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Original Research Article

COMPARATIVE EVALUATION OF RADIOLOGICAL FINDINGS IN RHEUMATOID ARTHRITIS ON LOW FIELD MRI AND DUAL ENERGY CT

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ABSTRACT

Objectives: To compare the imaging features of Rheumatoid arthritis (RA) using Magnetic Resonance Imaging (MRI) and Dual Energy Computed Tomography (DECT). **Material and Methods**: A total of 45 clinically diagnosed new cases of rheumatoid arthritis (1-6 months) aged 26-58 years underwent DECT and MRI evaluation for different imaging features. A total of eight imaging features, *viz.*, number of joints showing inflammation, signs of tenosynovitis, cartilage destruction, meniscus destruction, effusion, bone marrow edema, osteosclerosis and bone erosion were evaluated. For inflammation, tenosynovitis, cartilage and meniscus destruction, effusion and bone marrow edema, MRI was considered as the reference modality whereas for osteosclerosis and bone erosion DECT was taken as the reference modality. Data was analysed using SPSS 21.0 package. Level of agreement was assessed using Kappa-statistic. Sensitivity, specificity, positive and negative predictive values and accuracy of both imaging modalities were calculated against corresponding reference modality for different imaging features. **Results**: Mean age of patients was 43.16±9.63 years. Majority of them were females (57.8%), had ACR score 7 (55.6%) and involvement of five or more joints (51.1%). In all a total of 173 joints were studied. MRI diagnosed inflammation, tenosynovitis, effusion, cartilage destruction, meniscus destruction and bone marrow edema in 100%, 95.4%, 47.4%, 32.4%, 48.6% and 20.2% joints as compared to 91.9%, 27.7%, 32.4%, 25.4%, 42.2% and 17.3% joints respectively by DECT. A significant difference between two modalities was observed for number of inflammatory joints and joint effusion only ($p<0.05$). DECT diagnosed osteosclerosis and bone erosion in 27.7% and 60.1% joints respectively as compared to 19.7% and 45.7% joints respectively by MRI. A statistically significant difference was seen for bone erosion only. For different imaging features where MRI was the reference, moderate to almost perfect agreement ($\kappa>0.4$) with

DECT was observed for all the features except joint effusion and cartilage destruction that showed slight and fair agreement only (κ<0.4). For features where DECT was the reference, MRI showed substantial agreement for osteosclerosis (κ=0.674) and moderate agreement for bone erosion (κ=0.330). For different imaging features where MRI was reference, DECT had maximum sensitivity for tenosynovitis (94.5%) and maximum specificity for bone marrow edema (100%) whereas for features where DECT was reference, the sensitivity of MRI was 70.8% and 76% for osteosclerosis and bony erosion while specificity was 100% for both. **Conclusion**: The findings of study showed that MRI and DECT are complementary in evaluation of rheumatoid arthritis patients with specific features where one modality outperformed over the other. Combined use of both the modalities is recommended for comprehensive assessment of rheumatoid arthritis patients.

Key words: Rheumatoid arthritis, Magnetic Resonance Imaging, Dual Energy Computed Tomography, Imaging features, Combined use.

1. INTRODUCTION

Rheumatoid arthritis (RA) is a common, chronic, inflammatory, autoimmune disease of unknown etiology affecting approximately 1% of the world population.[1-3] The health-related quality of life in patients with RA is significantly reduced by the pain, fatigue, loss of bodily function, and heavy economic burden associated with disease progression.[4] Early diagnosis can be challenging as the serological and conventional radiological characteristics are often absent.[5] Traditionally, conventional radiographs of the hands and feet are used for diagnosis, management and treatment outcome evaluation. However, conventional radiography (X-ray), the traditional gold standard for imaging in RA, is not able to detect early disease manifestations such as inflammatory changes in the soft tissues (synovitis, tenosynovitis, enthesitis *etc*.) and the earliest stages of bone erosion.[6] As far as early evaluation is concerned, imaging modalities like magnetic resonance imaging (MRI) and ultrasonography (US) that allow direct visualization of early inflammatory and destructive joint changes have proven to be very useful. MRI provides multiplanar tomographic imaging with unprecedented soft tissue contrast, without the use of ionizing radiation, and allows assessment of all the structures involved in arthritic disease, i.e. synovial membrane, intra- and extra-articular fluid collections, cartilage, bone, ligaments, tendons and tendon sheaths. It has a definitive edge over conventional radiography in early detection of inflammatory and destructive joint changes[6] . It also successfully helps to identify inflammatory infiltrates in the bone marrow, *i.e.* osteitis.[7] MRI aided visualization of bone-marrow edema is a useful link between joint inflammation and bone destruction. Till recent years, computed tomography had a limited role in evaluation of RA as it was considered to be useful only for assessment of bone erosions. However, in the recent years, with the addition of multidetector CT and dual energy CT, the scenario has changed significantly. Multidetector CT helps to provide a multiplanar reconstruction and thus allows three-dimensional visualization of joints and thus has a definitive edge over conventional X-ray.[6] The sensitivity of CT in detection

