Extended Abstract

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The Anatomical Basis for Autonomic Dysfunction in Pelvic Surgery

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Keywords: Pelvic anatomy; Total mesorectal excision (TME), Autonomic dysfunction; Coloproctology

Objective: Urogenital dysfunction is a common problem in pelvic surgery. Operative neural damage after pelvic and perineal surgery may affect bladder or sexual function. The anatomical and physiological basis for autonomic dysfunction in surgical coloproctology is ascertained.

Methods: Electronic searches of the medline (PubMed) database, Cochrane library and science citation index were performed to identify original published studies on urogenital dysfunction after pelvic and perineal surgery. Relevant chapters in specialized texts on the anatomical and physiological basis of autonomic dysfunction and surgical implications were searched and all included.

Results: Sexual dysfunction is a common postoperative complication following pelvic surgery. Urinary dysfunction commonly follows perineal surgery. Radiotherapy affects sexual function without affecting urinary function. Pelvic autonomic nerves are especially at risk in cases of low rectal cancer, anterior encroaching tumours and during abdominoperineal excision. Total mesorectal excision for rectal cancer improves autonomic nerve preservation. Impotence is rare after rectal excision for inflammatory bowel disease but retrograde ejaculation have been recorded. Pelvic nerve injury would be best avoided by identification and preservation of autonomic nerves early in operation using 'intraoperative nerve stimulation'.

Conclusions: Structured education of surgeons with regard to pelvic neuroanatomy and systemic registration of identified nerves intra-operatively may improve functional outcome. The refinement of surgery for both benign and malignant pelvic and perineal diseases with regard to the better understanding of the anatomy and physiology of urinary and sexual function would decrease the incidence of urogenital dysfunction.

Introduction: Colorectal cancer is a major health problem being one of the most prevalent malignancies in the Western world. The mean age of occurrence is 60 years but in a younger age with the kras wild type in the developing world [1, 2]. The 5 year survival rate in 1971 was 20% but 50% in 2019 [1]. This is due to better pre-operative staging, peri-operative management and multimodal therapy enhanced by the understanding and application of surgical oncological principles. However, the quality of life issues are very important in rectal cancer surgery. These include (i) the preservation of continence, (ii) the preservation of reasonable bowel frequency and (iii) the avoidance of permanent sexual and urinary disturbance. The anatomical and physiological basis for autonomic dysfunction in pelvic surgery is discussed with regard to the latter. Urogenital dysfunction remain a common problem after rectal cancer surgery with a greater than 50% deterioration in sexual function (i.e. men having ejaculatory problems and impotence, women having vaginal dryness and dyspareunia) and greater than 30% urinary dysfunction [3, 4]. Surgical damage is the main cause. Radiotherapy seem to have a greater effect on sexual function than urinary function [4-6]. Although the pelvic autonomic nerves supply the blood vessels of the female internal genitalia and are involved in the neural control of the lubrication and swelling response,sexual problems in women after rectal surgery seem to be predominantly due to a local mechanical problem [6]. Acute urinary retention is a common post operative complication following surgery on benign anorectal diseases with an incidence ranging from 1-52% and increases hospital stay [7-9]. It is most common after haemorrhoidectomy and a 30% incidence after lateral internal sphincterotomy [7]. Gender-specific pathologies such as benign prostatic hyperplasia among others give a higher incidence of post-operative urinary retention in males (4.7%) than in women (2.9%) [4]. The risk increasing by 2.5 fold in patients over 50 years of age due to age-related progressive neuronal degeneration leading to bladder dysfunction [3, 4]. The incidence of urinary dysfunction also varies with the type of surgery; general surgical procedures (3.8%), hip joint arthroplasty (10.7-84%), and after hernia repair (5.9%-48%) [8].

