Open versus robotic-assisted laparoscopic posterior component separation in complex abdominal wall repair

Maxime Dewulf1, Maximo, Juha M. Hiekkaranta2, Elisa Mäkäräinen2, Juha Saarnio2, Maaike Vierstraete3, Filip Muysoms3 and Tero Rautio2

1Maastricht UMC+, Maastricht, The Netherlands
2Oulu University Hospital, Oulu, Finland
3Maria Middelares Hospital, Gent, Belgium

*Correspondence to: Maxime Dewulf, Department of Surgery, P. Debyelaan 25, 6229 HX Maastricht, The Netherlands (e-mail: dewulfmaxime@gmail.com)

Abstract

Background: Transversus abdominis release (TAR) is a surgical technique used in the treatment of complex ventral hernias. The aim of this study was to compare outcomes of open (oTAR) versus robotic-assisted (rTAR) posterior component separation by TAR.

Methods: Consecutive patients at two European hernia centres who underwent bilateral TAR were included. The primary endpoint was the duration of postoperative hospital stay.

Results: Data from 90 rTAR and 79 oTAR operations were evaluated. Patient demographics were similar between groups in terms of age, sex, BMI, and co-morbidities. There were more smokers, and hernias were larger in the oTAR group (width 8.7 cm versus 10.0 cm; \( P = 0.031 \), length 11.6 cm versus 14.1 cm; \( P = 0.005 \)). Duration of postoperative hospital stay was significantly shorter in the rTAR group (3.4 days versus 6.9 days; \( P < 0.001 \)). Short-term serious complications (Clavien–Dindo grade III and above) were more frequent (20.3 per cent versus 7.8 per cent; \( P = 0.018 \)), and there were more surgical site infections (12.7 per cent versus 3.3 per cent; \( P = 0.010 \)) in the oTAR group. During a median follow-up of 19 months in the rTAR group and 43 months in the oTAR group, reoperation (4.4 per cent versus 8.9 per cent; \( P = 0.245 \)), and recurrence rates (5.6 per cent versus 5.1 per cent; \( P > 0.009 \)) were similar.

Conclusion: Patients with ventral incisional hernias who undergo bilateral rTAR had significantly shorter postoperative hospital stays and fewer short-term complications compared with patients undergoing bilateral oTAR.

Introduction

The retrorectus position is often considered the most favourable plane for abdominal wall reconstruction1,2. Closure of the hernia defect is important3, although some incisional hernias are too wide to perform a closure of the defect without additional surgical techniques. Component separation techniques of the lateral abdominal wall muscles increase the likelihood of medializing the edges of a midline hernia defect and achieving a tension-free defect closure. When compared with open anterior component separation techniques, posterior component separation techniques (PCSTs) have the advantage that there is no need to create large subcutaneous skin flaps, minimizing additional morbidity. In 2012, Novitsky et al. described the open technique of transversus abdominis release (TAR), that allows mesh placement in the retrorectus and retromuscular position behind all three lateral abdominal wall muscles, after creation of a large retromuscular and preperitoneal space. More recently, TAR has been performed with minimally invasive laparoscopic techniques5,6, but these complex abdominal wall reconstructions requiring TAR are technically challenging to perform with laparoscopic instruments, because of the limited workspace and restricted angulation of instruments. These limitations have been overcome by the introduction of robotic-assisted surgery7. Robotic-assisted TAR (rTAR) is similar to open TAR (oTAR) in terms of defect closure and retromuscular mesh position but adds the benefits of minimally invasive surgery. Detailed descriptions of the surgical technique of rTAR have been published8,9. rTAR has rapidly gained popularity in recent years. Short-term results have been described and a recent meta-analysis comparing early outcomes after rTAR and oTAR demonstrated fewer complications and shorter length of postoperative hospital stay (LOS) in favour of the robotic approach9,10.

The aim of this study was to compare outcomes after oTAR and rTAR at two European hernia centres. The primary endpoint of the study was LOS. Secondary endpoints were intraoperative complications, in-hospital complications, overall and surgical site-related complications during the first 30 postoperative days, and overall and surgical site-related complications during the follow-up interval, including hernia recurrence.

Methods

Study design

This was a two-centre case–control study using a prospectively developed database (European Registry for Abdominal Wall Hernias (EuraHS)11) based on electronic clinical files from patients undergoing bilateral PCST (either open or robotic-assisted). The study protocol was sent for notification to the local ethics
committee at Maria Middelares Hospital, Ghent, The Netherlands, on 21 December 2021 (reference no. MMS.2021.068). The study protocol was published online on 19 January 2022, at ClinicalTrials.gov identifier NCT05195957.

