Hernia
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REVIEW

Outcomes after open posterior component separation via transversus abdominis release (TAR) for incisional hernia repair. A systematic review and meta-analysis

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Abstract

Purpose Given its potential advantages, open Transversus Abdominis Release (oTAR) has been proposed as a durable solution for complex AWR. However, its applicability in different scenarios remains uncertain. We aimed to analyze the current available evidence and determine surgical outcomes after oTAR.

Methods We performed a systematic electronic search on oTAR in PubMed/Medline, Embase, and Cochrane Central Register of Controlled Trials databases. Postoperative morbidity and recurrence rates were included as primary endpoints and Quality of life (QoL) was included as secondary endpoint. A random-effect model was used to generate a pooled proportion with 95% confidence interval (CI) between all studies.

Results A total of 22 studies with 4,910 patients undergoing oTAR were included for analysis. Mean hernia defect and mesh area were 394 (140–622) cm^2 and 1065 (557–2206) cm^2, respectively. Mean follow-up was 19.7 (1–32) months. The weighted pooled proportion of recurrence, overall morbidity, surgical site occurrences (SSO), surgical site infection (SSI), surgical site occurrences requiring procedural intervention (SSOPI), major morbidity and mortality were: 6% (95% CI, 3-10%), 34% (95% CI, 26-43%), 22% (95% CI, 16-29%), 11% (95% CI, 8-16%), 4% (95% CI, 3-7%), 6% (95% CI, 4-10%) and 1% (95% CI, 1-2%), respectively. A significant improvement in QoL after oTAR was reported among studies.

Conclusion Open TAR is an effective technique for complex ventral hernias as it is associated with low recurrence rate and a significant improvement in QoL. However, the relatively high morbidity rates observed emphasize the necessity of further patients' selection and optimization to improve outcomes.

Keywords Complex ventral hernia · Transversus abdominis release · TAR · Posterior component separation · Ventral hernia repair · Hernia recurrence

Introduction

Incisional hernias remain a common complication with an incidence that reaches up to 15% following a laparotomy [1], resulting in over 600.000 ventral hernia repairs annually in The United States [2, 3]. Furthermore, a not depreciable group of patients develop complex ventral hernias [4], which require a thorough preoperative work-up and advanced technical skills for their resolution.

The use of advanced surgical techniques for abdominal wall reconstruction (AWR) have increased over the last decades and many centers have adopted component separation techniques (CST) to improve outcomes [5, 6]. In the 60's, Albanese [7] was a pioneer in AWR who proposed relaxing incisions to treat large hernia defects, and in 1990 Ramirez and colleagues [8] introduced the anterior component separation technique (ACS) which was then widely embraced by the surgical community. However, the high rates of wound morbidity due to the large skin flaps required remain a concern about ACS [9]. Furthermore, the ACS has

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limitations for certain types of abdominal wall defects such as hernias close to bone structures, parastomal hernias and hernias with loss of domain [9].

Posterior component separation via transversus abdominis release (TAR) arose as a novel alternative for AWR. It was first described in 2012 by Novitsky and colleagues [10], and it consists in the creation of a large retromuscular space with preservation of neurovascular bundles, which allows for the placement of a large mesh in a well vascularized plane. As result, the abdominal wall is appropriately restored avoiding the creation of large skin flaps and reducing wound morbidity. These advantages postulated TAR as an attractive tool and it has become one of the procedures of choice for the treatment of large ventral hernias [5, 6, 11]. High-volume centers with appropriately selected and optimized patients have shown promising outcomes after open TAR. Conversely, devastating complications and poor outcomes have also been described [12, 13]. Therefore, recognizing the different scenarios for TAR applicability is still needed to improve postoperative outcomes.

We aimed to perform a systematic review and meta-analysis of the current evidence in order to determine surgical outcomes after open TAR (oTAR).

Materials and methods

After approval by the Institutional Review Board of our Institution, a systematic literature search of articles on open TAR for large abdominal wall incisional hernias was performed following the PRISMA "*Preferred Reporting Items for Systematic Reviews and Meta-Analyses"* [14]. The electronic search was conducted in the Medline database using the Pubmed search engine, Embase and Cochrane Central Register of Controlled Trials. The following key terms were used in all possible combinations to obtain the maximal number of relevant articles: "transversus abdominis release", "posterior component separation", "TAR", "transversus abdominis muscle release", "PCS- TAR", "large incisional hernia" and "incisional hernia".

Suitable studies for this meta-analysis included those with patients undergoing open TAR for the repair of large abdominal wall incisional hernias, including midline and non-midline repairs. All articles between 2012 and June 2022 were analyzed. The search was limited to the English language. Studies in pediatric patients, animals, those describing a minimally invasive approach, and case reports or case- series less than 10 patients were excluded from the analysis. When duplicate studies were published with a greater number of patients, only the most updated one was included in the qualitative assessment. In articles describing both conventional and minimally invasive techniques, only patients undergoing open approach were included.

A total of 788 articles were initially screened; after removing duplicates and excluding titles and abstracts that did not meet the inclusion criteria, 76 articles were revised by two independent authors (FL and ACV) based on the methodological quality of the publications. Discrepancies between the two reviewers were resolved by a third independent author (EES). Finally, 22 articles were included for the analysis (Fig. 1 PRISMA Flowchart).

All eligible publications were carefully analyzed. Data recovered from the studies included author, publication year, design, number of included patients, gender, mean age, body mass index (BMI), smoking, diabetes mellitus, patients' optimization, defect size, mesh size, mesh type, wound class III/IV following the Ventral Hernia Working Group (VHWG) classification [15], associated panniculectomy, operative time, bridged repair, reoperation, length of hospital stay, postoperative major morbidity (Clavien-Dindo III/IV) [16], surgical site occurrences (SSO), surgical site occurrences requiring procedural interventions (SSOPI), surgical site infections (superficial, deep and organ), quality of life (QoL) assessment, recurrence rates, and mortality.

Endpoints

Recurrence rates and postoperative morbidity (Clavien-Dindo III/IV) was used as primary endpoints to assess safety and efficacy. Postoperative QoL improvement was included as a secondary endpoint to assess patients' satisfaction.

Risk of bias assessment

The risk of bias in all included studies was assessed by two investigators independently using the quality assessment of diagnostic accuracy studies-2 (QUADAS-2) tool [17]. We have adapted the bias assessment tool QUADAS-2 specifically for a meta-analysis of proportions, ensuring that the questions are appropriate and relevant for this type of analysis (Fig. 2). Additionally, a tabular presentation of the QUADAS-2 results for each study is shown in Fig. 3. Discrepancies between the two reviewers were resolved by a third independent author.

Statistical analysis

A meta-analysis of proportions was conducted for the following variables: morbidity, QoL improvement, and recurrence. Heterogeneity was defined as a Cochran $Q < 0.10$ and I^2 values were interpreted as follows: 0–40%: might not be relevant; 30–60%: moderate heterogeneity; 50–75%: substantial heterogeneity; and 75–100%:

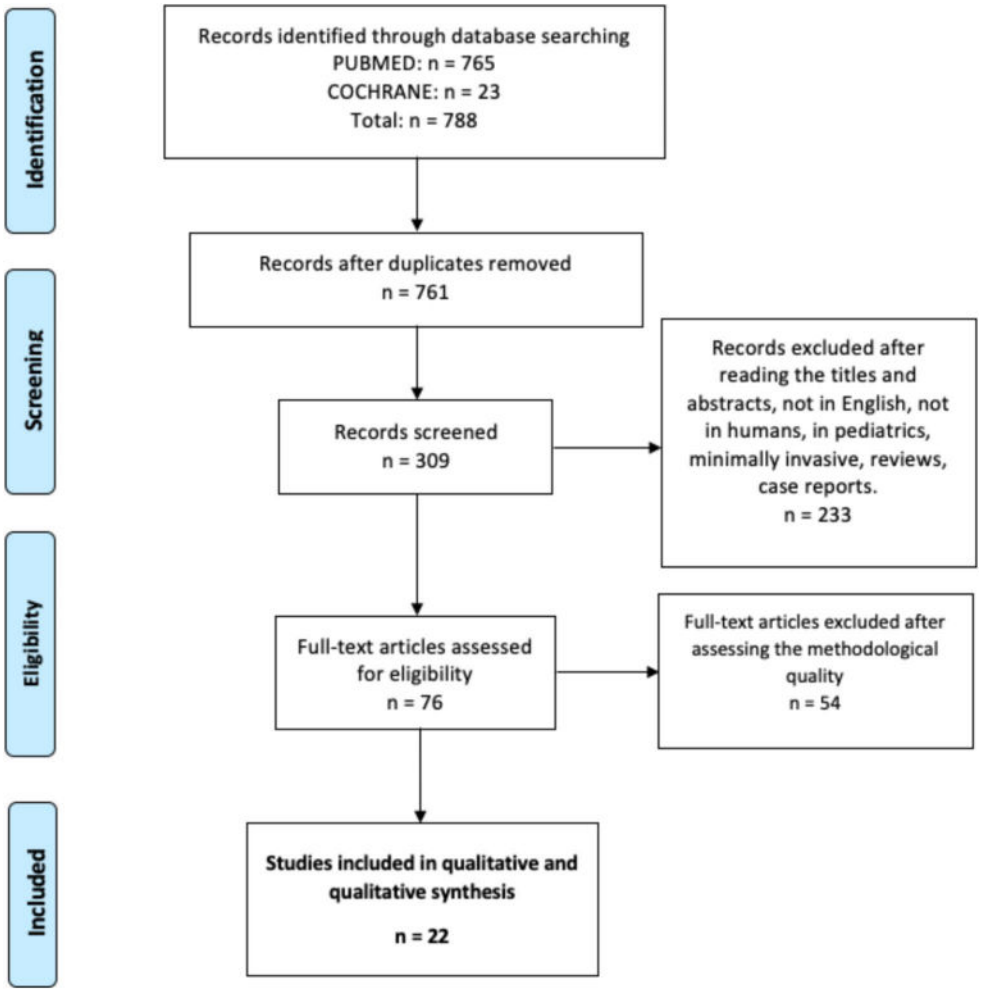

Fig. 1 PRISMA flow chart

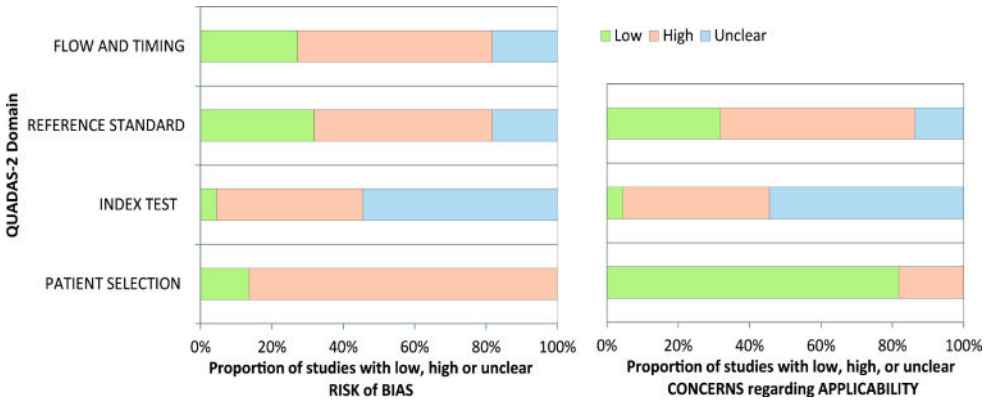

Fig. 2 QUADRAS-2 studies evaluation

considerable heterogeneity. As there was evidence of significant heterogeneity across studies, a random-effect model (DerSimonian-Laird method) was used to generate a pooled proportion with 95% confidence interval (CI) across all studies. Descriptive statistics were calculated by computing means and ranges. All statistical analyses were performed using R version 4.0.4.

Results

A total of 22 studies including 4910 patients undergoing open TAR for large incisional hernias were analyzed [18–39]; 48% of patients were men, and the mean age was 58 (52–64) years-old. The mean BMI was 32.2 ± 3 kg/m^2. The mean hernia defect was 394 (140–622) cm^2, and the mean mesh area was 1065 (557–2206) cm^2.

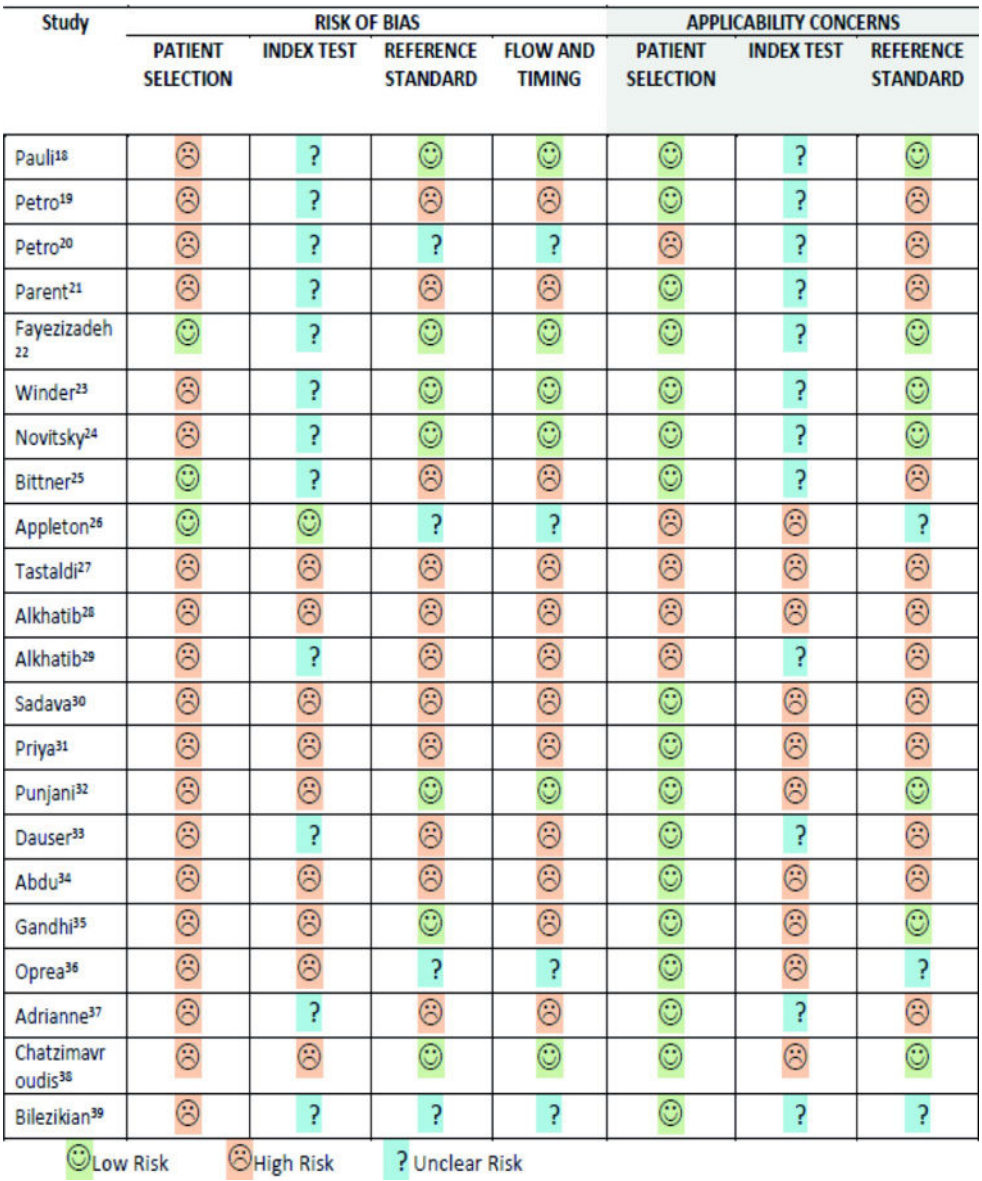

Fig. 3 Tabular presentation for QUADAS-2 results

The results of methodological quality of the studies included are summarized in Fig. 2. Overall, the studies showed a low-to-moderate risk of bias and the highest risk of bias was associated with flow and timing.