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of bone erosions is considered to be superior than MRI.[8,9] DECT, on the other hand, has also emerged as a useful tool for studying bone marrow edema and early evidence has shown that it not only has accuracy equivalent to MRI but also at a much lower cost and higher accessibility.[10,11] DECT iodine mapping is being proposed as a novel modality for evaluating rheumatoid arthritis. It can delineate inflammation of peripheral inflammatory arthritis. It has been proposed to have higher spatial resolution as compared to MRI. It can also be used successfully to assess the impact of treatment in patients of RA.[12] Despite these promising features, Dual Energy CT is one of the least employed imaging modalities for assessment of Rheumatoid arthritis in view of absence of extensive literature evaluating its clinical application. Hence, the present study was planned to study the imaging features of rheumatoid arthritis on magnetic resonance imaging and dual energy computed tomography.

2. MATERIAL AND METHOD

This descriptive study was carried out at Department of Radiodiagnosis, Era's Lucknow Medical College, Lucknow (India), on 45 newly diagnosed cases of rheumatoid arthritis (1-6 months) as per American College of Rheumatologists (2010) criteria among patients 20 to 60 years of age.[13] Pregnant women, previously diagnosed cases of juvenile RA, those with pacemaker or cochlear implants in whom MRI was contraindicated were excluded from the study.

All patients after clinical confirmation of Rheumatoid arthritis underwent MRI of the involved joint. The examinations were performed with an MRI system (3T using the dedicated coil. The joints were evaluated on the basis of T_1-weighted (at TR = 600 ms, TE = 11 ms), and PD/T_2-weighted (at TR = 3000 ms, TE = 33 ms) images (F_oV = 160 mm, matrix = 320 mm × 320 mm, thickness = 3 mm). All images were analyzed retrospectively on a work station using software that allowed for three-dimensional reconstructions and measurements. Examinations was evaluated by an experienced musculoskeletal radiologist.

All CT scans were performed on a 384 slice Dual Energy CT scanner (Somaton Force, Seimens Healthcare) and all the images were postprocessed on a work station using software that allowed analysis of images using three material decompositions. Examinations were evaluated by an experienced radiologist.

In both MRI and DECT evaluations, the following characteristics were noted:

- Number of joints showing inflammation
- Number of joints showing signs of tenosynovitis
- Number of bone erosion sites
- Number of joints showing osteosclerosis
- Cartilage destruction
- Meniscus destruction
- Number of joints with bone marrow edema
- Effusion

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

For inflammation, bone marrow edema, tenosynovitis, effusion, cartilage and meniscus destruction, Magnetic resonance imaging was considered as reference. For bone erosion and osteosclerosis CT was considered as gold reference.

Data Analysis: The data so collected was analysed using Statistical Package for Social Sciences (SPSS) 21.0 version. Chi-square test was used to compare the descriptive data. Level of agreement between MRI and CT for different imaging characteristics was assessed using Kappa statistic (κ). The level of agreement between reference modality and test modality was considered to be almost perfect, substantial, moderate, fair or slight for κ values >0.8, 0.61-0.8, 0.41-0.6, 0.21-0.4 and 0.01 to 0.20 respectively. A 'p' value less than 0.05 indicated a statistically significant association. Sensitivity, specificity, positive and negative predictive values and accuracy of both imaging modalities were calculated against corresponding reference modality for different imaging features.

3. RESULTS

Age of enrolled patients ranged from 26 to 58 yearas. Mean age of patients was 43.16±9.63 years. Majority of them were females (57.8%). ACR scores 6, 7, 8 and 9 were noted in 9 (20%), 25 (55.6%), 9 (20%) and 2 (4.4%) patients respectively. Number of joints involved ranged from 1 to 6; majority of patients had involvement of five or more joints (51.1%). In all a total of 173 joints were involved (Table 1).

