Evaluation of anterior versus posterior component separation for hernia repair in a cadaveric model

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Abstract

Background Component separation remains an integral step during ventral hernia repair. Although a multitude of techniques are described, anterior component separation (ACS) via external oblique release (EOR) and posterior component separation (PCS) via transversus abdominis muscle release (TAR) are commonly utilized. The extent of myofascial medialization after ACS or PCS has not been well elucidated. We conducted a comparative analysis of ACS versus PCS in an established cadaveric model.

Methods Fifteen cadavers underwent both ACS via EOR and PCS via TAR. Following midline laparotomy (MLL), baseline myofascial elasticity was measured. Steps for ACS included creation of subcutaneous flaps (SQF), external oblique release (EOR), and retrorectus dissection (RRD). For PCS, steps included retrorectus dissection (RRD), transversus abdominis muscle division (TAD), and retromuscular dissection (RMD). Maximal advancement of anterior rectus fascia (ARF) was measured following application of tension to the fascia as a whole, and separately at upper, middle, and lower segments. Statistical analysis was performed with Mann–Whitney U test. Values are represented as average myofascial medialization in centimeters.

Results Following MLL an average of 5.0 ± 0.9 cm (range 3.4–6.0 cm) of baseline medialization was obtained. Complete ACS provided 8.8 ± 1.2 cm (range 6.3–10.7 cm) of ARF advancement compared to 10.2 ± 1.7 cm (range 7.6–12.7 cm) with PCS, $p = 0.046$. In the upper and mid-abdomen, we noted increased ARF advancement with PCS versus ACS (8.1 ± 1.4 cm vs. 6.7 ± 1.2 cm and 11.4 ± 1.5 vs. 9.6 ± 1.4 cm, respectively, $p = 0.01$). Similar levels of ARF advancement were observed in the lower abdomen, 9.1 ± 1.7 cm versus 8.7 ± 1.8 cm, $p = 0.535$.

Conclusions Component separation via both anterior and posterior approaches provide substantial myofascial advancement. In our model, we noted statistically greater anterior fascial medialization after PCS versus ACS as a whole, and especially in the upper and mid-abdomen. We advocate PCS as a reliable and possibly superior alternative for linea alba restoration for reconstructive repairs, especially for large defects in the upper and mid-abdomen.

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Graphic Abstract

Comparative analysis of anterior versus posterior component separation in a cadaveric model
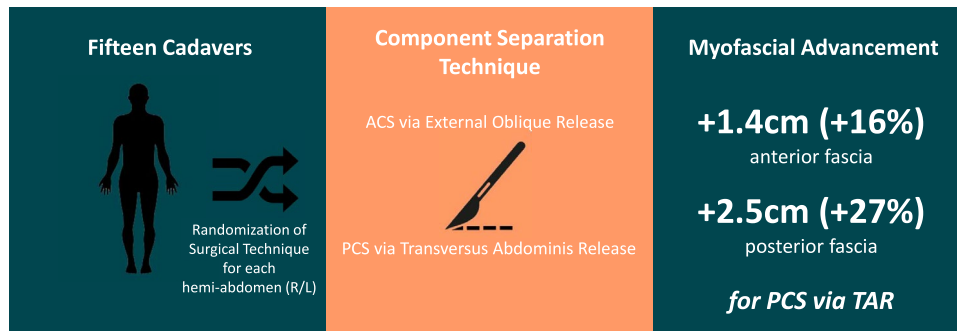
Component separation during ventral hernia repair has become an integral step in addressing large and complex defects. The ability to manipulate the myofascial components of the abdominal wall has allowed surgeons an avenue to not only restore linea alba, but also to utilize the latest in mesh reinforcement without the need for bridging repairs. The techniques considered hereafter are split into traditional anterior component separation (ACS) as originally described by Ramirez [1], and posterior component separation (PCS) via the transversus abdominis release procedure (TAR) [2]. Although TAR has been gaining in popularity worldwide, the use of ACS during complex hernia repair is still quite prevalent. Much of the clinical utilization of ACS versus PCS is likely driven by surgeon preference and experience, rather than an objective selection of technique based on merits offered. Ultimately, the exact physiologic basis and amount of myofascial advancement offered by each technique is not well elucidated.