Anatomy of the pelvic autonomic nervous system

The autonomic nervous system is an involuntary motor control system of the viscera. It consists of the parasympathetic nervous system (PSN) whose functions are involved in 'rest and digest', i.e. pupil constriction, stimulation of salivary glands, bronchoconstriction to decrease dead space, decrease heart rate and contractility, increase gut motility and relax sphincters, stimulate gut glandular secretions and bladder contraction. It however has specific (independent) functions such as accommodation of the lens, and vasodilatation of the genital organs thus stimulating erection and vaginal lubrication. The sympathetic nervous system is involved in 'emergency' (fight, fright and flight) conditions. Although its functions are mostly complementary to the PSN function i.e. pupil dilatation, inhibition of salivary secretions, increase heart rate and contractility, bronchodilatation, decrease gut motility and contracting sphincters, and inhibition of bladder contraction, it also has specific (independent) functions. These include stimulation of the adrenal glands, the homeostatatic temperature regulation (via sweating, pilomotor vasomotor mechanisms) and haemodynamic selective vasoconstriction in the splanchnics (viscera) when required, contraction of the bladder neck, seminal vesicles and prostate in males for ejaculation and orgasm (contraction of the bulbospongiosus) in females and vasoconstriction of the genital organs. The independent function of stimulating ejaculation and contracting the bladder neck during that process is to prevent retrograde ejaculation in the male. The parasympathetic output is cranio-caudal. The cranial components are cranial nerves III (occulomotor), VII (facial), IX (glossopharyngeal) and X (vagus). The vagus nerve is the true parasympathetic nerve arising directly from the parasympathetic nuclei in the medulla oblongata. The pre-ganglionic parasympathetic nerves to the foregut and midgut (up to proximal two-thirds of the transverse colon) travel in the vagus nerve. The hindgut and the pelvic organs receive their pre-ganglionic parasympathetic nerve fibres from the pelvic parasympathetic splanchnic nerves (nervi erigentes) which arise within the sacral plexus (S2, S3, S4). The parasympathetic supply are difficult to see as it is situated deep in the pelvis and distributed to the pelvic organs in the endopelvic fascia on the surface of the pelvic floor. The parasympathetic nerves that supply the erectile components of the penis and clitoris synapse in the tiny ganglia in pelvic plexuses and then run on as post-ganglionic nerve fibres which pierce the pelvic diaphragm and perineal membrane. From here they innervate the erectile tissue of crura and bulb of penis or clitoris directly (figures 1, 2). The sympathetic nerves (thoracic splanchnic nerves) arises from both sides of the thoracic spinal cord (T5-T12), pierce the diaphragmatic crura, flow down infront of the aorta and the root of the mesentery and enter the pelvis in front of the promontory of the sacrum as the hypogastric nerves. These pre-aortic nerves turn just beyond the aortic bifurcation into the superior hypogastric pelvic plexus of nerves. The sympathetic nerves are strengthened by the lumbar and sacral sympathetic nerves as they descend down the abdomen into

the pelvis (figure 1). They divide into two trunks, which pass to form the pelvic plexus (the inferior hypogastric plexus) on the side wall of the pelvis to be distributed to the pelvic organs by branches passing with the blood vessels, or with the parasympathetic nervi erigentes (pelvic splanchnic nerves) arising from the sacral segments (S2, S3, S4) of the spinal cord. The autonomic fibres penetrate levator ani and the perineal membrane to supply the deep and superficial perineal spaces, and the parasympathetic fibres have the independent function of stimulating erection of the penis/clitoris [10 -12]. The functional implications are that as the bladder and genital tract are supplied by autonomic nerves that are in close relationship with the rectum these would be at risk during rectal mobilization. Thus, pelvic autonomic nerves are especially at risk in cases of low rectal cancer and during abdomino-perineal excision [13]. Damage to the superior hypogastric plexus and hypogastric nerves will lead to retrograde ejaculation but bladder detrusor function will not be affected. However, damage to the inferior hypogastric plexus will lead to erectile dysfunction (impotence) and detrusor failure [14, 15.].