The study was performed at the departments of surgery at Oulu University Hospital, Oulu, Finland (OUH) and Maria Middelares Hospital, Ghent, Belgium (MMH). Patients were operated by a single surgeon in MMH and by two surgeons at OUH. An additional search of surgical logbooks was conducted at OUH to identify bilateral TAR patients not included in the database. The study included all consecutive patients undergoing bilateral PCST between December 2011 and October 2019 at MMH hospital, where the rTAR technique was introduced in October 2016, and consecutive patients undergoing bilateral PCST between August 2017 and May 2021 at OUH. After the introduction of the rTAR technique at OUH, the choice between a robotic-assisted or open approach was mainly guided by the availability of the robotic platform. All patients had a follow-up visit during the first 3 months after surgery. At MMH, a routine clinical follow-up visit 1 year after surgery was performed. Hernia recurrence was based on clinical evaluation, with supplementary CT if there was clinical uncertainty.

**Study population**

All patients undergoing bilateral PCST for the treatment of their ventral incisional hernia, either open, or robotic assisted, were considered eligible. Patients undergoing only unilateral PCST and patients with a stoma or parastomal hernia were excluded. The technique of rTAR was similar in both centres, as both surgeons at OUH were trained and proctored for their first cases by the participating surgeon from MMH. The robotic-assisted surgical procedures were performed with the DaVinci Xi or Si system (Intuitive Surgical, Sunnyvale, California, USA). The variables on which data were collected are added as Table S1.

**Statistical analysis**

Data analysis was carried out with Microsoft® Excel and SPSS® Statistics (IBM, Armonk, New York, USA). Continuous variables are presented as mean(s.d.). Categorical data are presented as percentages and proportions. Statistical analysis was performed according to the intention-to-treat principle. For normally distributed continuous variables, an independent samples t test was used. When a normal distribution could not be assumed, a Mann–Whitney U test was used. The chi-squared and Fisher’s test were used to compare categorical data. A P value of less than 0.05 was considered statistically significant.

**Results**

A total of 90 patients in the rTAR group and 79 patients in the oTAR group were included. Patient demographics are summarized in Table 1. No differences between patient groups were noted regarding age, sex, BMI, or co-morbidities. There were significantly more smokers in the oTAR group. Hernias were larger in the oTAR group in both width and length of fascial defect (width 8.7 cm versus 10.0 cm; P = 0.031, length 11.6 cm versus 14.1 cm; P = 0.005).

Intraoperative complications

|                      | rTAR n = 90 | oTAR n = 79 | P*     |
|----------------------|------------|------------|--------|
| Skin-to-skin operative time (min), mean(s.d.) | 242 (82)   | 188 (90)   | <0.001 |
| Wound contamination class† | 0.465     |            |        |
| Clean                 | 87 (96.7)  | 73 (92.4)  |        |
| Clean contaminated    | 2 (2.2)    | 4 (5.1)    |        |
| Contaminated          | 1 (1.1)    | 2 (2.5)    |        |
| Dirty                 | 0 (0)      | 0 (0)      |        |
| Antibiotic prophylaxis| 0.526      |            |        |
| Mesh type used        |            |            |        |
| Polyester             | 68 (75.6)  | 61 (77.2)  |        |
| Polyvinylidene        | 17 (18.9)  | 17 (21.5)  |        |
| Polypropylene         | 2 (2.2)    | 1 (1.3)    |        |
| Unknown               | 3 (3.3)    | 0 (0)      |        |
| Mesh size (cm²), mean(s.d.) | 980 (354) | 1344 (460) | <0.001 |
| Hernia defect closure | 89 (98.9)  | 74 (93.7)  | 0.119  |
| Combined surgical procedure | 1 (1.1) | 15 (19.0)  | <0.001 |
| Intraoperative complications | 8 (8.9)   | 13 (16.5)  | 0.137  |

rTAR, robotic-assisted transversus abdominis release; oTAR, open transversus abdominis release. Values are n (%) unless otherwise indicated. *For normally distributed continuous variables, an independent samples t test was used. When a normal distribution could not be assumed, a Mann–Whitney U test was used. The chi-squared and Fisher’s test were used to compare categorical data. A P value of less than 0.05 was considered statistically significant.

