Transanal total mesorectal excision: Towards standardization of technique

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Abstract

AIM: To describe the role of Transanal total mesorectal excision (TaTME) in minimally invasive rectal cancer surgery, to examine the differences in patient selection and in reported surgical techniques and their impacts on postoperative outcomes and to discuss the future of TaTME.

METHODS: MEDLINE (PubMed), EMBASE, and The Cochrane Library were systematically searched through the 1st of March 2015 using a predefined search strategy.

RESULTS: A total of 20 studies with 323 patients were included. Most studies were single-arm prospective studies with fewer than 100 patients. Multiple transanal access platforms were used, and the laparoscopic approach was either multi- or single port. The procedure was initiated transanally or transabdominally. If a simultaneous approach with 2 operating surgeons was chosen, the operative time was significantly reduced.

CONCLUSION: TaTME was also associated with better TME specimens and a longer distal resection margin. TaTME is thus feasible in expert hands, but the learning curve and safety profile are not well defined. Long-term follow-up regarding anal function and oncological outcomes should be performed in the future.

Key words: Laparoscopy; Colorectal surgery; Rectal cancer; Total mesorectal excision; Transanal total mesorectal excision; Natural orifice specimen extraction; Transanal; Transanal minimally invasive surgery; Reverse total mesorectal excision

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Core tip: Transanal total mesorectal excision (TaTME) is a result of recent developments in transanal endoscopic microsurgery, transanal minimally invasive surgery, natural orifice specimen extraction, natural orifice transluminal endoscopic surgery, transanal abdominal transanal proctosigmoidectomy, and laparoscopic total mesorectal excision. TaTME is an exciting convergence...
INTRODUCTION

Total mesorectal excision (TME) was first described by Heald et al.\(^1\) in 1982 and is the gold standard for the treatment of rectal cancer. This technique results in larger negative circumferential resection margins, with subsequent reductions in locoregional recurrence and improved oncological outcomes\(^2\). A minimally invasive approach to TME has additionally been developed to optimize postoperative short-term outcomes. Laparoscopic TME exhibits oncological outcomes similar to those of open TME\(^3,4,12-15\) and is also associated with better postoperative recovery, including lower postoperative morbidity and shorter hospital stays\(^7,8\). However, a steep learning curve is associated with laparoscopic TME, making the implementation of this technique a long process\(^9\). The technical challenges of laparoscopic TME are linked to operating in a deep and often narrow pelvis, with difficulties in obtaining adequate exposure. Laparoscopic ultra-low TME requires substantial retraction, which hampers visualization of the most distal part of the rectum. This critical step may lead to both breaches in the mesorectal fascia and incorrect identification of the distal resection margin, compromising oncological outcomes. Moreover, distal rectal transection using currently available laparoscopic staplers can be difficult. A suboptimal angle in the deep bony pelvis\(^10\) often requires different staple firings for rectal transection, and the need for more than 2 linear stapling firings is associated with increased postoperative morbidity and anastomotic leakage\(^11\). The abovementioned technical challenges of operating in a confined space result in considerable rates of conversion from laparoscopic to open TME. Conversion rates as high as 34%\(^16\) have been reported, and these conversions are linked to increased morbidity and worse oncological outcomes\(^13,16\). The risk of conversion is higher in males and obese patients\(^17\).

A recent transanal approach was introduced to facilitate mobilization of the most distal rectum and to overcome the inherent shortcomings of laparoscopic TME\(^18,19\). In particular, transanal total mesorectal excision (TaTME) is a new minimally invasive procedure that basically merges different concepts of transanal surgery. TaTME was developed as a result of combined experience in transanal endoscopic microsurgery (TEM)\(^20\), transanal abdominal transanal proctosigmoidectomy (TATA)\(^21\), transanal minimally invasive surgery (TAMIS)\(^22\), natural orifice specimen extraction (NOSE)\(^23\), and natural orifice transluminal endoscopic surgery (NOTES)\(^24,25\). However, although TaTME appears to be an attractive option for improving postoperative outcomes, the technique has not been extensively investigated. The aims of this systematic review were to describe the role of TaTME in minimally invasive rectal cancer surgery, to examine the differences in patient selection and in reported surgical techniques and their impacts on postoperative outcomes and to discuss the future of TaTME.

