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Anatomical study comparing medialization after Rives-Stoppa, anterior component separation, and posterior component separation ☆

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ABSTRACT

Background: Large incisional hernias require medialization of the rectus abdominis muscles to facilitate tension-free closure. Medialization may be achieved by Rives-Stoppa, anterior component separation, or posterior component separation. This study aims to compare medialization achieved by these techniques in postmortem human specimens.

Methods: First, the Rives-Stoppa procedure was performed. Subsequently, anterior and posterior component separation were performed on one side in each specimen, with each specimen functioning as its own control. Medialization was measured at three levels of the linea alba with three 1-kg weights. Both medialization obtained in addition to initial medialization after opening the linea alba and total medialization were measured. Results are presented as median and interquartile range.

Results: A total of 13 postmortem human specimens were included (Rives-Stoppa $n = 13$, component separation $n = 10$). Additional medialization after Rives-Stoppa was 1.2 cm (IQR: 0.3–2.2) for the anterior rectus sheath and 2.2 cm (IQR: 1.6–3.0) for the posterior rectus sheath (total medialization: 3.9 and 4.5 cm). For the anterior rectus sheath, additional medialization was 2.6 cm (IQR: 1.2–3.6) after anterior component separation and 1.9 cm (IQR: 0.4–3.4) after posterior component separation ($P = .125$, total medialization: 6.5 and 5.7 cm). For the posterior rectus sheath, additional medialization was 3.0 cm (IQR: 2.2–3.7) after anterior component separation and 5.2 cm (IQR: 4.2–5.9) after posterior component separation ($P < .001$, total medialization: 5.8 and 9.4 cm).

Conclusion: Posterior component separation yielded significantly more medialization of the posterior rectus sheath compared with Rives-Stoppa and anterior component separation. Anterior component separation may provide marginally more medialization of the anterior rectus sheath.

Introduction

Incisional hernia (IH) remains a prevalent complication after abdominal surgery. The prevalence of IH ranges between 10% and 20% in the general patient population and may be well over 30% in high-risk patients.[1–3] Moreover, recurrence rates after IH repair may be up to 37%.[4] Therefore, IHs remain a surgical challenge and results in approximately 350,000 surgical procedures per year in the United States alone.[5]

IHs are associated with (severe) physical and aesthetic complaints.[6,7] In addition, repair of large and complex IHs is associated with high morbidity and recurrence rates.[6,8–12] Today, the objective of IH repair is tension-free fascial closure with mesh augmentation.[11–14] To achieve tension-free closure in wide IHs, additional medialization of the rectus abdominis muscles is required. A well-known technique to obtain medialization is the Rives-Stoppa procedure.[15,16] However, medialization achieved by this technique can be insufficient to close large defects. Therefore, component

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separation techniques may be used to obtain additional medialization.[17–19]

Two regularly applied component separation techniques are anterior and posterior component separation. The anterior component separation was first described by Ramirez et al.[19] in 1990. The more recently developed posterior component separation or transverse abdominis release (TAR) was first described by Novitsky et al.[18] in 2012. Both techniques are regularly performed to repair large IHs.[6,17,20] However, data on the exact medialization potencies of these techniques is lacking. The total medialization distance that can potentially be achieved is vital to estimate the IH defect size that can be closed by a certain medialization technique. To date, no study has compared medialization obtained after anterior and posterior component separation techniques.

The extent of total medialization achieved is less suitable to compare different techniques in an experimental setting because it can be influenced by individual patient factors and might differ slightly between the abdominal sides.[21] Therefore, we propose to use the extent of medialization achieved in addition to the initial medialization after opening the linea alba.

The objective of this study was to assess and compare medialization after Rives-Stoppa, anterior component separation, and posterior component separation in postmortem human specimens. The primary outcome measurement was the medialization achieved after Rives-Stoppa, anterior component separation, and posterior component separation in addition to the initial medialization after opening the linea alba. Secondary outcomes comprise total medialization after these three techniques.

