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Original Articles

The performance of preoperative MRI in service-based centers in diagnosing deep myometrial invasion by endometrial carcinoma

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Summary

Objectives: This study investigates the performance of MRI performed in service-based centers in diagnosing deep myometrial invasion by endometrial cancer. It also investigates if the combined use of MRI and intraoperative gross examination of uterine specimen improve sensitivity. *Materials and Methods:* Endometrial cancer patients who had hysterectomy in Prince of Wales Hospital in Hong Kong from January 2007 to November 2014 were identified retrospectively. Those who had preoperative MRI assessment for myometrial invasion were included. Patient's records were reviewed for demographic, operative, MRI and pathology findings. The accuracy of MRI and operative findings were determined by correlating them with pathological findings. *Results:* This study included 343 patients. The accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and positive likelihood ratio (NLR) of MRI in diagnosing deep myometrial invasion were 78.4%, 68%, 81.3%, 50.5%, 90.1%, 3.64, and 0.39, respectively. Area under the curve (AUC) was 0.75. MRI performed within 20 days were more reliable than MRI performed more than 20 days before surgery (80.4% *vs*. 61%, p=0.01). The accuracy, sensitivity, and specificity of gross examination were 81.5%, 58.9%, and 87.6%, respectively. The accuracy, sensitivity, and specificity of combined assessment with MRI and gross examination were 75.3%, 76.7%, and 74.9%, respectively. *Conclusions:* The performance of MRI in service-based centers is comparable to research centers. The accuracy was lower if MRI was performed more than 20 days before surgery. The authors recommend combined assessment with MRI and intra-operative gross examination in view of the higher sensitivity in diagnosing deep myometrial invasion.

Key words: MRI; Myometrial invasion; Endometrial cancer; Hysterectomy.

Introduction

Endometrial cancer is the most common gynaecologic malignancy in the developed countries, with an annual incidence of 27.05 per 100,000 population in the United States [1]. Its incidence is also on the rise in the Hong Kong Chinese population [2]. The majority of patients present at an early stage and surgery is the mainstay of treatment [2]. MRI has been increasingly used in recent years in the preoperative assessment and a ten-fold increase over a ten-year period of time has been reported [3]. MRI is preferred to CT because it provides more accurate assessment of the depth of myometrial invasion, cervical invasion, and lymph node metastasis that may influence the surgical treatment [4].

Surgical morbidity is significantly higher after hysterectomy and lymphadenectomy compared to hysterectomy alone [5]. Study has shown that the risk of lymph node metastasis with superficial and deep myometrial invasion was 5% and 25%, respectively [6]. FIGO has suggested lymphadenectomy to be considered only in high-risk cases such as those with deep myometrial invasion [7]. Lymphadenectomy can be safely omitted if deep myometrial invasion has been excluded without concern that the treatment outcome would be inadequate [8]. Many studies have demonstrated the validity of MRI in assessing the depth of myometrial invasion [9-12], with a reported sensitivity of up to 90% [13]. In these studies, the MRIs were performed under standardized setting with strict adherence to a single MRI protocol and designated specialized radiologists were involved in the interpretation [7]. Since the accuracy of MRI varies with different MRI machines, imaging technique [10, 13-15] and experience of radiologist, whether the reported results can be achieved in service-based settings, is uncertain. In some studies, the reported sensitivity of MRI was only 65% [16].

Intraoperative gross examination and intraoperative frozen section of the uterine specimen after completion of hysterectomy have also been used to assess the depth of myometrial invasion. Intraoperative gross examination of specimen for deep myometrial invasion has a sensitivity of

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65% [17] and the performance of frozen section appears to be better [18]. However, the expertise to perform high-standard frozen section is often not available.

The primary aim of this study was to investigate the accuracy of MRI performed in service-based centers in diagnosing deep myometrial invasion. The secondary aim was to investigate whether the combined assessment with MRI and intraoperative gross examination of specimen achieves higher accuracy in diagnosing deep myometrial invasion.

