Title

Ex-vivo specimen MRI and pathology confirm a recto-sigmoid mesenteric waist at the junction of the mesorectum and mesocolon

Authors

N. D'Souza[1, 2, 3], A. Lord[1, 2, 3], A. Shaw[1, 2, 3], A. Patel[2], S. Balyasnikova[2], V. Tudyka[4], M. Abulafi[1], B. Moran[5], S. Rasheed[2, 3], P. Tekkis[2, 3], J.C. Coffey[6], M. Terlizzo[2], N.P. West[7], P. Quirke[7], G. Brown[2, 3]

1. Croydon University Hospital
2. Royal Marsden Hospital
3. Imperial College London
4. Kingston Hospital
5. Basingstoke Hospital
6. University Hospital Limerick and University of Limerick
7. Pathology & Data Analytics, Leeds Institute of Medical Research at St. James's, University of Leeds

Nigel D'Souza BA, MBBS, MRCS, MEd. Colorectal Research Fellow

Amy Lord MBBS, FRCS. Colorectal Research Fellow

Annabel Shaw MBBS, FRCS. Colorectal Research Fellow

Anisha Patel, MBChB, FRCR. Consultant Radiologist

Svetlana Balyasnikova MD, PhD. Clinical Fellow in Radiology

Vera Tudkya BSc, MSc, FRCS. Consultant Colorectal Surgeon

Muti Abulafi MS, FRCS. Consultant Colorectal Surgeon

Brendan Moran, MCh, FRCS, FRCSI (Gen). Consultant Colorectal Surgeon

Shanawaz Rasheed, BclinSci, MBBS, DIC, PhD, FRCS. Consultant Colorectal Surgeon and Senior Lecturer

Paris Tekkis BMedSci, MBBS, MD, FRCS. Professor of Colorectal Surgery

John Calvin Coffey, BSc, MBChB, PhD, FRCSI (Gen). Professor of Colorectal Surgery

Monica Terlizzo, MD, FRCPath. Consultant Histopathologist

Nicholas P. West, BSc, MBChB, PhD, FRCPath. Professor of Pathology

Philip Quirke, BM, PhD, FRCPath, FRCSEd (ad hominem), FMEdSci. Professor of Pathology

Gina Brown MBBS, MD, MRCP, FRCR, FASCRS. Professor of Gastrointestinal Imaging

Corresponding Authors

Nigel D'Souza: Nigel.D'Souza@nhs.net

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Abstract

Introduction

Continuity of the mesentery has recently been established and may provide an anatomical basis for optimal colorectal resectional surgery. Preliminary data from operative specimen measurements suggests there is a tapering in the mesentery of the distal sigmoid. A mesenteric waist in this area may be a risk factor for local recurrence of colorectal cancer. This study aimed to investigate the anatomical characteristics of the mesentery at the colorectal junction.

Methods

In this cross-sectional study, 20 patients were recruited. After planned colorectal resection, the surgical specimens were scanned in a magnetic resonance imaging (MRI) system, and subsequently dissected and photographed as per national pathology guidelines. Mesenteric surface area and linear measurements were compared on MRI and pathology to establish the presence and location of a mesenteric waist.

Results

Specimen analysis confirmed that a narrowing in mesenteric surface area was consistently apparent at the rectosigmoid junction. Above the anterior peritoneal reflection, the surface area and posterior distance of the mesentery of the upper rectum initially decreased before increasing as the mesentery of the sigmoid colon. These anatomical properties created the appearance of a mesenteric "waist" at the rectosigmoid junction. Using the anterior reflection as a reference landmark, the rectosigmoid waist occurred at a mean height of 23.6mm and 21.7mm on MRI and pathology respectively.

Conclusion

A rectosigmoid waist occurs at the junction of the mesorectum and mesocolon, and is a mesenteric landmark for the rectum that is found on both radiology and pathology.

What does this paper add to the literature?