Pelvic surgery

The concept of TME in rectal cancer

Heald et al [16] showed the discontinuous spread into the mesorectum of foci of adenorcarcinoma to form circumscribed nests of tumour often well distal to the lower border of the tumour (figure 2). The presence of this potential source of local recurrence has led to the doctrine that total mesorectal excision (TME) should accompany anterior resection (sphincter-sparing) of rectal cancer. With this approach local recurrence rates of less than 5% have been reported [14]. Given the potential of TME to minimize local recurrence, there is a strong argument that any tumour of the middle and lower third of rectum should be treated by a total rectal excision. This will therefore require a coloanal anastomosis as the routine form of restoration of intestinal continuity, and the addition of a colonic pouch to this reconstruction may optimize function [14]. The concept of total mesorectal excision in rectal cancer entails that the autonomic pelvic nerves in close contact to the visceral pelvic fascia that surrounds the mesorectum (fascia propria) is freed and dropped back without tearing or damaging the mesorectum has led to substantial improvement of autonomic nerve preservation in addition to oncological clearance. This entails sharp dissection under direct vision along pre-existing anatomical planes between visceral and parietal structures thereby preserving the autonomic nerves required for the maintenance of sexual function and urinary voiding [17]. Recognition of the importance of the circumferential resection margin (CRM) in predicting local recurrence of rectal cancer has led to pelvic magnetic resonance imaging (MRI) being a standard pre-operative technique for demonstrating the relationship of the tumour to the mesorectal fascia (the intended 'CRM' for a mesorectal excision (figure 3) [18]. A rectal cancer protocol MRI showing a positive CRM is an indication for neo-adjuvant radiotherapy [5]. It would also avoid the exploration of the anterior plane in a man with an anterior encroaching tumour until when tumour shrinkage may allow an uninvolved plane to be found. A pelvic exenteration can also be considered following chemoradiotherapy if the patient is young and fit. In women, as the vagina acts as a barrier to involvement of the bladder an en-bloc hysterectomy when the uterus/back of vagina is involved is effective oncological clearance. The distant margin is now largely irrelevant for most rectal cancers, as the amount of bowel removed is determined more by the policy of performing total mesorectal excision than it is by considering the distal clearance margin. This is manifested in the successful ultralow intersphincteric resections of rectal cancer [19]. However, a patient with an undoubtedly poor quality anus will not benefit from an ultra low anastomosis and would be better off with an abdomino-perineal excision and a permanent colostomy.

Finding the correct plane ('Holy Plane')

This is done by finding the plane behind the root of the 'pedicle package', i.e. the root of the hind gut mesentery [14, 17]. The visceral structure is carefully dissected away from the parietal structures of the posterior abdominal wall. The inferior mesenteric artery is ligated about 1-2cm from the aorta itself, just far enough to preserve the pre-aortic sympathetic nerve mini-trunks. The main sympathetic trunks are further back, but the mini-trunks are still worth preserving. The plane is most readily reviewed by looking at the things which cross it. These include the left common iliac artery, the gonadal vessels, the ureter and most subtly the superior hyopogastric plexus of sympathetic nerves. Stripping the plexus off the aorta as part of lympho-vascular (oncological) clearance adds nothing to the cure of the cancer but does mean the patient loses the ability to ejaculate and in various other subtle ways the autonomic nerve function is impaired. Nerve preservation in principle does not compromise resectability unless infiltrated with tumour. Finding a plane infront of these nerves, in a circumferential manner will lead down into the correct plane in the pelvis called the' Holy plane' which is between the mesorectum- the integral visceral mesentery of the hind gut and the surrounding nerves on which sexual function depends. This is easiest done at the back by first identifying the two superior hypogastric nerves that come from the superior hypogastric plexus and run down the pelvic side wall. Using St Mark's retractor, the mesorectum is lifted forward and the nearly avascular cleavage plane around the lateral pelvic wall developed to a point of adherence between the mesorectum and the inferior hypogastric plexuses low down laterally on the pelvic wall (figure 4). These are were the parasympathetic and sympathetic nerves meet often called the lateral ligaments which links the prerectal and retrorectal parts of the field of dissection. At this point it is easy to taper in the mesorectum with consequent bleeding. This is avoided by cutting at the adherence slightly inside the point where they swing away from the parietal fascia at the site of the planned rectal excision (figure 5). Thus, cutting the nervi erigentes that innervate only that aspect of the rectum which is being excised. In low anterior resection, the bowel should be divided at the anorectal junction to ensure removal of the entire mesorectum [14].