Materials and Methods

Patients diagnosed to have endometrial cancer and treated by surgery in the Prince of Wales Hospital in Hong Kong from January 2007 to November 2014 were identified retrospectively. Those with preoperative MRI to assess the depth of myometrial invasion were included in the study. The patient's records were reviewed to retrieve the demographic data and operative, MRI, and pathology findings. The standard surgical treatment for endometrial cancer includes hysterectomy and bilateral salpingo-oophorectomy. Pelvic and/or para-aortic lymphadenectomy may be performed depending on the surgical risk of the patient, tumour grade, histological type, cervical involvement, disease stage, enlargement of lymph node, and depth of myometrial invasion assessed by MRI and intraoperative examination. Most MRIs were performed by six service-based units. These centers were approached to gather information on the machine used and imaging protocol employed. Intraoperative gross assessment of specimen for depth of myometrial invasion was done by making an incision in the uterine specimen at the site where the bulk of tumor was identified. All surgical specimens were sent for pathological examination after completion of surgery.

MRI techniques: Center A

All MRI examinations were performed with a 3T machine. Axial images were obtained with T1 turbo spin echo (TSE), T2 TSE, T1 TSE fat saturation (FS), and gradient echo (GE) sequences. Sagittal images were obtained with T2 TSE blade sequence. Coronal images were obtained with T2 TSE short tau inversion recovery (STIR) sequence. T1 TSE blade sequence was applied perpendicular to the tumor. Post contrast axial, coronal, and sagittal images were obtained with T1 TSE FS sequence.

Center B

MRI were performed mainly by 3T machines. Axial images were obtained with T1 TSE and T2 TSE FS sequences. Sagittal image was obtained with T2 TSE FS sequence. Coronal images were obtained with T2 half-fourier acquisition single-shot turbo spin-echo (HASTE) and T2 3D sampling perfection with application optimized contrasts using different flip angle evolution (SPACE) sequences. Post-contrast axial images were obtained by T1 TSE FS sequence. Post-contrast coronal images were obtained with 3D gradient recalled echo sequence (GRE). Dynamic study with T1 3D GRE sequence was performed.

Center C

MRI were performed mainly by a 3T scanner . Axial images were obtained mainly with T1, T2, and T2 FS sequences. Sagittal image was obtained with T2 sequence. Coronal image was obtained with T2 sequence. Post- contrast sagittal, oblique axial, and axial image were obtained with enhanced T1 high resolution isotropic volume excitation (eTHRIVE) sequence.

Table 1. — *Patient characteristics*

	Number of patients	Percentage
Age, years (n=343)		
30-39	9	2.6%
40-49	50	14.6%
50-59	186	54.3%
60-69	67	19.5%
70-79	25	7.3%
≥ 70	6	1.7%
Mean age: 56.2, median age: 55		
Parity (n=301)		
0	68	22.6%
1	51	16.9%
2	101	33.6%
3	45	15%
4	18	6%
5	10	3.3%
>5	8	2.7%
Missing data = 42		
Stage of endometrial cancer (n=343)		
1A	231	67.3%
1B	40	11.7%
II	30	8.7%
IIIA	17	5%
IIIB	5	1.5%
IIIC1	12	3.5%
IIIC2	6	1.7%
IVB	2	0.6%
Final histology (n=343)		
Endometrioid	307	89.5%
Serous adenocarcinoma	6	1.7%
Clear cell carcinoma	6	1.7%
Undifferentiated adenocarcinoma	4	1.2%
Malignant mixed Müllerian tumor	6	1.7%
Others	11	3.2%
Benign	3	0.9%
Grade of tumor (n=307)		
Grade 1	196	63.8%
Grade 2	80	26.1%
Grade 3	31	10.1%
Menopause (n=343)	224	65.3%
Presence of adenomyosis (n=343)	47	13.7%
Presence of fibroid (n=343)	155	45.2%
Presence of fibroid > 4cm	25	7.3%
Presence of fibroid > 8cm	5	1.5%
Time between MRI and surgery		
≤ 10 days	162/332	48.8%
11 to ≤ 20 days	129/332	38.9%
> 20 days	41/332	12.3%
Missing data = 11		

Center D

MRI were performed by either 1.5T machine or 3T machine. Axial images were obtained with T1 TSE, T2 TSE, T2 FS, and T2 GE sequences. Sagittal images were obtained with T2 TSE sequence. Coronal images were obtained with T2 FS sequence. Post-contrast axial, sagittal, and coronal images were obtained with T1 FS sequence.

