Prospective comparative study between open perforator-preserving anterior component separation and transversus abdominis release operation in patients with large midline incisional hernia

Mahmoud Abdebaky Mahmoud, Ibrahim Magid Abdel-Maksoud, Ahmed Gamal Eldin Osman

Department of General Surgery, Faculty of Medicine, Ain Shams University, Cairo, Egypt

Correspondence to Mahmoud Abdebaky Mahmoud, MD, Department of General Surgery, Faculty of Medicine, Ain Shams University, Cairo 11772, Egypt. Mob: + 01011832904; e-mail: mahmoudhamza2222@gmail.com

Received: 11 November 2021
Accepted: 30 November 2021
Published: 10 October 2022

The Egyptian Journal of Surgery 2022, 41:252–261

Background
Ventral hernia repair is one of the most common operations performed nowadays. Ventral hernia presents a true challenge to the surgical team especially when huge and complex.
Objective
To evaluate postoperative morbidity and recurrence rate when using transversus abdominis release (TAR) technique in the management of large midline incisional hernia in comparison with open perforator-preserving anterior component separation. This study was conducted at Ain Shams University Hospitals.
Patients and methods
This was a randomized prospective comparative study that was carried out at Ain Shams University Hospitals on 70 patients diagnosed as having large midline incisional hernia with a defect equal to or more than 10 cm in width and operated upon between February 2018 and October 2019 with minimal follow-up of 24 months postoperatively. The patients were treated using TAR technique and open perforator-preserving anterior component separation.
Results
The perforator-preserving technique has less operative time by ~38 min when compared with the TAR technique, as the mean±SD operative time in TAR was 259.17 ± 43.29 min, whereas in the perforator-preserving technique was 221.62 ± 51.45 min. The postoperative pain assessment at 48 h postoperatively shows that the mean visual analog scale score for group A (TAR) was 5.86 ± 1.62 and for group B was 4.55 ± 1.51.
We also found that the mean hospital stay was higher when performing the TAR technique (6.6 days), whereas it was 4.25 days after the perforator-preserving approach. There is nearly equal percentage of postoperative wound complications and also no statistically significant different in the rate of recurrence between both methods, and incidences of wound complication and recurrence are significantly less than the classic commonly used method of anterior component separation.
Conclusion
After this comparative study, both TAR and perforator-preserving technique are effective and reliable methods in experienced hands, and if there is no special indication for either of them, the choice between both should depend on surgeon preference and experience.

Keywords:
large midline incisional hernia, transversus abdominis release, ventral hernia

Egyptian J Surgery 2022, 41:252–261

1110-1121

Introduction

Ventral abdominal wall hernias present a growing challenge that complicates 11–23% of all abdominal laparotomies [1].

The high incidence of hernia surgery has led to increase in the usage of reconstructive techniques. The goal of most, if not all, herniorrhaphies should be preservation of the functions of abdominal wall with autologous tissue repair strengthened by mesh reinforcement [2].

Anterior component separation techniques typically involve release of the external oblique muscle and fascia. The traditional approach described by Ramirez involves creation of large skin flaps and associated significant wound morbidity in up to 63% of cases [3].

Less-invasive modifications are known to decrease skin flaps and wound complications, but limit mesh placement to intraperitoneal underlay in most of cases [4].

For moderate-sized defects, classic Rives-Stoppa retrorectus repairs provide durable outcomes with low morbidity [5].

However, the major limitations of the classic retrorectus repair include limited medial myofascial advancement and lack of sufficient sublay space for wide overlap of the visceral sac in many hernias, fraught with disadvantages of limited myofascial medialization and/or neurovascular bundle damage [6,7].

Open perforator-preserving anterior component separation allows medial myofascial advancement, preserving continuous blood flow to anterior abdominal wall. Moreover, it does not need endoscopic instruments but still provides narrow space for retromuscular mesh placement [8].

To address the shortfalls of the traditional retromuscular repairs, Novitsky has recently developed another novel technique of posterior component separation using transversus abdominis muscle release [9], which allows for significant posterior rectus fascia advancement, wide lateral dissection, and preservation of the neurovascular supply of the rectus abdominis muscle and provides a large space for mesh sublay, but it allows less medial advancement of anterior sheath than the anterior component separation [9].

These techniques allow for medialization of the abdominal wall components without raising subcutaneous flaps.

Aim

This work aims to prospectively evaluate postoperative morbidity and recurrence rate when using transversus abdominis release (TAR) technique in the management of large midline incisional hernia in comparison with open perforator-preserving anterior component separation. This study was conducted at Ain Shams University Hospitals.

Patients and methods

Patients

This was a randomized prospective comparative study that was carried out at Ain Shams University hospitals on 70 patients diagnosed as having large midline incisional hernia with a defect equal to or more than 10 cm in width and operated upon between February 2018 and October 2019 with minimal follow-up of 24 months postoperatively. This research was performed at the Department of General Surgery, Ain Shams University Hospitals. Ethical Committee approval and written, informed consent were obtained from all participants.

