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The Anatomical and Radiological Basis of the Operation Extrafascial Excision of the Rectum

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Abstract

The operation of extrafascial excision dissects directly on the rectal fascia propria to remove the rectum and mesorectum within an intact fascial envelope. The studies contained in this thesis revolve around the recent finding that if a rectal cancer is contained within the fascia propria and the rectum is removed by extrafascial excision then local recurrence of the cancer will be exceptional. The thesis is presented in 4 parts as anatomical, radiological, clinical and operative sections.

Gross and microscopic examination of surgical specimens, post-mortem dissections and axial cross sectional anatomy images were used to define the anatomy of the fascia propria. It is shown to be a 150µm thick, collagen membrane completely surrounding the mesorectum. The hypogastric nerves and pelvic plexuses are embedded in the parietal fascia separated from the mesorectum and fascia propria by a loose areolar layer. A computerised three-dimensional model of the rectum and mesorectum has been generated based on 1mm axial cross sections of the anatomy of the area and axial MR scans offering the potential to visualise the rectum in its mesorectum preoperatively.

A systematic review of preoperative radiological staging has been reported comparing endorectal ultrasound, CT and MR imaging. The ability to determine the relation of the tumour to the fascia propria preoperatively has, however, not been previously explored. Cadaveric studies in this thesis have demonstrated that the fascia propria can be identified by axial CT and MR imaging. In a consecutive series of 43 patients with rectal cancer preoperative MR accurately predicted the relation of the deepest tumour invasion to this fascia.

In the third section extrafascial excision has been compared with conventional surgery at a single institution over a 16 year period. In a study population of 262 rectal cancer patients operated on with curative intent, extrafascial excision had a significantly lower local recurrence rate and prolonged cancer-free survival without an increase in cost or complication rates. Based on these studies a new description of the operation of extrafascial excision of the rectum is presented in the fourth section with emphasis on preventing complications.

This thesis has provided a new understanding of the surgical anatomy of the rectum and a novel management protocol for rectal cancer based on the relationship of the tumour to the fascia propria as detected by preoperative MR imaging.
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Abbreviations

ACC – Accuracy
Ant R – Anterior resection
APR – Abdomino-perineal resection
°C – Degrees Celsius
cm – centimetres
CT – Computerised tomography
EFE – Extrafascial excision of the rectum
ES – Endorectal sonography
EVG – Verhoeff’s method with van Gieson counterstain
F – female
FP – fascia propria
Gy – Gray
H&E – Haematoxylin and Eosin
HN – Hypogastric nerve
IMA – Inferior mesenteric artery
M – male
ml – millilitres
mm – millimetres
MR – Magnetic resonance
MRI – Magnetic resonance image
NIH – National Institute of Health
NLR – Negative likelihood ratio
NPV – Negative predictive value
PLR – Positive likelihood ratio
PP – Pelvic plexus
PPV – Positive predictive value
S4 – Fourth sacral vertebrae
SD – Standard deviation
SEN – Sensitivity
SHP – Superior hypogastric plexus
SPE – Specificity
TME – Total mesorectal excision
TNM – Tumour, node, metastasis
UC – Ulcerative Colitis
UK – United Kingdom
µm – microns
USA - United States of America
Chapter 1: The Evolution of Surgery for Rectal Cancer

Introduction

The history of rectal cancer surgery traces the quest for an ideal operation. This operation would overcome the problems of a high operative mortality rate, difficult surgical access, frequent local recurrence, loss of faecal continence, and damage to the pelvic autonomic nerves. Each advance that has occurred has been as a result of striving to overcome one or more of these complications. This chapter follows the evolution of rectal cancer surgery as it has reflected new understanding of its anatomy and pathology rather than offering an exhaustive review of its history.

This chapter will consider the initial perineal operations, the combined approaches, the sphincter-preserving operations, the extended operations and nerve sparing surgery. Each of these developments resulted from an attempt to draw nearer to the ideal operation.

Pre 1800

One of the earliest recorded descriptions of the presentation and natural history of rectal cancer was written in the early 14th century by John of Arderne who took a particular interest in diseases of the rectum and anus. After a lengthy description he concluded with,

I never saw nor heard of any man that was cured of cancer of the rectum, but I have known many that died of the foresaid sickness.\textsuperscript{91}

This dismal prognosis remained until the end of the 19th Century.

Morgagni (1689-1771 AD) was the first to propose an operation for cancer of the rectum\textsuperscript{47} and the first attempt at resection of the rectum was performed for an inflammatory lesion in 1739 by Fajet\textsuperscript{83}. This resulted in an uncontrollable sacral anus\textsuperscript{170}. 
Perineal procedures

Jacques Lisfranc is credited with the first rectal excision for cancer which he carried out in 1826. His operation was not based on any considerations of anatomy or pathology but was essentially a circumcision of the extra-peritoneal rectum. His description has been translated by Corman\(^47\), part of which appears below.

The patient lay on a bed prepared for this purpose. A retractor is introduced into the rectum and is secured by straps to the bed. A linen pad, coated with ointment, is introduced, a technique which we had previously practiced. Following slight tugging, the compress pulled out too soon. The aim of this apparatus was to facilitate eversion of the rectum. M. Lisfranc tried himself to insert the apparatus but the result was not helpful. He ordered the patient to make some strong efforts to introduce the packing into the rectum using the middle finger of the left hand, with his finger in a bent fashion, and in exercising some traction that everted rather imperfectly the rectum. He held strong, short scissors directed at a point in the circumference of a part of the tumour that was incised as deeply as possible without being completely detached. Then it became easier to grasp it with the finger, and in exercising some traction, not only caused greater protrusion, but yet one could completely deliver to the outside the entire disease process. He continued then to dissect in a circumferential manner, to lift out the mass of affected tissue, which is to say around two inches of mucous membrane. This resection was made with speed and care. One perceived then, when a portion of the sphincter was elevated, the operation was followed with heavy haemorrhage. M. Lisfranc allowed the blood to flow for about ten minutes. The patient lost about four palettes of venous and arterial blood. Then we tamponaded firmly with a square linen compress. The pressure dressing was maintained by a T-bandage. The patient was transported in his bed; the pulse was regular, a bit weak. We gave him some drink; three tankards of water with sweetened gym, and restricted the diet. Three assistants and M. Lisfranc, himself, remained for an hour near the patient. There was no untoward incident and the dressing did not change. At noon, the patient noted abdominal cramping, some chills, and a strong desire to move his bowels. He made such a great effort to do this that the plugged apparatus was expelled and was accompanied by at least three palettes of liquid and clotted blood. Then when the pulse became weak and thready, and the patient became syncopal, we reinserted the tamponade dressing, but with the precaution of deepening the compress in the center of the opening for fear of injuring the edge of the wound and of securing the area at the cut edge of the mucous membrane of the rectum. This time the tamponade was placed higher than the first, and presented a considerable volume. The apparatus was maintained in place by a tight T-dressing.
In spite of the heavy haemorrhage during and after the surgery the patient left hospital “completely recovered”. Pinault, a pupil of Lisfranc, published a thesis of 9 rectal excisions in 1829\textsuperscript{47}. This procedure was associated with a very high mortality and left the patient with a stoma in the perineum. It did not gain great acceptance by the surgeons of the day\textsuperscript{211}.

The inaccessibility of this lesion challenged the surgeons of the time and the next advance came by improving exposure to the rectum. Amussat was the first to practice coccygectomy and this was routinely used by Verneuil in 1873\textsuperscript{211}. Kocher in 1875 began using a purse-string suture to close the anus at the beginning of the operation to prevent contamination. His operation was more extensive; he opened the peritoneal cavity from below, mobilised the upper rectum and brought the pelvic colon down to the anus. He dissected close to the rectum and did not remove the perirectal tissue\textsuperscript{170}.

Kraske found that even after coccygectomy access was inadequate for tumours in the upper rectum. He undertook post-mortem dissections of the coccyx and sacrum and then resected the rectum preserving the anus. After performing the operation on a cadaver with a rectal cancer he attempted the first operation on a 64 year old woman in 1884. This involved a midline incision from posterior to the anus to the mid sacrum. The coccyx and left lower portion of the sacrum were excised then the rectum mobilised above the anal canal. The rectum was brought down into the wound and divided above the tumour. The rectal tumour was resected and the colon brought down and an anastomosis performed about “the width of one thumb” above the anus. The wound was left open and packed with iodoform gauze. The 2 patients initially presented were both continent 3 months after surgery\textsuperscript{99}.

Kraske’s operation had improved access to the rectum and also retained faecal continence in some patients and therefore became widely used. This procedure with many modifications became the accepted operation for rectal cancer surgery for the following 25 years.

Maunsell in 1892 described an operation where he dilated the rectum, divided the sphincters posteriorly and placed a speculum up to the level of the tumour. He then opened the abdomen, inserted a self-retaining retractor and a bowel shield before placing a tape around the bowel above the tumour. The bowel was then divided above the tumour and the tape passed out through the anus and the rectum prolapsed out and divided below the tumour. The colon was then sutured to the anus\textsuperscript{164}. This was modified by Weir in 1901 who did not divide the sphincters and resected the tumour before intussuscepting it through the anus\textsuperscript{271}. 
The results of perineal surgery

Tuttle\textsuperscript{259}, in 1897, compiled an impressive list of operations performed for cancer of the rectum up to that time including published results and those notified to him by other surgeons in the USA. He divided the results into 3 groups; pre 1885, 1885-92 and 1892-96, including a total of 1,256 patients. The pre 1885 patients all underwent perineal procedures before the advent of antisepsis. The operative mortality for this group was 22.4%. The second group included sacral operations for tumours higher in the rectum and the use of antisepsis techniques, with an operative mortality of 20%. There were 259 patients in the post 1892 group with an operative mortality of 11.7%. Figures for local recurrence were not reported for the first 2 groups and were incomplete for the third. Although it is not possible to calculate accurate survival figures from this study, at least 10% were free of disease after 3 years\textsuperscript{259}. In view of these results Tuttle’s conclusion\textsuperscript{260} was somewhat optimistic by today’s standard.

And thus we answer the question “What has modern surgery done for cancer of the rectum?” It has cured it, conquered all its disgusting features and relieved its pain, doubled and more the lease of life, and at comparatively small risk has given to the hopeless hope, not timorous and vague, but well-founded, which grows stronger and more confident every day they live without recurrence.

In 1900 Krönlein reported results of 881 operations for rectal cancer in a collected series of excisions performed during the preceding 25 years by Kocher, König, Czerny, Krönlein, Gussenbauer, von Bergmann, Madelung and Garre, Kraske, Küster, Hochenegg, and von Mikulicz. The operative mortality was 19.4% mostly due to sepsis and the 3 year survival rate was 14.8\%\textsuperscript{83}.

Although the posterior approach to rectal excision was widely practised from 1885-1910 the results did little to alter the gloomy prognosis that had been noted by John of Arderne nearly 6 centuries earlier. The operative mortality was around 20% and almost all surviving patients had recurrence of disease within 3 years.

The combined procedures

A major breakthrough came when Ernest Miles published his paper on abdomino-perineal resection of the rectum in the Lancet in 1908\textsuperscript{174}. He described the results of 57 perineal resections of the rectum he had performed up to December 1906. His carefully recorded follow up showed that 54 of these patients had developed recurrence. Post-mortem examinations of these patients
indicated that local recurrence occurred in the pelvic peritoneum, the pelvic mesocolon and the lymph nodes over the bifurcation of the left common iliac artery. He coined the phrase “the zone of upward spread” of rectal cancer and set about adapting his surgical technique to include this area. He stated,

The study of the spread of cancer from the rectum has led me to formulate certain essentials in the technique of the operation which must be strictly adhered to if satisfactory results are to be obtained—namely: (1) that an abdominal anus is a necessity; (2) that the whole of the pelvic colon, with the exception of the part from which the colostomy is made, must be removed because its blood-supply is contained in the zone of upward spread; (3) that the whole of the pelvic mesocolon below the point where it crosses the common iliac artery, together with a strip of peritoneum at least an inch wide on either side of it must be cleared away; (4) that the group of lymph nodes situated over the bifurcation of the common iliac artery are in all instances to be removed; and lastly (5), that the perineal portion of the operation should be carried out as widely as possible so that the lateral and downward spread may be effectively extirpated.

Miles then described the technique of abdomino-perineal resection in detail. His procedure followed the anatomical planes described by Waldeyer, almost certainly removing the rectum with its investing fascia propria. He stated among other things that the fascia propria of the rectum needs to be detached from the lower part of the sacrum to be removed with the resected specimen. His operative mortality was over 40% for his first 12 patients but at the time of publishing none of the survivors had recurrence.

In the same year Moynihan described an abdominal approach that was essentially the operation of anterior resection. This procedure included a high tie of the inferior mesenteric artery and resection of the sigmoid and upper rectum complete with their lymphatic drainage. He advocated mobilisation of the splenic flexure and immediate anastomosis either intra-abdominally or using Maunsell’s intussusception technique. He stated,

We have not yet sufficiently realised that the surgery of malignant disease is not the surgery of organs: it is the anatomy of the lymphatic system.

In this dictum he was in agreement with Miles but he did not agree that lymphatic spread distally to the levators and perineum occurred in rectal cancer. Unfortunately, this operation which avoided colostomy and preserved continence did not find wide acceptance for more than half a century.
The initially high operative mortality associated with the Miles procedure stimulated further interest in more limited surgical excision. In 1920 Lockhart-Mummery described an operation designed to “remove the rectum for cancer with a reasonable degree of safety without the serious mortality that has hitherto accompanied rectal excision”\textsuperscript{158}. This procedure involved initial colostomy formation followed by perineal excision of the anus and rectum. In 200 cases Lockhart-Mummery had an operative mortality of 8.5\% and his recurrence rate (local and distant) was about 50\% at 5 years. He noted, however, that “nearly 80\% of the patients presenting to the hospital for treatment were quite inoperable when first seen”\textsuperscript{157}. The limited scope of this procedure meant that only early lesions had the potential for cure\textsuperscript{83}.

Gabriel\textsuperscript{78} proposed an operation, perineo-abdominal excision of the rectum, which began with a posterior approach to mobilise the rectum. A laparotomy was then performed to complete the excision. Although the order of the steps differed from Miles’ operation it involved essentially the same level of dissection.

Devine\textsuperscript{56} and Lloyd-Davis\textsuperscript{155} simplified the combined operations of Miles and Gabriel with the description of the synchronised combined operation position. This allowed the complete operation to be performed without changing the position of the patient.

Rankin and Graham\textsuperscript{212} expressed the accepted approach to surgery for rectal cancer in 1939.

Happily there is no longer any disagreement as to the desirability of certain fundamental principles in all cases brought to operation after careful scrutiny. Radical removal of the offending growth with block dissection of the adjacent gland-bearing tissues, and secondary acceptance of colostomy as a necessary part of such a manoeuvre, no longer are questioned as essential features of the offensive.

**Sphincter-preserving surgery**

Dixon was willing to fly in the face of this dogma in championing sphincter-preserving anterior resection. Although the procedure had been previously described by others\textsuperscript{59, 187}, it was Dixon who popularised this approach. In 1939 he described the procedure in detail and indicated that he had carried out “more than 100 operations of this type”\textsuperscript{59}. The operation, when first described, involved 3 stages, an initial colostomy, 2-3 weeks later resection of the pelvic colon and its mesentery down to the level of the peritoneal reflection with anastomosis, and finally colostomy closure 3-4 weeks later. He claimed to have had only 3 patients who had subsequently required colostomy for local recurrence causing obstruction. His hypothesis was that the zone of upward spread was the most important area of local recurrence and that his operation was as radical as
Miles in removing this. His operative mortality although significant was less than that reported for abdomino-perineal resection and anterior resection had the added advantage of restoring the patient’s continence\(^{59}\).

The issue of contention became clearly focussed on whether anything less than an abdomino-perineal resection was adequate to remove rectal cancer. Miles’ findings of nodal involvement in the levator muscles and in the perineal skin had meant that any operation that did not remove these would be expected to result in an unacceptably high local recurrence rate. Evidence to refute this view took time to accumulate.

**Lymphatic drainage of the rectum**

Dukes\(^{60}\), in his classic paper in 1932, refined the staging system that Lockhart-Mummery had presented in 1926\(^{157}\). In this he proposed a staging system based two elements; the penetration of the bowel wall of the primary, and nodal involvement by tumour. He suggested that there was an orderly progression in the development of rectal cancer from an adenoma to intramural cancer to invasion of perirectal fat and then lymphatic involvement.

In 1935 Dukes in conjunction with Gabriel and Bussey\(^{80}\) presented the results of careful lymph node mapping of 100 rectal excisions collected prospectively. They showed that, in contrast to Miles’ earlier reports, lymph node involvement progressed sequentially from adjacent to the tumour proximally along the superior rectal chain. Paracolic lymph node involvement in the pelvic mesocolon only occurred in a single very advanced carcinoma. They also stated,

> Until the lymphatic channels accompanying the superior haemorrhoidal vessels are all blocked no downward or lateral spread is found, but when carcinomatous metastases are present in all the haemorrhoidal glands then there may be extension in other directions.

This finding could have had far-reaching consequences paving the way for radical surgery that did not remove the anal canal. However, the argument continued when Gilchrist and David reported the results of careful examination of 47 rectal cancer specimens dissected to identify all the lymph nodes involved\(^{84}\). They reported retrograde tumour deposits in nodes up to 4 cm distal to the rectal cancer in 2 cases and 4 cases with nodes involved within the levators. On the basis of their study, which included tumours involving the anal canal, they recommended that Miles’ operation should be performed for rectal cancer.

In the study by Coller et al\(^{45}\) of 53 cases of anal and rectal cancers, they did not find retrograde lymph spread a “significant distance” in a single case. The only cancers that showed any lateral
spread were less than three centimetres above the muco-cutaneous junction. They did find that lymph nodes were often involved proximally in the superior haemorrhoidal chain without nodes closer to the tumour necessarily being involved.

A further report from Gilchrist and David\textsuperscript{85} in 1948 of 153 tumours situated below the sacral prominence showed retrograde metastases in 7 of 153 tumours 1-5 centimetres below the tumour. They reiterated their earlier recommendations for the Miles operation for tumours below the peritoneal reflection. Most earlier papers had not clearly differentiated local and distant recurrence. They quoted their local recurrence rate at more than 30% for tumours below the peritoneal reflection.

Wangensteen and Toon\textsuperscript{268} stated “local occurrence is an indictment of any operation and is synonymous with inadequate excision”. They summarised an extensive experience of resection of rectal cancer with preservation of the sphincters either by anterior resection or by abdomino-anal pull through. They had no local recurrence in patients with tumours above 14 cm from the anal canal. There was a 13% local recurrence rate for tumours below 13 cm (but follow up was short on many of these patients). Tumours less than 8 cm from the anal verge had a local recurrence rate of 25%. They stated that if an anterior resection was performed with suture anastomosis then anal sphincter function was as good as preoperatively and that after abdomino-anal pull through, sphincter function was satisfactory but not as good as preoperatively. The discussion in their paper combined all reported data on retrograde nodal metastasis for rectal cancer. It showed that in only 8 of more than 240 patients with Dukes’ C rectal cancer were there nodes distal to the tumour (3%). They recommended: one stage anterior resection for high rectal tumours, anterior resection or abdomino anal pull through with a defunctioning stoma for mid rectal tumours, and abdomino-perineal resection for tumours less than 8 cm from the anal verge.

In an attempt to clarify the lymph drainage of the rectum Sauer and Bacon\textsuperscript{229} injected dye into 17 rectal tumours before resection. They showed that contrary to Miles’ initial description the lower rectum drained both up the superior haemorrhoidal chain and laterally to the pelvic side wall. The lateral nodes were not situated in the levators but in the lateral ligaments and on the pelvic side wall. Involvement of the levators occurs by direct spread rather than by nodal involvement. They recommended that all lesions below the middle valve of Houston should be managed by abdomino-perineal resection complemented by wide excision of the lateral ligament and dissection of the internal iliac nodes.

By the early 1950s there was adequate evidence that spread of tumour to nodes distal to the primary did occur but this was unusual and extension for more than 4 cm was unknown. This
pathological information was not enough, however, and clinical results were needed to prove that anterior resection was as safe and as “curative” as abdomino-perineal resection.

**Outcomes of anterior resection and abdomino-perineal excision**

During the 1960s cohort studies began to appear comparing the results of anterior resection and abdomino-perineal excision. The New York Memorial Hospital results, reported by Deddish and Stearns\(^5\), showed that local recurrence was no more common after anterior resection than abdomino-perineal resection in tumours more than 6 cm above the anal verge. Morson et al\(^1\), reporting on the St. Marks results, showed that the local recurrence rates were similar (7.9% for anterior resection and 8.1% for synchronous combined excision) in radical operations carried out for cure. They also noted that 80% of the local recurrences occurred in the first 2 years. In 1966 Williams et al\(^2\) of Ohio published the results of 118 curative operations carried out for cancer. They showed that the 5-year survival rates were similar (46% for abdomino-perineal and 57% for anterior resection). Subsequently these findings have been confirmed by many authors including; Slanetz et al\(^3\), Lockhart-Mummery et al\(^4\), Nicholls et al\(^5\), Chapuis et al\(^6\), Williams et al\(^7\), Wolmark and Fisher\(^8\), and Lavery et al\(^9\).

In his Bradshaw Lecture in 1965, Morgan\(^10\) showed the trends in treatment of rectal cancer at St. Marks Hospital over the preceding 40 years. The mortality for combined excision had dropped from 30% to 2.6% and the rate of performance of anterior resection had increased from 0% to 30% for rectal cancers.

The introduction of the stapling device in the late 1970s\(^1\) enabled low colorectal anastomosis to be performed in situations where only abdomino-perineal resection had previously been possible\(^2\). Beart and Kelly\(^3\) performed a randomised controlled trial and showed that the results of stapled anastomoses were as good as sutured anastomoses with respect to postoperative complications.

Although anterior resection had been shown to be comparable to abdomino-perineal resection with respect to local recurrence and survival, there were still significant questions to answer regarding the technique of rectal excision. In particular, the optimal distal and lateral resection margins required to prevent local recurrence had not been identified.
Distal resection margins

In patients undergoing an anterior resection rather than an abdomino-perineal excision how much bowel distal to the tumour needed to be resected to prevent local recurrence at the anastomosis? Grinnell\(^9\) reviewed the pathology of 93 tumours occurring from 5 to 18 cm from the dentate line and carried out serial sections at 1 cm intervals distal to the tumour. Definite retrograde mural spread was found in half of the cases of palliative resection and in 12% of the curative resections. The greatest extent in a curative resection was 4 cm. On the basis of this he recommended that rectal cancers be excised with a distal margin of 5 cm beyond the tumour edge. In his subsequent publication in 1966\(^93\) he reviewed 913 specimens of colon and rectal cancers and showed that all patients with atypical retrograde spread died despite radical excision.

This “5 cm rule” of distal excision was challenged by Williams et al\(^275\) who were able to show that only 10% of 50 consecutive rectal cancers removed by abdomino-perineal excision had distal intramural extension of the tumour for more than 1 cm and that despite the radical nature of the resection all were dead or dying of disseminated disease within 3 years. They also reviewed patients who had undergone anterior resection for rectal cancer at least 5 years previously and compared those who had greater than 5 cm distal margin with those having less distal margin resected. There was no difference in survival or recurrence between these 2 groups, but the study sample consisted of only 79 patients. These findings are in agreement with those of the Mayo clinic published in 1976\(^282\). In this study of 556 patients with tumours between 6 and 20 cm from the anal verge, wide distal resection margins did not influence either survival or the incidence of local recurrence. Shirouzu et al\(^236\) in 1995 published a comprehensive study of the histology of 610 consecutive rectal cancers with particular emphasis on the distal spread of the tumour. They found that distal spread was observed in only 3.8% of the patients and that this was confined within a 1 cm length. Most patients with distal spread had a lower survival rate and died of distant metastasis rather than local recurrence, even after curative surgery. They concluded that a “distal margin of resection of 1 cm may be appropriate clearance for most rectal cancers”.

Lateral resection margins

Most emphasis had been placed on achieving adequate distal clearance of the tumours but Quirke et al\(^209\) showed that lateral margins were also extremely important. In a prospective series of 52 rectal cancer patients they performed serial 5-10 mm transverse slices of the whole specimens. Local recurrence occurred in 85% of the patients with positive lateral resection margin and 3% of those with negative lateral resection margins. This finding was confirmed by others including; Ng et al\(^196\) who reported local recurrence in 60% of “curative” patients with involved lateral
margins compared to 17% in those without, Adam et al\textsuperscript{2} who found a local recurrence rate of 78% for those with involved circumferential margins and 10% in those without, and de Haas-Kock et al\textsuperscript{51} who reported similar results. When the rectum was removed with a complete mesorectum, however, circumferential margin involvement occurred much less often and when present was a marker of disseminated disease rather than local recurrence being associated with significantly decreased survival\textsuperscript{96}.