Table 2. — *MRI Findings versus Final Histology and MRI Performance in Diagnosing Deep Myometrial Invasion.*

		MRI: <50% invasion	MRI: ≥50% invasion	Accuracy	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	PLR (95% CI)	NLR (95% CI)	AUC (95% CI)
Overall (n=343)	Pathology: <50% invasion	n=218	n=50	78.4% (269/343)	68% (56.2% to 78.3%)	81.3% (76.2% to 85.8%)	50.5% (40.4% to 60.6%)	90.1% (85.6% to 93.5%)	3.64 (2.7 to 4.9)	0.39 (0.28 to 0.55)	0.75 (0.68 to 0.81)
	Pathology: ≥50% invasion	n=24	n=51								
Center A (n=166)	Pathology: <50% invasion	n=112	n=14	83.7% (139/166)	67.5% (50.9% to 81.1%)	88.9% (82.1% to 93.8%)	65.9% (49.4% to 79.9%)	89.6% (82.9% to 94.3%)	6.07 (3.54 to 10.41)	0.37 (0.23 to 0.57)	--
	Pathology: ≥50% invasion	n=13	n=27								
Center B (n=63)	Pathology: <50% invasion	n=33	n=20	65.1% (41/63)	80% (44.4% to 96.9%)	62.3% (47.9% to 75.2%)	28.6% (13.3% to 48.7%)	94.3% (80.8% to 99.1%)	2.12 (1.33 to 3.37)	0.32 (0.09 to 1.13)	--
	Pathology: ≥50% invasion	n=2	n=8								
Center C (n=52)	Pathology: <50% invasion	n=31	n=9	73.1% (38/52)	58.3% (27.8% to 84.7%)	77.5% (61.5% to 89.4%)	43.8% (19.8% to 70.1%)	86.1% (70.5% to 95.3%)	2.59 (1.23 to 5.48)	0.54 (0.27 to 1.07)	--
	Pathology: ≥50% invasion	n=5	n=7								
Center D (n=15)	Pathology: <50% invasion	n=10	n=2	86.7% (13/15)	100% (30.5% to 100%)	83.3% (51.6% to 97.4%)	60% (15.4% to 93.5%)	100% (69% to 100%)	6 (1.69 to 21.26)	0	--
	Pathology: ≥50% invasion	n=0	n=3								
Center E (n=12)	Pathology: <50% invasion	n=8	n=1	83.3% (10/12)	66.7% (11.6% to 94.5%)	88.9% (51.7% to 98.2%)	66.7% (11.6% to 94.5%)	88.9% (51.7% to 98.2%)	6 (0.8 to 45)	0.38 (0.07 to 1.89)	--
	Pathology: ≥50% invasion	n=1	n=2								
Center F (n=10)	Pathology: <50% invasion	n=7	n=0	80% (8/10)	33.3% (5.5% to 88.5%)	100% (58.9% to 100%)	100% (16.6% to 100%)	77.8% (40.1% to 95.5%)	--	0.67 (0.3 to 1.48)	--
	Pathology: ≥50% invasion	n=2	n=1								

PPV: positive predictive value, NPV: negative predictive value, PLR: positive likelihood ratio, NLR: negative likelihood ratio, AUC: area under the curve.

Center E

MRI were performed by either 1.5T GE or 3T machines. Axial images were obtained with T1 GE, T2 TSE, T1 GE, T1 GE FS, T2 HASTE, and T2 HASTE FS sequences. Sagittal images were obtained with T2 TSE sequence. Coronal images were obtained with T2 TSE and T2 HASTE sequences. Post-magnevist or dotarem contrast sagittal, coronal, and axial images were obtained by T1 GE FS sequence.

Center F did not reply to authors' enquiry on MRI technique

The overall and individual center's MRI accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and negative likelihood ratio (NLR) in detecting deep myometrial invasion were calculated. Accuracy, sensitivity, specificity, PPV, NPV, PLR, and NLR of intraoperative gross examination of specimen in detecting deep myometrial invasion alone and after combining it with MRI were also calculated. Chi square test was used to compare categorical variables. *T*-test was used to compare continuous with categorical variables. Receiver operating curve (ROC) for MRI, intraoperative gross examination of specimen, combined assessment with MRI, and gross examination of specimen were drawn. Analyses were performed with the Statistical Package for Social Science version 22.0. The significance level was set at $p < 0.05$.

