POST-PROSTATECTOMY AND ACQUIRED VOIDING DYSFUNCTION (V TSE, SECTION EDITOR)

The Effect of Major Pelvic Extirpative Surgery on Lower Urinary Tract Function

Kalli Spencer[1] · Vincent Tse[1,2]

Abstract

Purpose of Review This review will explore how lower urinary tract dysfunction may result from pelvic oncological extirpative surgery across multiple disciplines and how to avoid it.

Recent Findings Minimally invasive colorectal surgery offers superior dexterity, precise movements and improved vision to identify and carefully dissect off neurovascular bundles. This reduces the incidence of postoperative retention and improved subjective and objective urodynamic parameters. Pneumoperitoneum and inappropriate retraction techniques may however still lead to urinary tract dysfunction. Data regarding presacral surgery and its complications is limited. A better understanding of anatomy and modifications to the radical hysterectomy procedure has allowed for improved surgical outcomes and urinary tract function. Cautious dissection of the lateral parametria differentiates the hypogastric plexus (particularly the inferior branch) from vascular structures and ligaments.

Summary Bladder dysfunction can have a significant impact on a patient's quality of life. Surgical techniques to preserve important neurovascular structures have been described. Despite this, there is still a high incidence of urinary tract dysfunction. Surgical techniques in the future may be better refined to microscopically dissect off neurovascular bundles; improve assisted neurological monitoring; or enhance super-imposed imaging, to optimise and preserve lower urinary tract function.

Keywords Bladder dysfunction · Voiding dysfunction · Pelvic surgery · Cancer · Colorectal · Gynaecology

Introduction

Globally, the prevalence of cancer is increasing yearly. According to the World Health Organisation in 2018, colorectal cancer is the third most common cancer followed by prostate cancer [1]. Cervical cancer is the fourth most common cancer in woman [2]. With improved imaging, these cancers are detected earlier and often amenable to excision. Improved access and availability of minimally invasive surgical options makes this a more favourable approach in terms of identifying

important anatomic structures and avoiding injury but also faster recovery time for patients.

Major extirpative pelvic surgery occurs predominantly across three disciplines including urology, gynaecology and colorectal surgery. This article will mostly review the surgeries performed by colorectal surgeons and gynaecologists. Surgeries performed by colorectal surgeons that increase the risk of lower urinary tract dysfunction include abdominoperineal resections and low anterior resections [3]. Presacral procedures may include a rectopexy for prolapse, a neurectomy for pain control or a retrorectal tumour excision [4•]. Gynaecologists may perform hysterectomies for benign and malignant pathology or a sacrocolpopexy for pelvic organ prolapse [4•]. Through various mechanisms, these surgeries may result in lower urinary tract dysfunction. This article will review some of the current literature surrounding this topic as well as determining whether modern surgical techniques improve outcome. With this article, the authors hope that the readership will form a better cross-disciplinary understanding of the mechanisms of lower urinary tract

✉ Kalli Spencer
doctorkspencer@gmail.com

[1] Macquarie University School of Health Sciences, Sydney, Australia

[2] University of Sydney, Sydney, Australia

dysfunction after pelvic extirpative cancer surgery, and hence hopefully will be able to further improve surgical outcomes and minimise lower urinary tract complications.

Colorectal Surgery

Acute Urinary Retention After Rectal Surgery

The incidence of retention following surgery (requiring catheter re-insertion) is approximately 14% [5•]. Various risk factors have been identified including male gender, postoperative epidurals and large fluid volume intraoperatively [6]. Possible explanations for this include stimulation of the anal canal leading to activation of the alpha-adrenergic system and subsequent bladder outlet obstruction; change in bladder position, postoperative oedema; and damage to autonomic nerves [6]. Reflexes related to pain as well as pelvic nerve injury lead to internal urethral sphincter contraction with subsequent voiding dysfunction [7]. The findings of the COREAN trial suggest that urinary retention is more common after laparoscopic rectal cancer surgery than after open surgery. This may be as a result of neuropraxia from instruments used for retraction or due to reduced renal arterial supply and function secondary to raised intraperitoneal pressure [8••]. Kim et al. proposed a scoring system to ascertain when the catheter should be removed postoperatively. The scoring system comprises 3 components: male gender, anastomotic level and age. Using this scoring system, they showed that the urinary catheter could be removed in 56.4% of patients on the first postoperative day. In patients over the age of 65, there was a 7.8-fold increased risk, as well as in men (due to anatomical differences) and those patients who had a coloanal anastomosis (due to pain) [9•].To avoid urinary retention after rectal surgery, 2 days of prophylactic bladder drainage is advised [10].

Lower Urinary Tract Dysfunction After Rectal Surgery

Total mesorectal excision (TME) is the best technique for rectal cancer management, ensuring optimum cancer control and functional results, yet despite autonomic nerve–preserving techniques, urinary and sexual dysfunction remain a significant complication of this procedure [11].

