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Research article

Deep infiltrating endometriosis: Can magnetic resonance imaging anticipate the need for colorectal surgeon intervention?

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ABSTRACT

Objective: To identify magnetic resonance imaging (MRI) features associated with colorectal surgical bowel resection for treatment of deep infiltrating endometriosis (DIE).

Materials and methods: 122 preoperative pelvic MRIs in women with laparoscopically-proven DIE and subsequent surgery (2006–2015) were identified, and retrospective cohort analysis performed. MRIs were reviewed independently by two radiologists blinded to surgical/histopathological outcomes. Associations between MRI characteristics of middle/posterior compartment endometriosis and surgical outcomes were investigated to identify MRI features associated with colorectal surgical bowel resection.

Results: MRI features associated with colorectal surgical intervention were: presence of an MRI bowel lesion (sensitivity 95.3%, specificity 63.3%, ROC-AUC 0.79); MRI bowel lesions ≥20 mm in length (sensitivity 91%, specificity 77%, ROC-AUC 0.84); MRI bowel lesions invading the muscularis or submucosa/mucosa layers (sensitivity 95.3%, specificity 63.3%, ROC-AUC 0.90).

Conclusion: This study identifies MRI features that have potential diagnostic utility in identifying the need for colorectal surgical intervention in patients with DIE.

1. Introduction

Endometriosis is a common disease in women of childbearing age [1] with significant morbidity including dysmenorrhea, dyspareunia, infertility, dyschezia and dysuria. Endometriosis is defined as the presence of endometrial tissue outside the uterine cavity [2], with three distinct morphologies: superficial endometriosis, ovarian endometriosis (endometriomas) and deep infiltrating endometriosis (DIE). DIE represents endometriosis that infiltrates > 5 mm into the retroperitoneum/pelvic organs and is associated with scarring and adhesions. Common sites are the pelvic peritoneum (pouch of Douglas [POD], torus uterinus [TU], uterosacral ligaments[USLs]), bowel and bladder [3].

Clinical history and examination are unreliable in the diagnosis of DIE [4], and laparoscopy with histological confirmation is the diagnostic gold standard [5]. However, non-invasive preoperative investigations are increasingly utilized to assess disease extent, aiding surgical planning, assisting consent and facilitating resource and personnel allocation. Both ultrasound and magnetic resonance imaging (MRI) are increasingly used in this capacity [3,6,7], with MRI showing high sensitivity and specificity in the preoperative diagnosis of bowel DIE [7,8].

Treatment of DIE is challenging and requires consideration of patient symptoms, desire for fertility preservation and co-morbidities. First-line medical management consists of combined oral contraceptives, progestogens or gonadotrophin-releasing hormone analogues [9,10]. However, surgical management is generally considered the definitive treatment for DIE, particularly in patients who are symptomatic or have bowel involvement [10–12]. If bowel involvement with DIE is suspected, a multidisciplinary approach involving a colorectal surgeon may be required to reduce the risk of bowel injury and perform bowel resection [10,13,14]. Pre-operatively identifying patients at high risk for bowel resection allows for patient counselling and appropriate resource allocation, particularly pertaining to colorectal surgeon and

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theatre time.

Clinical decision pathways/guidelines are often employed to optimize patient care and avoid inconsistent, inadequate or excessive resource allocation [15]. The National Academy of Sciences Engineering and Medicine defines clinical practice guidelines as "statements that include recommendations, intended to optimize patient care, that are informed by a systematic review of evidence and an assessment of the benefits and harms of alternative care options" [16]. At the time of this study, we could find no published guidelines for the surgical management of bowel DIE [13,17]. Similarly, a meta-analysis by De Cicco et al. [18] reviewing 34 articles with 1889 bowel resections for DIE found that "the indications to perform a bowel resection were variable and were rarely described accurately".

The aims of this study were: (1) investigate how the current method of colorectal surgeon allocation at our institution compares to ideal practice, that is, a colorectal surgeon present at all operations requiring bowel resection, and not present at operations not requiring bowel resection; and (2) identify MRI features associated with colorectal surgical bowel resection which may perform better than current practice. We hypothesized that bowel lesion length, depth of bowel wall invasion, lesion number, adhesions and presence of DIE elsewhere in the middle/posterior compartments may be associated with colorectal surgical bowel resection.

2. Materials and methods

Ethics approval was obtained from the institutions of practice in accordance with National Health and Medical Research Council guidelines.

2.1. Study cohort

MRI reports were interrogated using an in-house database to identify pelvic MRIs performed from January 2006–December 2015. Studies were included if the referral source was from the endosurgical unit and clinical referral information included the terms "endometriosis", "endo" or "DIE". Studies were excluded if the indication was evaluation of disease other than endometriosis. This yielded a cohort of 196 MRIs, comprising 189 patients, 7 with 2 MRIs.