Results

A total of 372 endometrial cancer patients with preoperative MRI were identified, 343 patients were included in the study and 29 cases were excluded because the depth of myometrial invasion was not reported. The age of the patients ranged from 31 to 89 years, median age was 55 years, 65.3% were menopausal, 67.3% of cases had Stage 1A disease, 89.5% were endometrioid cancer, and 63.8% were grade 1 tumors. Fibroid was present in 45.2% of cases and adenomyosis was present in 13.7% of cases; 87.7% had definitive surgery performed within 20 days after the MRI (Table 1).

Three hundred eighteen MRIs were performed mainly in six service-based centers (Center A, B, C, D, E, and F) and the remaining 25 were performed in other serviced-based centers (Table 2). The overall accuracy of MRI in detecting deep myometrial invasion was 78.4%. Among the 74 inaccurately assessed cases, MRI overestimated myometrial invasion in 50 cases and underestimated myometrial invasion in 24 cases. The sensitivity, specificity, PPV, NPV, PLR, and NLR were 68%, 81.3%, 50.5%, 90.1%, 3.64, and 0.39, respectively (Table 2). The ROC of MRI in diagnosing deep myometrial invasion is shown in Figure 1. The area under the curve (AUC) was 0.75 (95% CI 0.68 to 0.81). The accuracy, sensitivity, specificity, PPV, NPV, PLR, and NLR of MRI in each of the six centers were calculated and the results are shown in Table 2. Performance of center with case load >100 (Center A) was better than those with case load < 100 (all centers except Center A) ($p = 0.03$). MRIs performed within 20 days of surgery were found to be more reliable than MRIs performed >20 days from surgery (80.4% *vs*. 61%, $p = 0.01$) (Table 3).

Age, menopausal status, presence of fibroid, > 4cm fibroid, adenomyosis, and lymphovascular space invasion were not found to affect performance of MRI (Table 3). MRI was more accurate in assessing depth of myometrial invasion in Stage 1A patients than in Stage 1B patients (82.3% *vs*. 57.5%, $p = 0.00$). The histology of tumor (endometrioid *vs*. non-endometrioid) did not affect MRI per-

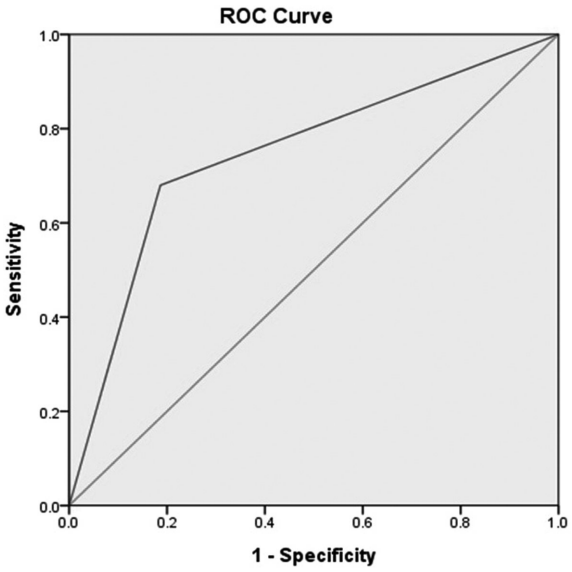

Figure 1. — ROC curve of MRI in diagnosing deep myometrial invasion.

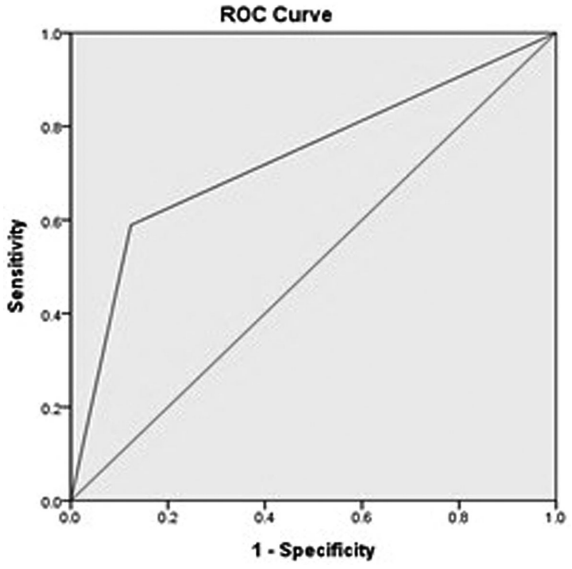

Figure 2. — ROC curve of gross examination of specimen in diagnosing deep myometrial invasion.