A narrowing of the sigmoid mesentery has been described but not formally investigated. This study identified a mesenteric waist at the rectosigmoid junction. This is a landmark for the rectum found on both pathology and radiology. Tumours in the rectosigmoid may be prone to local recurrence due to the paucity of surrounding mesenteric tissue.

Introduction

Recent investigations into mesenteric anatomy have confirmed mesenteric continuity and support anatomical approaches to surgery for colorectal cancer such as total mesorectal excision (TME) and complete mesocolic excision (CME) (1). The concept that the mesentery of the gastrointestinal tract is a continuous, single entity has been demonstrated in cadaveric and surgical studies (2, 3). Dissection in the mesenteric-based planes during resection of the intestine has been described in rectal cancer with total mesorectal excision (4), and more recently in colon cancer in complete mesocolic excision (5). Along the mesentery, there are points where dissection may be technically challenging and hazardous. This was previously found to be the case in the low rectum where involvement of the circumferential resection margin was common at the insertion of the levators and puborectalis, due to the paucity of surrounding mesenteric tissue (6, 7). Pre-operative imaging enables a bespoke, patient-specific treatment plan and surgical approach (8). The application of this approach in low rectal cancer, has led to a reduced risk of margin involvement by undertaking more extensive surgery if necessary (9).

Non-peritonealised resection margin involvement varies between 4-20% in resections for sigmoid colon cancer, contributing to a pooled local recurrence rate of 10.5% (10). Recently, Culligan *et al*. suggested that the mesentery narrows markedly at the junction between the mesosigmoid and mesorectum (3). It is important to investigate these suggestions as continuity between mesosigmoid and mesorectum could be of importance to cancer spread in either direction. In addition, a determination of the anatomical properties of this region of mesentery could have corresponding implications for sigmoid and rectal surgery.

This study aimed to characterise the anatomy of the mesentery at the colorectal junction by investigating whether a sigmoid mesenteric narrowing exists.

Methods

This cross-sectional, non-interventional single centre study was designed with patient involvement. The study received research ethics committee approval from the Health Research Authority in the UK (IRAS no 220869) as well as from the local institutional review board. An exploratory sample size of 20 was calculated based on a previous imaging/specimen study of the low rectal waist (6).

The primary endpoint was to determine if a mesenteric narrowing occurs in the sigmoid mesentery. Eligible patients were identified during the colorectal multidisciplinary team meeting at an international referral centre treating high volumes of patients with advanced pelvic malignancy. Patients were included if they were above 18 years, were due to undergo rectal cancer surgery that included the anterior peritoneal reflection and consented to take part in the study. Exclusion criteria were patients that could not undergo MRI, had undergone previous rectal or sigmoid colon surgery, or underwent surgery that did not include the anterior peritoneal reflection or the sigmoid mesentery.

Patients underwent routine pre-operative MRI scanning of their pelvis, reported on a standard proforma by two gastrointestinal radiologists, each with over 10 years experience. The pre-operative MRI determined patient eligibility ie requirement for low rectal resection. Surgery was performed using a mesenteric-based technique by one of two consultant colorectal surgeons, each with over 10 years experience. In cases of locally advanced low rectal cancer, a beyond TME approach was utilised.

Immediately following surgery, specimens were opened along the anterior peritoneal surface down to the level of the anterior peritoneal reflection, washed out and immersed in formalin for a minimum of 48 hours. Formalin-fixed specimens underwent MRI scanning whilst fixed to a corkboard along their longitudinal axis using wooden toothpicks (Figure 1). Cod liver oil tablets were sutured to the anterior peritoneal reflection to act as a marker. Specimens were scanned in a 3T Phillips MRI Imaging system. Axial slices were taken at 3mm intervals, in addition to coronal and sagittal views.

Figure 1: specimen photograph (top) prior to MRI scan (bottom, coronal view). Blue lines represent transverse/axial slices taken during pathology and MRI processing.

