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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%:

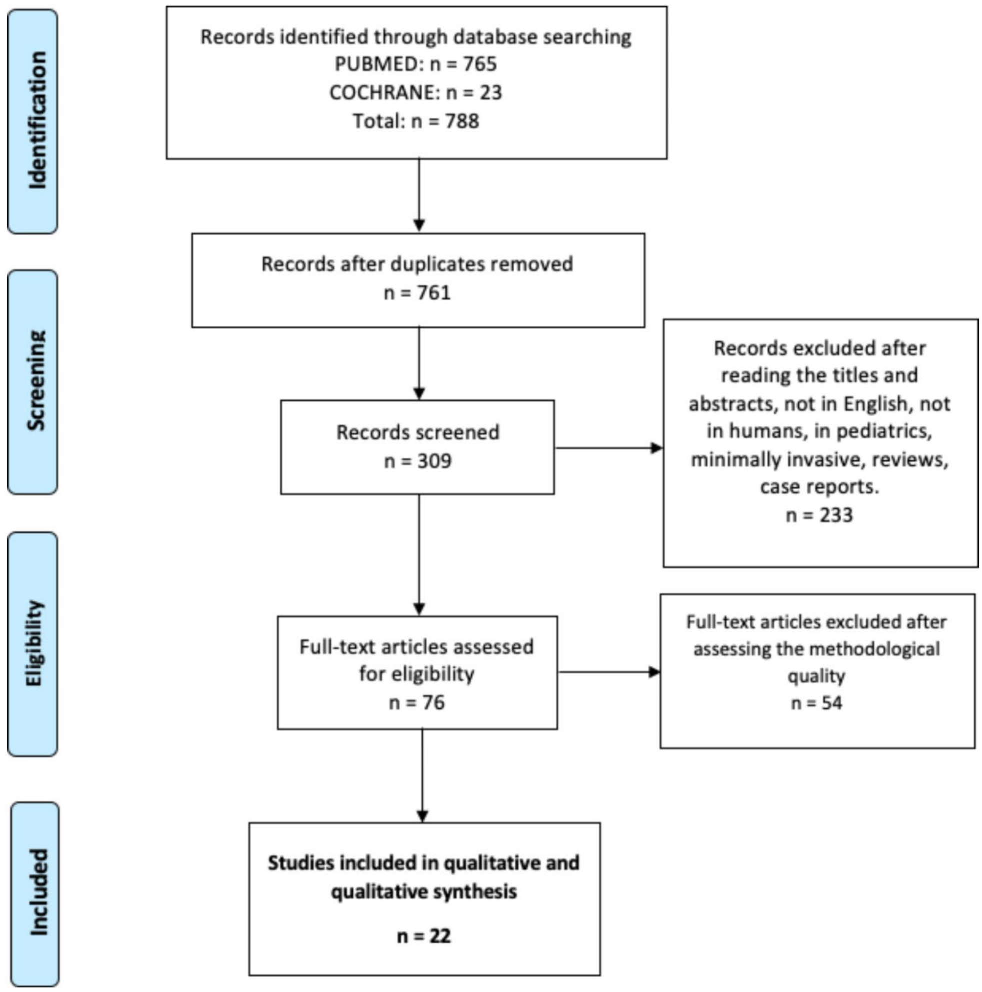



**Fig. 1** PRISMA flow chart

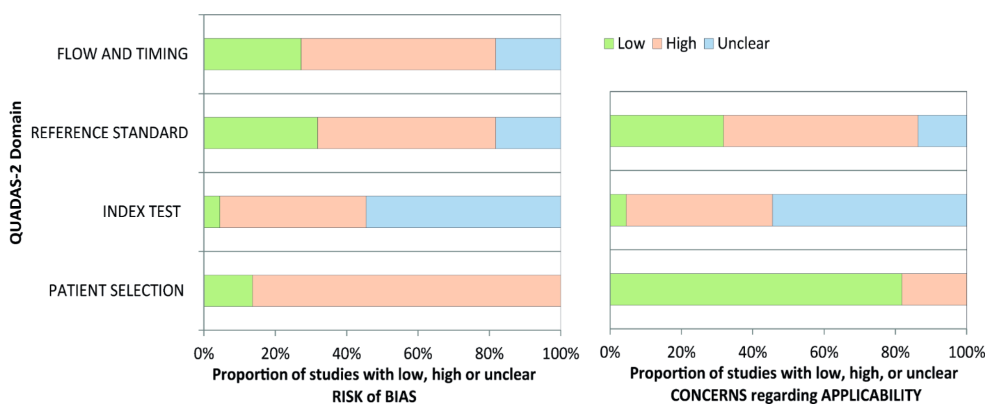



**Fig. 2** QUADRAS-2 studies evaluation

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 $32.2 \pm 3$ 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