MATERIALS AND METHODS

MEDLINE (PubMed), EMBASE, and The Cochrane Library were systematically searched through the 1\(^{st}\) of March 2015. Boolean AND/OR operators were used to combine keywords and subject headings. The following search criteria were used: (total mesorectal excision or TME) and (transanal or transanal minimally invasive surgery or TAMIS or transanal specimen extraction or natural orifice specimen extraction or NOSE or natural orifice transluminal endoscopic surgery or NOTES). Search results were supplemented with subject headings for Medline. The reference lists of retrieved articles were also hand searched for additional publications. Cross-referencing was continued until no further relevant publications were identified. Randomized controlled clinical trials as well as observational cohort studies (excluding case reports) that described a technique to mobilize the most distal rectum transanally using endoscopic instruments were considered for inclusion. Studies of paediatric surgery were excluded. Studies using cadaveric and animal series were also excluded. First, the titles were screened, and appropriate studies were selected. Second, the full text of these studies was acquired. There was no language restriction. The quality of the included studies was assessed using the Newcastle-Ottawa Scale. This scale assesses the quality of non-randomized clinical trials and evaluates patient selection, the comparability of study groups and outcome assessment. A maximum of 9 stars can be achieved\(^26,27\). Relevant data from the included studies were extracted using a standard fillable form of predefined parameters and were entered into an Excel database. The following data were extracted: publication year, study type, inclusion and exclusion criteria, sample size, patient
characteristics (age, gender, and body mass index (BMI)), neoadjuvant treatment, tumour characteristics (clinical stage and distance from anal verge or dentate line), surgical technique (approach, transanal platform used, specimen extraction, anastomotic technique, and defunctioning stoma), and operative outcomes (duration of surgery, estimated blood loss, postoperative complications, length of hospital stay, and follow-up). This systematic review was conducted in compliance with the PRISMA guidelines.²⁸

RESULTS

The predefined search strategy returned 1644 non-duplicated references (Figure 1). Publication titles and abstracts were screened, and 133 publications were retrieved for full-text review. Subsequently, 113 articles were excluded for the following reasons after a detailed review of the studies: 16 studies were off topic, 11 studies were case reports, 7 studies were reviews, 11 studies reported on cadaveric or animal series, 39 studies were abstracts, 14 studies were expert commentaries, 11 studies described the surgical technique or the anatomy involved in TaTME, and 4 studies were duplicate publications of the same clinical series. The article with the most comprehensive data was used in the last case. In total, 20 publications with a total of 323 patients were included.¹²⁻⁶⁸ Seventeen studies were prospective studies, 1 study was a case-control study, 1 study was a comparative study, and 1 study was a retrospective cohort study.

Patient selection

Only small studies, with fewer than 100 patients, were found (Table 1). Patients were predominantly male (male:female = 2:1), with a reported median age of approximately 65 years. The median BMI ranged from 22-31 kg/m². Eighteen of the 20 studies reported the tumour distance from either the anal verge or the dentate line. This distance ranged from 0-15 cm, with reported median distances of between 1.7 and 9.7 cm. Most patients in studies reporting on neoadjuvant therapy received induction chemoradiotherapy (231 of 296 patients). Patient and/or tumour characteristics played a role in patient selection. Specifically, patients were selected according to age (> 18 years old)¹²,¹³ BMI (BMI > 30 kg/m², BMI < 40 kg/m²)¹²,¹³,¹⁴,¹⁵, or pelvic anatomy (pubococygeal diameter < 10 cm)¹²,¹³,¹⁴,¹⁵; in 15 studies, tumour characteristics determined patient selection. Here, patients were selected if they were diagnosed with tumours located anteriorly in 1 study¹⁵, with low (< 5 cm) rectal cancer in 8 studies¹²,¹³,¹⁴,¹⁶,¹⁷,¹⁸,¹⁹,²⁰, or with tumours within 12 cm from the anal verge in 3 studies¹³,¹⁴,¹⁵. Only T1-T3 tumours, as staged by magnetic resonance imaging, were included in 1 study¹³, and tumours that...
Table 1  Types of studies and patient selection for transanal total mesorectal excision