According to the Center for Disease Control and Prevention (CDC) classification15.
In case of oTAR, all patients received prophylactic antibiotics before surgery, compared with 71.1 per cent in the rTAR cases. Several large-pore synthetic non-absorbable meshes were used (Table 2). The mean size of the mesh used was significantly larger in the oTAR group. Hernia defect closure rates were comparable between groups. Patients of the oTAR group underwent simultaneous operations more frequently (19.0 per cent versus 1.1 per cent; \( P < 0.001 \)). These included panniculectomy (\( n = 9 \)), colostomy closure (\( n = 2 \)), oncological colorectal resections (\( n = 2 \)), lymph node removal (\( n = 1 \)), and adrenalectomy (\( n = 1 \)). One patient in the rTAR group underwent simultaneous scar removal.

There were 8 intraoperative complications in the rTAR group and 13 in the oTAR group (\( P = 0.157 \)), the most frequent being bowel injury (\( n = 16 \)). Four of these were full-thickness injuries, with one requiring bowel resection with anastomosis. Three severe bleeding complications occurred: one from the liver, one from the abdominal wall, and one from the femoral vein. One patient had a small pleural injury.

There were eight conversions from rTAR to oTAR (8 of 90; 8.9 per cent) related to adhesions (\( n = 8 \)), severe bleeding (\( n = 2 \)), small bowel injury (\( n = 1 \)), and full-thickness stomach injury (\( n = 1 \)).

## Table 3
Description of outcome variables of a case-control study comparing robotic-assisted transversus abdominis release and open transversus abdominis release

|                | rTAR \( n = 90 \) | oTAR \( n = 79 \) |
|----------------|------------------|------------------|
| **Duration of postoperative hospital stay (days), mean(s.d.)** | 3.4 (0.4) | 6.9 (1.6) |
| **In-hospital complications** | 8 (8.9) | 21 (26.6) |
| Surgical site-related complications | 6 (6.7) | 6 (7.6) |
| **30-day complications** | 63 (70.0) | 39 (49.4) |
| Grade I | 10 (11.1) | 7 (8.9) |
| Grade II | 10 (11.1) | 16 (20.3) |
| Grade III | 4 (4.4) | 7 (8.9) |
| Grade IV | 1 (1.1) | 7 (8.9) |
| Grade V (mortality) | 2 (2.2) | 2 (2.5) |
| **30-day surgical site-related complications** | | |
| SSI | 3 (3.3) | 10 (12.7) |
| Superficial infection | 1 | 3 |
| Deep infection | 2 | 6 |
| Mesh infection | 2 | 1 |
| SSO | 18 (20.0) | 19 (24.1) |
| SSOFI | 6 (6.7) | 12 (15.2) |
| **30-day readmission rate** | 4 (4.4) | 6 (7.6) |
| Follow-up time (months), mean(s.d.) | 19 (14) | 43 (32) |
| Reoperation rate during follow-up | 4 (4.4) | 7 (8.9) |
| Hernia recurrence during follow-up | 5 (5.6) | 4 (5.1) |

rTAR, robotic-assisted transversus abdominis release; oTAR, open transversus abdominis release; SSI, surgical site infection; SSO, surgical site occurrence; SSOFI, surgical site occurrence requiring procedural intervention. Values are mean(s.d.) unless otherwise indicated.

Outcome data on primary and secondary endpoints are in Table 3. LOS was significantly longer in the oTAR group (3.4 days versus 6.9 days; \( P < 0.001 \)). As there were significantly more patients in the oTAR group that underwent simultaneous surgery, an additional analysis after exclusion of these patients still showed a significantly shorter LOS in the rTAR group (3.4 days versus 7.1 days; \( P < 0.001 \)). In a linear regression analysis adjusting for the possible confounding factors ‘smoking’ and ‘hernia width’, the oTAR group had 3.4 days (95 per cent c.i. 1.8 to 5.0, \( P < 0.001 \)) longer duration of postoperative hospital stay.

In-hospital complications, overall complication rates, and surgical site infections (SSIs) during the first 30 postoperative days were significantly lower in the rTAR group, whereas surgical site occurrences (SSOs), surgical site occurrences requiring percutaneous intervention (SSOFIs), and readmission rates were similar.

Major postoperative complications (Clavien–Dindo grade III and above) were significantly higher in the oTAR group (7.8 per cent versus 20.3 per cent; \( P = 0.018 \)). After adjusting for smoking and hernia width, the oTAR group had an OR of 2.4 (95 per cent c.i. 0.88 to 6.4; \( P = 0.087 \)) for major postoperative complications. Two deaths occurred in each group within 30 days after surgery.

