Pelvic autonomic nerve preservation in radical rectal cancer surgery: changes in the past 3 decades

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Abstract

The advent of total mesorectal excision (TME) together with minimally invasive techniques such as laparoscopic colorectal surgery and robotic surgery has improved surgical results. However, the incidence of bladder and sexual dysfunction remains high. This may be particularly distressing for the patient and troublesome to manage for the surgeon when it does occur. The increased use of neoadjuvant and adjuvant radiotherapy is also associated with poorer functional outcomes. In this review, we evaluate current understanding of the anatomy of pelvic nerves which are divided into the areas of the inferior mesenteric artery pedicle, the lateral pelvic wall and dissection around the urogenital organs. Surgical techniques in these areas are discussed. We also discuss the results in functional outcomes of the various techniques including open, laparoscopic and robotic over the last 30 years.

Key words: total mesorectal excision; pelvic autonomic nerve preservation; urinary dysfunction; sexual dysfunction

Introduction

Surgical management for rectal cancer is challenging due to the narrow pelvis and extreme proximity to contiguous organs; hence, recurrence rates are commonly reported. The advent of total mesorectal excision (TME) [1,2] together with minimally invasive techniques such as laparoscopic colorectal surgery [3–6] and robotic surgery [7–9] have not only improved surgical results but have also improved surgical technique, operative ability and surgical visibility. Nonetheless, the improved survival of patients due to surgeons’ increased ability to resect rectal cancers completely is not without problems. In particular, bladder and sexual dysfunction may be particularly distressing for the patient and troublesome to manage for the surgeon when they do occur.

The incidence of urinary dysfunction may be as high as 27% and includes difficulty emptying the bladder as well as urinary incontinence. Sexual dysfunction may also reach 11–55% after TME. For females, the inability to achieve orgasm, dyspareunia and reduction in vaginal lubrication may be distressing, even for some of the more elderly females. Many male surgeons do not realise that this is an important quality of life factor, especially for younger female patients. For males, nerve dysfunction may include erectile dysfunction, absence of ejaculation or retrograde ejaculation [10–13]. The increased use of neoadjuvant and adjuvant radiotherapy is associated with poorer functional outcomes. When radiotherapy is indicated, however, it cannot be withheld just because of the fear of nerve dysfunction. One of the main risk factors, poor surgical technique with resultant iatrogenic sexual and urinary dysfunction, however, may be prevented by thorough and practical understanding of pelvic nerve anatomy [14].

This review attempts to evaluate current understanding of the anatomy of pelvic nerves and the differences in outcomes of the various techniques including open, laparoscopic and robotic.
Surgical Pelvic Nerve Anatomy

Sexual and urinary dysfunction may be due to somatic and autonomic pelvic nerve damage. The lower pelvis can be divided into 2 anatomical levels: one above the levator ani (supplied by autonomic nerves) and the other below the levator (supplied by somatic innervation via the pudendal nerves) [15,26]. The autonomic plexus includes the superior hypogastric plexus (SHP) comprising sympathetic nerves, the inferior hypogastric plexus (IHP) comprising mixed sympathetic and parasympathetic nerves and the pelvic splanchnic nerves (which are parasympathetic nerves) [14,15].

The principles of sharp dissection and direct visualization of all structures during surgery of the rectum apply in all cases regardless of whether open, laparoscopic or robotic techniques are applied. The well-known TME technique requires high ligation of the inferior mesenteric artery pedicle and careful sharp dissection in the ‘holy plane’ down to the pelvic floor with transection of the rectum (with adequate margins) followed by end-to-end anastomosis. Limitations of direct visualization may result from the anatomical constraints of the narrow bony pelvis, especially with a very curved, prominent sacrum together with a narrow true pelvis which is often especially narrow in the android pelvis. This may be made worse in patients with high body mass index with bulky pelvic sidewall and mesorectal fat. Pelvic adhesions from radiotherapy or tumour inflammation or gross tumour adherence to contiguous organs may also require surgeons to perform extrafascial dissection to achieve good circumferential radial margins or clearance—and thereby increase the risk of damage. The possible need for lateral node dissection may also lead to further injury.

Inferior mesenteric artery (IMA) pedicle

Nerve anatomy

The SHP is located anterior to the body of the L5 vertebra and is found on the left anterolateral side of the aorta and its bifurcation [15]. The SHP arises from pre-aortic sympathetic trunks alongside the T10–L3 vertebrae, descends along the sacral promontory and then bifurcates into the bilateral hypogastric nerves [17]. These run 2 cm medial to the ureter and common iliac artery on both sides [13] (Figure 1). The hypogastric nerves move obliquely and anteriorly towards the rectum and then along the side of the rectal fascia where they are covered by the endopelvic fascia. These hypogastric nerves finally end as afferent fibres of IHP at the level of the intersection between the vas deferens and the ureter at [15,16,18].