Table 1: Demographic and Clinical Profile of Patients enrolled in the study

SN	Characteristic	Statistic
1.	Mean Age±SD (Range) in years	43.16±9.63 (26-58)
2.	Sex	
	Male	19 (42.2%)
	Female	26 (57.8%)
3.	Duration of complaints±SD (Range) in months	3.18±1.34 (1-6)
4.	ACR Score	
	6	9 (20%)
	7	25 (55.6%)
	8	9 (20%)
	9	2 (4.4%)
5.	Number of joints involved	
	One	1 (2.2%)
	Two	7 (15.6%)
	Three	14 (31.1%)
	Four	0
	Five	22 (48.9%)
	Six	1 (2.2%)
	Total number of joints involved	173

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

MRI detected inflammation, tenosynovitis, effusion, cartilage destruction, meniscus destruction and bone marrow edema in 173 (100%), 165 (95.4%), 82 (47.4%), 56 (32.4%), 84 (48.6%) and 35 (20.2%) joints as compared to 161 (93.1%), 159 (91.9%), 56 (32.4%), 44 (25.4%), 73 (42.2%) and 30 (17.3%) joints respectively by DECT. A significant difference between two modalities was observed for number of inflammatory joints and joint effusion only ($p<0.001$ and $p=0.004$ respectively). DECT diagnosed osteosclerosis and bone erosion in 48 (27.7%) and 104 (60.1%) joints respectively as compared to 34 (19.7%) and 79 (45.7%) joints respectively by MRI. A statistically significant difference was seen for bone erosion only ($p=0.007$) (Table 2).

Table 2: Comparison of DECT and MRI for different imaging features (n=173 joints)

SN	Feature	Detection rate by DECT	Detection rate by MRI	Significance of difference from reference
1.	Inflammation (MRI reference)	161 (93.1%)	173 (100%)	$\chi^2=12.4$; $p<0.001$
2.	Tenosynovitis sites (MRI reference)	159 (91.9%)	165 (95.4%)	$\chi^2=2.77$; $p=0.096$
3.	Osteosclerosis (CT reference)	48 (27.7%)	34 (19.7%)	$\chi^2=3.13$; $p=0.077$
4.	Bone erosion (CT reference)	104 (60.1%)	79 (45.7%)	$\chi^2=7.25$; $p=0.007$
5.	Joint effusion (MRI reference)	56 (32.4%)	82 (47.4%)	$\chi^2=8.15$; $p=0.004$
6.	Cartilage destruction (MRI reference)	44 (25.4%)	56 (32.4%)	$\chi^2=2.03$; $p=0.155$
7.	Meniscus destruction (MRI reference)	73 (42.2%)	84 (48.6%)	$\chi^2=1.41$; $p=0.235$
8.	Bone marrow edema (MRI reference)	30 (17.3%)	35 (20.2%)	$\chi^2=0.474$; $p=0.491$