Anterior dissection

In the anterior dissection, incorporating the peritoneal reflection as part of the specimen creates a dissection plane (cul-de-sac) behind the top and back of the seminal vesicles that goes down onto the fascia of Denonvillier. Although the antero-lateral lying neurovascular bundles of Walsh that supply the seminal vesicles may be injured, this is extremely unusual owing to the presence and protection of Denonvillier's fascia [20, 21]. This white fascia layer is useful because it is fairly firmly attached to the anterior mesorectal fat and closely applied to the prostate than the rectum. It lies just anterior to the fascia propria and would give the appropriate plane of dissection that would lead down to its adherence to the back of the prostate. By not excising Denonvillier's fascia postoperative sexual function can be minimized without compromising the oncological outcome [14, 22]. A 'U' shape incision on Denonvillier's fascia may also prevent damage to the antero-lateral nerves [14]. This is a difficult and challenging part of the dissection in low rectal tumours with regard to avoiding damage to the back of the prostate and consequent bleeding. Bladder injury may occur during rectal excision for an adherent rectal carcinoma especially low down on the posterior bladder wall or trigone. It is desirable to open the bladder in difficult dissections so that the orientation becomes easier and an injury to the trigone is avoided. In the female, the plane between the vagina and rectum is more difficult to find than its equivalent in the male. It lies between the postvaginal plexus and the fascia of Denovilliers and becomes apparent when the posterior vaginal wall is displaced anteriorly by blunt dissection [14, 22]. There is a reported 95% efficacy of continuous intraoperative monitoring using a nerve stimulator (pIOM) that enhances autonomic nerve identification during TME (figure 6) [23].

Advantages and limitations of TME

The en bloc excision of perirectal lymphatics and fatty tissue down to the pelvic floor in TME (figure 7) gives a low local recurrence rate of 4-5%

and improved survival [16, 24]. The recurrence may be due to (1) lateral pelvic wall lymph nodes occurring in 10-30% of patients and (2) 'coning' in on the distance clearance margin may leave some of the mesorectum behind on the pelvic wall, thus increasing the chance of local recurrence. Using the international prostate symptom score and international index of erectile function, TME with pelvic autonomic nerve preservation showed relative safety in preserving sexual and voiding function [25]. It reduced the problem of accidental bladder denervation from 50-60% with conventional rectal cancer surgery to <20% with TME, and the problem of post operative impotence from 70-100% to <30% (table 1) [26, 27]. Thus, although severe urinary dysfunction is rare, sexual impairment still remains a serious concern after rectal resection with TME. Laparoscopic approach for TME allows similarly favourable results with regards to postoperative urogenital function at best for tumours situated in the middle and upper third of rectum [28]. The risk factors are low rectal cancers, anterioly-encroaching tumours, the narrow male pelvis and abdomino-perineal excision (APE). Therefore, experience with, and the learning curve in the TME procedure play a major role with both autonomic nerve preservation and the oncological surgical outcome [29]. Lateral pelvic lymph nodes are usually associated with locally advanced disease and sexual function particularly ejaculation was often damaged after an associated radical pelvic lateral node dissection [30]. Toritani et al [31] recently demonstrated that following TME and lateral pelvic wall lymphadenectomy more than 20% of patients had urinary dysfunction and the preoperative risk factors were tumour location, tumour size and diabetes mellitus. They concluded that high risk patients with more than two of the above risk factors should be informed of the risk of urinary dysfunction following lateral pelvic wall lymphadenectomy. High resolution MRI have enabled more selective application of lateral lymph node dissection (LLND). The use of the enhanced visualization of laparoscopic or robotic surgery minimize bleeding and postoperative complications and may further decrease local recurrence rate even in patients with enlarged pelvic lymph nodes, [32]. LLND is not popular in the West, because of poor functional result as most patients had sexual and urinary disturbance, lengthy operation times, excessive blood loss and the perceived success of TME [33]. In addition, a Swedish study demonstrated only 2 of 33 pelvic recurrences attributed to lateral pelvic side wall lymph node involvement [34], and in the current era of neoadjuvant chemoradiotherapy for rectal cancer LLND may not be necessary [35]

