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Title

The Sigmoid Take-Off: An Anatomical Imaging Definition of the Rectum Validated on Specimen Analysis

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Running Head

The Sigmoid Take-Off

Keywords

Anatomy; Radiology; Rectosigmoid junction; Rectum; Sigmoid

Abstract

Introduction:

A pre-operative imaging landmark to define the rectum would optimise clinical care of rectal cancer patients and research efforts to improve outcomes. The sigmoid take-off has been suggested as an imaging landmark for the rectosigmoid junction (RSJ). This study aimed to investigate whether this imaging definition of the rectum was validated by surgical specimen analysis.

Methods:

This prospective study recruited 20 patients undergoing surgery and undertook radiological and pathological analysis of their rectal specimens. The radiological landmark of the sigmoid take-off was identified on pre-operative magnetic resonance imaging (MRI), and the distance to the anterior peritoneal reflection was measured by two readers. After surgery, the distance from the beginning of the sigmoid mesocolon to the anterior peritoneal reflection to the beginning of the sigmoid mesocolon on the specimen was measured, and compared to the distance on MRI using Pearson's Correlation Coefficient and Bland-Altman plots.

Results

In 17 patients, the mean distance from the anterior peritoneal reflection to the RSJ on MRI was 20.3mm and 23.1mm for two readers, and on pathology was 20.6mm. The mean differences between MRI and specimen measurements were -0.31mm (-2.83 to 2.20mm), and 2.51mm (95% confidence interval -0.31 to 5.33mm) for each reader, with correlation coefficients of 0.77 and 0.81.

Conclusion

The sigmoid take-off has been validated on specimen analysis to be an imaging landmark that defines the termination of the rectum. This anatomical landmark can be used to classify tumours and guide treatment and research of sigmoid colon and rectal cancer.

Introduction

A pre-operative landmark to define the rectum is needed to improve outcomes of rectal and sigmoid cancer. At present a range of landmarks for the rectosigmoid junction (RSJ) are in use internationally [1,2]. None of these landmarks have been validated with respect to the anatomy of the rectum, but came into use based on the diagnostic modalities available at the time (e.g. endoscopic visualisation for metric measurements, barium enemas for bony landmarks). Utilisation of these arbitrary landmarks that ignore individual patient anatomy has been shown to incorrectly localise tumours [3-6]. This may also explain the rise of the term rectosigmoid; to classify tumours that on imaging do not correspond to their localisation by landmarks. Unfortunately, rectosigmoid tumours are managed outside of any established pathways or guidelines.

On surveying multi-disciplinary experts in rectal cancer, over 93% agreed that a reliable definition was essential [7]. If rectal or sigmoid tumours are misclassified, patients may embark on radically different treatment pathways that could affect their outcomes, most pertinently the use of pre-operative therapy such as radiotherapy and referral to specialist rectal cancer surgeons, whose volumes could be more accurately. Equally, research studies into rectal cancer will have erroneously included sigmoid tumours and excluded some rectal tumours using these landmarks. Patients can be counselled appropriately about their oncological and functional prognosis [7].

The sigmoid take-off has recently been described as an imaging landmark for the RSJ based on anatomical principles [1,7]. The sigmoid take-off identifies the RSJ at the point where the fixed mesorectum ends and no longer tethers the rectum to the sacrum, and the mesocolon elongates [4]. On imaging this is seen as the sigmoid sweeps away from the sacrum with ventral projection in the axial plane and/or horizontal projection in the sagittal plane (Figure 1).