| Author, year | Type of study | No. of patients | Median age (yr) | Gender ratio (M:F) | Median BMI (kg/m²) | Neoadjuvant therapy | Median distance from AV/DL (cm) |
|--------------|---------------|----------------|----------------|-------------------|-------------------|---------------------|-----------------------------|
| Zorrion, 2010 | Prospective   | 9              | 63 (range, 52-81) | 5:4               | NR                | 4/9                 | AV 7.5 (range, 4-12)      |
| Dumont, 2012 | Prospective   | 4              | 67 (range, 70-66) | 4:1               | 23 (range, 22-25) | NR                  | AV 5.3 (range, 4-7)       |
| de Lacy, 2013 | Prospective   | 20             | 65 ± 10.2 (range, 44-77) | 11.9 | 25 ± 3.8 (range, 19-33) | 14/20 | DL 6.5 ± 3.3 (range, 2-15) |
| Lacy, 2013    | Prospective   | 3              | 73 (range, 71-75) | 2:7               | 22 (range, 16-25) | 2/3                 | 9.7 (range, 9-10)         |
| Rouanet, 2013 | Prospective   | 30             | 65 (range, 43-82) | 30:0              | 26 (range, 21-32) | 29/30               | AV Low rectum (0.5 cm) 20/30; Middle rectum (5-10 cm) 10/30; Upper rectum (10-15 cm) 0/30 |
| Sylla, 2013   | Prospective   | 5              | 49 ± 9.8          | 3:2               | 26 ± 2.3          | 2/5                 | AV 5.7 (range, 4-10)      |
| Atallah, 2014 | Prospective   | 20             | 57 (range, 36-73) | 14:6              | 24 (range 18-41)  | 17/20               | AV 5 (range 1-9)          |
| Chen, 2014    | Prospective   | 20             | 58 ± 10.1         | 11:9              | 25 ± 3            | 11/20               | AV 5.9 ± 1.7 (range, 2-8) |
| Choulllard, 2014 | Prospective   | 16             | 58 (range, 34-81) | 6:10              | 28 (range, 21-38) | Yes                 | NR                         |
| Fernandez-Hevia, 2014 | Prospective   | 37             | 65 ± 11.8         | 24:13             | 24 ± 3.6 (range, 18-31) | 27/37 | AV Middle rectum 8.1 ± 1.7; Low rectum 3.5 cm ± 1.2 |
| Kneist, 2014  | Comparative   | 6              | 56 (range, 45-65) | 5:1               | 25 (range, 23-28) | 4/6                 | DL 1.7 (range, 0-3)       |
| Meng, 2014    | Prospective   | 3              | 80 (range, 76-82) | 2:1               | NR                | 1/3                 | AV 4.3 (range, 4-5)      |
| Tuez, 2014    | Prospective   | 56             | 65 (range, 39-83) | 41:15             | 27 (range, 20-42) | 47/56               | AV 4 (range, 0-5)        |
| Velthuis, 2014| Prospective   | 25             | 64 (range, 49-86) | 18:7              | 25 (range, 20-36) | 25/25               | AV 8 (range, 0-16)       |
| Woithuis, 2014| Prospective   | 7              | 65 (range, 38-87) | 6:1               | 25 (range, 17-32) | NR                  | NR                         |
| Atallah, 2015 | Retrospective | 4              | 45 (range, 26-59) | 3:1               | 31 (range, 21-38) | 3/4                 | AV 3.3 (range, 1-4)      |
| Gomez Ruiz, 2015 | Prospective   | 5            | 53 (range, 38-67) | 4:1               | 26 (range, 22-31) | 4/5                 | AV 5 (range, 4-6)        |
| Knol, 2015    | Prospective   | 10             | 61 (range 36-70)  | 8:2               | 27 (range, 22-34) | 10/10               | DL 2.9 ± 1.21            |
| Muratore, 2015| Prospective   | 26             | 66 (range, 38-84) | 16:10             | 26 (range, 17-38) | 19/26               | 4.4 (range, 3-6)         |
| Prochazka, 2015 | Prospective   | 17             | 68 (range, 49-81) | 11:6              | 28 (range, 22-32) | 12/17               | AV 6 (range, 3-8)        |

Values reported as the mean ± SD. AV: Anal verge; DL: Dentate line; NR: Not reported; M: Male; F: Female; BMI: Body mass index.

responded well to neoadjuvant therapy were included in another study[36]. CT4 tumours were excluded in 4 studies[29,30,37,40], and Rullier type II/III[49] tumours were excluded in 1 study[40].