Following the MRI scan, specimens were returned to formalin for a minimum of 7 days. The specimen was subsequently sliced at 5mm intervals as per Royal College of Pathologists guidelines (11). Photographs were taken of these cross sectional slices using a high definition camera mounted on a tripod with a ruler for calibration (figure 2).

Figure 2: Serial cross-sectional slices through the formalin-fixed pathology specimen taken at 5 mm intervals, from top right. Posterior mesenteric distances (marked with black arrows) become greater from distal to proximal as the mesorectum becomes the sigmoid mesocolon. Waist in mesenteric surface area (marked with W) hypothesised to occur between sigmoid mesocolon and level of anterior peritoneal reflection (marked with star).

Mesenteric surface area and quadrant linear distances (posterior, left and right) above the anterior peritoneal reflection were measured per slice on MRI in the axial plane using Sectra PACS (Sectra Workstation IDS7, Sectra AB, Linköping, Sweden) and on pathology photographs using Digimizer (version 6.6.1, copyright MedCalc Software, Ostend, Belgium) software (see figure 3).

Figure 3: Measurements of mesenteric surface area and linear distances on were performed on each MRI and pathology specimen slices. Labelled: posterior (P), left (L) and right (R) mesenteric distances.

The area measurements were calculated by annotating the region between the outermost portion of the muscularis propria and the external border of the mesentery on both specimen cross sectional slice photos and MRI images (Figure 3). Linear distances were calculated by annotating the distance between the outer border of the muscularis propria and the left lateral, right lateral and posterior external border of the mesentery. Slice thickness on MRI (3mm) and pathology (5mm) was used to calculate the height from the anterior peritoneal reflection. All measurements were performed by the study investigator (ND) and reviewed by academic supervisors in pathology (NPW) and radiology (GB).

For each patient, the minimum surface area and posterior mesenteric distance was plotted against height from the anterior peritoneal reflection for specimen pathology and MRI on two-way plots with quadratic best fit lines. Waist height was compared using descriptive statistics. Independent samples t-tests or one-way analysis of variance (ANOVA) were used to investigate continuous dependent variables for independent groups, and linear regression was used to investigate relationships between continuous variables.

Results

Recruitment was undertaken between April 2017 and April 2018 during which time 20 patients were consented to participate in the study (demographics in table 1).

Patient Variable	

Mean Age (std. dev.)	58.5 years (12.5)
Mean Patient Height (std. dev.)	173.0cm (8.4)
Mean Patient Weight (std. dev.)	77.1kg (16.6)
Mean BMI (std. dev.)	25.6 kg/m² (4.5)
Gender	
Male	15 (75%)
Female	5 (25%)
Ethnicity	
White	17 (85%)
Indian	2 (10%)
Arabic	1 (5%)
Pre-operative radiotherapy	
Yes	18 (90%)
No	2 (10%)
Operation	
Exenteration	5 (25%)
Extra-levator abdomino-perineal excision	6 (30%)
Conventional abdomino-perineal excision	2 (10%)
Anterior Resection	7 (35%)

Table 1: Patient' demographics

All 20 patients underwent MRI scanning of their specimens. Mesenteric distances on MRI in one specimen could not be measured due to distortion by tumour. Specimen cross sectional slice photographs were adequate for analysis in 17 out of 20 specimens. The remaining three patients either did not undergo specimen photography or the photographs taken did not include slices of the sigmoid mesentery.

Mesenteric surface area (as measured in the axial plane) was measured from distal (starting at the anterior peritoneal reflection) to the proximal extent of the specimen, or 10cm above the peritoneal reflection. Mesenteric surface area above the anterior peritoneal reflection gradually decreased before increasing (figure 4) in the majority of specimens on MRI (18/20) and pathology (13/17), confirming the presence of a waist.

Figure 4: Overall mesenteric surface area on MRI (left) and pathology (right) per specimen, commencing at the anterior peritoneal reflection. Line of best fit (quadratic) imposed over scatterplot of observed measurements. In most specimens, the mesenteric surface area of the upper rectum initially decreases to a minimum value (the waist) before increasing proximally as the sigmoid mesentery.