An informed consent has been taken from all patients who accepted to participate in the study.

Inclusion criteria were as follows: clinically diagnosed large incisional hernia, age 20–80 years old, primary or recurrent hernia for the first time and without previous mesh, defect size 10 cm or more, midline hernia, and clean operative field.

Exclusion criteria were as follows: hernia with a defect less than 10 cm, recurrent hernia for many times, recurrent hernia after previous component separation or mesh repair, non-midline hernia, and patients having stoma either ileostomy or colostomy.

All of the patients in this study underwent procedures under the care of one surgical team under the supervision of a consultant surgeon where odd numbers were involved in group A and even numbers were involved in group B.

The first group (A) included 35 patients who underwent TAR with retromuscular polyprolene mesh placement.

The second group (B) included 35 patients who underwent open perforator-preserving anterior component separation and also with retromuscular insertion of polyprolene mesh.

Methods

All patients were subjected to the following:

Personal history, including the following:

(1) Age.
(2) Weight.
(3) Occupation.
(4) Special habits of medical importance particularly smoking.
(5) History of present illness.
(6) Number of previous laparotomies.
(7) Other body systems such as chest symptoms and gastrointestinal tract problems like constipation and urinary problems, especially prostatism.
(8) Past history of medical diseases, especially diabetes, drug allergy, previous blood transfusion, and previous operations.

Clinical examination: local examination of the hernia defect size, contents, and reducibility.

Investigations

Laboratory investigations included complete blood picture, coagulation profile, liver and kidney function tests, fasting blood sugar, chest radiograph, and pelvi-abdominal ultrasound. Special investigations were requested for patients with specific complaints such as pulmonary function tests for patients with manifestations of chronic obstructive airway disease, ECG for patients above the age of 40 years, and pelvi-abdominal computed tomography with contrast for patients with history of abdominal malignancies.

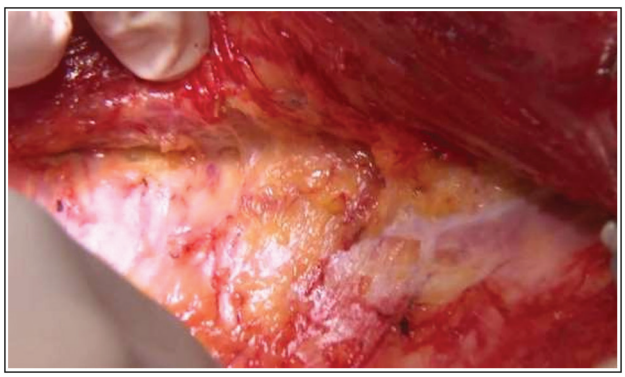
Intraoperative technique for group A was as follows (Figs 1–10):

(1) After a complete adhesiolysis after midline laparotomy, the posterior rectus sheath is incised about 0.5–1 cm from its edge. This is done at the level of the umbilicus.
(2) The retromuscular plane is developed toward the linea semilunaris, visualizing the junction between the posterior and anterior rectus sheaths.

Figure 1

Opening the posterior rectus sheath.

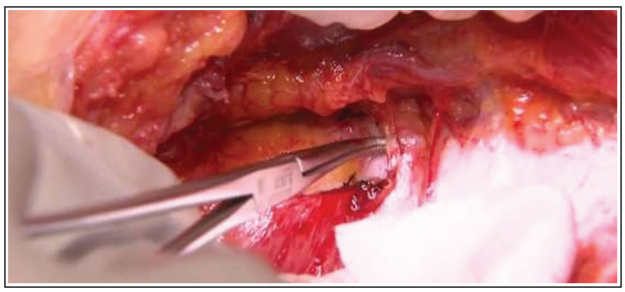
Figure 2



Retrorectus space with preserved neurovascular bundles.

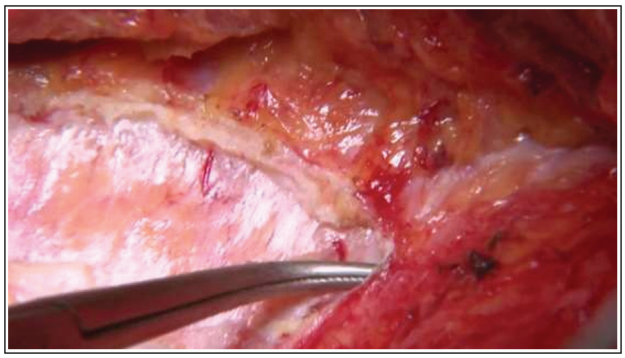
(3) The perforators to the rectus muscle (branches of the thoracoabdominal nerves, penetrating the lateral edge of the posterior rectus sheath) are visualized and preserved.
(4) Starting in the upper third of the abdomen, about 0.5 cm medial to the linea semilunaris, the posterior rectus sheath is incised to expose the underlying transversus abdominis muscle.
(5) The muscle is divided along its medial edge using diathermy.
(6) This step is initiated in the upper third of the abdomen where medial fibers of the transversus abdominis muscle are easier to identify and separate from the underlying fascia.