During the 1980s, in an attempt to reduce the incidence of local recurrence, two separate treatment modalities, adjuvant radiotherapy, and more extensive surgical resection were developed. Several randomised, controlled trials showed that the addition of radiotherapy to conventional surgery produced a significant reduction in local recurrence rates\textsuperscript{73, 81, 188}. Radiotherapy has since become an important component in the modern management of rectal cancer but a detailed description of its development is outside the scope of this chapter. The subject is dealt with in more depth in chapter 6. The more extensive surgical resections are considered below.

**Extended operations**

More extensive surgical resection was generally performed in one of two different ways; by wide excision of the pelvic lymphatics with the rectal specimen, or by sharp dissection in a plane outside the mesorectum removing the rectum within an intact, complete mesorectum.

**Extended pelvic lymphadenectomy**

Rectal cancer surgery in Japan developed independently based on an understanding of the lymphatic anatomy described Dr Yoshikiyo Senba, a surgeon and anatomist who in 1927 published his findings describing the lymphatic drainage of the rectum in 200 foetuses\textsuperscript{232}. Dr Masaru Kuru utilised Senba’s findings to develop a radical operation incorporating lateral lymph node dissection in the pelvis and high ligation of the inferior mesenteric artery\textsuperscript{147}. Dr Tamaki Kajitani further refined the operation to allow clearance of the internal iliac and obturator lymph node groups in a procedure referred to as extended pelvic lymphadenectomy. This rested on an understanding of the visceral fascia encompassing the pelvic plexuses and hypogastric nerves within the mesorectum\textsuperscript{250}. Enker et al also championed wide lymph node dissection in his publication in 1979\textsuperscript{66}. He produced impressive 5 year survival figures with a local recurrence rates of 9.4% for Astler-Coller\textsuperscript{11} stage B1, 11.9% for stage B2 and 27.9% for stage C2. Other authors using this extended dissection technique expressed differing opinions regarding its use.
Amato et al\textsuperscript{6}, Hojo et al\textsuperscript{121}, and Michelassi et al\textsuperscript{173} argued for its application to improve survival, but the results of a St Mark’s study by Glass et al\textsuperscript{87} did not indicate any survival advantage to those undergoing extended pelvic lymphadenectomy. These procedures were, however, associated with very high rates of urinary and sexual dysfunction\textsuperscript{121, 183}.

**Total mesorectal excision**

Heald et al in 1982\textsuperscript{106} described 5 cases of minute foci of adenocarcinoma in the mesorectum several cm distal to the lower edge of the tumour in a series of 50 consecutive curative resections for rectal cancer. He totally removed the mesorectum with the rectum using sharp dissection and, despite the presence of tumour in the distal mesorectum, he had no local recurrence after a minimum follow-up of 2 years. Heald’s high rate of distal mesorectal involvement was at variance with previous authors\textsuperscript{45, 268} but he considered this was explained by his detection of microscopic deposits of tumour that would have easily been missed in other series that only looked for involved nodes in the mesorectum. He then introduced the term Total Mesorectal Excision (TME) to describe the dissection. His results appeared to indicate that it was the distal mesorectum rather than the distal bowel wall that harboured the cells that caused local recurrence. Subsequent findings relating to the importance of avoiding a positive lateral resection margin have shown that there are other features of TME that may be important in preventing local recurrence. Several other authors published the results of TME over the next 10 years\textsuperscript{20, 46, 130, 141, 180, 249}.

Bokey et al, introduced a standard operative technique, which was called total anatomical dissection, in 1981 to the colorectal unit in Concord, Sydney. This involved resection of the rectum using diathermy dissection in the fascial plane inside the hypogastric nerves. They emphasised the mobilisation of the splenic flexure, separate high ligation of the inferior mesenteric artery and vein and the removal of the total mesorectum only for those with mid and low rectal cancers. They reported a low local recurrence in their series of over 500 patients\textsuperscript{28}.

In an attempt to determine whether there was any difference in outcome following extended pelvic lymphadenopathy, TME or conventional surgery, McCall et al performed a systematic review of the English literature initially published in 1995\textsuperscript{166} and updated in 1997\textsuperscript{167}. In a combined study population of more than 10,000 patients undergoing “curative” surgery for rectal cancer they showed pooled local recurrence rates of 8.8%, 12.4% and 20.5% for TME, extended pelvic lymphadenopathy, and unspecified excision techniques respectively. The results for TME compared favourably with those in the radiotherapy groups of the randomised controlled trials.
Hill and Rafique\textsuperscript{117} described a technique of rectal excision that initially identified the fascia propria of the rectum and dissected directly on this to remove the mesorectum within its fascial envelope. Using this technique, they had only 3 local recurrences in a series of 84 curative resections for cancer and 2 of these were at the anastomosis after inadequate distal resection margins. They called this operation, extrafascial excision of the rectum (EFE), and showed that if the tumour was contained within the fascia propria and EFE was performed then local recurrence was exceptional.

**Nerve sparing surgery**

Although the initial problems of high operative mortality, difficult surgical access and loss of faecal continence had been largely overcome and local recurrence significantly reduced by the operation of anterior resection, pelvic autonomic nerve damage remained a significant problem\textsuperscript{21, 121, 149, 183, 194, 226, 243, 270}. The anatomy of the pelvic autonomic nerves was extensively described in 1946 by Ashley and Anson\textsuperscript{10} but the relation of the nerves to the planes of dissection in rectal excision has been poorly understood. This subject is explored in detail in chapter 2 and a study performed to define the plane of the nerves more accurately is outlined in chapter 4.

Several authors have described different techniques of dissection to preserve the nerves. Stelzner et al\textsuperscript{244} proposed that a small anterior patch of rectal muscle covering the diaphragmatic part of the urethra should be left behind in male patients undergoing total proctocolectomy in order to preserve potency. He reported 18 male patients who all retained potency following abdomino-perineal resection using this new technique. This procedure has not been widely implemented. Hojo et al\textsuperscript{122} reported 134 patients with rectal cancer who underwent extended pelvic lymphadenectomy and selective pelvic autonomic nerve preservation. In the whole group only 31% recovered erectile function and 19% ejaculation in the first year. Even in the group that apparently had complete preservation of all the pelvic autonomic nerves 20% were impotent and 40% had no ejaculation. In 1992 Enker\textsuperscript{63} described his technique of “autonomic nerve-preserving pelvic sidewall dissection” with both ejaculation and potency retained in over 85% of the men studied. Havenga et al carried out cadaveric dissections to clarify the anatomical basis of this operation in 1996\textsuperscript{100}.

Moriya took the Japanese operation to the Netherlands and in conjunction with Dutch surgeons operated on 47 patients with careful documentation of any nerves that were sacrificed during the procedures. They showed that impotence was related to sacrifice of the inferior hypogastric plexus (pelvic plexus) and that the superior hypogastric plexus was crucial to ejaculation\textsuperscript{160}. They
recommended that their technique of nerve-preserving surgery be considered for adoption as a standard surgical procedure for primary rectal cancer.

The description of TME by Heald et al\(^{106}\) includes reference to preservation of the autonomic nerve plexuses by pursuing the lipoma-like outer surface of the mesorectum. His later publication with MacFarlane\(^{161}\) included a picture of a preserved erigent nerve root after TME. Enker, whose initial descriptions\(^{66,67}\) appeared to propose much wider pelvic dissection than Heald’s TME, has more recently described his dissection in a plane that is close to that of Heald\(^{64,65}\).

**Summary**

In this chapter we initially considered how rectal cancer surgery began as perineal procedures with an operative mortality of greater than 20%, loss of faecal continence and almost invariable recurrence of tumour. We have seen how the understanding of the pathology and anatomy of tumour spread then led to combined procedures which removed the sigmoid colon, rectum, and anus complete with associated lymphatics providing greatly improved local control of the cancer but at the expense of a high operative mortality and permanent loss of faecal control. Sphincter-preserving procedures were only widely adopted when it became clear that the lymphatic spread of rectal cancer was predominantly superiorly along the mesorectal nodes associated with the superior rectal vessels. The advent of stapling devices then made preservation of the sphincters technically possible even for low rectal tumours. An understanding of the concept of the “mesorectum” led to operations performed by sharp dissection under direct vision removing the mesorectum intact. Today we have the situation where the rectum can be removed with preservation of continence in most cases, an operative mortality of about 2.5%\(^{165}\) and local recurrence in less than 10% of patients\(^{167}\).

This thesis further explores the operation of extrafascial excision described by Hill and Rafique\(^{117}\). **Section 1** considers the anatomical basis concentrating particularly on the fascia propria of the rectum and its relations. **Section 2** offers an overview of preoperative radiological staging of rectal cancer then proposes a new assessment system based on the radiological identification of the fascia propria. **Section 3** applies the findings to the clinical arena comparing the results and costs of EFE with those of conventional surgery. **Section 4** takes the findings of the initial studies and incorporates these in a detailed description of the anatomy and technique of EFE.
Section 1: The Anatomical Basis of Extrafascial Excision of the Rectum for Cancer
Chapter 2: An Introduction to Pelvic Fascial Anatomy

Introduction

The foundation of all operative surgery is a detailed knowledge of the anatomy of the region. This is especially true for the surgery of cancer. The particular area of interest to surgeons is the identification of oncologically safe planes of dissection and the relationship of these to adjacent vital structures. In the case of rectal cancer this involves understanding the dissection planes of the pelvis. The anatomy of the fascial layers of the pelvis is complex, as has been acknowledged by those workers who have studied this area extensively. Surprisingly, many modern texts and atlases of anatomy make no mention of the surgically important mesorectum and fascia propria and their figures show the rectum bare of any mesorectum. A brief history of the evolution of the understanding of the anatomy of the pelvic fasciae and its influence on surgical techniques will be presented before describing our studies.

Definitions

The rectum is the terminal portion of the alimentary tract continuous above with the sigmoid colon and below with the anal canal. Its junction with the sigmoid colon is indicated by the lower end of the sigmoid mesocolon at about the level of the third sacral vertebrae. At the anorectal junction, situated 2 to 3 cm in front of and slightly below the tip of the coccyx, the gut turns from passing downwards and forwards to pass downwards and backwards as the anal canal.

A fascia is a sheet of regularly oriented fibres of connective tissue large enough to be identified by the unaided eye.

Early Descriptions

The details of the pelvic fasciae began to appear in the anatomical literature in the early nineteenth century. Wilson, in 1845, described the inferior layer of the pelvic fascia that
“passes behind the rectum, and with the layer of the opposite side, completely invests that organ”.

Jonnesco in 1892\textsuperscript{133} published a thesis on the anatomy of the colon and rectum which formed the basis of his later descriptions of the perirectal fascia published in Poirier and Charpy’s “Traité d’Anatomie Humaine”\textsuperscript{134}. He split the sacrum in the posterior midline and noted that there was a strong fibrous layer enveloping the rectum. When this layer was opened the superior haemorrhoidal vessels and their branches were encountered. He described enucleating the rectum without damaging its surrounding envelope. He appears to be the first to have identified the fascia that encapsulates the rectum and its supporting vessels.

In 1899, Waldeyer published his classic “Das Bechen”\textsuperscript{266}. In it he made a full description of the fasciae of the pelvis. He wrote of the “fascia recti”, part of the visceral layer of the pelvic fascia that covered the rectum where it is not covered by peritoneum. He wrote that the rectal fascia starts caudally between the levator ani and the internal anal sphincter, being continuous with the arcus tendineus fascia. He stated that the rectal fascia disappeared at the level of the rectosigmoid junction by becoming thinner and breaking up into loose connective tissue lamellae.

Stoney\textsuperscript{246} dissected eight male pelves that had been hardened by formalin. He divided them in the mid-sagittal plane, removed the rectum, bladder and prostate, and described the visceral fascia that remained. He noted that both organs were clothed with a visceral fascia and identified a fusion between the parietal and visceral fasciae at the site of the junction of the 4\textsuperscript{th} and 5\textsuperscript{th} pieces of the sacrum. He and his contemporary, Cameron\textsuperscript{32}, however, included the fascia over the levators as part of the visceral fascia.

**Miles and Gabriel**

Miles, in his Lettsomian lectures based on his personal series of 587 patients with rectal cancer, appeared to recognise the importance of the fascia propria to rectal cancer surgery\textsuperscript{175}. He stated that the fascia propria of the rectum needs to be detached from the lower part of the sacrum to be removed with the resected specimen. He also described a plane of dissection anteriorly between the fascia propria and the rectovesical fascia and in the figure he published in 1926 (figure 2.1) there appears to be a clearly defined fascia propria clothing the excised specimen. From this evidence it seems likely that he was dissecting in the extrafascial plane.
Figure 2.1: Illustration of an opened rectal carcinoma specimen from Miles\textsuperscript{175}. Note the clearly identifiable fascia propria on the mesorectal surface marked by an arrow.

Gabriel, although not specifically describing the fascia propria in his dissection, shows what appears to be the fascia propria as a shiny surface on the specimen in his diagrams of dissection of the rectum (figure 2.2). His dissection would appear to have been performed in the extrafascial plane.

Figure 2.2: An illustration of the perineal dissection in rectal excision for cancer from Gabriel\textsuperscript{79}. The glistening surface of the fascia propria is shown overlying the mesorectum.
The 1940s

In the late 1940s there was considerable interest in the anatomy of the fasciae of the pelvis and several authors published on this area.

Ashley and Anson\textsuperscript{10} described the anatomy of the pelvic autonomic nerves in greater detail than had been published previously. Their descriptions were based on the serial dissection of an embalmed male pelvis with supplementary diagrams based on coronal sections of a second male specimen. They noted that the inferior hypogastric nerves were lodged in a fine areolar layer deep to the peritoneum. They described this layer as containing the hypogastric nerves and the pelvic plexus that chiefly sends branches to the rectum noting that it was superficial to the pelvic fascia. They identified deeper elements that were embedded in a heavy layer lateral to this inner pelvic plexus. They did not specifically address the relationship of these structures to the fascia propria.

Close\textsuperscript{43} “found it necessary to dissect many human pelves, to make comparative studies of many animals, and to carry out extensive research into all available literature” to gain a true understanding of the pelvic fascia. He noted that the posterior mesorectum was laden with fat and that there was very little sheath clothing the anterior aspect of the rectum. He stated that the fascia propria was carried medially by vessels and nerves from the common neuro-vascular sheath to ensheath the rectum and was reinforced from the tissue carrying the superior haemorrhoidal vessels and lymphatics posteriorly. He was the first to label the “presacral fascia”. His diagram of a sagittal hemisection of a female pelvis clearly shows a plane between the presacral fascia and the fascia propria. In his opinion the “raison d’etre” of the presacral fascia was to ensheath the hypogastric or presacral nerve plexus. He, therefore, appears to have identified a dissection plane between the fascia propria and the presacral fascia.

Tobin and Benjamin\textsuperscript{256} studied sections from 11 human foetuses and dissections of 3 third trimester foetuses and 2 newborn infants. They described Denonvilliers’ fascia in detail and noted that the rectal fascia was a separate fascia lying posterior to it and sometimes called the posterior layer of Denonvilliers’ fascia.
Uhlenhuth’s Contribution

Uhlenhuth\textsuperscript{261} in his classic paper “The visceral endopelvic fascia and the hypogastric sheath”, stated how complex the descriptions of the visceral endopelvic fasciae were and the lack of uniformity for the description of structures. His description rests mainly on the dissection of the embalmed pelvis of a 29 year old female. The pelvis was divided in the median sagittal plane and dissected in steps. His description is supplemented by dissections of other cadavers. He describes “the superior haemorrhoidal sheath, a distinct perivascular sheath differentiated out from the dorsal visceral endogastric fascia around the branches of the inferior mesenteric arteries”. He stated that as it descended behind the rectum it fused with the presacral hypogastric wing. He also stated that the visceral endopelvic fascia was disposed in the form of well-defined, strong sheet-like structures of definite location, attachment and function. These fascial sheets arising over the internal iliac artery divided the pelvis from side to side in several fascial compartments (see figure 2.3). The presacral wing of the hypogastric sheath was a two layered structure, the ventral part enveloping the rectum with a sheath and the dorsal lying posterior to it with the hypogastric nerve intimately involved in it. The retrorectal space lay between this and the more posterior parietal fascia and was contained laterally by the fusion of the presacral wing with the hypogastric sheath. Thus, according to his description, the retrorectal space lay posterior to the hypogastric nerves and their fascia.

\textbf{Figure 2.3:} An illustration of the pelvic fascial layers as described by Uhlenhuth\textsuperscript{261}. Note the layers are disposed as leaves of a book with the spine of the book situated at the internal iliac vessels.

The consequences of this changing concept of the fascial planes of the pelvis was a shift from recognising a fascia propria enveloping the rectum to an understanding that involved multiple fascial layers completely dividing the pelvis. This meant that dissection in the retrorectal space must take the surgeon out to the lateral side walls of the pelvis where the sheath-like fascia
containing the hypogastric nerves had then to be divided to continue to dissect lateral to the rectum. As we shall see, subsequent descriptions of rectal dissection highlighted this.

The Japanese Understanding

The Japanese understanding of the lymphatic and fascial anatomy is based on the pioneering work of Yoshikiyo Senba in 1927. He investigated the lymphatic drainage of the rectum in 200 foetuses and made reference to its clinical relevance. This research was applied clinically by Masaru Kuru who, in 1940, reported his results and stressed the importance of lateral lymph node dissection and high ligation of the inferior mesenteric artery in radical surgery. This work was continued by Tamaki Kajitani who outlined the well-defined dissection planes around the rectum in accordance with the anatomy of the lymphatics. The present understanding of the rectal fascial anatomy has been described by Takahashi et al who have produced a diagrammatic representation of the different extents of rectal dissection (Figure 2.4). It can be seen that the pelvic plexus is contained within the visceral fascia (or fascia propria). Rectal excision, therefore, requires developing a plane lateral to the pelvic plexus on the pelvic side wall. The pelvic plexus would then be removed if a dissection outside the visceral fascia were employed.

Figure 2.4: Schematic transection of the midrectum as described by Takahashi et al. P. Plex, pelvic nerve plexus; I. IL.A, internal iliac artery; D-F, Denonvilliers’ fascia. N1, N2, N3 indicate the different levels of lymph node dissection. Note the pelvic plexus is within the visceral fascia.

Havenga

Havenga, in association with Enker, reported on the surgical anatomy of the pelvis. Their understanding of the visceral fascia was based on his dissection of the embalmed pelves of 3
female and 3 male cadavers. The specimens were hemisected in the mid-sagittal plane and then dissected. Their description is similar to that of the Japanese with the hypogastric nerves lying anterior to the visceral fascia within the substance of the mesorectum\textsuperscript{100}. Their description identifies the visceral fascia as “a hammock suspending the mesorectum between the left and right internal iliac arteries”\textsuperscript{101}. Dissection outside this plane is clearly outside the hypogastric nerves and directs the surgeon to the pelvic side walls and the associated structures. This is illustrated in figure 2.5\textsuperscript{101}. This understanding has led to detailed descriptions of dissection of the pelvic autonomic nerves to protect them while carrying out rectal excision\textsuperscript{102, 182, 183}.

![Figure 2.5: The relation of the hypogastric nerve to the visceral fascia, parietal fascia and mesorectum according to Havenga\textsuperscript{101}.](image)

**The Mesorectum**

Heald highlighted the fact that the rectum was surrounded by a mesorectum that itself was separated from the surrounding fascia by a relatively avascular plane, which he called “the Holy Plane”\textsuperscript{104}. He argued that the plane existed because of the differing embryological origins of the rectum and mesorectum from the surrounded parietal tissues. This is illustrated in the figure 2.6. Heald, however, did not consider that the fascia propria was complete circumferentially but that there was an area of fat uncovered by fascia on the anterolateral aspect of the mesorectum (personal communication, 1999).
Figure 2.6: Illustration of a cross-section of the lower rectum showing the plane of dissection for rectal excision according to Heald. Note the lack of fascia propria in the antero-lateral aspect of the mesorectum.

Church et al., in a detailed review of the literature on pelvic anatomy, summarised the anatomy of the rectum and produced a diagram demonstrating the anatomy schematically (figure 2.7). He shows the fascia propria as surrounding the mesorectum circumferentially with the hypogastric nerves, nervi erigente, and the pelvic plexuses situated outside this fascia.
Figure 2.7: Schematic representation of a transverse section through the lower rectum according to Church et al\textsuperscript{42}. Note the fascia propria as a structure surrounding the rectum.

Helga Fritsch carried out extensive studies on the embalmed bodies of 79 human foetuses and 7 newborn children using 400 – 800 µm thick plastinated cross-sections of the pelvis\textsuperscript{74, 76}. Each section was stained to identify the connective tissue layers. She showed that the outer layer of the rectal tube in the early foetus developed into the mesorectum of later life. From her studies she redefined the anatomical compartments of the pelvis, not as transverse leaves of fascia but rather as peri-visceral compartments as shown in figure 2.8\textsuperscript{75}. 
Figure 2.8: Semischematic drawings of transverse sections through the male (a) and female (b) pelvis at the level of the peritoneal pouches. The dense connective tissue constitutes a circular or semicircular system (from Fritsch\textsuperscript{75}).

Summary

As can be seen from this brief history, the descriptions of the pelvic fasciae are blatantly conflicting. Uhlenhuth and Havenga envisage the fascial planes as septa dividing the pelvis from one internal iliac artery to the other. They and the Japanese include the hypogastric nerves inside the fascia propria. Fritsch and Church recognise fascial planes enveloping the pelvic organs whereas Heald considers the fascia propria is deficient on the antero-lateral aspect. Both Church and Heald claim the hypogastric nerves and pelvic plexuses lie outside the fascia propria. As these have particular consequences on the performance of surgery for removal of rectal cancer a clear resolution of these opposing anatomical views is urgently needed. This anatomical section will seek to do this by first considering the detailed anatomy of the fascia propria (visceral fascia) of the rectum and then by examining the relations of this fascia to the autonomic nerves of the pelvis and finally, by using a three dimensional reconstruction of the fascia propria.
Chapter 3: The Surgical Anatomy of the Fascia Propria

BACKGROUND

In the introductory chapter the evolution of rectal cancer surgery was traced from blunt perineal dissection through wide abdomino-perineal dissection to the recent recognition of the importance of removing the complete mesorectum in rectal cancer surgery in an attempt to prevent local recurrence. Extrafascial Excision of the rectum for cancer (EFE) is one such operation designed to remove the rectum within an intact mesorectum. This operation involves dissection on the fascia propria circumferentially and makes strenuous efforts to keep it intact as the rectum is mobilised. In a retrospective review of 122 rectal cancer patients in whom the rectum was removed by the technique of EFE it was found that local recurrence was exceptional if the cancer was contained within the fascia propria and an adequate distal margin had been obtained\textsuperscript{117}. This surgery is based on careful dissection along anatomical planes. As has been shown above, however, the anatomy of the fascial planes in this area is still disputed.

Because a clear understanding of the surgical anatomy of the fascia propria is essential to the performance of EFE and because of the major implications of tumour containment within it, a comprehensive study of the gross and microscopic anatomy of the fascia propria was undertaken.
PATIENTS AND METHODS

Patients

Thirteen patients having EFE of the rectum at Auckland Hospital were included in the study. The study design was approved by the Auckland Ethics Committee. Table 3.1 summarises the patient data.