Surgical technique

Ligation of the IMA begins with tenting the sigmoid colon. The promontory and aortic bifurcation are identified, and the surgeon should be aware that the peritoneal layer covering this area holds the hypogastric nerves (Figure 2). In a medial-to-lateral approach, the incision is made medial to the right iliac vessels and may extend up to the duodenojejunal flexure. Care is taken to push back the sympathetic pre-aortic nerves together with the retroperitoneal structures, such as the left ureter and left gonadal vessels located just below the peritoneum, using sharp dissection to expose the IMA origin. Technical points:

i. Ligation of the IMA should be performed 1.5–2 cm from its aortic origin to avoid damage to SHP fibres lying in front of the aorta [15,18].

ii. Avoid mass clamping of the IMA which may increase damage to the left trunk of the SHP due to its closer proximity compared with the right trunk of SHP located in the aortocaval plane [19].

iii. Preserve Gerota’s fascia during mobilisation of the ureter and gonadal vessels as these contain SHP fibres [20].

iv. At the level of the sacral promontory, the transition from mesosigmoid to mesorectum is an area where damage is possible to the presacral plexus and hypogastric nerves. To avoid the wrong plane of dissection, it is important to dissect only immediately posterior to the superior rectal artery and to remain within the plane anterior to the parietal presacral fascia. It has been suggested that this should be approximately 2 cm anterior to the promontory [20,21].

Lateral pelvic wall

Nerve anatomy

The IHP receives pelvic parasympathetic fibres from roots S2–S5 (splanchnic nerves or erector nerves of Eckard). These nerves are covered by the parietal fascia, pierce the endopelvic fascia, cross the retrorectal space and form branches into the rectum via the lateral ligaments [15]. Fibres from the IHP also innervate the seminal vesicles, prostate and bladder, cervix and vagina. These nerves are responsible for penile erection, detrusor contractility, female arousal and vaginal lubrication. The pelvic parasympathetic nerves join the sympathetic hypogastric nerves in a Y-shaped connection to form the pelvic plexus (Figure 3).

The lateral ligaments are thought to be a condensation of endopelvic connective tissue located on the anterolateral side of the subperitoneal rectum. Some authors suggest that ‘lateral ligaments’ do not exist and are not distinct anatomical structures; instead, these ligaments are perhaps an artefact produced by surgical dissection. These ligaments may or may not contain an insignificant or small middle rectal artery [15,16,22]. Other authors suggest that the lateral ligaments join the parietal fascia to the fascia propria and that part of the IHP lies within the lateral ligaments, giving branches to the rectum. These arise bilaterally about 2 cm below the peritoneal reflection [15,23]. Others, however, suggest that all lymphatics are located within the mesorectum and are arranged around the superficial rectal artery with no lymphatic drainage into the lateral ligaments [24].

Surgical technique

The opinion that anatomic dissection of the rectum does not require over-zealous lateral dissection arose from this latter understanding. Dissection of the lateral ligaments is best done after posterior dissection has gone as far down to the pelvic floor as possible. [16] With adequate traction and countertraction, the hypogastric nerves can be visualised as they enter the deep layers of the parietal fascia to the IHP. It is suggested that the adherent nerves can be eased off the mesorectal fascia laterally. The surgeon should avoid hooking the tissue laterally with the finger; neither should there be a need to cross-clamp the middle rectal pedicle to avoid damaging the nerves [25,26].

Dissection around urogenital organs

Nerve anatomy

The pelvic plexus is a network of nerves, located at the level of the lower third of the rectum, that innervate the rectum, bladder, seminal vesicles, prostate, ureters, membranous urethra, corpora cavernosa, uterus and vagina [15,21]. In men, neurovascular bundles (of Walsh) from the pelvic plexus include the
cavernous nerves which are responsible for erectile function and run laterally outside Denonvilliers fascia, lie at the lateral corners of the seminal vesicles at the 2 and 10 o’clock positions and eventually lie anterior to the postero-lateral border of the prostate and continue onto the periprostatic plexus \[25\]. In women, the nerves enter the vesicovaginal and rectovaginal septa and run underneath the crossing point of the ureter and uterine artery \[21\].

**Surgical technique**

Dissection of the infra-peritoneal rectum from the prostate, seminal vesicles and vagina which are areas at high risk of nerve injury \[15,21\]. Heald et al in their original technique considered that the Denonvilliers fascia should be resected in TME surgery as it forms the anterior surface of the mesorectum \[2\]. It is however suggested that this extra-mesorectal resection should only be performed if there are concerns about a compromised circumferential resection margin, especially for anterior-based tumours. In such a case, care during dissection should be taken along all dissection planes within the propria fascia of the rectum. Once below the rectoprostatic fascia, the correct plane is along the muscular wall of the rectum \[15,26,27\]. For posterior and lateral rectal tumours, it is suggested that the entire rectoprostatic fascia be left intact \[28\] (Figure 4). There are, however, additional difficulties in identifying Denonvilliers fascia in elderly patients following neoadjuvant radiotherapy or in those patients with a narrow bony pelvis or very large bulky tumours.

During the perineal phase of an abdominoperineal resection, care should be taken especially at the level of the prostate which contains the dorsal nerve of the penis and plays an important role in erection and ejaculation \[13,29\]. This is commonly damaged during excessive traction or excessive or prolonged cautery in the anterolateral plane of dissection.

**Comparison of Functional Outcomes with Regards to Open, Laparoscopic and Robotic TME**

The introduction of TME was important not only for reducing local recurrence but also for preserving urogenital function \[2\]. The emphasis on sharp pelvic dissection in anatomical planes of the pelvis must be obeyed regardless if the technique is open, laparoscopic or robotic TME. However, postoperative sexual and urinary dysfunction occurs due to inadvertent avulsion or direct injury of nerve plexus.

Laparoscopic rectal surgery is technically difficult, and advanced laparoscopic surgical skills are required. As technology has improved over the years and high-definition cameras replaced traditional optic lenses and reduced ‘smoky’ images due to use of energy devices, the advances in dissection have produced convincing evidence of short-term benefits of reduced pain, shorter hospital stays and earlier returns to normal work.
Figure 3. Anatomy of the pelvic autonomic nerves with relation to rectum. The inferior hypogastric plexus comprises nerves from the hypogastric and pelvic splanchnic nerves at lateral pelvic wall.