The area of mesenteric waisting included a reduction in the amount of posterior tissue (see figure 2) with the posterior mesenteric distance of the upper rectum initially reducing above the anterior peritoneal reflection, before elongating as the sigmoid mesocolon. This was evident on MRI (17/19) scans and pathology (15/17) specimens. The overall mesenteric waist occurred uniformly before the posterior mesenteric distance increased as the sigmoid colon (figure 5). The lateral mesentery typically decreased between the peritoneal reflection and the overall mesenteric waist, and continued to diminish while the sigmoid mesocolon elongated (figure 5).

Figure 5: Posterior and lateral mesenteric distances on MRI (left) and pathology (right) per specimen, commencing at level of anterior peritoneal reflection. Red vertical reference line marking the level of the maximal point of overall mesenteric waisting. Above the level of the waist, the posterior mesenteric distance increased as the sigmoid mesentery lengthened to its apex. The mesenteric waist occurred near/at the minimum posterior mesenteric distance, and before the sigmoid mesocolon began in all cases, suggesting it could be a mesenteric landmark for the rectum. The lateral mesenteric distances had diminished/were diminishing at the point of the mesenteric waist.

The mesenteric surface area decreased to a minimum at a mean distance of 23.6mm above the anterior peritoneal reflection on MRI, and 21.7mm on pathology. The posterior mesenteric distance also reduced to a minimum at a mean distance above the anterior peritoneal reflection of 22.3mm on MRI, and 20.9mm on pathology. On MRI, the posterior waist occurred within 6mm (2 MRI slices) of the circumferential waist in 18/19 cases. On pathology, the posterior waist was within 10mm (2 pathology slices) of the circumferential waist in 17/17 cases. There was no significant difference in the distance to the circumferential and posterior waist on MRI (p=0.234) or pathology (p=0.92).

Landmark	*n*	Mean	St dev	Min	Max	95% CI
MRI mesenteric area waist	20	23.6	8.7	9	36	20.6 – 31.3
Pathology overall area waist	17	21.7	9.2	5	35	16.5 – 25.3
MRI posterior waist	19	22.3	9.4	9	42	17.6 – 26.3
Pathology posterior waist	17	20.9	8.1	5	35	16.6 – 24.6

Table 2: Distance from the anterior peritoneal reflection (in mm) to waist (minimum overall surface area or posterior diameter) on MRI or pathology

There was no significant relationship between mesenteric surface area (on pathology) at the level of the waist, and age (*p*=0.33), ethnicity (*p*=0.15) pre-operative radiotherapy (*p*=0.77), height (*p*=0.07) or BMI (*p*=0.10). Mesenteric area at the waist was significantly higher in men (*p*=0.04), and with increasing weight (*p*=0.04). Distance to the circumferential waist from the anterior peritoneal reflection (on pathology) did not vary by any variable, including age, (*p*=0.99), sex (*p*=0.57), ethnicity (*p*=0.49), weight (*p*=0.42), height (*p*=0.64), BMI (*p*=0.25) or pre-operative radiotherapy (*p*=0.25).

Discussion

In this detailed matched imaging and specimen anatomical assessment of the rectosigmoid region, a mesenteric narrowing was identified at the junction of the mesosigmoid and mesorectum. The narrowing created an appearance of a mesenteric waist, which may be an area of potential high risk for lateral resection margin involvement in cancer surgery, particularly if the posterior margin is threatened. The waist was consistently identified approximately 20mm proximal to the anterior peritoneal reflection, and did not vary by age, sex, height, weight, BMI, or use of pre-operative radiotherapy. Above this point, the mesorectum transitioned to the sigmoid mesocolon; this anatomical transition was reflected by an increase in the posterior mesenteric distance as the sigmoid mesentery elongates to the apex of the sigmoid loop (see figure 2). This leads to the suggestion that the recto-sigmoid mesenteric narrowing or "waist" could serve as a landmark to define the anatomical rectum and sigmoid.