The use of traditional ACS has been shown to be both safe in reliable among many populations [3, 4]. Owing to a fairly straightforward surgical technique, it is easily adopted and deployed across many institutions. However, due to substantial wound morbidity from raising large subcutaneous flaps, further modifications such as perforator sparing and endoscopic techniques have been described with improvements in both wound morbidity and hernia recurrence [5–8]. For the purposes of this paper we will consider the classic open ACS as originally described by Ramirez, including a posterior sheath release.

In recent years, posterior component separation via TAR has become a mainstay across various hernia centers in the US [9–11]. Clinically, the TAR approach has shown benefits in terms of offering both substantial myofascial advancement

with the ability to close large defects, as well as providing a large space for sublay mesh placement wherein it is "hidden away" from both the intra-abdominal compartment/viscera and superficial tissues of the abdominal wall. This large sublay mesh reinforcement of the visceral sac is the defining philosophy of the repair, following the principles originally described by Rives et al. [12, 13].

Though both techniques have respective benefits, we aimed to objectively evaluate the various steps involved in each release technique as well as the myofascial medialization offered at each major operative step. We also aimed to perform a comparative analysis of ACS and PCS in regard to myofascial advancement both as a whole, and segmentally across the vertical segments of the abdomen.

Materials and methods

After consulting with and obtaining IRB exemption for our study, we utilized our previously established cadaveric model [14] in which to perform and test both anterior and posterior component separation during each step of the procedures. We utilized 15 fresh cadaveric torsos for testing. All cadavers had a BMI of 25–35, with no prior midline hernia defects and no prior midline laparotomy. Our previously utilized apparatus for cadaveric testing is described in detail hereafter.
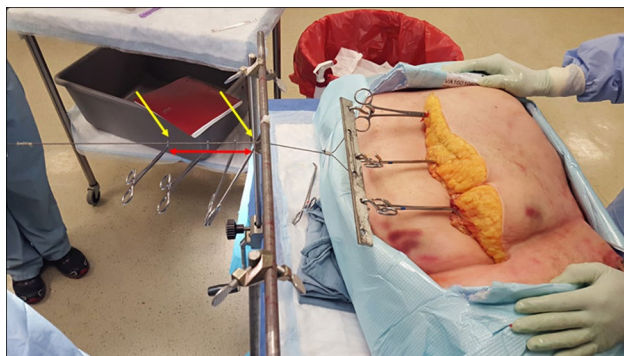
Measurement apparatus

The main apparatus consists of two straight metal rods (0.5″ diameter) attached to the bed rails of a standard operating table with clamps. A similar-sized cross rod was attached to

each upright rod via right angle clamps. The cross bar was positioned parallel to the torso and so that it would extend along the length of the abdominal wall. A single one-inch pulley was suspended from the cross bar with fine gage metal wire suspended across the pulley. The wire was attached to a straight metal bar ($1.5'' \times 8''$) with evenly spaced holes on one end and to a hook on the opposite end for attaching weight. The straight bar on the end of the wire was attached to the Kocher or towel clamps with 'S' hooks spaced evenly along the midline with upper, middle, and lower attachment points along the fascia to allow for even application of tension, as well as allow for isolation of upper, middle, and lower abdominal segments.

Myofascial advancement was measured by application tension to the wire of the apparatus while connected to the fascia. Maximal advancement was measured, defined as the point at which no further fascial advancement occurred with increased force applied to the fascia, or with any tearing/disruption of the fascia due to increased force. Measurements of fascial advancements were taken by noting the position of the wire at the vertical junction with the pulley with fine hemostats. The difference in position the hemostats from initial position to final position was measured as a direct 1:1 corollary of fascial advancement as tension was applied (Fig. 1). This eschewed more unreliable methods of measurement such as marking midline with a drawn line or suspended string, or by comparing the edge of fascia to a grid overlay.

