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Original Research Article

Role of Magnetic Resonance Imaging in Evaluation and Staging of Colo-Rectal Carcinoma

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Abstract

Background: Currently colorectal cancer is staged with computed tomography (CT). However, magnetic resonance imaging (MRI) is giving superior results in the detection of colorectal liver metastasis and in local staging of colorectal cancer. Optimal (local) staging of colorectal cancer could become crucial in selecting patients for neoadjuvant treatment (FOXTROT trial). In this study, we find out the diagnostic performance of MRI in staging the disease and compare with histopathological study and thus find the accuracy of MRI in staging colorectal cancer preoperatively.

Aim and Objective:

1. To study the role of MRI in staging of Colo-Rectal carcinoma.
2. To assess its impact on evaluation and management pattern.

Patients and Methods:

It is a prospective study taking 44 number of colorectal cancer patient who were admitted to the MKCG Medical and Hospital during the period from August 2020 to May 2022. All the patients were undergone MRI scan (1.5 Tesla: T1, T2 and diffusion weighted imaging) of the abdomen and pelvis. Patients were staged accordingly. Early staged cancer patients were selected for surgery and locally advanced cancer patients were undergone neoadjuvant chemotherapy and again restaged after completion of chemotherapy and then again surgery was performed. The results were recorded on various parameters like size and extent of tumour, serosal involvement, extramural vascular invasion, circumferential resection margin (CRM), mesorectal fat invasion and compared with histopathological reports.

Results:

The overall accuracy of T-staging when all cases were combined was 77.9% in our study with 69.4% sensitivity and 79.3% specificity. All cases combined (N=44): N-staging showed accuracy of 81.2%, sensitivity of 74.2% and Specificity of 85.5%. The specificity of predicting

CRM invasion was 91.7% and negative predictive value was 84.6%. Accuracy of 80.7%, 68.2% sensitivity and 87.5% specificity were noted in prediction of presence of extramural vascular invasion for the whole study population. For detecting serosal involvement and extramural vascular invasion MRI had a high sensitivity and moderate specificity and a moderate sensitivity and specificity in the detection of nodal involvement.

Conclusion: Our study shows that MRI has the potential to become a valuable tool in preoperative staging and restaging post chemoradiation therapy in locally advanced disease of colorectal cancer, Identification of invasion of mesorectal fascia and anal sphincter complex is therapeutically more important than the tumor stage. Combination of diffusion weighted images with high resolution oblique axial T2 weighted image perpendicular to the rectal wall, gives good accuracy for T staging and identification of malignant lymph nodes, mesorectal fascia invasion and extramural vascular invasion. High resolution T2 oblique coronal sections parallel to anal canal helps in planning sphincter sparing surgery thereby improving the quality of life. In addition, MRI seems to have a high sensitivity for additional risk factors, such as serosal involvement and EMVI. Combined with its known superiority in detecting liver metastasis, MRI could become the most optimal abdominal staging method for colorectal cancer patients.

Introduction

Colorectal cancers are abnormal growths in the wall of rectum or colon, most commonly appearing as adenomatous polyps that eventually become cancerous. Vast majority of the cancers are adenocarcinomas that begin in the mucus glands lining the colon and rectum. [1]

Colorectal carcinoma is the second most diagnosed cancer in the world. [2] It is the 4th most common cause of death due to cancer. [3] Only 30% - 40% of all Colorectal carcinomas are Rectal cancers, and the remaining are Colon Cancers. Rectal carcinoma is defined as cancer occurring in the distal 15 cm of the gastrointestinal tract as measured from the anal verge. [4]

In Indian scenario, annual incidence rate of colon cancer and rectal cancer is 4.4 and 4.1 per one lakh population, respectively. The incidence rate increases with age and peaks in the seventh decade of life (mean age 60-65 years). [5]

Colorectal carcinoma is the third leading cause of cancer-related deaths and new cancer cases among both sexes in the United States of America. The prevalence is higher in more developed countries than in less developed countries. However, the mortality rate in more developed countries is lower, reflecting increased screening and improvements in colorectal cancer staging and treatment.

The risk factors can be broadly divided into Lifestyle or Environmental factors (Westernized Lifestyle, Obesity, Sedentary Lifestyle, Fat Rich - Fiber Deficient Diet, Smoking, Alcohol) and Genetic preponderance (Inflammatory Intestinal Conditions, Family History of Colorectal Cancer or Polyps). Given the vitality of the difficult anatomy of the large intestine accurate preoperative staging by suitable imaging modality is essential to determine the treatment.

Various imaging techniques such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET) scan and Endoscopic Ultra sonography (EUS) are used for diagnosing and staging of the

malignancy. With continuously improving treatment options, even for complete cure of colorectal carcinoma, local staging is extremely crucial for determining the treatment modality.

Out of these imaging techniques contrast enhanced CT is usually used due to its easy availability and affordability. Colonoscopy is considered gold standard screening of colorectal carcinoma. Endoscopic ultrasonography will not assess deeper or higher nodes in the mesorectum and may misinterpret inflammatory or fibrotic changes as metastasis.

Distant and local staging of colorectal cancer is currently mainly performed with computed tomography (CT). However, according to a recent meta-analysis CT has a limited sensitivity of 75% for detecting liver metastasis [6].