Follow-up was significantly longer in the oTAR group (43 versus 19 months; \( P < 0.001 \)) and revealed a reoperation rate of 4.4 per cent in the rTAR group and 8.9 per cent in the oTAR group (\( P = 0.246 \)). Hernia recurrence was similar between groups (5.6 per cent versus 5.1 per cent).

## Discussion

In this series rTAR was associated with significantly shorter duration of postoperative hospital stay and fewer short-term postoperative complications compared with oTAR, at the expense of longer operative times. Hernia recurrence rates between groups were comparable, although the rTAR group had shorter follow-up.

Six cohort studies have reported outcomes of rTAR compared with oTAR\(^{14-19}\). Of these, two focused of hybrid robotic-assisted TAR\(^{14,17}\), the remaining four had sample sizes varying between 26 and 114 patients\(^{15-18}\). All demonstrated a significant decrease in LOS after rTAR, consistent with the present results. Regarding overall complications, only two studies reported a significant decrease in overall complications after rTAR\(^{14,16}\), although a recent meta-analysis identified a decrease in overall complications after pooling of results\(^{12}\). The significantly longer operative times when performing robotic-assisted TAR have been reported in all studies. With regard to short-term outcomes, only one study has reported outcomes beyond 30 days\(^{15}\).

While the present study looked at late outcomes, follow-up periods were markedly different at 19 months in the rTAR group, and 43 months in the oTAR group. This is an important limitation to this study, reflecting its observational nature and the later introduction of rTAR. The comparable recurrence rates should be therefore viewed with caution. The choice of the surgical technique varied between centres. At MMH, the implementation of the robotic platform into practice led to a shift from open to robotic-assisted surgery. After the introduction of the robot, only nine open TARs were performed. This induced a potential selection bias, as patient, and hernia characteristics may have influenced the surgeon’s choice. At OUH, the choice of surgical technique was mainly dependent on the availability of the robot, which again could have led to a selection bias. More complex patients, prone to intra- and postoperative complications and longer operative times, may also have made...
up a larger proportion of the oTAR patients. Hernias and meshes used were significantly larger in the oTAR group, although it is worth noting that after adjusting for smoking and hernia width, LOS was still shorter in the rTAR group. A learning curve may have been included, with a possible influence on final outcomes, although no clear reduction in either operative times or complication rates seemed apparent with time. Current recommendations advocate the use of CT to detect hernia recurrence. In this study, hernia recurrence was evaluated principally by clinical examination, with CT used to resolve clinical uncertainty. The true recurrence rate may have been underestimated. This cohort study reports on data from two European high-volume hernia centres, so there remain questions about generalizability of these results.

Future investigations on this topic should have a prospective design and randomization between oTAR and rTAR. Recently, a proposal for a European multicentre randomized clinical trial has been presented at the Fourth Annual Symposium on Robotic Abdominal Wall Surgery (Gent, Belgium). On the basis of the proposal for a European multicentre randomized clinical trial has been presented at the Fourth Annual Symposium on Robotic Abdominal Wall Surgery (Gent, Belgium). On the basis of the proposal for a European multicentre randomized clinical trial has been presented at the Fourth Annual Symposium on Robotic Abdominal Wall Surgery (Gent, Belgium). On the basis of the proposal for a European multicentre randomized clinical trial has been presented at the Fourth Annual Symposium on Robotic Abdominal Wall Surgery (Gent, Belgium). On the basis of the proposal for a European multicentre randomized clinical trial has been presented at the Fourth Annual Symposium on Robotic Abdominal Wall Surgery (Gent, Belgium).

Acknowledgements
The authors thank A. Ramaswany for revision of the manuscript. M.D. and J.M.H. contributed equally to this manuscript.

Disclosure
M.D., J.H., J.S., M.V., and P.O. have no conflicts of interest or financial ties to disclose. E.M. reports having received consultancy fees from Medtronic. T.R. reports having received consultancy fees from Intuitive. F.M. reports having received research grants from Intuitive, Medtronic, and Dynamesh, and has received speaker honorarium from Medtronic, Bard-Davol, Dynamesh, Intuitive, and W.L. Gore, and received consultancy fees from Medtronic, Intuitive, and CMR Surgical.

Funding
The authors have no funding to declare.

Supplementary material
Supplementary material is available at BJS Open online.

Data availability statement
Data are available upon reasonable request.