Measurements of fascia were taken as the whole unit with all three clamps attached to the length of the fascia and then segmentally with single clamps attached to the middle of the cross bar for the upper, middle, and lower attachment points individually. All measurements were taken for each cadaver separately and data were compiled in aggregate. The values are presented as a maximal mean advancement along with standard deviation at each step. Of note, each step includes the advancement obtained from the previous step and are not incremental increases but rather aggregate ones.

Procedure

We began with a midline laparotomy (MLL) and measurement of baseline myofascial advancement prior to any component separation. Functionally, this was a measurement of fascial elasticity rather than true advancement, but an important parameter to establish as all further interventions provide additional release from this baseline value.

ACS was performed under supervision of an experienced plastic surgeon (HS). Although the classical description of ACS by Ramirez involved retrorectus dissection first followed by external oblique release, in our study we performed the retrorectus portion last, as it is performed clinically by our supervising plastic surgeon. The procedure began with the raising of lipocutaneous flaps (SQF) just superficial to the anterior rectus sheath and external oblique fascia, laterally. The lipocutaneous flaps were developed laterally towards the anterior axillary line. Following this, we incised the external oblique fascia approximately 1–2 cm lateral to linea semilunaris which was extended above the costal margin and down to the inguinal ligament. We then developed the retromuscular plane deep to the external oblique and superficial to the internal oblique muscle (EOR) (Fig. 2). Finally, we performed a retrorectus dissection (RRD), which involved incision into the posterior rectus sheath approximately 1 cm from the medial edge of the rectus muscle and the retrorectus plane was carried to just medial to the linea semilunaris along the length of the abdomen (Fig. 3).
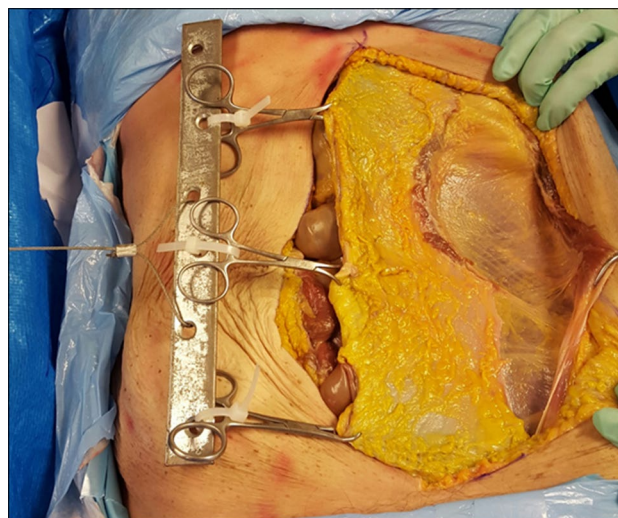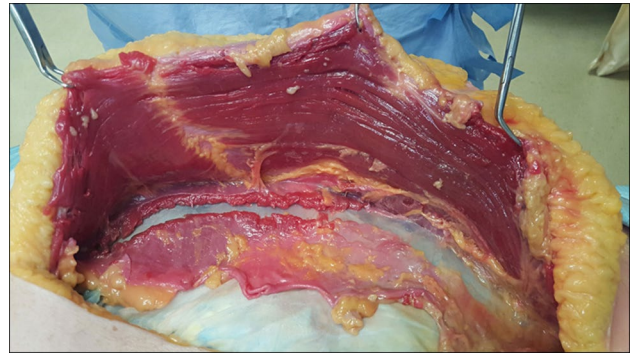

Fig. 1 Complete apparatus with pulley suspended at the level of the fascia from the cross bar. Left yellow arrow represents initial position of wire at baseline, right yellow arrow represents final position of wire at maximal advancement. Fascial advancement is represented by red arrow (Color figure online)
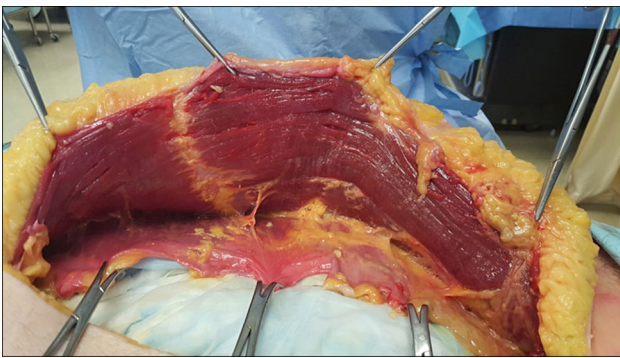