Low anterior resections (LAR) and abdominoperineal resections (APR) have a high rate of postoperative bladder dysfunction with an incidence of 15–25% and 50%, respectively [3].

The most common symptoms of urinary dysfunction are urgency, frequency, stress incontinence, overflow incontinence, difficulty in emptying the bladder and loss of bladder fullness sensation [12].

Tekkis et al. identified potential risk factors that may increase lower urinary tract dysfunction: tumour location < 5 cm from the anal verge, intra-abdominal sepsis, a history of previous pelvic radiation, having an APR versus a LAR [13]. Duran and colleagues noted that localisation of a tumour in the middle or lower rectal third is a significant risk factor for new onset of urinary dysfunction [14]. Another study found that surgical experience, male gender and T stage (T1–2 vs T3–4) had an impact on identification of pelvic nerves and hence postoperative function [15]. In females, urgency and urge- or stress-related incontinence were noted in 60–80% of patients with significant associated distress (quarter to a third). Symptoms of voiding difficulties ranged from 20 to 35% [16•].

Dar et al. looked at urodynamic parameters to quantify postoperative bladder dysfunction and found an abnormality in 85% and 30% at 1 month and 3 months postoperatively, respectively. They also measured residual urine volume with an increase of more than 10 ml as compared to preoperative measured residual urine volume regarded as significant. They found 82% of participants had abnormal residual volumes at 1 month and 30% at 3 months. Abnormal peak flow rates were detected in 70% of participants at 1 month and 28% at 3 months. These results were consistent with previously reported outcomes [17••].

Minimally Invasive Rectal Cancer Surgery

In 2002, the first robotic procedure was performed, and subsequently many studies have shown that robotic TME is an oncologically safe and effective procedure [18].

This is due to the superior dexterity and precision of robotic arm movements and magnified three-dimensional views allowing the operator improved vision and better ergonomic comfort for the dissection of neurovascular structures [19]. This is particularly pertinent during anterior isolation of the mesorectum where the inferior hypogastric plexus may be at risk [20]. It allows better judgement of the loose connective tissue between the parietal and visceral fascia [21••]. The increased flexibility of the robot allows the arms to move into narrow spaces such as the conically shaped male pelvis reducing the risk of collateral damage to neighbouring structures [22].

Various studies have looked at outcomes of minimally invasive surgery with current evidence favouring a quicker recovery [23••]. Kim et al. noted an improvement in the IPSS (International Prostate symptom score) for robotic TME compared to laparoscopic-TME with a recovery period of 3 months versus 6 months, respectively [24••]. Dulskas et al. found earlier recovery in voiding and sexual dysfunction [25••]. On the contrary, Althumairi et al. found no difference in outcome between conventional open surgery and minimally invasive surgery [26•]. Whether the approach is open or minimally invasive functional outcomes tends to improve with time [23••].

Pathogenesis of Nerve Injury

Lower urinary dysfunction is as a result of autonomic nerve injury or anatomical changes within the pelvis [26•]. This may result from ischemic injury, nerve stretching, thermal damage, local inflammatory effects or ligation of the sacral splanchnic plexus or hypogastric nerve during dissection [17••].

Excessive traction may lead to neuropraxia which may cause a temporary or unrecoverable blockage of nerve conduction depending on the duration and grade of traction [27].

Damage to the pelvic nerves may take place during abdominoperineal resection or intersphincteric resection [28, 29•] There is a close correlation between the mesorectum and the pelvic nerves making the nerves difficult to identify [30] It is therefore important to control excessive bleeding as identification of nerves may be compromised [31].

Four zones have been described as high risk for nerve injury: (1) lateral dissection of the mesorectum, (2) anterior isolation of the rectum, (3) ligation of the inferior mesenteric artery. (4) posterior dissection of the mesorectum [28, 29•].

When the parasympathetic nerves are damaged, the bladder becomes non-contractile due to detrusor hypoactivity. These nerves may be directly injured if the endopelvic fascia is breached during blunt dissection of the rectum [32]. This may cause overflow incontinence [33].

Anatomical changes may be due to posterior tilting of the bladder resulting in bladder emptying difficulty [34]. Loss of bladder support may alter the vesicourethral angle and cause failure of bladder neck opening [35].

Denervation procedures may result in insufficient urethral closure. There may be a decrease in bladder neck and urethral resistance resulting in leakage when there is raised intra-abdominal pressure. Damage to the pudendal nerve or its branches from Alcock's canal can also result in striated urinary sphincter weakening [36].

The urethra may be injured during the perineal component of an abdominoperineal resection. Bulky tumours' anterior extension or significant desmoplastic reaction is at highest risk. The membranous urethra is the most frequent part to be damaged followed by the prostatic urethra [32].