The 196 MRIs were cross-checked against the clinical notes. 74 MRIs were excluded as there were no surgical notes or histopathological results within the study period; 17 had no information regarding the patient's endometriosis diagnosis within the medical record, and 57 did not have surgery (reasons listed in Fig. 1).

This resulted in a total of 122 MRIs with subsequent surgery, comprising 119 patients, 3 with 2 MRIs.

2.2. MRI technique

All MRIs were acquired at 1.5T (Siemens Avanto, Germany) using a standardized protocol, supine positioning, a phased-array surface coil and pre-imaging intravenous hyoscine butylbromide (Buscopan) 20 mg.

High resolution 3D T2 weighted images (T2WI) were obtained in the coronal plane (repetition time [TR] 1500 ms/echo time [TE] 131 ms; field of view [FOV] 400 mm; section thickness 1 mm; matrix 384 × 384) with 3 mm 3-plane reformats in axial, coronal and sagittal planes; axial T1-weighted images (T1WI) (TR 546 ms/TE 9.3 ms; FOV 320 mm; section thickness 7 mm; intersection gap 1 mm; matrix 224 × 320) and three-plane T1 fat saturated imaging (T1FS) (TR 724 ms/TE 9.6 ms; FOV 220 mm; section thickness 4 mm; intersection gap 0.4 mm; matrix 269 × 384). Intravenous [2,19] and rectal contrast [8,20,21] were not administered. Scans were performed independent of the patient's menstrual cycle [22].

2.3. Image analysis

Two radiologists with an interest in endometriosis independently analysed the MRIs, blinded to patient clinical information, previous imaging, MRI reports, surgical outcomes and histopathological reports.

Each reader independently assessed image quality of T2WI, T1FS and the rectosigmoid colon using a three-point Likert scale: non-diagnostic (artefact resulting in non-clinically useful imaging), borderline, or diagnostic (no artefact/minor artefact not adversely impacting clinical use). Reasons for borderline/non-diagnostic image quality were recorded (Table 1). The presence and number bowel endometriotic lesions were recorded. The criteria for diagnosis of bowel DIE, described by Bazot et al. [7], were: presence of a soft-tissue mass on the anterior rectal or inferior sigmoid wall; loss of the fat plane between the uterus and rectosigmoid colon; loss of normal anterior rectosigmoid wall T2-hypointense signal. For the dominant bowel lesion (lesion with either greatest depth of invasion or longest length), the craniocaudal extent (measured in millimetres, Fig. 2a) and greatest depth of invasion (serosal, muscular or mucosal/submucosal, Fig. 2b–d) were recorded. Depth of invasion was assessed as per Busard et al. [8]: serosal invasion (minimal bowel wall thickening with slight T2 hyperintensity [compared to muscle], extending in continuity with a T2 hypointense mass on the serosal aspect of the bowel); muscularis invasion (T2 isointense [compared to muscle] muscularis thickening associated with a fan shaped configuration, +/− smooth thickening of the T2 hyperintense mucosa/submucosa); and mucosal/submucosal invasion (extensive T2 isointense [compared to muscle] muscularis wall thickening with T2 hyperintense mucosal/submucosal wall thickening and irregularity).

Non-colonic posterior compartment involvement of the TU, USLs, POD and rectovaginal septum (RVS), as defined by Botterill et al. [22], were recorded. The presence or absence of ovarian endometriomas, adhesions and adenomyosis was recorded [23–28].

2.4. Clinical symptoms, surgical data and histopathology

The medical records, operative notes and histology reports were reviewed. Symptoms related to potential bowel involvement were recorded – specifically dyschezia and haematochezia.

Surgical findings related to sites of endometriosis involvement were recorded – specifically POD, TU, USLs, RVS, ovaries and rectosigmoid colon. Operative management of bowel disease was recorded and classified as a rectal shave, wedge resection, disc resection or anterior resection [29]. The type of procedure performed was at the discretion of the attending gynaecologist or colorectal surgeon, and exact indications were not available at the time of data collection. Bowel surgery was classified as complete or incomplete based upon the operative findings, and reasons for incomplete surgery recorded. The presence or absence of a colorectal surgeon at the operation was recorded.

Data collected from the histopathology report included site of biopsy/resection and presence or absence of endometriosis at those sites. Histological depth of bowel wall invasion was not recorded, as the purpose of this study was not to correlate histological and MRI findings (which have previously been demonstrated [8,20]), but to determine MRI findings associated with clinical outcomes of colorectal bowel resection.

2.5. 'Gold standard' calculation

A 'gold standard' of ideal practice to determine if a colorectal surgeon was required at the time of operative management was determined for each patient. This 'gold standard' was determined by assessing whether the surgical procedure required a colorectal surgeon (wedge resection, disc resection or anterior resection) or if surgery was deemed 'incomplete'. Incomplete surgery was defined as bowel disease not resected due to absence of a colorectal surgeon or surgery incomplete due to other factors (Fig. 1).