At diagnosis, 15-23% of colorectal cancer (CRC) patients have liver metastasis [7,8]. Detection is crucial because it means poor prognosis and a different clinical approach and treatment[4]. Multiple studies already demonstrated that magnetic resonance imaging (MRI) is superior to CT for the detection of liver metastasis. Both the introduction of diffusion-weighted imaging (DWI) and the use of liver specific hepatobiliary contrast agents have contributed to the superior results of MRI in detecting small liver lesions. Unlike in rectal cancer where local staging with imaging is crucial to determine the proper (neoadjuvant) treatment strategy, imaging in colon cancer is mostly used as a surgical roadmap. However, the role of imaging for local staging of colon cancer emerging and several small studies and case reports showed additional value of neo-adjuvant treatment in locally advanced colon cancer. Furthermore, a large multicenter study, FOXTROT [9], is currently recommending the neo-adjuvant chemotherapy for patients with locally advanced colon cancer. The FOXTROT confirms initial promising reports and neoadjuvant treatment in colon cancer patients will be adopted as standard therapy, just like in rectal cancer patients. If so, preoperative imaging will become a crucial tool to select patients for neo-adjuvant treatment. In the FOXTROT trial, CT is used to detect locally advanced colon cancer and thus eligibility for neo-adjuvant treatment. Nonetheless a recent meta-analysis showed disappointing results for staging colon cancer with CT. However, little is known about the local staging and distant staging of colorectal cancer with MRI.

Meso-rectal fascia (MRF) involvement is the key factor in local staging of rectal carcinoma, which determines the treatment plan. Thus, MRI is superior over CT since it can detect the meso-rectal fascial involvement. Use of MRI in diagnosing the stage of rectal cancer is recommended by the European Society of Gastrointestinal and Abdominal Radiology (ESGAR).

Recent studies reflect the importance of the meso-rectal fascia also known as the circumferential resection margin for surgical resection of the rectum. The mid and distal rectum is encircled by the meso-rectal fat which is then encircled by the meso-rectal fascia. Removal of the tumour along with the encircling meso-rectal fascia has a recurrence rate of less than 10% even without adjuvant chemo-radiation therapy.

The prognosis of rectal cancer is directly related to tumour infiltration into the mesorectum and the ability to surgically achieve negative circumferential resection margins (CRMs). The use of Total Meso-rectal Excision (TME) as the standard treatment of rectal cancer and the adoption of neoadjuvant chemoradiotherapy for patients with locally advanced rectal cancers (LARCs), diagnosed on the basis of MRI features, has led to substantial improvements in local disease control.

MRI pelvis can differentiate early resectable stage of colorectal carcinoma from locally advanced stage which requires neoadjuvant chemoradiation therapy to downstage the tumour. MRI is a highly

accurate and reliable technique for the prediction of circumferential resection margin infiltration and thus represents a non-invasive tool for identifying those patients who may benefit from pre-operative chemotherapy or radiation therapy and those who should undergo surgery.

Thus, MRI pelvis has become an indispensable tool to decide the treatment for each patient. Moreover, MRI is the imaging modality of choice for restaging colorectal carcinoma post chemoradiation therapy as it can differentiate residual viable tumour tissue from necrotic and fibrotic tissue with a good accuracy. [8]

If MRI is able to accurately stage colorectal tumours, it might be the ideal imaging tool for simultaneous local and distant staging. With the above background, the present study has been designed to evaluate the diagnostic efficacy of MRI in such cases in Southern Odisha. Therefore, the aim of this study was to evaluate the role of MRI for local staging of colorectal cancer patients.

Aim and Objective of the Study:

1. To study the role of MRI in staging of Colo-Rectal carcinoma.
2. To assess its impact on evaluation and management pattern.

Materials:

It is a prospective study taking 44 number of colorectal cancer patient who were admitted to the MKCG Medical and Hospital during the period from August 2020 to May 2022.

Inclusion criteria:

1. Patients of all age groups and both sexes with Histo-pathologically proven / diagnosed cases of Colo-Rectal carcinoma, who will be undergoing surgery / Neoadjuvant chemoradiotherapy.

Exclusion criteria:

1. Patients refusing to participate in the study.
2. Pregnancy.
3. Patients who have previously taken any Neo-adjuvant therapy or have undergone any surgery for Colo-rectal cancer in the past.
4. Patients unsuitable for surgery.
5. Patients with history of allergy or anaphylaxis to contrast agent.
6. Patients with Absolute Contraindication for MRI, like Claustrophobia, patients on Cardiac Pacemakers or patients with any metallic implants or metallic foreign bodies in the body.

Methods:

All patients with biopsy proven colorectal carcinoma referred to the Department of Radiodiagnosis at MKCG Medical college hospital for MRI of pelvis were considered for the study. After informed consent, a copy of the biopsy report proving the diagnosis of rectal carcinoma was collected. MRI scan was done as mentioned in the Technique below.

In patients newly diagnosed with colorectal carcinoma on biopsy, the MRI images were analysed and the imaging features noted down in the structured proforma and the tumour staged. Many patients diagnosed with early-stage disease were taken up for surgery as per the current management protocols. Hence, the Histopathology staging of postoperative specimen was taken as the gold standard.

Many patients diagnosed with locally advanced colorectal Carcinoma underwent Neoadjuvant Chemoradiotherapy as per the current management protocols. Patients who underwent preoperative MRI staging six weeks after Neoadjuvant Chemoradiotherapy, formed a subset in the study. The post CT/RT MRI images were analysed for imaging features and MRI staging was done. Here also Histopathological staging of the surgical specimen was the gold standard.