Methods

Fresh frozen postmortem human specimens were included. All included postmortem human specimens had consented to tissue donation for scientific purposes. We did not have access to the medical history of the included specimens for this study because of Dutch and European regulations. Specimens with visible or palpable abdominal wall morbidity (eg, herniations) or previous surgery that might compromise measurements were excluded.

The Rives-Stoppa procedure was performed on both sides of the abdominal wall in all specimens. The anterior and posterior component separation procedures were performed on one side in each specimen, such that each specimen functioned as its own control. The side and procedure to start with were randomly assigned. Before the surgical procedure, the abdominal dimensions were measured (ie, circumference at the umbilical level, distance from the xyphoid process to the pubic bone, and the distance from the anterior superior iliac spine [ASIS] to the ASIS).

Rives-Stoppa procedure

A median skin incision from the xiphoid process to the pubic bone was performed. Subsequently, subcutaneous tissue was dissected and the linea was alba identified. The linea alba was then incised longitudinally from the xyphoid process to the pubic bone. If necessary, adhesiolysis was performed. The rectus sheath was opened across its medial edge from the xyphoid process to the pubic bone. Thereafter, the rectus muscle was separated from the posterior rectus sheath until the semilunar line was identified, concluding the Rives-Stoppa procedure. After this, either an anterior component separation or posterior component separation procedure was performed.

Anterior component separation procedure

After the Rives-Stoppa dissection, the subcutaneous tissue was dissected laterally from the anterior rectus sheath until the aponeurosis of the external oblique muscle was identified. Subsequently, the aponeurosis between the rectus sheath and the external oblique muscle was incised up to the external fascia of the internal oblique muscle, leaving the internal oblique muscle intact. Thereafter, the internal and external oblique muscles were separated laterally by blunt dissection, allowing for additional medialization of the anterior and posterior rectus sheath (Fig 1).

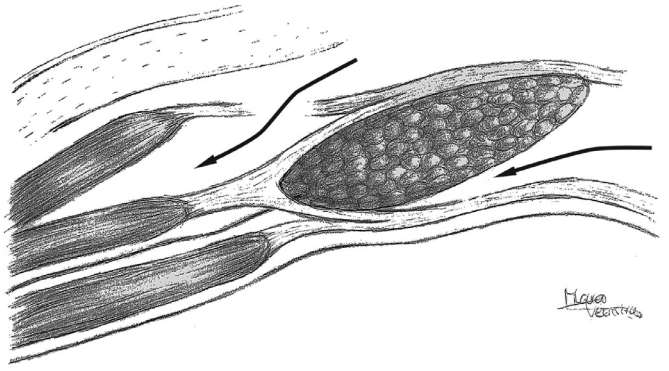

Fig 1. Anterior component separation technique. The external oblique muscle was incised up to the external fascia of the internal oblique muscle, leaving the internal oblique muscle intact. Blunt dissection was performed for medialization of the anterior and posterior rectus sheath.

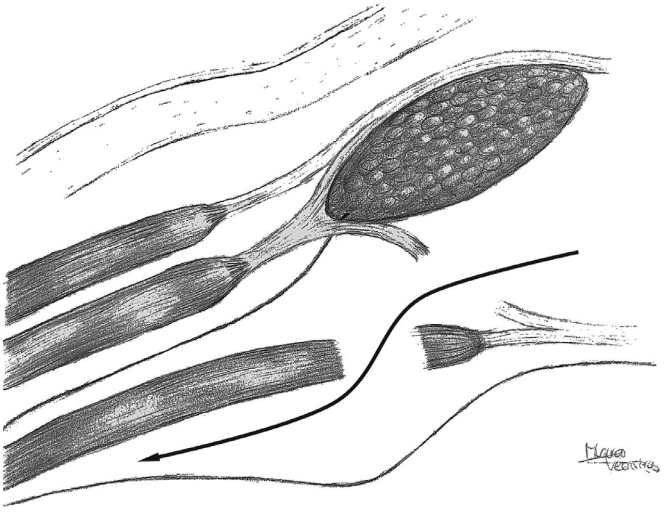

Fig 2. Posterior component separation technique. The lamina posterior of the internal oblique muscle and the transverse abdominis muscle were transected until the fascia transversalis or the peritoneum. Blunt dissection was performed for medialization of the anterior and posterior rectus sheath.