Figure 3



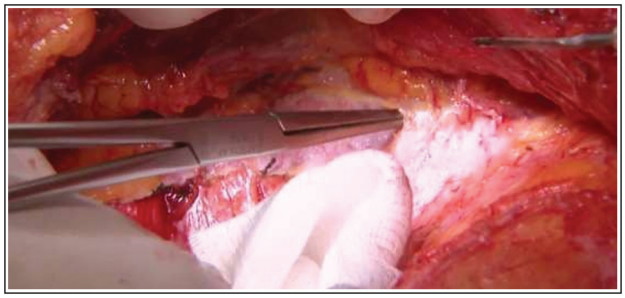
Division of transversus abdominis muscle (a).

Figure 4



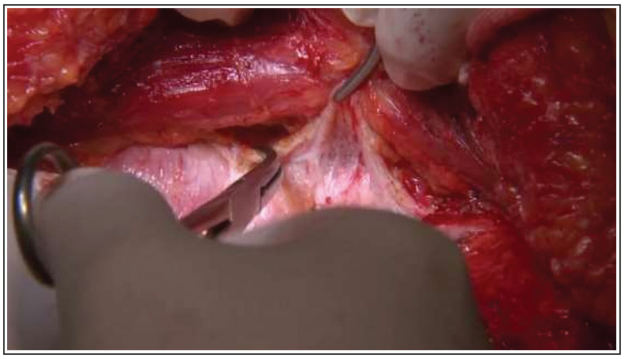
Division of transversus abdominis muscle (b).

Figure 5



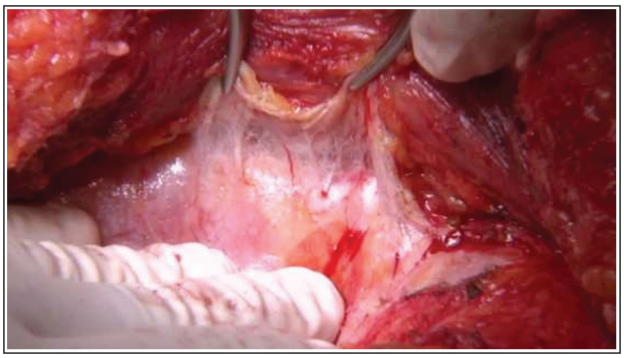
Division of transversus abdominis muscle (c).

Figure 6



Entry to the retromuscular space dorsal to transversus abdominis.

Figure 7



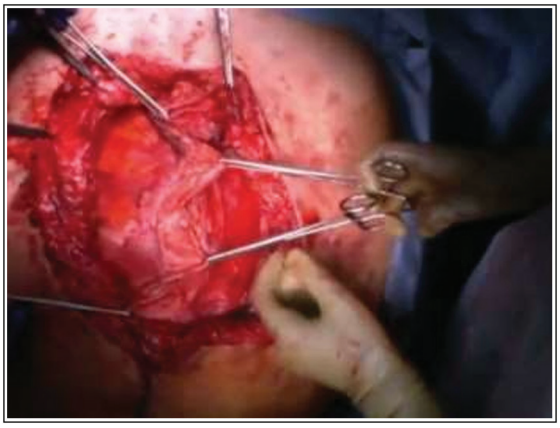
Exposure of fascia transversalis after raising cut edge of transversus abdominis muscle.

Figure 8

Dissection of retromuscular space by electro-cautery.

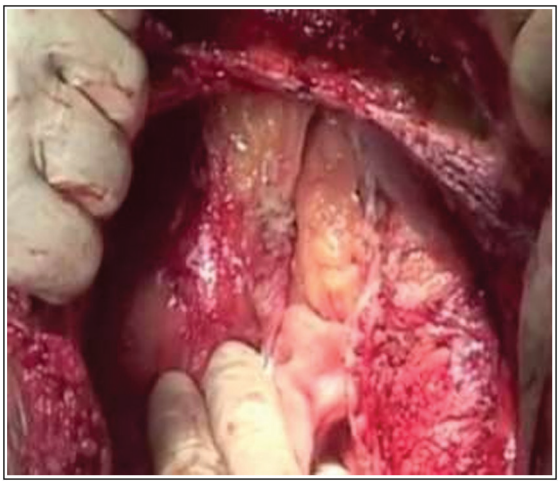
(7) This step facilitates entrance to the space between the transversalis fascia and the divided transversus abdominis muscle.
(8) This space is contiguous with the retroperitoneum and can be extended laterally to the psoas muscle, and if necessary, extended superiorly to the costal margins and dorsal to the sternum by dragging the peritoneum/transversalis fascia off the diaphragm developing the retroxyphoid space and extended inferiorly to the space of Retzius (in front of the urinary bladder) to expose the pubis symphysis and both Cooper ligaments.
(9) Once a similar release is performed on both sides, the posterior rectus sheaths are reapproximated in the midline and closed.