Table 3.1: Patient Data

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Operation</th>
<th>Pathology</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>86</td>
<td>M</td>
<td>Ant R</td>
<td>Dukes' C Ca</td>
<td>4-Quadrant</td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>F</td>
<td>Ant R</td>
<td>Dukes' C Ca</td>
<td>4-Quadrant</td>
</tr>
<tr>
<td>3</td>
<td>74</td>
<td>M</td>
<td>Ant R</td>
<td>Dukes' B Ca</td>
<td>4-Quadrant</td>
</tr>
<tr>
<td>4</td>
<td>53</td>
<td>F</td>
<td>Ant R</td>
<td>Dukes' C Ca</td>
<td>4-Quadrant</td>
</tr>
<tr>
<td>5</td>
<td>69</td>
<td>M</td>
<td>Ant R</td>
<td>Dukes' “D” Ca</td>
<td>4-Quadrant</td>
</tr>
<tr>
<td>6</td>
<td>84</td>
<td>M</td>
<td>Ant R</td>
<td>Dukes' C Ca</td>
<td>X-Section</td>
</tr>
<tr>
<td>7</td>
<td>68</td>
<td>M</td>
<td>Ant R</td>
<td>Dukes' A Ca</td>
<td>X-Section</td>
</tr>
<tr>
<td>8</td>
<td>78</td>
<td>M</td>
<td>Ant R</td>
<td>Dukes' C Ca</td>
<td>X-Section</td>
</tr>
<tr>
<td>9</td>
<td>44</td>
<td>F</td>
<td>Ant R</td>
<td>Dukes' A Ca</td>
<td>X-Section</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>M</td>
<td>Ant R</td>
<td>UC</td>
<td>X-Section</td>
</tr>
<tr>
<td>11</td>
<td>36</td>
<td>M</td>
<td>Ant R</td>
<td>UC</td>
<td>FP-Dissection</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>F</td>
<td>APR</td>
<td>Dukes' A Ca</td>
<td>FP-Dissection</td>
</tr>
<tr>
<td>13</td>
<td>62</td>
<td>M</td>
<td>APR</td>
<td>Dukes' A Ca</td>
<td>FP-Dissection</td>
</tr>
</tbody>
</table>

Abbreviations: Ant R, anterior resection; APR, abdomino-perineal resection; Ca, carcinoma; UC, ulcerative colitis; X-section, cross-section; FP, fascia propria.
The Technique of Extrafascial Excision

After mobilisation of the sigmoid colon and its mesentery the inferior mesenteric vessels are located and separated from the superior hypogastric plexus lying on the front of the aorta. By following the posterior aspect of the superior rectal artery a shiny membrane (fascia propria) surrounding the mesorectum is encountered at the pelvic brim. The dissection proceeds directly on the fascia propria well anterior to the fascia lying on the front of the sacrum and medial to that covering the hypogastric nerves and pelvic plexuses. At the junction of the upper rectum with the horizontal rectum around the level of the fourth sacral vertebra the fascia propria may be tethered to the presacral fascia (the so-called “recto-sacral ligament“). This is divided sharply taking care to dissect along the surface of the fascia propria without straying posteriorly into the presacral fascia or anteriorly into the mesorectum. The dissection is carried forward on the fascia propria up to the ano-rectal junction. Anteriorly the peritoneum is divided just posterior to the seminal vesicles in the male and anterior to the reflection of the peritoneum in the pouch of Douglas in the female. The dissection is carried down on and in front of Denonvilliers’ fascia which is divided transversely one centimetre below the base of the prostate in the male and opposite the vault of the vagina in the female. The dissection is continued down to the pelvic floor (in tumours in the upper rectum the mesorectum is divided at least 5 cm below the distal edge of the tumour). The fascia propria surrounding the lateral aspects of the rectal tube is then identified and the tissues lateral to it, which contain the nerves passing medially from the pelvic plexus, are divided sharply paying special attention not to broach the endopelvic fascia enclosing the plexus. This completes the dissection around the entire rectum down to the pelvic floor.

Processing of Specimens

The 13 excised rectums were examined fresh at the operation room before fixation. Particular attention was paid to the presence or absence of the recto-sacral ligament, Denonvilliers’ fascia, the integrity of the fascia propria and the presence or absence of nerve plexuses on the surface or embedded within it. The rectal specimens were then processed in one of three ways: fresh dissection of the fascia propria off the mesorectum, fixation after filling the lumen with formalin for giant cross-sections of the whole rectum, or fixation after longitudinal section for four quadrant histology sections.
Fresh Dissection of the Fascia Propria

Three fresh rectal specimens were taken for circumferential dissection of the fascia propria from the underlying mesorectum. The dissection commenced by identifying the fascia propria immediately posterior to the superior rectal artery on the posterior aspect of the upper mesorectum and incising it transversely at that level. The fascia propria was then dissected sharply off the posterior mesorectum. Where the dissection met the peritoneum on the anterior and lateral aspects of the rectum the peritoneum was divided allowing the fascia propria to be dissected off the anterior and lateral mesorectum. The dissection then proceeded distally as the fascia propria was dissected off the mesorectum as a complete sleeve down to the ano-rectal junction. Each specimen was photographed. After dissection the whole specimen was fixed in 4% formalin for a minimum of 72 hours. The dissected fascia propria was then “defatted” by immersing it in a solution of chloroform and alcohol (Chloroform 66 ml, Methyl alcohol 33 ml, concentrated hydrochloric acid 1 ml and distilled water 4 ml). The fixed specimen was then photographed.

Giant Cross-Sections

Five specimens were prepared for giant cross-sections. After initial examination of the fresh rectum the surface was inked to identify the peritoneum, the fascia propria, Denonvilliers’ fascia and the rectosacral ligament. The rectum was distended with 4% formalin, its ends closed, and immersed in 4% formalin for at least 3 days. After fixation the rectum was sectioned transversely at 1 cm intervals from the ano-rectal junction to the upper rectum. These sections were defatted as above before embedding in paraffin, cutting, mounting on giant slides and staining with Haematoxylin and Eosin (H&E). These slides were used to demonstrate the transverse relations of the rectum, mesorectum, peritoneum and fascia propria. The thickness of the fascia propria was measured at 3 levels (the distal 2 cm of the rectum, 1 cm below the peritoneal reflection and 2 cm above the peritoneal reflection). At each level the thickness was measured on the anterior, posterior, right and left aspects. Two of the authors (IPB and KYC) jointly examined each section microscopically. The thickness of the fascia propria was measured as a jointly agreed proportion of a known microscopic field projected onto a video screen. In measuring the fascia propria sites immediately adjacent to tumour were avoided. Where there was variation in thickness the portion with the most consistent thickness was measured.
Four Quadrant Thickness Measurement

In the remaining 5 specimens the fasciae were inked as above then the specimen was opened on its anterior aspect, pinned out and fixed in 4% formalin for a minimum of 48 hours. Full thickness sections were then taken from the 4 quadrants of the specimen at 3 levels as above. Each section included the rectal wall, the mesorectum and the fascia propria. These sections were embedded in paraffin, cut, mounted on slides and stained with H&E. The fascia propria was measured as above.

Special Stains

Sections were taken from selected blocks at different sites around the fascia propria and stained with Masson Trichrome, and Verhoeff’s method with van Gieson counterstain (EVG) to identify collagen, smooth muscle, nerves and elastin.

Electron Microscopy

1mm cubes of tissue were taken from the fascia propria of a freshly dissected rectal specimen and placed in phosphate buffered Karnovsky's fixative. After fixation for 1 week at 4°C the specimens were rinsed in 0.1 molar phosphate buffer, post fixed in 1% buffered osmium tetroxide, dehydrated through a graded ethanol series, infiltrated and embedded in Agar 100 (Agar Scientific, UK) resin and polymerised at 60°C for 48 hours. Sections were cut on an LKB5 ultramicrotome, stained with lead citrate and uranyl acetate and viewed in an Hitachi H7000 electron microscope.

The Rectosacral Ligament

This was a separate study involving dissection of the rectosacral ligament in post-mortem subjects. Ethical approval for this study was granted by the Auckland Ethics Committee. The study included 10 adult, unembalmed cadavers who required a post-mortem. Patients who had previously undergone pelvic surgery or who had been dead more than 36 hours were excluded. Consent was obtained from relatives of the deceased. The post-mortem was initially performed by the pathologist leaving the pelvic organs intact. Dissection of the pelvis was performed immediately following the pathologist’s post-mortem. The age, sex and cause of death of those included were recorded.
An extrafascial dissection of the rectum was performed. The dissection involved operating through the midline incision that had already been performed for the post-mortem. The dissection began at the aortic bifurcation and continued directly on the fascia propria. Any attachments between the fascia propria and the parietal fascia over the sacrum were identified. The position of this attachment with respect to the sacrum was determined by palpation of the sacral segments and recorded. The transverse and longitudinal dimensions of the attachment were measured in millimetres using callipers.

**Statistical Analysis**

The measurements of fascia propria thickness on each aspect of the rectum and at each level were entered into a database. The data, which were not normally distributed, were log transformed to satisfy the assumptions of normality and homogeneity of variance. Data were analysed as a randomised block design with quadrant and level as separate factors and specimen as a blocking factor. Tukey’s Multiple Comparison Procedure was used to detect pair-wise differences with the p value set at 0.05 throughout.

**RESULTS**

**Rectal Excision**

Circumferential extrafascial total excision of the rectum was successfully completed in all 13 patients. At each operation the fascia propria immediately posterior to the superior rectal artery at the pelvic brim was identified and it was noted that the fascia continued in a cranial direction in the retroperitoneum in a plane posterior to the inferior mesenteric vessels. In 6 patients at the expected site of the recto-sacral ligament (S4) an attachment of the fascia propria to the presacral fascia was identified and this was divided sharply. Denonvilliers’ fascia was seen in all cases and was divided transversely posterior to the prostate or vaginal vault. With upward and anterior retraction the fascia propria could be dissected down to the pelvic floor as far as the ano-rectal junction.
Gross Appearance of the Intact Specimens

Figure 3.1 shows the posterior aspect of one of the resected specimens. The rectum has been divided distally at the ano-rectal junction and proximally in the distal sigmoid colon. Two sutures have been used to elevate the “recto-sacral ligament” (A) demonstrating its relationship to the fascia propria (B). There is a significant length (in this case 4cm) of fascia propria distal to the insertion of the recto-sacral ligament. A fascial attachment at the expected site of the recto-sacral ligament was identified in 6 of the 13 specimens. It was not noted either during dissection or on the specimen in the other 7. The outer surface of the fascia propria, as it surrounds the mesorectum, gives the specimen its shiny appearance. A ligature (C) has been placed around the superior rectal artery proximally where it is situated directly anterior to (or inside) the fascia (Figure 3.2).

Figure 3.1: Fresh rectal specimen after EFE. The rectosacral ligament (A) has been elevated by 2 sutures. The shiny surface of the fascia propria (B) can be seen encircling the mesorectum. The superior rectal artery (C), immediately anterior to the fascia propria, is lifted by a suture.
Figure 3.2: Photograph of the superior rectal artery and the fascia propria (13x magnification, H&E stain). The superior rectal artery (A) lies immediately anterior to the fascia propria (B) at the sacral promontory.

**Denonvilliers’ fascia**

In each case Denonvilliers’ fascia was visible on the anterior surface of the specimen. It extended inferiorly from the peritoneum to the point where it was surgically divided posterior to the prostate or vagina. A complete layer of fascia propria posterior to Denonvilliers’ fascia was identified in each of the 3 freshly dissected specimens. Smooth muscle fibres were found in Denonvilliers’ fascia in 6 of the 10 specimens undergoing histological study. In 1 patient mesothelial cysts were present in this fascia (figure 3.3).

Figure 3.3: Mesothelial cysts lying within Denonvilliers’ fascia (20x magnification, H&E stain).
The Rectosacral Ligament

Table 3.2 shows whether the rectosacral ligament was identified in each post-mortem dissection and its position and width when present.

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Rectosacral ligament present</th>
<th>Position</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>M</td>
<td>Yes</td>
<td>S4-5</td>
<td>45</td>
</tr>
<tr>
<td>85</td>
<td>M</td>
<td>Yes</td>
<td>S3-4</td>
<td>50</td>
</tr>
<tr>
<td>59</td>
<td>M</td>
<td>Yes</td>
<td>S4</td>
<td>23</td>
</tr>
<tr>
<td>67</td>
<td>M</td>
<td>Yes</td>
<td>S3-4</td>
<td>24</td>
</tr>
<tr>
<td>78</td>
<td>M</td>
<td>R only</td>
<td>S4</td>
<td>14</td>
</tr>
<tr>
<td>64</td>
<td>F</td>
<td>Yes</td>
<td>S3-4</td>
<td>30</td>
</tr>
<tr>
<td>80</td>
<td>M</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>M</td>
<td>Yes</td>
<td>S3-4</td>
<td>13</td>
</tr>
<tr>
<td>52</td>
<td>M</td>
<td>Yes</td>
<td>S2-3</td>
<td>28</td>
</tr>
<tr>
<td>58</td>
<td>M</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The rectosacral ligament was present in 8 of the 10 dissections carried out. The position varied from the second and third sacral vertebral junction to that of the fourth and fifth sacral vertebrae, the most frequent site being the junction of S3-4. When present the transverse dimension of the rectosacral ligament ranged from 13 to 50 mm with a median of 26 mm.

Dissection posterior to the attachment identified that in only 1 of the 8 subjects in whom a rectosacral ligament was present was it attached to the sacral periosteum. In the other 7 it could be dissected off the underlying sacral periosteum without difficulty.

The Nature of the Fascia Propria

Dissection of the Fascia Propria

The fascia propria was completely dissected off the fresh rectal specimen in each of the 3 cases in which this was attempted. The fascia propria was a continuous structure surrounding the rectum and mesorectum circumferentially fusing with the peritoneum where the peritoneum reflects off the rectum. Inferiorly, as the dissection approached the ano-rectal junction the mesorectum thinned out to the point where, at the junction, the fascia was intimately attached to the longitudinal muscle of the bowel and difficult to dissect off it (Figure 3.4).
Figure 3.4: Photograph of the fascia propria (A) and the rectal wall (B) at the level of the ano-rectal junction showing the fusion of the fascia propria to the outer layer of the longitudinal muscle coat.

Figure 3.5 shows that the fascia propria is a complete “sock” totally surrounding the mesorectum posteriorly, laterally and anteriorly. In figure 3.5A, the posterior view, the characteristic bi-lobed appearance of the mesorectum is demonstrated and the “sock” of the fascia propria is everted. A midline raphe (figure 3.5A) was noted in each of the freshly dissected specimens.
Figure 3.5: Photograph of the everted fascia propria and mesorectum from the recto-sigmoid to the ano-rectal junction. The fascia propria has been dissected intact off the mesorectum but kept attached at the ano-rectal junction. The fascia propria was separated from the peritoneum at the junction of the fascia with the peritoneum and then everted intact off the mesorectum. There is a midline raphe running down the posterior aspect of the mesorectum (5A) and its attachment to the inner surface of the fascia propria is clearly seen. In 5B, the anterior view, a significant thickness of fat lies anterior to the rectal wall forming the anterior mesorectum.
Figure 3.6 shows that the fascia propria encircles the mesorectum distal to the peritoneal reflection and can be dissected off a transverse section of the resected specimen as a complete ring.

Figure 3.6: A cross-section of the rectum caudal to the peritoneal reflection. The fascia propria has been dissected off the mesorectum and pinned out. It can be seen to be a complete ring encircling the mesorectum.

**Histology**

The giant cross-sections and the four quadrant biopsies from 10 patients formed the basis for the histology study. The appearance of the fascia varied from a single thin layer of 20 microns thickness to a multi-layered structure of 1,000 microns thickness. Excluding the sections where the fascia had fused with the submesothelial fibrous layer of the peritoneum the fascia was multilayered in 80% and a single layer in 20%. In the 4 specimens subjected to histology in which there was an identifiable rectosacral ligament on the specimen the fascia propria distal to the attachment of the ligament was multilayered in all 4 and had an average thickness of 245 (S.D. 194) microns. The fascia propria was also multilayered in all 6 histologically examined specimens in which a rectosacral ligament was not identified and the average thickness (203 ±S.D. 164 microns) in these specimens was not significantly different. Figure 3.7 demonstrates that at the peritoneal surface (A) anterior to the rectum the fascia propria cannot be demonstrated as a
separate entity. The fascia propria (B) fuses with the submesothelial fibrous layer of the peritoneum at the lateral borders of the recto-vesical pouch.

Figure 3.7: The fascia propria and the peritoneum (6.5x magnification, H&E stain). The peritoneum (A) of the recto-vesical pouch is shown anterior to the rectal wall. The fascia propria (B) can be seen fusing with the submesothelial fibrous layer of the peritoneum laterally.

Special Stains

Masson Trichrome confirmed the presence of smooth muscle in Denonvilliers’ fascia. In 6 of 13 EVG stained sections no elastin could be detected in the fascia propria and in the other 7 there were very sparsely scattered, isolated elastin fibres. Likewise, Denonvilliers’ fascia contained a few fibres of elastin widely scattered in dense collagen. Nerves or nerve plexuses were not seen in these sections. The main component stained in the fascia propria was collagen.
Electron Microscopy

Figure 3.8 shows that the fascia propria is made up of multiple bundles of collagen fibres.

Figure 3.8: An electron micrograph of the fascia propria (12,800x magnification). The tightly packed bundles of collagen can be seen in a background matrix.

Fascia Propria Thickness

The geometric means (±1 S.D.) of the thickness of the fascia propria at the sites of measurement are shown in Table 3.3. On the anterior, right, posterior and left aspects these were 100 (48-210), 182 (68-487), 185 (67-510) and 168 (71-400) microns respectively. The mean for all sites in the 10 specimens was 154 (61-391) microns. The fascia propria was significantly thinner anteriorly than posteriorly (Tukey’s Multiple Comparison Procedure p< 0.05) as shown in figure 3.9. There was no difference detected between the thickness on the posterior, right and left aspects of the fascia propria.
Table 3.3: Geometric Means of Thickness of the Fascia Propria in the 12 Sites of Measurement in Microns (N=10)

<table>
<thead>
<tr>
<th></th>
<th>Anterior</th>
<th>Right</th>
<th>Posterior</th>
<th>Left</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>94</td>
<td>116</td>
<td>146</td>
<td>188</td>
<td>132</td>
</tr>
<tr>
<td>Middle</td>
<td>95</td>
<td>183</td>
<td>173</td>
<td>182</td>
<td>153</td>
</tr>
<tr>
<td></td>
<td>(41-221)</td>
<td>(91-368)</td>
<td>(52-582)</td>
<td>(91-364)</td>
<td>(63-375)</td>
</tr>
<tr>
<td>High</td>
<td>112</td>
<td>284</td>
<td>250</td>
<td>139</td>
<td>183</td>
</tr>
<tr>
<td></td>
<td>(76-167)</td>
<td>(108-747)</td>
<td>(121-516)</td>
<td>(51-380)</td>
<td>(76-436)</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>182†</td>
<td>185†</td>
<td>168</td>
<td>154</td>
</tr>
<tr>
<td></td>
<td>(48-210)</td>
<td>(68-487)</td>
<td>(67-510)</td>
<td>(71-400)</td>
<td>(61-391)</td>
</tr>
</tbody>
</table>

* Interval encompasses 1 S.D. above and below the mean
† Statistically different from anterior thickness (Tukey’s Multiple Comparison Procedure p< 0.05).

Figure 3.9: The thickness of the fascia propria. The geometric mean (standard error) of the thickness of the posterior (closed circle) and anterior (open circle) aspects of the fascia propria at the high, mid and low levels of the rectum in microns are shown. The fascia propria is
significantly thicker posteriorly than anteriorly (Tukey’s Multiple Comparison Procedure p<0.05).

**DISCUSSION**

The results show that the fascia propria is a continuous structure that completely surrounds the rectum and its encircling mesorectum. At surgery it is possible to dissect along it in the extrafascial plane medial to the hypogastric nerves and the pelvic plexus. The fascia, which is mostly collagen, is of variable thickness being thicker posteriorly than anteriorly and having an average thickness of about 150 microns. Anteriorly the fascia propria lies immediately posterior to the fascia of Denonvilliers. Posteriorly it runs up behind the inferior mesenteric vessels into the retroperitoneum. Opposite the fourth sacral vertebra it may adhere to the presacral fascia and distally it fuses with the longitudinal muscle at the ano-rectal junction. It also fuses with the submesothelial fibrous layer of the peritoneum anterior and lateral to the rectum.

The measurements of the thickness of the fascia were made in formalin fixed specimens so the “in vivo” thickness of the fascia propria is likely to be somewhat thicker as the fixation may cause some shrinkage of the specimen. This should not affect the relative difference in thickness of the fascia in each specimen. In an attempt to exclude changes in fascia propria thickness due to local pathology patients with active inflammation of the rectum or preoperative radiotherapy were excluded and measurements were not taken from areas of the fascia adjacent to tumour.

There are conflicting reports in the surgical literature regarding the position and nature of the fascia propria. Adequate resection of the rectum and the mesorectum for prevention of local recurrence in rectal cancer requires an accurate understanding of its anatomy as has been highlighted by Takahashi and his colleagues. Their descriptions of the rectal fascia, however, show the inferior pelvic plexus contained within the fascia propria itself, a misunderstanding which has major implications when radical surgery is undertaken. Havenga, working with Enker et al, has described the visceral fascia of the rectum as a hammock, suspending the mesorectum between the left and right internal iliac arteries with the hypogastric nerves directly anterior to it. The fascia described by these workers is not the fascia propria which we have shown is medial to and separate from the hypogastric nerves. The fascia described by Havenga et al is therefore posterior to the fascia propria and is part of the endopelvic fascia which contains the hypogastric nerves. In a recent study of 10 patients the pelvic plexus was demonstrated to be outside the fascia propria of the rectum and nerves to the rectum pass in the lateral ligaments from this plexus across the extrafascial space to reach the mesorectum. This present study has shown that by dissecting directly on the fascia the entire mesorectum and its surrounding fascia
propria can be removed circumferentially with the rectum and its mesentery enclosed in a “sock” of fibrous fascia leaving the hypogastric nerves and the pelvic plexuses safely on the pelvic side wall.

In the course of this study of the fascia propria, observations of the nature of the rectosacral ligament have been made. It is not easily identified in all patients. When present, it is that area, opposite the fourth sacral vertebra, in which the fascia propria may be adherent to the presacral fascia. This varies from several layers of parietal fascia passing forwards and attaching to the fascia propria of the rectum as a “ligament” to a diffuse adherence between the 2 fasciae. Distal to this attachment between the fascia propria and the parietal fascia lies a space below the horizontal part of the rectum. Once the surgeon has divided this attachment the parietal fascia clothing the distal sacrum frequently appears thinner below this level and the fascia propria over the distal mesorectum appears thicker and may be composed of two distinct layers. In the separate post-mortem study of 10 subjects the rectosacral ligament was present in 8 patients and varied in position from the junction of S2-S3 to that of S4-S5 most commonly being found at the level of S3-S4. These findings are in close accord with those of Sato and Sato. It is interesting to note that in only 1 of 10 subjects was there a discernible attachment to the sacral periosteum that could be described as a “ligament”.

The anatomy of the fascia of Denonvilliers has recently been reviewed by van Ophoven and Roth and Lindsey et al. They concluded that Denonvilliers’ fascia is a single layer arising from fusion of the 2 walls of the embryologic peritoneal cul-de-sac and that a so-called posterior layer is in reality the rectal fascia propria. The present study has shown that the fascia of Denonvilliers is anterior to the fascia propria and is able to be dissected off it. Histologically it is predominantly made up of collagen but also contains smooth muscle. Unlike Richardson who found the rectovaginal septum to be made up of dense elastin we found that elastin fibres were only sparsely scattered in the fascia. The presence of mesothelial cysts in the fascia of Denonvilliers has been noted by other authors and was seen in one of the specimens in this study. This has previously been cited as evidence that Denonvilliers’ fascia is a derivative of the fusion of the 2 leaves of the recto-vesical peritoneal pouch of early foetal development.

It has previously been shown that if EFE is carried out for rectal cancer (i.e. dissection on the fascia propria as described) and the tumour is contained within the fascia propria then local recurrence is exceptional. The 3 local recurrences that did occur in that series could each be explained by a breach in the technique of extrafascial excision of the rectum. This study has shown that in specimens removed by EFE a complete fascial tube can be identified both grossly and microscopically encompassing the mesorectum. By dissecting directly on this fascia, a “safe
track” around the mesorectum is identified that removes the rectum as an intact “package” without encountering the pelvic autonomic nerves.

The following chapter will determine whether the hypogastric nerves and pelvic plexuses remain intact after EFE.
Chapter 4: The Location of the Hypogastric Nerves, the Pelvic Plexuses and their Branches to the Rectum.