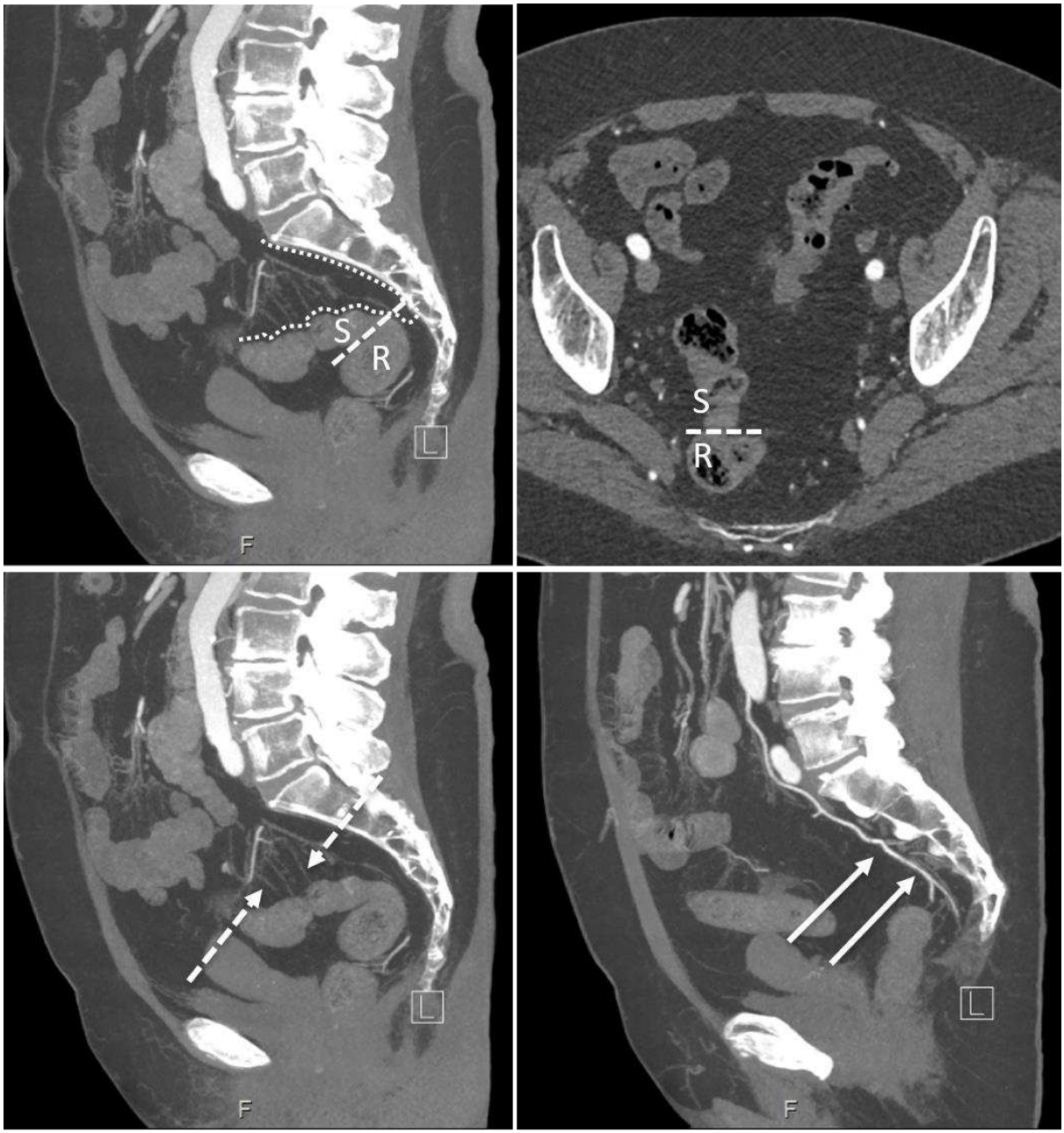


Figure 1: Top left: Sigmoid sweeping horizontally on U-shaped mesentery on sagittal view. Top right: sigmoid projecting forwards on axial view. Bottom left: CT angiogram demonstrating spidery sigmoid vessels proximal to take off. Bottom right: superior rectal artery bifurcating beyond take-off.

Labels: Sigmoid take-off identified with dashed line. Sigmoid marked by S, rectum marked by R. U-shaped sigmoid mesocolon (posteriorly) identified with dotted line. Sigmoid arteries marked with dashed arrow. Superior rectal artery marked with solid arrow.

A consensus of international experts agreed that the sigmoid take-off should be used as a standardised definition of the rectum in clinical practice and for research[7]. Despite the consensus,

there was been some doubt that the radiological identification of RSJ anatomy corresponds to anatomy as seen on pathology. The aim of this study was to investigate whether the pre-operative landmark of the sigmoid take-off was validated by measurements on specimen analysis to define the rectum.