Inflammatory bowel disease

Since the presacral nerves are situated well posterior or lateral to the rectum, it should not be difficult to avoid damage when operating for inflammatory bowel disease as the dissection stays close to the rectum. As the lateral ligaments are divided close to the rectum in inflammatory bowel disease bladder and sexual dysfunction is kept to a minimum. Impotence is rare after rectal excision for inflammatory bowel disease and fashioning of ileo-anal pouch but cases of retrograde ejaculation have been reported [36]. Although the risk of impotence is low, warnings are vital as these patients are often young, and impotence will be a particularly severe disaster. Some women have dyspareunia (pain on sexual intercourse) after rectal excision due to the vaginal wall falling back to the sacrum [37]. Dyspareunia has been reported in 7-28% of females after ileo pouch-anal anastomosis [4, 6, 37]. This can be prevented or minimized by by transporting the omentum or other tissue into the area in front of the rectum.

Perineal surgery

Abdomino-perineal excision of rectal cancer

The surgical innovation in the abdominal-perineal excision for rectal/anal cancer by Miles in 1908 [38] was inspired by Halstead radical surgical oncological principles based on pathological lymph node spread. The distal spread was important to Miles which Dukes later found to be limited [39]. However, the procedure is indicated for anal cancer or low rectal cancer involving the sphincter. Unfortunately, there is a higher positive circumferential resection margin (CRM) with this procedure and significant autonomic dysfunction [40, 41] for technical and oncological reasons (table 3) In the male the perineal dissection is among the most difficult in colorectal surgery. Having freed the rectum posteriorly and laterally, the retroprostatic plane may be difficult to enter but guided by the landmark of the superficial border of the superficial transverse perineal muscles the plane will gradually become apparent. There is a tendency of 'coning' of the specimen at the level of the levators and these low tumours are usually locally advanced (T4) with nodal spread [42]. Thus the oncological importance of excising widely at the level of the pelvic floor (extralevator excision) and a TME in the abdominal phase (Figure 8). The prone position in performing the perineal part of the operation facilitates the wide pelvic floor excision with improved circumferential resection margin [42].

Autonomic dysfunction in perineal surgery

Post-operative pain, rectal distension and anal dilatation increase bladder neck sympathetic tone through a sympathetic reflex with the afferents being the somatic and visceral sensory nerves. In either sex, the sympathetic response to pain may lead to abnormal bladder sphincteric activity (autonomic dysreflexia) causing difficulty in voiding and thence urinary retention [43, 44]. Disease severity, amount of analgesia required, simultaneous operations i.e. sphincterotomy, haemorrhoidectomy, fistulotomy, incision and drainage of abscess etc, were risk factors of post-operative urinary retention [45]. An inserted, haemostatic anal pack usually cause post-operative pain and thus the insertion of an indwelling urinary catheter for 24 hrs may avoid acute urinary retention [9]. The frequency of acute urinary retention is greater in males than females because of benign prostatic hyperplasia providing a 'weak' bladder with no pushing power [4, 9, 15]. Excessive fluid intravenous administration may cause over distension of the bladder with the sequelae of inhibiting the detrusor and decreasing bladder compliance. A bladder volume greater than 270 mls has a 2-3 fold risk of post operative urinary retention [46]. Spinal anaesthesia blocks afferent and efferent nerves causing the lack of sensation of bladder-filling and would thus exacerbate the over- distention of the bladder. General anaesthesia interfere with ANS function precipitating bladder atony. Systemic opioids both by intravenous and intramuscular routes inhibit the release of acetycholine from the parasympathetic sacral neurons that control detrusor contractility and increase the incidence of acute urinary retention. This is because the axons of pre-ganglionic parasympathetic fibres also contain enkephalins that are transported to the parasympathetic ganglia and have an inhibitory modulatory effect on the release of acetylcholine [43, 44]. Patients greater than 50 year old have age-related neuronal degeneration. Urodynamic investigations will distinguish bladder atonia from obstruction if not clinically deduced. If atonia, urethral catheterization will allow recovery but a prostatectomy is definitive treatment for obstruction from BPH [44]. The neuroanatomical basis for autonomic dysfunction in surgical coloproctology is summarized in table 2, and the autonomic dysfunctions of surgical coloproctological procedures in table 3 .