| Study | RISK OF BIAS | | | | APPLICABILITY CONCERNS | | |
|---|---|---|---|---|---|---|---|
| | PATIENT SELECTION | INDEX TEST | REFERENCE STANDARD | FLOW AND TIMING | PATIENT SELECTION | INDEX TEST | REFERENCE STANDARD |
| Pauli[18] | ☹ | ? | ☺ | ☺ | ☺ | ? | ☺ |
| Petro[19] | ☹ | ? | ☹ | ☹ | ☺ | ? | ☹ |
| Petro[20] | ☹ | ? | ? | ? | ☹ | ? | ☹ |
| Parent[21] | ☹ | ? | ☹ | ☹ | ☺ | ? | ☹ |
| Fayezizadeh[22] | ☺ | ? | ☺ | ☺ | ☺ | ? | ☺ |
| Winder[23] | ☹ | ? | ☺ | ☺ | ☺ | ? | ☺ |
| Novitsky[24] | ☹ | ? | ☺ | ☺ | ☺ | ? | ☺ |
| Bittner[25] | ☺ | ? | ☹ | ☹ | ☺ | ? | ☹ |
| Appleton[26] | ☺ | ☺ | ? | ? | ☹ | ☹ | ? |
| Tastaldi[27] | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Alkhatib[28] | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Alkhatib[29] | ☹ | ? | ☹ | ☹ | ☹ | ? | ☹ |
| Sadava[30] | ☹ | ☹ | ☹ | ☹ | ☺ | ☹ | ☹ |
| Priya[31] | ☹ | ☹ | ☹ | ☹ | ☺ | ☹ | ☹ |
| Punjani[32] | ☹ | ☹ | ☺ | ☺ | ☺ | ☹ | ☺ |
| Dauser[33] | ☹ | ? | ☹ | ☹ | ☺ | ? | ☹ |
| Abdu[34] | ☹ | ☹ | ☹ | ☹ | ☺ | ☹ | ☹ |
| Gandhi[35] | ☹ | ☹ | ☺ | ☹ | ☺ | ☹ | ☺ |
| Oprea[36] | ☹ | ☹ | ? | ? | ☺ | ☹ | ? |
| Adrianne[37] | ☹ | ? | ☹ | ☹ | ☺ | ? | ☹ |
| Chatzimavroudis[38] | ☹ | ☹ | ☺ | ☺ | ☺ | ☹ | ☺ |
| Bilezikian[39] | ☹ | ? | ? | ? | ☺ | ? | ? |

☺ Low Risk ☹ High Risk ? Unclear Risk

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 $14.6 \pm 2.7$ 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/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 % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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.