MR imaging protocol

Imaging was performed with a 1.5T MRI (Cura Magna Momentum®, 1.5 Tesla) using a phased array body coil. Patients were placed in feet first supine position. Bowel preparation consisted of >3 hours fasting before the MR examination. To minimize peristaltic movements, patients received an intravenous bolus injection before the MR examination, of 20 mg Hyoscine Butylbromide (Buscopan) before the start of the MR examination, or 1mg of glucagon. in case of a contra-indication to receive Hyoscine Butylbromide. The scan protocol consisted of a MR liver protocol combined with an additional MR colon protocol covering the whole abdomen. After scout imaging, T2 sagittal image was acquired to identify the tumor location within the rectum. Then axial sections of T1WI, T2WI and DWI were obtained. Post gadolinium contrast T1 fat suppressed 3D sequence was obtained at the end. High resolution T2 axial sections were taken perpendicular to rectal wall at the site of the tumor in cases of upper and mid rectal carcinomas. High resolution T2 weighted coronal sections were taken parallel to the anal canal in cases of low rectal carcinomas. These T2 weighted images were taken with 3mm slice thickness and 1mm inter-slice gap with reduced Field of View (FOV) for achieving high resolution. Acquisition time of the MR colon protocol was 18 minutes. Total acquisition time of the colon + liver protocol was 50 minutes.

DIAGNOSTIC CRITERIA USED:[10]

T-Staging

T1/T2, T3 and T4 stages as per TABLE 1

T0: Complete resolution- No tumour tissue with demonstrable diffusion restriction post chemoradiation.

Table 1: T-staging on MRI [10,11]

T1/T2	Tumor confined to rectal wall. not breaching the T2 hypointense muscularis propria
T3	Tumor invades into mesorectal fat: broad based or nodular tumor bulge invading through T2 hypointense outer rectal wall muscle into the mesorectum. (Thin speculations are not considered)
T4	T4a – invasion of peritoneal reflection
	T4b – invasion of pelvic organs

N-Staging

As per TABLE 2 for T2 WI taken as positive OR
Lymph nodes with Diffusion restriction taken as positive
Any of the two is necessary

Table 2: N stage and morphological criteria for suspicious nodes on tT WI [12]

Malignant characteristics	Shape - round
	Border – irregular
	Heterogenous signal intensity
Short axis	<5mm needs 3 malignant characteristics
	5-9mm needs any 2 malignant characteristics
	>9mm always suspicious
N stage	N0 – no suspicious lymph nodes
	N1 – 1-3 suspicious lymph nodes
	N2 – 4 or more suspicious lymph nodes

Circumferential resection margin (CRM) positive/invaded: [10]

Applied only if the tumour is below the level of the peritoneal reflection

Tumour within 1mm of mesorectal fascia or invading it.

Suspicious lymph node within 1mm of mesorectal fascia/CRM

Extramesorectal suspicious lymph nodes/ deposits

Extramural vascular invasion reaching up to 1mm of CRM.

Extramural vascular Invasion (EMVI)

On T2 WI: heterointense tumor invading T2 hypointense mesorectal vein OR

On T1 Postcontrast: Heterogeneously enhancing tumor invading replacing lumen of contrast enhancing vein.

Data Analysis and Results:

The demographic details, size, shape, location, relations and appearance of tumor in various MRI sequences were classified and analysed in terms of frequency and percentage. Collected data was analysed and 2 X 2 tables will be constructed by taking each subcomponent of the T and N stage separately. Thus, determining the sensitivity, specificity, positive predictive value, negative predictive value and accuracy. The same was done for Circumferential resection margin (CRM) and Extramural vascular invasion (EMVI). Our study has two subset of population, 21 patients where initial staging MRI was compared with histopathology staging, and another subset of 23 patients where post chemoradiation (CT/RT) MRI was compared with histopathology staging. For each of the parameters studied, overall, 44 patients were taken for analysis and, whenever appropriate, each of the subset of patients were additionally analyzed separately.

Table 3: Study population

Group	Number of patients
Total sample size	44
Staging MRI	21
Post CT/RT MRI	23

Gender Distribution

Our study shows a male predominance with 59% of the patients being males and 41% females.

Age Distribution

The mean age was 59 years with youngest patient being 21 years and the oldest 87 years. 51-60 years was the age group most commonly affected, involving about one third of the study population (32%), followed by 61- 70 years (25%)

History at Presentation

We noted that bleeding per rectum was the most common presenting complaint (79.5% patients) followed by constipation (34%), pain abdomen (13.6%) and loose stools (13.6%). This was followed by weight loss (9%), abdominal distension (4.5%), fever (2.2%) and fecal incontinence (2.2%).

Duration of Symptoms

The most common duration of onset of symptoms was about 2 months (25%) prior consultation, followed by 3 months (18%) and 1 month (16%). The mean duration was about 4 months (128 days) and the median was 2 months. The shortest history was 4 days and the longest was 2 years (7%)

Surgery Performed

About 13.6 % of patients underwent right hemicolectomy,22.7 % of patients were undergone for extended right hemicolectomy.13.6 % were done left hemicolectomy and 4.5 % were undergone

extended left hemicolectomy,15.9% patients underwent Abdomino-perineal resection (APR). Sphincter sparing surgeries were done in the rest 29.5% patients, of which commonly done was anterior resection (AR).