Operative technique
TaTME was initiated transanally in 7 studies[31,32,40,41,44,46,47], and the abdominal phase was performed first in 7 other studies (Table 2)[29,30,35-37,42,45]. TaTME was performed simultaneously with the presence of laparoscopic and perineal operative teams[32,34,38,39,43,48]. This simultaneous approach was taken to reduce the operative time. Seven different transanal access platforms were used: the GelPOINT Path Transanal Access Platform (Applied Medical, Inc., Rancho Santa Margarita, CA, United States), SILS Port (Covidien, Mansfield, MA, United States), TriPort (Olympus Medical Europe Holding GmbH, Germany), TEO proctoscope (Karl Storz, Tuttinglen, Germany), TEM proctoscope (Richard-Wolf, Knittlingen, Germany), Endorec Trocar (Aspide Medical, La Talaudiere, France), and PAT transanal access port (Developia, Mansfield, MA, United States), TriPort (Olympus Medical Europe Holding GmbH, Germany), TEO proctoscope (Karl Storz, Tuttinglen, Germany), TEM proctoscope (Richard-Wolf, Knittlingen, Germany), Endorec Trocar (Aspide Medical, La Talaudiere, France), and PAT transanal access port (Developia, Mansfield, MA, United States). The tumour distance, as measured from the anorectal junction, determined the type of anastomosis (stapled or hand-sewn) before insertion of the transanal access platform. Therefore, the tumour height dictated the type of dissection. Intersphincteric dissection was required using an open approach under direct vision if the tumour was located at the anorectal junction. A Lone Star Retractor (Lone Star Medical Products Inc., Houston, TX, United States) was first inserted. Circumferential sleeve mucosectomy was then performed at the dentate line to safeguard the internal sphincter, and the rectum was closed using a purse-string suture. In particular, the rectal lumen was occluded with a purse string if the distal tumour margin (at least 1 cm below the tumour) allowed for a stapled coloanal anastomosis. Subsequently, the transanal access platform was placed into the anal muscular cuff, and insufflation was initiated with CO₂ to a pressure of 8-15 mmHg using a conventional CO₂ insufflator. The TME plane was identified in a reverse manner, beginning at the top of the puborectal muscle. The posterior TME plane was developed under direct vision using conventional laparoscopic instruments via incision of the endopelvic fascia and dissection in front of the presacral fascia to preserve the mesorectal envelope. Anterior dissection was performed in the rectovaginal septum or Denovilliers’ fascia (rectoprostatic plane) as cephalad as possible until the pouch of Douglas could be opened. Lateral dissection involved division of the middle rectal artery and connection of the anterior and posterior planes bilaterally. Only one study reported pure NOTES TaTME[31], whereas TaTME was performed with laparoscopic assistance (Hybrid TaTME) in most studies. Laparoscopy was performed using multiport laparoscopy (3-5 ports)[32,34,40,43,44,46,47] or single-port access[31,33,44,45,48]. The single port was placed in the future ileostomy site. High ligation
| Author, year | Transanal first | Transanal platform | Pure NOTES | Number of laparoscopic ports | Splenic flexure mobilization | Specimen extraction | Anastomosis | Defunctioning stoma (loop ileostomy) |
|-------------|----------------|-------------------|------------|-----------------------------|-----------------------------|---------------------|-------------|----------------------------------|
| Zorron, 2010 | Yes            | TriPort           | No         | 3                           | Yes                         | Transanal 7; transabdominal 2 | Hand-sewn 1/9, hand-sewn J-pouch 3/9, stapled 5/9 | Yes                |
| Dumont, 2012 | Yes            | GelPOINT Path     | No         | GelPOINT                    | Yes                         | Transabdominal 1         | Hand-sewn                      | Yes                |