Advanced Colorectal Disease

Patients with this disease profile may require chemotherapy and/or radiation. The effect on urinary dysfunction may be evident after 1 year of surgery and remain an independent predictor long term [37••]. Patients treated with preoperative radiotherapy have high risk of dysfunction such as interrupted urinary stream [16•]. This neoadjuvant therapy may make identification of nerve plexuses more difficult [15]. Adjuvant radiation therapy results in fibrosis of the urethral sphincter and bladder affecting vascular integrity which has an effect on bladder function [38]. Qiao et al. however showed that

recovery may be possible due to compensation by contralateral nerve fibres and that effect on function may be transient [39•]. They also showed that urodynamic parameters (including subjective IPSS and UDI-6 scores, residual and voided volumes and maximal flow rate) recovered at 6 months post-surgery [39•]. Treatment planning should therefore be cautiously performed on all admitted patients [21••].

Prevention of Lower Urinary Tract Dysfunction After Rectal Cancer Surgery

The quality of dissection and preservation of urinary and sexual function are directly related [40]. Delicate handling of the neurovascular tissue is important to protect the vasa nervorum and avoid ischemic damage to the nerves. Traction-free techniques and gentle handling may be difficult due to the lack of haptic feedback as the surgeon has not yet learnt how to compensate the lack of sensation with visual integration. The assistant surgeon should also be cognisant of this when providing countertraction [41].

During dissection, it is important to identify all components of the hypogastric plexus [15]. A novel technique employs pelvic intraoperative neuromonitoring to help identify nerves [37••]. Extensive use of cautery should be avoided on the lateral plane of dissection because of the proximity of the hypogastric plexus to the mesorectal fascia, and on the antero-lateral plane, near the vesicles to the neurovascular bundle abutting the rectum. Surgical clips may be a more suitable alternative [20].

Training should include how to protect pelvic autonomic nerves, focusing on how to lean against the mesorectum and keep away from the nerves as much as possible [21••].

Rectal resection should be standardised and new functional outcome research should use the same validated outcome questionnaires [25••].

Outcome of Urinary Function After Rectal Surgery

Difficulty in bladder emptying improves after 3 months, but symptoms persisting after 6 months are permanent, as Lange et al. reported in 31% of patients [28]. The transient reduction in Qmax (peak flow rate) might be explained by postoperative inflammatory changes in the perivesical tissues and resolution of partial nerve damage with time [42]. Prolonged urinary retention is likely to be a result of permanent damage to nerves [32]. Urinary and sexual dysfunction caused by bilateral resection of the inferior hypogastric plexus are severe and often permanent [34].

Management of Urinary Dysfunction After Rectal Surgery

Detrusor underactivity may be detected on a urodynamic assessment (recommended at 3–6 months) featuring weak, low

pressure, intermittent contractions of the detrusor muscle and incomplete bladder emptying. This could be managed with clean intermittent self-catheterisation where possible [32].This results in continued 'cycling' of the bladder. If the patient is unable to self-catheterise, then a permanent indwelling catheter may be inserted as a last resort. Without treatment, the patient may develop a small capacity bladder which is poorly compliant with high pressures that may ultimately cause upper tract deterioration [36].

In patients with sphincteric damage, symptoms may not be reliable for diagnosing and recommending treatments. Treatment and follow-up are highly individualised based on urodynamic findings, patient abilities and family support [36]. In male patients with possible bladder outlet obstruction, the use of alpha antagonists may be beneficial prior to trial of void. Surgical intervention with transurethral prostatic resection or laser ablation may also be required [32].

Presacral Tumour Surgery

The literature in this space is limited. Much of the work focuses on the effects of prescral neurectomy (intentional transection of the contained neural plexus to relieve refractory pelvic pain) and their effects on bowel and bladder function. The rate of bladder dysfunction ranges from 0 to 8.33%. The studies are flawed because no objective measurements for bowel and bladder postoperative function and specific information regarding presentation, severity or onset of symptoms were included [4•].

Presacral tumours include neurogenic lesions such as meningoceles, osseous tumours and congenital lesions such as dermoid and tailgut cysts [43]. Typically, lesions above S3 or lesions below S3 with involvement of the pelvic sidewall or viscera require an abdominal approach or a combined abdominal and posterior approach [4•].

Chereau et al. noted development of new-onset bladder and bowel symptoms to be common with an 11% incidence of urinary symptoms. This was determined using the Cleveland Clinic incontinence score and perineal pain score [44]. Jao et al. assessed outcomes in as subset of patients who also required resection of the sacral nerve. Of the 17 patients who underwent sacral nerve resection, four had postoperative bowel and bladder dysfunction, and four developed bladder dysfunction alone. Of the cohort, 15% developed postoperative neurogenic bladder. No clear conclusions can be drawn as to the absolute risk of postoperative neural dysfunction following iatrogenic nerve transection [45].

Gynaecological Surgery

A hysterectomy may be performed for benign pathology such as symptomatic fibroids or for malignancies such as cervical or endometrial cancer. The focus will be on radical hysterectomies.

Incidence of Lower Urinary Tract Dysfunction After Gynaecological Surgery

Lower urinary tract dysfunction is the most common long-term complication of radical surgery [46]. The incidence of bladder dysfunction ranges from 12 to 85% depending on the method used to determine dysfunction and the duration of follow-up [47, 48]. Plotti et al. found an overall incidence of 72% [49].