Table 4: Surgery performed

Type	Number	Percentage
Right Hemicolectomy	6	13.6 %
Extended Right Hemicolectomy	10	22.7 %
Left Hemicolectomy	6	13.6%
Extended Left Hemicolctomt	2	4.5%
Anterior Resection	2	4.5
Low Anterior Resection (LAR)	11	25%
Abdominoperineal Resection (APR)	7	15.9
Total	44	100 %

Histology of the Tumor

Adenocarcinoma was the most common histology, noted in 90% cases. Mucinous carcinoma was noted in 7.8% cases and 2.2% had signet ring cell carcinoma. Other rare variants were not present in our study population.

Degree of Differentiation of Adenocarcinoma

Of the 40 cases of adenocarcinoma, 77.5% were well differentiated which was the most common. 20% were moderately differentiated and only 2.5% were poorly differentiated.

Table 5: Degree of differentiation of adenocarcinoma

Histology	Number	Percentage
Well Differentiated	31	77.5 %
Moderately Differentiated	8	20 %
Poorly Differentiated	1	2.5 %
Total	40	100 %

T1 Weighted MRI: Appearance of The Tumor

In our study, of total 44 patients, 41% cases of colorectal carcinoma were T1 hyperintense with respect to skeletal muscle, 32% isointense and 27% hypointense.

Table 6: Tumor signal intensity on T1 weighted images

Subset	Staging MRI (N=21)		Post CT/RT MRI (N=23)		Total	
T1 - Signal Intensity	N	%	N	%	N	%
Hyperintense	11	52.3%	8	34.7 %	18	40.9 %
Isointense	5	23.8 %	9	39.1 %	14	31.8 %
Hypointense	5	23.8 %	6	26 %	12	27.2 %
Total	21	100 %	23	100 %	44	100 %

T2 Weighted MRI: Appearance of The Tumor

Table 7: Tumor signal intensity on T2 WI

Subset	Staging MRI		Post CT/RT MRI		Total	
T2 - Signal Intensity	N	%	N	%	N	%
Hyperintense	20	95.2%	21	91.3 %	41	93.1 %
Very Hyperintense	1	4.8 %	2	8.7 %	3	6.9%
Total	21	100 %	23	100 %	442	100 %

In our study there was only one case of mucinous adenocarcinoma in the staging MRI which appeared highly hyperintense consistent with the histology.

In post CT/RT cases there were two cases of mucinous adenocarcinoma which were identified with high hyperintense signal on T2 weighted MRI.

A case of well differentiated adenocarcinoma showed highly hyperintense signal on T2 WI. This can be explained due to areas of necrosis which appear very hyperintense on T2 WI as response to chemoradiation, also known as the mucinous change.

Tumor on Diffusion Weighted MRI

In our study 100% cases in staging MRI showed diffusion restriction of which all were true positive for malignancy.

Table 8: Tumor on diffusion weighted MRI

Subset	Staging MRI		Post CT/RT MRI		Total	
Diffusion Restriction	N	%	N	%	N	%
Present	21	100 %	19	82.6 %	40	90.9 %
Absent	0	0%	4	17.4 %	4	9.1%
Total	21	100 %	23	100 %	44	100 %

In our study 82.6% cases (19/23) of post chemoradiation cases showed diffusion restriction of which 18/19 cases (94.7%) had residual tumor on histopathology (true positive) and one cases didn't (false positive 5.3%).

In our study 17.4% cases (4/23) cases showed no diffusion restriction of which 3 cases (75%) showed complete response/ absent residual tumor on histopathology and one case (25%) had residual tumor (false negative).

So, in our study for predicting complete response to chemoradiation the sensitivity was 75%, specificity 90.9% and accuracy 90.6%.

Post Contrast Enhancement

Table 9: Tumor on T1 post contrast images

Subset	Staging MRI		Post CT/RT MRI		Total	
Enhancement Pattern	N	%	N	%	N	%
Heterogenous	20	95.2 %	19	82.6 %	39	88.6 %
Homogenous	1	4.8 %	4	17.4 %	5	11.4%
Total	21	100 %	23	100 %	44	100 %

Location of Tumor

In our study, it was noted that the tumors mostly involved more rectum.

Table 10: Location of tumor (n=44)

S.N.	Location	N	Percentage
1	Caecum	6	13.6
2	Ascending Colon	7	15.9
3	Transverse Colon	3	6.8
4	Descendind Colon	4	9.1
5	Sigmoid Colon	6	13.6
6	Proximal Rectum	11	25
7	Distal Rectum	7	15.9
	Total	44	100%

Length of Tumor

In our study the mean tumor length in staging MRI was 5.4cm and in post CT/RT cases was 5.8cm.

Thickness of Tumor

In our study on staging MRI the mean thickness of tumor was 21.3mm with 7mm being minimum thickness and 45 mm maximum. In post chemoradiation MRI the mean thickness of tumor was 17.3mm with 5mm being minimum thickness and 45 mm maximum.

Shape of Tumor

In our study, it is seen that Circumferential wall thickening is the most common shape, seen in staging and post chemoradiation MRI followed by asymmetrical wall thickening. Polypoid lesions were noted alone and along with circumferential wall thickening.