formance. The accuracy, sensitivity, specificity, PPV, NPV, PLR, and NLR for grade 1, grade 2 and grade 3 tumors are shown in Table 4. MRI was less accurate in grade 2 tumors than grade 1 and 3 tumors ($p = 0.04$) (Table 3).

Among the 343 cases, 340 cases had depth of myometrial invasion assessed clinically after hysterectomy. The accuracy of gross examination of specimen for deep myometrial invasion was 81.5%. Among the 63 inaccurately assessed cases, gross examination overestimated 33 cases and underestimated 30 cases. The sensitivity, specificity, PPV, NPV, PLR, and NLR were 58.9%, 87.6%, 56.6%, 88.6%, 4.77, and 0.47, respectively (Table 5). The ROC of gross examination of specimen in diagnosing deep myometrial invasion is shown in Figure 2. The AUC was 0.73 (95% CI 0.66 to 0.81).

Among 47 cases classified as ≥ 50% myometrial invasion on MRI but < 50% myometrial invasion on gross examination, 72% actually had < 50% myometrial invasion on final pathology. Among 24 cases with ≥ 50% myometrial invasion on gross examination of specimen but <50% myometrial invasion on MRI, 75% actually had < 50% myometrial invasion on final pathology. When combining the use of MRI with gross examination to diagnose deep myometrial invasion, and positive diagnosis was made if either one or both assessments show deep myometrial invasion,

Table 3. — *Factors affecting MRI in diagnosing deep myometrial invasion.*

	Accurate	Inaccurate	*p*-value
Time between MRI & surgery (n=332)			
≤ 20 days	234/291 (80.4%)	57/291 (19.6%)	0.01*
> 20 days	25/41 (61%)	16/41 (39%)	
Center case load (n=343)			
> 100 cases	139/166 (83.7%)	27/166 (16.3%)	0.03*
< 100 cases	130/177 (73.4%)	47/177 (26.6%)	
Menopausal status (n=343)			
Menopause	176/224 (78.6%)	48/224 (21.4%)	1
Not menopause	93/119 (78.2%)	26/119 (21.8%)	
Fibroid (n=343)			
Present	124/155 (80%)	31/155 (20%)	0.61
Absent	145/188 (77.1%)	43/188 (22.9%)	
Fibroid > 4 cm (n=343)			
Present	20/25 (80%)	5/25 (20%)	1
Absent	249/318 (78.3%)	69/318 (21.7%)	
Adenomyosis (n=343)			
Present	42/47 (89.4%)	5/47 (10.6%)	0.08
Absent	227/296 (76.7%)	69/296 (23.3%)	
LVSI (n=254)			
Present	46/58 (79.3%)	12/58 (20.7%)	1.0
Absent	152/196 (77.6%)	44/196 (22.4%)	
Stage of tumor (n=271)			
Stage 1A	190/231 (82.3%)	41/231 (17.7%)	0.00*
Stage 1B	23/40 (57.5%)	17/40 (42.5%)	
Histology of tumor (n=343)			
Endometrioid	243/307 (79.2%)	64/307 (20.8%)	0.46
Non-endometrioid	26/36 (72.2%)	10/36 (27.8%)	
Grade of tumor (n=307)			
Grade 1	161/196 (82.1%)	35/196 (17.9%)	0.02*
Grade 2	55/80 (68.8%)	25/80 (31.3%)	
Grade 3	27/31 (87.1%)	4/31 (12.9%)	
Age, years	Mean 55.9 (SD: 8.69)	Mean 57.4 (SD: 9.93)	0.22

*Statistically significant, LVSI: lymphovascular space invasion.