Methods

This prospective, non-interventional single-centre study was designed with patient involvement. Ethics approval was received from the UK health research authority (IRAS no 220869) and the local institutional review board. An exploratory sample size of 20 was calculated, based on a previous similar imaging/specimen study of the low rectal waist[8].

The primary endpoint was to investigate whether the sigmoid take-off on imaging correlated to the mesorectal-mesocolic transition on specimen analysis. The sigmoid take-off was identified on pre-operative MRI as described above [4]. On pathology, the mesorectal-mesocolic transition was identified when the posterior diameter of the mesentery began to increase above the peritoneal reflection, reflecting the transition from the mesorectum into the U-shaped sigmoid mesocolon.

Consecutive patients undergoing low rectal surgery were approached to take part in the study. Patients were eligible for inclusion in the study if they were aged above 18 years, were due to undergo rectal cancer surgery that would resect the anterior peritoneal reflection and consented to take part in the study. Exclusion criteria for patients were contra-indication to MRI, previous rectal or sigmoid colon surgery, or surgery that did not include the anterior peritoneal reflection or the sigmoid mesentery.

Patients underwent routine pre-operative MRI scans of their rectum reported on a standard proforma by two gastrointestinal radiologists with over 10 years' experience. Following surgery, the specimens were opened, washed out and immersed in formalin. To transport the specimens for their

MRI scan, they were removed from formalin and fixed to a corkboard along their longitudinal axis using wooden toothpicks. Cod liver oil tablets were sutured to the anterior peritoneal reflection to act as an MRI 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.

Following the scan, the specimens were returned to formalin for a minimum of 7 days. They were subsequently sliced at 5mm intervals as per the Royal College of Pathologists guidelines [9]. Photographs were taken of these slices using a high definition camera mounted on a tripod with a ruler for calibration.

Measurements on pathology photographs were performed using Digimizer software and on MRI using the Sectra picture and archiving communication system (Sectra PACS Workstation IDS7, Sectra AB, Linköping, Sweden).

The sigmoid take-off was identified on pre-operative MRI. The distance was then measured from the corresponding point of the anterior colon to the anterior peritoneal reflection using PACS (Figure 2). On pathology, measurements of the posterior mesenteric distance were performed on each slice: the slice with the shortest distance before it elongated corresponded to the mesorectal-mesocolic transition and hence the RSJ. The distance to the APR was measured by the number of slices and their thickness (5mm).

To ensure the reliability of the MRI measurements, they were performed by 2 paired observers: a specialist gastrointestinal radiologist (Reader 1) and a surgical colorectal research fellow (Reader 2). MRI and pathology measurements were reviewed by an academic gastrointestinal radiologist and pathologist respectively