Only 10/22 studies [20, 28, 31–36, 38] included information regarding patients' optimization. Unfortunately, it was not reported which proportion of patients achieved the expected optimization and how optimization modified postoperative results. A preoperative computed tomography to assess the abdominal wall status to all of their patients was obtained in 7/22 studies [25, 30, 32, 33, 35, 36, 38]. The mean preoperative hernia defect was 323 (130–622) cm^2, and the mean mesh area was 993.2 (557–2206) cm^2. Only 5 out of 22 studies describe the width defect measurement, with an average of 14.6 ± 2.7 cm. High heterogeneity existed regarding the selected mesh. It was reported in 21 of 22 studies, and polypropylene mesh was the most common prosthesis 1423/1799 (79.1%). In 162 (3.3%) patients fascial reapproximation could not be achieved (bridged repairs). The mean operative time was 289 (189–383) minutes, and the mean length of hospital stay was 7.5 (4,5–14,4) days. Table 1 summarized demographics and perioperative variables.

Overall morbidity was reported in 19/22 studies (Fig. 4). The heterogeneity chi-squared was 163.6 ($p < 0.01$) with an inconsistency (I^2) statistic of 89%. The weighted pooled proportion of overall morbidity across studies was 34% (95% CI, 26-43%). Overall major morbidity (Clavien-Dindo III/IV) was assessed in 14/22 studies (Fig. 5). The heterogeneity chi-squared was 25.3 ($p = 0.02$) with an I^2 statistic of 49%. The weighted pooled proportion of major morbidity was 6% (95% CI, 4-10%), which included deep SSI (3.6%),

Table 1 Demographics and perioperative variables of all studies included. NA: not available, BMI: body mass index, VHWG: ventral hernia Working Group classification

Author	Year	Study design	*n*	Age	Sex (male)	BMI (kg/m^2)	Diabetes mellitus (%)	Smoking (%)	Patient's optimization	Defect area (cm^2)	Defect width (cm)	Mesh area (cm^2)	Mesh type	VHWG III/IV %	Operative time (min)	Panniculectomy	Bridged repair %
Pauli [18]	2014	Retrospective	29	59	11	36	31	17	No	410	NA	1289	24 Synthetic, 5 biologic	34	271	NA	NA
Petro [19]	2015	Retrospective	11	52	7	32	45	18	No	320	NA	900	9 Polypropylene, 2 acellular porcine dermis	9	250	NA	NA
Petro [20]	2015	Retrospective	34	54	24	32.5	24	35	Yes	431	NA	NA	19 Synthetic, 15 biologic	61	285	NA	NA
Parent [21]	2016	Retrospective	67	56	39	30.6	18	13	No	340	NA	NA	30 biological mesh, 37 synthetic mesh	40	366	1	NA
Fayezizadeh [22]	2016	Retrospective	77	56	34	35	39	22	No	306	NA	557	77 Biologic mesh	58	294	NA	NA
Winder [23]	2016	Retrospective	37	57	14	32.1	24	27	No	392	NA	930	30 Polypropylene, 2 porcine dermal matrix, 5 biologic/permanent synthetic hybrid	22	359	NA	NA
Novitsky [24]	2016	Retrospective	428	58	186	34.4	21	9	No	606	NA	1220	360 Polypropylene, 68 Polyester	8	251	NA	NA
Bittner [25]	2017	Retrospective	76	55	35	32.1	22	13	No	260	NA	713	50 Permanent synthetic, 9 Absorbable synthetic, 13 Hybrid, 4 Biologic	NA	287	NA	NA
Appleton [26]	2017	Retrospective	12	62	9	30.8	8	0	No	NA	13	950	6 Porcine, 3 acellular dermal 2 monofilament synthetic, 1 absorbable polyglactin	91	383	NA	0
Tastaldi [27]	2019	Retrospective	44	60	33	30.7	34	NA	No	NA	20	NA	44 Synthetic	2	NA	NA	7
Alkhatib [28]	2019	Retrospective	96	60	54	32	23	4	Yes	622	NA	2206	74 Polypropylene, 22 polyester	12	NA	NA	100
Alkhatib [29]	2019	Retrospective	59	57	26	36.6	22	7	No	340	NA	1114	52 Permanent synthetic, 4 biologic, 2 reabsorbable synthetic	17	NA	NA	NA
Sadava [30]	2020	Retrospective	50	65	30	28.5	16	20	Yes	420	NA	900	42 Polypropylene, 3 Physiomesh, 3 Gore BioA, 1 Proceed, 1 Polyester	22	252	30	8
Priya [31]	2020	Retrospective	44	NA	NA	29	NA	NA	Yes	NA	13.4	857.9	44 Polypropylene	0	189	NA	9

Table 1 (continued)

Author	Year	Study design	*n*	Age	Sex (male)	BMI (kg/m²)	Diabetes mellitus (%)	Smoking (%)	Patient's optimization	Defect area (cm²)	Defect width (cm)	Mesh area (cm²)	Mesh type	VHWG III/IV %	Operative time (min)	Panniculectomy	Bridged repair %
Punjani [32]	2020	Retrospective	100	53	38	30.8	41	7	Yes	140.1	NA	1344	100 Polypropylene	3	250	NA	19
Dauser [33]	2020	Retrospective	10	62	5	25.7	NA	NA	Yes	NA	NA	750	10 Synthetic	NA	NA	211.5	NA
Abdu [34]	2020	Retrospective	285	61	131	35	25	16	Yes	228	NA	NA	271 Synthetic	32	NA	NA	6
Gandhi [35]	2021	Retrospective	92	52	43	27.9	44	NA	Yes	NA	13.2	900	92 Polypropylene	2	NA	232	10
Oprea [36]	2021	Retrospective	101	64	45	31.8	37	27	Yes	247.1	NA	NA	101 Polypropylene	NA	NA	NA	7
Adrianne [37]	2021	Retrospective	24	60	11	29.7	17	13	No	449	NA	NA	Biosynthetic P4HB	29	NA	208.5	NA
Chatzimavroudis [38]	2021	Retrospective	125	58	67	34.8	26	6	Yes	NA	14.1	1140	77 Polypropylene; 22 PVDF; 26 P4HB; 3 Biologic	10	NA	240	2
Bilezikian [39]	2021	Retrospective	3109	59	1496	33	NA	NA	NA	NA	14	NA	NA	11	NA	NA	NA

respiratory disorders (0.9%), bleeding (0.6%), thromboembolic events (0.45%), and acute kidney failure (0.45%).

Surgical site occurrences (SSO) were reported in all studies (Fig. 6). The heterogeneity chi-squared was 180.9 ($p < 0.01$) with an inconsistency (I^2) statistic of 83%. The weighted pooled proportion of SSO was 22% (95% CI, 16-29%). SSI was reported in all studies and the heterogeneity chi-squared was 122.2 ($p < 0.01$) with an inconsistency (I^2) statistic of 83% (Fig. 7). The weighted pooled proportion of SSI was 11% (95% CI, 8-16%). All studies reported SSOPI and the heterogeneity chi-squared was 99.3 ($p < 0.01$) with an inconsistency (I^2) statistic of 79% (Fig. 8). The weighted pooled proportion of SSOPI was 4% (95% CI, 3-7%). Mortality was reported in 17/22 studies (Table 2). The heterogeneity chi-squared was 34.9 ($p < 0.01$) with an inconsistency (I^2) statistic of 54%. The weighted pooled proportion of mortality was 1% (95% CI, 1-2%). Alkhabit et al. [29] reported 6 deaths (6%) after repairing massive incisional hernias, 1 mortality was related to pulmonary embolism and the remaining were late and not associated to surgery. Priya et al. [31] reported 2 deaths (5%) related to myocardial infarction, both in the first postoperative month.