Fig. 2 Completed subcutaneous flaps (SQF) and external oblique release (EOR) for anterior component separation
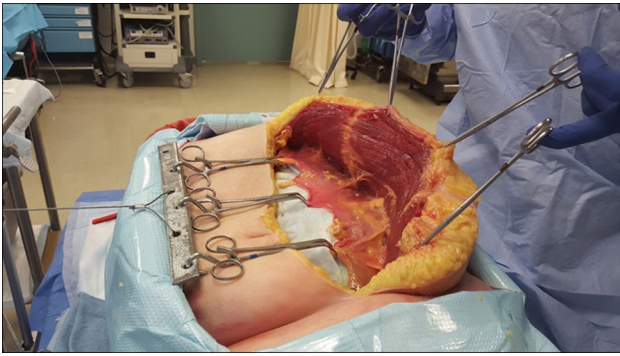
Fig. 3 Completed retrorectus dissection (RRD) for anterior component separation
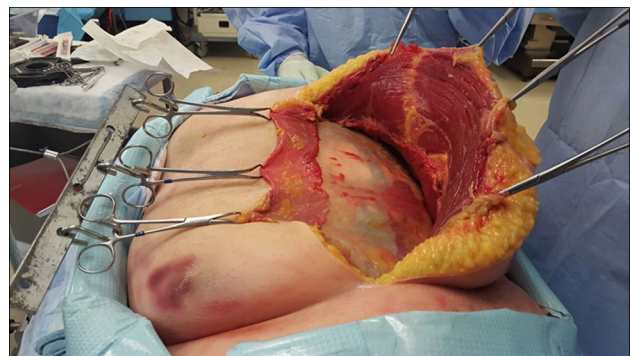

Fig. 4 Completed retrorectus dissection (RRD) for posterior component separation

Fig. 5 Completed division of posterior lamina of internal oblique and transversus abdominis muscle (TAD) for posterior component separation

Fig. 6 Completed retromuscular dissection (RMD) for posterior component separation

For PCS via the TAR procedure, following MLL we proceeded with retrorectus dissection (RRD) as during a Rives-Stoppa ventral hernia repair and similar to the last step of ACS. Again, this involved incision into the posterior rectus sheath approximately 1 cm from the medial edge of the rectus muscle, which was then carried along the length of the entire abdominal wall. The retrorectus plane was then developed towards the linea semilunaris, ending just medial to the perforators to the rectus abdominis (Fig. 4). Once complete, we incised the ventral aspect of the posterior rectus sheath, specifically the posterior lamina of the internal oblique aponeurosis and subsequent transversus abdominis muscle division (TAD) (Fig. 5). The final step was retromuscular dissection (RMD), which involved developing the plane deep to the transversus abdominis from the underlying transversalis fascia and peritoneum beginning lateral to the point of division in the previous step, thus resulting in complete separation of anterior and posterior fascial components towards the psoas (Fig. 6). Myofascial advancement was measured after each step and upper, middle, and lower thirds of the abdomen once each release technique was complete.

Data were compiled for myofascial advancement with maximal tension for each step and along upper, middle, and lower segments of the abdomen as well as the fascia as a whole. Data are represented as mean advancement in centimeters ± standard deviation (SD). A Mann–Whitney U test (Wilcoxon Rank-Sum test) was used to compare each respective step and weight.

Results

Baseline fascial elasticity

Prior to the steps of component separation, we began by establishing baseline fascial advancement (elasticity) following MLL alone. This represents a baseline value not established by historical experiments done by Ramirez, but establishes and reconfirms from our previous study, a point of reference from which further advancement is obtained. We documented an average of 5.0 ± 0.9 cm (range 3.4–6.0 cm) of medial myofascial advancement with application of maximal tension. Mean advancement for all steps is summarized in Table 1.