Table 4. — *Grade of Endometrioid Tumor and Respective MRI Performance.*

		MRI: <50% invasion	MRI: ≥50% invasion	Accuracy	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	PLR (95% CI)	NLR (95% CI)
Grade 1 (n=196)	Pathology: <50% invasion	n=145	n=23	82.1% (161/196)	57.1% (37.2% to 75.5%)	86.3% (80.2% to 91.1%)	41.0% (25.6% to 57.9%)	92.4% (87.0 to 96%)	4.17 (2.54 to 6.86)	0.5 (0.32 to 0.76)
	Pathology: ≥50% invasion	n=12	n=16							
Grade 2 (n=80)	Pathology: <50% invasion	n=40	n=22	68.8% (55/80)	83.3% (58.6% to 96.2%)	64.5% (51.3% to 76.3%)	40.5% (24.8% to 57.9%)	93% (80.9% to 98.7%)	2.35 (1.58 to 3.48)	0.26 (0.09 to 0.74)
	Pathology: ≥50% invasion	n=3	n=15							
Grade 3 (n=31)	Pathology: <50% invasion	n=13	n=1	87.1% (27/31)	82.4%% (56.6% to 96%)	92.9% (66.1% to 98.8%)	93.3% (68% to 98.9%)	81.3% (54.3% to 95.7%)	11.53 (172 to 77.2)	0.19 (0.07 to 0.54)
	Pathology: ≥50% invasion	n=3	n=14							

PPV: positive predictive value, NPV: negative predictive value, PLR: positive likelihood ratio, NLR: negative likelihood ratio.

Table 5. — *Performance of Gross Examination of Specimen in Diagnosing Deep Myometrial Invasion.*

		Clinical: <50% invasion	Clinical: ≥50% invasion	Accuracy	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	PLR (95% CI)	NLR (95% CI)	AUC (95% CI)
Gross examination of specimen (n=340)	Pathology: <50% invasion	n=234	n=33	81.5% (277/340)	58.9% 46.7 to 70.3%)	87.6% (83.1% to 91.3%)	56.6% (44.7% to 68%)	88.6% (84.2% to 92%)	4.77 (3.28 to 6.92)	0.47 (0.35 to 0.62)	0.73 (0.66 to 0.81)
	Pathology: ≥50% invasion	n=30	n=43								

PPV: positive predictive value, NPV: negative predictive value, PLR: positive likelihood ratio, NLR: negative likelihood ratio, AUC: area under the curve.

Table 6. — *Performance of Combined Assessment with MRI and Gross Examination of Specimen in Diagnosing Deep Myometrial Invasion.*

		MRI or clinical: <50% invasion	MRI or clinical: ≥50% invasion	Accuracy	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	PLR (95% CI)	NLR (95% CI)	AUC (95% CI)
Combine MRI with gross examination (n=340)	Pathology: <50% invasion	n=200	n=67	75.3% (256/340)	76.7% (65.4% to 85.8 %)	74.9% (69.3% to 80%)	45.5% (36.5% to 54.8%)	92.3% (87.8% to 95.4%)	3.06 (2.4 to 3.9)	0.31 (0.2 to 0.47)	0.76 (0.69 to 0.82)
	Pathology: ≥50% invasion	n=17	n=56								

PPV: positive predictive value, NPV: negative predictive value, PLR: positive likelihood ratio, NLR: negative likelihood ratio.

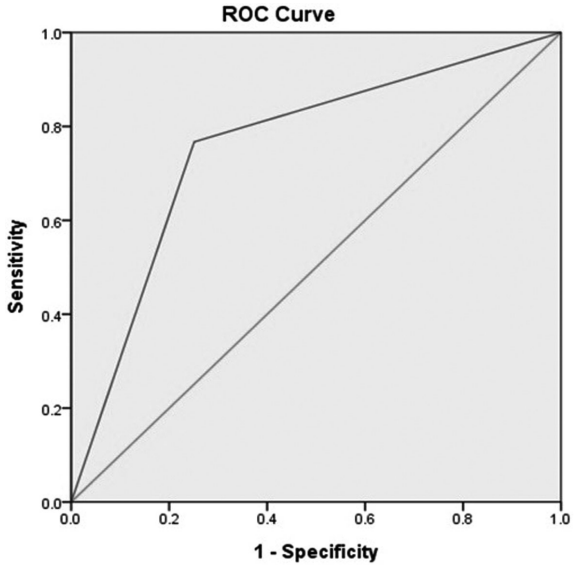

Figure 3. — ROC curve of combined assessment with MRI and gross examination of specimen in diagnosing deep myometrial invasion.