Distance from anal Verge

Out of 18 rectal cancers, the mean distance of the lower end of the tumor from the anal verge was 5.7cm with minimum of 2.1cm and maximum of 10cm. Most common distance was 30-40mm in 17.7% patients, followed by 70-80mm, 16.1%: 60-70mm, 14.5%.

Anal Sphincter Involvement

In or study, out of 18 rectal cancers, anal sphincter complex appeared to be involved on thin oblique coronal T2 Weighted MRI sections in 38.8% cases. All of them underwent APR. In rest 61.2% it appeared to be spared. Sphincter sparing surgery was performed in 61% patients.

Table 11: Anal sphincter involvement on MRI

On T2 Oblique Coronal Sections	Number	Percentage
Involved	7	38.8%
Spared	11	61.2%
Total	18	100%

Peritoneal Reflection

The peritoneal reflection was identified in 38 cases (86.3%), and not seen in 6 cases (13.7%). Of the total 44 cases, 5 cases were of T4 stage of which 4 cases had invasion of peritoneal reflection on histopathology. Of these, 2 were missed on MRI, of which in 1 case the peritoneal reflection could not be identified and in other case it was seen but, tumor infiltration could not be made out. However, in 38 out of 40 patients (95%), invasion of the peritoneal reflection was correctly ruled out on MRI.

Table 12: Peritoneal Reflection on MRI

On T2 Weighted Images	Number of Patients	Percentage
Visualized	38	86.3 %
Not Visualized	6	13.7 %
Total	44	100 %

T – STAGING ACCURACY IN STAGING MRI (FRESH CASES, N=21)

Tumor staging was done by considering the findings in High resolution T2 WI, DWI, T1 sequence and Post contrast T1 images. T1 and T2 stage cannot be differentiated on phased array body coil, hence both were taken into one group for analysis.

We found 63.2% sensitivity for T1/T2 stage. Low sensitivity of T1/T2 stage may be due to over staging of T2 tumors into T3 stage due to misinterpretation of fibrosis and stranding in mesorectal fat as tumor tissue. Specificity was good 81.4% both in our study as well as similar study.

For T3 stage, our study showed 75.8% sensitivity and 72.4% specificity and low

sensitivity of 50% and high specificity of 100% in diagnosing T4 stage. This was because the invasion of peritoneal reflection was missed in 2 cases resulting in under- staging.

Table 13: Comparison of T-stage on MRI and histopathology in fresh cases (n=21)

Tool	Histopathology (Gold STD)				
MRI (Test)	STAGE	T1/T2	T3	T4	Total
	T1/T2	6	3	1	10
	T3	2	8	1	11
	T4	0*	0*	0*	0*
	Total	8	11	2	21

(Note: * Whenever a case was identified as T4 stage on MRI, it was referred for chemoradiation as per treatment protocol, hence most T4 stage cases fell into our exclusion criteria. However, few cases were missed which got into false negative.)

Table 14: T – Staging accuracy in staging MRI (fresh cases, n=21)

Diagnostic Test	T1/T2 Stage	T3 Stage	T4 Stage	Overall T-Stage
Sensitivity	80%	78%	0*	73.4%
Specificity	75%	75%	100%	76.7%
PPV	61.5%	82.4%	**	73.3%
NPV	88.2%	69.2%	93.3%	77.1%
Accuracy	76.7%	76.7%	93.3%	81.7%

(Note: *Whenever a case was identified as T4 stage on MRI, it was referred for chemoradiation as per treatment protocol, hence fell into out exclusion criteria. ** Hence, PPV calculation was not possible.)

T – Staging Accuracy in Post Chemoradiation Cases (n=23)

Table 15: comparison of T-stage on MRI and histopathology in post chemoradiation cases (n=23)

Tool	Histopathology (Gold STD)					
MRI (Test)	Stage	T0	T1/T2	T3	T4	Total
	T0	2	1	1	0	4
	T1/T2	0	3	2	0	5
	T3	0	3	7	1	11
	T4	1	0	0	2	3
	Total	3	7	10	3	23

Table 16: T – Staging accuracy in post chemoradiation cases (N=32)

Diagnostic Test	T0- Stage/ Complete Resolution	T1/T2 Stage	T3 Stage	T4 Stage	Overall T-Stage
Sensitivity	75%	44.4%	73.3%	75%	65.6%
Specificity	92.9%	86.9%	70.6%	96.4%	81.2%
PPV	60%	57.1%	68.8%	75%	65.2%
NPV	96.3%	80%	75%	96.4%	81.7%
Accuracy	90.6%	75%	71.9%	93.8%	77.8%

ACCURACY OF T - STAGING (OVERALL, N=44)

Table 17: Comparison of T-stage on MRI and histopathology taking all cases together (n=44)

	Histopathology (Gold STD)					
MRI (Test)	Stage	T0	T1/T2	T3	T4	Total
	T0	2	1	1	0	4
	T1/T2	0	9	5	1	15
	T3	0	5	15	2	22
	T4	1	0	0	2	3
	Total	3	15	21	5	44

Table 18: Accuracy of T- staging (overall, n=44)

Diagnostic Test	T0- Stage/ Complete Resolution	T1/T2 Stage	T3 Stage	T4 Stage	Overall T-Stage
Sensitivity	75%	63.2%	75.8%	50%	69.4%
Specificity	96.6%	81.4%	72.4%	98.2%	79.3%
Ppv	60%	60%	75.8%	75%	69.9%
Npv	98.3%	83.3%	72.4%	94.8%	79.6%
Accuracy	95.2%	75.8%	74.2%	93.6%	77.9%

There were 5 patients with T4 stage on pathology, of whom 1 had invasion of cervix (T4B), 3 had invasion of peritoneum (T4A) and one case had invasion of uterus and peritoneum.