Operative step (ACS)	ACS Adv	PCS Adv	Operative step (PCS)
Table 1 Anterior fascial advancement for operative steps (mean ± standard deviation)			
Midline laparotomy (MLL)	5.0 ± 0.9 cm	3.7 ± 0.9 cm	Midline laparotomy (MLL)
Subcutaneous flaps (SQF)	6.4 ± 1.1 cm	7.6 ± 1.2 cm	Retrorectus dissection (RRD)
External oblique release (EOR)	7.8 ± 1.3 cm	8.9 ± 1.4 cm	Transversus Abd division (TAD) (TAD)
Retrorectus dissection (RRD)	8.8 ± 1.2 cm	10.2 ± 1.7 cm	Retromuscular dissection (RMD)
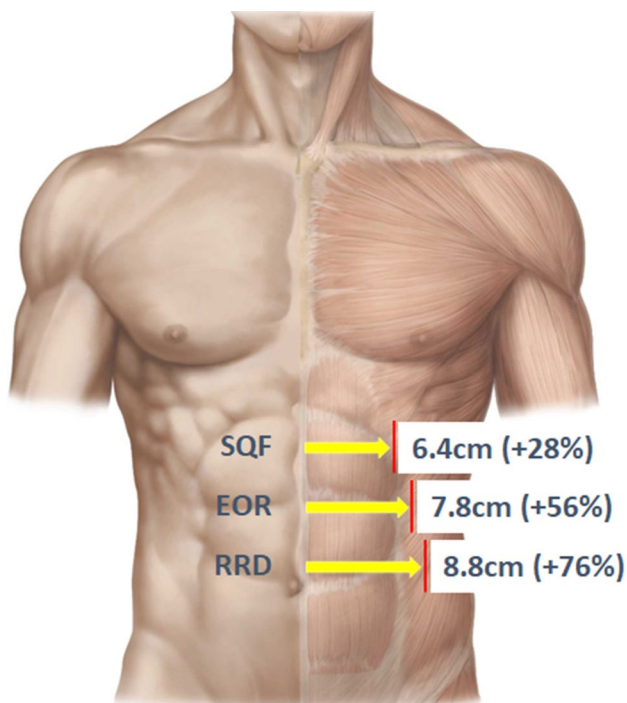
Fig. 7 Anterior fascial advancement following each step of ACS

Fig. 8 Posterior fascial advancement following each step of PCS via the TAR procedure

Fascial advancement with ACS

Following MLL, we began by measuring maximal anterior fascial advancement following creation of SQF flaps which provided a total of 6.4 ± 1.1 cm of advancement, corresponding to a 1.4-cm (28%) gain from baseline. Completion of the EOR provided a total of 7.8 cm ± 1.3 cm of release, a total gain of 2.8 cm (56%) from baseline. Finally, the RRD provided a total of 8.8 ± 1.2 cm of release, or 3.8 cm (76%) from baseline (Fig. 7).

Following completion of ACS, we measured maximal advancement segmentally for the anterior fascia. We noted 6.7 ± 1.2 cm of advancement in the upper abdomen, 9.6 ± 1.4 cm in the mid-abdomen, and 8.7 ± 1.8 cm in the lower abdomen. For the posterior fascia, we found an average of 9.3 ± 1.5 cm for the fascia as a whole. Segmentally, we noted advancement of 8.1 ± 1.4 cm in the upper abdomen, 9.9 ± 1.7 cm in the mid-abdomen, and 9.2 ± 1.6 cm in the lower abdomen.

Fascial advancement with PCS

Following the common MLL to both procedures, we began with RRD which provided 7.6 ± 1.2 cm of AF advancement, corresponding to a 2.6-cm (52%) increase from baseline. Subsequent TAD provided a total of 8.9 ± 1.4 cm of release, a total gain of 3.9 cm (78%) from baseline. Finally, the RMD provided a total of 10.2 ± 1.7 cm of advancement, or 5.2 cm (104%) increase from baseline (Fig. 8).