Posterior component separation procedure

After the Rives-Stoppa dissection, the neurovascular bundles were identified. Subsequently, the lamina posterior of the internal oblique muscle and the transverse abdominis muscle were transected until either the fascia transversalis or the peritoneum, depending on the level of the abdomen, was identified. Thereafter, the transversal fascia or peritoneum was separated from the transverse abdominis muscle laterally by blunt dissection, allowing for additional medialization of the anterior and posterior rectus sheath (Fig 2). Any incidental defects created in the transversal fascia or peritoneum were closed with 4-0 sutures.

Measurements

A specially designed test setup was constructed to measure abdominal wall medialization in a standardized and reproducible

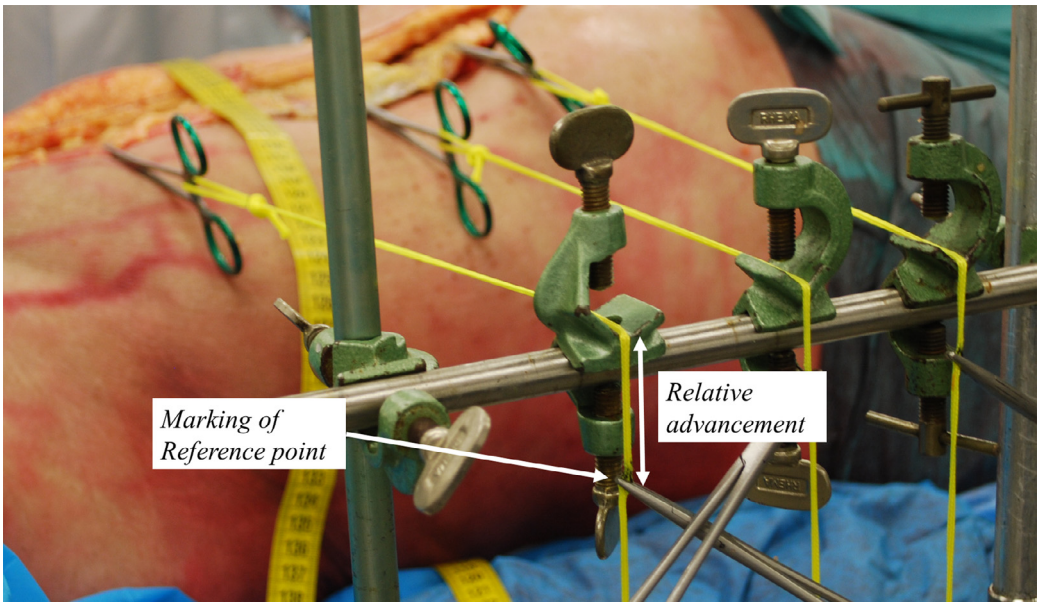

Fig 3. Test setup.

fashion (Fig 3). Three identical Kocher clamps were placed along the anterior and posterior rectus sheath at three marked levels of the abdomen: (1) halfway between the xiphoid process and the umbilicus (upper abdomen); (2) At the umbilicus (mid abdomen); (3) Halfway between the umbilicus and the pubic bone (lower abdomen).