For newly diagnosed cases who did not undergo chemoradiation, T-Staging had an accuracy of 81.7% with 73.4% sensitivity and 76.7% specificity.

For patients who underwent chemoradiation, the accuracy of T-staging was 77.8%, slightly less than for fresh cases. Even the sensitivity was lower (65.6%), but the specificity was higher (81.2%). Sensitivity was low in post chemoradiation cases since staging inaccuracy occurred in differentiation of T1/T2 stage from T3 cases. Difficulty was faced in T2 WI and post contrast images to differentiate T2 stage from early T3 stage, where post radiation stranding had to be differentiated from tumor invasion of mesorectal fascia.

However, overall accuracy of T-staging when all cases were combined was 77.9% in our study with 69.4% sensitivity and 79.3% specificity.

Prediction of complete response to chemoradiation:

In our study, a combination of conventional MRI and diffusion weighted imaging (DWI) was used for predicting complete response or T0 stage post chemoradiation therapy. We found a sensitivity of 75%, specificity of 92.9% and accuracy if 90.6%.

There was one case where ovarian metastasis was diagnosed on histopathology. On MRI, bulky bilateral ovaries with heterogenous enhancement were reported. So, the patient underwent hysterectomy and salpingo-ophorectomy along with APR.

N – STAGING ACCURACY IN STAGING MRI (FRESH CASES, N=21)

Combination of morphological criteria on high resolution T2 WI and Diffusion weighted MRI was used for lymph node assessment

Fresh cases/Staging MRI (N=21): Showed accuracy of 82.5%, sensitivity of 76.6% and Specificity of 86%.

Table 19: Comparison of N-stage on MRI and histopathology in fresh cases (n=21)

Tool	Histopathology (Gold STD)				
MRI (Test)	Stage	N0	N1	N2	Total
	N0	6	1	0	7
	N1	1	7	1	9
	N2	1	1	3	5
	Total	8	9	4	21

Table 20: N – Staging accuracy in staging MRI (fresh cases, n=30)

Diagnostic Test	N0	N1	N2	N Stage Overall
Sensitivity	72.7%	76.9%	83.3%	76.6%
Specificity	89.5%	82.4%	87.5%	86%
PPV	80.0%	76.9%	62.5%	75.2%
NPV	85.0%	82.4%	95.5%	86%
Accuracy	83.3%	80%	86.7%	82.5%

N – Staging Accuracy in Post Chemoradiation Cases (N=23)

Post Chemoradiation Cases (N=23): Showed Accuracy Of 80.6%, Sensitivity Of 71.9% And Specificity Of 85.1%.

Table 21: Comparison of N-stage on MRI and histopathology in post chemoradiation cases (n=23)

Tool	Histopathology (Gold STD)				
MRI (Test)	Stage	N0	N1	N2	Total
	N0	5	1	1	7
	N1	2	7	1	10
	N2	1	1	4	6
	Total	8	9	6	23

Table 22: N– Staging accuracy in post chemoradiation cases (n=23)

Diagnostic Test	N0	N1	N2	N-Stage Overall
Sensitivity	66.7%	76.9%	71.4%	71.9%
Specificity	89.9%	79.0%	88.0%	85.1%
PPV	80.0%	71.4%	62.5%	72.7%
NPV	81.8%	83.3%	91.7%	84.6%
Accuracy	81.3%	78.1%	84.4%	80.6%

Accuracy of N - Staging (Overall, N=44)

Table 23: Comparison of n-stage on MRI and histopathology taking all cases together (n=44)

Tool	Histopathology (Gold STD)				
MRI (Test)	Stage	N0	N1	N2	Total
	N0	11	2	1	14
	N1	3	14	2	19
	N2	2	2	7	11
	Total	16	18	10	44

Table 24: Accuracy of N - staging (overall, n=44)

Diagnostic Test	N0	N1	N2	Overall N-Stage
Sensitivity	69.6%	76.9%	76.9%	74.2%
Specificity	89.7%	80.6%	87.7%	85.5%
PPV	80.0%	74.1%	62.5%	73.8%
NPV	83.3%	82.7%	93.5%	85.8%
Accuracy	82.3%	79%	83.5%	81.2%

All cases combined (n=44): N-staging showed accuracy of 81.2%, sensitivity of 74.2% and Specificity of 85.5%.

Invasion Of Circumferential Resection Margin (CRM)

In our study, out of 44 patients, only in 7 cases the tumor was below the peritoneal reflection. So only in these 7 cases assessment of CRM was applicable.

Table 25: Comparison of CRM invasion on MRI and histopathology taking all eligible cases together (n=07)

CRM	Patho+	Patho-	Total
MRI+	1	1	2
MRI-	1	4	5
Total	2	5	7

Table 26: Accuracy of prediction of CRM invasion (N=07)

Diagnostic Test	Value	95% CI
Sensitivity	50.0 %*	4.3-77.7%
Specificity	91.7%	73-98.9%
PPV	75%*	14.9-85.1%
NPV	84.6%	75.5-90.8%
Accuracy	80%	61.4-92.3%

The specificity of predicting CRM invasion was 91.7% and negative predictive value was 84.6%. Sensitivity and positive predictive values are falsely low as most of the patients with CRM invasion were not operated, hence are lost by exclusion criteria of the study.