Figure 4. The relationship of the rectum and pelvic autonomic nerves during open surgery when standing on the patient’s left. The ligation of the inferior mesenteric artery should be performed 1.5–2 cm from its origin from the aorta to avoid damaging the superior hypogastric plexus. At the pelvis, for posterior and lateral tumours, dissection should be directed below the Denonvilliers fascia to avoid damaging the neurovascular bundles that run along the tip of the seminal vesicle (2 and 10 o’clock directions).
without compromising oncology outcomes. Energy devices, however, produce more heat laterally in contrast to electrocautery, and initial concerns were increased risk of nerve damage.

Certain limitations continue to plague laparoscopic surgery, however, particularly the use of unarticulated rigid instruments. A good assistant is especially important during TME because two-dimensional view and poor ergonomics can negatively impact any surgeon attempting to visualize nerves during rectal dissection. The marked interest in robotic surgery was largely due to several reasons: (a) the EndoWrist function with seven degrees of freedom; (b) the magnified view of the operative field; (c) the decrease of inherent operator tremor and (d) the precision of instruments was said to be associated with improved functional outcomes. Next, we review the current published literature and compare the outcomes with respect to the different techniques of rectal surgery.

**Urinary dysfunction**

The studies of open TME are largely cohort studies. In older studies between the years 1990 and 2002, the median follow-up ranged from 3 to 41 months, and the number of study subjects ranged from 68 to 199 patients (Table 1) [11,12,30–36]. While reporting incidences and outcomes varied with different classifications, the overall incidence can be as high as 33%. When non-conventional TME was performed, 19% vs 7% of subjects who underwent standard TME had increased difficulty in voiding [35,36].

In newer studies between the years 2003 and 2013, the median follow-up ranged from 7 to 218 months (Table 1) [37–48]. The number of study subjects ranged from 20 to 292 patients, although 3 studies were performed at the same study center [37,38,42]. When autonomic nerve preservation (ANP) was practiced, the incidence of urinary dysfunction ranged from 2.1 to 24.4% [37–41,45–48]. This was significantly higher (between 22.4 and 79.1%) if ANP was not observed during surgery [37,38,42,45–48]. Long-term indwelling catheter use was 2.1–10.8% with ANP, but 30–40% of these patients had successful trial of void within 6 months and improvement of function [37,38,42]. In patients who had pelvic lymph node dissection (PLND), the incidence in these studies noted a high rate of urinary dysfunction [32,41,43], and patients may take 2–3 weeks to return to presurgical residual urinary volume [42].

For laparoscopic TME, there were 2 randomized controlled trials comparing laparoscopic vs open TME techniques which reported functional outcomes [10,49]. While function was not the primary endpoint, there were no significant overall differences in urinary function between the laparoscopic and TME groups. This finding was also supported by other recent cohort studies (Table 1) [50–53,59]. Of note, Jayne et al. and Hur et al. reported that voiding function would reduce after surgery with some restoration by 6 months and full recovery to preoperative levels by 12 months [49,51]. The incidence of minor urinary dysfunction was low regardless of technique (7.3% open TME vs 5.4% laparoscopic TME) [50]. When laparoscopic TME was compared with robotic TME, Kim et al. noted that restoration of urinary function was faster at 3 months [54]. There are, however, no differences seen in bladder function between the 2 groups 12 months after surgery in other studies as well [55–58]. In all studies the incidence of permanent IDC was very low at 0.5%.

**Sexual dysfunction**

For open TME studies, the incidence of sexual dysfunction ranges from 11% to 85%. If ANP is performed, the incidence of male erectile dysfunction ranges from 1.5% to 49.15%, and the incidence of male ejaculatory dysfunction ranges from 12% to 44.2% (Table 2) [11,12,29–36,39–41,43–48,56,60–62]. There were, however, 2 other studies that noted a very high incidence of erectile dysfunction (69%) and ejaculatory dysfunction (85%) even with ANP [30,32]. If ANP is not performed, the incidence can be as high as 100% [40]. Only a few studies have reported female sexual dysfunction (due to low questionnaire response rate of female candidates compared with male counterparts). The incidence of orgasmic dysfunction reported in females is significantly lower at 0 to 10.5% [12,34,35,45,58], with only 2 studies reporting incidence of dyspareunia ranging from 4.15% to 66.7% [35,45]. If pelvic lymph node dissection is performed, the incidence of dysfunction can range from 21.5% to as high as 90% [33,41].

Post-laparoscopic TME results in 12.8% to 57% erectile dysfunction, 40% to 43.7% ejaculatory dysfunction and 7.1% to 41% overall male sexual dysfunction (Table 2) [10,49–57,59,63]. When comparing the incidence of sexual dysfunction following laparoscopic TME with open TME, the benefit of minimally invasive surgery is inconsistent. Jayne et al. and Quah et al. randomized trials suggested worse sexual functioning in laparoscopic rectal surgery (23.9–41%) compared with open surgery (10.8–18%) [10,49]. However, Liu’s randomized trial demonstrated lower incidence of sexual dysfunction in laparoscopic TME with ANP vs open procedure (11.6% vs 16.9%); it is worth noting that the result shows no statistical significance [63]. In a more recent cohort study and a non-randomized trial, there is no statistically significant difference in the incidence of both erectile and ejaculatory dysfunction among laparoscopic vs open TME [51,56], but one study noted worse functioning of both sexes in the open group [50]. When robotic surgery was compared with laparoscopic TME, Kim et al. and Park et al. noted no difference in function between both arms [54,58], but D’Annibale et al. noted that while the erectile function worsened 1 month after surgery, it was almost completely restored at 12 months in the robotic group but only partially restored in the laparoscopic group with an incidence of 57% [55].