Background

Having clarified the anatomy of the fascia propria, we turn to the position of the hypogastric nerves and the pelvic plexuses. These can often be seen during the operation of EFE but they have not been specifically dissected during surgery. The importance of these nerves has only become clear over the last 15-20 years. During the 1980s many authors reported the urinary and sexual complications of rectal excision\textsuperscript{13, 82, 119, 121, 140, 149, 194, 226, 274}. From these studies it became clear that urinary and sexual dysfunction were common following this surgery. In 1985 Lepor et al.\textsuperscript{151} published a study in which he identified the nerves responsible for potency and described their course in the pelvis based on serial giant sections of the pelvis of a cadaver. The 10μ thick sections were reconstructed into 3-dimensional illustrations. This was of particular importance for the performance of radical prostatectomy but also shed light on the site of injury to the nerves of potency during rectal excision. The last 10 years has seen several descriptions of surgical techniques to preserve the nerves\textsuperscript{100, 105, 160, 185}. As noted in the history section however, these authors have described the pelvic autonomic nerves as lying in different fascial planes. In particular, the relationship of the nerves to the fascia propria has profound implications on surgery for rectal cancer. Radiological identification of the position of the pelvic plexus would also allow preoperative assessment of tumour proximity to the plexuses facilitating decision making and planning of surgery.

The aims of the studies outlined in this chapter were:

1. To dissect the pelvic plexuses and hypogastric nerves to confirm their integrity after EFE.

2. To identify the length and position of the nerves passing from the pelvic plexuses to the rectum during EFE.

3. To identify the position of the pelvic plexuses in relation to a known radiological landmark.
4. To clarify the site of the hypogastric nerves in the retrorectal fascial planes.

**Methods**

Ethical approval for this study was granted by the Auckland Ethics Committee. The study included 10 adult, unembalmed cadavers who required a post-mortem. Patients who had previously undergone pelvic surgery or who had been dead more than 36 hours were excluded. Consent was obtained from relatives of the deceased. The post-mortem was initially performed by the pathologist leaving the pelvic organs intact. Dissection of the pelvis was performed immediately following the pathologist’s post-mortem. The age, sex and cause of death of those included were recorded.

**Study 1: The rectal branches of the pelvic plexus**

In this study the “lateral ligaments” refer to the condensation of connective tissue encountered on the anterolateral aspect of the dissection in the extrafascial plane below the peritoneal reflection. They contain the autonomic nerves passing to the rectum from the pelvic plexuses. An extrafascial dissection of the rectum was performed as has been described in chapter 2. The dissection involved operating through the midline incision that had already been performed for the post-mortem. The dissection began at the aortic bifurcation and continued directly on the fascia propria. The extrafascial dissection was continued up to the “lateral ligaments” of the rectum. Mobilization of the rectum anterior to these attachments was then carried out. The length of the nerves from their exit from the pelvic plexus on the parietal fascia to the point of their entry into the fascia propria after mobilization of the rectum was measured in millimetres using callipers. The position of the uppermost nerve fibres in the “lateral ligament” was then determined in relation to the lateral peritoneal reflection, and a plane through the tip of the greater trochanter. The distance from the most superior nerve to the peritoneum on the lateral side of the rectum was measured in millimetres using callipers (see figure 4.1). The greater trochanter was then palpated through the skin on each side and a Kirschner wire inserted transversely immediately above it until the point was visible in the pelvic cavity. The distance in millimetres from the tip of the wire to the uppermost nerve of the “lateral ligament” was measured on each side.
**Figure 4.1**: A photograph showing the right lateral ligament during dissection of the rectum. The distance from the peritoneum to the upper nerve fibres in the lateral ligament is identified by an arrow. Adapted from Rutegard et al\textsuperscript{222}.

**Study 2: The pelvic plexuses**

The pelvic plexuses were identified on the pelvic sidewall after extrafascial excision of the rectum. Using a calliper the vertical and horizontal dimensions of the plexuses were measured in millimetres and recorded. Radio-opaque skin staples were attached to the upper, lower, anterior and posterior borders of the pelvic plexuses. An AP X-ray of the pelvis was performed to demonstrate the position of the pelvic plexuses in the bony skeleton. The midpoint of the pelvic plexuses were plotted on the X-rays by finding the point of transection of lines drawn through the skin staples. A line was then drawn joining the upper surface of the acetabulum on both sides. The distance from the midpoint of the pelvic plexus to the upper acetabular line was then measured for each side on the X-ray films.

**Study 3: The fascial planes**

After the removal of the rectum and measurement of the pelvic plexuses the parietal fascia enveloping the superior hypogastric plexus immediately anterior to the aortic bifurcation was dissected off the underlying vessels. This dissection was continued down anterior to the sacrum and around to the lateral walls of the true pelvis. For each dissection the following details were recorded; the position of the hypogastric nerves and pelvic plexuses in relation to the parietal fascia dissected, the presence of a further layer of “presacral” fascia posterior to the dissected fascia, and the presence of any parietal fascia distal to the recto-sacral ligament. The size and
position of the pelvic splanchnic nerves as they pass forward from S3, S4 were not recorded in this study.

The data were then analysed using mean and standard deviation for continuous, numerical measurements and percentages for the categorical descriptions of position.

Results

Subjects

The subjects consisted of 10 unembalmed cadavers, 9 male and 1 female aged 52 - 85 years.

Nerve preservation

In all 10 subjects the right and left hypogastric nerves and pelvic plexuses remained in the pelvis embedded in a layer of the parietal fascia after EFE. Figure 4.2 shows an extrafascial dissection with the hypogastric nerves and pelvic plexuses preserved. Figures 4.3 and 4.4 show the right and left pelvic plexuses respectively.

Figure 4.2: Photograph of the hypogastric nerves (A) and pelvic plexuses (B) after extrafascial dissection. The rectum and mesorectum are retracted anteriorly to the right of the picture.
Figure 4.3: The right pelvic side wall after extrafascial dissection. The right hypogastric nerve (A) can be seen passing from the sacrum to the pelvic plexus (B) lateral to the rectum.

Figure 4.4: The left pelvic side wall after extrafascial dissection. The left hypogastric nerve (A) can be seen passing from the sacrum to the partially dissected pelvic plexus (B) lateral to the rectum.
Study 1: The rectal branches of the pelvic plexus

The length and position of the nerves to the rectum from the pelvic plexus in relation to the peritoneum and the tip of the Kirschner wires (pins) after mobilisation of the rectum in the extrafascial plane are shown in table 4.1.

Table 4.1: Length and position of the rectal branches of the pelvic plexuses

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Right nerves</th>
<th>Left nerves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Length (mm)</td>
<td>distance below peritoneum (mm)</td>
</tr>
<tr>
<td>71</td>
<td>M</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>85</td>
<td>M</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>59</td>
<td>M</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>67</td>
<td>M</td>
<td>12</td>
<td>32</td>
</tr>
<tr>
<td>78</td>
<td>M</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>64</td>
<td>F</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>80</td>
<td>M</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>74</td>
<td>M</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>52</td>
<td>M</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>58</td>
<td>M</td>
<td>16</td>
<td>17</td>
</tr>
</tbody>
</table>

The mean (SD) of the lengths of the right and left nerves to the rectum from the pelvic plexuses were 13.7 (4.7) mm and 12.4 (4.0) mm respectively. The mean (SD) of the distance from the lateral peritoneum to the uppermost nerves on the right and left was 18.7 (7.1) mm and 19.3 (5.1) mm respectively. In one patient it was not possible to insert the pins through the iliac bone above the greater trochanter as the bone was extremely dense and the pin bent on attempted insertion. The mean (SD) distances to the tip of the pin in the remaining 9 patients was 27.3 (12.1) mm and 38.9 (8.2) mm for the right and left nerves respectively. Although the pin was inserted immediately above the greater trochanter the tip of the pin deviated markedly from the line joining the greater trochanter on each side (see figure 4.5) and limited the use of this measurement in localising the rectal branches of the pelvic plexuses.
Figure 4.5: An AP X-ray of the pelvis after insertion of Kirschner wires above the greater trochanter on both sides. The pelvic plexuses have also been marked with skin staples. Note the deviation of the wires from the strictly horizontal plane making their use in localization of the plexuses unreliable.

Study 2: The pelvic plexuses

The size of the right and left pelvic plexuses measured in millimetres after excision of the rectum are shown in table 4.2.

Table 4.2: Dimensions of the pelvic plexuses in mm.

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Right PP height</th>
<th>Right PP width</th>
<th>Left PP height</th>
<th>Left PP width</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>M</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>45</td>
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<tr>
<td>67</td>
<td>M</td>
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<td>35</td>
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<tr>
<td>78</td>
<td>M</td>
<td>26</td>
<td>32</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>64</td>
<td>F</td>
<td>30</td>
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<td>31</td>
<td>22</td>
</tr>
<tr>
<td>80</td>
<td>M</td>
<td>31</td>
<td>34</td>
<td>29</td>
<td>37</td>
</tr>
<tr>
<td>74</td>
<td>M</td>
<td>23</td>
<td>31</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>52</td>
<td>M</td>
<td>34</td>
<td>28</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>58</td>
<td>M</td>
<td>30</td>
<td>30</td>
<td>33</td>
<td>35</td>
</tr>
</tbody>
</table>

PP, pelvic plexus

In the 8 subjects in whom the pelvic plexuses were measured the vertical dimensions, mean (SD), were 28.6 (5.2) mm and 29.8 (3.6) mm and horizontal dimensions were 32.8 (3.7) mm and 32.4 (7.6) mm for right and left sides respectively.
**Figure 4.6** shows an X-ray of the pelvis of one of the patients with the pelvic plexuses marked with staples. In the 7 patients in whom it was marked, the mean (SD) distance to midpoint of the pelvic plexus below a line drawn joining the superior border of the acetabulum on each side was 4.6 (15.0) mm and 6.4 (12.1) mm for the right and left sides respectively.

**Figure 4.6**: An AP X-ray of the pelvis in which the pelvic plexuses have been marked with skin staples. A dotted line joins the superior border of the acetabulum on both sides and the position of the midpoint of the left pelvic plexus in relation to this has been measured (double-headed arrow).

**Study 3: The fascial planes**

The parietal fascia was still present distal to the rectosacral ligament after dissection of the rectum in the extrafascial plane in all 10 subjects but was noted to be very thin in one.

After dissection of the hypogastric nerves with their enclosing fascia off the underlying structures there was still discernable presacral fascia present posterior to the nerves in seven of the ten subjects but in 2 of these it was very thin. The commonest arrangement of the fascial planes in the retrorectal area above the recto-sacral attachment is shown in **Figure 4.7**.
Figure 4.7: The conceptualised arrangement of the fascial planes in the retrorectal area. The fascia propria is separated from the parietal fascia by a plane of loose areolar tissue. The parietal fascia contains several layers and encloses the hypogastric nerves. There is often a further loose areolar plane posterior to the hypogastric nerves and anterior to a further leaf of the parietal presacral fascia. The presacral veins are immediately posterior to this leaf of fascia and anterior to the sacral periosteum. This arrangement was present in 7 of the 10 dissections. In the other 3 dissections the parietal fascia containing the hypogastric nerves lay immediately anterior to the presacral veins without a further layer of parietal fascia intervening between them. The pelvic splanchnic nerves are not shown in this figure.

Discussion

These dissections have shown that following EFE the hypogastric nerves remain undisturbed in the parietal fascia of the pelvis. The nerves from the pelvic plexus to the rectum can be mobilised to a length of 10-15 mm by dissecting in the extrafascial plane and they are found about 2cm below the point where the peritoneum reflects lateral to the rectum. The pelvic plexuses are about 30 by 30 mm in size and are encountered in the parietal fascia centred about 5 mm below a line joining the upper surface of the two acetabula. In the retrorectal area there is a loose areolar layer between the fascia propria and that layer of the parietal fascia containing the hypogastric nerves. In the majority of subjects there was a further loose areolar layer posterior to the hypogastric nerves within the parietal fascial layers.

The lateral ligaments of the rectum have recently been shown to be composed of the nerves running to the rectum from the pelvic plexus ensheathed in a loose bundle of collagen fibres\textsuperscript{222}. Sato\textsuperscript{227} included the whole of the pelvic plexus and the middle rectal vessels as part of the lateral ligaments but others\textsuperscript{29, 42} recognise the lateral ligament as lying medial to the pelvic plexus. The
surgical importance of the lateral ligaments relates to the fact that medial traction on the rectum can “tent” the pelvic plexus and allow it to be damaged during rectal excision\textsuperscript{190}. Dissection in the extrafascial plane both anterior and posterior to the nerves allows a 10-15mm portion of these nerves to be exposed. This can be safely divided without damage to the pelvic plexus.

Yamakoshi et al\textsuperscript{287} have carried out en bloc dissections of the pelvic organs in cadavers and then performed transverse sections at 10mm intervals to identify the distance from the rectal wall to the pelvic plexuses. They found that in surgical specimens removed for rectal cancer the mean distance to the pelvic plexus from the rectal muscularis propria was $14.7 \pm 4.5$mm. This short distance, they argued, mitigated against preserving the pelvic plexus during rectal excision. They did not, however, dissect the planes between the pelvic plexus and the rectum to identify whether there was a safe dissection plane inside the pelvic plexus. Our approach differed from this in that we developed the extrafascial plane before measuring the nerves passing to the rectum from the pelvic plexuses.

The dimensions of the pelvic plexus were described as 2 by 3 by 1 cm by Ashley\textsuperscript{10} and 25-30mm in height and 40mm in length by Sato\textsuperscript{228}. The mean size in our dissections was 29mm vertically and 32mm horizontally, comparable with these authors. The thickness of the plexus was not measured in the present study.

Although the position of the lumbosacral plexus has been described on cross-sectional imaging\textsuperscript{251}, the position of the pelvic plexus on such imaging has not been previously reported. Walsh\textsuperscript{151} described the anatomy of the nerves from the pelvic plexus to the corpora cavernosa based on histological cross-sections of the pelvis. He demonstrated the position of the pelvic plexuses on these sections. This present study’s identification of the associated bony landmarks opens the way for assessment of the spread of rectal cancer in relation to the pelvic plexus using preoperative cross-sectional imaging. This would provide more preoperative information to aid in the planning of surgery.

The identification of multiple layers in the parietal fascia with the presence of intervening loose areolar tissue illuminates the underlying reason for differing anatomical descriptions. It is possible to dissect outside the hypogastric nerves in a separate layer of the parietal fascia while considering that the plane is the “holy plane” between the visceral and parietal fascia. This will lead to inadvertent removal of the hypogastric nerves with associated ejaculatory dysfunction in men. It also risks the severe complication of bleeding from the venous plexuses in the presacral area in those patients in whom there is no further layer of the parietal fascia posterior to the hypogastric nerves (as was the case in 3 of the 10 subjects in the present study).
The findings of this study confirm that EFE removes the rectum and mesorectum without damage to the hypogastric nerves or pelvic plexuses. The anatomy of the retrorectal fasciae in relation to the hypogastric nerves has been described explaining the ease with which the wrong plane can be entered posterior to the mesorectum. The study also offers clarification of the site and dimensions of the nerves passing from the pelvic plexuses to the rectum in the lateral ligaments. Preoperative identification of the position of the pelvic plexuses is made possible. This opens the way for the clinician to assess the proximity of the tumour to the pelvic plexuses on preoperative axial imaging. Such information would assist in surgical planning and allow more accurate patient counselling before surgery.
Chapter 5: Three-Dimensional Anatomy of the Fascia Propria of the Rectum

Background

Cross-sectional diagrams can give an approximation of the surgical anatomy but do not accurately depict the in situ shape and contours of the rectum and mesorectum. The resected rectum appears to be a tapering cylindrical tube, before excision however, the rectum and mesorectum conform to the surfaces of the surrounding structures. Safe and accurate dissection of the rectum requires precise dissection between the fascia propria and the surrounding structures. This chapter uses images of cross-sectional anatomy to develop illustrations of the fascia propria in three-dimensions.

Methods

Study 1: Reconstruction using the Visible Human Data set

A license agreement to use the Visible Human Data Set was obtained from the National Library of Medicine, Bethesda, Maryland, USA. This data set consists of digitised images of photographs taken of cross-sections of gross anatomy. The sections were produced from a cadaver that had been preserved by freezing and sectioned at 1mm intervals. The pelvic axial anatomy sections from the level of the third part of the sacrum to the pelvic floor (images numbered 1830-1915) were loaded on to a personal computer. The position of the fascia propria (as had been confirmed by the MR and dissection experiment chapter 8) was outlined on each of 85 sequential images using the program “Paint Shop Pro” (Jasc Software incorporated, 11011 Smetana Road, Minnetoka, MN 55343, USA). The area inside the fascia propria was filled with a uniform colour that did not appear in any of the sections. Each of the sections with the fascia propria and mesorectum outlined was loaded on to an “Onyx” workstation (Silicone Graphics Computer Systems, SGI, 1600 Amphitheatre Parkway, Mountain View, CA 94043, USA).
Using a “contouring” program with the “turtle algorithm”, the outer edge of the fascia propria marked on each individual image was identified as a black line. The consecutive sections were then formed into a video clip that showed the position of the fascia propria at the different levels of the rectum.

To create a three-dimensional model of the mesorectum a program that “blocked out” all those points outside the marked area on the individual section images was used. These “blocked out” images were then entered into a volume-rendering program, “Voxel-View” (Vital Images, Inc. 505N, 4th Street, Fairfield, IA 52556, USA). Volume rendering algorithms are capable of revealing internal structures that would normally be hidden or omitted when using traditional surface rendering techniques. These algorithms work directly on the actual sample values, creating translucent renderings of the full data set. This program then produced a three-dimensional image that could be viewed at any angle and was recorded as a video clip.

**Study 2: Reconstruction of an MRI of the rectum**

The images used in study 2 for reconstruction were obtained from a preoperative MRI of the rectum of a patient with rectal cancer. The patient was a 51 year old male with a locally advanced rectal cancer who had undergone 5 weeks of preoperative radiotherapy. The MRI was performed using a Siemens Vision 1.5 Tesla machine with a phased array body coil. The images were obtained in the axial plane at 1mm thickness with T2 weighting over a distance of 100mm. Each image was converted to a “.tif” format and loaded into a personal computer.

As outlined in study 1 the fascia propria was marked on each image and the individual images were loaded onto the “Onyx” workstation (Silicone Graphics Computer Systems, SGI, 1600 Amphitheatre Parkway, Mountain View, CA 94043, USA). The same steps as outlined in study 1 were employed to create a 3-dimensional reconstruction of the rectal MR images.
Results

Study 1: Reconstruction using the Visible Human Data set

Figure 5.1 is a cross sectional image of the pelvis from the Visible Human Data Set showing the rectum at the level of the seminal vesicles. In figure 5.2 the fascia propria and the enclosed rectum and mesorectum have been manually coloured for identification by the computer program. Figure 5.3 is an image with the position of the fascia propria shown in black. Figure 5.4 is an image that only includes the rectum, mesorectum and fascia propria for entry into the volume-rendering program.
Figures 5.5, 5.6, and 5.7 show the reconstructed three-dimensional model from the posterior, lateral and anterior aspects respectively. Although after excision the tube of rectum, mesorectum and fascia propria appear as a cylinder that tapers down at the pelvic floor, before dissection it takes the shape of the surrounding structures in the pelvis. It can be seen that the fascia propria tube angles sharply forward at the level of S4, S5.
Study 2: Reconstruction of an MRI of the rectum

Figure 5.8 is a T2 weighted axial scan of the pelvis from the MRI of the study patient showing the rectum at the level of the seminal vesicles. In figure 5.9 the fascia propria and the enclosed rectum and mesorectum have been manually coloured for identification by the computer program. Figure 5.10 is an image with the position of the fascia propria shown in black. Figure 5.11 is an image that only includes the rectum, mesorectum and fascia propria for entry into the volume-rendering program.
Figures 5.12, 5.13, and 5.14 show the reconstructed 3-dimensional model of the rectal MRI from the posterior, lateral and anterior aspects respectively. It can be seen in this post-radiotherapy MRI that the angulation at the junction of the vertical and horizontal rectum is less marked than that of the anatomy model. The model can then be sectioned at any plane to demonstrate the tumour and its relation to the fascia propria as shown in the sagittal section (figure 5.15). The thickened bowel wall caused by circumferential tumour infiltration is clearly seen.
Further details of the three-dimensional study can be seen in the Compact Disc in the inside cover of this manuscript. It contains a video clip that demonstrates the position of the fascia propria around the mesorectum in sequential sections passing from the upper rectum to the anorectal junction and back again in the Visible Human images. The three-dimensional reconstruction of the fascia propria tube is then shown initially from above and then as it rotates through 270°. A similar view of the MRI model is also included.

**Discussion**

This study has taken cross-sectional anatomy and MR images and outlined the fascia propria on each 1mm image then reconstructed the mesorectum and surrounding fascia propria to demonstrate the three-dimensional anatomy of these structures. This offers the surgeon the ability to identify the spatial relationship of the tumour to the fascia propria and also visualise the dissection plane required for extrafascial excision of the rectum. When used in conjunction with the findings of chapter 4, it allows the surgeon to assess the proximity of the tumour to the pelvic plexus preoperatively. Computer generated models of the fascia propria, mesorectum and rectum can then be manipulated on the screen to allow visualisation from any angle and sectioning in any plane. Examples of this are illustrated in figures 5.16 and 5.17 illustrating coronal and axial sections. The size, shape and position of the tumour could also be accurately determined preoperatively for either surgical or radiotherapy planning. At present, 3-dimensional reconstruction of MR images is not practical for all patients as the outlining of the fascia propria manually on each individual image is too time consuming. This technique would become feasible for routine use if a computer program that automatically outlined the fascia propria could be produced.
**Figure 5.15**: Coronal section of the three-dimensional model of the MR of the rectum, mesorectum and fasica propria showing extension of the tumour into the mesorectal fat.

**Figure 5.16**: Axial section of the three-dimensional MR model showing the tumour extending in tongues into the mesorectal fat but not reaching the fascia propria.
Section 2: The Radiological Basis of Extrafascial Excision of the Rectum for Cancer
Chapter 6: An Introduction to Radiological Assessment of Rectal Cancer

Introduction

In Chapter 3 we have shown that the rectum and mesorectum are completely surrounded by a 150 µm thick, collagen fascia. This fascia propria extends superiorly from the anorectal junction to fuse with the peritoneum anteriorly and enter the retroperitoneum posteriorly. It can be separated from the more peripheral parietal fascia that contains the hypogastric nerves and pelvic plexuses embedded in it as we demonstrated in the post-mortem dissections in chapter 4. The three dimensional anatomy of the fascia propria was illustrated in chapter 5.

We now turn to the preoperative radiological assessment of rectal cancer. The purpose of radiological assessment is to select the most appropriate treatment for each rectal cancer patient. Broadly speaking, these treatments include; local excision, surgery alone, and surgery combined with adjuvant radiotherapy or chemoradiotherapy. The treatment of the primary tumour is aimed at eradication of the tumour from the pelvis and prevention of local recurrence. Although the exact cause of local recurrence in individual cases may be unclear, local recurrence occurs when residual viable tumour cells are left in the pelvis after excision of the primary cancer. Several factors have been shown to increase local recurrence rates. These include the stage of the tumour, the height of the tumour above the anal verge, the grade of the tumour, and the circumferential and distal margins of the resected specimen. To date the preoperative radiological assessment of rectal cancer has concentrated on predicting the stage of the tumour rather than the likelihood of an involved circumferential margin.

To understand the role of preoperative assessment of rectal cancer we must first consider the staging of rectal cancer and its relation to radiotherapy in the present management of this disease.
Pathological Staging

Dukes\textsuperscript{60} proposed a system for staging rectal cancer that is still the basis of most pathological staging systems today. He classified rectal cancers according to their extent of spread. Stage A tumours had “growth limited to wall of rectum”, stage B tumours had “extension of growth to extrarectal tissues but no metastases in regional lymph nodes”, and stage C had “metastases in regional lymph nodes”. Many refinements of this system have been produced including Astler-Coller\textsuperscript{11} and ACPS\textsuperscript{50}. The TNM classification uses the extent of invasion of the tumour through the bowel wall (T), the amount of nodal involvement of the lymph nodes with tumour (N), and the presence or absence of metastases (M) in classifying the cancer (Table \ref{Table 6.1}). These staging systems have been shown to correlate with the prognosis of the patient\textsuperscript{293}.

\begin{table}[h]
\centering
\begin{tabular}{ll}
\hline
\textbf{T – Primary Tumour} & \\
TX & Primary tumour cannot be assessed \\
T0 & No evidence of primary tumour \\
T1 & Tumour invades submucosa \\
T2 & Tumour invades muscularis mucosa \\
T3 & Tumour invades through muscularis propria into subserosa or pericolic/perirectal tissues \\
T4 & Tumour directly invades other structures or perforates visceral peritoneum \\
\hline
\textbf{N – Regional lymph nodes} & \\
NX & Regional lymph nodes cannot be assessed \\
N0 & No regional lymph node metastasis \\
N1 & Metastasis in one to three pericolic or perirectal lymph nodes \\
N2 & Metastasis in four of more pericolic or perirectal lymph nodes \\
N3 & Metastasis in any lymph node along the course of a named vascular trunk and/or metastasis to apical node(s) \\
\hline
\textbf{M – Distant metastasis} & \\
MX & Presence of distant metastasis cannot be assessed \\
M0 & No distant metastasis \\
M1 & Distant metastasis \\
\hline
\textbf{R – Residual tumour} & \\
RX & Presence of residual tumour cannot be assessed \\
R0 & No residual tumour \\
R1 & Microscopic residual tumour \\
R2 & Macroscopic residual tumour \\
\hline
\end{tabular}
\caption{TNM system\textsuperscript{112}}
\end{table}

Adjuvant Radiotherapy

In 1990 the NIH consensus conference\textsuperscript{200} released a consensus statement regarding the use of adjuvant therapy in colorectal cancer. Based on several randomised controlled trials\textsuperscript{73, 81, 146} they recommended, among other things, that patients with Dukes’ B and C rectal cancers receive postoperative radiotherapy to reduce the incidence of local recurrence. The evidence available at that time indicated that radiotherapy reduced the local recurrence rate by about 30%. This treatment was, however, associated with significant side effects, more than 40% experiencing short-term reactions and 6.7% having severe delayed reactions\textsuperscript{146}. 