Accuracy of Detection of Extramural Vascular Invasion (EMVI)

Accuracy of 80.7%, 68.2% sensitivity and 87.5% specificity were noted in prediction of presence of extramural vascular invasion for the whole study population. Staging MRI cases had higher sensitivity (71.4%) compared to Post chemoradiation cases (62.5%). Positive predictive values were 83.3% for staging MRI, 62.5% for post chemoradiation cases and 75% overall. EMVI was present only in stage T3 and T4. It was not seen in T1/T2 stage in our study.

Table 27: Comparison of EMVI positivity on MRI and histopathology

	Staging MRI (N=21)		Post CT/RT MRI (N=23)		Overall (N=44)	
	PATHO+	Patho-	Patho+	Patho-	Patho+	Patho-
MRI+	7	2	4	2	11	4
MRI-	10	2	15	2	25	4

Table 28: Accuracy of detection of extramural vascular invasion

Diagnostic Test	Staging MRI (N=21)	Post CT/RT MRI (N=23)	Overall (N=44)
Sensitivity	71.4%	62.5%	68.2%
Specificity	87.5%	87.5%	87.5%
PPV	83.3%	62.5%	75%
NPV	77.7%	87.5%	83.3%
Accuracy	80%	81.2%	80.7%

Discussion:

The Study Population

Of the 44-biopsy proven rectal carcinoma cases, 21 patients were newly diagnosed and underwent MRI and surgery. Another 23 patients underwent neoadjuvant chemoradiation therapy followed by MRI restaging and surgery.

The gender distribution, Age distribution. Clinical symptoms, duration of symptoms, surgery performed, location of tumour, length of tumour, thickness of tumour, histology and shape of tumour were in agreement with similar type of study.

Accuracy of T-Staging

Accuracy of individual stages:

T1 and T2 stage cannot be differentiated on phased array body coil, hence both were taken into one group for analysis. Our results of overall T-staging was compared with findings of two observers in study done by Beets-Tan RGH et al [13] on 76 patients in whom 60 patients were newly diagnosed and 16 patients received chemoradiation.

In our study, we found 63.2% sensitivity for T1/T2 stage whereas Beets-Tan et al [13] found only 38% and 46%. Low sensitivity of T1/T2 stage may be due to over staging of T2 tumors into T3 stage due to misinterpretation of fibrosis and stranding in mesorectal fat as tumor tissue. Specificity was good 81.4% both in our study as well as similar study.

For T3 stage, our study showed 75.8% sensitivity and 72.4% specificity which was more or less in agreement with results of average results of Beets-Tan et al [13]. Our study showed low sensitivity of 50% and high specificity of 100% in diagnosing T4 stage. This was because the invasion of peritoneal reflection was missed in 2 cases resulting in under-staging.

Accuracy of T-staging on MRI

MRI staging was noted to have poor accuracy in the older studies due the inability of T2 WI to differentiate tumor tissue from colon wall edema and tumor infiltration from post radiation fibrosis. Contrast enhanced sequences had similar disadvantage due to the same cause.

However, the newer studies have shown the role of diffusion weighted MRI in differentiating viable and nonviable tumor tissue. Addition of DWI to conventional sequences proved to be effective with good accuracy in predicting tumor stage, lymph node metastasis and CRM invasion.

Beets-Tan RGH et al [13] found 95% accuracy in predicting T3 tumor stage, which is the most important stage as it decides the treatment plan. They found that Diffusion weighted imaging (DWI) had sensitivity of 62-94% and specificity of 74-91% in restaging colorectal carcinoma post chemoradiation. Ghieda U et al [14] found an accuracy of 84% in T-staging in a study on 21 cases.

Meta-analysis done by Al-Sukhni et al [15] found 87% sensitivity and 75% specificity in prediction of T-stage in colorectal cancer.

In our study, tumor staging was done by considering the findings in High resolution T2 WI, DWI, T1 sequence and Post contrast T1 images. Findings of cases undergoing staging MRI and patients post

chemoradiation were analyzed separately and overall accuracy was also calculated. For newly diagnosed cases who did not undergo chemoradiation an accuracy of 81.7% was noted with 73.4% sensitivity and 76.7% specificity.

For patients who underwent chemoradiation, in our study the accuracy for T-staging was 77.8%, lesser than pre radiation cases. Even the sensitivity was lower (65.6%), but the specificity was high (81.2%). Sensitivity was low in post chemoradiation cases as staging inaccuracy occurred in differentiation of T1/T2 stage from T3. Difficulty was faced on T2 WI and post contrast images to differentiate T2 stage from early T3 stage where post radiation stranding had to be differentiated from tumor invasion of mesorectal fascia and surrounding structure. Similar findings and difficulty was faced in similar studies.

However, overall accuracy of T-staging when all cases were combined was 77.9% in our study with 69.4% sensitivity and 79.3% specificity.

Prediction of complete response to chemoradiation:

In our study, a combination of conventional MRI and diffusion weighted imaging (DWI) was used for predicting complete response or T0 stage post chemoradiation therapy. We found a sensitivity of 75%, specificity of 92.9% and accuracy if 90.6%.