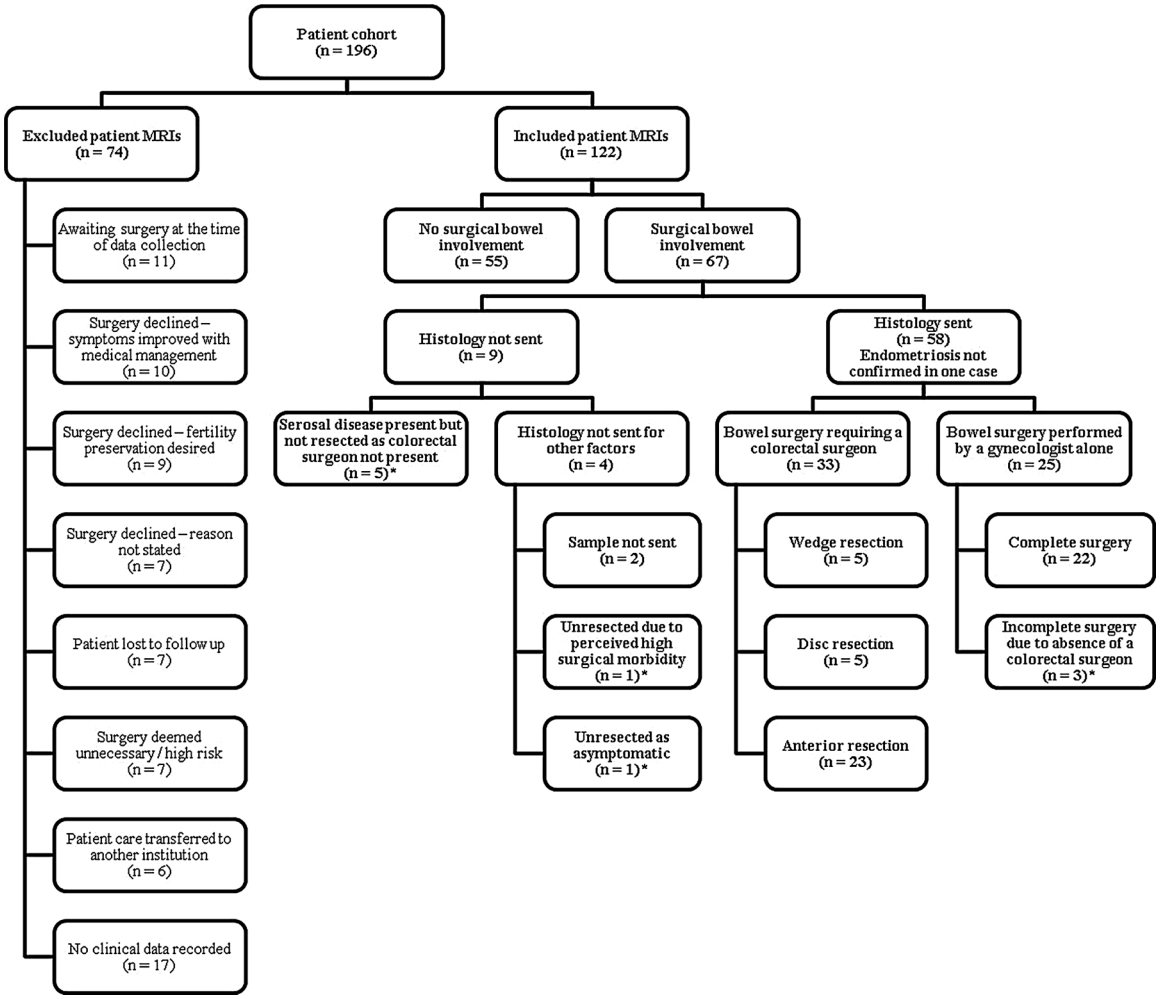

Fig. 1. Patient cohort. Excluded patient MRIs (n = 74) with reasons for exclusion. Included MRIs (n = 122), with surgical/histopathological data. MRIs with incomplete surgery (n = 10), marked with *.

Table 1
Reasons for borderline/non-diagnostic image quality.

Total reads = 244	T2	T1-Fat Saturated (T1-FS)	Rectosigmoid
Quality			
Diagnostic	209	210	186
Borderline	32	32	57
Non-diagnostic	3	2	1
Reasons for borderline / non-diagnostic imaging			
Patient movement	22	10	38
Bowel peristalsis	24	0	12
Rectal gas / faecal matter	3	16	15
Limited sequence	1	2	4
Poor fat saturation (T1-FS/ rectosigmoid only)	–	2	2
Susceptibility artefact (T1-FS/ rectosigmoid only)	–	11	4
Number with 2 (or more) reasons	15	7	16 (1 with 3 reasons)

2.6. Statistical analysis

Statistical analysis was performed using Stata IC13 (StataCorp, College Station, TX, USA). Baseline patient characteristics were summarized as median, interquartile range (IQR) and counts (proportions), and compared between included and excluded patients using Wilcoxon-Mann-Whitney ranksum test or Fisher's exact test as appropriate to investigate potential selection bias.