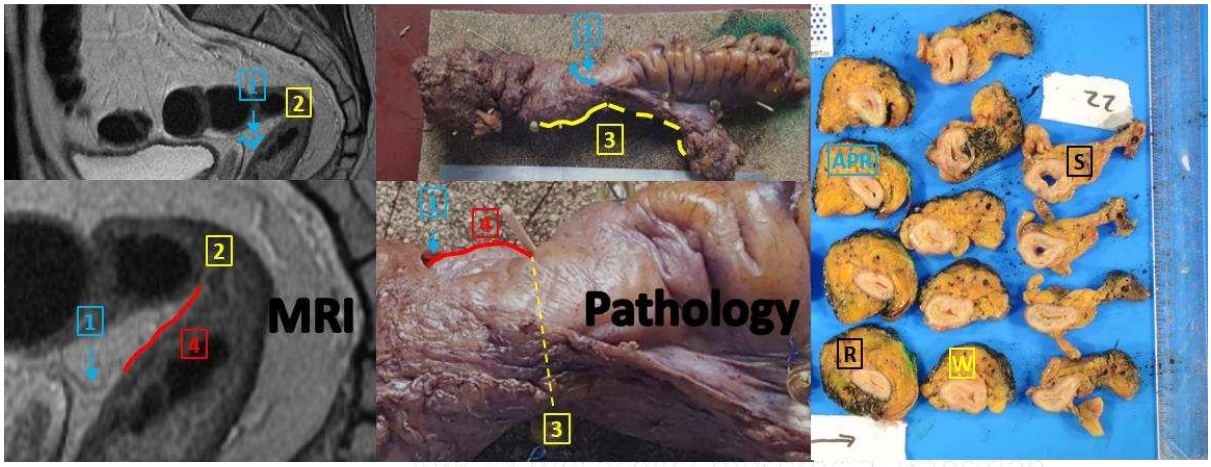


Figure 2: Left: MRI image demonstrating distance from the anterior peritoneal reflection (APR) to the sigmoid take-off. Middle: Pathology specimen image demonstrating distance from the anterior peritoneal reflection (APR) to the beginning of the sigmoid mesocolon. Right: Pathology cut-up specimen, demonstrating posterior mesenteric elongation from the mesorectum to mesocolon.

Labels: 1. Anterior peritoneal reflection (MRI and pathology), 2. Sigmoid Take-Of on MRI 3. Mesorectal (solid line) -Mesocolic (dashed line) transition on pathology 4. Distance (anterior) from APR to sigmoid take-off (MRI), and from APR to mesorectal-mesocolic transition (pathology). Cut-up: R. Mesorectum, APR. Anterior Peritoneal Reflection, W. Mesenteric waist (transition from mesorectum to mesocolon), S. Sigmoid mesocolon

The analysis was planned with academic statisticians. Endpoints were summarised using graphical methods and descriptive statistics including Pearson's Correlation Coefficient. Bland-Altman methods were used to illustrate differences in paired MRI-pathology measurements from the anterior peritoneal reflection to the rectosigmoid junction. A mean difference between paired measurements of greater than 10mm was defined as being clinically significant.

Results

Twenty patients were recruited to the study (Table 1) between April 2017 to April 2018. MRI measurements were not feasible in one patient due to distortion by a locally advanced tumour, but were available for the remaining 19 patients. In 3 patients, the specimens were not dissected according to the study protocol, but measurements were available for the remaining 17 patients.

The mean patient age was 58.5 years (range 32-78), and 25% of patients were female. Pre-operative radiotherapy had been given in 90% of patients.

On imaging, the mean distance from the anterior peritoneal reflection to the sigmoid take-off was 21.7mm for both readers (table 1). On pathology, the mean distance from the anterior peritoneal reflection to the mesorectal-mesocolic transition was 20.6mm.

	MRI: APR → sigmoid take-off (in mm)		Pathology: APR → mesocolon (in mm)
	Reader 1	Reader 2	
Mean	20.3	23.1	20.6
St Dev	5.61	9.4	7.7
Median	19.5	20	20
25%	16	13.9	15
75%	25	31.7	30
Pearson's rank correlation	0.77	0.81	
Mean Difference (95% confidence interval)	-0.31mm (-2.83 to 2.20mm)	2.51mm (-0.31 to 5.33mm)	
Limits of Agreement	-9.89 to 9.27mm	-13.3 to 8.24mm	