References
1. Parker S, Halligan S, Liang M, Muysoms F, Adrales G, Boutilier A et al. International classification of abdominal wall planes (ICAP) to describe mesh insertion for ventral hernia repair. Br J Surg 2020;107:209–217
2. Rives J, Pire J, Flament J, Convers G. Le traitement des grandes éventrations a propos de 133 cas) [Treatment of large evntrations (apropos of 133 cases)]. Minerva Chir 1977;32:749–756
3. Tandon A, Pathak S, Lyons NJR, Nunes QM, Daniels IR, Smart NJ. Meta-analysis of closure of the fascial defect during laparoscopic incisional and ventral hernia repair. Br J Surg 2016;103:1598–1607
4. Sneiders D, Yurtkap Y, Kroese LF, Jeekel J, Muysoms FE, Kleinrensink G et al. Anatomical study comparing medialization after Rives-Stoppa, anterior component separation, and posterior component separation. Surgery 2019;165:996–1002
5. Balla A, Alarcón I, Morales-Conde S. Minimally invasive component separation technique for large ventral hernia: which is the best choice? A systematic literature review. Surg Endosc 2020;34:14–30
6. Novitsky Y, Elliott H, Orenstein S, Rosen M. Transversus abdominis muscle release: a novel approach to posterior component separation during complex abdominal wall reconstruction. Am J Surg 2012;204:709–716
7. Belyansky I, Daes J, Radu VG, Balasubramanian R, Reza Zahiri H, Welz AS et al. A novel approach using the enhanced-view totally extraperitoneal (eTEP) technique for laparoscopic retromuscular hernia repair. Surg Endosc 2018;32:1525–1532
8. Radu VG, Lica M. The endoscopic retromuscular repair of ventral hernia: the eTEP technique and early results. Hernia 2019;23:945–955
9. Gokcal F, Morrison S, Kudsi OY. Robotic retromuscular ventral hernia repair and transversus abdominis release: short-term outcomes and risk factors associated with perioperative complications. Hernia 2019;23:375–385
10. Grossi JVM, Lee B, Belyansky I, Carbonell AM, Cavazzola LT, Novitsky YW et al. Critical view of robotic-assisted transverse abdominal release (r-TAR). Hernia 2021;25:1715–1725
11. Dietz UA, Kudsi OY, Garcia-Ureña M, Baur J, Ramser M, Maksimovic S et al. Robotic hernia repair III. English version: Robotic incisional hernia repair with transversus abdominis release (r-TAR). Video report and results of a cohort study. Chirurg 2021;92:28–39
12. Bracale U, Corcione F, Neola D, Castiglioni S, Cavallaro G, Stabilini C et al. Transversus abdominis release (TAR) for ventral hernia repair: open or robotic? Short-term outcomes from a systematic review with meta-analysis. Hernia 2021;25:1471–1480
13. Muysoms F, Campanelli G, Champault GG, DeBeaux AC, Dietz UA, Jeekel J et al. EurAHS: the development of an international online platform for registration and outcome measurement of ventral abdominal wall hernia repair. Hernia 2012;16:239–250
14. Abdu R, Vasylyuk A, Reddy N, Huang L-C, Halka JT, DeMare A et al. Hybrid robotic transversus abdominis release versus open: propensity-matched analysis of 30-day outcomes. Hernia 2021;25:1491–1497
15. Bittner JG, Alrefai S, Vy M, Meabe M, Del Prado PAR, Clingempeel NL. Comparative analysis of open and robotic transversus abdominis release for ventral hernia repair. Surg Endosc 2019;33:727–734
16. Dauser B, Hartig N, Vedadinejad M, Kirchner E, Trummer F, Herbst F. Robotic-assisted repair of complex ventral hernia: can it pay off? J Robot Surg 2021;15:45–52
17. Halka JT, Vasylyuk A, Demare A, Iaco A, Janczyk R. Hybrid robotic-assisted transversus abdominis release versus open transversus abdominis release: a comparison of short-term outcomes. Hernia 2019;23:37–42
18. Martin-Del-Campo LA, Welz AS, Belyansky I, Novitsky YW. Comparative analysis of perioperative outcomes of robotic versus open transversus abdominis release. Surg Endosc 2018;32:840–845
19. Reeves J, Mehta S, Prabha RD, Salama Y, Mittal A. Robotic versus open transversus abdominis release and incisional hernia repair: a case–control study. Laparoscop Endoscops Robot Surg 2020;3:59–62
20. Holihan JL, Karanjawala B, Ko A, Askenasy EP, Matta EJ, Gharbaoui L et al. Use of computed tomography in diagnosing ventral hernia recurrence: a blinded, prospective, multispecialty evaluation. JAMA Surg 2016;151:7–13