Clinical implications of autonomic dysfunction in surgical coloproctology

Parasympathetic nerve dysfunction occurs through the mechanisms of (a) neuropraxia, (b) intentional division (tumour extension), or (c) an unintentional division. This is corroborated by the study which showed that pelvic nerves (S2, S3, S4) were identified in only 5 of 19 patients [30]. Bladder dysfunction is as a result of a lower motor neurone lesion from injury to motor PSN to detrusor causing a hypotonic bladder or urinary retention. The treatment options are the insertion of a suprapubic catheter, intermittent self catheterization or urethral catheterization. The parasympathomimetic agent, bethanecol, in a dose of 10mg subcutaneously significantly lowers the incidence of postoperative urinary catheterization and should be considered as initial treatment of postoperative urinary retention following anorectal surgery. However, it seldom works on the detrusor that is exhausted by obstruction or

rendered unstable from whatever cause [15, 43, 44]. Further studies would establish the role of alpha antagonists in the prevention of postoperative urinary retention among patients undergoing anorectal surgery [15]. The mechanisms of sympathetic nerve dysfunction are (1) pelvic plexus (SHP & IHP) damage or (2) vasculogenic from internal iliac artery, rarely pudendal artery or bilateral internal iliac artery embolization. The management of male impotence depends upon if it is neurogenic and psychogenic which requires pharmacotherapy, or vasculogenic requiring a vacuum device or a penile prosthesis [47]. With the knowledge that parasympathetic nerve-mediated sexual function cause erection of the penis and clitoris and in addition genital lubrication and engorgement in females, Banbrick et al [48] demonstrated significant changes in sexual function in 262 women 3 months following restorative proctocolectomy for ulcerative colitis. These included vaginal dryness (22%), dyspareunia (26%), pain interfering with ability to feel sexual pleasure (20%) probably due to a local mechanical problem and fear of stool leakage (17%). Van Driel et al [49] reported 5 series of female sexual functioning after radical surgical treatment of rectal and bladder cancer with follow-up at 3 months to 23 years. 20-78% had decreased libido, 21-50% had severe dyspareunia and 38-65% had a disappearance of coitus post-operation. The treatment of female sexual dysfunction include viagra which increase genital blood flow, libido, sexual interests, vaginal elasticity and sensation after hysterectomy, and Eros (urometrics) which is a battery driven vacuum device [50]. Preoperative counseling in surgical coloproctology is thus important, in addition to attention to the meticulous details of the operative techniques entailed in rectal excision. Patients who still have voiding and/ or erectile dysfunction at 3 months should be referred to the urologist.

Conclusions: Urogenital dysfunction remains a common problem in surgical coloproctology. Sexual dysfunction is a common postoperative complication following pelvic surgery and urinary dysfunction following perineal surgery. At-risk patients should have their functional status evaluated before and after surgery. Structured education of surgeons with regard to pelvic neuroanatomy and systemic registration of identified nerves intra-operatively using 'intraoperative nerve stimulation' may reduce autonomic dysfunction in patients undergoing pelvic surgery. The oncological benefits of neo-adjuvant radiotherapy should be balanced against the additive effects on urogenital dysfunction in rectal cancer surgery.

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	Conventional Rectal Cancer Surgery	**Total Mesorectal Excision**
Accidental bladder denervation	50-60%	<20%
Post-operative impotence	70-100%	<30%

Tables

Table 1: Autonomic dysfunction: conventional rectal cancer surgery vs total mesorectal excision

	Sympathetic pathway	Parasympathetic pathway
Pre-ganglionic:	anterior roots of T11-T12 (least splanchnic n) pass via paravertebral sympathetic chain	ant roots of S2-4 cross medial surface of levator ani (pelvic splanchnic nerves)
Ganglionic	superior hypogastric plexus	pelvic plexus (inf hypogastric)
Post-ganglionic	L& R hypogastric nerves to pelvic plexus	cavervous nerves and vesical branches
Function	Ejaculation	voiding and sexual function (erection)

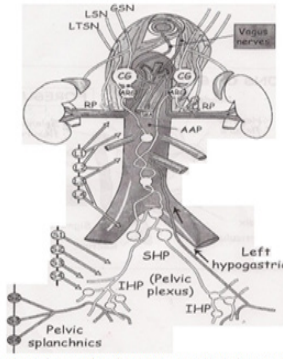
Table 2: Summary of autonomic nervous system pathways and function