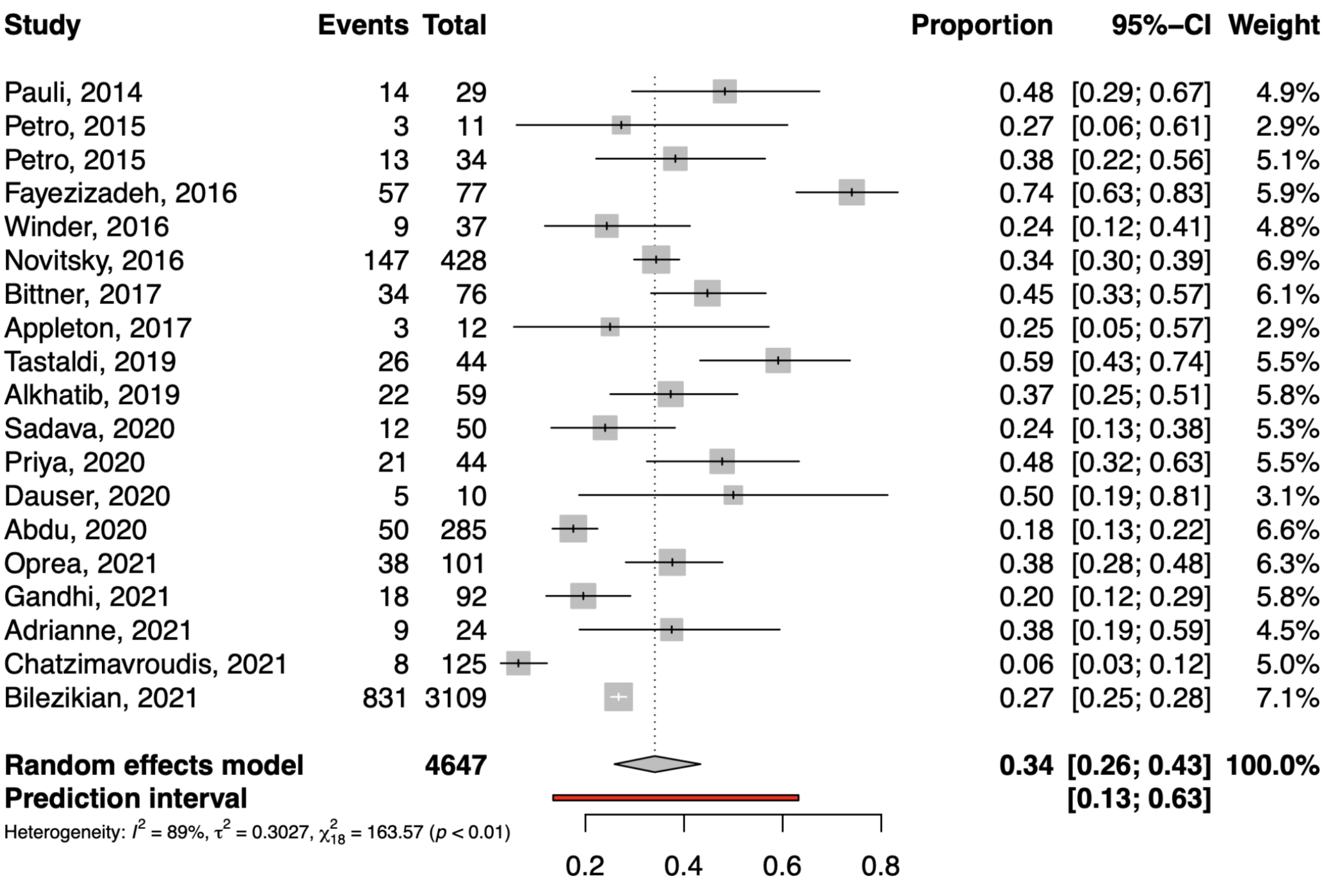
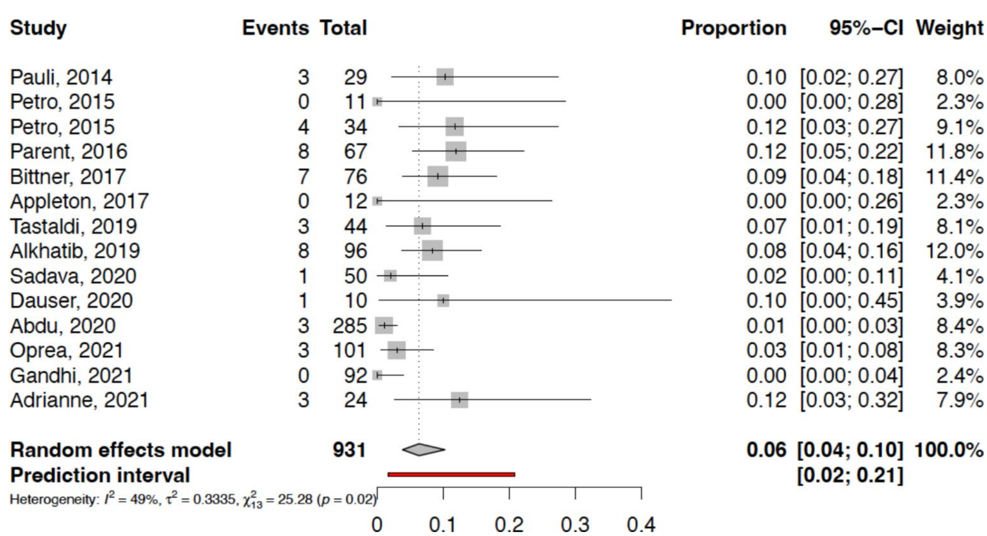