Table 1

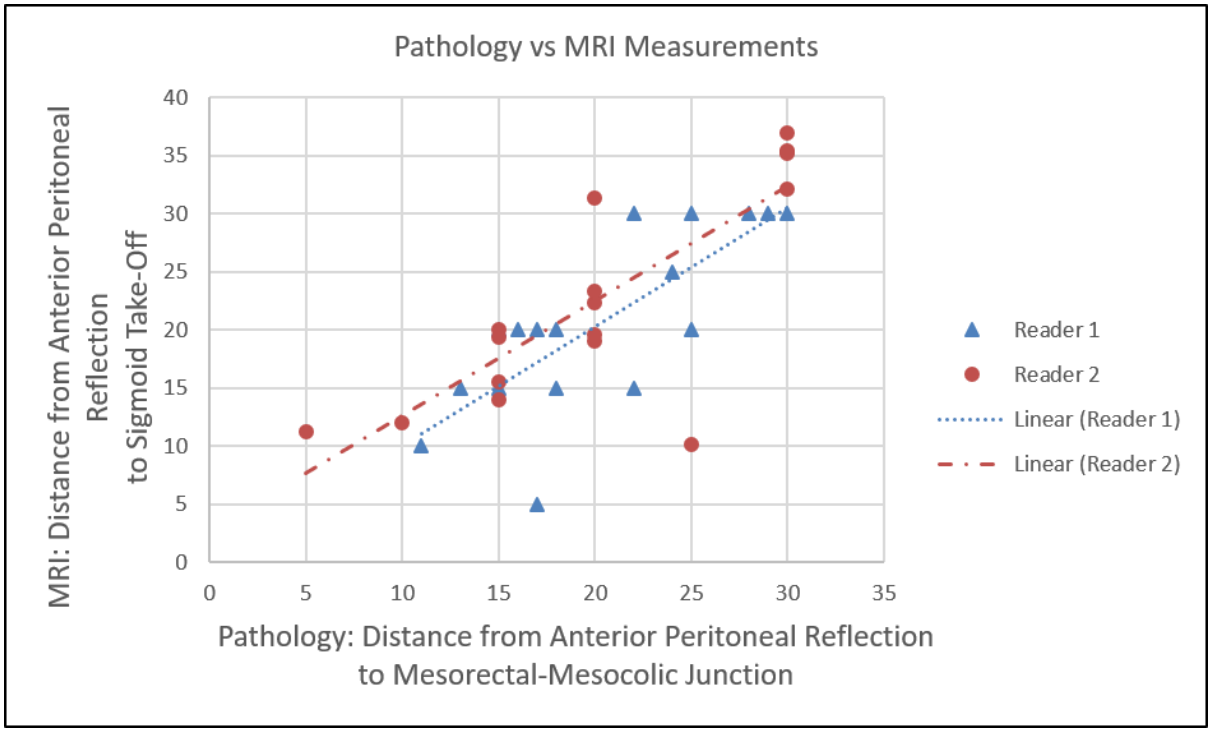
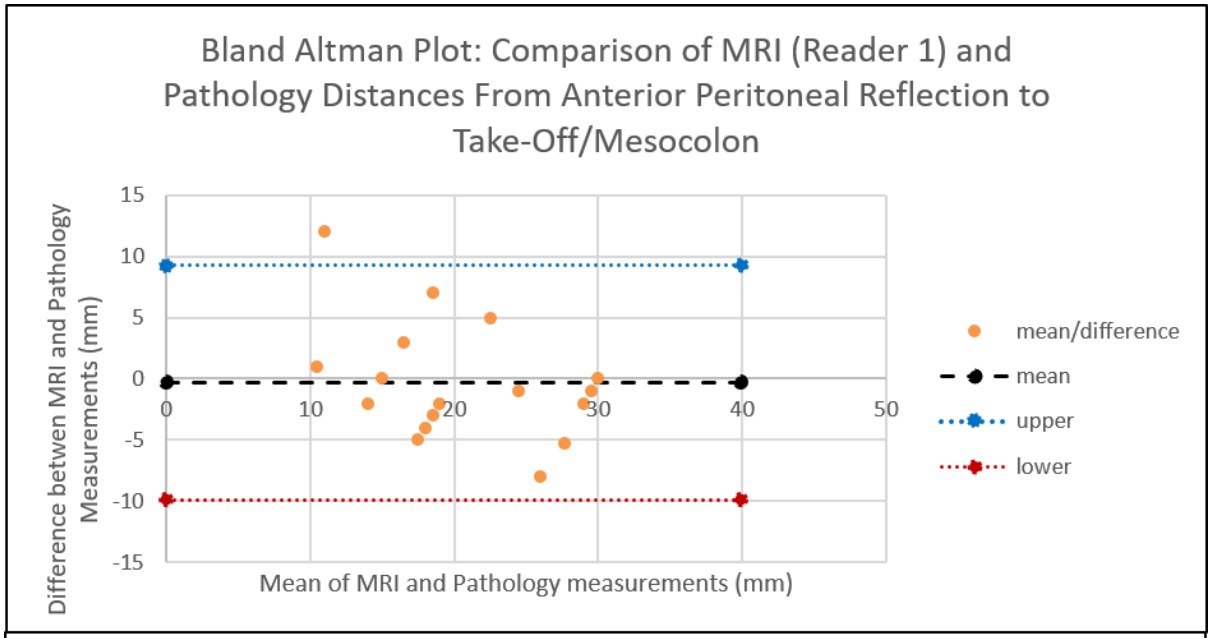


