%	0.006
Suprapubic right rectus height	-6%	-5%	0.715
Suprapubic left rectus width	8%	-1%	0.006
Suprapubic left rectus height	-5%	-6%	0.712
Suprapubic width between semilunaris	2%	-3%	0.018

Bold indicates statistical significance at $p < 0.05$

bPRS vs cPRS) (Table 4). Linear regression analysis was also performed and demonstrated a significant decrease in both rectus width and width between semilunaris at the levels of umbilicus, middle, and suprapubic when comparing bPRS to cPRS (Table 5).

Discussion

The rectus abdominis muscles are a paired, vertically oriented muscle group that form the anterior abdominal wall and play a critical role in core stability, posture, and respiration. Each originates from the pubic symphysis and pubic crest and inserts onto the xiphoid process and the fifth to seventh costal cartilages [10, 11]. The primary function of the rectus abdominis is to flex the trunk, assist in expiration by compressing the abdominal contents, and maintain postural control. They work synergistically with the oblique and transversus abdominis muscles to stabilize the torso and support dynamic movements such as bending, lifting, and rotation. This functional role is particularly significant in maintaining intra-abdominal pressure, which is crucial for respiration, defecation, and stabilization during physical activity [12].

Table 5 Linear regression analysis for pre- and post-operative CT imaging

	Beta	SE	<i>p</i> -value
Epigastric right rectus width	-1.8	2.9	0.530
Epigastric right rectus height	8.7	4.6	0.062
Epigastric left rectus width	-4.1	3.6	0.263
Epigastric left rectus height	9.1	5.6	0.106
Epigastric width between semilunaris	-3.3	1.7	0.060
Middle right rectus width	-9.0	3.4	0.009
Middle right rectus height	2.5	5.0	0.614
Middle left rectus width	-14.0	3.3	< 0.001
Middle left rectus height	3.1	4.7	0.512
Middle width between semilunaris	-9.0	2.7	0.001
Umbilical right rectus width	-10.8	3.1	0.001
Umbilical right rectus height	5.6	3.9	0.147
Umbilical left rectus width	-10.3	3.3	0.002
Umbilical left rectus height	2.3	4.1	0.583
Umbilical width between semilunaris	-6.4	2.9	0.031
Suprapubic right rectus width	-7.8	2.8	0.006
Suprapubic right rectus height	1.3	3.6	0.715
Suprapubic left rectus width	-8.6	3.1	0.006
Suprapubic left rectus height	-1.3	3.5	0.712
Suprapubic width between semilunaris	-4.8	2.0	0.018

Bold indicates statistical significance at $p < 0.05$

Above the arcuate line, the rectus muscles are enveloped by anterior and posterior rectus sheaths that fuse medially to form the linea alba. Less understood are the consequences of component separation procedures on the morphology and function of the abdominal wall, particularly when they involve division and decoupling of the posterior rectus sheath. It is important to understand the anatomical contributions to both the anterior and posterior rectus sheaths. The anterior rectus sheath receives aponeurotic contributions from the external oblique aponeurosis and the anterior lamella of the internal oblique. The posterior rectus sheath receives contributions from the posterior lamella of the internal oblique and the transversus abdominis. In this way, the anterior rectus sheath carries anterior and medial forces distributed along the external oblique and anterior lamella of the internal oblique, while the posterior rectus sheath carries posterior and medial forces distributed along the posterior lamella of the internal oblique and the transversus abdominis.

In our early experience with eTEP access surgery, where the posterior rectus sheath was routinely bridged with peritoneum from the falciform and umbilical ligaments, we reported low recurrence rates of hernia repair [13]. The anterior layer closure remained intact, and mesh placement was in the extraperitoneal space. This approach reduced the risk

of visceral adhesions to the mesh and eliminated the need for excessive mesh fixation. Clinically, we noted that some patients still exhibited bulging with core engagement, particularly involving the entire rectus complex from one linea semilunaris to the other. We hypothesized that this occurred as a direct result of bridging the posterior rectus sheath, a step that decreases the amount of tension distributed on the posterior lamella of the internal oblique and the transversus abdominis.

Separating the posterior rectus sheath allows the anterior myofascial flap to advance medially, helping to close midline defects. This advancement increases the width of the rectus muscle while decreasing its height, effectively thinning the muscle. Without the opposing pull from the posterior sheath, the semilunar lines tend to drift laterally, widening the space between them (Table 4). Our study provides objective CT-based evidence of these morphologic changes. We believe that the decrease in posterior anchoring forces results in increased bulging of the rectus complex without true hernia recurrence.