Each clamp was attached to a 1-kg and subsequently 2-kg weight through a pulley system to ensure a force perpendicular to the linea alba. After opening the linea alba, the clamps were attached first, and the initial advancement was marked with a reference point on the wire (Fig 3). Subsequent medialization measurements were added up to this reference point (additional medialization). Therefore, these measurements are relative to the initial advancement after opening the linea alba. Measurements with three 1-kg weights (total 3 kg) and three 2-kg weights (total 6 kg) were performed separately. The measurements with the 2-kg weights were performed to assess whether medialization would increase when more lateral force was applied. All measurements were performed with the use of an analogue-measuring gauge. After the three procedural steps, the following measurements were performed:

- Incision of the linea alba
  - Reference measurement
- Rives –Stoppa procedure
  - Advancement anterior rectus sheath
  - Advancement posterior rectus sheath
- Component separation procedures
  - Advancement anterior rectus sheath
  - Advancement posterior rectus sheath

Supplementary, total medialization measurements were taken only for the final 7 specimens included (7/13 specimens included for Rives-Stoppa and 6/10 specimens included for component separation). A string was fitted from the xiphoid process to the pubic bone to assess total medialization. During the reference measurement, the distance between the string and the edge of the incision through the linea alba was measured at the same 3 aforementioned abdominal levels while applying lateral force with three 1-kg or 2-kg weights.

Reporting of data and statistical analysis

Statistical analyses were performed using the SPSS Software Package (IBM SPSS Statistics for Windows, v 21.0, Armonk, NY). A sample-size calculation was not performed because comparative studies were unavailable. Therefore, no adequate effect estimation could be made. Discrete variables are presented as absolute numbers; continuous variables are presented as median and corresponding interquartile range (IQR) or graphically as mean and standard deviation (SD). Approximated overall medialization was calculated for each specimen as the mean of the medialization measured at the three abdominal levels. Medialization achieved in addition to the initial medialization after opening the linea alba is presented for measurements with three 1-kg weights. Only these relative measurements, representing net tension-free advancement after Rives-Stoppa and component separation, were used for the comparative analysis. Because of the relatively small sample size and non-normally distributed data, the nonparametric Wilcoxon signed-rank test was used.

Results

A total of 13 postmortem human specimens (5 females, 8 males) were included. The Rives-Stoppa procedure was performed on all 13 specimens, and the component separation procedure was performed on 10 specimens. One specimen was excluded from the component separation analysis because of an unnoticed Spigelian hernia, another specimen was excluded because of a large defect in the fascia transversalis (compromising the measurements), and another specimen was excluded because of a measurement error during the component separation procedure. Abdominal dimensions for each specimen are presented in supplement.

Additional medialization achieved after the Rives-Stoppa procedure alone

Additional medialization achieved after Rives-Stoppa alone is graphically presented (Fig 4). Additional medialization for the individual cases is presented in supplement. For the anterior rectus sheath, overall additional median medialization obtained