A Thai study found that 25.1% of patients who underwent a radical hysterectomy were symptomatic in the early postoperative period displaying symptoms such as frequency, nocturia, terminal dribbling, urgency, incomplete emptying and dysuria [50].

Fuji showed 92% of the patients would have the sensation of bladder fullness, and only 71% obtained the satisfaction of micturition 14 days after surgery. These were objectively evaluated by measuring post void urine residual volume under 50 ml in 46% of patient's 14 days after surgery [51].

Plotti et al. found that 24.4% of their patients had detrusor dysfunction with low compliance, 24.5% had mixed urinary incontinence and 40% had stress urinary incontinence. Studies with a follow-up more than 12 months after primary surgery reported that the above-mentioned rates reduce to 35%, 17% and 38%, respectively. [49]

Types of Surgery

Over the years, various surgical approaches have been adapted to maintain oncological control while preserving bladder function. In the last 20 years, less radical surgeries have been performed using the cervical diameter as a preoperative criterion. This has been achieved through modifying the approach to the excision of the lateral parametria [52, 53].

Querleu and Morrow's classification takes the curative effect of surgery including adverse consequences (for example, bladder dysfunction) into account [54].

Four types of radical hysterectomy include a few subtypes that involve paracervical lymphadenectomy and nerve preservation. The goal is to dissect the relevant pericervical structures while preserving parasympathetic and sympathetic innervation of pelvic organs [55]. By better identifying surgical landmarks and visceral nerve fibres, it is easier to dissect the neural portion from the vascular portion of the parametrium [55].

The extent of cervical cancer surgery should be adjusted to patient- and tumour-related factors. Women with invasion of less than one half of stromal tissue or invasion less than 10 mm or tumours < 2 cm in diameter are subject to a lower

risk of disease in the paracervix and the pelvic lymph nodes [56, 57••].

Pathogenesis of Nerve Injury

It has been reported that during a radical hysterectomy the following nerves are affected when the associated structures are dissected: the proximal part of the inferior hypogastric plexus and the splanchnic nerves during resection of the dorsal paracervix and preparation of the pararectal space; distal part of the inferior hypogastric plexus during resection of the caudal part of the vesico-uterine ligaments; inferior hypogastric plexus and splanchnic nerves during resection of the lateral part of the paracervix in the space under the uterine vein [58]; hypogastric nerves during resection of the uterosacral and rectovaginal ligaments [59]. During blunt lymph node dissection in the presacral space between the rectum medially and the common iliac artery, the superior pelvic plexus can be injured [58]. The anatomy of these nerves is complicated and not that easy to appreciate during surgery. In order to accomplish a nerve-sparing radical hysterectomy, it is essential to reveal the inferior hypogastric plexus and to transect only the uterine branch from the inferior hypogastric plexus [51].

Damage to the parasympathetic fibres will lead to a hypocontractile bladder with reduced sensation, increased storage pressure and bladder neck incompetence [60]. Damage to the pudendal nerve may result in pelvic floor muscle and external urethral sphincter weakness. This will result in pelvic organ prolapse and incontinence [60].

Evaluation of Lower Urinary Tract Function After Radical Hysterectomy

To assess bladder function recovery, a urodynamic examination may be useful for a comprehensive evaluation. Dysfunction may be divided into an early (3–6 months) and late stage (> 6 months) [61•].

During the early stage (3–6 months), there is detrusor underactivity and reduced compliance [61•]. This may require urethral catheterisation. The residual volume tends to increase at 2 and 6 weeks after surgery and then reduce after that. Uroflowmetry shows a reduction in maximal flow rate up to 3 months [62].

Late dysfunction usually results in voiding difficulty with abdominal straining, detrusor overactivity, urinary incontinence and decreased bladder compliance. This can resolve within 6 to 12 months or persist for longer [63].

The long-term bladder function is marked by an increase in residual urine volume, reduction of the maximum cystometric capacity and increase in first voiding desire. Due to damage to the pelvic plexus and pudendal nerves and subsequent loss of periurethral tone, a significant reduction in maximal urethral closure pressure may be noted. Detrusor overactivity and stress incontinence may be due to lack of sympathetic input with excessive parasympathetic stimulation of the detrusor muscle and relaxation of bladder neck and proximal urethra [64]. The other reason for stress incontinence is due to lack of bladder neck support due to over excision of the upper vagina and parametrium [48]. Urodynamic measures change over time, and therefore a prolonged period of follow-up may be required [55].