2.6.1. Measurement reliability

To confirm the reliability of the main measures, interobserver agreement between radiologists was estimated using Cohen's kappa coefficient for presence/absence of: bowel lesion, adhesions, TU, USL and POD involvement, adenomyosis and ovarian involvement; weighted kappa with quadratic weights for number of bowel lesions and lesion depth; and Lin's concordance coefficient for craniocaudal extent.

To estimate concordance between MRI and surgical findings of bowel lesions, agreement between the presence of MRI and surgical bowel lesions was estimated using Cohen's kappa coefficient.

For all agreement analyses, the strength of agreement was classified according to Landis and Koch [30], with the values above 0.8 interpreted as almost perfect, 0.61–0.80 as substantial agreement, and 0.41–0.60 as moderate agreement.

Aim 1: investigate how well the current method of colorectal surgeon allocation at our institution compares to ideal practice

Agreement between the calculated 'gold standard' for requirement of a colorectal surgeon and the observed presence was estimated using Cohen's kappa coefficient. The recorded presence of a colorectal surgeon was investigated as a diagnostic tool for the 'gold standard' using ROC curve analysis.

Aim 2: identify MRI findings associated with colorectal surgical

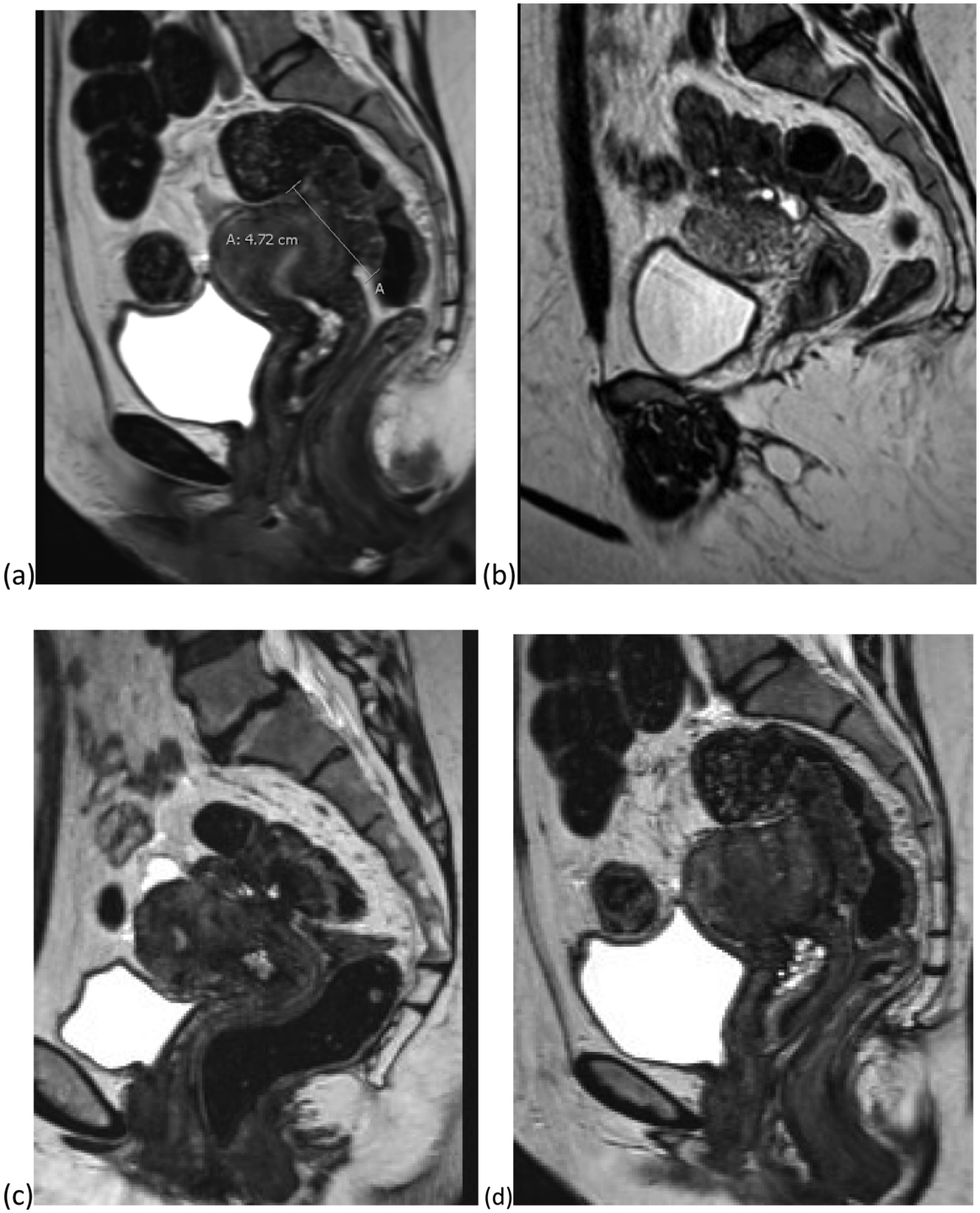

Fig. 2. Examples of (a) measurement of bowel lesion maximal length; (b) bowel lesion with serosal involvement; (c) bowel lesion with muscularis involvement; and (d) bowel lesion with submucosa/mucosa involvement.

resection which may perform better than current practice

Multivariable association between the MRI findings and the calculated 'gold standard' for colorectal surgical intervention was investigated using logistic regression modelling, with the need for the colorectal surgical resection as the output and individual diagnostic MRI features as inputs. The potential diagnostic utility of selected MRI features that were significantly associated with the outcome on both univariate and multivariable analyses were subsequently investigated using ROC curve analysis. Specifically, the presence of a bowel lesion on MRI, lesion depth of invasion into the bowel wall and lesion length were used as individual diagnostic tools for the calculated 'gold standard' requirement of a colorectal surgeon and current practice. Areas under the ROC curve for different diagnostic tools were compared using the Chi-square test.

3. Results

3.1. Patient characteristics and symptoms