65
In an attempt to reduce the incidence of side effects from postoperative radiotherapy there has been a trend to the use of preoperative radiotherapy. Although there is ample evidence from a meta-analysis involving 18 trials and 4000 patients that preoperative radiotherapy reduces local recurrence with at least the same benefit as postoperative radiotherapy\textsuperscript{69}, there has only been one randomised controlled trial directly comparing pre- and postoperative radiotherapy\textsuperscript{77}. This study included 471 patients randomised to preoperative short-term irradiation (25.5 Gy in one week) for all patients or prolonged postoperative irradiation (60 Gy over 7-8 weeks) only for patients with Dukes’ B and C tumours. It showed a significant reduction in the local recurrence rate at 5 years in the preoperative group and an increased small bowel obstruction rate in the postoperative group, but the radiation dose was higher in the postoperative radiation group.

Preoperative radiotherapy, however, must be given before the definitive pathological staging is available. In the above trials it was, therefore, given to all rectal cancer patients rather than just those with Dukes’ B and C tumours. The challenge has been to accurately predict the pathological stage during preoperative assessment. This would not only allow the selective use of preoperative radiotherapy, but also may identify patients with tumours confined to the rectal submucosa that would be suitable for local excision rather than anterior resection of the rectum\textsuperscript{36, 269}. This preoperative staging may be based on clinical or radiological findings.

**Clinical Staging**

In 1976 York Mason proposed the first clinical staging system for preoperative assessment of rectal cancer\textsuperscript{289}. He divided tumours into 4 groups based on digital rectal examination, as shown in Table 6.2.

<table>
<thead>
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<th>Table 6.2: York Mason clinical staging</th>
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<tbody>
<tr>
<td>CS I</td>
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<td>CS III</td>
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<tr>
<td>CS IV</td>
</tr>
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</table>

These four stages were refined by Nicholls and York Mason\textsuperscript{197} and in the series that they produced consultants had an accuracy that varied from 67-83%. Others using the same clinical assessment have been less accurate\textsuperscript{23, 277}. Digital examination, however, only allows assessment of tumours in the lower rectum and the degree of fixity noted may be related to inflammation rather than direct tumour spread\textsuperscript{61}. 66
Radiological Staging

Three main “radiological” modalities are used in preoperative staging of rectal cancer: computerized tomography (CT), endorectal sonography (ES) and magnetic resonance (MR) imaging. CT was the first modality developed and it was useful in demonstrating advanced disease and distant metastases, but less useful in determining the degree of tumour extension through the bowel wall and local lymph node metastases. With the development of ES, the extent of tumour invasion and perirectal lymph node metastases can be evaluated, although neither liver metastases nor distant nodal involvement can be assessed. MR is a relatively new development and it can be used to assess wall penetration, perirectal nodal involvement and distant metastases.

Although a recent review has described the different modalities in the preoperative staging of rectal cancer, there has been no recent systematic review evaluating CT, ES and MR quantitatively. Furthermore, many original series had small sample sizes and lacked statistical power. Chapter 7 contains a systematic review which examines and compares the values of these modalities in the preoperative staging of rectal cancer. In this review, the ability of these modalities to assess local tumour invasion and perirectal nodal involvement, but not distant metastases is considered. It should be noted that none of the papers reviewed considered the ability of preoperative radiological assessment to predict whether an adequate circumferential margin would be achieved by surgery.

The Fascia Propria in Preoperative Assessment

A recent study has shown that if the rectal cancer is contained within the mesorectum (i.e. inside the rectal fascia propria) and an extrafascial excision (EFE) is performed then local recurrence will be exceptional. Patients whose tumour invades through the fascia propria are, however, still at high risk of local recurrence although they are also likely to develop distant disease. If patients whose tumour is contained within the fascia propria could be identified preoperatively they could be selected for EFE without radiotherapy.

A “perirectal fascia” was identified on preoperative CT scans by Grabbe in 1983 and he proposed that involvement of this fascia rendered the tumour irresectable. Only a single pilot study has explored the use of this fascia in preoperative assessment. In this retrospective report of 51 patients the local recurrence rate was much higher in the 14 patients in whom the tumour appeared to be attached to or extending beyond the perirectal fascia on CT. A recent study using
thin-section MR imaging for rectal cancer staging identified the “mesorectal fascia” in each of 28 patients. If it were shown that this plane was the fascia propria of the rectum and that preoperative MR imaging could accurately predict the relation of the deepest invasion of the cancer to the fascia propria then it would be possible to select patients with rectal cancer for whom EFE without adjuvant radiotherapy was appropriate.

Chapter 8 describes a series of experiments performed to determine the relationship of the CT and MR visualised “perirectal fascia” to the surgical fascia propria. This involves extrafascial dissection and serial MR and CT imaging of a formalin fixed cadaver. A series of preoperative MR and CT images from rectal cancer patients is also reviewed to determine the visibility of the “perirectal fascia” at different levels of the rectum.

In Chapter 9 a new method of preoperative assessment for rectal cancer is presented based on the findings of Chapter 8. This involves determining the relation of the deepest invasion of the cancer to the fascia propria on preoperative MR images and comparing this with the histopathological results after EFE.

Summary

Section 2, therefore, begins with a review of the present approach to preoperative radiological assessment of rectal cancer based on staging. This is followed by a study to determine whether preoperative CT and MRI can identify the rectal fascia propria. The final section introduces a new method of preoperative assessment of rectal cancer based on its relationship to the fascia propria.
Chapter 7: A Systematic Review of Preoperative Staging of Rectal Cancer

Aim

This systematic review aims to assess and compare the ability of Computerised Tomography (CT), Endorectal Sonography (ES), and Magnetic Resonance imaging (MR) in predicting the pathological stage of rectal cancer preoperatively.

Methods

Selection of Papers

A Medline-based search was undertaken for papers published in English between January 1980 and November 1998 reporting results of using of CT, ES and/or MR in the preoperative staging of rectal cancer. The list of papers was supplemented by extensive cross-checking of citation lists. A set of criteria defined prospectively was used to select studies for inclusion in the analysis. Studies were included if they presented (1) pathological staging of rectal cancer as a gold standard; (2) a minimum of 20 patients in the whole study; (3) sufficient raw data to allow data extraction and (4) original data. Reviews, comments and editorials where no new data was presented were excluded from analysis. When data was presented in more than one article, only the latest was included. If the inclusion criteria were met by only a subset of the results in an article, only that subset was included for analysis. Papers containing internal inconsistency were excluded. All articles were evaluated independently by two of the authors (HK, IPB), and any disagreements were resolved by consensus. Excluded articles, together with the reason for exclusion, were recorded.
**Definition of Terms**

Disease stage was described in terms of wall penetration and nodal involvement. Wall penetration was classified as “through wall” (i.e. invading through the muscularis propria) or “not through wall” and, where possible, according to the T component of the TNM system. Patients staged by other staging systems (Dukes, Astler-Coller, ACPS, Thoeni CT scale) were reclassified according to the conversion matrix established by the 1990 World Congress of Gastroenterology Working Party on Clinicopathological Staging.

Nodal involvement was recorded as either “positive” or “negative”. The imaging criteria determining “positive nodal involvement” varied between studies. In the present study, no attempts were made to standardise these and the criteria used were noted as they were reported. Where a study described only one of these aspects, only the relevant section was recorded.

For studies examining more than one modality, the results for each modality were entered separately. The study type (prospective/retrospective), years of publication and investigation, patient demographics (age, gender mix), details of examination technique, examiner blinding, tumour factors (advanced tumour, low rectal tumour, mobile tumour) and the use of radiotherapy (none, before test, between test and surgery, mixed regime) were recorded for each study.

**Analysis**

Data extracted from each paper were entered on a standard form and then transferred to a computerised database. The data extracted were checked by a second reviewer for accuracy. Tables comparing radiological and pathological staging results were constructed for wall penetration and nodal involvement for each modality. Accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR) and negative likelihood ratio (NLR) of the radiological examination in assessing bowel wall penetration and nodal status were determined. Positive and negative likelihood ratios are measures characterising how effective a diagnostic test is in determining the presence (PLR) or absence (NLR) of a disease and they allow the determination of the post-test probability by rapidly using a simple nomogram. The importance of these different values in assessing a diagnostic test has been described elsewhere.

For T stage results, accuracy, percentage under-staged and percentage over-staged were calculated.

Due to the diversity of the included studies descriptive analysis, but not statistical analysis, was used to summarise the data. For clarity, data obtained by combining patients from different papers has been prefixed as “pooled”.

70
Results

Characteristics of Included Studies

A total of 275 papers were identified by Medline and cross-checking of citation lists. Eighty-six papers were excluded because they had an irrelevant topic or focus. Forty papers were excluded because the number of patients in the whole study was less than 20. Fifteen papers were excluded because the presented data was insufficient to allow the comparison of radiological and pathological staging results. Twenty papers were excluded because the data were repeated in subsequent papers. Thirty-six reviews, which presented no new data, were also excluded. (A list of excluded papers is available from the authors). Seventy-eight papers were thus included in the final analysis. This represented 83 studies, as 5 papers included two separate studies. Of these studies, 21 used a prospective design, 15 stated the blinding technique used; none were randomised. Twelve studies excluded patients who received radiotherapy, whereas 9 studies explicitly included patients who had had radiotherapy.

The 83 included studies reported data on 4,897 patients. Some of these patients were subject to examination by a combination of CT, ES and MR, while some received either wall penetration or nodal status assessment. Overall, the numbers of patients receiving preoperative staging by CT, ES and MR were 1,429, 3,640 and 665 respectively.

Wall Penetration

The application of CT in the preoperative assessment of local tumour penetration was examined in 23 studies (from 22 papers), which included a total of 1,395 patients (Appendix A Table A.1). Of these, 1,116 patients met the inclusion criteria and were included in the analysis. The pooled sensitivity, specificity and accuracy were 78%, 63% and 73% respectively. There were only four studies that classified wall penetration according to TNM notation. These four studies included 135 patients, of which 80% were correctly staged, 13% were over-staged and 7% were understaged (Table 7.1 a, b).
Table 7.1a: Pooled results of detection of bowel wall penetration

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Table 7.1b: Pooled results of T-staging

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<td>11%</td>
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<td>MR</td>
<td>246</td>
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<td>MRerc</td>
<td>124</td>
<td>81%</td>
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<td>6%</td>
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</table>

p, pathological staging; CT, computed tomography staging; ES, endorectal sonography staging; MR, magnetic resonance staging; MRerc, staging with endorectal coil; (+), tumour penetrates wall; (-), tumour not through wall; Acc, accuracy, Sen, sensitivity, Spe, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; %O/S, percentage over-staged; %U/S, percentage under-staged.
Assessment of wall penetration with ES was tested in 53 studies (from 48 papers). These involved a total of 3,176 patients, of which 2,915 were included in the analysis (Appendix A Table A.2). The pooled sensitivity, specificity and accuracy were 93%, 78% and 87% respectively. Of the 53 studies, 31 reported wall penetration using TNM notations. These represented 1,852 patients, of which 84% were correctly staged, 11% were over-staged, 5% were under-staged (Table 7.1 a, b).

Wall penetration was evaluated with MR in 18 studies (from 15 papers), including 521 patients (Appendix A Table A.3). For analysis, 546 MR scans were included (this number is greater than the total number of patients because some patients were assessed by more than one type of MR technique). The pooled sensitivity, specificity and accuracy were 86%, 77%, 82% respectively. Eight studies, which included 246 patients, reported their results using the TNM system. 74% of these patients were correctly staged according to the TNM system, whereas 13% and 13% of these patients were over- and under-staged respectively (Table 7.1a, b).

It has been claimed that MR performed with endorectal surface coil could give more accurate results\(^{264}\). We therefore performed a subanalysis of studies using an endorectal surface coil. Six studies were included, and these include 169 MR patients. The pooled sensitivity, specificity and accuracy for these series were 89%, 79% and 84% respectively (Table 7.1a). Four studies, which include 124 MR patients, reported their results using TNM notation. The pooled accuracy of these 4 studies was 81%, with 12% of the patients being over-staged and 6% of them being under-staged (Table 7.1b).

**Nodal Involvement**

Nodal assessment by CT was examined in 18 studies (from 17 papers), reporting data from 1,088 patients (Appendix A Table A.4). A total of 945 patients were included in the analysis. The pooled sensitivity, specificity and accuracy were 52%, 78% and 66% respectively (Table 7.2). For ES, 38 studies (from 36 papers) were included (Appendix A Table A.5). Eighty-four percent (2,056 patients) of a total of 2,448 patients were included in the analysis. The pooled sensitivity, specificity and accuracy were 71%, 77% and 74% respectively (Table 7.2). Local lymph node involvement was evaluated by MR in 15 studies (from 14 papers) involving 483 patients (Appendix 2 Table A.6). A total of 436 MR scans were included in the analysis. The pooled sensitivity, specificity and accuracy were, respectively, 65%, 80% and 74% (Table 7.2). One hundred and eighty-one patients (from 6 studies) received MR with an endorectal surface coil. The pooled
sensitivity, specificity and accuracy for these series were 82%, 83% and 82% respectively (Table 7.2).

Table 7.2: Pooled results of local lymph node metastases detection

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<tr>
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<td>2056</td>
<td>74%</td>
<td>71%</td>
<td>77%</td>
<td>69%</td>
<td>78%</td>
<td>3.05</td>
<td>0.38</td>
</tr>
<tr>
<td>MR</td>
<td>436</td>
<td>74%</td>
<td>65%</td>
<td>80%</td>
<td>72%</td>
<td>75%</td>
<td>3.27</td>
<td>0.43</td>
</tr>
<tr>
<td>MRec</td>
<td>181</td>
<td>82%</td>
<td>82%</td>
<td>83%</td>
<td>76%</td>
<td>87%</td>
<td>4.70</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Comparing CT, ES and MR

The overall results (Table 7.3) showed that for assessing wall penetration, ES had the highest sensitivity, specificity and accuracy among the modalities. MR assessment of wall penetration had lower sensitivity, specificity and accuracy than ES, although when performed with an endorectal coil, the sensitivity, specificity and accuracy were similar to those of ES. For assessment of nodal involvement, MR performed with an endorectal coil had the highest sensitivity, specificity and accuracy, ES had similar results to MR overall in detecting nodal metastases. CT had the lowest sensitivity, specificity and accuracy for both wall penetration and nodal involvement.

The table of pooled data for T-staging (Table 7.1b) allows an assessment of each test to detect whether a tumour is confined within the mucosa/submucosa (T1) or not. If the data are grouped as T1 and “non-T1” then the results for ES, all MR and MR using an endorectal coil for sensitivity are 82%, 73% and 79%, for specificity are 99%, 96% and 99% and for accuracy are 96%, 91% and 94% respectively.
Table 7.3: Preoperative staging of rectal cancer: total pooled results and subgroup analysis by date and radiotherapy status

<table>
<thead>
<tr>
<th>Modality</th>
<th>Subgroup</th>
<th>Wall Penetration Detection</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Nodal Involvement Detection</th>
<th></th>
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<tr>
<td></td>
<td></td>
<td>n</td>
<td>Acc</td>
<td>Sen</td>
<td>Spe</td>
<td>PPV</td>
<td>NPV</td>
<td>PLR</td>
<td>NLR</td>
<td>n</td>
<td>Acc</td>
<td>Sen</td>
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<td>CT</td>
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<td>78%</td>
<td>63%</td>
<td>82%</td>
<td>58%</td>
<td>2.11</td>
<td>0.35</td>
<td>945</td>
<td>66%</td>
<td>52%</td>
</tr>
<tr>
<td></td>
<td>Pre-1990</td>
<td>787</td>
<td>73%</td>
<td>76%</td>
<td>67%</td>
<td>83%</td>
<td>57%</td>
<td>2.29</td>
<td>0.36</td>
<td>619</td>
<td>66%</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>Post-1990</td>
<td>329</td>
<td>73%</td>
<td>82%</td>
<td>54%</td>
<td>79%</td>
<td>59%</td>
<td>1.80</td>
<td>0.33</td>
<td>326</td>
<td>65%</td>
<td>64%</td>
</tr>
<tr>
<td></td>
<td>No radiotherapy</td>
<td>242</td>
<td>78%</td>
<td>79%</td>
<td>75%</td>
<td>86%</td>
<td>64%</td>
<td>3.19</td>
<td>0.28</td>
<td>240</td>
<td>66%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>Radiotherapy (Any)</td>
<td>168</td>
<td>60%</td>
<td>66%</td>
<td>45%</td>
<td>72%</td>
<td>38%</td>
<td>1.21</td>
<td>0.75</td>
<td>96</td>
<td>54%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Not specified</td>
<td>706</td>
<td>75%</td>
<td>80%</td>
<td>63%</td>
<td>82%</td>
<td>60%</td>
<td>2.17</td>
<td>0.31</td>
<td>609</td>
<td>67%</td>
<td>56%</td>
</tr>
<tr>
<td>ES</td>
<td>Total pooled</td>
<td>2915</td>
<td>87%</td>
<td>93%</td>
<td>78%</td>
<td>87%</td>
<td>87%</td>
<td>4.31</td>
<td>0.09</td>
<td>2056</td>
<td>74%</td>
<td>71%</td>
</tr>
<tr>
<td></td>
<td>Pre-1990</td>
<td>798</td>
<td>88%</td>
<td>92%</td>
<td>80%</td>
<td>91%</td>
<td>81%</td>
<td>4.56</td>
<td>0.10</td>
<td>397</td>
<td>74%</td>
<td>69%</td>
</tr>
<tr>
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<td>Post-1990</td>
<td>2117</td>
<td>87%</td>
<td>93%</td>
<td>78%</td>
<td>85%</td>
<td>89%</td>
<td>4.25</td>
<td>0.09</td>
<td>1659</td>
<td>74%</td>
<td>71%</td>
</tr>
<tr>
<td></td>
<td>No radiotherapy</td>
<td>595</td>
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<td>93%</td>
<td>74%</td>
<td>84%</td>
<td>89%</td>
<td>3.66</td>
<td>0.09</td>
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<td>73%</td>
<td>75%</td>
</tr>
<tr>
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<td>74%</td>
<td>56%</td>
<td>65%</td>
<td>67%</td>
<td>1.68</td>
<td>0.46</td>
<td>132</td>
<td>69%</td>
<td>49%</td>
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<tr>
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<td>81%</td>
<td>89%</td>
<td>88%</td>
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<td>0.08</td>
<td>1493</td>
<td>75%</td>
<td>72%</td>
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<td>82%</td>
<td>86%</td>
<td>77%</td>
<td>83%</td>
<td>81%</td>
<td>3.70</td>
<td>0.19</td>
<td>436</td>
<td>74%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>Pre-1990</td>
<td>n/a</td>
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<td></td>
<td></td>
<td>23</td>
<td>39%</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>Post-1990</td>
<td>546</td>
<td>82%</td>
<td>86%</td>
<td>77%</td>
<td>83%</td>
<td>81%</td>
<td>3.70</td>
<td>0.19</td>
<td>413</td>
<td>76%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>No radiotherapy</td>
<td>64</td>
<td>81%</td>
<td>90%</td>
<td>74%</td>
<td>75%</td>
<td>89%</td>
<td>3.40</td>
<td>0.14</td>
<td>64</td>
<td>72%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>Radiotherapy (Any)</td>
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<td>82%</td>
<td>79%</td>
<td>88%</td>
<td>70%</td>
<td>3.93</td>
<td>0.23</td>
<td>92</td>
<td>68%</td>
<td>56%</td>
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<tr>
<td></td>
<td>Not specified</td>
<td>414</td>
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<td>81%</td>
<td>3.75</td>
<td>0.18</td>
<td>280</td>
<td>76%</td>
<td>71%</td>
</tr>
</tbody>
</table>

CT, computed tomography staging; ES, endorectal sonography staging; MR, magnetic resonance staging; Acc, accuracy; Sen, sensitivity; Spe, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; n/a, not applicable.
**Year of Publication**

The time when the investigations were carried out may influence observed accuracy of the modality. For the purpose of this study, the papers were sub-grouped by the years of publication into a pre-1990 group and a post-1990 group for further analysis. The cut-off year 1990 was chosen arbitrarily because it gives two subgroups covering similar duration of time. Subgroup analysis was not possible for MR because there was only one included study prior to 1990 that examined the use of MR in preoperative staging of rectal cancer. The results of the sub-analysis were given in Table 7.3. The results indicated that the accuracy did not appear to differ between the subgroups. The relative accuracy ranking of modalities in the pre-1990 (CT & ES only) and post-1990 (CT, ES & MR) groups did not differ from the overall results.

**Radiotherapy**

All studies containing patients receiving radiotherapy, regardless of the regimen, were combined for analysis (Table 7.3). In patients having radiotherapy preoperative staging using CT and ES had the lowest sensitivity and specificity, however, staging using MR to assess wall penetration, appeared less affected by radiotherapy. Comparison between the “no radiotherapy” and the “not specified” groups yielded no clear conclusion, presumably because the “not specified” group contained a large proportion of patients who did not receive radiotherapy.

**Discussion**

This systematic review reports the effectiveness of CT, ES and MR in the preoperative staging of rectal cancer. Our results show that ES has the highest sensitivity and specificity when assessing wall penetration. ES has a higher sensitivity than CT and MR in assessing nodal involvement but MR has a higher specificity. When MR is performed with an endorectal coil, it has a similar sensitivity, specificity and accuracy to ES in assessing wall penetration and a higher sensitivity, specificity and accuracy in assessing nodal involvement. In the present study, although the three modalities were compared quantitatively and it is concluded that MR performed with an endorectal coil is the most useful technique for preoperative staging of rectal cancer, no statistical test was applied because the diversity of the included papers made this inappropriate. The use of the simple “through” or “not through” wall penetration staging system in the current study means that some details are lost. We found this down conversion necessary due to the huge array of different staging systems used in the literature. This is unlikely to reduce the usefulness of the results because the most important prognostic factors in the preoperative staging of rectal cancer.
cancer relate to tumour penetration through the bowel wall and nodal involvement. The staging system used here represents a compromise between usefulness and convenience. The loss of detail is also circumvented by including pooled T-staging results where they are available. Using these T-staging results it is possible to show that both ES and MR using an endorectal coil have a sensitivity of about 80% and a specificity of 99% for detecting T1 tumours i.e. those that are potentially amenable to local excision.

Although early CT studies reported good results for assessing wall penetration, the present study shows that CT has the lowest overall accuracy when compared to ES and MR. This discrepancy has been reported by other authors, who attributed this observation to the fact that most patients in the earlier series had advanced disease in which CT performs well. Because CT cannot determine the depth of tumour invasion within the wall or reliably determine immediate perirectal invasion, its value in assessing early tumour is limited. CT lacked accuracy in detecting metastatic lymph nodes in this study as had been reported previously.

The current study shows that ES is better than CT and MR in assessing wall penetration. This is in agreement with Heriot et al. This can be explained by its ability to distinguish the different layers of the bowel wall. The benefit of ES over CT has been clearly demonstrated in many studies, but little is available comparing ES and MR directly. The present study presents evidence that ES is better than MR in wall penetration assessment. This is not unexpected because MR using body coils or no coil at all suffers the same limitations as CT in that it cannot determine the extent of tumour infiltration within the bowel wall. However, newer MR techniques using an endorectal coil do not have this limitation. Our sub-analysis of studies using endorectal coils appears to confirm this.