Following completion PCS, again we measured maximal advancement segmentally for the anterior fascia. We measured 8.1 ± 1.4 cm of advancement in the upper abdomen, 11.4 ± 1.5 cm in the mid-abdomen, and 9.1 ± 1.7 cm in the lower abdomen. For the posterior fascia, we found an average of 11.8 ± 2.4 cm for the fascia as a whole. Segmentally, we measured 11.2 ± 2.3 cm of posterior sheath advancement in the upper abdomen, 14.5 ± 1.9 cm in the mid-abdomen, and 12.6 ± 1.8 cm in the lower abdomen.

Comparative analysis

Ultimately, the ability to advance the anterior rectus fascia remains the purpose of all component separation techniques with the goal of restoring linea alba. Comparing ACS versus PCS techniques for fascia as a whole, we noted an additional 1.4 cm of advancement for PCS (8.8 ± 1.2 cm vs. 10.2 ± 1.7 cm, $p = 0.046$). In the upper abdomen we also noted an additional 1.4 cm of advancement (6.7 ± 1.2 cm vs. 8.1 ± 1.4 cm, $p = 0.010$), while in the mid-abdomen we observed 1.8 cm of advancement in favor of PCS (9.6 ± 1.4 cm vs. 11.4 ± 1.5, $p = 0.011$). Interestingly in the lower abdomen, this advantage was no longer significant 8.7 ± 1.8 cm vs. 9.1 ± 1.7 cm, $p = 0.535$ (Table 2).

Although restoration of the posterior sheath to re-create the visceral sac is of secondary importance, we did note significant advantage in the ability of PCS to provide posterior sheath advancement. This was seen for the fascia as a whole, with an additional 2.5 cm of advancement for PCS (9.3 ± 1.5 cm vs. 11.8 ± 2.4 cm, $p < 0.01$). Segmentally, this advantage was seen across the abdomen with an additional 3.1 cm in the upper abdomen (8.1 ± 1.4 cm vs. 11.2 ± 2.3 cm, $p < 0.01$), 4.6 cm in the mid-abdomen (9.9 ± 1.7 cm vs. 14.5 ± 1.9 cm, $p < 0.01$), and 3.4 cm in the lower abdomen (9.2 ± 1.6 cm vs. 12.6 ± 1.8 cm, $p < 0.01$) (Table 3).

Discussion

Component separation during hernia repair has proven a useful tool in the armamentarium of the general surgeon allowing for the repair of larger and more complex hernia defects. Although there are many techniques described, the ability to obtain myofascial medialization, thus allowing restoration of linea alba, remains the cornerstone of component separation techniques. Both anterior and posterior approaches have proven clinical track records and are valuable tools for reconstructive surgeons. The absolute value obtained for maximal advancement following ACS are in keeping with those reported by Ramirez historically of around 10 cm [1]. However, in our established cadaveric model, we demonstrated that PCS not only offers substantial anterior sheath advancement, but likely more so than the ACS approach.

For epigastric defects, especially in subxiphoid region, obtaining fascial advancement is notoriously difficult and leads to high recurrence rates. In some studies, open repair has been shown to improve high recurrence rates compared to laparoscopic repair [15]. The ability of posterior component separation in restoring linea may perhaps be of greatest significance in the upper and mid-abdomen, where we noted an additional 1.4 and 1.8 cm of advancement, respectively. This corresponds to a relative gain of approximately 20% over the advancement offered by ACS in these segments, and thus provides advancement to cover defects nearly 3 cm larger in the upper abdomen and nearly 4 cm larger in the mid-abdomen. For open repairs, PCS may provide a superior ability to address these defects where every incremental amount of advancement is crucially important.