**Fig. 4** The Forest plot for overall morbidity

**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

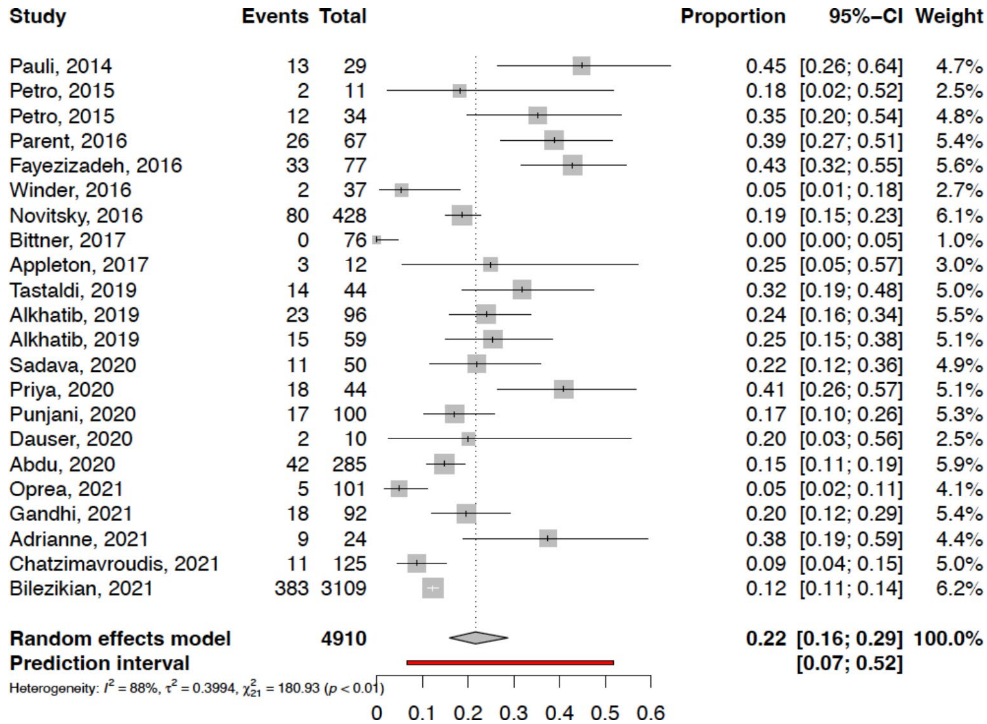



**Fig. 6** The Forest plot for SSO

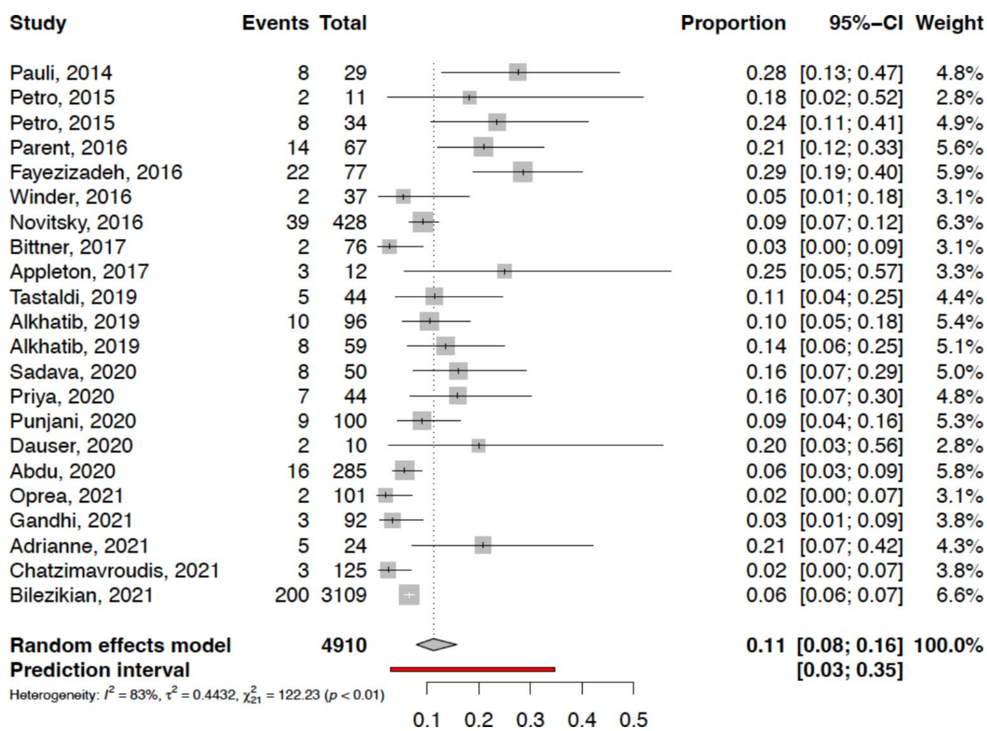
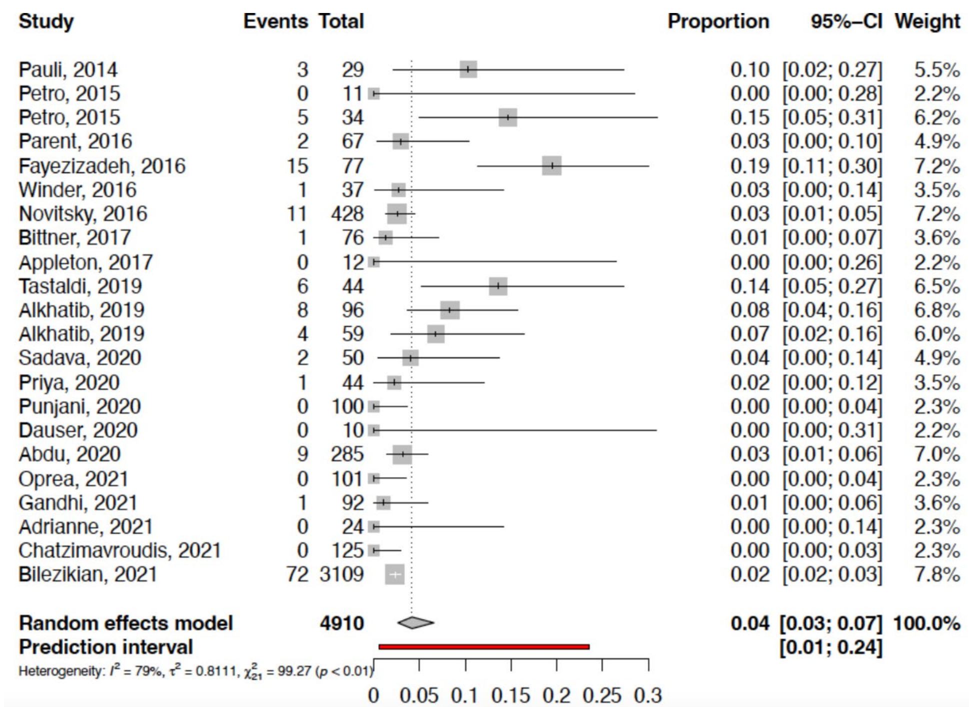