the accuracy was 75.3%. The sensitivity, specificity, PPV, NPV, PLR, and NLR were 76.7%, 74.9%, 45.5%, 92.3%, 3.06 and 0.31, respectively (Table 6). The ROC for combined assessment with MRI and gross examination of specimen diagnosed as deep myometrial invasion is shown in Figure 3. The AUC was 0.76 (95% CI 0.69 to 0.82) (Table 6).

Discussion

Endometrial cancer is a surgically staged disease. Full surgical staging involves lymphadenectomy which carries risk of complications such as lymphedema, lymphocyst, and chylous ascites. Surgical morbidity is significantly higher after hysterectomy and lymphadenectomy compared to hysterectomy alone [5]. Studies have demonstrated that lymphadenectomy can be omitted in low-risk endometrial cancer patients without compromising survival [8]. Therefore, accurate assessment on myometrial

invasion preoperatively or intraoperatively can be important to influence the decision to perform full lymphadenectomy or not. Assessment of myometrial invasion has been done preoperatively by MRI, CT, ultrasound, and PET-CT and intraoperatively by gross examination of uterine specimen or frozen section.

MRI has been widely used in preoperative assessment of endometrial cancer because published reports showed that MRI is better than CT and ultrasound scan (USG) in assessing myometrial invasion [4]. However, a recent study has shown the accuracy and sensitivity of USG in evaluating myometrial invasion reached 84% and 83%, respectively [19]. MRI is preferred to USG because the latter does not provide adequate assessment of nodal and distant metastasis. PET-CT had been reported to have promising results with sensitivity of 93% in predicting myometrial invasion [9]. However, data on PET-CT is limited and it is expensive. MRI has an advantage of being more readily available and less expensive.

The published sensitivity of MRI in diagnosing myometrial invasion was up to 90% in a research center [13]. It is known that MRI accuracy varies with different MRI techniques and the use diffusion weighted imaging may increase the sensitivity in detecting deep myometrial invasion [14]. The interobserver variability of radiologist in interpreting myometrial invasion is another issue and the agreement is only fair among radiologists (Kappa coefficient = 0.39) [20]. It is questionable if MRI performed outside research centre without strict study protocol and interpreted by designated MRI experts could achieve the same good result [15, 16].

Antonsen *et al.* had recently published a randomized controlled trial (RCT) including 318 consecutive patients with preoperative PET-CT, MRI, and ultrasound performed [9]. The accuracy, sensitivity, and specificity of MRI in detecting deep myometrial invasion were 66%, 87%, and 57%, respectively. The accuracy, sensitivity, and specificity of MRI in detecting deep myometrial invasion in the present study were 78.4%, 68%, and 81.3%, respectively. The present figures had a lower sensitivity, but higher specificity and are consistent with the published data in another study (sensitivity 73%, specificity 83%) [12].

The PPV of MRI in detecting deep myometrial invasion was only 50.5% in the present study. The figure was 44% in Antonsen *et al.* RCT [9] and 65% in a recently published meta-analysis by Wu *et al.* that included 11 studies with 548 patients altogether [10]. The consistently low PPV may be due to the low incidence of deep myometrial invasion in endometrial cancer patients. MRI tended to overestimate myometrial invasion in the present study. Among 74 inaccurately assessed cases, 68% (50/74) were overestimated and 24 were underestimated. This observation is consistent with findings from McComiskey *et al.*, where they found that MRI tended to overdiagnose deep myometrial invasion [12]. This may be due to marked inflammatory reaction surrounding the tumor. These errors in assessment led to lymphadenectomy performed in 50 low-risk cases and full surgical staging, including lymphadenectomy that was not performed in 24 high-risk cases.