Conclusion

Bladder dysfunction can have a significant impact on a patient's quality of life leading to embarrassment or even social isolation [65•]. Patients already have a cancer diagnosis to work through compounded by lower urinary tract dysfunction. This places an extra burden on the patient and their carer. In most of the surgeries described in this article research has been conducted to develop better surgical techniques to preserve important neurovascular structures. Despite this, there is still a high incidence of urinary tract dysfunction. Minimally invasive colorectal surgery offers the advantage of improved vision and flexible instruments, but retraction techniques and the effects of pneumoperitoneum may be detrimental. There is a paucity of data detailing methods to prevent significant damage in presacral surgery and no comprehensive review of the outcomes and preservative techniques has been compiled [4•]. Nerve-sparing radical hysterectomies are still a non-standardised technique with controversies surrounding its functional advantage and oncological safety [66•]. Surgical techniques in the future may be better refined to microscopically dissect off neurovascular bundles; improve assisted neurological monitoring or enhance super-imposed imaging, to optimise and preserve lower urinary tract function.

Compliance with Ethical Standards

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. World Health Organisation. Cancer. Geneva: World Health Organization; 2018. Sept [Cited 2019 Feb 21]. Available from: https://www.who.int/news-room/fact-sheets/detail/cancer

2. World Health Organisation. Cancer. Geneva: World Health Organization. [Cited 2019 Feb 21]. Available from: https://www.who.int/cancer/prevention/diagnosis-screening/cervical-cancer/en/

3. Chaudhri S, Maruthachalam K, Kaiser A, Robson W, Pickard RS, Horgan AF. Successful voiding after trial without catheter is not synonymous with recovery of bladder function after colorectal surgery. Dis Colon Rectum. 2006;49(7):1066–70. https://doi.org/10.1007/s10350-006-0540-3.

4.• Huber SA, Northington GM, Karp DR. Bowel and bladder dysfunction following surgery within the presacral space: an overview of neuroanatomy, function, and dysfunction. Int Urogynecol J. 2015;26:941–6. https://doi.org/10.1007/s00192-014-2572-x. **Effect of presacral surgery on urinary function.**

5.• Grass F, Slieker J, Frauche P, Sola J, Blanc C, Demartines N, et al. Postoperative urinary retention in colorectal surgery within an enhanced recovery pathway. J Surg Res. 2017;2017:70–6. https://doi.org/10.1016/j.jss.2016.08.089 **Risk factors for acute urinary retention after surgery.**

6. Lee SY, Kang S, Kim D, Oh H, Ihn MI. Risk factors and preventive measures for acute urinary retention after rectal cancer surgery. World J Surg. 2015;39:275–82. https://doi.org/10.1007/s00268-014-2767-9.

7. Benoist S, Panis Y, Denet C, Mauvais F, Mariani P, Valleur P. Optimal duration of urinary drainage after rectal resection: a randomized controlled trial. Surgery. 1999;125:135e141.

8.•• Kang SB, Park JW, Jeong SY, Nam BH, Choi HS, Kim DW, et al. Open versus laparoscopic surgery for mid or low rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): short-term outcomes of an open-label randomised controlled trial. Lancet Oncol. 2010;11:637–45. https://doi.org/10.1016/S1470-2045(10)70131-5. **The COREAN trial showed less urinary dysfunction after laparoscopic vs. open rectal cancer surgery.**

9.• Kim HO, Kim YSCH, Lee SR, Jung KU, Chun H. Scoring systems used to predict bladder dysfunction after laparoscopic rectal cancer surgery. World J Surg. 2016;40:3044–305. https://doi.org/10.1007/s00268-016-3636-5. **Two scoring systems using three risk factors (age, male gender and anastomosis level) may predict postoperative bladder dysfunction.**

10. Kwaan MR, Lee JT, Rothenberger DA, Melton GB, Madoff RD. Early removal of urinary catheters after rectal surgery is associated with increased urinary retention. Dis Colon Rectum. 2015;58:401–5. https://doi.org/10.1097/DCR.0000000000000317.

11. Schmidt C, Daun A, Malchow B, Küchler T. Sexual impairment and its effects on quality of life in patients with rectal cancer. Dtsch Arztebl Int. 2010;107:123–30. https://doi.org/10.3238/arztebl.2010.0123.

12. Moriya Y. Functional preservation in rectal cancer surgery. Int J Clin Oncol. 2006;11:339–43. https://doi.org/10.1007/s10147-006-0608-z.

13. Tekkis PP, Cornish JA, Remzi FH, Tilney HS, Strong SA, Church JM, et al. Measuring sexual and urinary outcomes in women after rectal cancer excision. Dis Colon Rectum. 2009;52(1):46–54. https://doi.org/10.1007/DCR.0b013e318197551e.

14. Duran E, Tanriseven M, Ersoz N, Oztas M, Ozerhan IH, Kilbas Z, et al. Urinary and sexual dysfunction rates and risk factors following rectal cancer surgery. Int J Colorectal Dis. 2015;30:1547–55. https://doi.org/10.1007/s00384-015-2346-z.

15. Junginger T, Kneist W, Heintz A. Influence of identification and preservation of pelvic autonomic nerves in rectal cancer surgery on bladder dysfunction after total mesorectal excision. Dis Colon Rectum. 2003;46:621–8. https://doi.org/10.1097/01.DCR.0000059327.55102.96.