Figure 9



Approximation of posterior sheath.

Figure 10



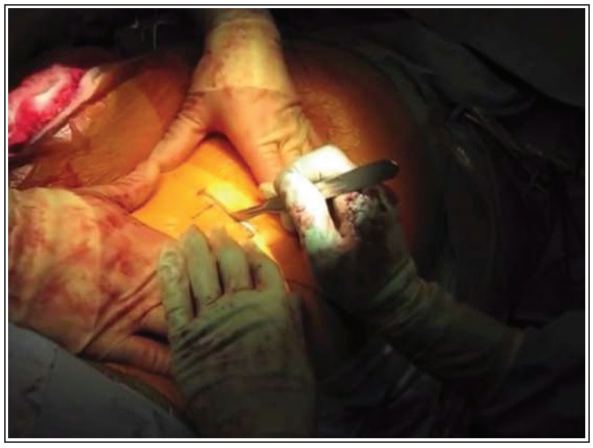
Posterior and anterior sheaths after release.

(10) A nonabsorbable mesh is placed as a sublay in the retromuscular space and fixated by full-thickness, transabdominal sutures.
(11) The inferior edge of the mesh is fixated to both Cooper ligaments by interrupted sutures.
(12) Closed suction drains are placed on top of the mesh. The anterior rectus sheaths are reapproximated in the midline to restore the linea alba ventral to the mesh.

Intraoperative technique for group B was as follows (Figs 11–16):

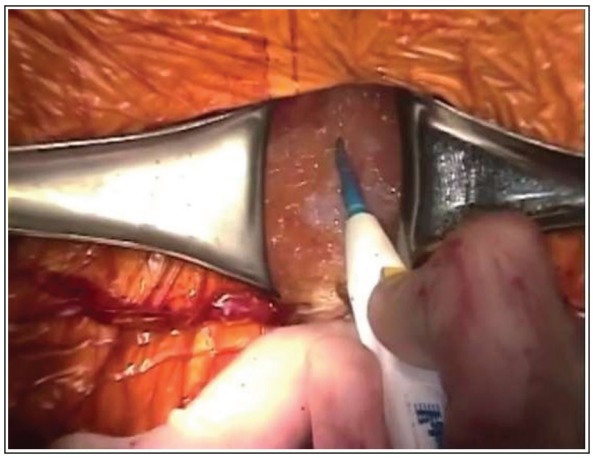
(1) A midline incision and dissection of the sac from skin and subcutaneous tissue.
(2) Elevation of the skin and subcutaneous flap to a point 4–5 cm lateral to linea alba.
(3) Incision of the posterior rectus sheath just lateral to linea alba and developing the retromuscular space.

Figure 11



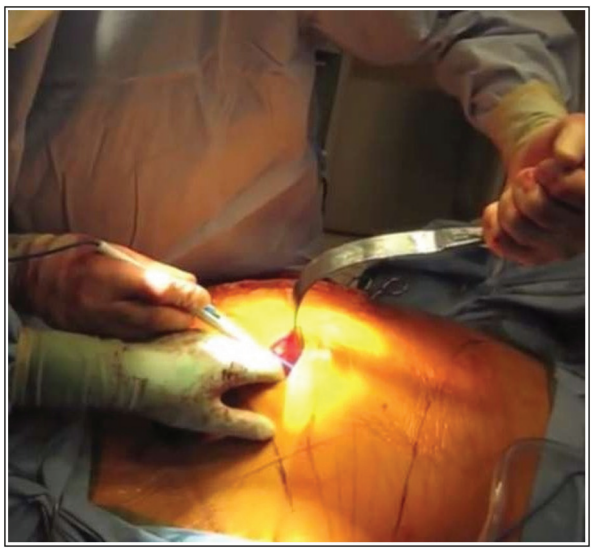
Transverse skin incision with its center just lateral to linea semilunaris.

Figure 12



Incision till reaching external oblique.

Figure 13

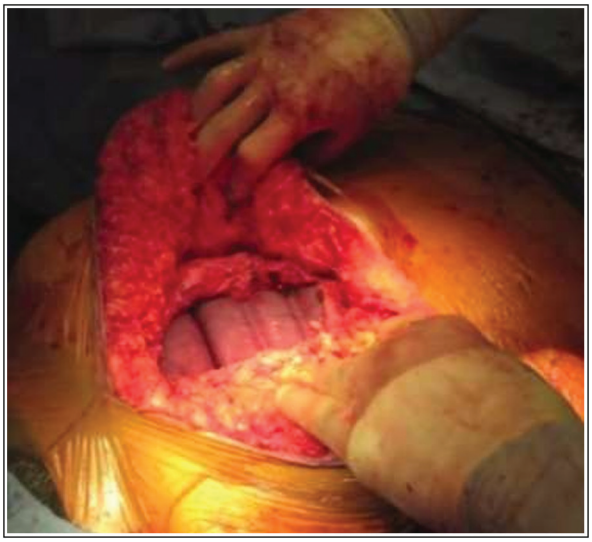


Rising of subcutaneous flap superiorly.