Local recurrence after sigmoid cancer resection has been under-reported and hence its incidence under-estimated. Some reports suggest it may be as high as 20% (10). "Rectosigmoid" tumours pose considerable challenges in terms of staging and the planning of adjunctive treatments (12). A narrowing of the mesentery into a waist-like region, between the rectum and sigmoid, could increase the risk of margin involvement by tumours at this level. As with low rectal cancer the relative paucity of mesenteric tissue at this level renders oncological resection more challenging. Surgery outside the mesocolic plane or the presence of involved margins may adversely affect survival (13). However, while low rectal tumours may be managed using an extra-levator approach when the margin is threatened, posterior tumours may encroach on S1 and hence be deemed inoperable. Ensuring an adequate resection margin with wide excision requires planning and careful dissection and where this is not possible preoperative therapy may be beneficial. Such an approach requires review of each sigmoid cancer in a multidisciplinary team (MDT) meeting, where each specialty will be contributing and sharing their expertise to optimize patient management. When this MDT process was implemented at the Royal Marsden, 3-year cancer specific survival for predicted poor prognosis tumours of the sigmoid, rectosigmoid and upper rectum improved from 62% to 81% (14). Our data supports descriptions by others who recently found that the sigmoid mesocolon tapers to a "point of maximal convergence" before widening to continue as the mesorectum (3). This point was found to correspond with the coalescence of the taenia coli, providing a mesenteric landmark at which the rectosigmoid junction occurs, and therefore defining the rectum. The lack of anatomical evidence for the rectosigmoid junction has been previously established (12, 15). A pilot study of pathological specimens at the University of Leeds confirmed the presence of a waist in the sigmoid mesentery, but without reference to specific anatomical landmarks. In this study, the presence of a waist was confirmed—but as hypothesised by Coffey's group, this occurred at the junction of the mesorectum and mesocolon.

Limitations

As an exploratory study, this study was designed to generate a hypothesis rather than definitively confirm or refute the presence of a waist. Nonetheless, a waist was found in nearly all patients, despite the heterogeneity that would be expected from anatomy and surgery in a small sample size. The omission of usable specimen photographs for three patients was unfortunate and was due to urgent service pressures to report the histopathology of patients with cancer, and the required prolonged immersion time in formalin was not possible in these cases.

The slight discrepancy of specimen measurements and waist position between MRI and pathology may be due to several factors. This includes slices off the longitudinal axis on MRI or variable thickness of slices made on pathology. The consistently smaller measurements on pathology could be explained by formalin immersion in the interval between specimen MRI and pathology, which is associated with specimen shrinkage (16, 17). Thinner slices on MRI (3mm) compared with pathology (approximately 5mm) may have also contributed to a discrepancy in measurements. To pre-empt these problems, we performed measurements using both modalities (imaging and tissue analysis). There was some variation in mesenteric surface area by weight and sex, but none in distance from the anterior peritoneal reflection to the waist by any other variable. Nonetheless, there may be variation not detected due to lack of power in this small exploratory study, certainly with regards to pre-operative radiotherapy, when only 2/20 patients were not pre-operatively irradiated. It may be worthwhile repeating this study to examine the impact of radiotherapy on mesenteric dimensions. In only one case was the tumour high enough to distort the mesentery and peritoneum above the anterior peritoneal reflection, and in retrospect, high rectal tumours should have been a trial criterion for exclusion.

The rectosigmoid junction in this study was found to be only approximately 20mm (and maximum 32mm) above the anterior peritoneal reflection. This is consistent with estimates of upper rectal length from the National Cancer Institute (18). The waist and by extension the peritoneal reflection could therefore be a landmark for the rectum, as previously suggested(2, 3, 15, 19).

Conclusion

Above the anterior peritoneal reflection, a mesenteric waist exists that marks the junction of the mesorectum and mesocolon. The rectosigmoid waist is a landmark for the rectum that is found on both radiology and pathology.

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Tables and Figures

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