122 MRIs were included in the analysis. Median age at the time of MRI was 35 years (IQR: 30–39 years) and median age at the time of surgery was 35 years (IQR: 31–39 years). The median number of days

Table 2
Patient characteristics.

		Included (n = 122)	Excluded (n = 74)	
Median age (years)	At MRI	35 (IQR 30–39)	37 (IQR 32-41)	p = 0.080
	At surgery	35 (IQR 31–39)	–	
Median days between MRI and surgery		163 (IQR 104–233)	–	
Symptoms	Dyschezia	71 (58.2%)	31 (41.9%)	p = 0.870
	Haematochezia	18 (14.8%)	3 (4.1%)	p = 0.085
	Clinical symptoms not recorded	0 (0%)	17 (23%)	

Table 3
Current practice and MRI findings compared against the calculated 'gold standard'.

	Sensitivity	Specificity	Odds ratio (95%CI, p-value)	Area under the curve (95%CI)
Current practice	58.9%	84.9%	8.0 (3.4–18.9, p < 0.001)	0.74 (0.66–0.82)
Bowel lesion	95.3%	63.3%	35.3 (8.0–157.0, p < 0.001)	0.79 (0.73–0.86)
Bowel lesion with length ≥20 mm	90.7%	77.2%	33.0 (10.4–104.9, p < 0.001)	0.84 (0.76–0.90)
Bowel lesion with depth into at least the muscularis layer	95.3%	63.3%	156.2 (26.7–911.8, p < 0.001)	0.90 (0.85–0.96)

between MRI and surgery was 163 (IQR: 104–233 days).

71/122 patient MRIs (58.2%) experienced dyschezia, and 18/122 patient MRIs (14.8%) experienced haematochezia. 15 patients had both symptoms (12.3%), and 48 patients had neither symptom (39.3%).

Of the 74 MRIs excluded from analysis, median patient age at the time of MRI was 37 years (IQR: 32–41 years) (p = 0.080) (Table 2). 17 patients had no clinical data available. For the 57 MRIs for which there was clinical information, 31/57 had dyschezia (41.9%) and 3/57 had haematochezia (4.1%). There was no statistically significant difference in dyschezia (p = 0.870) or haematochezia (p = 0.085) between the included and excluded groups. Therefore, no evidence of selection bias with regards to age or symptoms was identified between the two groups.

3.2. Surgical bowel involvement

67/122 patient MRIs (55%) had surgical evidence of bowel involvement with DIE. Of these, 58/67 (87%) had specimens sent for histology (rectal shave, wedge resection, disc resection or anterior resection), 57/58 (98%) of which confirmed the diagnosis of DIE. Of these, 33/58 (57%) had a procedure requiring a colorectal surgeon (wedge resection, disc resection or anterior resection) (Fig. 1).

Of the 67 patients with surgical evidence of bowel involvement, 9 patients (13.4%) did not have a specimen sent for histology (Fig. 1).

3.3. Interobserver agreement for MRI findings

The readers demonstrated substantial agreement on T2 image quality (kappa = 0.69, 95%CI:0.47–0.81), and almost perfect agreement on T1FS (kappa = 0.83, 95%CI:0.71–0.94) and rectosigmoid image quality (kappa = 0.81, 95%CI:0.68–0.92).