**Conclusion**

It is evident from this summary of outcomes that there is still more work to be done. It must be remembered that colorectal surgery underwent a huge wave of change in the time frame of the conducted studies. There was a radical shift from open to minimally invasive and robotic techniques, as well as a worldwide application of neoadjuvant chemoradiotherapy for locally advanced rectal cancers, which was all largely happening in the preceding 10–15 years. Many of the cohort studies also appear to have strong selection bias and perhaps include many institutions’ learning curves for the minimally invasive techniques. In addition, many of these studies have a short follow-up of < 2 years with a relatively small number of subjects. We must therefore interpret all study results cautiously. While open TME results initially appeared to have high urinary and sexual dysfunction rates, the later studies showed no differences in outcomes between laparoscopic and open techniques in terms of urinary dysfunction. There appeared to be worsened sexual functioning in the earlier studies for laparoscopic TME, but no difference was observed in the later studies. The argument of...
| Literature | Year of publication | Study design | Procedure type | Subjects evaluated | Duration of follow-up (months) | Complications |
|------------|---------------------|--------------|----------------|-------------------|-------------------------------|---------------|
| **Open TME** | | | | | | |
| Hojo et al. [30] | 1990 | Case series - Retrospective | TME and ANP | 134 | 12 | Multi-level sacrifice of HP and PP contributes to more severe urinary dysfunction and increasing bladder hypertonia |
| Havenga et al. [29] | 1996 | Case series - Retrospective | TME | 136 | | No significant change in both male and female urinary function |
| Sugihara et al. [31] | 1996 | Case series - Prospective | TME and ANP | 199 | 12 | Urinary dysfunction: 0% in intact HP and PP, 3.9% in sacrifice HP and intact bilateral PP, 6.5% in sacrifice HP and unilateral PP, 30.8% in complete resection of pelvic autonomic nerves |
| Saito et al. [32] | 1998 | Case series | TME and ANP | 167 | | No requirement for long-term indwelling catheter |
| Ishikura et al. [33] | 1999 | Case series - Prospective | TME and ANP with PLND | 49 | Median 41 | Urinary dysfunction in both sexes: 18.4% |
| Maas et al. [35] | 2000 | Case series - Prospective | TME and ANP with radical rectal resection | 47 | Median 42 | Urinary frequency in both sexes: 22%; |
| Nesbakken et al. [34] | 2000 | Case series - Prospective | TME | 49 | 3 | Minor incontinence in both sexes: 19% |
| Maurer et al. [36] | 2001 | Case control | TME vs Non-TME conventional rectal excision | 60 | Minimum 3 | No significant change in urinary symptom score (both sexes) except for increase in female incontinence score |
| Pocard et al. [12] | 2002 | Case series - Prospective | TME | 20 | Up to 60 | No significant change in urinary symptom among both groups |
| Kim et al. [11] | 2002 | Case series - Prospective | TME | 68 | Median 8.7 | Both sexes requiring indwelling catheter: 0%. |
| Junginger et al. [38] | 2003 | Case series - Prospective | TME with pelvic plexus visualisation | 150 | Median 24 | No significant change in urinary symptom score (both sexes) |
| Kneist et al. [37] | 2004 | Cohort study | TME or partial mesorectal excision | 229 | | Overall urinary dysfunction (both sexes): 12%. |
| Shirouzu et al. [40] | 2004 | Case control | TME with vs without ANP | 292 | Median 218 | Complete or partially visualised ANP 4.5% vs non-visualised: 38.5%. |
| Sterk et al. [39] | 2005 | Case series - Prospective | TME | 52 | 3 | Required short-term indwelling catheter (both sexes): 10.7%. |
| Wang et al. [45] | 2005 | Case control | Open TME with vs without ANP | 96 | | Overall urinary dysfunction (both sexes): 4.1% with complete ANP vs 22.4% without ANP. |

