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Review

REVIEW

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 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.

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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) [15,16]. 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 [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 duodenojejuenal 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 propia 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 superior 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

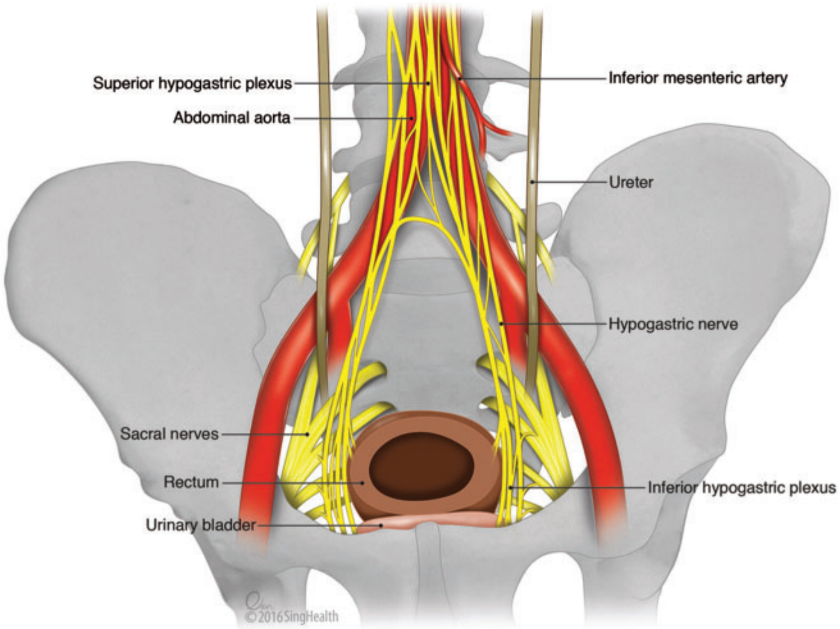

Figure 1: General overview of anatomy of the autonomic nerve distribution. The superior hypogastric plexus around the inferior mesenteric artery descends to the sacral promnotry and bifurcates into hypogastric nerves. These usually run 1–2 cm medial to the ureters and cross the common iliac arteries and S1 in the sacrum.

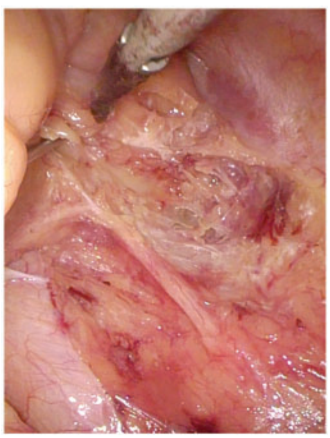

Figure 2: Inferior hypogastric nerve with branches to the rectum on a robotic view with medial-to-lateral dissection approach.

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

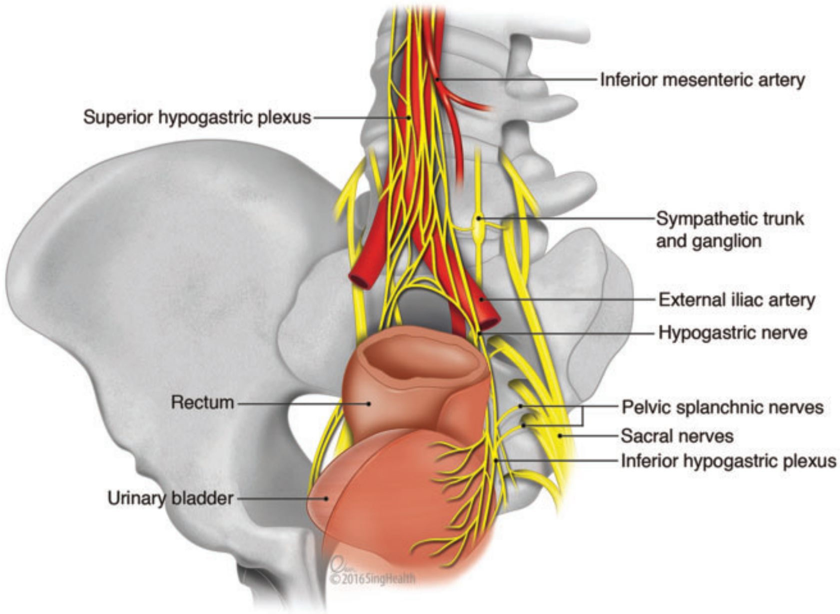

Figure 3: Anatomy of the pelvic autonomic nerves with relation to rectum. The inferior hypogastric plexus comprises nerves from the hypogastric and pelvic splanchnic nerves at lateral pelvic wall.