Figure 3: measurements from the Anterior Peritoneal Reflection to the Rectosigmoid Junction on MRI vs pathology

Increasing distance from the anterior peritoneal reflection to the RSJ was matched on both imaging and specimen landmarks (Figure 3), demonstrated by Pearson's correlation coefficient (r) was 0.77 and 0.81 for each reader. The mean difference between imaging and specimen landmarks for the rectosigmoid junction to the anterior peritoneal reflection was -0.31 and 2.51mm for each reader, as illustrated by Bland-Altman plots (Figure 4). There was less than 10mm difference in 31/34 (91%) paired MRI-pathology measurements.



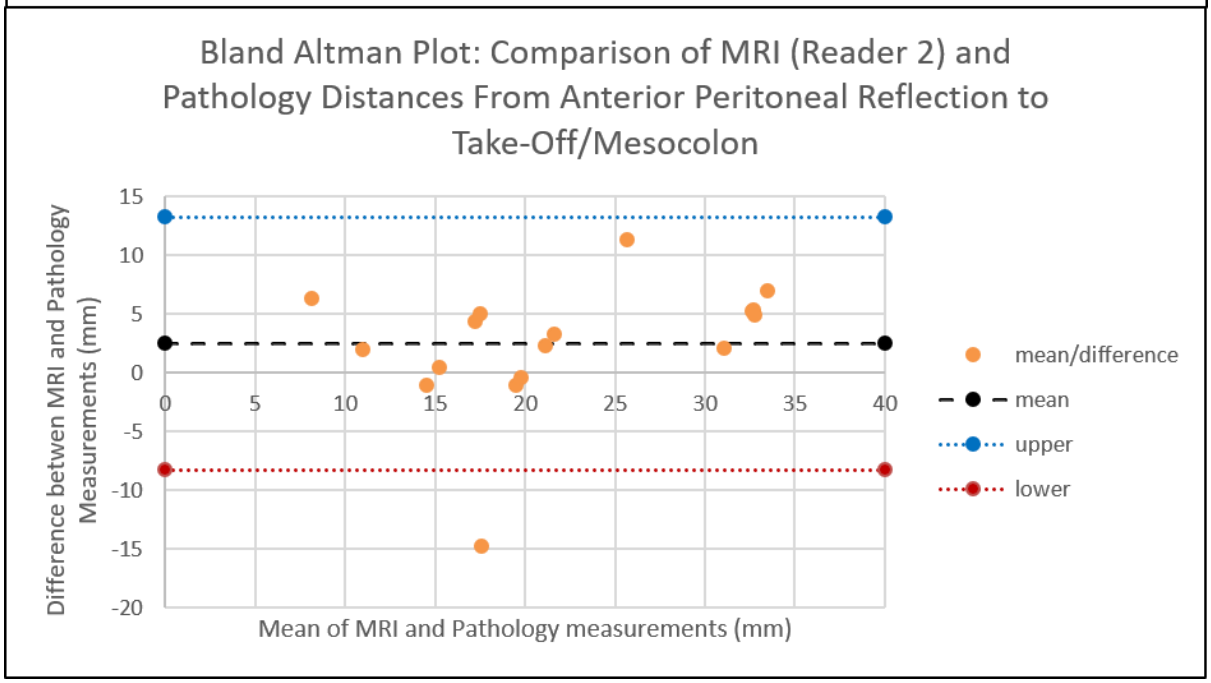


Figure 4: Bland-Altman plots the differences between paired measured MRI and pathology distances (y axis) against the mean of the two values (x axis), for Readers 1 (top) and 2 (bottom). Positive measurements on y axis = greater distance on MRI than pathology.

Discussion

The sigmoid take-off was found to identify the rectosigmoid junction on pre-operative imaging, with mean differences from a specimen-based definition of less than 10mm (-0.31 and 2.51mm) and a strong correlation of 0.77 and 0.81. The pre-operative definition was within 10mm of the beginning of the rectum in 91% of measurements. Clinically, this would appear to be a highly significant correlation and agreement, that validates the sigmoid take-off as an imaging definition of the rectum based on specimen anatomy.