(continued)
| Literature     | Year of publication | Study design          | Procedure type                                                                 | Subjects evaluated | Duration of follow-up (months) | Complications                                                                                                                                                                                                 |
|---------------|---------------------|-----------------------|-------------------------------------------------------------------------------|--------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Laing et al.  | 2006                | Case control          | Open TME with vs without ANP                                                  | 236                |                               | Residual urine > 50 ml: 10.41% with ANP vs 31.25% without ANP. Significantly longer duration to recover from urinary symptoms in patients without ANP. Overall male urinary dysfunction: 12.71% with ANP vs 70.33% without ANP (SD only occurred in Duke A and Duke B comparative groups) |
| Kyo et al.    | 2006                | Case control          | Open TME and ANP with vs without PLND                                         | 37                 | Minimum 7                     | Male urinary dysfunction: 33% with PLND vs 9.5% without PLND. Failed urinary catheter removal on post-op day 3: 9.7% Urinary dysfunction (both sexes): 2.1% with complete ANP vs 60% without ANP. |
| Dong et al.   | 2007                | Case series - Retrospective Cohort study | Open TME with ANP, bladder neurophysiology monitor with vs without ANP | 124 | Median 20 | Both sexes required long-term indwelling catheter: 2.1% vs 33.3% without ANP. Significantly worse in urinary symptom score without ANP. Bilateral pelvic-plexus preservation without PLND: 4% Bilateral pelvic-plexus preservation with PLND: 27% Unilateral pelvic-plexus preservation with PLND: 76% No pelvic-plexus preservation with PLND: 100% Male urinary dysfunction: 24.4% in TME and ANP vs 79.1% in TME alone (SD) Male urinary dysfunction: 25% Male requiring long-term indwelling catheter: 5% |
| Kneist et al. | 2007                | Case series - Prospective | LAR/APR with selected ANP and PLND                                             | 69                 | 0.5                           | Residual urine > 50 ml at day 14 (SD) Bilateral pelvic-plexus preservation without PLND: 4% Bilateral pelvic-plexus preservation with PLND: 27% Unilateral pelvic-plexus preservation with PLND: 76% No pelvic-plexus preservation with PLND: 100% Male urinary dysfunction: 24.4% in TME and ANP vs 79.1% in TME alone (SD) Male urinary dysfunction: 25% Male requiring long-term indwelling catheter: 5% |
| Quah et al.   | 2002                | Randomized controlled trial | Laparoscopic assisted vs open TME                                             | 80                 | Median 36                     | Urinary dysfunction (both sexes): 0%. Males required long-term indwelling catheter: 2.5% in laparoscopic vs 0% in open (no SD). Females required long-term indwelling catheter: 2.5% in laparoscopic vs 0% in open (no SD). Urinary dysfunction (both sexes): 21% in laparoscopic colonic, 35% in open/ laparoscopic rectal. No significant change in urinary symptom score after 6 months. |
| Zhao et al.   | 2011                | Case control          | Open TME and ANP vs TME alone                                                | 84                 | Up to 24                      | Male urinary dysfunction: 24.4% in TME and ANP vs 79.1% in TME alone (SD) Male urinary dysfunction: 25% Male requiring long-term indwelling catheter: 5% |
| Cakabay et al.| 2012                | Case series - Prospective | TME                                                                            | 20                 | 12                            | Male urinary dysfunction: 25% Male requiring long-term indwelling catheter: 5% |
| Liang et al.  | 2007                | Case series - Prospective | Laparoscopic TME                                                              | 74                 | Minimum 3                     | Urinary dysfunction (both sexes): 17.6% |
|               |                     |                       |                                                                               |                    |                               |                                                                               |
|               |                     |                       |                                                                               |                    |                               |                                                                               |
| Literature            | Year of publication | Study design       | Procedure type                  | Subjects evaluated | Duration of follow-up (months) | Complications                                                                 |
|-----------------------|---------------------|--------------------|--------------------------------|--------------------|------------------------------|------------------------------------------------------------------------------|
| Kim et al. [54]       | 2012                | Cohort study       | Laparoscopic vs robotic TME    | 38                 | 12                           | Urinary dysfunction (both sexes): 3.3% in robotic vs 5.1% in Lap (no SD)     |
| McGloen et al. [50]   | 2012                | Cohort study       | laparoscopic vs open TME       | 143                | Minimum 6                    | No significant change in urinary symptom score (both sexes)                  |
| D’Annibale et al. [55]| 2013                | Cohort study       | Laparoscopic vs robotic TME    | 60                 | 12                           | Male urinary dysfunction: 0%                                                 |
| Runkel et al. [53]    | 2013                | Case series - Prospective | Laparoscopic nerve orientated mesorectal excision | 274                | 12                           | Male requiring long-term indwelling catheter: 0.5%                             |
| Luca et al. [57]      | 2013                | Case series - Prospective | Totally robotic TME            | 74                 | 17.03                        | Male urinary dysfunction: 0% Female urinary dysfunction: 0%                   |
| Hur et al. [51]       | 2013                | Non-randomized control trial | Laparoscopic vs open TME       | 97                 | 12                           | Urinary dysfunction (both sexes): 5.4% in laparoscopic vs 7.3% in open (no SD) |
| Zeng et al. [59]      | 2013                | Cohort study       | Laparoscopic vs open TME with ANP | 81                 | 6                            | Overall male urinary dysfunction: 16.28% in laparoscopic vs 15.79% in open (no SD) |
| Park et al. [56]      | 2014                | Case control       | Laparoscopy vs Robotic TME     | 64                 | 12                           | No difference in IPSS scores                                                  |

ANP: autonomic nerve preservation; PLND: pelvic lymph node dissection; IPSS: International Prostate Symptom Score; SD: statistical significant difference; HP: Hypogastric plexus; PP: Pelvic Plexus
Table 2. Incidence of sexual dysfunction when comparing open, laparoscopic and robotic total mesorectal excision (TME)