| de Lacy, 2013 | Simultaneous   | GelPOINT Path     | No         | 3.2 ± 0.8° (range, 3-4)     | NR                          | Transabdominal 1         | Hand-sewn                      | 16/20              |
| de Lacy, 2013 | Simultaneous   | GelPOINT Path     | No         | 4                           | 2/3                         | Transanal                | Hand-sewn straight 12/30       | Yes                |
| Rouanet, 2013 | Not systematically | TEO proctoscope | No         | NR                          | Yes                         | Transanal                | Hand-sewn straight 12/30       | Yes                |
| Sylla, 2013   | Simultaneous   | TEO proctoscope   | No         | 4 or 5                      | Yes                         | Transanal                | Hand-sewn straight 11/20, stapled 4/20 | Yes                |
| Atallah, 2014 | No             | SILSTM™ Port or GelPOINT path | No         | NR                          | Yes                         | Transanal                | Hand-sewn straight 12/30       | 14/20              |
| Chen, 2014    | No or simultaneous | GelPOINT Path   | No         | GelPOINT + 1                | 4/20                        | Transanal                | Hand-sewn 6/20, stapled 14/20 | Loop colostomy 12/20, loop ileostomy 5/20 |
| Chouillard, 2014 | Yes           | SILSTM™ Port or GelPOINT path | Yes (10/16) | GelPOINT                  | NR                         | NR                     | Hand-sewn | Loop ileostomy 4/16, permanent ileostomy 1/16 |
| Fernandez-Hevia, 2014 | Simultaneous | GelPOINT Path | No         | 3 or 5                     | 14/37                      | Transanal 36; transabdominal 1 | Hand-sewn 16/37, stapled 21/37 | 32/37              |
| Kneist, 2014  | No             | SILSTM™ Port or GelPOINT path | No         | 3-5                         | Yes                        | Transanal                | Hand-sewn J-pouch 2/6, hand-sewn E-E 2/6, hand-sewn S-E 1/6, stapled J-pouch 1/6 | Yes                |
| Meng, 2014    | Simultaneous   | TEM platform      | No         | 5                          | Yes                        | Transabdominal           | Hand-sewn J-pouch 4/5,6, hand-sewn S-E 29/56, hand-sewn straight 13/35 | Permanent colostomy 4/56, permanent ileostomy 44/56 |
| Tuch, 2014    | Yes            | SILSTM™ Port or GelPOINT path or Endorec® | No         | 4 or single port in future ileostomy site | NR                         | Transanal                | Hand-sewn or stapled | Loop ileostomy 19/25, permanent colostomy 6/25 |
| Velthuis, 2014 | 5/25          | SILSTM™ Port or GelPOINT path | No         | SILSTM™ Port                | Yes                        | Transanal                | Hand-sewn or stapled          | Loop ileostomy 3/4, permanent ileostomy 1/4 |
| Wolthuis, 2014 | Yes           | GelPOINT Path     | No         | 3                          | Yes                        | Transanal                | Hand-sewn                      | Yes                |
| Atallah, 2015 | No             | GelPOINT Path     | No         | NR                         | Yes                        | Transabdominal           | Hand-sewn straight 2/5, stapled 3/5 | Yes                |
| Gomez Ruiz, 2015 | No             | Transanal access port proctoscope | No         | 4                           | Yes                        | Transanal                | Hand-sewn straight 2/5, stapled 3/5 | Yes                |
| Knol, 2015    | No             | GelPOINT Path     | No         | 4 or 5                     | 8/10                       | Transanal 1; transabdominal 9 | Hand-sewn J-pouch 7/10, stapled 17/26 | Yes                |
| Muratore, 2015 | Yes            | SILSTM™ Port      | No         | 3                          | Yes                        | Transanal                | Hand-sewn straight 17/26, hand-sewn J-pouch 8/26 | Yes                |
| Prochazka, 2015 | Yes           | SILSTM™ Port or GelPOINT path or Endorec® | No         | NR                         | Yes                        | Transanal                | Hand-sewn                      | Yes                |