16.• Bregendahl S, Emmertsen KJ, Lindegaard JC, Laurberg S. Urinary and sexual dysfunction in women after resection with and without preoperative radiotherapy for rectal cancer: a population-based cross-sectional study. Color Dis. 2017;17(1):26–37. https://doi.org/10.1111/codi.12758. **Preoperative radiotherapy increases risk of lower urinary tract dysfunction after surgery.**

17.•• Dar MS, Parray FQ, Bhat AH, Chowdri NA, Wani ML. Impact of total mesorectal excision on bladder and sexual function in rectal cancer. Cancer Surg. 2016;1:110. **Comparison of peak flow rates and post void residual volumes pre- and post-surgery.**

18. Pigazzi A, Luca F, Patriti A, Valvo M, Ceccarelli G, Casciola L, et al. Multicentric study on robotic tumor-specific mesorectal excision for the treatment of rectal cancer. Ann Surg Oncol. 2010;17(6):1614–20. https://doi.org/10.1245/s10434-010-0909-3.

19. Antoniou SA, Antoniou GA, Koch OO, Pointner R, Granderath FA. Robot-assisted laparoscopic surgery of the colon and rectum. Surg Endosc. 2012;26(1):1–11. https://doi.org/10.1007/s00464-011-1867-y.

20. Luca F, Valvo M. Nerve preservation in robotic rectal surgery. In: Obias V, editor. Robotic colon and rectal surgery. Switzerland: Springer International Publishing; 2017. https://doi.org/10.1007/978-3-319-43256-4_14.

21.•• Wang G, Wang Z, Jiang Z, Liu J, Zhao J, Li J. Male urinary and sexual function after robotic pelvic autonomic nerve-preserving surgery for rectal cancer. Int J Med Robotics Comput Assist Surg. 2017;13:e1725. https://doi.org/10.1002/rcs.1725. **Robotic surgery shows distinct advantages in protecting the pelvic autonomic nerves.**

22. Luca F, Cenciarelli S, Valvo M, Pozzi S, Faso FL, Ravizza D, et al. Full robotic left colon and rectal cancer resection: technique and early outcome. Ann Surg Oncol. 2009;16:1274–8. https://doi.org/10.1245/s10434-009-0366-z.

23.•• Panteleimonitis S, Ahmed J, Harper M, Parvaiz A. Critical analysis of the literature investigating urogenital function preservation following robotic rectal cancer surgery. *World J Gastrointest Surg*. 2016;8(11):744–54. https://doi.org/10.4240/wjgs.v8.i11.744. **Systematic review analysing the urogenital functional outcomes of patients receiving robotic rectal cancer surgery.**

24.•• Kim JY, Kim NK, Lee KY, Hur H, Min BS, Kim JH. A comparative study of voiding and sexual function after total mesorectal excision with autonomic nerve preservation for rectal cancer: laparoscopic versus robotic surgery. Ann Surg Oncol. 2012;19:2485–93. https://doi.org/10.1245/s10434-012-2262-1. **Robotic TME associated with better urinary function recovery than laparoscopic TME.**

25.•• Dulskas A, Miliauskas P, Tikuisis R, Escalante R, Samalavicius NE. The functional results of radical rectal cancer surgery: review of the literature. Acta Chir Belg. 2016;116(1):1–10. https://doi.org/10.1080/00015458.2015.1136482. **Systematic review reports on urinary tract function after open and minimally invasive surgery.**

26.• Althumairi AA, Efron JE. Genitourinary considerations in reoperative and complex colorectal surgery. Clin Colon Rectal Surg. 2016;29:145–51. https://doi.org/10.1055/s-0036-1580629. **Early detection and management of iatrogenic injury can avoid long-term dysfunction.**

27. Tewary A, Srivastava A, Sooriakumaran P, et al. Technique of traction-free nerve sparing robotic prostatectomy: delicate tissue handling by real-time penile oxygen monitoring. Int J Impot Res. 2012;24(1):11–9. https://doi.org/10.1038/ijir.2011.40.

28. Lange MM, van de Velde CJ. Urinary and sexual dysfunction after rectal cancer treatment. Nat Rev Urol. 2011;8(1):51–7. https://doi.org/10.1038/nrurol.2010.206.

29.• Moszkowicz D, Alsaid B, Bessede T, Penna C, Nordlinger B, Benoît G, et al. Where does pelvic nerve injury occur during rectal surgery for cancer? Color Dis. 2011;13:1326–34. https://doi.org/10.1111/j.1463-1318.2010.02384.x. **A review of surgical anatomy.**

30. Lindsey I, Guy RJ, Warren BF, Mortensen NJ. Anatomy of Denonvilliers' fascia and pelvic nerves, impotence, and

implications for the colorectal surgeon. Br J Surg. 2000;87:1288–99. https://doi.org/10.1046/j.1365-2168.2000.01542.x.

31. Havenga K, DeRuiter MC, Enker WE, Welvaart K. Anatomical basis of autonomic nerve-preserving total mesorectal excision for rectal cancer. Br J Surg. 1996;83:384–8.