Kim et al [16] investigated role of Diffusion weighted MRI for predicting complete response. They noted that the accuracy improved to 82-88% from 66-68% and sensitivity improved to 82-91% from 45-55% by adding DWI to conventional MRI sequences.

Franklin JM et al [16] in a study, concluded that MRI appearance of T0 stage is heterogeneous. Hence MRI cannot identify majority of the cases with complete response post CT/RT. This was contrary to our finding.

Beets-Tan RGH et al [17] reported that addition of DWI to T2 WI improved sensitivity from 47% to 71% and Negative predictive value from 78% to 85% in prediction of complete response to chemoradiation.

Lambregts et al [18] found that adding DWI to conventional MRI sequences improved sensitivity to 77%, with 86%specificity, 63% PPV and 93% NPV in prediction of complete response to chemoradiation. This was in agreement with our study.

N-Staging

In our study, combination of morphological criteria on high resolution T2 WI and Diffusion weighted MRI was used for lymph node assessment. Fresh cases/Staging MRI (N=21) showed accuracy of 82.5%, sensitivity of 76.6% and Specificity of 86%. Post chemoradiation cases (N=23) showed accuracy of 80.6%, sensitivity of 71.9% and Specificity of 85.1%. All cases combined (N=44) showed accuracy of 81.2%, sensitivity of 74.2% and Specificity of 85.5%. This was in agreement with the similar studies as described below.

Ono K et al [19] used diffusion-weighted MRI for identification of regional metastatic lymph nodes in patients with untreated colorectal cancer. It gave a sensitivity of 80%, specificity of 76.9% and accuracy of 78.3%.

Koh et al [20] studied detection of nodal disease in post CT/RT cases using morphological criteria like irregular margins and internal heterogeneity. Their study showed 80% PPV, 90% NPV and 88% accuracy. They also demonstrated that acellular mucinous degeneration can occur in lymph nodes which appears T2 hyperintense which is a sign of treatment response.

Bipat et al [21] conducted a meta-analysis of 90 studies. A sensitivity of 66% (54-76%) and specificity of 76% (59-87%) was

noted for detection of lymph node involvement on MRI.

Mizukami et al [22] combined DWI and conventional MRI to study accuracy of metastatic lymph nodes detection in 129 patients. Their study demonstrated a sensitivity of 93%, specificity of 81% and accuracy of 87%.

Meta-analysis done by Al-Sukhni et al [15] found 77% sensitivity, 71% specificity and

Invasion of Circumferential Resection Margin (CRM)

The Mercury study [23] showed that after chemoradiation, MRI had 92% specificity in prediction negative CRM. Kaur H et al [24] also got 92% specificity for negative CRM prediction.A study in irradiated pelvis, by Beets-Tan RGH et al [13] showed 76% sensitivity and 86% specificity in CRM assessment. Meta-analysis done by Al-Sukhni et al [15] found 77% sensitivity, 94% specificity for prediction of CRM.

Our study shows 91.7% specificity in prediction of CRM invasion and 84.6% Negative predictive value. Sensitivity was not considered as it comes falsely low because whenever a patient is noted to have CRM invasion on MRI, they undergo neoadjuvant chemoradiation to down-stage the tumor and do not undergo surgery immediately. Our study shows that CRM invasion can be ruled out on MRI with high accuracy and is in agreement with similar studies.

Extramural Vascular Invasion (EMVI)

Rectal carcinoma is known to spread through the vessels in the mesorectum. It is one of the causes for extra mesorectal tumor deposits. On MRI it can be identified on T2 W1 as heterogeneous tumor tissue in vessel adjacent to rectal growth and it appears as serpiginous or tubular in shape, similarly it was seen adjacent to colonic growth also. It shows heterogenous post contrast enhancement.

In a study done by Brown et al [12], MRI had 62% sensitivity and 88% specificity in identification of EMVI. In a study by Smith et al [25], prediction of EMVI had 86% positive predictive value.

In our study, EMVI was present only in stage T3 and T4. It was not seen in T1/T2 stage as in other studies. 80.7% accuracy as noted in prediction of presence of extramural vascular invasion for the whole study population. Staging MRI cases had higher sensitivity (71.4%) compared to Post chemoradiation cases (62.5%). [26] Positive predictive values were 83.3% for staging MRI, 62.5% for post chemoradiation cases and 75% overall. We got 68.2% sensitivity and 87.5% specificity which was in agreement with similar studies. There was one case where ovarian metastasis was diagnosed on histopathology. On MRI, bulky bilateral ovaries with heterogenous enhancement were reported. So, the patient underwent hysterectomy and salpingo-ophorectomy along with APR.

Conclusion:

Our study shows that MRI has the potential to become a valuable tool in preoperative staging and restaging post chemoradiation therapy in locally advanced disease of colorectal cancer, Identification of invasion of mesorectal fascia and anal sphincter complex is therapeutically more important than the tumor stage. Combination of diffusion weighted images with high resolution oblique axial T2 weighted image perpendicular to the rectal wall, gives good accuracy for T staging and identification of malignant lymph nodes, mesorectal fascia invasion and extramural vascular invasion. High resolution T2 oblique coronal sections parallel to anal canal helps in planning sphincter sparing surgery thereby improving the quality of life.

In addition, MRI seems to have a high sensitivity for additional risk factors, such as serosal involvement and EMVI. Combined with its known superiority in

detecting liver metastasis, MRI could become the most optimal abdominal staging method for colorectal cancer patients.

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