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Values reported as the mean ± SD. E-E: End-to-end; NR: Not reported; S-E: Side-to-end.

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**Wolthuis AM et al. Review on TaTME**

**Table 2 Operative techniques reported for transanal total mesorectal excision**
of the inferior mesenteric artery and vein was performed. In 12 studies, after full mobilization of the left and sigmoid colon and connection to the TME plane were performed, the specimen was extracted transanally. This extraction was only performed if the specimen was not too bulky. Adequate length was obtained via mobilization of the splenic flexure. Nine studies described hand-sewn coloanal anastomoses, and only stapled anastomoses were performed in 2 studies. Both hand-sewn and stapled coloanal anastomoses were created in another 9 studies. Additionally, a diverting-loop stoma (loop ileostomy or loop colostomy) was created in nearly every case.

### Outcomes

The median total surgery duration ranged from 143-375 min (Table 3). This time included the transabdominal and transanal operative times. The operative times were significantly reduced when TaTME was performed using a 2-team approach compared with laparoscopic TME. The reported median blood loss ranged from 45-225 mL. Overall, rendezvous was not possible using laparoscopy in 9 patients, so conversion to laparotomy was performed. The reasons for conversion included small-bowel adhesions (3 patients), obesity (2 patients: 1 male and 1 female), a posteriorly fixed tumour (2 patients), and uncontrolled bleeding from the presacral plane (1 patient). Seventeen studies also reported postoperative morbidity. The anastomotic leak rate in the included studies was calculated to be 3.8%. There were also 3.4% pelvic abscesses. Other postoperative complications noted in the studies were (prolonged) postoperative ileus (15 patients), urinary tract infection (7 patients), surgical site infection (4 patients), high-output ileostomy (3 patients), adhesive small-bowel obstruction (2 patients), haemorrhage/pelvic haematoma (2 patients), and urinary tract infection (1 patient). The median length of hospital stay ranged from 4-14 d, and there was no 30-day mortality.