The mean follow-up was reported in 18/22 studies, with an average of 19.7 (1–32) months. Recurrence was reported in 17/22 studies (Fig. 9). The heterogeneity chi-squared was 149.2 ($p < 0.01$) with an inconsistency (I^2) statistic of 89%. The weighted pooled proportion of recurrence was 6% (95% CI, 3-10%). Postoperative QoL assessment was reported in 5/22 studies. The evaluation methods utilized were HerQles survey, Patient-Reported Outcome Measurement Information System (PROMIS), and visual analogue scale. Despite using different measurement tools, all of them reported improvements in postoperative QoL. Table 2 summarized postoperative outcomes.

Discussion

The aim of this study was to summarize the current evidence and determine the surgical outcomes after oTAR. We found that (a) oTAR is an effective technique with an overall recurrence rate of 6%, (b) overall morbidity remains relatively high, and (c) QoL improves significantly after oTAR.

Open TAR was introduced as an alternative to other component separation techniques for the management of complex AWRs. Recurrence rate is a critical outcome when assessing the results of a surgical technique for AWR. It has been observed that both the risk of failure and healthcare costs increment significantly after a second repair [40, 41]. In our analysis, the overall pooled recurrence among the included studies was 6%. Considering that oTAR was performed in several diverse type of complex patients (e.g.

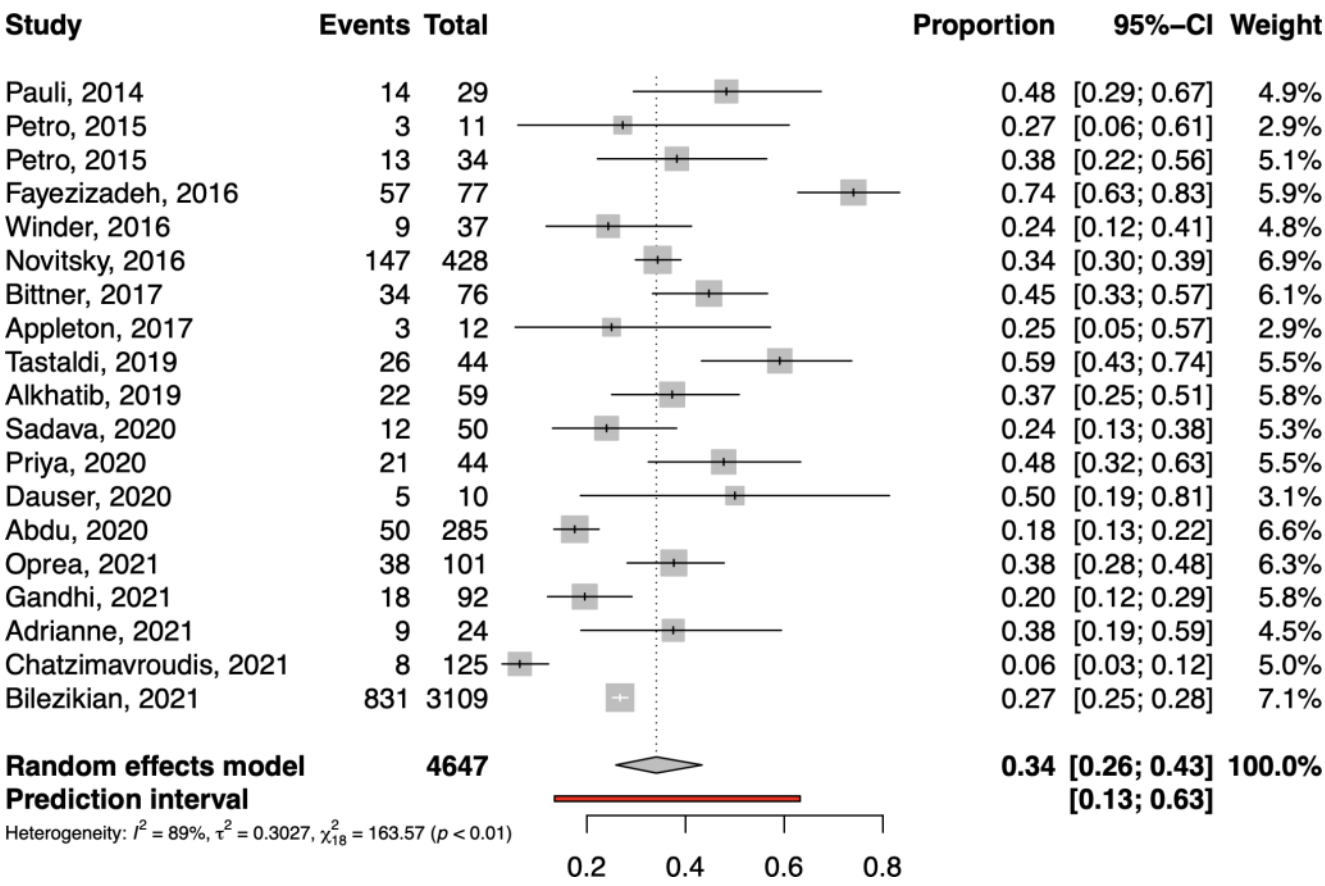

Fig. 4 The Forest plot for overall morbidity

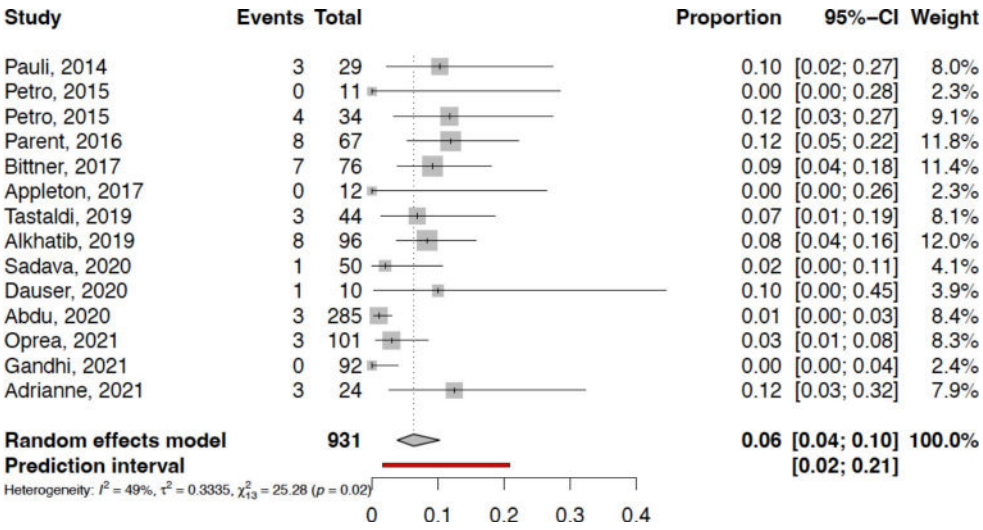

Fig. 5 The Forest plot for major morbidity

multiple comorbidities, previous recurrences, contaminated fields), this recurrence rate seems to be acceptable. Similar results were found in another meta-analysis 2018 [6], which compared oTAR and open ACS showing a recurrence rate of 5.7 and 9.5%, respectively. Similarly, a previous systematic review including only 5 articles with 646 patients undergoing oTAR reported a recurrence rate of 4% [5]. On the other hand, in a recent meta-analysis [42] the authors reported a recurrence rate of 1.6%, and this overwhelming discrepancy is likely related to the selected studies in their analysis. For instance, our analysis included studies with complex patients and high associated recurrence rates such as bridged repairs in which the linea alba could not be restored (45.8% recurrence rate) [28], liver transplant