Figure 14

Opening of external oblique aponeurosis.

Figure 15



Insertion of mesh at retrorectus space after closure of posterior sheath.

Figure 16

Image at the end of the procedure.

(4) On each side, a 6-cm transverse skin incision is done between costal margin and iliac crest with its center 2 cm lateral to linea semilunaris and dissected down to external oblique aponeurosis.
(5) Rising of subcutaneous flap superiorly till above the costal margin and inferiorly nearly to the inguinal canal.
(6) Opening of external oblique aponeurosis longitudinally from costal margin to anterior superior iliac spine at the level 1–2 cm lateral to linea semilunaris and then dissect the plane between oblique muscles.
(7) Closure of posterior rectus sheath at midline with insertion of the mesh in the retromuscular plane with fixation of the mesh anteriorly.
(8) Restoration of linea alba above the mesh.
(9) Insertion of closed suction drain at the retromuscular plane and at each of transverse wounds and subcutaneous drain if needed. Closure of subcutaneous and skin layers.

Both groups were compared regarding the following:

(1) Operative time.
(2) Hospital stay.
(3) Postoperative complications.
(4) Recurrence detected either clinically or by pelvi-abdominal computed tomography with contrast.
(5) Wound infection and dehiscence.
(6) Postoperative pain.
(7) Seroma or hematoma.
(8) Postoperative ileus.

Outcomes were evaluated at hospital and then after 2 weeks, after 6 months, and after 1 year.

Statistical analysis

Data were collected, revised, coded, and entered to the Statistical Package for the Social Sciences (IBM SPSS). Statistical analysis was done using IBM SPSS statistics for windows, Version 23.0 (IBM Corp., Armonk, NY, USA). The quantitative data were presented as mean, SDs, and ranges when their distribution was found parametric. Moreover, qualitative variables were presented as number and percentages. The comparison between groups with qualitative data was done using χ^2 test and Fisher's exact test, which was used instead of the χ^2 only when the expected count in any cell was found less than 5. The comparison between two independent groups with quantitative data and parametric distribution was done using independent *t* test. The confidence interval was set to 95%, and the margin of error accepted was set to 5%. So, the *P* value was considered significant as follows: *P* value more than 0.05: nonsignificant, *P* value less than 0.05: significant, and *P* value less than 0.01: highly significant.

Results

This study was conducted on 70 adult patients presenting with large midline incisional hernias. They were divided into two equal groups of 35 patients each. The first group (A) included 35 patients who were operated upon by the TAR posterior component separation technique, whereas the second group (B) included 35 patients who were operated upon by the perforator-sparing anterior component separation technique.

All participants underwent surgical and anesthesiological evaluation at the time of randomization into the study. They also underwent a postoperative evaluation at the hospital and at 2 weeks, 30 days, and 6 months after the surgical procedures.

Patients were followed up by routine clinical examination for 12 months to calculate the incidence of postoperative complications and recurrence rate during the period of follow-up.

Preoperative parameters

In total, 70 hernias were operated on. The demographic data and preoperative data are summarized in Table 1.

The age of the patients included in group A (TAR) ranged from 23 to 62 years, with a mean age of 47.23 ± 7.46 years. However, the age of the patients in group B (perforator preserving) ranged from 22 to 64 years, with a mean age of 45.67 ± 10.56 years.

There was no significant difference between both groups regarding sex, with more male patients in the group that underwent perforator-preserving ACS (male : female ratio=20 : 15) and nearly the same number of males and females (22 : 13) in the group that underwent TAR operation.

The number of diabetics in group A (TAR) was seven (20%) patients, whereas in group B was 10 (28.57%) patients, with a *P* value of 0.403 (nonsignificant difference).

Smokers were 13 (37.14%) patients in TAR group and nine (25.71%) patients in perforator-preserving group, and all were males, with *P* value of 0.303 (nonsignificant).

Further history was taken and patients were examined well at the preoperative visit to exclude patients with defect size less than 10 cm. Moreover, patients with previous mesh repair were excluded as well as patients with present stoma or intestinal fistula.

Intraoperative assessment

The mean operative time (in min) in group A (TAR) was 259.17 ± 43.29 min, whereas in group B (perforator) was 221.62 ± 51.45, showing a significant difference (*P*=0.002) between both groups, as the mean time was shorter in perforator group by about 38 min (Table 2).