There was almost perfect agreement for adenomyosis (kappa = 0.84, 95%CI:0.73–0.95), and POD (kappa = 0.82, 95%CI:0.69–0.95), ovarian (kappa = 0.86, 95%CI:0.76–0.95) and RVS involvement (kappa = 0.85, 95%CI:0.57–1.00); substantial agreement for the presence of TU (kappa = 0.70, 95%CI:0.56–0.83) and USL involvement (kappa = 0.65, 95%CI:0.51–0.78); and moderate agreement for the presence of adhesions (kappa = 0.60, 95%CI:0.45–0.76).

There was substantial agreement for the presence (kappa = 0.68, 95%CI:0.55–0.81) and number of bowel lesions (weighted kappa = 0.65, 95%CI:0.57–0.75), and the length of bowel lesions (Lin's concordance coefficient 0.73, 95%CI:0.66–0.81). There was almost perfect agreement on the depth of invasion of a bowel lesion (kappa = 0.82, 95%CI:0.74–0.88).

3.4. Agreement between MRI and surgical findings: presence of a bowel lesion

There was almost perfect agreement between MRI and surgical bowel involvement, with agreement in 111/122 (91%) of cases (kappa = 0.82, 95%CI:0.71–0.92).

Aim 1: Current practice versus the calculated 'gold standard' for requirement of a colorectal surgeon

According to the 'gold standard', 43 patients were identified as requiring a colorectal surgeon at operation (recorded operation requiring a colorectal surgeon [n = 33] or incomplete bowel surgery [n = 10]). Bowel surgery was deemed incomplete (Fig. 1) for the following reasons: disease not resected as the colorectal surgeon was not present (n = 5), disease more extensive than predicted and a colorectal surgeon was not present to assist (n = 3), disease not excised due to perceived morbidity (n = 1) and disease not excised as the patient was asymptomatic (n = 1).

There was only moderate agreement between the calculated 'gold standard' and the recorded presence of a colorectal surgeon (kappa = 0.45, 95%CI:0.29–0.60, sensitivity 58.9%, specificity 84.9%, ROC-AUC 0.74) (Table 3).

Dyschezia and haematochezia were not associated with colorectal surgical resection as determined by the calculated 'gold standard' (p = 0.565 and p = 0.792 respectively).

Aim 2: MRI findings associated with 'gold standard' colorectal surgical resection

There was a significant association between the presence of a rectosigmoid lesion on MRI and 'gold standard' colorectal surgical resection (OR = 35.3, 95%CI:8–157, p < 0.001). The presence of a rectosigmoid lesion on MRI demonstrated a potentially high diagnostic utility for predicting colorectal surgical resection (sensitivity 95.3%, specificity 63.3%, ROC-AUC 0.79).

There was a significant association between the length of rectosigmoid DIE on MRI and colorectal surgical resection. Logistic regression analysis demonstrated for every extra millimetre increase in lesion length, there was a corresponding 11% increase in the odds of requiring colorectal surgical resection (OR = 1.11, 95%CI:1.07–1.46, p < 0.001). The optimal ROC cut-point for lesion length on MRI requiring colorectal surgical resection was 19.5 mm (sensitivity 91%, specificity 77%, ROC-AUC 0.84) (Table 3).

There was a significant association between lesion depth and colorectal surgical resection. Compared to patients with no bowel lesion on MRI (n = 52), patients with serosal involvement had an eight-fold increase in the odds of needing a colorectal surgical involvement (n = 32, OR = 8.3, 95%CI:1.64–42.3, p = 0.011). Respective effects for patients with muscular or mucosal/submucosal involvement were