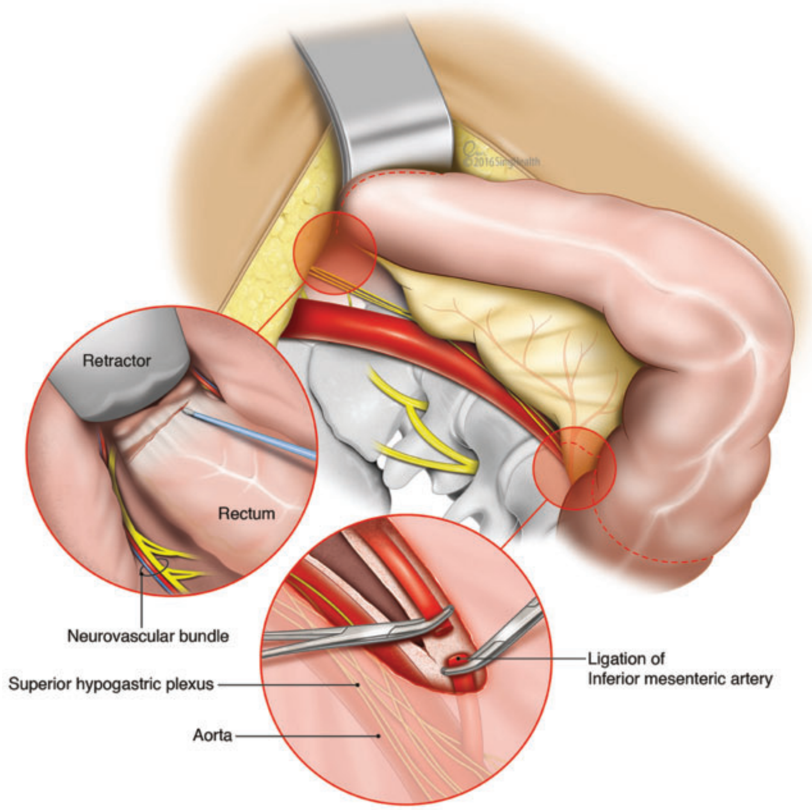

Figure 4: The relationship of the rectum and pelvic autonomic nerves during open surgery when standing on the patient's left. The ligation of the inferior mesenteric artery should be performed 1.5–2 cm from its origin from the aorta to avoid damaging the superior hypogastric plexus. At the pelvis, for posterior and lateral tumours, dissection should be directed below the Denonvillliers 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 years1990 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) [11,12,29–36,39–41,43–48,58,60–62]. There were, however, 2 older 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

Table 1. Incidence of urinary 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	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%; Minor incontinence in both sexes: 19%
Nesbakken *et al.* [34]	2000	Case series - Prospective	TME	49	3	No significant change in urinary symptom score (both sexes) except for increase in female incontinence score
Maurer *et al.* [36]	2001	Case control	TME *vs* Non-TME conventional rectal excision	60	Minimum 3	No significant change in urinary symptom among both groups
Pocard *et al.* [12]	2002	Case series - Prospective	TME	20	Up to 60	Both sexes requiring indwelling catheter: 0%. No significant change in urinary symptom score (both sexes).
Kim *et al.* [11]	2002	Case series - Prospective	TME	68	Median 8.7	Males requiring long-term indwelling catheter: 0%. No significant change of male IPSS score.
Junginger *et al.* [38]	2003	Case series - Prospective	TME with pelvic plexus visualisation	150	Median 24	Overall urinary dysfunction (both sexes): 12%. Complete or partially visualised ANP 4.5% *vs* non-visualised: 38.5%. Required short-term indwelling catheter (both sexes) : 10.7%.
Kneist *et al.* [37]	2004	Cohort study	TME or partial mesorectal excision	229		Overall urinary dysfunction (both sexes): 4.1% with complete ANP *vs* 22.4% without ANP. Both sexes long-term indwelling catheter 8.8%.
Shirouzu *et al.* [40]	2004	Case control	TME with *vs* without ANP	292	Median 218	Overall urinary dysfunction (both sexes): $<$ 20% with complete ANP *vs* $>$ 90% without ANP
Sterk *et al.* [39]	2005	Case series - Prospective	TME	52	3	Urinary dysfunction (both sexes): 24.4% at 14 days and 8.1% at 3 months
Wang *et al.* [45]	2005	Case control	Open TME with *vs* without ANP	96		Female urinary dysfunction: 6.25% with ANP *vs* 31.25% without ANP (SD).

(continued)

Table 1. Continued

Literature	Year of publication	Study design	Procedure type	Subjects evaluated	Duration of follow-up (months)	Complications
						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.
Laing *et al.* [46]	2006	Case control	Open TME with *vs* without ANP	236		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.* [41]	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
Dong *et al.* [47]	2007	Case series - Retrospective	Open TME with ANP	124		Failed urinary catheter removal on post-op day 3: 9.7%
Kneist *et al.* [42]	2007	Cohort study	Open TME, operative bladder neurophysiology monitor with *vs* without ANP	62	Median 20	Urinary dysfunction (both sexes): 2.1% with complete ANP *vs* 60% without ANP. Both sexes required long-term indwelling catheter: 2.1% with ANP *vs* 33.3% without ANP. Significantly worse in urinary symptom score without ANP.
Akasu *et al.* [43]	2009	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%
Zhao *et al.* [48]	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)
Cakabay *et al.* [44]	2012	Case series - Prospective	TME	20	12	Male urinary dysfunction: 25% Male requiring long-term indwelling catheter: 5%
Laparoscopic/robotic TME						
Quah *et al.* [10]	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).
Jayne *et al.* [49]	2005	Randomized controlled trial	Laparoscopic colonic *vs* open rectal *vs* laparoscopic rectal	246	Up to 76	Urinary dysfunction (both sexes): 21% in laparoscopic colonic, 35% in open/laparoscopic rectal. No significant change in urinary symptom score after 6 months.
Liang *et al.* [52]	2007	Case series - Prospective	Laparoscopic TME	74	Minimum 3	Urinary dysfunction (both sexes): 17.6%