Postoperative parameters

Postoperative pain evaluation

Using the visual analog scale score, the postoperative pain was assessed 48 h postoperatively. The mean visual analog scale score for group A (TAR) was 5.86 ± 1.62 and for group B was 4.55 ± 1.51. There was a highly significant difference between the two groups, with *P* value of 0.001 (Table 3).

Early postoperative wound complications

Regarding the wound complications (surgical site occurrence) in both groups, a higher percentage of patients experienced wound complications in the TAR group (25.7%) than the perforator group (20.0%), but it did not reach statistical significance (*P*=0.569).

Nine patients in TAR group and seven in perforator group experienced wound complications, which were as follow:

Two patients in the TAR group and one in the perforator group developed seroma needed frequent evacuation.

Two patients in the perforator group developed hematoma, who were managed by close follow-up, whereas in the TAR group, three patients developed hematoma: two of them needed to be reoperated and presented after 6 months with recurrent hernia, which was a small defect at the epigastric region above the edge of the inserted mesh.

Two patients in the TAR group were complicated with wound infection, and they developed significant wound dehiscence, which was managed by vacuum dressing.

Three patients in the perforator group developed wound infection: two of them were in the form of turbidity

Table 1 Patient demographics

	TAR group *N*=35	Perforator group *N*=35	Test value	*P* value	Significance
Age					
Mean±SD	47.23 ± 7.46	45.67 ± 10.56	0.714a	0.478	NS
Range	23–62	25–67			
Sex [*n* (%)]					
Female	22 (62.9)	20 (57.1)	0.238	0.626	NS
Male	13 (37.1)	15 (42.9)			
DM [*n* (%)]					
No	28 (80.0)	25 (73.43)	0.699	0.403	NS
Yes	7 (20.0)	10 (28.57)			
Smoking [*n* (%)]					
No	22 (62.86)	26 (74.29)	1.061	0.303	NS
Yes	13 (37.14)	9 (25.71)			

DM, diabetes mellitus; TAR, transversus abdominis release. *P* value more than 0.05: nonsignificant (NS); *P* value less than 0.05: significant (S); *P* value less than 0.01: highly significant (HS). [a]Independent *t* test.

Table 2 Operative time in both groups

Operative time	TAR group *N*=35	Perforator group *N*=35	Test value	*P* value	Significance
Mean±SD	259.17 ± 43.29	221.62 ± 51.45	–3.304a	0.002	HS
Range	165–375	120–355			

P value more than 0.05: nonsignificant (NS); *P* value less than 0.05: significant (S); *P* value less than 0.01: highly significant (HS). [a]Independent *t* test.

Table 3 Comparison between both groups as regard postoperative pain using the visual analog scale

Pain score	TAR group *N*=30	Perforator group *N*=30	Test valuea	*P* value	Significance
Mean±SD	5.86 ± 1.62	4.55 ± 1.51	–3.290	0.001	HS
Range	3–9	2–8			

TAR, transversus abdominis release. [a]Independent *t* test. *P* value more than 0.05: nonsignificant (NS); *P* value less than 0.05: significant (S); *P* value less than 0.01: highly significant (HS).

and positive culture seen in the inserted drain and managed only with antibiotics. Another two patients developed wound dehiscence and were also managed by vacuum dressing.

The postoperative wound complications are shown in Table 4.

The postoperative outcome of the studied patients

Regarding reoperation, two patients in the whole study were reoperated for evacuation of hematoma after the TAR technique.

Postoperative ileus was higher in the TAR group, which may be attributed to more adhesiolysis needed in this group, but it was statistically nonsignificant (*P*=0.403), as shown in Table 5.

The mean postoperative hospital stay was 6.6 versus 4.25 days in the TAR group and the perforator group, respectively. This difference was significant (*P*=0.001).

Regarding readmission, three (8.57%) patients in the TAR group were readmitted after initial discharge by hematoma, which was reoperated upon. In the perforator group, four (11.43%) patients were readmitted by wound infection and dehiscence and were managed conservatively.

Regarding recurrence, there were five recurrent cases in both groups: two in the TAR group and the other three were in the perforator-preserving group.

Discussion

Acceptable results for incisional hernia repairs continue to be reported with a variety of techniques. Fascial component separation restores a close approximation of the original anatomy and physiology. The weak point of the classic fascial component separation technique, which is a large flap, impairing skin vascularity and increasing wound morbidity, is not found in both techniques in this study. Moreover, there is no

Table 4 Postoperative wound complications

	TAR group	Perforator group	Test value*	*P* value	Significance
SSO [*n* (%)]					
No	26 (74.3)	28 (80.0)	0.324	0.569	NS
Yes	9 (25.7)	7 (20.0)			
Infection [*n* (%)]					
Yes	2 (5.7)	3 (8.6)	0.215	0.642	NS
Dehiscence [*n* (%)]					
Yes	2 (5.7)	2 (5.7)	0.000	1.000	NS
Seroma [*n* (%)]					
Yes	2 (5.7)	1 (2.9)	0.348	0.555	NS
Hematoma [*n* (%)]					
Yes	3 (8.6)	2 (5.7)	0.215	0.642	NS

SSO, surgical site occurrence; TAR, transversus abdominis release. *χ^2 test. *P* value more than 0.05: nonsignificant (NS); *P* value less than 0.05: significant (S); *P* value less than 0.01: highly significant (HS).