32. Heriot AG, Simpson JAD. The iatrogenic complications of pelvic surgery. In: Beynon J, Harris DA, Davies M, Evans M, editors. Coloproctology. Switzerland: Springer International Publishing; 2017. https://doi.org/10.1007/978-3-319-55957-5_6.

33. Ho VP, Lee Y, Stein SL, Temple LK. Sexual function after treatment for rectal cancer: a review. Dis Colon Rectum. 2011;54:113–25. https://doi.org/10.1007/DCR.0b013e3181fb7b82.

34. Daniel IR, Woodward S, Taylor FGM, Raja A, Toomey P. Female urogenital dysfunction following total mesorectal excision for rectal cancer. World J Surg Oncol. 2006;4:6–9. https://doi.org/10.1186/1477-7819-4-6.

35. Abdelhady MM, Hassouna MM. Voiding dysfunction after pelvic surgery. Clin Colon Rect Surg. 2003;16(1):13–8. https://doi.org/10.1055/s-2003-39033.

36. Delacroix SE Jr, Winters JC. Voiding dysfunction after pelvic colorectal surgery. Clin Colon Rectal Surg. 2010;23:119–27. https://doi.org/10.1055/s-0030-1254299.

37.•• Kauff DW, Lang H, Kneist W. Risk factor analysis for newly developed urogenital dysfunction after total mesorectal excision and impact of pelvic intraoperative neuromonitoring—a prospective 2-year follow-up study. J Gastrointest Surg. 2017;21:1038–47. https://doi.org/10.1007/s11605-017-3409-y. **The benefit of intraoperative neuromonitoring to avoid injury.**

38. Song PH, Yun SM, Kim JH, Moon KH. Comparison of the erectile function in male patients with rectal cancer treated by preoperative radiotherapy followed by surgery and surgery alone. Int J Color Dis. 2010;25:619–24. https://doi.org/10.1007/s00384-010-0879-8.

39.• Qiao Q, Che X, Li X, He S, Qiu G, Lu J, et al. Recovery of urinary functions after laparoscopic total mesorectal excision for T4 rectal cancer. J Laparoendosc Adv Surg. 2016;26(8):2016. https://doi.org/10.1089/lap.2015.0479. **Assessment of urinary tract function after advanced rectal cancer surgery.**

40. Eveno C, Lamblin A, Mariette C, Pocard M. Sexual and urinary dysfunction after proctectomy for rectal cancer. J Visc Surg. 2010;147:e21–30. https://doi.org/10.1016/j.jviscsurg.2010.02.001.

41. Kowalczyk KJ, Huang AC, Hevelone ND, Lipsitz SR, Yu HY, Ulmer WD, et al. Stepwise approach for nerve sparing without countertraction during robot-assisted radical prostatectomy: technique and outcomes. Eur Urol. 2011;60(3):536–47. https://doi.org/10.1016/j.eururo.2011.05.001.

42. Sterk P, Shekarriz B, Günter S, Nolde J, Keller R, Bruch HP, et al. Voiding and sexual dysfunction after deep rectal resection and total mesorectal excision: prospective study on 52 patients. Int J Color Dis. 2005;2005(20):423–7. https://doi.org/10.1007/s00384-004-0711-4.

43. Woodfield JC, Chalmers AG, Phillips N, Sagar PM. Algorithms for surgical management of retrorectal tumors. Br J Surg. 2008;95:214–21. https://doi.org/10.1002/bjs.5931.

44. Chereau N, Lefevre JH, Meurette G, Mourra N, Shields C, Parc Y, et al. Surgical resection of retrorectal tumours in adults: long-term results in 47 patients. Color Dis. 2012;15:e476–82. https://doi.org/10.1111/codi.12255.

45. Jao SW, Beart RW, Spencer RJ, Reiman HM, Ilstrup DM. Retrorectal tumors: Mayo Clinic experience 1960–1979. Dis Colon Rectum. 1985;28:644–52.

46. Ralph G, Winter R, Michelitsch L, Tamussino K. Radicality of parametrial resection and dysfunction of the lower urinary tract after radical hysterectomy. Eur J Gynaecol Oncol. 1991;12:27–30.

47. Wit EM, Horenblas S. Urological complications after treatment of cervical cancer. Nat Rev Urol. 2014;11(2):110–7. https://doi.org/10.1038/nrurol.2013.323.

48. Zullo MA, Manci N, Angioli R, Muzii L, Panici PB. Vesical dysfunctions after radical hysterectomy for cervical cancer: a critical review. Crit Rev Oncol Hematol. 2003;48(3):287–93.

49. Plotti F, Angioli R, Zullo MA, Sansone M, Altavilla T, Antonelli E, et al. Update on urodynamic bladder dysfunctions after radical hysterectomy for cervical cancer. Crit Rev Oncol Hematol. 2011;80:323–9. https://doi.org/10.1016/j.critrevonc.2010.12.004.