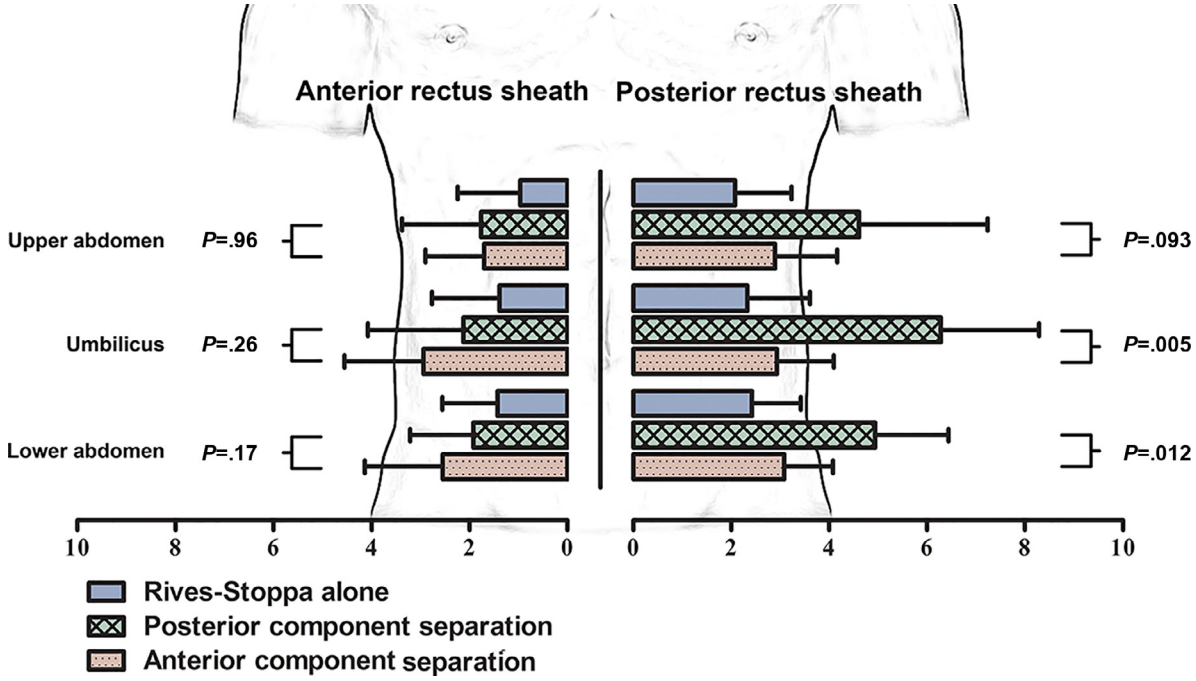

Fig 4. Additional medialization after Rives-Stoppa and component separation techniques.
Medialization additional to initial medialization after opening the linea alba (in centimeters), columns represent mean medialization and error bars represent the standard deviation.

was 1.2 cm (IQR: 0.3–2.2). Additional median medialization was 0.9 cm (IQR: 0–1.9) in the upper abdomen, 1.3 cm (IQR: 0.5–2.5) at the umbilicus, and 1.2 cm (IQR: 0.5–2.6) in the lower abdomen. For the posterior rectus sheath, overall additional median medialization obtained was 2.2 cm (IQR: 1.6–3.0). Additional median medialization was 1.9 cm (IQR: 1.3–3.1) in the upper abdomen, 2.0 cm (IQR: 1.5–3.3) at the umbilicus, and 2.4 cm (1.5–3.4) in the lower abdomen.

Additional medialization of the anterior rectus sheath after component separation

Additional medialization after the component separation procedures is graphically presented (Fig 4). Additional medialization for individual cases is presented in supplement. Overall additional median medialization obtained was 2.6 cm (IQR: 1.2–3.6) after anterior component separation and 1.9 cm (IQR: 0.4–3.4) after posterior component separation ($P = .125$). No statistically significant difference was present between additional medialization after anterior and posterior component separation at any abdominal level (Table 1). When subtracting additional medialization obtained by the Rives-Stoppa procedure alone, median extra medialization was 1.0 cm (IQR: 0.7–1.8) after anterior component separation and 0.5 cm (IQR: 0.1–1.2) after posterior component separation ($P = .84$).

Additional medialization of the posterior rectus sheath after component separation

Additional medialization after component separation procedures is graphically presented (Fig 4). Additional medialization for individual cases is presented in supplement. Overall additional median medialization obtained was 3.0 cm (IQR: 2.2–4.2) after anterior component separation and 5.2 cm (IQR: 4.2–5.9) after posterior component separation ($P < .001$). Statistically significant differences in medialization between the two techniques were present at the umbilicus and lower abdomen (Table 1). When subtracting the additional medialization obtained by the Rives-Stoppa procedure alone, median extra medialization was 0.8 cm (IQR: 0.1–1.3) after anterior component separation and 2.2 cm (IQR: 0.8–3.3) after posterior component separation ($P = .005$).

Total medialization

Total medialization was assessed in seven specimens for the Rives-Stoppa procedure and in six specimens for the component separation procedures. After incising the linea alba (reference measurement), overall median medialization with three 1-kg weights (total 3 kg) was 2.5 cm (IQR: 1.8–3.0). When applying double the weight to the linea alba (three 2 kg weights, total 6 kg), medialization increased by another 2.2 cm (IQR: 1.5–2.0). After the Rives-Stoppa procedure alone, total median medialization was 3.9 cm (IQR: 3.3–5.2) for the anterior and 4.5 cm (IQR: 3.6–6.5) for the posterior rectus sheath. Total medialization after the component separation procedures is summarized in the Table 1 and in Fig 5. Increased lateral force resulted in increased total medialization. However, additional medialization did not increase by applying increased force. For example, when attaching three 2-kg weights, overall additional medialization of the posterior rectus sheath remained similar (2.1 cm, after anterior component separation and 4.5 cm after posterior component separation).