Table 5 Postoperative outcome of the studied patients

	TAR group [*n* (%)] *N*=35	Perforator group [*n* (%)] *N*=35	Test value*	*P* value	Significance
Reoperation					
No	33 (94.29)	35 (100.0)	2.058	0.151	NS
Yes	2 (5.71)	0			
Ileus					
No	25 (71.43)	28 (80.0)	0.699	0.403	NS
Yes	10 (28.57)	7 (20.0)			
Hospital stay					
Mean±SD	6.6±2.81	4.25±2.68	–3.580[a]	0.001	HS
Range	4–17	3–14			
Readmission					
No	32 (91.43)	31 (88.57)	0.158	0.690	NS
Yes	3 (8.57)	4 (11.43)			
Recurrence					
No	33 (94.29)	32 (91.43)	0.215	0.642	NS
Yes	2 (5.71)	3 (8.57)			

TAR, transversus abdominis release. *χ^2 test. *P* value more than 0.05: nonsignificant (NS); *P* value less than 0.05: significant (S); *P* value less than 0.01: highly significant (HS).

available randomized controlled study comparing both techniques.

In both techniques, we used the same type of synthetic polyprolene mesh and at the same retromuscular position. However, in TAR, the mesh was significantly large.

We tried to compare both techniques conducted on the same disease and within a clean operative field to guide the surgeons in management of this relatively abdominal wall reconstruction, as the choice of appropriate component separation method is still difficult.

The study enrolled 70 patients with large midline incisional hernia who underwent repair in an elective setting during the years 2019–2021, and the patients were divided into two groups:

The first group (A) included 35 patients who underwent TAR with retromuscular polyprolene mesh placement.

The second group (B) included 35 patients who underwent open perforator-preserving anterior component separation and also with retromuscular placement of polyprolene mesh.

Patients in both groups were similar with respect to age. The patients' ages ranged from 20 to 80 years, with a mean age in both groups of around 46 years. There is no significant difference regarding male-to-female ratio between the two groups, with more male patients in the group that underwent perforator-preserving ACS and nearly the same number of males and females in the group that underwent TAR operation.

The age group in our study is younger than that in American studies for TAR done by Novitsky *et al.* [10], where the mean age was 58 years, and Krpata *et al.* [11], where the mean age was 54.7 years. Moreover, it was also younger than the study done by Ghali *et al.* [12] involving perforator preservation, where the mean age was 63.4 years.

Regarding comorbidities, there was no significant difference between the two groups in our study as well as between our study and Novitsky *et al.* [10] for TAR and Ghali *et al.* [12] for perforator-preserving group. The percentage of diabetics ranged from 20 to 23% in all groups.

The patient demographics between two groups in our study showed no statistically significant difference.

Mean operative time in the TAR group was 259.17 ± 43.29 min and was very close to the operation time taken during a prospective trial conducted by Novitsky *et al.* [10], as their mean operation time was 251 min, and the study by Krpata *et al.* [11], where the mean time was 228 min.

In our study, the mean operative time was significantly lower in the perforator-preserving ACS technique by about 38 min, as it was 221.62 ± 51.45 min., with *P* value 0.001. When comparing early postoperative wound complications, which included seroma, hematoma, wound infection, and wound dehiscence, previous comparative studies compared between either of these two techniques and the classic open anterior component separation, which had a major disadvantage of significant wound morbidity; however, in our study, there was no significant difference between the two techniques.

In our study, the incidence of seroma was equal between two groups, hematoma was higher in TAR technique, whereas wound infection and dehiscence were higher in the perforator-preserving technique.

The early wound complications in the perforator preserving group is comparable to that in other studies, taking in consideration that they used biologic mesh or even repair without mesh, as shown in the study by Clarke [13].

Our study results were near to the studies of Ghali *et al.* [12], Butler and Campbell [14], and Patel *et al.* [15], which used mesh in their repair, but higher than those of Saulis and Dumanian [8] and Clarke [13], which did not insert a mesh.

The mean postoperative hospital stay was 6.6 and 4.25 days in TAR group and perforator group, respectively. This period is comparable to the median length of hospitalization for patients included in the study by Novitsky *et al.* [10], which was 5.9 days, ranging from 2 to 34 days.

In our study, postoperative ileus and postoperative pain score were lower in the perforator-preserving group.