### Table 3 Operative outcomes after transanal total mesorectal excision

| Author, year | Median duration of surgery (min) | Median blood loss (mL) | Postoperative morbidity | Median length of stay (d) | Median follow-up (mo) | NOS |
|--------------|---------------------------------|------------------------|-------------------------|---------------------------|-----------------------|-----|
| Zorron, 2010 | 311 (range, 200-420)            | 96 (range, 20-250)     | Anastomotic leakage 1/9 | 7 (range, 4-27)           | NR                    | 3   |
| Dumont, 2012 | 360 (range, 270-460)            | 175 (range, 50-300)    | Anastomotic leakage 1/4 | 13 (range, 10-21)         | 4.3 (range, 3-9)      | 4   |
| de Lacy, 2013 | 234.7 ± 56 (range, 150-325)    | 45 ± 15 (range, 10-110)| High-output ileostomy 1/20 | 6.5 ± 3.1^1 | NR                      | 6   |
| Lacy, 2013    | 143 (range, 125-155)            | 65 (range, 15-30)      | High-output ileostomy 1/3 | 5 (range, 4-5)           | NR                    | 4   |
| Rouanet, 2013 | 304 (range, 120-432)            | 5 (range, 4-5)         | Pelvic abscess 2/30      | 14 (range, 9-25)         | 21 (range, 10-41)     | 6   |
| Sylla, 2013   | 274 ± 85 (range, 80-300)       | 166 (range, 80-300)    | POI 1/5, transient urinary dysfunction 2/5 | 5.2 ± 2.6^1 | 5.4 ± 2.3^1 | 5   |
| Atallah, 2014 | 243 (range, 140-495)            | 153 (range 30-500)    | SSI 2/20, Pelvic abscess 4/20, POI 4/20, Anastomotic leakage 1/20 | 4.5 (range, 3-24) | 6 (range, 1-24) | 6   |
| Chen, 2014    | 200.8 ± 47.7^2                  | 68 ± 10^6^            | Urinary retention 3/20, pelvic abscess 2/20 | 8.85 ± 2.5^1 | NR                    | 6   |
| Chouillard, 2014 | 265 (range, 155-440)         | 225 (range, 50-600)    | SBO 2/14, pelvic abscess 1/16 | 10 (range, 4-29) | 9 (range, 3-29) | 6   |
| Fernandez-Hevia, 2014 | 215 ± 60 (range, 120-360) | NR                      | Anastomotic leakage 2/3, haemorrhage 1/3, urinary retention 1/3, POI 4/37 | 6 (range, 3-17) | NR | 8   |
| Kneist, 2014  | NR                               | NR                      | Pelvic haematoma 1/7     | 9 (range, 3-14)           | 6 (range, 2-14)      | 6   |
| Meng, 2014    | NR                               | NR                      | Pelvis haematoma 1/7     | 9 (range, 3-14)           | 6 (range, 2-14)      | 6   |
| Tucech, 2014  | 270 (range, 150-495)            | NR                      | Anastomotic leakage 3/56, pelvic sepsis 3/56, transient urinary dysfunction 5/56 | 10 (range, 6-21) | 29 (range, 18-52) | 6   |
| Velthuis, 2014 | NR                               | NR                      | Pelvis haematoma 1/7     | 9 (range, 3-14)           | 6 (range, 2-14)      | 6   |
| Wolthuis, 2014 | 148 (range, 85-250)            | 49 (range, 0-150)      | Pelvis haematoma 1/7     | 9 (range, 3-14)           | 6 (range, 2-14)      | 6   |
| Atallah, 2015 | 376 (range, 40-409)             | 200 (range, 50-300)    | Pelvis haematoma 1/7     | 9 (range, 3-14)           | 6 (range, 2-14)      | 6   |
| Gomez Ruiz, 2015 | 375 (range, 270-450)        | 76 (range, 25-120)     | Anastomotic leakage 1/5  | 6 (range, 5-7)           | NR                    | 4   |
| Kool, 2015    | 235 (range, 150-290)            | 220 (range, 65-480)    | POI 1/10                 | 6 (range, 5-9)           | NR                    | 4   |
| Muratore, 2015 | 241 (range, 150-360)           | NR                      | Urinary retention 1/26   | 7 (range 3-25)           | 18 (range, 16-30)     | 6   |
| Prochazka, 2015 | 280 (range, 212-375)         | 200 (range, 40-900)    | Anastomotic leakage 2/17, POI 2/17, UTI 1/17, SSI 1/17 | 9 (range, 6-30) | NR | 4   |

^1Values reported as the mean ± SD. NR: Not reported; POI: Postoperative ileus; SBO: Small-bowel obstruction; SSI: Surgical site infection; UTI: Urinary tract infection.

Wolthuis AM et al. Review on TaTME
DISCUSSION

This systematic review of TaTME for rectal cancer demonstrated that TaTME is feasible in select patients. The abdominoperineal rectum amputation rate is approximately 21% for low rectal cancer, but most patients are candidates for reconstruction after TME to avoid permanent colostomy.\(^{[49]}\). Acceptance of a shorter distal resection margin (1 cm)\(^{[50]}\), an increased interval after neoadjuvant chemoradiotherapy\(^{[51]}\) and (partial) intersphincteric dissection increase the rates of sphincter-saving surgery in patients with distal rectal cancer.\(^{[49]}\). The recent introduction of TaTME suggests that every patient who is selected for sphincter-saving surgery would undergo a minimally invasive approach, without conversion to laparotomy. This review clearly demonstrated that TaTME is currently performed in a non-standardized manner, which reflects surgeons exploring the technical boundaries of ultra-low rectal cancer surgery. Heterogeneity in patient selection and operative techniques leads to differences in surgical, oncological, and functional outcomes, which in turn hinder inter-study comparisons. Operative techniques specifically differed among studies in the present analysis, with use of different numbers of ports, different transanal platforms and different methods of performing TaTME. The procedure can be initiated either transabdominally or transanally, and the extent of dissection from either side can be tailored to each individual patient. The additional use of Airseal technology leads to a stable workspace (pneumoperitoneum), which avoids any “flapping” of the specimen and facilitates pneumodissection.\(^{[52]}\).