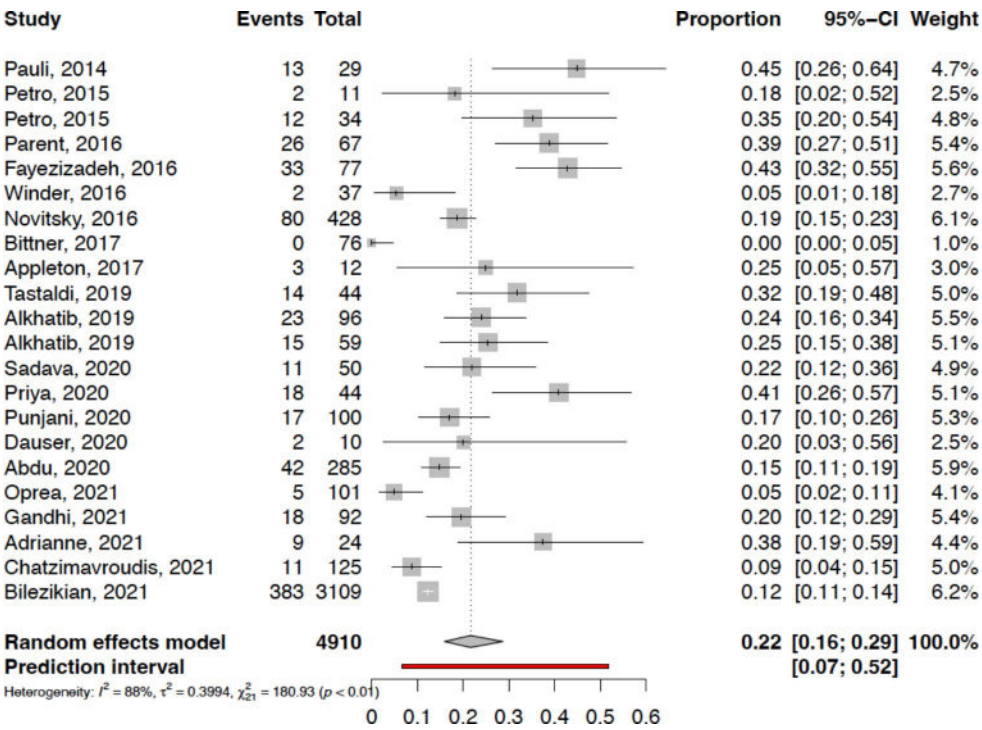

Fig. 6 The Forest plot for SSO

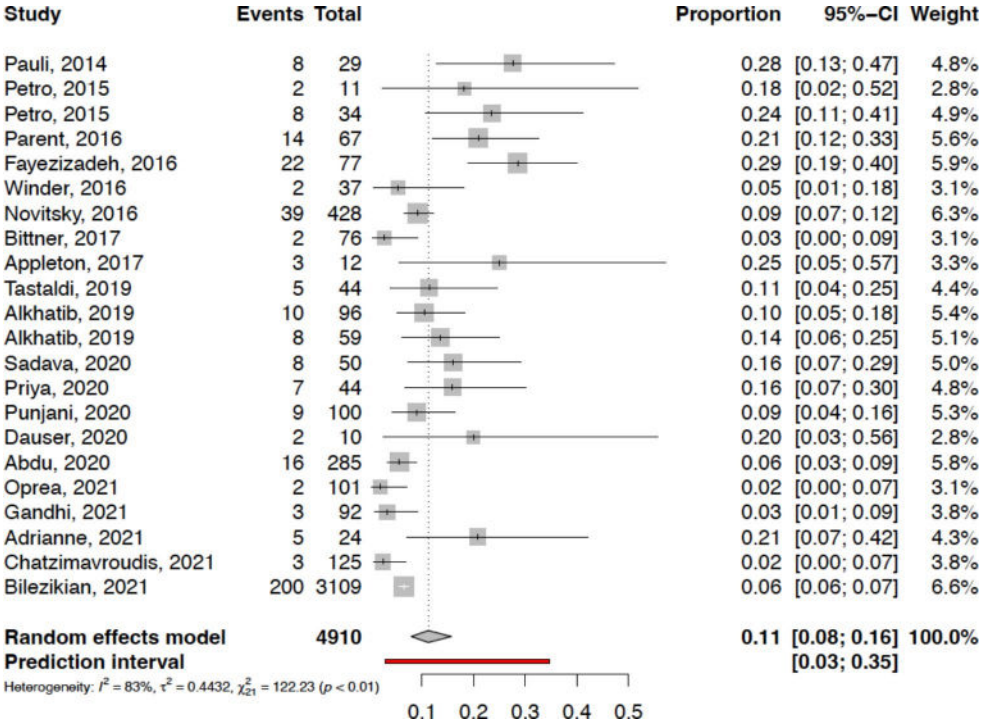

Fig. 7 The Forest plot for SSI

recipients (25% recurrence rate) [27], and kidney transplant recipients (9% recurrence rate) [19]. These results highlight the benefits of obtaining complete closure of the midline in complex AWR and how immunosuppression affects mesh repairs performance. Finally, the length of follow- up is also a determinant factor for recurrence A recent study from the Cleveland Clinic analyzed 1203 patients undergoing oTAR repairs and showed an overall recurrence rate of 26% after a median follow-up of 2 years [43]. The average follow-up in our analysis was 19.7 months, which demonstrates that most studies lack long-term follow-up.

We found a relatively high overall pooled morbidity after oTAR (34%). Similar findings have been reported in previous studies [39, 42]. In our analysis, however, major

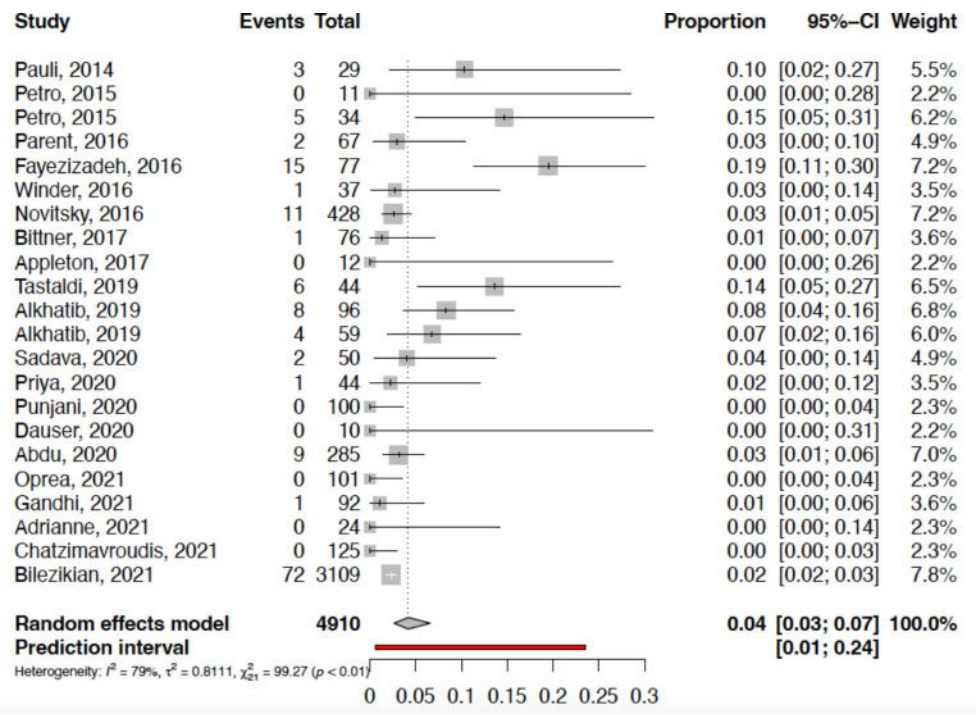

Fig. 8 The Forest plot for SSOPI

complications (Dindo-Clavien III/IV) represented only 6% of all complications. A high variability of major morbidity was observed after oTAR. Previous research has shown that having comorbidities, poor patients' optimization or an inadequate technique are associated to poor outcomes after oTAR [12, 13]. In concordance, we found that an ASA score > 3, orthotopic liver transplant or bridged repairs were risk factors for major postoperative complications [25, 27, 28, 34]. Most frequently reported major morbidity was SSI, often managed without mesh removal [19, 21, 28, 30, 34, 36, 37]. The retromuscular position of the mesh in this technique is likely to provide better protection to surgical site infections, offering the possibility to avoid removing the mesh in these patients. In contrast, when oTAR was combined with enterocutaneous fistula takedown or other intestinal resection, there appears to be higher risk of deep SSIs and organ space SSIs with need for mesh removal [18], which highlights the importance of appropriate patient selection and potential staged repair in some cases. Non-surgical complications such as pulmonary disorders, thromboembolic events and/or acute kidney failure might also occur after oTAR [21, 25, 27, 36]. Therefore, careful and multidisciplinary postoperative follow up is needed in most patients.