In the studies comparing TAR or perforator-preserving group with the classic open ACS technique, there is always a higher incidence in recurrence in the classic technique, which may be attributed to significantly higher incidence of wound complication, which is a major risk factor for recurrence. In our study, among 70 patients, five cases presented with recurrence during

1 year of follow-up—two of them was operated by TAR technique and the other three were operated by perforator-preserving technique.When comparing recurrence rate after TAR technique in previous studies, the rate is relatively high in the studies by Petro *et al.* [16] and Fayezizadeh *et al.* [17], but this may be attributed to the high rate of contaminated operative fields in those studies. However, the rates of recurrence in the studies by Krpata *et al.* [11] and Novitsky *et al.* [10] studies are nearly the same as in our study in the TAR group.

Recurrence after the perforator-preserving technique was relatively high in the studies by Saulis and Dumanian [8] and in Clarke [13], which may be attributed to non-mesh insertion. However, in other studies, they showed nearly similar results to our study.

Conclusion

After this comparative study, both TAR and perforator-preserving technique are effective and reliable methods in experienced hands and if there is no special indication to one of them, the choice between both should depend on surgeon preference and experience. However, the TAR technique is lengthy and more painful postoperatively, with more hospital stay postoperatively than the perforator-preserving technique.

Financial support and sponsorship

Nil.

Conflicts of interest

No conflict of interest.

References

1 Cassar K, Munro A. Surgical treatment of incisional hernia. Br J Surg 2002; 89:534–545.

2 Flum DR, Horvath K, Koepsell T. Have outcomes of incisional hernia repair improved with time? A population-based analysis. Ann Surg 2003; 237:129–135.

3 de Vries Reilingh TS, van Goor H, Charbon JA, Rosman C, Hesselink EJ, van der Wilt GJ, *et al*. Repair of giant midline abdominal wall hernias: 'components separation technique' versus prosthetic repair: interim analysis of a randomized controlled trial. World J Surg 2007; 31:756–763.

4 Lowe JB, Garza JR, Bowman JL, Rohrich RJ, Strodel WE. Endoscopically assisted 'components separation' for closure of abdominal well defects. Plast Reconstr Surg 2000; 105:720–729.

5 Mehrabi M, Jangjoo A, Tavoosi H, Kahrom M, Kahrom H. Long-term outcome of rives-Stoppa technique in complex ventral incisional hernia repair. World J Surg 2010; 34:1696–1701.

6 Carbonell AM, Cobb WS, Chen SM. Posterior components separation during retromuscular hernia repair. Hernia 2008; 12:359–362.

7 Iqbal CW, Pham TH, Joseph A, Mai J, Thompson GB, Sarr MG. Long-term outcome of 254 complex incisional hernia repairs using the modified Rives-Stoppa technique. World J Surg 2007; 31:2398–2404.

8 Saulis AS, Dumanian GA. Periumbilical rectus abdominis perforator preservation significantly reduces superficial wound complications in 'separation of parts' hernia repairs. Plastic Reconstr Surg 2002; 109:2275–2280.

9 Novitsky YW, Elliott HL, Orenstein SB, Rosen MJ. Transversus abdominis muscle release: a novel approach to posterior component separation during complex abdominal wall reconstruction. Am J Surg 2012; 204:709–716.

10 Novitsky YW, Fayezizadeh M, Majumder A, Neupane R, Elliott HL, Orenstein SB. Outcomes of posterior component separation with transversus abdominis muscle release and synthetic mesh sublay reinforcement. Ann Surg 2016; 264:226–232.

11 Krpata DM, Blatnik JA, Novitsky YW, Rosen MJ. Posterior and open anterior components separations: a comparative analysis. Am J Surg 2012; 203:318–322.

12 Ghali S, Turza KC, Baumann DP, Butler CE. Minimally invasive component separation results in fewer wound-healing complications than open component separation for large ventral hernia repairs. J Am Coll Surg 2012; 214:981–989.

13 Clarke JM. Incisional hernia repair by fascial component separation: results in 128 cases and evolution of technique. Am J Surg 2010; 200:2–8.

14 Butler CE, Campbell KT. Minimally invasive component separation with inlay bioprosthetic mesh (MICSIB) for complex abdominal wall reconstruction. Plastic Reconstr Surg 2011; 128:698–709.

15 Patel KM, Nahabedian MY, Gatti M, Bhanot P. Indications and outcomes following complex abdominal reconstruction with component separation combined with porcine acellular dermal matrix reinforcement. Ann Plastic Surg 2012; 69:394–398.

16 Petro CC, Como JJ, Yee S, Prabhu AS, Novitsky YW, Rosen MJ. Posterior component separation and transversus abdominis muscle release for complex incisional hernia repair in patients with a history of an open abdomen. J Trauma Acute Care Surg 2015; 78:422–429.

17 Fayezizadeh M, Majumder A, Belyansky I, Novitsky YW. Outcomes of retromuscular porcine biologic mesh repairs using transversus abdominis release reconstruction. J Am Coll Surg 2016; 223:461–468.