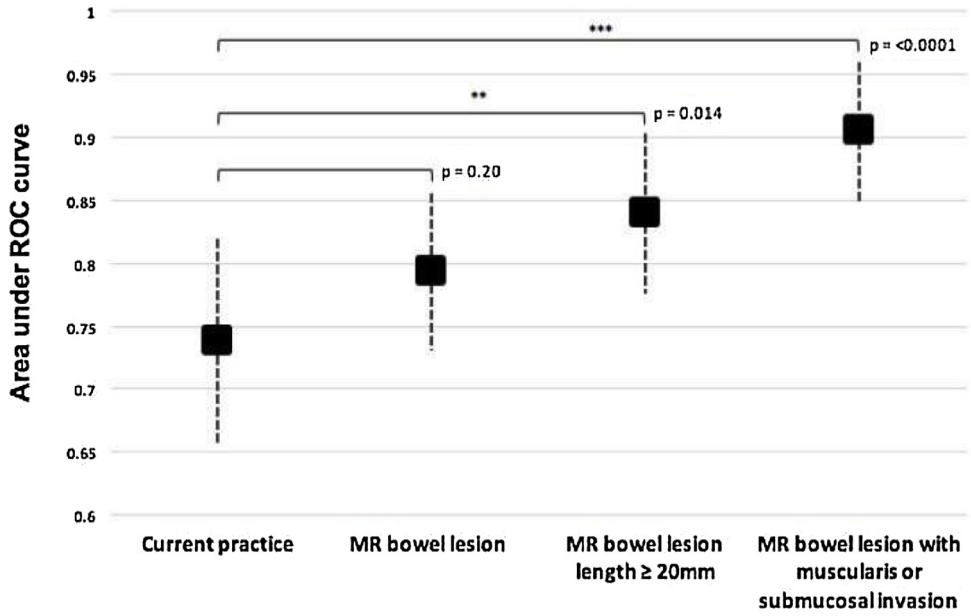

Fig. 3. MRI bowel lesions ≥20 mm in length or infiltrating into the muscularis or submucosa/mucosa layers of the bowel are significantly more associated with 'gold standard' colorectal surgical resection than the current model of practice.

significant (n = 29, OR = 156.2, 95%CI:26.7–911.8, p < 0.001; n = 9, OR = 200, 95%CI:16.2–2470, p < 0.001), but should be interpreted with caution due to small patient numbers. The optimal cut-point for diagnostic purposes was muscular or mucosal/submucosal involvement (sensitivity 95.3%, specificity 63.3%, ROC-AUC 0.90) (Table 3).

3.5. Comparison between current practice and MRI features

Current practice (defined as the recorded presence of a bowel surgeon at the time of surgery) was moderately successful at determining when a colorectal surgeon was needed (ROC-AUC 0.74, 95%CI:0.66–0.82). Identifying an MRI bowel lesion appeared more strongly associated with colorectal surgical resection (ROC-AUC 0.79, 95%CI:0.73–0.86), but was not statistically significant (p = 0.23). MRI bowel lesions ≥20 mm in length (ROC-AUC 0.84, 95%CI:0.78–0.90) and bowel lesions invading into at least the muscularis (ROC-AUC 0.90, 95%CI:0.85–0.96) performed statistically significantly better than current practice (p = 0.014 and p < 0.0001 respectively) (Fig. 3).

3.6. MRI findings not found to be associated with bowel resection

Adhesions (p = 0.185); involvement of the TU (p = 0.175), USLs (p = 0.337), POD (p = 0.066), ovaries (p = 0.081) and RVS (p = 0.558); adenomyosis (p = 0.677); and number of bowel lesions (optimal cut-point ≥1 lesion, sensitivity 95.4%, specificity 63.3%) were not found to have a statistically significant association with 'gold standard' colorectal surgical resection.

4. Discussion

Treatment of bowel DIE is challenging. Medical management of DIE with colorectal extension is based on symptom suppression, but can result in side effects [31] with high rates of recurrence upon withdrawal of medical management. While there is some controversy within the literature regarding the role of bowel resection [32], general consensus is that surgical management is the primary treatment for bowel endometriosis [10–12,17,29].

Currently, there are no clear guidelines for the surgical management of bowel endometriosis [13,17]. The optimal surgical technique is widely debated, and several different techniques have been employed, each with its own advantages and disadvantages [17,33]. One approach to management which avoids bowel resection, used in our centre and others internationally [29,34,35] is to use the 'shave' technique which may be performed by the gynaecologist alone, without involvement of the bowel surgeon. The aim of our paper was to assist gynaecologists working within this paradigm in the decision-making process of when to involve a colorectal surgeon, in order to optimise resource allocation. As the cost of healthcare rises [36], appropriate resource allocation becomes increasingly important - particularly in public healthcare, where increasing patient numbers and burgeoning costs are straining budgets [37] and prolonging patient wait-times [38]. Pre-treatment information that assists resource allocation, particularly if available from the routine pre-treatment work-up, is of increased importance.

Appropriate resource allocation is a cost-saving measure which potentially improves patient care and outcomes. For patients with suspected bowel DIE, the accurate allocation of the colorectal surgeon's time is a critical resource management issue. Correct allocation of the colorectal surgeon's time can reduce the number of subsequent completion operations (resulting in reduced material and personnel costs, reduced morbidity and overall reduced patient recovery time), and increase the colorectal surgeon's efficiency (e.g. avoiding unnecessary presence at surgery and optimizing the use of the colorectal surgeon's expertise appropriately).

At our centre, patients with DIE are managed through a multidisciplinary approach, involving gynaecologists, colorectal surgeons and imaging specialists. Despite this multidisciplinary approach, the final decision to involve a colorectal surgeon is variable - influenced by individual gynaecologist preference, level of experience, and a non-specific combination of ultrasound and MRI findings. Our data shows that the current practice has resulted in only moderately accurate allocation of resourcing (kappa = 0.45, 95%CI:0.29–0.60, ROC-AUC 0.74).