TaTME has certain advantages over laparoscopic TME, but there are still issues that must be addressed. TaTME is advocated in the case of a narrow male pelvis, so most studies have selected male patients. Only a few studies considered BMI or pelvic anatomy for patient selection. Less than half of the studies included here exclusively selected low (i.e., < 5 cm from the anal verge) rectal tumours for TaTME. TaTME is an attractive alternative to laparoscopic TME because of several benefits, including determination of the distal resection margin, creation of a single stapled anastomosis, and avoidance of abdominal wall incision for specimen retrieval. If TaTME is first initiated in the transanal phase, then the distal resection margin and the level of the future anastomosis can be chosen under direct vision. A significantly longer distal resection margin has been reported using TaTME compared with conventional laparoscopic TME.\(^{[28]}\). TaTME also results in better TME specimens.\(^{[28]}\). Furthermore, this review demonstrated that a hand-sewn anastomosis was performed in approximately half of the studies, which may reflect the selection of patients with ultra-low rectal cancers. A stapled coloanal anastomosis using the double purse-string technique results in a single stapled anastomosis. This technique may eventually lead to a decreased anastomotic leak rate, but whether this technique improves functional outcomes is not clear. Moreover, TaTME will ultimately be performed as a pure NOTES procedure, which may be its greatest advantage. In this way, the diseased target organ can be reached transanally, so future developments should focus on pure NOTES TaTME. If laparoscopy can be omitted in this setting, then true NOTES may become possible in a consecutive series of patients. Mobilization and extraction of the specimen can presently be performed via the anus if the splenic flexure is mobilized using laparoscopic assistance. Therefore, TaTME is a NOSE technique that shares all of the advantages of NOSE. The avoidance of abdominal wall incision that is tailored to specimen and tumour sizes is important because the extraction site carries a morbidity risk. A wound infection rate of 9% has been documented, albeit generally, with only local septic complications in particular.\(^{[53]}\). This review demonstrated that specimens were extracted transanally in 12 studies. Differences between transanal NOSE techniques involving laparoscopic TME using the anus as the extraction site and techniques involving transanal TME in the literature must be highlighted. Both procedures are transanal NOSE techniques, but transanal TME is performed in a reverse manner. TaTME may offer several advantages over laparoscopic and open TME, but it also has limitations. One major perioperative complication that is specific to TaTME is urethral injury. For example, Rouanet et al.\(^{[42]}\) described two urethral injuries that were sutured transanally. Moreover, the impact of TaTME on the anal sphincter is not known, and therefore, functional outcomes after TaTME are of interest. Additionally, this technique is in its infancy, so the learning curve is ill defined. Further prospective studies will therefore be required to describe the safety profile of and learning curve for TaTME. However, it is clear that a reverse approach to the mesorectum forces surgeons to recognize new anatomical landmarks and to perform the fundamental steps of TaTME.\(^{[54,55]}\). Most studies have only reported short-term outcomes, which reflects the novelty of TaTME. Whether this new approach exhibits similar oncological outcomes in terms of local recurrence, disease-free survival and cancer-specific survival will require further study in prospective trials that compare TaTME with conventional laparoscopic or robotic TME over substantial follow-up periods.

In conclusion, this state-of-the-art narrative review presents recent developments in the TaTME technique. The technical possibilities and shortcomings of TaTME are also described. A new era of further optimization of distal rectal cancer surgery has dawned: standardization of surgical technique and implementation in daily practice are the steps required to take TaTME to the next level. In addition, large prospective studies should focus on safety and functional and oncological outcomes, and the presumed benefits of TaTME must be studied in controlled trials.
The aims of this systematic review were to describe the role of TaTME in minimally invasive rectal cancer surgery, to examine the differences in patient selection and in reported surgical techniques and their impacts on postoperative outcomes and to discuss the future of TaTME.

Innovations and breakthroughs
A total of 20 studies with 323 patients were included. Most studies were single-arm prospective studies with fewer than 100 patients. Multiple transanal access platforms were used, and the laparoscopic approach was either multi- or single port. The procedure was initiated transanally or transabdominally. If a simultaneous approach with 2 operating surgeons was chosen, the operative time was significantly reduced.

Applications
TaTME was also associated with better TME specimens and a longer distal resection margin. TaTME is thus feasible in expert hands, but the learning curve and safety profile are not well defined.

Peer-review
Well written paper, well conducted review.

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