(continued)

Table 1. Continued

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). Required long-term indwelling catheter (both sexes): 0%. No significant changes in IPSS score between both groups.
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%
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 erectile dysfunction with incomplete ANP: 20% Male ejaculatory dysfunction with complete 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%
Saito *et al.* [32]	1998	Case series	TME and ANP	167		Unsuccessful in preserving sexual function
Ishikura *et al.* [33]	1999	Case series - Prospective	TME and ANP with PLND	15	Median 41	Male sexual dysfunction: 21.5%
Maas *et al.* [35]	2000	Case series - Prospective	TME and ANP with radical rectal resection	47	Median 42	Male erectile dysfunction 8.3% with preserved SHP and 100% without complete preservation of ANP. Male ejaculatory dysfunction 12.5% with preserved SHP and 100% with sacrifice of SHP. Female dyspareunia: 66.7%
Nesbakken *et al.* [34]	2000	Case series - Prospective	TME	49	6	Male erectile dysfunction: 16.7% Male ejaculatory dysfunction: 7.6% Female orgasmic dysfunction: 0%
Maurer *et al.* [36]	2001	Case control	TME *vs* Non-TME Conventional Rectal Excision	60	Minimum 3	Male sexual dysfunction increased from 33% preop to 93% postop in conventional group *vs* from 47% to 78% in TME group. Male erectile dysfunction increased from 25% preop to 94% postop in conventional group *vs* from 42% to 74% in TME group. Male ejaculatory dysfunction increased from 12% preop to 91% postop in conventional group *vs* from 24% to 47% in TME group Insufficient data for female sexual dysfunction analysis
Kim *et al.* [11]	2002	Case series - Prospective	TME	68	Median 8.7	Male erectile dysfunction: 19.1% Male ejaculatory dysfunction: 13.2% Significant worsening of IIEF Score in all domains

(continued)

Table 2. 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		Male sexual dysfunction: 35.2%
Wang *et al.* [62]	2005	Case control	Open TME with *vs* without ANP	105	Up to 84	Male erectile dysfunction: 33.3% with ANP *vs* 63.2% without ANP (SD) 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) Male ejaculatory dysfunction: 90% with PLND *vs* 30% without PLND (SD)
Dong *et al.* [47]	2007	Case series - Retrospective	Open TME with ANP	124		Male erectile dysfunction: 37.7% Male ejaculatory dysfunction: 42.9%
Akasu *et al.* [43]	2009	Case series - Prospective	Open LAR/APR with selected ANP and PLND	66	12	Male erectile dysfunction (SD) 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%
Zhao *et al.* [48]	2011	Case control	Open TME and ANP *vs* TME alone	84	Up to 24	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)
Cakabay *et al.* [44]	2012	Case series - Prospective	TME	20		Male erectile dysfunction: 5% Male ejaculatory dysfunction: 10%

(continued)

Table 2. Continued

Literature	Year of publication	Study design	Procedure type	Subjects evaluated	Duration of follow-up (months)	Complications
Laparoscopic/ Robotic TME						
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.
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 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.
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)
McGloen *et al.* [50]	2012	Cohort study	Laparoscopic *vs* open TME	143	Minimal 6	Worse IIEF score in male open group, especially erectile function (SD). Worse FSFI score in female open group (SD).
Kim *et al.* [54]	2012	Cohort study	Laparoscopic *vs* robotic TME	38	12	Male erectile dysfunction: 13.3% in robotic *vs* 12.8 % in laparoscopic (no SD)
D'Annibale *et al.* [55]	2013	Cohort study	Laparoscopic *vs* robotic TME	60	12	Male erectile dysfunction: 5.6% in robotic *vs* 57% in laparoscopic at 12 months(SD)
Luca *et al.* [57]	2013	Case series - Prospective	Totally Robotic TME	74	17.03	No change in IIEF or FSFI score
Runkel *et al.* [53]	2013	Case series - Prospective	Laparoscopic nerve orientated mesorectal excision	42	12	Male erectile dysfunction: 18.2%
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.
Zeng *et al.* [59]	2013	Cohort study	Laparoscopic *vs* open TME with ANP	81	6	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).
Park *et al.* [56]	2014	Case control	Laparoscopic *vs* robotic TME	64	12	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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