| Literature       | Year of publication | Study design          | Procedure type | Subjects evaluated | Duration of follow-up (months) | Complications                                                                                     |
|------------------|---------------------|-----------------------|----------------|--------------------|--------------------------------|-----------------------------------------------------------------------------------------------|
| **Open TME**     |                     |                       |                |                    |                                |                                                                                               |
| Hojo et al. [30] | 1990                | Case series - Retrospective | TME and ANP   | 39                 | 12                             | Male erectile dysfunction: 69%                                                                 |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction: 85%                                                              |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction: 13%                                                               |
|                  |                     |                       |                |                    |                                | < 60 year-old sexual dysfunction (both sexes): 14%                                              |
|                  |                     |                       |                |                    |                                | > 60 year-old sexual dysfunction (both sexes): 33%                                               |
|                  |                     |                       |                |                    |                                | Male sexual dysfunction with and without ANP: 66.7%                                            |
|                  |                     |                       |                |                    |                                | Male sexual dysfunction with complete ANP: 29.6%                                               |
|                  |                     |                       |                |                    |                                | Male erectile dysfunction with complete ANP: 3.8%                                               |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction with complete ANP: 20%                                             |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction with incomplete ANP: 18.5%                                         |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction with incomplete ANP: 100%                                          |
| Havenga et al. [29] | 1996         | Case series - Retrospective | TME            | 136                |                                |                                                                                               |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction: 13%                                                               |
|                  |                     |                       |                |                    |                                | > 60 year-old sexual dysfunction (both sexes): 14%                                              |
|                  |                     |                       |                |                    |                                | < 60 year-old sexual dysfunction (both sexes): 33%                                               |
| Sugihara et al. [31] | 1996        | Case series - Prospective | TME and ANP   | 57                 | Median 53                       | Male sexual dysfunction with and without ANP: 66.7%                                            |
|                  |                     |                       |                |                    |                                | Male sexual dysfunction with complete ANP: 29.6%                                               |
|                  |                     |                       |                |                    |                                | Male erectile dysfunction with complete ANP: 3.8%                                               |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction with complete ANP: 20%                                             |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction with incomplete ANP: 18.5%                                         |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction with incomplete ANP: 100%                                          |
| Enker et al. [58] | 1997                | Case control           | TME and ANP in APR vs LAR | 136                | up to 60                        |                                                                                               |
|                  |                     |                       |                |                    |                                |                                                                                               |
|                  |                     |                       |                |                    |                                | Male sexual dysfunction in LAR: 14%                                                             |
|                  |                     |                       |                |                    |                                | Male sexual dysfunction in APR: 43%                                                             |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction in LAR: 12%                                                         |
|                  |                     |                       |                |                    |                                | Male ejaculatory dysfunction in APR: 15%                                                         |
|                  |                     |                       |                |                    |                                | Female sexual dysfunction: 14%                                                                |
|                  |                     |                       |                |                    |                                | Female orgasmic dysfunction: 9%                                                                |
|                  |                     |                       |                |                    |                                | Unsuccessful in preserving sexual function                                                       |
|                  |                     |                       |                |                    |                                |                                                                                               |
| Saito et al. [32] | 1998                | Case series            | TME and ANP    | 167                |                                |                                                                                               |
|                  |                     |                       |                |                    |                                |                                                                                               |
| Ishikura et al. [33] | 1999         | Case series - Prospective | TME and ANP with PLND | 15                 | Median 41                       |                                                                                               |
|                  |                     |                       |                |                    |                                |                                                                                               |
| Maas et al. [35]  | 2000                | Case series - Prospective | TME and ANP with radical rectal resection | 47                 | Median 42                       |                                                                                               |
|                  |                     |                       |                |                    |                                |                                                                                               |
| Nesbakken et al. [34] | 2000     | Case series - Prospective | TME            | 49                 | 6                               |                                                                                               |
|                  |                     |                       |                |                    |                                |                                                                                               |
| Maurer et al. [36] | 2001                | Case control           | TME vs Non-TME Conventional Rectal Excision | 60                 | Minimum 3                       |                                                                                               |
|                  |                     |                       |                |                    |                                |                                                                                               |
| Kim et al. [11]   | 2002                | Case series - Prospective | TME            | 68                 | Median 8.7                      |                                                                                               |
|                  |                     |                       |                |                    |                                |                                                                                               |