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

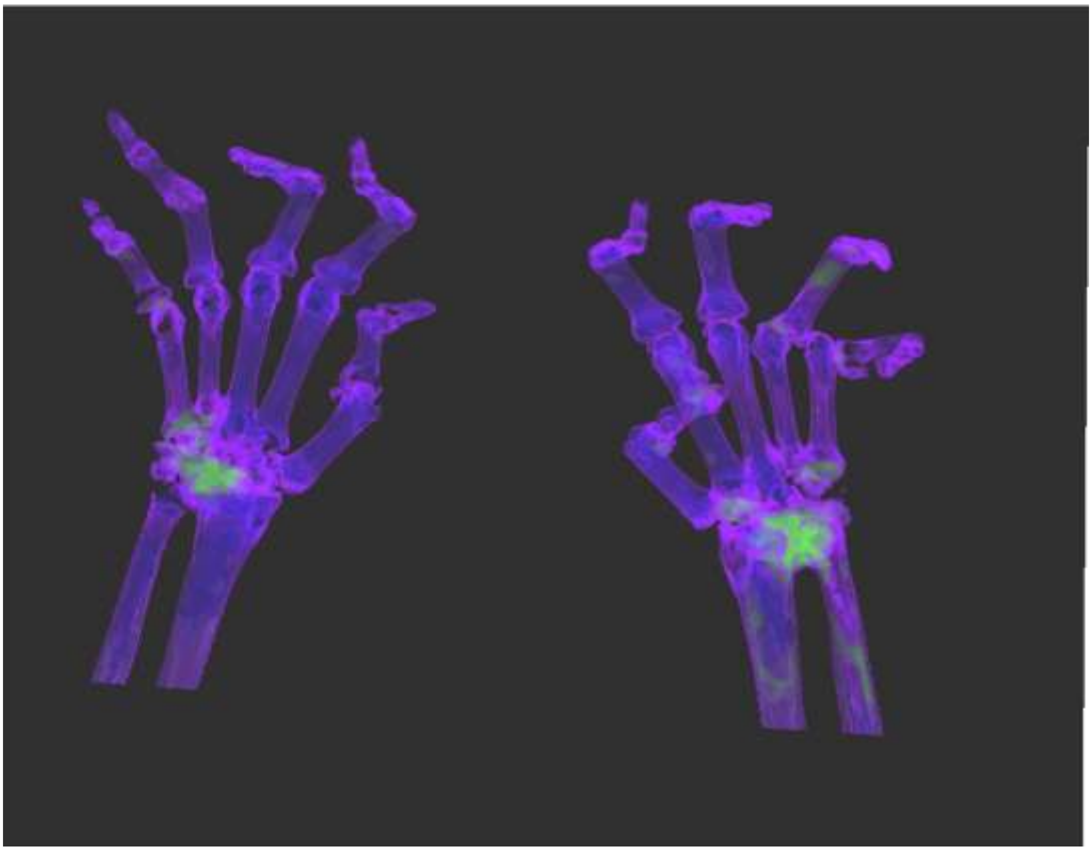

FIGURE 1: Volume rendered DECT image of bilateral wrist in Rheumatoid arthritis patient showing swan neck and boutonniere deformity with edematous changes in carpal bones.

For different imaging features where MRI was the reference, moderate to almost perfect agreement (κ>0.4) with DECT was observed for all the features except joint effusion and cartilage destruction that showed slight and fair agreement only (κ<0.4). For features where DECT was the reference, MRI showed substantial agreement for osteosclerosis (κ=0.674) and moderate agreement for bone erosion (κ=0.330). For MRI features inflammation, tenosynovitis, joint effusion, cartilage destruction, meniscus destruction and bone marrow edema DECT showed under diagnosis rate of 24.4%, 22.2%, 42.2%, 57.8%, 37.8% and 11.1% respectively. DECT over diagnosed tenosynovitis, joint effusion and meniscus destruction in 4.4%, 20% and 6.7% cases respectively. On the other hand, MRI had an under diagnosis for osteosclerosis and bone erosion in 10 (22.2%) and 23 (51.1%) cases respectively (Table 3).

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

FIGURE 2: Coronal DECT image of bilateral wrist reveals erosive changes.

FIGURE 3: Coronal MRI image (STIR sequence) of Right Knee in Rheumatoid Arthritis patient showing bone marrow edema in distal femur.