Discussion

In this anatomic study on 13 postmortem human specimens, medialization, in addition to the initial medialization after opening the linea alba, was measured. The posterior component separation resulted in substantially more lateral advancement of the posterior rectus sheath as compared with the anterior component separation (3.0 cm versus 5.2 cm, $P < .001$). Medialization of the anterior rectus sheath was not significantly different between both techniques (2.6 cm versus 1.9 cm, $P = .125$). However, when considering the additional advancement to Rives-Stoppa alone, the anterior component separation may provide marginally more ad-

Table 1
Medialization after anterior and posterior component separation.

	Additional medialization; median (IQR)				Total medialization; median (IQR)		
	Anterior CST	Posterior CST	*P*	N	Anterior CST	Posterior CST	N
Anterior rectus sheath							
Overall	2.6 (1.2–3.6)	1.9 (0.4–3.4)	.125	10	–	–	–
Upper abdomen	1.5 (0.9–2.7)	2.1 (0.1–3.1)	.96	10	5.0 (3.5–6.1)	5.0 (2.0–6.1)	6
Umbilicus	2.7 (1.8–4.1)	1.7 (0.8–4.1)	.26	10	6.5 (5.2–7.6)	5.7 (2.3–7.3)	6
Lower abdomen	2.8 (1.3–3.6)	2.5 (0.2–2.9)	.17	10	6.1 (4.8–7.0)	5.0 (3.7–5.9)	6
Posterior rectus sheath							
Overall	3.0 (2.2–4.2)	5.2 (4.2–5.9)	**< .001**	10	–	–	–
Upper abdomen	2.5 (2.1–4.4)	4.4 (3.3–5.3)	0.093	10	5.5 (4.1–7.1)	6.9 (4.9–9.4)	6
Umbilicus	3.0 (1.8–3.7)	6.0 (5.5–6.5)	**.005**	10	5.8 (4.6–7.8)	9.4 (6.9–11.1)	6
Lower abdomen	3.1 (2.3–3.6)	4.6 (4.0–5.8)	**.012**	10	5.8 (5.4–6.7)	7.4 (5.9–9.3)	6

CST, component separation; *IQR*, interquartile range.
Note: All measurements are presented in centimeters.