(continued)
| Literature                | Year of publication | Study design               | Procedure type                                           | Subjects evaluated | Duration of follow-up (months) | Complications                                                                 |
|--------------------------|---------------------|----------------------------|----------------------------------------------------------|--------------------|--------------------------------|--------------------------------------------------------------------------------|
| Pocard et al. [12]       | 2002                | Case series - Prospective  | TME                                                      | 20                 | Up to 36                       | Male erectile dysfunction: 0%                                                   |
|                          |                     |                            |                                                          |                    |                                | Male ejaculatory dysfunction: 11.0%                                             |
|                          |                     |                            |                                                          |                    |                                | Female orgasmic dysfunction: 0%                                                 |
|                          |                     |                            |                                                          |                    |                                | Female dyspareunia: 0%                                                         |
| Wang et al. [60]         | 2003                | Case control               | Open TME with vs without ANP                            | 104                |                                | Male erectile dysfunction: 32.7% with ANP vs 63.5% without ANP (SD)           |
|                          |                     |                            |                                                          |                    |                                | Male ejaculatory dysfunction: 44.2% with ANP vs 71.2% without ANP (SD)        |
| Shirouzu et al. [40]     | 2004                | Case control               | TME with ANP vs without ANP                             | 129                | Median 218                     | Male erectile dysfunction: 21% with ANP vs 100% without ANP.                   |
|                          |                     |                            |                                                          |                    |                                | Male ejaculatory dysfunction: 35% with ANP vs 100% without ANP.                |
| Sterk et al. [39]        | 2005                | Case series - Prospective  | TME                                                      | 29                 | 3                              | Male erectile dysfunction: 55.1%                                               |
|                          |                     |                            |                                                          |                    |                                | Male ejaculatory dysfunction: 3.6%                                              |
| Wang et al. [61]         | 2005                | Case series - retrospective| Open TME                                                | 105                | Up to 84                       | Male erectile dysfunction: 33.3% with ANP vs 63.2% without ANP (SD)           |
| Wang et al. [82]         | 2005                | Case control               | Open TME with vs without ANP                            | 105                |                                | Male ejaculatory dysfunction: 43.8% with ANP vs 70.0% without ANP (SD)        |
| Wang et al. [45]         | 2005                | Case control               | Open TME with vs without ANP                            | 96                 |                                | Female dyspareunia: 4.15% with ANP vs 37.5% without ANP (SD)                  |
|                          |                     |                            |                                                          |                    |                                | Female orgasmic dysfunction: 10.5% with ANP vs 45.9% without ANP (SD)         |
|                          |                     |                            |                                                          |                    |                                | Female sexual arousal dysfunction: 12.5% with ANP vs 54.16% without ANP       |
| Laing et al. [46]        | 2006                | Case control               | Open TME with vs without ANP                            | 236                |                                | Overall Male erectile dysfunction: 49.15% with ANP vs 95.76% without ANP (SD) |
| Kyo et al. [41]          | 2006                | Case control               | TME and ANP with vs without PLND                        | 30                 | Minimum 7                      | Male erectile dysfunction: 50% with PLND vs 10% without PLND (no SD)           |
| Dong et al. [47]         | 2007                | Case series - Retrospective| Open TME with ANP                                       | 124                |                                | Male ejaculatory dysfunction: 90% with PLND vs 30% without PLND (SD)           |
| Akasu et al. [43]        | 2009                | Case series - Prospective  | Open LAR/APR with selected ANP and PLND                 | 66                 | 12                             | Male erectile dysfunction: 37.7%                                                |
|                          |                     |                            |                                                          |                    |                                | Male ejaculatory dysfunction: 42.9%                                              |
|                          |                     |                            |                                                          |                    |                                | Male erectile dysfunction (SD)                                                 |
| Zhao et al. [48]         | 2011                | Case control               | Open TME and ANP vs TME alone                           | 84                 | Up to 24                       | Bilateral pelvic-plexus preservation without PLND: 5%                         |
|                          |                     |                            |                                                          |                    |                                | Bilateral pelvic-plexus preservation with PLND: 44%                            |
|                          |                     |                            |                                                          |                    |                                | Unilateral pelvic-plexus preservation with PLND: 55%                          |
|                          |                     |                            |                                                          |                    |                                | No pelvic-plexus preservation with PLND: 100%                                  |
|                          |                     |                            |                                                          |                    |                                | Male erectile dysfunction: 29.3% in TME and ANP vs 76.7% in TME alone (SD)     |
|                          |                     |                            |                                                          |                    |                                | Male ejaculatory dysfunction: 26.8% in TME and ANP vs 79.1% in TME alone (SD) |
|                          |                     |                            |                                                          |                    |                                | Male erectile dysfunction: 5%                                                   |
|                          |                     |                            |                                                          |                    |                                | Male ejaculatory dysfunction: 10%                                               |