**Fig. 7** The Forest plot for SSI

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. Nonsurgical 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 $50.9 \pm 22.9$ versus post $91.8 \pm 18$, $p < 0.001$). 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 |

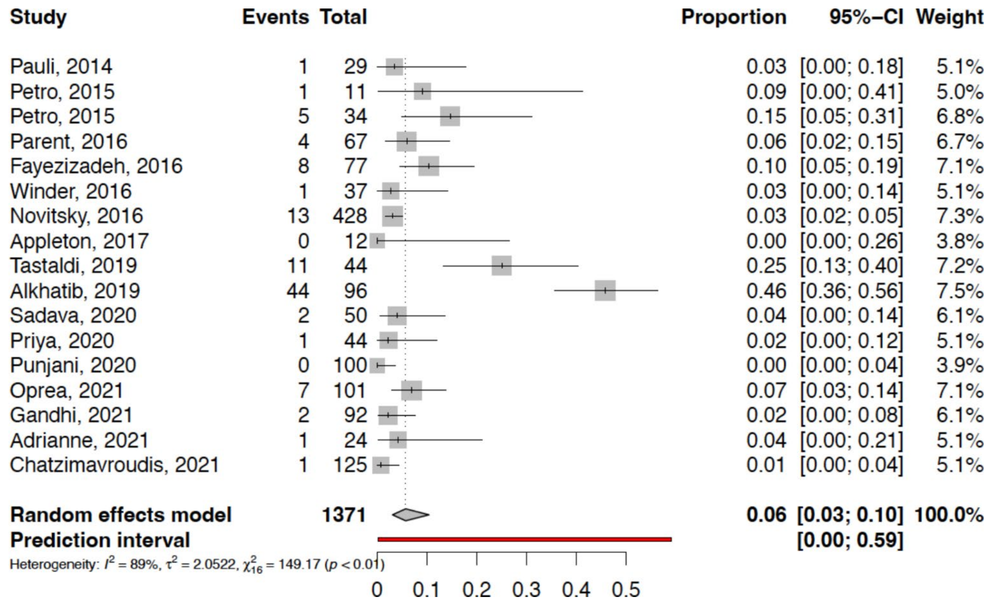



**Fig. 9** The Forest plot for hernia recurrence

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.

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