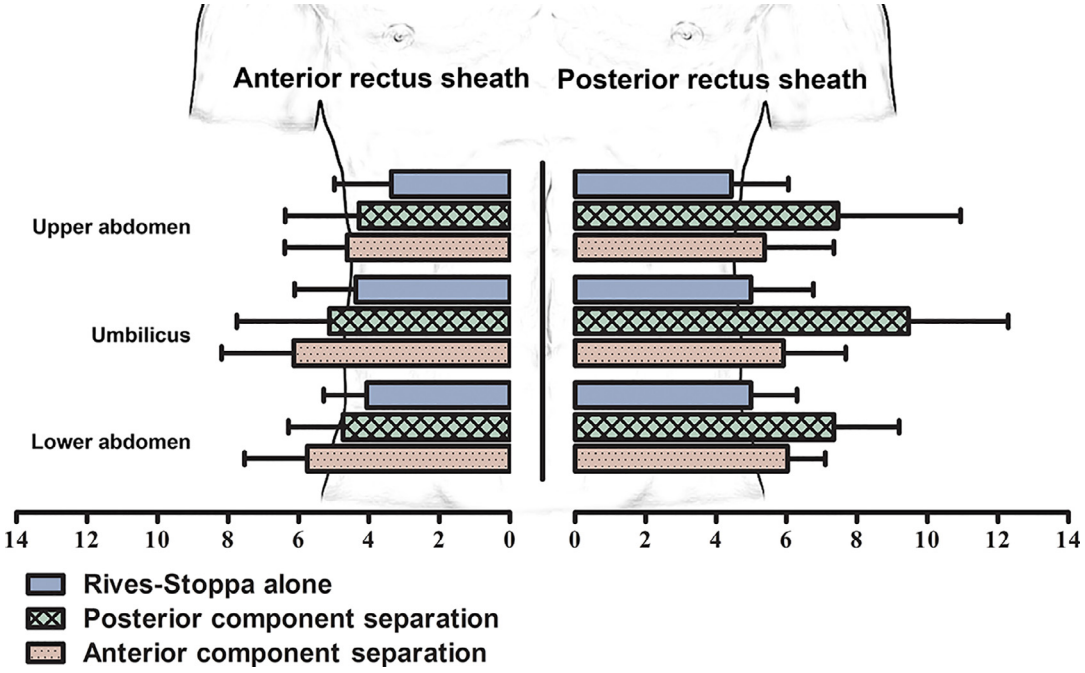

Fig 5. Total medialization after Rives-Stoppa and component separation techniques. Total medialization (in centimeters), columns represent mean medialization, and error bars represent the standard deviation.

vancement of the anterior rectus sheath compared with the posterior component separation (1.0 cm vs 0.5 cm; $P = .84$). Medialization was usually lowest in the epigastric area of the abdomen. Applying more lateral force to the anterior and posterior rectus sheath (ie, pulling with more force on the rectus sheaths) did not result in an increased net effect of the Rives-Stoppa or component separation procedures. However, total medialization did increase when applying more lateral force. This implies that increased medialization, which can be observed when applying increased lateral force, may be obtained through stretching of the fascial layers.

Two previous anatomic studies evaluated the medial advancement after anterior component separation.[19,22] However, both studies used a substantially different methodologic approach compared with this report and only reported total medialization after component separation. Total medialization measurements will likely be influenced more by individual patient variation.[23] Moreover, one of these studies used explanted abdominal walls, and therefore the studied situation deviated substantially from the in vivo condition. Nevertheless, the total medialization reported in the study by van Geffen et al.[22] (2.7–4.5 cm) is reasonably similar to the total medialization found in the present study. The study by Ramirez et al.[19] reported a generally higher total medialization of 5 cm in the epigastric region, 10 cm at the waistline, and 3 cm in the suprapubic region. Both our study and van Geffen et al.[22] found medialization to be lowest in the epigastric region and relatively similar in the umbilical region and lower abdomen. However, the halfway point between the umbilicus and the pubic bone might be too high to find a lower lateral advancement that is likely present in the adjacent suprapubic region.[19] A recently published study by Majumder et al.[24] reported an overall mean total advancement after posterior component separation of 7.9 cm for the anterior and 9.6 cm for the posterior rectus sheath. In our series, we were unable to attain a similarly high total medial advancement for the anterior rectus sheath (median: 5.8 cm). However, in Majumder et al.,[24] the initial total advancement after opening the linea alba and after the Rives-Stoppa procedure was also approximately 2 to 3 cm in comparison to our series. Therefore, the difference in results may be partially attributable to individual variation in the study samples or differences in the

measurement methodology. Considering current and previous results, most advancement of the anterior rectus sheath is already obtained after retrorectus dissection alone.[24] For the posterior component separation in particular, every subsequent procedural step may provide some additional medialization. Dissection of the transverse abdominis muscle probably allows for less lateral strain on the integral rectus sheath, including anterior and posterior layers, providing additional medialization of the anterior rectus sheath.[24]

Considering the limited sample size, exact effects of varying abdominal dimensions on medialization after component separation techniques are difficult to quantify. However, it is conceivable that obtained medialization, in absolute terms, will usually be greater as abdominal dimensions increase (supplement). Considering total medialization reported in present and other studies, fascial closure relatively free of tension may in general be achieved by Rives-Stoppa alone in IHs up to approximately 8 cm in width. In giant IHs, defined as 10 cm or more in width, component separation techniques will likely contribute substantially to tension-free fascial closure.[7,19,22]