In 2020, we began reloading the posterior rectus sheath, hypothesizing that it would help preserve posterior anchoring forces and reduce the postoperative bulging observed in the bridged posterior rectus sheath group. Morphological findings in the reloaded posterior rectus sheath group, as shown in Table 4, indicate that posterior rectus sheath release and decoupling resulted in an increase in the width of the rectus abdominis. This was expected, as advancing the anterior myofascial flap to close the midline defect stretches the width of the rectus abdominis without posterior resistance. Interestingly, the increase in rectus width in the reloaded posterior rectus sheath group was significantly smaller than in the bridged posterior rectus sheath group.

Table 5 presents findings from the linear regression analysis of preoperative and postoperative CT imaging comparing the bridged and reloaded posterior rectus sheath groups. Negative regression values at all levels indicate that when the posterior rectus sheath was not reloaded but left bridged, the rectus width underwent a consistently larger postoperative increase. Additionally, when the posterior rectus sheath was bridged, the distance between the linea semilunaris was consistently larger postoperatively compared to preoperative measurements. In contrast, when the posterior rectus sheath was reloaded, the distance between the linea semilunaris actually decreased postoperatively, as demonstrated by statistically significant negative values in the linear regression model in Table 5. These morphological differences are important for surgeons to consider. Reloading and closing the posterior rectus sheath may preserve posterior forces on the posterior lamella of the internal oblique and the transversus abdominis, maintaining their function while still providing the benefits of posterior rectus sheath release. Not reloading the posterior rectus sheath results in a decrease

in posterior forces, leading to lateral migration of the linea semilunaris and a wide rectus abdominis complex bulge.

While most studies focus on recurrence rates and mesh-related outcomes, our findings highlight the importance of post-repair abdominal wall morphology. The narrowing and centralization of the rectus muscles after PRS closure may preserve normal force distribution and core architecture. These differences could affect both functional recovery and long-term patient satisfaction, although further studies are needed to explore this connection.

This study has certain limitations. A significant difference in postoperative readmissions was observed between the two groups; however, several cases, including acute pancreatitis and esophageal food impaction, were deemed incidental and unrelated to posterior rectus sheath closure based on clinical assessment. We expect higher postoperative complication rates and readmissions in this study population, as inclusion criteria required postoperative axial imaging to facilitate comparison of pre- and postoperative anatomic measurements. Since postoperative imaging is not routinely obtained as part of standard postoperative care, imaging was performed only when clinically indicated by physical exam findings or patient symptoms.

The study population is small and limited to a single surgeon at a single institution, and the retrospective study design presents inherent limitations. A standardized, objective measure to correlate morphological changes with functionality is lacking. Larger prospective studies utilizing validated assessments of abdominal wall function are necessary to determine the clinical benefits of posterior rectus sheath closure. The shift from laparoscopic to robotic surgery during the study period resulted from increased institutional access to the robotic platform, rather than changes in surgical technique. All procedures used the same core steps for PRS release and closure. Imaging-based inclusion criteria may have introduced selection bias, since postoperative imaging was only performed in symptomatic patients or when clinically indicated.

Our findings should be interpreted with caution, as systemic closure and reloading of the posterior rectus sheath is a technically challenging step. If tension is not well-distributed along the posterior suture line, dehiscence can occur, potentially necessitating emergent intervention. Some authors have described techniques to reduce the risk of posterior layer failure [14]. We believe that the decision to perform posterior rectus sheath release and bridging should involve a thorough discussion with the patient regarding expectations. Despite advances in hernia repair, there remains no standardized functional assessment for core muscle recovery. Restoring the retromuscular space may improve core function, respiratory mechanics, and postoperative quality of life. Current research relies on patient-reported outcomes, endurance tests, and indirect physiological markers, but there is no

universally accepted metric for postoperative core strength or abdominal wall function. Further studies should focus on patient satisfaction, cosmesis, and, most importantly, core function.

Conclusions

This study demonstrates significant morphologic changes in the rectus muscle and a decreased distance between the left and right semilunar lines following PRS closure. Our findings suggest that PRS closure alters abdominal wall morphology in ways that may preserve native anatomy and support long-term function. These results support the need for future prospective studies that evaluate both objective muscle changes and functional outcomes.

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Declarations

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