	Sexual dysfunction	Urinary dysfunction
Pelvic surgery		
TME for rectal cancer4,-6, 8-11	+++	+
Proctocolectomy for UC6, 43, 44	+	+
Restorative proctocolectomy43, 44, 63	+	+
Colectomy6		
	+	+
Perineal surgery		
Haemorrhoidectomy6 ,9, 54, 56	+	++
Internal sphincterotomy6, 57, 63	+	++
Abdomino-perineal excision for anal/rectal cancer6, 55, 60	+++	+

Table 3: Summary of autonomic dysfunctions in surgical coloproctology

+++= very common, ++= common, += not common, UC= Ulcerative colitis

Figures



GSN- greater splanchnic nerve (T5-9), **LSN**- lesser splanchnic nerve (T10-11), **LSTSN**- least splanchnic nerve (T12), **CG**-coeliac ganglion, **AAP**- abdominal aortic plexus, **RP**-renal plexus, **SHP**-superior hypogastric plexus, **IHP**- inferior hypogastric plexus., **lumbar splanchnics** (L1-4), **sacral splanchnics** (S1-4)

Fig 1: Schematic diagram of the abdominal and pelvic autonomic nervous pathways [14] (with permission)

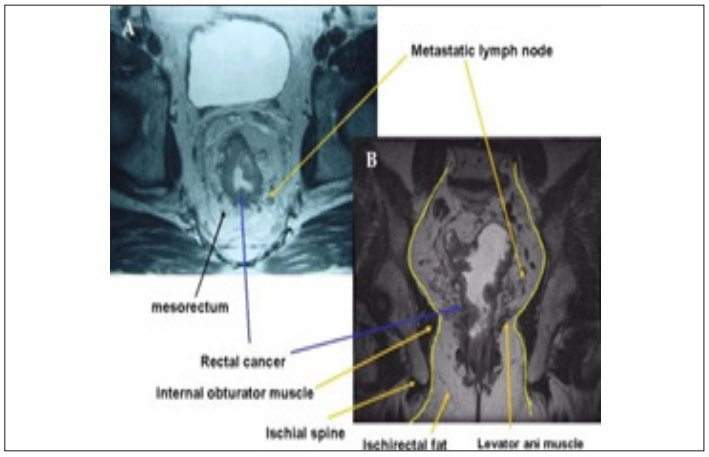


Fig 2: Pre-operative MRI of mesorectum in rectal cancer surgery

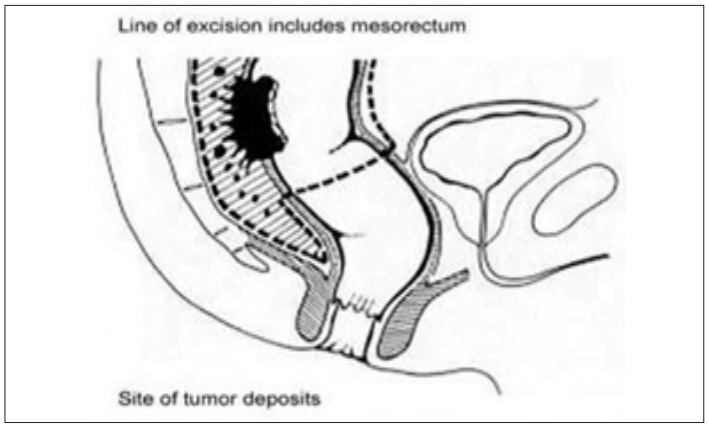


Fig 3: Schematic diagram of line of total meserectal excision which includes tumour and satellite deposits