The present study found a high NPV of 90% of MRI in diagnosing deep myometrial invasion. This finding of high NPV is also consistent with a meta-analysis [10]. With a negative finding on MRI, it is highly likely that deep myometrial invasion is absent and full surgical staging can be avoided. It appeared that MRI performed by service-based centers was reasonably accurate and specific with a high NPV in diagnosing deep myometrial invasion though the sensitivity and PPV were suboptimal. The present authors have also studied factors that may have affected the performance of MRI. These included time gap between MRI and surgery, center case load, and disease stage. They found that a delay for more than 20 days between MRI and surgery was related to a significantly lower accuracy of MRI. When they compared the MRI performance between center with case load > 100 (Center A) to those with case load < 100 (all centers except Center A), they found that the center with higher case load has a higher MRI accuracy than centers with lower case load. This finding is consistent with a previous study that demonstrated accuracy of MRI in assessing myometrial invasion that increased with increased case load [21].

Previous study showed that the presence of fibroid and adenomyosis may lower the accuracy of MRI [22] but the present authors did not make the same observation. They noticed that the accuracy of MRI was lower for grade 2 tumors compared to grade 1 or 3 tumors. They believe that this might be an incidental and insignificant finding as the reproducibility of grade 2 endometrial tumour is low [23, 24].

Intraoperative gross examination of specimen had long been used to assess myometrial invasion. A previous study reported a high accuracy of 88.2% with a sensitivity of 83.7% [25]. However, this high figure is not reproduced in subsequent studies [17, 26], with a reported sensitivity of only 65% [17]. The present authors have found that gross examination of uterine specimen was comparable to MRI in terms of accuracy (81.5% *vs*. 78.4%) and specificity (87.6% *vs*. 81.3%) in diagnosing deep myometrial invasion, though the sensitivity was lower (58.9% *vs*. 68%).

Intraoperative frozen section has been demonstrated to have a higher sensitivity of 73% [18]. A retrospective study with 175 cases reported sensitivity as high as 85.7% [11]. Some also suggested the advantage of frozen section being able to assess the grade of tumor, which is also an important factor in the decision of lymphadenectomy. However, a study has shown a high concordance rate of 92.6% between preoperative tumor grade and postoperative tumor grade [5]. Another study also could not demonstrate advantage of intraoperative frozen sec-

tion over evaluation of the tumor grade by preoperative biopsy, with similar sensitivity showed for both tests (74% *vs*. 75%) [27]. Therefore, the benefit of frozen section to be able to assess grade of tumor may not be that significant.

A recently published study combined MRI with intraoperative frozen section and found a high sensitivity of 86.7% for diagnosing deep myometrial invasion [11]. In that study, the addition of MRI to frozen section only increased the sensitivity from 85.7% to 86.7%. Although frozen section appeared to have better sensitivity over gross examination of specimen, availability of histopathological staff at designated time and site were not readily available. Frozen section prolongs the surgical time, increases costs, and may increase surgical and anaesthetic morbidities. Conversely, gross examination of specimen is readily available time though the accuracy appears to be lower.

The AUC of MRI and gross examination of uterine specimen were 0.75 and 0.73, respectively, and both perform fairly in diagnosing deep myometrial invasion. Combining MRI and intraoperative gross assessment increased the sensitivity to 76.7% but lowered the specificity to 74.9%. The AUC for combined assessment was 0.76 and was not any better than that of MRI alone or gross examination of specimen. The present authors prefer an assessment method with a higher sensitivity so that full surgical staging is less likely to be omitted in high risk patients.

The strength of the present study was a large sample size. The limitations included the retrospective nature of the study. The depth of myometrial invasion was not reported in 8% (29/372) of cases. If the depth of myoinvasion was not reported because difficulty was encountered in the assessment, then the accuracy of MRI may not have been as high as 78.4%. The surgeons were not blinded to the MRI findings when they performed the gross examination of specimen. There was no designated pathologist to interpret the final pathology and they may not have been blinded to MRI and operative findings.

Conclusion

MRI performed in service-base centers has comparable performance to MRI performed in research centers. It has high accuracy of 78.4% and specificity of 81.3% in diagnosing deep myometrial invasion with a sensitivity of 68%. The accuracy of MRI performed within 20 days before surgery in diagnosing deep myometrial invasion was 80.4% and the accuracy was lower if the wait for surgery was prolonged. The present authors recommend combined assessment with MRI and intraoperative gross examination to increase sensitivity in diagnosing deep myometrial invasion.

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