To date, two meta-analyses and one comparative observational study comparing clinical results after anterior and posterior component separation have been performed.[20,25,26] Both reports largely included single-armed retrospective studies, compromising direct comparison between both techniques. Nevertheless, neither of these reviews reported increased rates of surgical site infections, complications, reoperations, or recurrences after posterior component separation, reassuring the safety of this still relatively new technique.[17,26] Moreover, Cornette et al.[17] reported a slightly decreased recurrence rate after posterior component separation. However, this could very well be attributable to differences in patient characteristics, given the observational design of the available evidence. Considering the present study data, posterior component separation results in comparable medialization to anterior component separation and allows for the closure of large IHs. The advancement of the anterior rectus sheath was marginally higher after anterior component separation compared with posterior component separation. However, the anterior rectus sheath may withstand up to two times more lateral force as compared with the posterior rectus sheath.[21,27] Therefore, this minor additional fascial strain might be of less concern. Meanwhile, posterior component separation likely allows for nearly tension-free fascial closure of the posterior rectus sheath in most cases, also preventing contact between abdominal contents and the mesh. Apart from component separation alone, recent observational studies have reported positive results of botulin toxin injections and preoperative progressive pneumoperitoneum.[28,29] These techniques may allow for additional medialization and may diminish potentially negative effects of muscle contraction in the postoperative period. However, long-term reports on these techniques, to date, are scarce, and botulin toxin injections could in theory further weaken the abdominal musculature, which might impair long-term outcomes.

Recent meta-analyses did not report substantial differences in clinical outcomes between anterior and posterior component separation procedures.[17,25] Theoretically, posterior component separation has several advantages. After transverse abdominis release, blunt dissection may be performed down to the psoas muscle. This allows for the placement of a mesh with a wider overlap compared with the retrorectus placement.[18] In addition, there is little room for mesh migration because of the large defect overlap. Therefore, less or even no fixation tags or sutures are required.[26,30] Blood supply of the abdominal cutis, subcutis, and rectus muscles is provided by perforators of deep epigastric vessels and may be compromised by subcutaneous dissection, resulting in complications.[31] Anterior component separation has been associated with high rates of skin necrosis and wound infections.[26,32] In addition, in spite of continuing wound drainage, subcutaneous dissection may lead to an increased risk of seromas.[3]

Considering the present study data and recent systematic reviews, prospective clinical trials, although challenging, are needed to assess which component separation technique provides more favorable results in terms of short-term morbidity and long-term recurrence.

This study has several limitations. The specimens included did not suffer from any abdominal defect. Although this differs from the usual patient population treated by component separation techniques, it allowed for objective comparison of both sides of the abdomen. In addition, specimens with IHs would vary greatly, potentially compromising the analysis.[10,33] Another limitation is the postmortem study design. Although fresh frozen specimens were used, tissue characteristics after death deviate from the in vivo situation. However, because within-specimen randomization and measurements relative to the initial advancement after opening the linea alba were performed, comparative analysis remains valid. Nevertheless, total medialization may be larger in an in vivo setting. In addition, muscle contraction during the postoperative period may negatively influence obtained medialization, causing additional fascial strain. Still, measurements in this study would be very difficult, if not impossible, to replicate in vivo. Finally, because of the small sample size, individual variation between the two abdominal sides might have contributed to the observed results. However, the side and procedure at which to begin were randomly assigned before opening the linea alba and therefore these effects will be mostly nondifferential.

In conclusion, based on the results obtained in 13 postmortem human specimens, IHs up to 8 cm in width may in general be closed by Rives-Stoppa alone. For IHs $\geq$ 10 cm in width, component separation techniques will be beneficial to attain tension-free fascial closure. Anterior component separation may provide marginally more medialization of the anterior rectus sheath as compared with posterior component separation. Posterior component separation yielded substantially more medial advancement of the posterior rectus sheath as compared with Rives-Stoppa and anterior component separation.

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Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.surg.2018.11.013.

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