| Cakabay et al. [44]      | 2012                | Case series - Prospective  | TME                                                      | 20                 |                                | (continued)                                                                   |
| Literature            | Year of publication | Study design                  | Procedure type                        | Subjects evaluated | Duration of follow-up (months) | Complications                                                                                           |
|-----------------------|---------------------|--------------------------------|---------------------------------------|--------------------|--------------------------------|----------------------------------------------------------------------------------------------------------|
| Quah et al. [10]      | 2002                | Randomized controlled trial   | Laparoscopic assisted vs open TME     | 80                 | Median 36                       | Sexual dysfunction (both sexes) 23.9% in laparoscopic vs 10.8% in open. Male erectile dysfunction: 40% in laparoscopic vs 13.7% in open. Male ejaculatory dysfunction: 40% in laparoscopic vs 4.6% in open. Male sexual dysfunction: 41% in laparoscopic rectal, 23% in open rectal and 4% in laparoscopic colonic. Male erectile and ejaculatory dysfunction more common in laparoscopic and open rectal surgery but none in laparoscopic colonic. Female sexual dysfunction: 28% in laparoscopic rectal, 18% open rectal, 18%, and 8% in laparoscopic colonic. Male erectile dysfunction: 37.5% Male ejaculatory dysfunction: 43.7% Female orgasmic dysfunction: 32.1% Female dyspareunia: 39.2% |
| Jayne et al. [49]     | 2005                | Randomized controlled trial   | Laparoscopic rectal vs open rectal vs laparoscopic colonic | 246                | Up to 76                        | Male sexual dysfunction: 41% in laparoscopic rectal, 23% in open rectal and 4% in laparoscopic colonic. Male erectile dysfunction: 37.5% Male ejaculatory dysfunction: 43.7% Female orgasmic dysfunction: 32.1% Female dyspareunia: 39.2% |
| Liang et al. [52]     | 2007                | Case series - Prospective     | Laparoscopic TME                      | 60                 | 6                              | Male erectile dysfunction: 37.5% Male ejaculatory dysfunction: 43.7% Female orgasmic dysfunction: 32.1% Female dyspareunia: 39.2% |
| Liu et al. [63]       | 2009                | Randomized control trial      | Laparoscopic vs open TME with ANP     | 119                | 12                             | Male sexual dysfunction: 11.6% in laparoscopic vs 16.9% in open (no SD) Worse IIEF score in male open group, especially erectile function (SD). Worse FSFI score in female open group (SD). Male erectile dysfunction: 13.3% in robotic vs 12.8 % in laparoscopic (no SD) Male erectile dysfunction: 5.6% in robotic vs 57% in laparoscopic at 12 months (SD) No change in IIEF or FSFI score Male erectile dysfunction: 18.2% |
| McGloen et al. [50]   | 2012                | Cohort study                  | Laparoscopic vs open TME              | 143                | Minimal 6                       | Male sexual dysfunction: 11.6% in laparoscopic vs 16.9% in open (no SD) Worse IIEF score in male open group, especially erectile function (SD). Worse FSFI score in female open group (SD). Male erectile dysfunction: 13.3% in robotic vs 12.8 % in laparoscopic (no SD) Male erectile dysfunction: 5.6% in robotic vs 57% in laparoscopic at 12 months (SD) No change in IIEF or FSFI score Male erectile dysfunction: 18.2% |
| Kim et al. [54]       | 2012                | Cohort study                  | Laparoscopic vs robotic TME           | 38                 | 12                             | Male sexual dysfunction: 22.7% in open vs 7.1% in laparoscopic. No significant change of IIEF score by 12 months in both groups. Male erectile dysfunction: 27.91% in laparoscopic vs 28.95% in open (no SD). Male ejaculatory dysfunction: 25.58% in laparoscopic vs 23.68% in open (no SD). IIEF Scores for robotic group higher at 6 months compared to laparoscopic group |
| D’Annibale et al. [55]| 2013                | Cohort study                  | Laparoscopic vs robotic TME           | 60                 | 12                             | Male sexual dysfunction: 22.7% in open vs 7.1% in laparoscopic. No significant change of IIEF score by 12 months in both groups. Male erectile dysfunction: 27.91% in laparoscopic vs 28.95% in open (no SD). Male ejaculatory dysfunction: 25.58% in laparoscopic vs 23.68% in open (no SD). IIEF Scores for robotic group higher at 6 months compared to laparoscopic group |
| Luca et al. [57]      | 2013                | Case series - Prospective     | Totally Robotic TME                  | 74                 | 17.03                          | Male sexual dysfunction: 22.7% in open vs 7.1% in laparoscopic. No significant change of IIEF score by 12 months in both groups. Male erectile dysfunction: 27.91% in laparoscopic vs 28.95% in open (no SD). Male ejaculatory dysfunction: 25.58% in laparoscopic vs 23.68% in open (no SD). IIEF Scores for robotic group higher at 6 months compared to laparoscopic group |
| Runkel et al. [53]    | 2013                | Case series - Prospective     | Laparoscopic nerve orientated mesorectal excision | 42                 | 12                             | Male sexual dysfunction: 22.7% in open vs 7.1% in laparoscopic. No significant change of IIEF score by 12 months in both groups. Male erectile dysfunction: 27.91% in laparoscopic vs 28.95% in open (no SD). Male ejaculatory dysfunction: 25.58% in laparoscopic vs 23.68% in open (no SD). IIEF Scores for robotic group higher at 6 months compared to laparoscopic group |
| Hur et al. [51]       | 2013                | Non-randomized control trial  | Laparoscopic vs open TME              | 50                 | 12                             | Male sexual dysfunction: 22.7% in open vs 7.1% in laparoscopic. No significant change of IIEF score by 12 months in both groups. Male erectile dysfunction: 27.91% in laparoscopic vs 28.95% in open (no SD). Male ejaculatory dysfunction: 25.58% in laparoscopic vs 23.68% in open (no SD). IIEF Scores for robotic group higher at 6 months compared to laparoscopic group |
| Zeng et al. [59]      | 2013                | Cohort study                  | Laparoscopic vs open TME with ANP     | 81                 | 6                              | Male sexual dysfunction: 22.7% in open vs 7.1% in laparoscopic. No significant change of IIEF score by 12 months in both groups. Male erectile dysfunction: 27.91% in laparoscopic vs 28.95% in open (no SD). Male ejaculatory dysfunction: 25.58% in laparoscopic vs 23.68% in open (no SD). IIEF Scores for robotic group higher at 6 months compared to laparoscopic group |
| Park et al. [56]      | 2014                | Case control                  | Laparoscopic vs robotic TME           | 64                 | 12                             | Male sexual dysfunction: 22.7% in open vs 7.1% in laparoscopic. No significant change of IIEF score by 12 months in both groups. Male erectile dysfunction: 27.91% in laparoscopic vs 28.95% in open (no SD). Male ejaculatory dysfunction: 25.58% in laparoscopic vs 23.68% in open (no SD). IIEF Scores for robotic group higher at 6 months compared to laparoscopic group |

ANP: autonomic nerve preservation; PLND: pelvic lymph node dissection; SHP: superior hypogastric plexus; APR: abdominoperineal resection; LAR: low anterior resection; IIEF: International index of Erectile Function; FSFI: Female Sexual Function Index; SD: statistical significant difference
robotic technique also remains largely undecided with perhaps improved shorter-term urinary function within 3 months, but no difference in 12 months. There is no similar benefit for sexual function as well. It is important that successful rectal surgery be based not only on histopathological oncologic outcomes but also on the quality-of-life indices of every patient being restored to near normal as soon as possible. The decision about which technique to use will largely depend on a multitude of factors including tumour factors, pelvic anatomy and perhaps cost effectiveness. Nonetheless, regardless of the technique to be applied, the rectal surgeon must be aware of anatomical landmarks and hazards while dissecting to avoid nerve injury and make a dedicated attempt to preserve for autonomic nerve functioning.

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