50. Charoenkwan K, Pranpanas S. Prevalence and characteristics of late postoperative voiding dysfunction in early stage cervical cancer patients treated with radical hysterectomy. Asian Pac J Cancer Prev. 2007;8(3):387–9.

51. Fujii S. Anatomic identification of nerve-sparing radical hysterectomy: a step-by-step procedure. Gynecol Oncol. 2008;111(2 Suppl):S33–41. https://doi.org/10.1016/j.ygyno.2008.07.026.

52. Landoni F, Bocciolone L, Perego P, Maneo A, Bratina G, Mangioni C. Cancer of the cervix, FIGO stages IB and IIA: patterns of local growth and paracervical extension. Int J Gynecol Cancer. 1995;5:329–34.

53. Landoni F, Maneo A, Cormio G, Perego P, Milani R, Caruso O, et al. Class II versus class III radical hysterectomy in stage IB-IIA cervical cancer:a prospective randomized study. Gynecol Oncol. 2001;80:3–12. https://doi.org/10.1006/gyno.2000.6010.

54. Querleu D, Morrow CP. Classification of radical hysterectomy. Lancet Oncol. 2008;9:297–303. https://doi.org/10.1016/S1470-2045(08)70074-3.

55. Laterza RM, Sievert K, de Ridder D, Vierhout ME, Haab F, Cardozo L. Bladder function after radical hysterectomy for cervical cancer. Neurourol Urodyn. 2015;34:309–15. https://doi.org/10.1002/nau.22570.

56. Panici PB, Angioli R, Palaia I, Muzii L, Zullo MA, Manci N, et al. Tailoring the parametrectomy in stages IA2-IB1 cervical carcinoma: is it feasible and safe? Gynecol Oncol. 2005;96:792–8. https://doi.org/10.1016/j.ygyno.2004.11.018.

57.•• Aue-aungkul A, Kietpeerakool C, Galaal K, Temtanakitpaisan T, Ngamjarus C, Lumbiganon P. Postoperative interventions for preventing bladder dysfunction after radical hysterectomy in women with early-stage cervical cancer. Cochrane Database Syst Rev. 2017;11:CD012863. https://doi.org/10.1002/14651858.CD012863. **A systematic review looking at postoperative interventions for preventing bladder dysfunction.**

58. Rob L, Halaska M, Robova H. Nerve-sparing and individually tailored surgery for cervical cancer. Lancet Oncol. 2010;11:292–301. https://doi.org/10.1016/S1470-2045(09)70191-3.

59. Raspagliesi F, Ditto A, Hanozet F, Martinelli F, Solima E, Zanaboni F, et al. Nerve-sparing radical hysterectomy in cervical cancer: evolution of concepts. Gynecol Oncol. 2007;107(1Suppl 1):S119–221. https://doi.org/10.1016/j.ygyno.2007.07.020.

60. Benson J, Walters M. Neurophysiology and pharmacology of the lower urinary tract. In: Walters M, Karram M, editors. Urogynecology and reconstructive pelvic surgery. Philadelphia: Mosby Elsevier; 2007. p. 31–43.

61.• Manchana T, Prasartsakulchai C, Santingamkun A. Long-term lower urinary tract dysfunction after radical hysterectomy in patients with early postoperative voiding dysfunction. Int Urogynecol J. 2010;21:95–101. https://doi.org/10.1007/s00192-009-0996-5. **Altered long-term urodynamic parameters in patients who had early post hysterectomy urinary tract dysfunction.**

62. Chuang TY, Yu KJ, Penn IW, Chang YC, Lin PH, Tsai YA. Neurourological changes before and after radical hysterectomy in patients with cervical cancer. Acta Obstet Gynecol Scand. 2003;82:954–9.

63. Chen GD, Lin LY, Wang PH, Lee HS. Urinary tract dysfunction after radical hysterectomy for cervical cancer. Gynecol Oncol. 2002;85:292–7. https://doi.org/10.1006/gyno.2002.6614.

64. Benedetti-Panici P, Zullo MA, Plotti F, Manci N, Muzii L, Angioli R. Long-term bladder function in patients with locally advanced

cervical carcinoma treated with neoadjuvant chemotherapy and type 3–4 radical hysterectomy. Cancer. 2004;100:2110–7. https://doi.org/10.1002/cncr.20235.

65.• Zhou W, Yang X, Dai Y, Wu Q, He G, Yin G. Survey of cervical cancer survivors regarding quality of life and sexual function. J Cancer Res Ther. 2016;12(2):938–44. https://doi.org/10.1016/j.ygyno.2004.11.018. **Treatment-related complications significantly affect patients' quality of life after radical hysterectomy.**

66.• Aoun F, van Velthoven R. Lower urinary tract dysfunction after nerve-sparing radical hysterectomy. Int Urogynecol J. 2015;26:947–57. https://doi.org/10.1007/s00192-014-2574-8. **A review showing that nerve-sparing radical hysterectomy reduces lower urinary tract dysfunction.**