No other pre-operative definition of the rectum has been anatomically validated. Previous definitions were employed based on the modalities available at the time. The third sacral segment was the traditional landmark used by anatomists: this was probably seen in relation to the coalescence of the taenia coli. The most commonly employed landmarks today according to recent surveys of surgeons and guidelines [7] are metric measurements. These came into practice when endoscopic visualisation of tumours became possible, but before cross-sectional imaging was available. Cross-sectional imaging enables identification of anatomical features that differentiate the rectum from the sigmoid. The mesorectum can be identified, and consequently so can the rectum. Identification of the rectosigmoid junction is necessary to differentiate the colon from the rectum. Using the sigmoid take-off, the mesocolon can be differentiated from the mesorectum, and the cascade of spidery sigmoid vessels can be distinguished from the larger calibre superior rectal artery that usually continues from the inferior mesenteric artery (see figure 1).

No previous data has been published that justifies the use of particular metric measurements (e.g. whether 12, 15 or 16cm) or bony landmarks to define the rectum. Data has been repeatedly published that highlights the variation in the length of the rectum [4-6] and its position against bony landmarks. By using these arbitrary landmarks, tumours will be erroneously localised to the sigmoid

or rectum. This may lead to radically different management for patients. It will inevitably have meant that rectal cancer trials that used metric measurements, including laparoscopic surgery [10] or neoadjuvant therapy [11], will have included patients with sigmoid cancer, and been confounded. It also remains unclear whether distal sigmoid cancers, or rectosigmoid cancers, are best managed using a rectal cancer treatment strategy.

This study showed a high level of clinically relevant correlation and agreement between MRI and pathology measurement for the RSJ. The take-off was accurate to within 10mm of the RSJ on specimen analysis in 91% of measurements.

Limitations

The sigmoid take-off is usually intuitive and can be seen on any form of cross-sectional imaging on 2 views. While the results show good correlation and agreement, on a patient-by-patient basis there may be some discrepancies. We inspected the outlying results in our study with a discrepancy between their pathological-imaging distances. In these cases, we found the rectum was tortuous on coronal imaging. Viewing images in this third plane may be required. Discrepancies between in-vivo MRI and specimen analysis may also be due to variation in formalin immersion time between patients as formalin immersion is associated with specimen shrinkage [12,13]. Thinner slices on MRI (3mm) than pathology (approximately 5mm) may have contributed to a discrepancy in measurements. Finally, some degree of error will be inevitable when measuring anatomy in millimetres.

While we have correlated radiology with pathology, it is possible that pathology may not be the optimal gold standard for distinguishing between the rectum and sigmoid. The vascular supply and drainage may be more oncologically relevant, but this cannot be routinely assessed on pathology specimens. Further investigations regarding the vascular drainage of the rectum vs. the sigmoid may provide more appropriate distinction between the 2 structures.

While tumours can now be localised to the rectum or sigmoid using the sigmoid take-off, it remains unclear how best to classify and manage tumours that straddle the take-off. These tumours are true rectosigmoid tumours; further research can be directed to investigate whether these tumours are best managed according to rectal cancer protocols.

The sigmoid take-off has now been validated on specimen analysis, and agreed to define the rectum by a Delphi consensus of international experts [7]. Investigation of its inter-observer reliability may be required before adoption by trials and guidelines for rectal cancer treatment. In the interim, we would suggest that tumour position is checked routinely against the sigmoid take-off, for every patient with sigmoid or rectal cancer in the MDT.

Conclusion

The sigmoid take-off has been validated on specimen analysis to be an imaging landmark that defines the rectum. If used routinely in the MDT, rectal or sigmoid tumours will be correctly localised so that patients embark on the correct treatment strategy. The sigmoid take-off should be employed in future rectal cancer trials as a standardised definition of the rectum.

Acknowledgements

The authors have no conflicts of interest. Nigel D'Souza had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Thanks to the South London Bowel Cancer Support Group for their perspectives and input on the study, and Karen Thomas for her expert statistics advice.

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