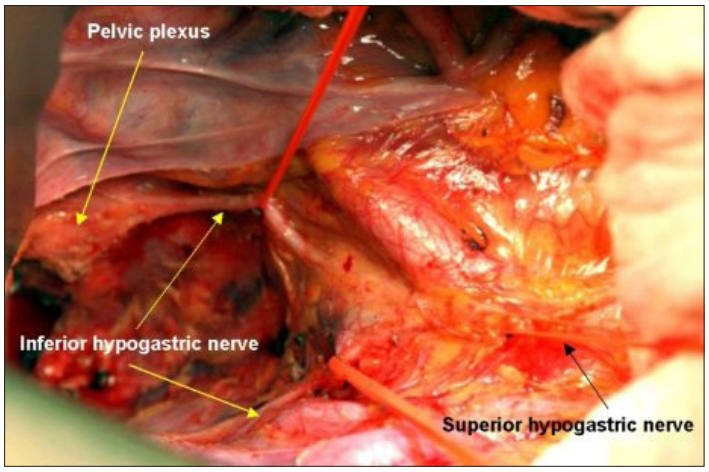


Fig 4: Intraoperative view of the superior hypogastric plexus, the hypogastric nerves and pelvic inferior hypogastic plexus on the lateral pelvic wall after total mesorectal excision with nerve preservation [27] (with permission)

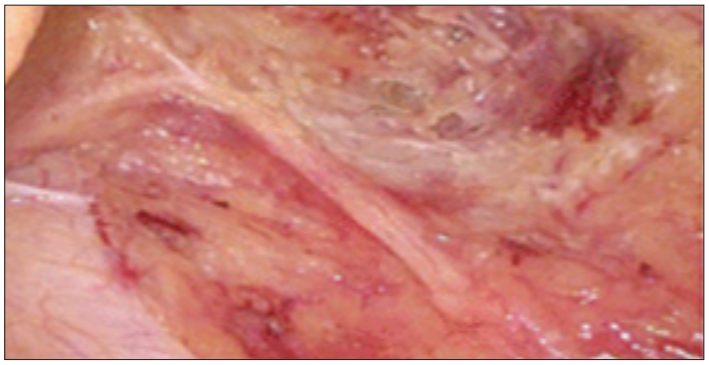


Fig 5: Robotic view with medial-to- lateral dissection approach of Inferior hypogastric nerve with branches to the rectum. Note the tenting of the inferior hypogastric nerve with medial traction and risk of damage.

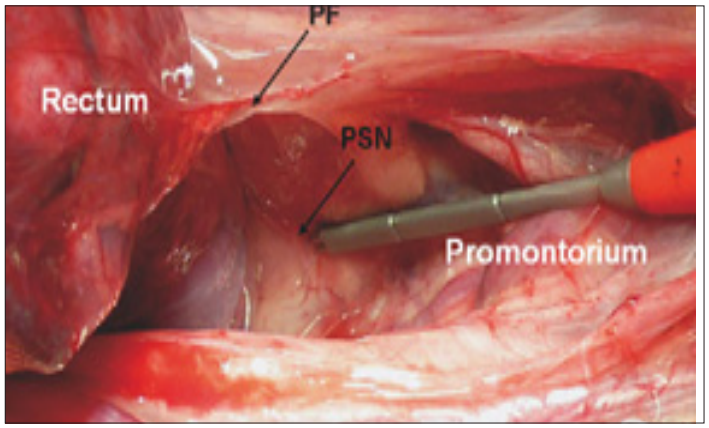


Fig 6: Intraoperative autonomic nerve monitoring

Fig 7: An ideal total mesorectal excision specimen with an unbreached mesorectum

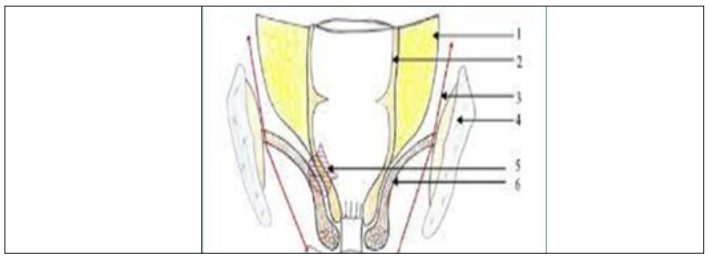


Fig 8: Schematic diagram of Extralevator abdominoperineal excision (ELAPE) of rectal cancer; 1: mesorectum; 2: rectum; 3: margin; 4: iliac bone; 5: tumour; 6: levator ani.

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