Although Heriot et al argued that nodal involvement can not be accurately assessed by any modality, we found that MR using an endorectal surface coil was the most accurate modality in this setting with both sensitivity and specificity above 80%.

It has previously been reported that radiotherapy impairs staging accuracy. It has been proposed that this is caused by preoperative radiotherapy producing changes in the perirectal fat that can simulate the changes of advanced tumours, resulting in over-staging. We have shown, however, that in the limited number of scans available for analysis, the results obtained by MR appear little affected by radiotherapy. For patients who have received radiotherapy, MR is the most effective imaging modality.

ES is the most effective single modality to assess tumour penetration of the rectal wall. It does not however allow the assessment of distant metastatic disease. MR can give information on local and distant spread and appears to be the modality of choice in patients after radiotherapy. When
used with an endorectal coil, MR is as effective as ES in assessing wall infiltration and is the most effective in assessing nodal involvement. MR with an endorectal coil offers the maximum information of a single test in preoperative staging of rectal cancer.

This chapter has considered the ability of preoperative radiological assessment to predict the pathological stage of tumours. It represents the present evidence in preoperative staging of rectal cancer but does not address the question of identifying those patients likely to have circumferential margin involvement after resectional surgery. The preoperative identification of the fascia propria of the rectum will be explored in the following chapter.
Chapter 8: Preoperative Identification of the Fascia Propria

Aim

The aim of this study was to determine whether the surgical fascia propria can be identified preoperatively and to ascertain the level of the rectum over which it can be visualised.

Methods

This study involved imaging and dissection of the formalin-fixed cadaver of a 63 year old male with no known history of colorectal disease. It was approved by the Inspector of Anatomy working under the jurisdiction of the Human Tissues Act (1964).

Baseline CT and MR images of the pelvis were performed before dissection. 5mm axial CT scans of the pelvis were obtained using a General Electric Hi Speed RP Helical CT Scanner. T1-weighted axial MR images (slice thickness 4.0mm, slice gap 0.8mm, TR 1013, TE 12, field of view 260, matrix size 228x512) were performed using a Siemens Vision 1.5 Tesla machine with a phased array body coil.

Study 1: Radiological and Anatomical Correlation

After baseline imaging the cadaver was transferred to an operating area where an extrafascial dissection of the rectum as described previously was performed in stages interspersed with MR imaging of the pelvis. The extrafascial plane was marked using aluminium foil and the pelvic MR repeated after initial dissection in the posterior plane only, after further dissection on the right and finally after dissection on both sides as far down as possible in the fixed pelvis.
**Study 2: Rectal Level of Fascial Visibility**

Two radiologists (CFF, DMH) had earlier noted that the fascia propria was usually visible up to the level of the superior margin of the femoral head on MR imaging. This investigation sought to determine the distance from the anal verge which corresponded to this level of the fascia. Using CT guidance and standard interventional techniques, 0.05 ml methylene blue was injected into the fat adjacent to the fascia propria at the level of the superior margin of the femoral head. A radio-opaque embolisation coil was also injected at the same position. The correct position of the coil was confirmed with CT.

The cadaver was then transported to the dissection room and an abdomino-perineal resection of the rectum performed. The distance from the area on the perirectal tissue marked by methylene blue to the anal verge was measured on the removed rectal specimen. The distance from the anal verge to the coil on the pelvic side wall was measured. A sigmoidoscope was passed up the resected rectum and measurements were made from the anal verge to the ano-rectal junction, the blue dye on the perirectal tissue, and the peritoneal reflection.

**Study 3: Visibility of Fascia Propria**

This study sought to identify the number of patients with rectal cancer in whom the fascia propria was visible on preoperative CT and MR images up to the level of the superior margin of the femoral head. Nineteen CT scans and 19 MR studies of patients with rectal cancer were reviewed jointly by 2 radiologists (CCF and DMH). Patients with previous radiotherapy were excluded. Axial scans taken through the level of the superior margin of the femoral head were selected from each patient. The radiologists recorded whether the fascia propria was visible on each side for the scans at this level.
Results

Study 1: Radiological and Anatomical Correlation

Figure 8.1 shows the pre-dissection MRI with the perirectal fascial plane marked with arrows.

Figure 8.1: A T1-weighted axial MR image of the cadaveric pelvis before dissection. The white arrows indicate the line of the perirectal fascia.

The MR performed after the placement of the aluminium foil in the extrafascial plane during dissection is shown in figure 8.2. In figure 8.2 it can be seen that the aluminium foil (central arrow) marking the plane of extrafascial excision is situated in the line of the radiological fascia propria (outer arrows). The pre-dissection and post-dissection MR images using aluminium foil as a marker confirmed that the perirectal fascial plane visible on pelvic MR images was indeed the same fascia propria identified during extrafascial excision.
Figure 8.2: An enlarged view of the T1-weighted axial MR image of the cadaveric pelvis after extrafascial dissection of the rectum. The central, white arrow identifies the aluminium foil placed in the plane of dissection. The outer, black arrows indicate the line of the perirectal fascia. It can be seen that the foil is lying in the plane of the fascia.

Study 2: Rectal Level of Fascial Visibility

Figure 8.3 is a CT scan in the prone position showing the fascia propria (A) marked at the level of the upper limit of the visualized fascia propria. The radio-opaque embolisation coil (B) has been placed just outside the fascia propria at that level.
Figure 8.3: An axial CT scan in the prone position at the level of the superior margin of the femoral head. The line of the fascia propria (A) is seen and the radio-opaque embolisation coil (B) can be seen lying just outside the fascia propria.

The distance from the anal verge to the anorectal junction, the methylene blue mark on the perirectal tissue and the peritoneal reflection measured on the resected rectum using a sigmoidoscope were 3cm, 10 cm and 13cm respectively. Likewise, the distance measured inside the pelvis from the anal verge to the embolisation coil was 10 cm.

**Study 3: Visibility of Fascia Propria**

Preoperative CT scans from 19 rectal cancer patients were reviewed. On the axial scans from the level of the superior margin of the femoral head the perirectal fascia was visible on both sides in 7 patients and on 1 side in 2 patients. The fascia was not seen in 10 scans. An axial CT scan at the level of the superior margin of the femoral head is shown in figure 8.4. The fascia propria is visible on both sides.
Preoperative axial MR images from 19 rectal cancer patients were reviewed. The majority of these scans were performed with a General Electric 1.5 Tesla MR with T1- and T2-weighting (slice thickness 4mm, slice gap 0.5-2mm, TR 440-700, TE 9-14 for T1 scans, TR 3900-4500, TE 96-128 for T2 scans, field of view 24x24, matrix size 256x192). On the axial scans from the level of the superior margin of the femoral head the perirectal fascia was visible on both sides in 13 patients and on 1 side in 2 patients. The fascia was not seen in 4 patients. In figure 8.5 an axial MR scan at the level of the superior margin of the femoral head is shown with the fascia propria visible on both sides.
Discussion

These results show that the sock-like fascia propria that encircles the rectum and its surrounding mesorectum can be identified around the lower two-thirds of the rectum on MRI in most patients. This is of potential clinical importance for it has been postulated that if rectal cancer has been contained within this fascia and an extrafascial excision of the rectum is performed then local recurrence of the cancer will be exceptional. If this hypothesis is proven prospectively, radiotherapy designed to prevent local recurrence will be necessary only in the minority of patients in whom the cancer has been identified as penetrating the fascia.

In 1983 the identification of a perirectal fascia on CT was first reported and its possible use in staging rectal cancer was proposed\textsuperscript{90}. Since that time little has been published on the radiology of this fascia. A pilot study\textsuperscript{201} noted that the local recurrence rate of rectal cancer was especially high in patients where the abnormal tissue as judged by CT was attached to the perirectal fascia or extending beyond it. A second recent study using MR imaging for staging rectal cancer...
reported that a fascial plane surrounding the mesorectum could be visualised in each of 28 cases\textsuperscript{31}. The present study has shown that this fascia is the surgical fascia propria. During the operation of extrafascial excision of the rectum, it is removed together with the enclosed mesorectum (Chapter 3).

The finding that the fascia propria surrounding the mesorectum can be reliably identified preoperatively by MR has significant implications for the management of rectal cancer. If the relationship of a rectal tumour to the fascia propria can be accurately predicted by preoperative MR then treatment decisions regarding adjuvant therapy can be made more reliably before surgery.

The following chapter addresses this issue.
Chapter 9: Preoperative Assessment of the Relation of Tumour Invasion to the Fascia Propria Using MR Imaging

Aim

The aim of this study was to determine the accuracy of preoperative MR in assessing the relation of the deepest invasion of rectal cancer to the fascia propria.

Methods

Patients

All patients who had had preoperative MR imaging prior to rectal excision for cancer between 1 July 1995 and 31 August 1999 in the colorectal surgical unit at Auckland Hospital were included in the study group. Sixteen patients presenting before 31 May 1998 were studied retrospectively and the remainder (27 patients) prospectively.

Imaging

MR scans were performed using a phased-array torso coil employing a General Electric 1.5 Tesla magnet in 32, a Siemens Vision 1.5 Tesla magnet in 8 and a Phillips 1.5 Tesla ASC NT Gyroscan in 3 patients. Scans were performed in axial and angled axial planes including coronal and sagittal planes in selected cases. Acquisitions were obtained with T1- and T2-weighting (slice thickness 4mm, slice gap 0.5-2mm, TR 440-700, TE 9-14 for T1 scans, TR 3900-4500, TE 96-
128 for T2 scans, field of view 24x24, matrix size 256x192). An endorectal coil was used in 4 patients.

The MR films were read independently by two radiologists (CCF, DMH) who had been blinded to the patient identity for the retrospective patients. The radiologists recorded the relation of the deepest tumour invasion to the fascia propria. The relation to the fascia propria was reported as “inside” the fascia propria, “up to” the fascia propria, or “through” the fascia propria. Only those patients with clear evidence of invasion into the extra-fascial tissues were included in this third group. Patients in the “inside” and “up to” groups were analysed together as “not through” the fascia propria.

Pathology

The excised rectal specimens were examined fresh. The glistening surface of the intact fascia propria was identified and inked. Two methods of preparing the specimens were used. All the specimens for retrospective study and some for prospective study were cut open longitudinally while fresh, pinned on a corkboard and fixed. They were then examined according to the guideline of the Association of Clinical Pathologists Broadsheet235. The tumour containing segments were sectioned serially in 5mm slices. Seventeen of the specimens for prospective study were filled with formalin and fixed before opening. After adequate fixation the tumour containing segments were also serially cut in 5mm slices along the transverse plane. For all specimens, the deepest tumour invasion and narrowest fascia propria margin were determined and blocks were prepared for histological examination at these sites. All the histological slides were stained with Haematoxylin and Eosin. One histopathologist (KYC) independently examined the histology slides for all patients and the gross specimens from the patients entered prospectively. He recorded the relation of the deepest tumour invasion to the fascia propria resection margin in each patient.

Clinical

Clinical details recorded for each of the patients included: age, sex, interval between scan and surgery, radiotherapy and its relation to the scan and surgery, the height of the tumour at sigmoidoscopy, the clinical stage of the tumour by digital examination during examination under anaesthesia by the consultant and the type of resection performed.
Analysis

All data were entered into a spreadsheet. A 2x2 table comparing preoperative imaging with pathological results was constructed. If at surgery the tumour was fixed and not able to be resected (3 patients) the tumour was assumed to invading through the fascia propria. The tables were used to calculate sensitivity, specificity, accuracy, positive and negative predictive values and positive and negative likelihood ratios for penetration of the fascia propria by the tumour. Variation between observers was calculated by assessing percentage of test results in agreement.

Results

Patients

Forty-three patients (median age 64 (24-86) years, 17 female) had preoperative imaging at a median of 13 (1-60) days preoperatively. Six patients had preoperative radiotherapy given before the scan. The height of the tumour as measured from the anal verge by sigmoidoscopy was 0-7cm in 27 patients, 7-11cm in 12 patients and 11-15cm in 4 patients. Eleven patients had abdomino-perineal resections, 27 had anterior resections, 2 had a Hartmann’s resection and 3 had stoma formation only because the tumour was fixed. There were 6 Dukes’ A, 9 Dukes’ B and 21 Dukes’ C tumours and a further 6 patients had macroscopic residual intra-abdominal disease. One patient, who had received preoperative radiotherapy, had no viable tumour in the resected specimen although there was fibrosis involving the perirectal fat out to the fascia propria. The MR scan in another patient only included part of the tumour. These 2 patients were excluded, leaving 41 patients for analysis.
MR Imaging

Figure 9.1 shows a tumour contained within the fascia propria. In figure 9.2 tumour can be seen penetrating through the fascia propria.

Figure 9.1: A T2 weighted axial MR image of a patient with rectal cancer showing the fascia propria (A) with the tumour (B) contained within it.

Figure 9.2: A T1 weighted MR of a patient with rectal cancer showing the tumour (A) penetrating through the fascia propria (B).
Assessment of Fascia Propria Invasion

The results of assessment of tumour invasion through the fascia propria using MR are shown in Table 9.1. Radiologist A could not determine the relationship to the fascia propria in 1 patient. The test had a sensitivity of 67%, a specificity of 100% and an accuracy of 95%. Radiologist B could not determine the relationship to the fascia propria in 2 patients, in the other 39 patients there was agreement with Radiologist A in 37 (95%).

<table>
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<td>36</td>
</tr>
<tr>
<td>Total</td>
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<td>34</td>
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</table>

Sensitivity 67%  Specificity 100%
Accuracy 95%
Positive predictive value 100%
Negative predictive value 95%
Positive likelihood ratio N/A
Negative likelihood ratio 0.33

N/A, Not able to be calculated.

Discussion

Having shown that the sock-like fascia propria that encircles the rectum and its surrounding mesorectum can be identified on MR (in Chapter 8), this present study has shown that it is possible to assess preoperatively whether a tumour is locally contained within the mesorectum with an accuracy of about 95%. This is of potential clinical importance for it has been postulated that if rectal cancer has been contained within this fascia and EFE is performed then local recurrence of the cancer will be exceptional.117
Although the numbers involved are small, this study suggests that these patients can be accurately identified preoperatively using MR. Patients whose tumour invades through the fascia propria are likely to have involved circumferential margins and thus are at greatest risk of local recurrence after surgery alone. In the present study patients whose initial imaging indicated invasion through the fascia propria or who had very bulky tumours were offered a 6 week course of radiotherapy (50 Gy) followed by surgery 6 weeks later. The initial MR was reported as showing tumour through the fascia propria in 7 patients. Of these, one patient’s tumour was reported as being inside the fascia after radiotherapy, 2 patients did not come to surgery after radiotherapy and were therefore excluded, and the other 4 are included in the “through” group in table 7.1. As only patients who had a further scan after radiotherapy and also came to surgery were included, the number in this group was small (6 patients whose tumour penetrated the fascia propria). Despite this, all of the 34 patients whose tumour was contained within the fascia propria histologically were correctly reported on MR scan.

There were 2 patients with “false negative” reports. One patient had a small area of invasion into the prostate that was not identified on MR. The second had preoperative radiotherapy because of the bulk of the tumour. The post-radiotherapy MR scan on this patient was reported as showing no direct tumour penetration of the fascia propria but enlarged nodes outside the fascia propria and in the retroperitoneum. At surgery the patient was found to have a fixed pelvic tumour, extensive intra-abdominal disease and hepatic metastases. A colostomy was fashioned without resection of the tumour and therefore, although the tumour was classified as penetrating “through” the fascia propria because of its fixity, it was not possible to confirm this by histology. Radiotherapy was given to this patient on the basis of the initial MR scan findings indicating that the clinical management of the patient was appropriate even though the study recorded the MR scan as a “false negative” result.

The finding that the fascia propria surrounding the mesorectum can be reliably identified preoperatively, and that the relation of the tumour to this fascia can be assessed by MRI may prove to be a breakthrough for the management of rectal cancer. If, as appears likely, local recurrence after rectal cancer surgery does not occur when the tumour is contained within the fascia propria and the rectum has been removed with an intact fascial envelope and an adequate distal margin, then many patients may be spared unnecessary radiotherapy. We now have the potential to predict preoperatively which rectal tumours can be safely resected by EFE with minimal chance of local recurrence, and to identify those patients most likely to benefit from preoperative radiotherapy.
Section 3: The Results of Extrafascial Excision of the Rectum
Introduction

In Section 1 the anatomical basis of extrafascial excision was outlined by describing the nature, extent and attachments of the fascia propria. The relation of the extrafascial dissection plane to the hypogastric nerves and pelvic plexuses was identified and a three-dimensional reconstruction of the fascia propria performed. Section 2 explored the place of preoperative radiological assessment, producing a new method for assessing rectal cancer preoperatively based on the tumour’s relation to the fascia propria. This section will consider the results of EFE in clinical practice.

The operation of EFE was introduced to Auckland in 1980 by Professor Graham Hill based on the principle of sharp dissection under vision directly on the fascia propria to remove the rectum for rectal cancer. This procedure has further developed over the ensuing 20 years with the growing understanding of the anatomy of the pelvic nerves and the importance of avoiding an involved lateral resection margin. The basic principles have, however, remained unchanged. Several other surgeons have been taught the procedure and their results are presented in Chapter 10, which is a 16 year cohort study carried out in Auckland comparing conventional surgery and EFE in the treatment of rectal cancer.
Chapter 10: Results of Extrafascial Excision and Conventional Surgery for Rectal Cancer at Auckland Hospital

Background

There are many treatment options in the management of rectal cancer including conventional surgery alone, adjuvant preoperative and postoperative radiotherapy and chemotherapy, total mesorectal excision (TME), and extended pelvic lymphadenectomy. Experts disagree as to which is most appropriate\textsuperscript{128, 185, 200, 273}. A recent study has shown that if a rectal cancer is contained inside the fascia propria and an extrafascial excision of the rectum (EFE) is performed then local recurrence of the tumour will be exceptional\textsuperscript{117}. EFE is a technique in which dissection is performed hard on the surface of the fascia propria which enables the rectum and its surrounding mesorectum to be removed intact within its fascial envelope\textsuperscript{24, 25}. In high rectal tumours the total mesorectum is not necessarily removed if 5cm of mesorectum distal to the tumour can be safely resected without including the most distal part of the mesorectum.

A randomised trial comparing EFE and conventional surgery, although desirable, is practically and ethically impossible to perform. This study aimed to compare retrospectively 2 cohorts of patients undergoing surgery for rectal cancer at the same institution during the same time period. One group comprised all patients operated on by surgeons employing extrafascial excision and the other comprised all patients who were operated on using conventional techniques.
The following null hypotheses were tested:

EFE has a higher complication rate than conventional surgery.

Local recurrence is less common following EFE than conventional surgery.

EFE conveys a survival advantage over conventional surgery.

EFE is more expensive than conventional surgery.

**Patients and Methods**

**Patients**

All patients undergoing primary rectal excision for adenocarcinoma in Auckland Hospital from January 1980 to December 1996 were included in the study. Patients were identified from the hospital operating register, the surgical audit database, hospital discharge coding, the hospital pathology database and oncology records. The hospital notes for each patient were obtained and the following details recorded: name, age, sex, hospital number, date of birth, pre-existing medical conditions, operation date, type, length and intent (curative/palliative), the surgeon, the operative technique, stoma utilization and closure, tumour distance from anal verge, Dukes’ stage, distal resection margin, histological grade, microscopic distal and circumferential margin involvement, hospital stay, postoperative complications, adjuvant therapy, local and systemic recurrence, date of recurrence, management of recurrence, date of last follow-up, deaths and causes of death. During the study period the pathological reporting was carried under the supervision of 2 pathologists with a particular interest in rectal cancer. Circumferential margin involvement was routinely reported after 1989.

**Definitions**

The definitions used in this study are outlined in Table 10.1.
Table 10.1: Definitions of Terms used in the Study

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumour height</td>
<td>Distance from anal verge on rigid sigmoidoscopy</td>
</tr>
<tr>
<td></td>
<td>Low 0-7 cm, mid 7-11 cm, high 11-15 cm, rectosigmoid 15-20 cm</td>
</tr>
<tr>
<td>Curative resection</td>
<td>No <em>macroscopic</em> tumour remaining in the pelvis or abdomen</td>
</tr>
<tr>
<td>Palliative resection</td>
<td>Residual <em>macroscopic</em> local disease or hepatic metastases</td>
</tr>
<tr>
<td>EFE</td>
<td>Excision of rectum with an intact fascia propria, in practice, defined as</td>
</tr>
<tr>
<td></td>
<td>an excision carried out by a surgeon trained in EFE</td>
</tr>
<tr>
<td>Conventional surgery</td>
<td>Surgery in which there was no record of attention to preservation of an</td>
</tr>
<tr>
<td></td>
<td>intact mesorectum or TME/EFE having been performed</td>
</tr>
<tr>
<td>Distal resection margin</td>
<td>Distance from resection margin to tumour measured by pathologist</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>Total stay from admission to discharge, including preoperative stay</td>
</tr>
<tr>
<td>Local recurrence</td>
<td>All patients with clinical or histological recurrence of tumour in the</td>
</tr>
<tr>
<td></td>
<td>pelvis or perineum with or without distant metastases</td>
</tr>
<tr>
<td>Cancer free survival</td>
<td>Survival from surgery to time of first recurrence of tumour at any site,</td>
</tr>
<tr>
<td></td>
<td>those who died without recurrence were censored at death</td>
</tr>
</tbody>
</table>

Local recurrence

A second observer reviewed the notes of all patients who were identified as having had a local recurrence. Details of any treatment given specifically for the local recurrence were recorded, including outpatient appointments, operations and their length, hospital stay, and radiotherapy.

Mortality and Survival

All patients who were operated on with curative intent were further studied. If less than 5 years follow-up was available from the notes then a manual search for their names was performed in the New Zealand National Death Register. The death certificates were obtained for all those that had died and any local recurrence that had been identified was included. A further search was carried out in the New Zealand Electoral Roll for all those patients not encountered in the Death Register. The Electoral Roll had been updated in August 1999 in preparation for the coming elections and only included those who had responded. Patients who were alive and had not returned to the hospital for treatment were assumed to be free of tumour.


Analysis

The data obtained from the above sources were entered into a spreadsheet and divided into 2 groups, conventional surgery and EFE. Demographic, operation, tumour, complication and local recurrence data were analysed for both groups and compared using the Chi-square test with Yates correction, where an expected cell value was less than 5 Fisher’s exact test was used. Overall and cancer-free survival curves were produced using the Kaplan-Meier technique\textsuperscript{136} and curves were compared using the log-rank test. The level of significance was set at 0.05 throughout.

Cost

Present costs for treatment at Auckland Hospital were obtained from the management for bed stay per day, operating time per minute, outpatient visits, chemotherapy and radiotherapy per session. Costs were calculated for each individual patient using the above parameters for their initial hospital stay and for the treatment of any local recurrence. This cost was then averaged for each initial treatment and for those who developed a local recurrence.

Results

Patients

There were 315 patients who had rectal excision for rectal cancer during the time period. Notes were obtained for them all. Fifty-three patients had palliative surgery (31 conventional and 22 EFE). The remaining 262 patients (138 conventional surgery and 124 EFE patients) who had “curative surgery” made up the study group. Twenty-three surgeons were involved in the study, 5 of whom performed EFE. Consultants were the operating surgeons in greater than 80% of the procedures in both groups. As shown in Table 10.2 the groups were similar with respect to age, sex, and operation performed.
Table 10.2: Patient demographics and operations performed

<table>
<thead>
<tr>
<th></th>
<th>Conventional (n=138)</th>
<th>EFE (n=124)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in years): median (range)</td>
<td>69 (35-92)</td>
<td>68 (24-94)</td>
<td></td>
</tr>
<tr>
<td>M/F</td>
<td>73/65</td>
<td>75/49</td>
<td>0.3</td>
</tr>
<tr>
<td>AR*</td>
<td>93 (67%)</td>
<td>94 (76%)</td>
<td></td>
</tr>
<tr>
<td>APR†</td>
<td>32 (23%)</td>
<td>18 (15%)</td>
<td>0.2</td>
</tr>
<tr>
<td>Other</td>
<td>13 (10%)</td>
<td>12 (10%)</td>
<td></td>
</tr>
</tbody>
</table>

* Anterior resection, † Abdomino-perineal excision of the rectum

Medical co-morbidities were common in both groups (Table 10.3). Seventeen patients in the conventional surgery group had adjuvant therapy (6 chemotherapy, 14 radiotherapy) and 21 in the EFE group (8 chemotherapy, 19 radiotherapy) (p=0.38). The median (range) hospital stay and operating time for conventional surgery were 16 (4-97) days and 177.5 (70-320) minutes and for EFE were 15.5 (3-60) days and 184 (60-405) minutes respectively.