Although restoration of the posterior fascial layers is not the chief goal of incisional hernia repair, depending on the type of repair being performed, this can certainly be advantageous. For sublay repairs where wide mesh overlap is desired, a concept originally espoused by Wantz [13, 16], complete restoration of the visceral sac allows for mesh to be placed widely as a sublay and may serve to reduce recurrence rates. In our study, PCS demonstrated a markedly superior ability to advance the posterior fascia throughout the abdomen, with over 25% relative advantage to ACS for the fascia as a whole. Segmentally, this advantage grew to over 35% for upper and lower extremes and over 45% for the middle third. When considered bilaterally, this provides coverage for an additional 5 cm overall and up to 9 cm centrally. Although surrogate materials can be used to close the posterior fascia safely, including absorbable mesh bridges [17], in our opinion the ability to restore native tissue is nearly always preferred to foreign

Table 3 Comparative analysis for posterior fascial advancement (mean ± standard deviation)

Fascia location	ACS (cm)	PCS (cm)	Delta	%	p
Whole fascia	9.3 ± 1.5	11.8 ± 2.4	+2.5 cm for PCS	26.9	**< 0.01**
Upper abdomen	8.1 ± 1.4	11.2 ± 2.3	+3.1 cm for PCS	38.2	**< 0.01**
Middle abdomen	9.9 ± 1.7	14.5 ± 1.9	+4.6 cm for PCS	46.4	**< 0.01**
Lower abdomen	9.2 ± 1.6	12.6 ± 1.8	+3.4 cm for PCS	36.9	**< 0.01**

Table 2 Comparative analysis for anterior fascial advancement (mean ± standard deviation)

Fascia location	ACS	PCS (cm)	Delta	%	p
Whole fascia	8.8 ± 1.2 cm	10.2 ± 1.7	+1.4 cm for PCS	15.9	**0.046**
Upper abdomen	6.7 ± 1.2 cm	8.1 ± 1.4	+1.4 cm for PCS	20.9	**0.010**
Middle abdomen	9.6 ± 1.4 cm	11.4 ± 1.5	+1.8 cm for PCS	18.8	**0.011**
Lower abdomen	8.7 ± 1.8 cm	9.1 ± 1.7	n/a	n/a	0.535

materials if given the option. For patients with complex hernia defects and loss of domain, our study demonstrates the PCS provides significant advantages in restoring the posterior fascial components allowing surgeons to more reliably exclude the viscera, especially for mesh placed as a sublay.

Despite the significant parity as far as operative technique in our cadaveric model, when comparing to hernia repair in native tissue, certain limitations exist. As outlined in our original model, the use of cadavers, although fresh and never embalmed, ultimately cannot replicate the true character of live, perfused tissues in a patient. Thus, the absolute numerical values of medialization should be interpreted with caution, though they remain in the realm of the values reportedly historically by Ramirez. We believe the trends of advancement for each step are more revealing as to the physiologic basis for these releases rather than the final numbers. Specifically, we were able to show that each step of both ACS and PCS contributes to the total advancement as a whole rather there being a single maneuver that provides the majority of the advancement. Furthermore, although the entire Ramirez description of ACS was performed, we did the RRD last, whereas it was originally described as the first step. We are not certain whether this change provided any difference in absolute advancement for ACS but may serve as a point of further investigation. As mentioned in our previous work, the cadavers used in this model, similar to our previously published study did not have hernias as would be the parallel during actual surgery. Unfortunately, the scarcity in supply of fresh cadavers with standardized hernia defects is prohibitive to carrying out the study in a timely manner. Finally, the use of maximal tension is somewhat subjective compared to standard weight values. However, clinically we do not use a standard weight or standardized force to medialize the tissues. In fact, we often place the fascia at 'maximal' tension to restore linea alba, sometimes requiring multiple interrupted sutures along the length of fascia for reapproximation. Thus, maximal advancement is perhaps the most clinically relevant value in regard to complex hernia repair with large defects.

Overall, component separation via anterior or posterior approaches provides substantial myofascial advancement. In our model, we observed statistically significant increases in anterior fascial medialization after PCS via TAR versus traditional ACS for the fascia as a whole, but especially in the upper and mid-abdomen. Additionally, PCS demonstrated a markedly superior ability to medialize posterior layers and restore the visceral sac, this is important for sublay repairs with wide mesh overlap. While this study was not designed to provide any treatment recommendations, we advocate PCS via TAR as a reliable and possibly superior alternative for linea alba restoration for reconstructive repairs, especially for large defects in the upper and mid-abdomen.

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