The pooled rate of SSO and SSI were 22% and 11%, respectively. As the rate of SSO include a heterogeneous group with several subcategories with potential risk of bias, the rate of SSOPI (4%) might serve as a better proxy of wound complications (procedures such as wound debridement, percutaneous drainage or mesh removal significantly impact on outcomes and patients' QoL). Interestingly, when we focus on studies with high incidence of wound infections (> 20%) [18, 20–22, 25, 26, 33, 37], we noticed that there was a higher proportion of patients with VHWG class 3–4 (24.1% r:21–45 vs. 9.9% r:0–22) and a higher proportion of non-permanent mesh utilized (53.5% r:0-100 vs. 5.5% r:0–23). These results are somehow hidden in the pooled analysis because the studies with higher proportion of wound complications have smaller samples and low proportional weight. However, they highlight the importance of both patients and mesh selection when performing complex AWR. Incisional hernias certainly affect patients' quality of life (QoL). A prospective cohort study showed a direct association between incisional hernias and patients' complaints and related symptoms [44]. However, patient-reported outcomes measures after incisional hernia repair are under-reported [45]. In fact, only 5/24 studies reported postoperative patients' QoL. The HerQLes quality of life survey [46] was the most frequent tool utilized (4 out of 5) and a significant improvement in QoL after oTAR was observed in all studies. In previous study, our group [30] evaluated 50 patients undergoing oTAR; 38 patients (76%) completed the HerQLes survey before and six months after the operation, and a statistically significant postoperative improvement was found (pre 50.9 ± 22.9 versus post 91.8 ± 18, $p < 0.001$). Alkhatib et al. [28] used the HerQLes and the PROMIS (Patient-Reported Outcome Measurement Information System) [47] surveys for patients' postoperative QoL and pain assessment in 96 patients underwent oTAR (bridged repairs), and found a statistically significant improvement

Table 2 Postoperative outcomes after oTAR. NA: not available, SSO: surgical site occurrences, SSI: surgical site infection, SSOPI: surgical site occurrences with procedural intervention, QoL: quality of life

Author	Overall morbidity (%)	Clavien III/IV (%)	SSO (%)	SSI (%)	SSOPI (%)	SSI (sup)	SSI (prof)	SSI (org)	Reop-eration (%)	Hospital stay (days)	QoL improvement	QoL Scale	Follow-up (months)	Recur-rence (%)	Mor-tal-ity (%)
Pauli [18]	48	10	45	28	10	17	7	3	10	9	NA	NA	11	3.5	0
Petro [19]	27	0	18	18	9	18	0	0	0	NA	NA	NA	12	9.1	0
Petro [20]	38	12	35	24	15	9	9	6	3	NA	NA	NA	18	8.9	0
Parent [21]	NA	12	39	21	3	21	3	NA	12	NA	NA	NA	8	6	NA
Fayezizadeh [22]	74	NA	43	29	19	9	18	1	NA	9.5	NA	NA	28.2	10.4	0
Winder [23]	24	NA	5	5	3	3	3	0	NA	6	NA	NA	21	2.7	NA
Novitsky [24]	34	NA	19	9	3	7	3	0	NA	5.9	NA	NA	31.5	3.7	NA
Bittner [25]	45	9	0	3	1	1	1	0	3	6	NA	NA	NA	NA	0
Appleton [26]	25	0	25	25	0	25	0	0	0	7.5	Yes	Visual Analogue	24	0	NA
Tastaldi [27]	59	5	32	11	9	2	9	0	7	7	NA	NA	13	25	0
Alkhatib [28]	NA	8	24	10	8	3	8	0	1	8	Yes	HerQles - PROMIS	20	45.8	6
Alkhatib [29]	37	NA	25	14	7	7	5	2	5	6	NA	NA	NA	NA	0
Sadava [30]	24	2	22	16	4	12	4	0	0	4.5	Yes	HerQles	28.2	4	0
Priya [31]	48	NA	41	16	2	14	2	0	0	5.25	NA	NA	21	2.3	5
Punjani [32]	NA	NA	17	9	0	9	0	0	NA	6.6	NA	NA	20.2	0	NA
Dauser [33]	50	10	20	20	0	20	0	0	0	13.5	NA	NA	NA	NA	0
Abdu [34]	17	1	15	6	3	4	3	0	5	5	NA	NA	1	NA	0
Gandhi [35]	20	0	20	3	1	2	1	0	0	14.4	NA	NA	12	2.2	0
Oprea [36]	38	3	5	2	0	2	0	0	3	7.21	NA	NA	32	6.9	0
Adrianne [37]	38	13	38	21	0	21	0	0	4	5	82/93	HerQLes/AHQ	24.1	4.2	0
Chatzimavroudis [38]	6	NA	9	2	0	2	0	0	1	6.1	NA	NA	29.8	1	0
Bilezikian [39]	27	NA	12	6	2	4	2	0	NA	7	NA	HerQLes/AHQ	NA	NA	1

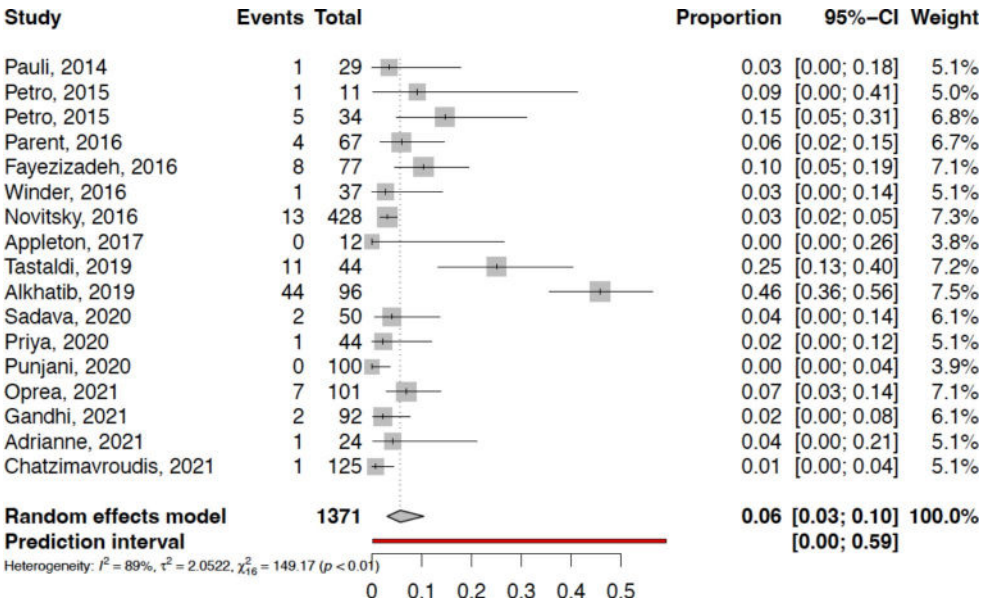

Fig. 9 The Forest plot for hernia recurrence

in both aspects. Similarly, Belizekian and col. [39] showed an improvement in QoL 30 days after oTAR. Finally, Appleton et al. [26] used visual analogue scales (0–100 score) to assess patients' satisfaction and aesthetic outcomes at a median follow-up of 24 months; patients showed favorable satisfaction 90/100 and appearance approval 83/100. Furthermore, even in series with high recurrence rates the QoL of patients was improved following oTAR [28]. Overall, current evidence suggests that this operation significantly improves patients' QoL.