Table 10.3: Incidence of significant medical co-morbidities

<table>
<thead>
<tr>
<th></th>
<th>Conventional (n=138)</th>
<th>EFE (n=124)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>13 (9%)</td>
<td>11 (9%)</td>
<td>0.95</td>
</tr>
<tr>
<td>Renal Impairment</td>
<td>3 (2%)</td>
<td>6 (5%)</td>
<td>0.31†</td>
</tr>
<tr>
<td>Ischaemic Heart</td>
<td>27 (20%)</td>
<td>22 (18%)</td>
<td>0.83</td>
</tr>
<tr>
<td>Congestive Heart</td>
<td>11 (8%)</td>
<td>9 (7%)</td>
<td>0.99</td>
</tr>
<tr>
<td>COAD*</td>
<td>13 (9%)</td>
<td>18 (15%)</td>
<td>0.28</td>
</tr>
<tr>
<td>Hypertension</td>
<td>29 (21%)</td>
<td>38 (31%)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

* Chronic obstructive airways disease, † Two–tail Fisher’s exact test
Tumour Characteristics

Dukes’ stage and tumour differentiation are shown in Table 10.4. The sites of the tumours in the rectum are shown in Table 10.5. The 4x2 Chi-square analysis showed that there was a difference between the groups (p=0.02). This difference was attributable to more proximal tumours in the conventional surgery group and more low tumours in the EFE group. The distal resection margin as recorded by the pathologist was 1 cm or less in 16 (12%) of the conventional surgery patients and 14 (11%) of the EFE patients.

Table 10.4: Stage and differentiation of tumours

<table>
<thead>
<tr>
<th></th>
<th>Conventional (n=138)</th>
<th>EFE (n=124)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dukes A</td>
<td>28 (20%)</td>
<td>30 (24%)</td>
<td></td>
</tr>
<tr>
<td>Dukes B</td>
<td>52 (38%)</td>
<td>55 (44%)</td>
<td>0.2</td>
</tr>
<tr>
<td>Dukes C</td>
<td>58 (42%)</td>
<td>39 (32%)</td>
<td></td>
</tr>
<tr>
<td>Well differentiated</td>
<td>23 (17%)</td>
<td>16 (13%)</td>
<td></td>
</tr>
<tr>
<td>Moderately differentiated</td>
<td>99 (72%)</td>
<td>101 (81%)</td>
<td>0.17</td>
</tr>
<tr>
<td>Poorly differentiated</td>
<td>15 (11%)</td>
<td>7 (6%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 10.5: Site of tumour within the rectum

<table>
<thead>
<tr>
<th></th>
<th>Conventional (n=138)</th>
<th>EFE (n=124)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>48 (35%)</td>
<td>59 (48%)</td>
<td>0.05</td>
</tr>
<tr>
<td>Mid</td>
<td>40 (29%)</td>
<td>27 (22%)</td>
<td>0.23</td>
</tr>
<tr>
<td>High</td>
<td>26 (19%)</td>
<td>29 (23%)</td>
<td>0.45</td>
</tr>
<tr>
<td>Rectosigmoid</td>
<td>24 (17%)</td>
<td>9 (7%)</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Complications

The complication rates for the 2 techniques of rectal excision were comparable as shown in Table 10.6. Anastomotic leaks included major leaks requiring laparotomy and minor leaks managed without reoperation. There were 6 major leaks in the conventional surgery group and 10 in the EFE group (p=0.45).

**Table 10.6: Postoperative complications**

<table>
<thead>
<tr>
<th></th>
<th>Conventional (n=138)</th>
<th>EFE (n=124)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wound infection</td>
<td>25 (18%)</td>
<td>17 (14%)</td>
<td>0.42</td>
</tr>
<tr>
<td>Intra-abdominal abscess</td>
<td>3 (2%)</td>
<td>8 (6%)</td>
<td>0.16</td>
</tr>
<tr>
<td>Septicaemia</td>
<td>6 (4%)</td>
<td>8 (6%)</td>
<td>0.63</td>
</tr>
<tr>
<td>Chest infection</td>
<td>13 (9%)</td>
<td>15 (12%)</td>
<td>0.62</td>
</tr>
<tr>
<td>Haemorrhage</td>
<td>2 (2%)</td>
<td>2 (2%)</td>
<td>1.00*</td>
</tr>
<tr>
<td>Anastomotic leak†</td>
<td>13 (14%)</td>
<td>12 (13%)</td>
<td>0.98</td>
</tr>
<tr>
<td>Postoperative death</td>
<td>3</td>
<td>2</td>
<td>1.00*</td>
</tr>
</tbody>
</table>

* Two-tail Fisher’s exact test, † Only includes patients having anterior resection

Stoma formation

Among the patients who had an anterior resection there were 34 patients (37%) who had a stoma to defunction the anastomosis (8 ileostomies, 26 colostomies) in the conventional surgery group and 38 patients (40%) with a defunctioning stoma (27 ileostomies and 11 colostomies) in the EFE group. Eighty-two percent of the conventional surgery group and 87% of the EFE group had their stomas closed.

Follow-up

Surgeons employed individual follow-up protocols but, in general, patients were seen 6-monthly for the first 2 years and annually thereafter. Follow-up to a minimum of 5 years, death or to August 1999 was complete in 251 of the 262 patients (96%). There were only 4 patients (2 EFE, 2 conventional surgery) whose names were on the latest electoral roll and were assumed to be
recurrence free without being able to confirm this by contacting them personally. The mean follow up of the survivors was 7.0 years.

**Local recurrence**

Local recurrence occurred in 37 patients in all. The median time from surgery to local recurrence was 13 months and 71% of local recurrences had occurred within 2 years. The median time from local recurrence to death was 11 months and 76% of patients were dead by 2 years. There was only one patient who had had local recurrence who was alive beyond 5 years following surgery. Local recurrence of the cancer occurred in 8 patients (6%) in the EFE group and 29 patients (21%) in the conventional surgery group. Figure 10.1 shows the Kaplan-Meier curves for local recurrence indicating a lower local recurrence rate in the EFE patients (p=0.0006). There was a higher local recurrence rate for each of the Dukes’ stages in the conventional surgery group but this only reached statistical significance in the Dukes’ C patients (**Table 10.7**).

![Figure 10.1: Actuarial local recurrence rates to 6 years. Comparison of the curves using the log-rank test indicated a lower local recurrence rate in the EFE group (p=0.0006). Conv, conventional surgery.](image-url)
### Systemic recurrence

Systemic recurrence rates were similar occurring in 23 patients (17%) who had conventional surgery (10 of these had associated local recurrence) and in 20 patients (16%) following EFE (2 also had local recurrence) (p=0.9)

### Survival

Overall (crude) survival for the conventional surgery and EFE groups is shown in Fig 10.2. The 5 year overall survival in the conventional surgery group was 54% and in the EFE group 60% (p=0.23). The median survival for the conventional surgery group was 6.4 years and for the EFE group, 9.5 years. The 5-year cancer-free survival rate is shown in Fig 10.3. There was an increased 5-year cancer-free survival in the EFE group (p=0.02). The 5-year cancer-free survival for each Dukes’ stage is shown in Table 10.8.
Figure 10.2: Overall (crude) survival to 5 years. Comparison of the survival curves using the log-rank test gave a p value of 0.23.
Figure 10.3. Cancer-free survival to 5 years. Comparison of the curves using the log-rank comparison indicated that EFE patients had a longer cancer-free survival than the conventional surgery patients (p=0.02).

Table 10.8: Cancer-free survival at 5 years

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>EFE</th>
<th>p *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dukes’ A</td>
<td>82%</td>
<td>86%</td>
<td>0.14</td>
</tr>
<tr>
<td>Dukes’ B</td>
<td>64%</td>
<td>77%</td>
<td>0.23</td>
</tr>
<tr>
<td>Dukes’ C</td>
<td>53%</td>
<td>61%</td>
<td>0.32</td>
</tr>
<tr>
<td>Total</td>
<td>63%</td>
<td>74%</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* Log-rank comparison of survival curves
**Cost**

The average cost for the initial treatment by conventional surgery was NZ$15,717 and for EFE was NZ$15,158. The average cost of treatment of a local recurrence for the 35 patients for whom all data was complete was NZ$10,471.

**Discussion**

The outcome of conventional surgery alone for rectal cancer is less than optimal and is followed by high local recurrence rates\(^1\) and 5-year cancer-free survival in the order of 50\%.\(^2\) Although there have been no randomised controlled trials comparing TME and conventional surgery in the treatment of rectal cancer a recent systematic review has suggested a considerably lower local recurrence rate for TME over other surgical techniques.\(^3\) Our operation, EFE, is a simplified technique for mesorectal excision in which the dissection is conducted well medial to the hypogastric nerves and pelvic plexuses hard on the shiny membranous fascia propria (see chapters 3 and 4). In this way the nerves and vessels are preserved and yet cancer clearance is not compromised. The results of this study show that in patients treated at a single institution over the same time period with comparable disease those treated by EFE had a lower local recurrence rate and improved cancer-free survival over those subjected to conventional surgery. The cost of the initial treatment for both groups was comparable and complication rates were similar.

Other studies have shown that local recurrence rates are related to Dukes’ stage of the cancer,\(^4\) tumour grade,\(^5\) tumour distance from the anal verge,\(^6\) inadequate distal and circumferential margins,\(^7\) and the use of adjuvant radiotherapy,\(^8\) as well as surgical technique.\(^9\) As this study is retrospective, factors other than surgical technique could confound the results. The local recurrence rate for EFE was lower than that for conventional surgery for each Dukes’ stage in this study (Table 7) making this an unlikely confounder. Histological differentiation of the tumours was similar in both groups and exclusion of the poorly differentiated tumours did not affect the analysis. There were more low and fewer high rectal cancers in the EFE group making local recurrence more likely in this group, indicating that this study should underestimate any decrease in local recurrence in the EFE patients. The importance of microscopic involvement of the circumferential margins has recently been identified but was reported by the pathologist in only 5 conventional surgery patients and 3 EFE patients. If these patients were excluded the results with respect to local recurrence and disease-free survival remained unchanged. A distal resection margin of 1 cm or less was
present in a similar percentage of patients in both groups and their exclusion did not alter the findings. Adjuvant radiotherapy was used in similar proportions of both groups and sub-analysis of the patients who did not have radiotherapy did not differ from the overall results. It would appear, therefore, that the difference in recurrence rate observed between the groups is truly related to surgical factors such as the technique, training and experience of the operator.

The crude local recurrence rates of 21% following conventional surgery and 6% after EFE are comparable with the pooled crude local recurrence rates reported by McCall\(^{167}\) of 8.8% for TME and 20.5% for patients having other techniques of resection.

Much of the variation in survival rates between studies can be attributed to differences in the make-up of the study populations. Factors such as inclusion of patients treated by palliative surgery, differing definitions of “curative surgery”, and different mix of stages in the study populations may have as much influence on survival rates in these studies as the individual treatment modalities. Overall 5-year survival rates for patients with Dukes’ B and C rectal cancer following surgery alone have been quoted from around 45\(^{73,81}\) to 74\(^{68}\). The present study, in which inclusion criteria and survival calculation were identical in the 2 groups, identified an overall 5-year survival rate of 60% for EFE and 54% for conventional surgery (ns). Cancer-free survival has been calculated in 2 different ways in the literature. Fisher\(^{73}\) required that patients be both alive and free of tumour to qualify, giving a lower cancer-free 5-year survival than overall survival (30% versus 43% respectively for surgery alone). Most authors, however, have calculated the cancer-free survival as the survival to recurrence of the tumour (patients who die of other causes without clinical recurrence being censored at death)\(^{81,107,117,184,290}\). Using this definition, studies employing TME by Heald\(^{107}\), Zaheer\(^{290}\), and Moriya\(^{184}\) have reported 5-year cancer-free survival rates of 80%, 78% and 69.4% respectively. The present study, reporting 5-year cancer-free survival rates of 74% for EFE and 63% for conventional surgery (p=0.02), provides evidence that EFE improves the cancer-free survival of rectal cancer patients.

Several authors have suggested that anastomotic leak rates are higher following total excision of the mesorectum\(^{18,33,88}\). This has been based on leak rates of 10-20% in selected studies\(^{3,33,95,137}\). Other series have reported leak rates of 5% or less after mesorectal excision\(^{68,290}\). Anastomotic leak is more common after low anterior resection\(^{12,221}\) and this has been cited as the reason for higher leak rates following TME\(^{18,88}\). In the present study leak rates for EFE and conventional surgery were similar (13% and 14% respectively) despite the fact that there were significantly more low tumours in the EFE group. Colonic J-pouch anastomosis may have a lower leak rate than end to end anastomosis\(^{97}\) but this technique has only been used in the most recent EFE patients. This study does not support the contention that excision of the complete mesorectum leads to higher leak rates.
Goldberg\textsuperscript{88} has claimed that TME is associated with a greater need for stomas to provide proximal diversion for the anastomosis. Although a diversion rate of 70\% has been reported for TME\textsuperscript{9} this study reported a stoma rate of 40\% for EFE and 37\% for conventional surgery with a similar numbers proceeding to successful closure.

Hospital stay was significantly longer following TME in one study that compared 76 patients having TME with 76 patients operated on before the introduction of TME. This was true even when patients with complications were excluded\textsuperscript{9}. The present study, with almost twice as many patients, shows no difference in hospital stay between EFE and conventional surgery patients.

Ideally sexual function should be assessed prospectively both preoperatively and postoperatively as has been demonstrated by Maas et al\textsuperscript{160} who showed that potency depended on intact pelvic plexuses and ejaculation required functioning hypogastric nerves. Unfortunately this could not be done in the present study as it was retrospective. However, an attempt was made to assess the sexual function of men after surgery for rectal cancer by EFE and conventional surgery. In this study 224 male patients who had undergone excisional surgery for rectal cancer at Auckland Hospital between 1980 and 1999 were identified. Of these 113 had died and another 17 could not be contacted. The remaining 94 patients were contacted with a questionnaire and 34 refused to participate in the study. This left 55 patients for assessment, 32 of whom had conventional surgery and 23 had EFE. Only 27 of the conventional surgery group were fully potent preoperatively and postoperatively 19 remained fully potent while 4 had partial potency and 4 were impotent. In the EFE patients 16 were fully potent preoperatively and postoperatively 12 remained fully potent while 3 had partial potency and 1 was impotent. Despite the large numbers initially involved the final numbers were inadequate to make any meaningful comment from these results. A further prospective study will be required to determine the actual rates of sexual dysfunction following EFE.

Treatment costs have assumed increasing importance in recent years and this issue has not been addressed previously in comparing EFE with conventional surgery. The present study has shown that initial treatment costs for both groups were similar. Local recurrence, however, has a significant financial cost (average NZ$10,471 in this study) as well as its associated morbidity and mortality.

In conclusion, this study adds further support to the growing evidence that excision of an intact mesorectum reduces local recurrence rates after surgery for rectal cancer. There appears to be an associated improvement in cancer-free survival. Complication rates and cost were not increased in the patients having EFE.
Section 4: The Practical Application-The Technique of Extrafascial Excision of the Rectum
Chapter 11: Extrafascial Excision of the Rectum for Cancer: How to Avoid the Complications of Rectal Mobilisation.

Introduction

The findings of the thesis have been incorporated into a new description of the operation of EFE. This chapter initially presents the anatomy of the rectum and its surrounding structures based on the findings of studies within this thesis and an extensive literature review. The technique of the operation is then described with particular emphasis on avoiding the complications of rectal cancer surgery.

Complications of Rectal Excision

The outcome of rectal cancer surgery depends on operative technique with complication rates varying widely between different surgeons [27,208]. The complications that may occur during mobilisation of the rectum include ureteric injury, rectal perforation, haemorrhage, and autonomic nerve damage [42], local recurrence of the tumour in the pelvis may occur later due to dissemination of the cancer during the rectal excision (Table 11.1).


Table 11.1: Complications of rectal excision

<table>
<thead>
<tr>
<th>Organ at Risk</th>
<th>Frequency</th>
<th>Cause of Damage</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ureter</td>
<td>1-4%&lt;sup&gt;17,8&lt;/sup&gt;</td>
<td>Failure to identify the ureter during mobilisation</td>
<td>Urinary leak, renal damage</td>
</tr>
<tr>
<td>Rectal Tube</td>
<td>20-25%&lt;sup&gt;207,238&lt;/sup&gt;</td>
<td>Excessive traction on rectum, blind dissection inside the mesorectum</td>
<td>Pelvic sepsis, increased local recurrence&lt;sup&gt;207,238&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rectal mesentery</td>
<td></td>
<td>Dissection inside the fascia propria</td>
<td>Haemorrhage&lt;sup&gt;267&lt;/sup&gt;</td>
</tr>
<tr>
<td>Presacral venous plexus</td>
<td>4%&lt;sup&gt;267&lt;/sup&gt;</td>
<td>Disruption of the presacral fascia by blunt or sharp dissection</td>
<td></td>
</tr>
<tr>
<td>Sacral basivertebral veins</td>
<td>1%&lt;sup&gt;267&lt;/sup&gt;</td>
<td>Disruption of the presacral fascia by blunt or sharp dissection</td>
<td>Life-threatening haemorrhage&lt;sup&gt;267&lt;/sup&gt;</td>
</tr>
<tr>
<td>Superior hypogastric plexus</td>
<td>19-59%&lt;sup&gt;160&lt;/sup&gt;</td>
<td>Dissection too far posterior at pelvic brim</td>
<td>Ejaculatory dysfunction&lt;sup&gt;14&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hypogastric nerves</td>
<td>19-59%&lt;sup&gt;160&lt;/sup&gt;</td>
<td>Dissection within the parietal fascia in pelvis</td>
<td>Ejaculatory dysfunction&lt;sup&gt;160&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pelvic plexus (Inferior hypogastric plexus)</td>
<td>14-100%&lt;sup&gt;270,63&lt;/sup&gt;</td>
<td>Dissection too far lateral in pelvis</td>
<td>Impotence and urinary dysfunction&lt;sup&gt;160,213&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
As described in Chapter 3, the operation of EFE involves dissecting directly on the fascia propria to remove the rectum and surrounding mesorectum intact. In this simple way total mesorectal excision can be accomplished without damage to the nerves and vessels in close proximity to the mesorectum, as demonstrated in Chapter 4, and local recurrence of the rectal cancer is reduced to a minimum (Chapter 10). To minimise the risks of mobilisation of the rectum meticulous dissection of the rectum in the correct plane is required. The performance of this relies upon a clear understanding of the anatomy of the rectum and its surrounding structures.

**Surgical Anatomy**

A schematic picture of pelvic anatomy is given in figure 11.1. It can be seen that the fascia propria surrounds the rectum and its mesorectum posteriorly and the fat and blood vessels posteriorly and laterally. There is a plane of loose areolar tissue separating the fascia propria from the parietal fascia in which is imbedded the autonomic nerve supply of the pelvic organs.

**Figure 11.1:** Schematic representation of a transverse section showing the relationship of the rectum to surrounding fasciae, blood vessels and nerves in the male pelvis (produced with the assistance of Mr. Arthur Ellis, medical illustrator).
The reality that faces the operating surgeon is more closely represented by the situation shown in figure 11.2, an axial section through the lower third of the rectum. It can be seen that the mesorectum fills the pelvis with the fascia propria pressing on the parietal fascia and the pelvic plexus. By traction and counter-traction the surgeon develops the areolar plane between the two fasciae in order to dissect directly on the glistening fascia propria.

Figure 11.2: An axial section of a cadaver at the level of the upper seminal vesicles showing the bladder (A) the seminal vesicles (B), the mesorectum (C), the fascia propria (D) and the pelvic plexus (E) abutting on the fascia propria. Reproduced from the Visible Human Data Set.

The fascia propria

In Chapter 3 it was shown that the fascia propria completely surrounds the rectum and mesorectum and can be dissected like a sock off freshly excised rectal specimens removed by extrafascial excision (figure 11.3). It has an average thickness of 154μm but is thicker on the posterior aspect. It is an upward capsular projection from the pelvic floor passing to the retroperitoneum and fusing with the submesothelial fibrous layer of the peritoneum where they meet. It is the fascial envelope in which the fat, blood vessels, nerves and lymphatics of the rectum are contained.
The parietal fascia

The parietal fascia is the loose, multilayered fascia that lines the walls of the pelvis. It is of variable thickness and its gossamer-like layers can be split surgically much like the skins of an onion (Moriya 1999 personal communication). It contains the superior hypogastric plexus, the hypogastric nerves and the pelvic plexuses as they run their course within the pelvis. The parietal fascia is thickened where it is adherent to the periosteum over the sacrum (the presacral fascia) where it is tightly adherent to the concavity of the sacral periosteum especially in the midline and around the margins of the anterior sacral foramina. When it is intact it provides protection to the presacral veins and nerves that lie within it. Crapp and Cuthbertson described...
an attachment between the parietal fascia and the fascia propria at the level of the body of S4, 3-5cm proximal to the ano-rectal junction, which they have called “the rectosacral ligament”. What is seen by the operating surgeon, whilst applying firm pressure and anterior traction on the rectum, is that the fascia propria and the parietal fascia fuse in most patients around the level of S4. This varies from several layers of parietal fascia passing forwards and attaching to the fascia propria of the rectum as a “ligament” to a diffuse adherence between the 2 fasciae. Distal to this attachment between the fascia propria and the parietal fascia lies a space below the horizontal part of the rectum. Once the surgeon has divided this attachment the parietal fascia clothing the distal sacrum frequently appears thinner below this level and the fascia propria over the distal mesorectum appears thicker and may be composed of two distinct layers.

The lateral ligaments

There is considerable confusion surrounding the nature of the lateral ligaments. Some claim that they are merely an artefact produced by the surgical dissection, but others state that they represent real structures joining the parietal fascia overlying the pelvic sidewall to the fascia propria medially. Boxall showed that the middle rectal artery did not pass in the lateral ligament but that an accessory, middle rectal artery, could be found in the ligament unilaterally in 25% of individuals. This has been substantiated by others. Rutegard et al have clarified the situation by showing that the main components of the lateral ligament are autonomic nerves passing from the pelvic plexus to the rectum within a condensation of connective tissue. The studies in Chapter 4 have shown that these nerves can be identified about 2 cm below the lateral peritoneal reflection and are about 12mm in length after dissection in the extrafascial plane.

The fascia of Denonvilliers

The fascia of Denonvilliers (the rectovesical fascia in the male and rectovaginal septum in the female) is formed by the fusion of the 2 leaves of the peritoneum of the rectovesical pouch during embryonic life. It is white, thick and quite distinct to the surgical eye in young people but may be difficult to identify in the very old. It lies anterior to the fascia propria passing from the peritoneum of the rectovesical pouch above, to the pelvic floor in the region of the perineal body below. Its lateral edges are not clearly defined.
The retrorectal space

The retrorectal space is the avascular plane of loose areolar tissue that lies between the parietal fascia and the fascia propria anteriorly. It is the “holy plane” referred to by Heald\textsuperscript{104}. This space continues down to the adherence of these fasciae at the “rectosacral ligament” and is crossed laterally by the variable lateral ligaments. After division of the “rectosacral ligament” a similar space continues below the horizontal rectum to the ano-rectal junction. Thus, apart from the lateral ligaments and the rectosacral ligament, there is a plane of loose connective tissue that completely surrounds the fascia propria. This plane is easily identified posteriorly but may be difficult to develop laterally in the lower third of the rectum. Where the fascia of Denonvilliers is closely adherent to the fascia propria anteriorly the surgeon can, with careful traction and counter-traction develop an areolar plane between the two.

The mesorectum

Within the envelope of the fascia propria lie the terminal branches of the inferior mesenteric artery (IMA), the associated veins and lymphatics and a variable pad of supporting fat - the mesorectum. This fat pad may be hugely thick and bulky which in a narrow pelvis makes insertion of the surgeon’s hand difficult or in wasted patients quite thin and almost non-existent in its most distal portion. This structure, although lying posterior to the rectum at the rectosigmoid junction, completely surrounds the rectum over most of its length (figure 11.2). It is not always realized that at the point where the fascia propria and the parietal fascia are adherent the mesorectum with the contained rectal tube sharply angulates anteriorly. The surgeon dissecting on the fascia propria on the posterior surface of the mesorectum from above passes initially posteriorly then after division of the rectosacral ligament the dissection plane turns abruptly anteriorly at a right angle at the level of S4. This anterior angulation on the posterior surface of the mesorectum is illustrated in figure 11.4 (from Chapter 5).