The aim of this study was to identify MRI findings that would more objectively predict the need for colorectal surgical treatment of DIE. This study focused on MRI rather than ultrasound, as retrospective review of MRIs is more reproducible and objective, and MRI has good interobserver reproducibility as evidenced in this study (kappa = 0.60–0.86) and others [22,39–41]. Several imaging features were chosen as possible predictive findings. Maximal lesion length was

assessed as it was hypothesized that increased lesion size may correlate with more radical surgery. Depth of bowel wall invasion was chosen as several studies have demonstrated that MRI prediction of endometriotic invasion into the serosal and muscularis layers is both sensitive and specific [8,42], and the depth of invasion alters the surgical approach [17]. Whilst these studies demonstrated reduced sensitivity in distinguishing between lesions of increased penetrance, this study has demonstrated that from a practical perspective the distinction is immaterial, as lesions with muscularis or mucosal/submucosal invasion were statistically more likely to require colorectal surgical intervention compared with serosal invasion. Number of bowel lesions was assessed, with reasoning that increased number of lesions may correlate with more extensive disease and therefore more radical surgery. Assessment of further posterior/middle pelvic compartment sites of disease was performed for the same reason.

This study identified three MRI features that outperform the current model of colorectal surgeon allocation at our centre for the surgical management of DIE. When compared to the calculated 'gold standard', bowel lesions invading beyond the serosa, or measuring ≥ 20 mm in length were associated with increased requirement for colorectal surgical resection ($p < 0.0001$ and $p = 0.014$ respectively; compared to the current practice). Although prediction for colorectal surgical intervention was improved when MRI detected a bowel lesion, this was not statistically significant compared to current practice.

Within the literature, there is a lack of data pertaining to MRI factors associated with bowel resection in DIE, with only two other studies examining the question. Scardapane et al. [43] identified two factors (short axis length ≥ 11 mm and stenosis $\geq 30\%$) correlating to colorectal surgeon bowel resection with high sensitivity and specificity. However, this required MRI colonography, an invasive procedure, to identify and quantify the degree of stenosis. By contrast, our study was able to identify predictive factors without invasive bowel distention. Perandini et al. [44], a smaller study with 52 patients, identified lesion length as a predictive factor, however their cut-off length was longer (32 mm) compared to this study (20 mm). Our larger study cohort more accurately estimates the optimal cut-point.

This retrospective study has several limitations, including the relatively small cohort size and lack of power. Additionally, incomplete or poorly recorded clinical data for some patients may have affected results. A larger patient cohort, ideally in the setting of a prospective trial, would be required to validate our findings. Additionally, the median wait time between the MRI and time of surgery was 163 days, a relatively long time during which disease extend and severity could have changed; despite this, there was still almost perfect agreement between MRI identified bowel involvement and surgical bowel involvement (agreement in 91%, kappa = 0.82, 95%CI:0.71–0.92). While this study focused on MRI findings of bowel DIE. In practice, many centres also use ultrasound in the decision-making process [45]. Integration of these findings with ultrasound data may more comprehensively reflect clinical practice and therefore have more clinical relevance than suggestions based solely on MRI. Another potential criticism of this study is selection bias, as many of the patients were referred to MRI on the basis of clinically suspected bowel DIE. However, 45% patients did not have evidence of bowel DIE at the time of surgery, and this correlated well with the MRI findings (kappa = 0.817, 95%CI:0.714–0.920).

It should be emphasized that the findings in our study reflect local practice and expertise. We appreciate that surgical approaches to bowel endometriosis vary greatly – some centres may always include colorectal surgeons and other may have gynaecologists more comfortable with bowel resection. However, for gynaecologists and colorectal surgeons working within the same paradigm as our centre, our findings should be helpful in improving the allocation of colorectal surgical time.

5. Conclusion

This study identifies features of DIE on MRI which have an association with colorectal surgical bowel resection. We propose that if a bowel lesion is identified on pre-operative MRI, the single most important factor is lesion depth, with extension beyond the serosa considered good evidence for the inclusion of a colorectal surgeon at surgery. Lesions ≥ 20 mm in length also have a high likelihood of requiring colorectal surgical intervention, and inclusion of a colorectal surgeon should be considered for these patients.

These findings provide a basis for prospective studies to validate these findings and provide additional data for development of predictive scoring systems to aid surgical planning and resource allocation for the surgical treatment of DIE.

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CRediT authorship contribution statement

Ana Brusic: Writing - original draft, Data curation, Formal analysis. **Stephen Esler:** Data curation, Writing - review & editing. **Leonid Churilov:** Formal analysis, Methodology, Writing - review & editing. **Prathima Chowdary:** Data curation. **Matthew Sleeman:** Data curation. **Peter Maher:** Resources, Writing - review & editing. **Natalie Yang:** Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Writing - review & editing.

Declaration of Competing Interest

None.

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