Authors' comments

Although several alternatives exist for AWR, the best technique for complex hernias has not been elucidated. Open TAR has emerged as a novel technique with the enthusiasm of a reduction in postoperative wound complications due to limited mobilization of skin flaps. Its worldwide implementation is reflected in the higher number of publications over time. This technique has indeed shown to accomplish the principles of AWR with a large mesh in the retromuscular space and linea alba restoration. However, several drawbacks of the procedure should also be considered. Performing oTAR in complex cases such as transplant recipients, emergency or when the linea alba cannot be restored significantly increases recurrence rates (by 3 or more times). Furthermore, contrary to what is believed, oTAR is associated with considerable overall postoperative morbidity. Contamination of the field along with both patient and mesh selection are critical elements related to outcomes that should always be contemplated.

On the other hand, patients' perspective seems to balance oTAR performance because an improvement in QoL is observed, even in studies with adverse outcomes such a high recurrence rate. Overall, although only a decade has passed since the introduction of the technique, current research suggests that oTAR is a useful and versatile tool to manage complex ventral hernias as any other component separation technique. Future research on minimally invasive TAR technique will show us if the main benefits of TAR are maintained while improving morbidity rates.

The main limitation of this meta-analysis is the retrospective nature of all included studies. In addition, the high heterogeneity found in all the analyzed outcomes could affect the results. Furthermore, although the operation has been standardized, each patient with a large and complex hernia represents a unique challenge, which further increases the heterogeneity of the results. Finally, most patients included in the analysis had obesity (mean BMI 32) and we were not able to accurately determine how this risk factor affected the outcomes of the operation.

Despite these limitations, we consider that our study determines the overall performance of open TAR in a large cohort of patients and could be used as support for future investigations.

Conclusion

Open TAR is an effective and versatile technique for complex incisional hernias as it is associated with low recurrence rates and a significant improvement in QoL. However, the relatively high morbidity rates observed emphasize the

necessity of further patients' selection and preoperative optimization in order to improve outcomes.

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Declarations

Competing interests All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

References

1. Schlosser KA, Renshaw SM, Tamer RM, Strassels SA, Poulose BK (2023) Ventral hernia repair: an increasing burden affecting abdominal core health. Hernia 27(2):415–421. https://doi.org/10.1007/s10029-022-02707-6
2. Bower C, Roth JS, Economics of abdominal wall reconstruction (2013) Surg Clin North Am 93:1241–1253. https://doi.org/10.1016/j.suc.2013.06.007
3. Reynolds D, Davenport DL, Korosec RL, Roth JS (2013) Financial implications of ventral hernia repair: a hospital cost analysis. J Gastrointest Surg 17:159–166 (discussion 66–67). https://doi.org/10.1007/s11605-012-1999-y
4. Slater NJ, Montgomery A, Berrevoet F, Carbonell AM, Chang A, Franklin M, Kercher KW, Lammers BJ, Parra-Davilla E, Roll S, Towfigh S, van Geffen E, Conze J, van Goor H (2014) Criteria for definition of a complex abdominal wall hernia. Hernia 18(1):7–17. https://doi.org/10.1007/s10029-013-1168-6
5. Wegdam JA, Thoolen JMM, Nienhuijs SW, de Bouvy N Vries Reilingh (2019) Systematic review of transversus abdominis release in complex abdominal wall reconstruction. Hernia 23(1):5–15. https://doi.org/10.1007/s10029-018-1870-5
6. Hodgkinson JD, Leo CA, Maeda Y, Bassett P, Oke SM, Vaizey CJ, Warusavirame J (2018) A meta-analysis comparing open anterior component separation with posterior component separation and transversus abdominis release in the repair of midline ventral hernias. Hernia 22(4):617–626. https://doi.org/10.1007/s10029-018-1757-5
7. Albanese AR (1966) Liberating incisions in the treatment of large supraumbilical eventrations. Prensa Med Argent 23(38):53 PMID: 4870724
8. Ramirez OM, Ruas E, Dellon AL (1990) Components separation method for closure of abdominal-wall defects: an anatomic and clinical study. Plast Reconstr Surg 86(3):519–526. https://doi.org/10.1097/00006534-199009000-00023
9. Krpata DM, Blatnik JA, Novitsky YW, Rosen MJ (2012) Posterior and open anterior components separations: a comparative analysis. Am J Surg 203(3):318–322 discussion 322. https://doi.org/10.1016/j.amjsurg.2011.10.009
10. Novitsky YW, Elliott HL, Orenstein SB, Rosen MJ (2012) Transversus abdominis muscle release: a novel approach to posterior component separation during complex abdominal wall reconstruction. Am J Surg 204:709–716. https://doi.org/10.1016/j.amjsurg.2012.02.008
11. Cornette B, De Bacquer D, Berrevoet F (2018) Component separation technique for giant incisional hernia: a systematic review. Am J Surg 215(4):719–726. https://doi.org/10.1016/j.amjsurg.2017.07.032
12. Zolin SJ, Fafaj A, Krpata DM (2020) Transversus abdominis release (TAR): what are the real indications and where is the limit? Hernia 24(2):333–340. https://doi.org/10.1007/s10029-020-02150-5
13. Kushner B, Holden S, Blatnik J (2021) Surgical error traps of open posterior component separation-transversus abdominis release. Hernia 25(6):1703–1714. https://doi.org/10.1007/s10029-020-02321-4
14. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw J M, Hróbjartsson A, Lalu MM, Li T, Loder E, Mayo-Wilson E, McDonald S, McGuinness LA, … Moher D (2021)The PRISMA 2020 statement: an updated guideline for reporting systematic reviews.Sys Rev 10(1):89. doi:10.1186/s13643-021-01626-4
15. Ventral Hernia Working Group, Breuing K, Butler CE, Franz M, Hultman CS, Kilbridge JF, Rosen M, Silverman R, Vargo D (2010) Incisional ventral hernias: review of the literature and recommendations regarding the grading and technique of repair. Surgery 148(3):544–558. https://doi.org/10.1016/j.surg.2010.01.008
16. Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, de Sadntibañes E, Pekolj J, Slankamenac K, Bassi C, Graf R, Pradbury R, Cameron JL, Makuuki M (2009) The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg 250(2):187–196. https://doi.org/10.1097/SLA.0b013e3181b13ca2
17. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, Moher D, Becker BJ, Sipe Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, Leeflang MM, Sterne JA, Bossuyt PM, QUADAS-2 Group (2011) QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med 155(8):529–536. https://doi.org/10.7326/0003-4819-155-8-201110180-00009
18. Pauli EM, Wang J, Petro CC, Juza RM, Novitsky YW, Rosen MJ (2015) Posterior component separation with transversus abdominis release successfully addresses recurrent ventral hernias following anterior component separation. Hernia 19:285–291. https://doi.org/10.1007/s10029-014-1331-8
19. Petro CC, Como JJ, Yee S, Prabhu AS, Novitsky YW, Rosen MJ (2015) 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 78(2):422–429. https://doi.org/10.1097/TA.0000000000000495
20. Petro CC, Orenstein SB, Criss CN, Sanchez EQ, Rosen MJ, Woodside KJ, Novitsky YW (2015) Transversus abdominis muscle release for repair of complex incisional hernias in kidney transplant recipients. Am J Surg 210(2):334–339. https://doi.org/10.1016/j.amjsurg.2014.08.043
21. Parent B, Horn D, Jacobson L, Hinojosa M, Yates R, Wright AS, Louie O (2017) Wound morbidity in minimally invasive anterior component separation compared to Transversus Abdominis Release. Plast Reconstr Surg 139(2):472–479. https://doi.org/10.1097/PRS.0000000000002957
22. Fayezizadeh M, Majumder A, Belyansky I, Novitsky YW (2016) Outcomes of Retromuscular Porcine Biologic Mesh repairs using Transversus Abdominis Release Reconstruction. J Am Coll Surg 223(3):461–468. https://doi.org/10.1016/j.jamcollsurg.2016.06.008
23. Winder JS, Behar BJ, Juza RM, Potochny J, Pauli EM (2016) Transversus Abdominis Release for Abdominal Wall Reconstruction: early experience with a novel technique. J