The mesorectum, contained within the fascia propria, constitutes the visceral compartment of the rectum and the contents within the fascial envelope should be removed intact in rectal cancer surgery to prevent local recurrence\textsuperscript{18, 108}. Beart has described this graphically as the removal of the rectum without “cracking” the fascial envelope\textsuperscript{18}. 

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Figure 11.4: A three-dimensional reconstruction of the rectum, mesorectum and fascia propria. This model was reconstructed from 80 separate 1mm axial slices of the pelvis obtained from the Visible Human Data Set with permission. Note the abrupt angulation (arrow) as the rectum turns anteriorly at the level of S4.

**Presacral veins**

The large venous plexus on the surface of the low sacrum may be damaged by the surgeon but even more severe is the extensive haemorrhage that may occur from the sacral basivertebral veins that connect the presacral venous plexus to the intrasacral canal venous plexus\textsuperscript{267}. Stripping of the presacral fascia with the underlying periosteum off the sacrum can rupture these connecting veins that then retract into the sacral foramina and bleed profusely\textsuperscript{267}. Ensuring that the plane of dissection in rectal excision is anterior to the presacral fascia avoids this complication. Surgeons should learn to dissect in the extrafascial plane without touching the presacral fascia during the operation of rectal excision.

**Pelvic Nerves**

The pelvic autonomic nerves surround the rectum and mesorectum and are at risk in rectal surgery. They lie in the parietal fascia and comprise the superior hypogastric plexus (SHP), the hypogastric nerves (HN), the pelvic splanchnic nerves, and the pelvic plexuses (PP) sometimes
referred to as the inferior hypogastric plexuses. Based on dissections performed for the studies presented in chapters 3 and 4, a simplified schema, which shows the essential anatomy of importance to the surgeon, is shown in Figure 11.5.

![Figure 11.5: Pelvic autonomic nerves after mobilisation of the rectum in the extrafascial plane. The peritoneum is shown in blue and the parietal fascia by partial white shading. The diagram is based on photographs of the dissections in Chapters 3 and 4. The proportions of the different organs are not strictly maintained in this schematic figure.](image)

**Superior hypogastric plexus**

The SHP is a network of pre- and post-ganglionic fibres (T10-L2) anterior to the body of L5. It is a continuation of the pre-aortic sympathetic trunks. It lies in a layer of parietal fascia which, above the pelvic brim is quite adherent to the fascia propria and these nerves are at risk early on when the inferior mesenteric and superior rectal vessels are being mobilised. The plexus can be identified by the surgeon as tight cords of nerve fibres that can be palpated posterior to the inferior mesenteric artery as it runs down into the pelvis. Mass clamping of the inferior mesenteric vessels may damage these fibres leading to ejaculatory disorders. It gives rise to the two HNs over the prominence of the sacrum (figure 11.5).
**Hypogastric nerves**

The HNs pass down around the lateral wall of the pelvis from the SHP to the PP. They vary in gross anatomy, sometimes consisting of fine filaments spreading out over a width of about 1 cm, and sometimes being distinct flat nerves 5-8 mm wide\(^2\). They run in a course parallel with the ureter 1-2 cm medial to it\(^1\). They join the pelvic parasympathetics to form the pelvic plexus on each side\(^1\). A recent study\(^\) has shown that division of these nerves leads to ejaculatory dysfunction in men. The HNs are at particular risk as the rectum is retracted anteriorly to dissect in the retrorectal space. If the nerves appear to run into the mesorectum at this level, the surgeon should understand that the dissection plane is too posterior and is, in fact, within the parietal fascia. It is necessary then to redevelop a more anterior plane on the fascia propria immediately posterior to the superior rectal artery.

**Pelvic splanchnic nerves**

The pelvic splanchnic nerves (pelvic parasympathetics) arise from the anterior nerve roots of S3 and S4 (occasionally S2) about 1 cm distal to their point of emergence from the piriformis muscle. At this point the nerves lie deep to the parietal pelvic fascia that covers the piriformis muscle\(^1\). As the nerves approach the ischial spine they enter the parietal fascia to lie in its superficial portion where they join the PP. The surgeon who is dissecting hard on the fascia propria is unlikely to see or damage these nerves as they lie outside the plane of dissection embedded in the parietal fascia.

**Pelvic Plexus**

This is a network of sympathetic and parasympathetic fibres from the HN and pelvic splanchnic nerves. It lies outside the fascia propria in the superficial layer of parietal fascia (Figure 11.1) as a plaque of nerves about 3 x 3 cm in size\(^2\) (see Chapter 4). During EFE, the dissecting plane is more medial and the surgeon will rarely see the plexus except in very thin patients. Its most superficial (medial) portion contains the HNs and that part of the PP that sends branches to the rectum\(^1\). These nerves passing to the rectum can be identified about 2 cm below the peritoneal reflection on each side (see Chapter 4) and as pointed out above are the substance of the so-called “lateral ligament” of the rectum. Damage to the PP is associated with urinary dysfunction and impotence in men\(^1, 121, 213\). A neurovascular bundle that passes from the pelvic plexus to supply the corpora has been identified lying immediately anterior to Denonvilliers’ fascia coursing along the lateral surface of the seminal vesicles\(^1\) (Figure 11.6). This is particularly at risk in dissecting the antero-lateral aspect of the lower part of the rectum.
Figure 11.6: An axial section through the lower seminal vesicle showing the bladder neck (A), the seminal vesicles (B), Denovilliers’ fascia (C), the rectum (D), and the neurovascular bundle (E) that is passing down to the corpora. Reproduced from the Visible Human Data Set.

The Technique of Extrafascial Excision

This technique for rectal mobilisation has been entitled “extrafascial excision” (EFE) to emphasize the importance of dissecting directly on the outer surface of the fascia propria. It is a total mesorectal excision (TME) as described by Heald\textsuperscript{108} with emphasis on the fascia propria as the landmark for dissection rather than the loose areolar tissue (the “holy plane”) outside it.

A detailed description of the pre- and postoperative management of these patients is beyond the scope of this chapter, but the essentials include preoperative counselling, stoma marking, bowel preparation and antibiotic and thromboembolism prophylaxis. The patient is placed in the Lloyd-Davies position and an indwelling urethral catheter inserted. A good headlight, 2 assistants and the St Mark’s deep pelvic retractor are all helpful for adequate exposure. The choice between a long, left paramedian or midline incision depends on previous incisions and the stoma site but the incision should extend down to the pubic symphysis for maximal exposure in the pelvis.
Initially a thorough laparotomy is performed especially looking for metastatic disease in the liver or retroperitoneum and synchronous colonic lesions. A large self-retaining retractor is inserted into the wound and the small bowel is packed away from the operative field.

Mobilisation of the sigmoid colon

Any abnormal attachments between the sigmoid colon and the peritoneum are divided to display the “white line” of attachment of the sigmoid mesentery to the paracolic peritoneum. A tape is placed around the distal sigmoid and tied to prevent movement of contents in either direction. The sigmoid colon is then grasped in the hand of the assistant and retracted medially as the surgeon dissects sharply along the “white line” and the filmy fascia that separates the sigmoid mesocolon from the retroperitoneal structures. As this is performed the gonadal vessels and ureter are left undisturbed in the retroperitoneum after definitive identification. This dissection continues to the midline in the intersigmoid fossa where the fingers of the left hand are passed behind the inferior mesenteric vessels allowing the safe incision of the peritoneum on the right side of the sigmoid mesocolon. This incision in the peritoneum is extended up to the third part of the duodenum. The inferior mesenteric artery is palpated between the thumb and index finger and any nerve fibres that are felt as tight bands posterior to the artery are carefully separated and pushed back with the other retroperitoneal structures. After again checking the position of the left ureter, the inferior mesenteric artery is isolated and divided just proximal to its left colic branch. This leaves 1-2cm of the origin of the inferior mesenteric artery in place to prevent damage to the superior hypogastric plexus lying on the front of the aorta. The inferior mesenteric vein is taken separately just below the inferior border of the pancreas. It may be helpful at this stage to divide the sigmoid colon with the GIA stapler allowing easier anterior retraction in the pelvic dissection.

Posterior pelvic dissection

It is essential to enter the pelvis in the correct plane as straying posteriorly puts the superior hypogastric plexus and hypogastric nerves at risk. Dissection anterior to the fascia propria almost certainly means broaching the mesorectum and may result in higher rates of pelvic recurrence of cancer106. The outer surface of the fascia propria marks the watershed between the mesorectum and the surrounding parietal structures and this structure is identified at the pelvic brim. The key to finding the correct plane is the superior rectal artery at the pelvic brim. The superior rectal artery lies immediately anterior to the fascia propria at the sacral promontory. By dissecting hard on the posterior surface of the artery the surgeon is led onto the glistening fascia propria. The combination of dissection on the artery and anterior retraction of the distal
sigmoid colon opens the extrafascial plane posterior to the mesorectum, which should be entered by sharp dissection hard on the shiny fascia overlying the superior rectal artery. The principle of EFE is to dissect on the fascia propria i.e. the scissors slide along it (in this way they do not roam laterally damaging nerves and veins). Dissection in this plane will take the surgeon down into the retrorectal space anterior and well medial to the hypogastric nerves in their enveloping parietal fascia. In fact, if the hypogastric nerves are coming into the dissection the surgeon is in the wrong plane. At about the level of S4 the adherence between the fascia propria and the presacral fascia is encountered. Traction on the rectum often makes this into a rectosacral ligament which is divided sharply to enter the space lying inferior to the horizontal (distal) rectum. Once this adherence between the fascia propria and the parietal fascia is divided dissection, which now passes sharply forward, is continued directly on the fascia propria right up to the ano-rectal junction.

**Anterior dissection**

The anterior dissection is best done after the posterior dissection has gone as far as possible. The anterior peritoneum is divided just behind the seminal vesicles in the male and anterior to the reflection of the peritoneum in the pouch of Douglas in the female. The dissection for cancer is carried down on and in front of Denonvilliers’ fascia that is divided transversely 1 cm below the base of the prostate in the male and opposite the vault of the vagina in the female. The autonomic nerves are at risk at this point as they lie laterally just anterior to the fascia of Denonvilliers. In benign disease the anterior dissection is carried out in the plane between the fascia propria and Denonvilliers’ fascia. The anterior plane between Denonvilliers’ fascia and the fascia propria is developed by firm anterior retraction by means of the deep pelvic retractor (with its lip inserted just deep to Devonvilliers’ fascia) and firm posterior traction exerted by the left hand of the surgeon. In this plane the dissection passes distally down to the ano-rectal junction.

**Lateral dissection**

Once the anterior dissection is done then the most difficult part of the operation, the lower third lateral dissection, can more easily be accomplished. The peritoneum lateral to the rectum is divided as the posterior dissection is continued laterally hard on the fascia propria. In very thin patients the fascia propria can be seen fairly easily but in others firm medial traction on the rectum and gentle lateral counter-traction demonstrate the loose areolar plane just outside the fascia. The lateral ligaments containing the nerves to the rectum from the pelvic plexus are situated about 2 cm below the peritoneum lateral to the rectum222 (see Chapter 4). They can be
palpated between the fingers once anterior and posterior dissection has been completed. Dissection in the extrafascial plane allows them to be stretched to a length of 1-1.5cm so that they can be divided safely without disturbing the pelvic plexus on the pelvic sidewall. Extensive traction, however, will cause “tenting” of the pelvic plexus and put it at risk\textsuperscript{190}. As they seldom contain any blood vessels of note the lateral ligaments can be safely divided without ligation. The dissection is continued down to the pelvic floor laterally and anteriorly (except in tumours in the upper rectum where the mesorectum is divided at least 5 cm below the distal edge of the tumour). A complete dissection of the rectum in the extrafascial plane has been performed down to the pelvic floor. The rectum can now be transected or a perineal approach performed for abdomino-perineal excision.

Summary

The key to the prevention of the complications of rectal mobilisation is a clear understanding of its anatomy and the surgeon’s determination to preserve the fascial envelope surrounding the mesorectum. The left ureter needs to be identified early in sigmoid mobilisation and preserved. Identification of the fascia propria at the pelvic brim and dissecting circumferentially directly on its surface will ensure that the pelvic nerves are not damaged, the presacral veins remain undisturbed, the rectum is removed intact and local recurrence rates will be minimal.
Chapter 12: Summary and Conclusions

Research Questions

The present studies have addressed several important areas of uncertainty in the management of patients with rectal cancer by answering the following research questions.

Does the fascia propria surround the mesorectum as a complete membrane?

What are the characteristics (composition, thickness and attachments) of the fascia propria?

Where do the pelvic autonomic nerves lie as they pass through the pelvis?

What are the relations of the fascia propria and the pelvic autonomic nerves?

Can the fascia propria be identified using preoperative imaging?

Can preoperative imaging determine the relationship of the deepest tumour invasion to the fascia propria?

Does extrafascial excision of the rectum (EFE) have a lower local recurrence rate than conventional surgery?

Does EFE have a higher cost and complication rate than conventional surgery?

Is survival or disease free survival improved by EFE?

The Anatomy of the Fascia Propria

Findings

Although differing descriptions have been reported of the anatomy of the fascia propria\textsuperscript{42, 75, 101, 250, 261}, the present study is the first to conclusively demonstrate that the fascia propria is a complete, circumferential membrane surrounding the mesorectum. This was achieved both by dissecting the intact “sock” of fascia propria off the underlying mesorectum and by identifying
and measuring the fascia propria on all four quadrants of histological cross-sections of the rectum. The fascia propria fuses with the outer muscle of the rectum at the ano-rectal junction and with the submesothelial layer of the peritoneum above. It is also adherent to the parietal fascia at about the level of S4 posteriorly and is joined by the nerves passing to the rectum from the pelvic plexuses antero-laterally.

The ultrastructure of the fascia propria has been demonstrated by electron microscopy for the first time. This and specially stained histological sections have shown that it is composed predominantly of collagen and is about 150µm thick being thicker on its posterior aspect.

The first described three-dimensional model of the anatomy of the fascia propria has also been constructed both from anatomical sections and MR images from preoperative rectal cancer patients. This computerised model is an aid to the surgeon in conceptualising extrafascial dissection along the surface of the fascia propria.

**Applications**

These anatomical findings provide a sound foundation for the understanding of any operation attempting to remove the intact mesorectum within its fascial envelope. In particular, the operation of extrafascial excision (EFE) is a logical expression of this anatomical understanding. The fascia propria can be easily identified at the pelvic brim and the fascia itself offers a surface against which the surgeon is able to safely dissect circumferentially to remove the mesorectum. The discovery of a complete envelope “containing” the rectum and its tumour-bearing lymphatics also has significant oncological implications. Not only does the fascia propria provide a guide to the surgeon but it also represents the watershed between the visceral and parietal lymphatic drainage systems.

These findings have an important application in the training and accreditation of surgeons for the future. The anatomy is now clearly described and accurate diagrams can assist surgeons in training and be incorporated into workshops to ensure that those operating for rectal cancer perform the best operation. The three-dimensional models also help the surgeon to “visualise” the orientation of the planes of dissection as the different surfaces of the fascia propria are encountered.
The Anatomy of the Pelvic Autonomic Nerves

Findings
The position of the pelvic autonomic nerves has been clearly defined. They lie embedded in the parietal fascia well outside the membrane of the fascia propria. The pelvic plexuses have been measured and shown to be 3cm by 3cm in size. Their position in the bony pelvis has been pinpointed for the first time using cadaveric dissection and x-ray localisation. The midpoint of the plexus lies just below a line joining the two acetabula as seen on an AP pelvic x-ray. A plane of loose areolar tissue posterior to the hypogastric nerves has been identified in the majority of dissections performed. There is, however, considerable individual variation in the retrorectal fascial anatomy with 3 of the 10 subjects having no clear plane identifiable posterior to the hypogastric nerves.

Applications
The high incidence of sexual dysfunction reported following surgery for rectal cancer often results from inadvertent injury to the pelvic autonomic nerves during dissection. The clear identification of the fascial plane in which the hypogastric nerves and the pelvic plexuses are found has the potential to reduce the morbidity of this surgery especially when it is coupled with the description of a technique of operating directly on the fascia propria inside this plane. Further, the localisation of the pelvic plexuses radiologically allows the clinician to accurately assess the relation of the tumour to the pelvic plexuses using axial imaging. This knowledge in the preoperative setting provides the surgeon with the opportunity to plan surgery more precisely and counsel the patient with greater confidence regarding the risks of nerve damage.

Preoperative Imaging

Findings
Although many studies have been carried out assessing the ability of CT, ES, and MR in predicting both bowel wall penetration and lymph node involvement by tumour, the accuracy of preoperative radiology at assessing the deepest tumour invasion in relation to the fascia propria has not been reported previously. The present studies have used cadaveric dissection in
combination with CT and MR imaging to show for the first time that the perirectal fascia seen on axial imaging is in fact the fascia propria that is the landmark for dissection in EFE. This fascia is seen more clearly on MR than CT being able to be visualised in the vast majority of patients. By comparing preoperative thin-sliced axial MR images with postoperative histological findings in over 40 patients we have also shown that the relationship of the tumour to the investing fascia propria can be assessed accurately. These images can also be combined to generate a three-dimensional model of the rectum, mesorectum, and tumour within the fascia propria which can be sectioned in any plane and visualised from any angle.

**Applications**

Present management protocols recommend radiotherapy for all patients with Dukes’ stage B or C cancer\(^{200}\) to reduce the incidence of local recurrence. Recent studies\(^{107, 117}\), however, suggest that this treatment, with its associated side-effects, can be avoided in patients whose tumour is contained within the fascia propria provided their surgery involves an extrafascial excision. The finding that the fascia propria can be located on MR imaging and that the relation of the deepest tumour invasion to it can be accurately predicted opens the way for a new approach to the management of rectal cancer surgery. Preoperative thin-sliced MR imaging can be used to select patients for individualised treatments. Patients whose preoperative MR images indicate that the tumour is contained within the fascia propria can proceed directly to EFE, whereas those whose MR indicates that the tumour has invaded through the fascia propria can be selected for preoperative radiation. This approach should have the combined benefits of sparing patients the morbidity of radiotherapy and the health system the associated cost of this treatment without increasing the risk of patients developing local recurrence. In Auckland Hospital rectal cancer patients are already being managed according to this regimen, the results in terms of local recurrence rates and survival, however, will not be available for several years.

**Clinical Results of EFE**

**Findings**

A cohort study involving 262 patients undergoing curative surgery for rectal cancer in a single institute over a 16 year time period has been reported. Although other studies have compared the results of different surgeons and techniques, this study is unique in that it takes all rectal cancer patients operated on in a single institution over the same time period using different techniques. This has shown that EFE is associated with a significantly lower local recurrence
rate and a prolonged cancer-free survival when compared with patients undergoing conventional surgery. Other authors have claimed that TME is associated with longer hospital stays\textsuperscript{33}, higher rates of defunctioning stoma formation\textsuperscript{88} and more anastomotic leaks\textsuperscript{33, 88} than conventional surgery. The present study, however, has shown no difference in the hospital stay, stoma rates or anastomotic leak rates. The cost of initial treatment for both groups was similar but local recurrence added an extra cost of over $10,000 for those who experienced it.

Applications

The results indicate that those surgeons who have been taught to perform EFE have improved results when compared with other surgeons. This has significant implications for the training and ongoing accreditation of colorectal surgeons. Those involved in the management of rectal cancer patients should be able to demonstrate their ability to perform a rectal excision in the extrafascial plane. It also has ethical and legal ramifications for those involved in the assignment of medical resources. In the present climate, where the quality of medical treatment and clinical outcomes are audited, institutions that accept less than optimal treatment may be held accountable if they accept less than optimal management of patients.

The Future

The studies reported in this thesis have implications for research and treatment in the future. The anatomical findings suggest further studies to determine whether the fascia propria has a role as a barrier to tumour spread, and to identify the changes (both in ultrastructure and composition) that occur in the fascia propria in response to tumour invasion. The individual variation in the anatomy of the retrorectal fascial planes and the hypogastric nerves requires further study to elucidate the frequency of such variability and its impact on surgery.

The three-dimensional reconstruction of the tumour and fascia propria could be applied to conformal radiotherapy allowing high-dose radiation to a more accurately localised area. One can even imagine in the near future, with improvements in imaging and computer software, these findings may lead to the ability to perform preoperative imaging, reconstructed in three-dimensions, that would lead to virtual planning of the surgery. Each step of the operation could be planned on the computer reconstruction to ensure adequate tumour clearance while still preserving the pelvic autonomic nerves. The applications could perhaps even extend to robotics and telesurgery.
The logical outworking of the clinical study would involve a randomised controlled trial of EFE with selective preoperative radiotherapy, based on the relation of the deepest tumour invasion to the fascia propria on MR imaging, versus EFE with routine preoperative radiotherapy. The findings of an ongoing study in Holland will shed light on this issue.

For today, however, this thesis demonstrates that accurate preoperative assessment, appropriate selection of patients for adjuvant therapy, and careful surgery, performed under direct vision along a known fascial plane, are essential to provide optimal outcomes for rectal cancer patients.
## Appendix A: Tables of Systematic Review of Radiological Staging of Rectal Cancer

### Table A.1: Studies assessing wall penetration with CT

<table>
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<th>First Author</th>
<th>Ref Year</th>
<th>Patient Subgroup</th>
<th>No of patients</th>
<th>Scan thickness</th>
<th>Contrast</th>
<th>Patients Analysed</th>
<th>ACC</th>
<th>SEN</th>
<th>SPE</th>
<th>PPV</th>
<th>NPV</th>
<th>PLR</th>
<th>NLR</th>
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<td>Not specified</td>
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<td>53%</td>
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Max: 100% 100% 100% 100% 100% 8.86 1.22 |
Min: 52% 53% 27% 56% 15% 0.92 0.00 |
Median: 79% 85% 67% 83% 74% 2.19 0.22 |

CT, computed tomography staging; ACC, accuracy; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; n/a, not applicable.
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Max: 98% 100% 100% 100% 100% 18.86 2.00
Min: 43% 0% 0% 43% 33% 0.83 0.00
Median: 89% 93% 81% 89% 88% 4.43 0.09

ES, endorectal sonography staging; ACC, accuracy; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; n/a, not applicable.
<table>
<thead>
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<th>ACC</th>
<th>SEN</th>
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* In these studies, the same group of patients underwent tests of different types

Max: 95% 100% 100% 100% 100% 11.00 0.40
Min: 73% 64% 42% 69% 54% 1.52 0.00
Median: 82% 83% 80% 82% 80% 4.00 0.22

MR, magnetic resonance staging; PPA, pelvic phased array coil; ACC, accuracy; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; n/a, not applicable.
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Max: 100% 100% 100% 100% 100% 12.92 1.00
Min: 35% 25% 50% 33% 20% 1.00 0.00
Median: 71% 46% 83% 78% 69% 2.66 0.72

CT, computed tomography staging; ACC, accuracy; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; n/a, not applicable.
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Max: 87% 94% 100% 100% 95% 10.42 1.20
Min: 44% 0% 0% 25% 0% 0.50 0.09
Median: 74% 65% 78% 70% 79% 2.96 0.42

ES, endorectal sonography staging; ACC, accuracy; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; n/a, not applicable.
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<th>Patients Analysed</th>
<th>ACC</th>
<th>SEN</th>
<th>SPE</th>
<th>PPV</th>
<th>NPV</th>
<th>PLR</th>
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<td>Barbaro B.</td>
<td>15</td>
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<td>61</td>
<td>Size</td>
<td>29</td>
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<td>38%</td>
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<td>&gt; 5mm</td>
<td>46</td>
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<td>83%</td>
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<td>76%</td>
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<td>3.17</td>
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<td>57%</td>
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<td>53%</td>
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<tr>
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<td>&gt; 5mm, Consistency</td>
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<td>84%</td>
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<td>100%</td>
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<td>57%</td>
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<td>100%</td>
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<td>n/a</td>
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* In these studies, the same group of patients underwent tests of different types

Max: 94% 100% 100% 100% 100% 13.71 0.99
Min: 39% 13% 0% 67% 35% 1.00 0.00
Median: 78% 62% 82% 74% 81% 3.40 0.46

MR, magnetic resonance staging; ACC, accuracy; SEN, sensitivity; SPE, specificity; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; n/a, not applicable.
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