Am Coll Surg 223(2):271–278. https://doi.org/10.1016/j.jamcollsurg.2016.06.008
24. Novitsky YW, Fayezizadeh M, Majumder A, Neupane R, Helliot HL, Orenstein SB (2016) Outcomes of posterior component separation with Transversus Abdominis muscle release and synthetic mesh sublay reinforcement. Ann Surg 264(2):226–232. https://doi.org/10.1097/SLA.0000000000001673
25. Bittner JG, Alrefai S, Vy M, Mave M, Del Prado PAR, Clingempeel NL (2018) Comparative analysis of open and robotic transversus abdominis release for ventral hernia repair. Surg Endosc 32:727–734. https://doi.org/10.1007/s00464-017-5729-0
26. Appleton ND, Anderson KD, Hancock K, Scott MH, Walsh CJ (2017) Initial UK experience with transversus abdominis muscle release for posterior components separation in abdominal wall reconstruction of large or complex ventral hernias: a combined approach by general and plastic surgeons. Ann R Coll Surg Engl 99(4):265–270. https://doi.org/10.1308/rcsann.2016.0241
27. Tastaldi L, Blatnik JA, Krpata DM, Petro CC, Fafaj A, Alkhabit H, Svestka M, Rosenblat S, Prabhu AS, Rosen MJ (2019) Posterior component separation with transversus abdominis release (TAR) for repair of complex incisional hernias after orthotopic liver transplantation. Hernia 23:363–373. https://doi.org/10.1007/s10029-019-01918-8
28. Alkhatib H, Tastaldi L, Krpata DM, Fafaj A, Alkhabit H, Svestka M, Rosenblat S, Rosen MJ, Prabhu AS (2020) Outcomes of transversus abdominis release (TAR) with permanent synthetic retromuscular reinforcement for bridged repairs in massive ventral hernias: a retrospective review. Hernia 24:341–352. https://doi.org/10.1007/s10029-019-02046-z
29. Alkhatib H, Tastaldi L, Krpata DM, Fafaj A, Olson M, Rosenblat S, Rosen MJ, Prabhu AS (2019) Outcomes of transversus abdominis release in non-elective incisional hernia repair: a retrospective review of the Americas Hernia Society Quality Collaborative (AHSQC). Hernia 23:43–49. https://doi.org/10.1007/s10029-019-01878-z
30. Sadava EE, Peña ME, Bras Harriott C, Casas MA, Schlottmann F, Laxague F (2022) Long-term outcomes and quality of life assessment after posterior component separation with transversus abdominis muscle release (TAR). Surg Endosc 36:1278–1283. https://doi.org/10.1007/s00464-021-08402-4
31. Priya P, Kantharia N, Agrawal JB, Agrawal A, Agrawal L, Afaque MY, Rizvi ASA, Baig SJ (2020) Short- to midterm results after posterior component separation with Transversus Abdominis Release: initial experience from India. World J Surg 44:3341–3348. https://doi.org/10.1007/s00268-020-05644-6
32. Punjani R, Arora E, Mankeshwar R, Gala J (2021) An early experience with transversus abdominis release for complex ventral hernias: a retrospective review of 100 cases. Hernia 25:353–364. https://doi.org/10.1007/s10029-020-02202-w
33. Dauser B, Hartig N, Vedadinejad M, Kichner E, Trummer F, Herbst F (2021) Robotic-assisted repair of complex ventral hernia: can it pay off? J Robot Surg 15(1):45–52. https://doi.org/10.1007/s11701-020-01078-3
34. Abdu R, Vasyluk A, Reddy N, Huang LC, Halka JT, DeMare A, Janczyk R, Iacco A (2021) Hybrid robotic transversus abdominis release versus open: propensity-matched analysis of 30-day outcomes. Hernia 25:1491–1497. https://doi.org/10.1007/s10029-020-02249-9
35. Gandhi J, Shinde P, Chaudhari S, Banker A, Deshmukh V (2021) Decalogue of Transversus Abdominis Release Repair- Technical Details and lessons Learnt. Pol Przegl Chir 93(2):16–25. https://doi.org/10.5604/01.3001.0014.7989
36. Oprea V, Mardale S, Buia F, Gheorghescu D, Nica R, Zdroba S, Grad O (2021) The influence of Transversus Abdominis Muscle Release (TAR) for complex incisional hernia repair on the intraabdominal pressure and pulmonary function. Hernia 25:1601–1609. https://doi.org/10.1007/s10029-021-02395-8
37. Christopher AN, Fowler C, Patel V, Mellia JA, Morris MP, Brach RB, Fischer JP (2022) Bilateral transversus abdominis release: complex hernia repair without sacrificing quality of life. Am J Surg 223(2):250–256. https://doi.org/10.1016/j.amjsurg.2021.03.020
38. Chatzimavroudis G, Kotoreni G, Kostakis I, Voloudakis N, Chirstoforidis E, Papaziogas B (2022) Outcomes of posterior component separation with transversus abdominis release (TAR) in large and other complex ventral hernias: a single-surgeon experience. Hernia 26(5):1275–1283. https://doi.org/10.1007/s10029-021-02520-7
39. Bilezikian JA, Tenzel PL, Faulkner JD, Bilezikian MJ, Powers WF, Hope WW (2021) Comparing the outcomes of external oblique and transversus abdominus release using the AHSQC database. Hernia 25(2):365–373. https://doi.org/10.1007/s10029-020-02310-7
40. Rhemtulla IA, Hsu JY, Broach RB, Mauch JT, Serletti JM, DeMatteo RP, Fischer JP (2021) The incisional hernia epidemic: evaluation of outcomes, recurrence, and expenses using the healthcare cost and utilization project (HCUP) datasets. Hernia 25(6):1667–1675. https://doi.org/10.1007/s10029-021-02405-9
41. Alli VV, Zhang J, Telem DA (2018) Impact of incisional hernia development following abdominal operations on total healthcare cost. Surg Endosc 32(5):2381–2386. https://doi.org/10.1007/s00464-017-5936-8
42. Vasavada BB, Patel H (2023) Outcomes of open transverse abdominis release for ventral hernias: a systematic review, meta-analysis and meta-regression of factors affecting them. Hernia 27(2):235–244. https://doi.org/10.1007/s10029-022-02657-z
43. Zolin SJ, Krpata DM, Petro CC, Prabhu AS, Rosenblat S, Rosen S, Thompson R, Fafaj A, Thomas JD, Huang LC, Rosen MJ (2023) Long-term clinical and patient-reported outcomes after Transversus Abdominis Release with Permanent Synthetic Mesh: a single Center analysis of 1203 patients. Ann Surg 277(4):e900–e906. https://doi.org/10.1097/SLA.0000000000005443
44. van Ramshorst GH, Eker HH, Hop WC, Jekeel J, Lange JF (2012) Impact of incisional hernia on health- related quality of life and body image: a prospective cohort study. Am J Surg 204(2):144–150. https://doi.org/10.1016/j.amjsurg.2012.01.012
45. Sandø A, Rosen MJ, Heniford BT, Bisgaard T (2020) Long-term patient-reported outcomes and quality of the evidence in ventral hernia mesh repair: a systematic review. Hernia 24(4):695–705. https://doi.org/10.1007/s10029-020-02154-1
46. Krpata DM, Schmotzer BJ, Flocke S, Jin J, Blatnik JA, Ermlich B, Novitsky YW, Rosen MJ (2012) Design and initial implementation of HerQLes: a hernia-related quality-of-life survey to assess abdominal wall function. J Am Coll Surg 215(5):635–642. https://doi.org/10.1016/j.jamcollsurg.2012.06.412
47. DeWalt DA, Rothrock N, Yount S, Stone AA, PROMIS Cooperative Group (2007) Evaluation of item candidates: the PROMIS qualitative item review. Med Care 45(5 Suppl 1):S12–21. https://doi.org/10.1097/01.mlr.0000254567.79743.e2