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

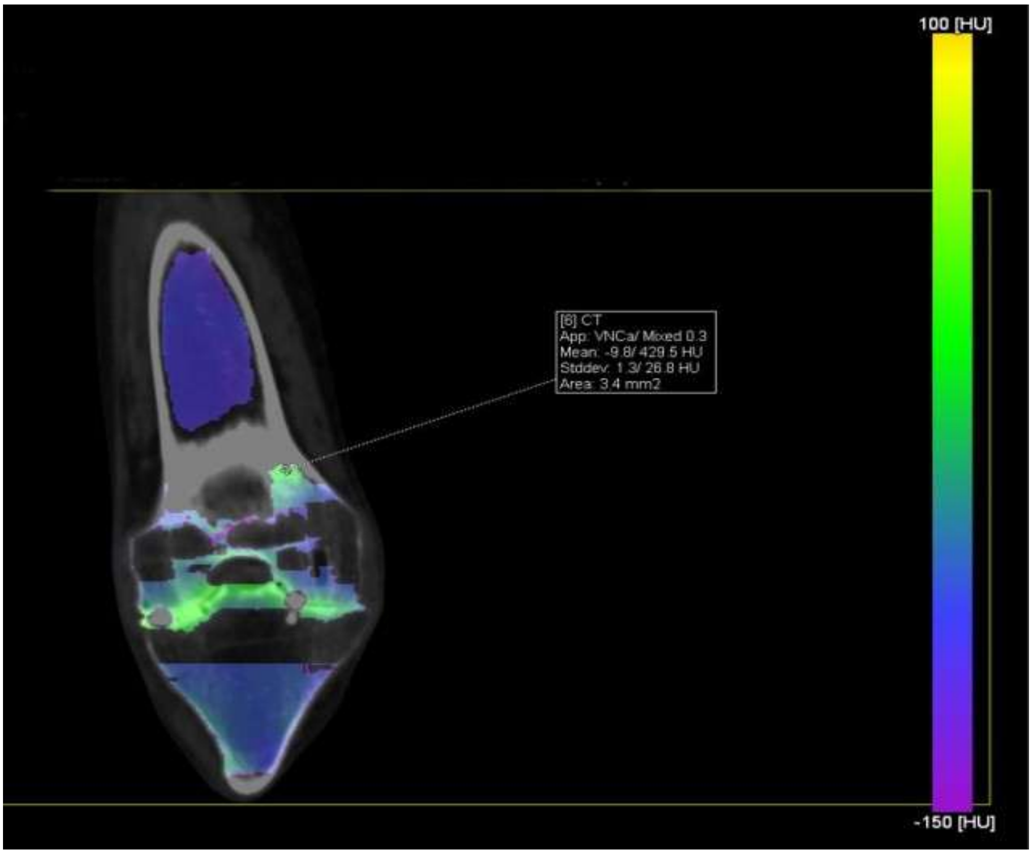

Figure 4: Coronal DECT image of Right Knee in Rheumatoid Arthritis patient revealing bone marrow edema in distal femur.

Table 3: Comparison of diagnosis pattern of CT and MRI against reference modality for different imaging features (n=45)

Feature	Diagnosed by reference modality (No. of joints)	Diagnosed by test modality (No. of joints)	Performance of test modality against reference modality (No. of patients)			Level of agreement (Kappa; p-value)
			Matched	Under-diagnosis	Over-diagnosis	
(a) Reference Modality – MRI; Test Modality – DECT						
Inflammation	173 (100%)	161 (93.1%)	34 (75.6%)	11 (24.4%)	0 (0%)	κ=0.651; p<0.001
Tenosynovitis	165 (95.4%)	159 (91.9%)	33 (73.3%)	10 (22.2%)	2 (4.4%)	κ=0.645; p<0.001
Joint effusion	82 (47.4%)	56 (32.4%)	17 (37.8%)	19 (42.2%)	9 (20.0%)	κ=0.157; p=0.064
Cartilage destruction	56 (32.4%)	44 (25.4%)	19 (42.2%)	26 (57.8%)	0	κ=0.254; p=0.001
Meniscus	84 (48.6%)	73 (42.2%)	25	17	3 (6.7%)	κ=0.41;

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

destruction			(55.6%)	(37.8%)		p<0.001
Bone marrow edema	35 (20.2%)	30 (17.3%)	40 (88.9%)	5 (11.1%)	0	κ=0.82; p<0.001
(b) Reference modality – DECT; Test Modality – MRI						
Osteosclerosis	48 (27.7%)	34 (19.7%)	35 (77.8%)	10 (22.2%)	0	κ=0.674; p<0.001
Bone erosion	104 (60.1%)	79 (45.7%)	22 (48.9%)	23 (51.1%)	0	κ=0.330; p<0.001

For different imaging features where MRI was reference, the sensitivity & specificity of DECT was 93.1% & -%, 94.5% & 62.5%, 68.3% & 97.8%, 51.3% & 95.8%, 76.2% & 96.6% and 85.7% & 100% respectively for inflammation, tenosynovitis, joint effusion, cartilage destruction, meniscus destruction and bone marrow edema respectively. On the other hand, for features where DECT was reference, MRI showed sensitivity & specificity of 70.8% & 100% and 76% & 100% respectively for osteosclerosis and bony erosion respectively (Table 4).

Table 4: Diagnostic Efficacy of DECT and MRI for different imaging features as compared to reference modality

SN	Feature	TP	FP	FN	TN	Sens	Spec	PPV	NPV	Accuracy
(a) Reference Modality – MRI; Test Modality – DECT										
1.	Inflammatory joints	161	0	12	0	93.1	-	100	-	93.1
2.	Tenosynovitis	156	3	9	5	94.5	62.5	98.1	35.7	93.1
3.	Joint Effusion	56	2	26	89	68.3	97.8	96.6	77.4	83.8
4.	Cartilage destruction	40	4	38	91	51.3	95.8	90.9	70.5	75.7
5.	Meniscus destruction	64	3	20	86	76.2	96.6	95.5	81.1	86.7
6.	Bone marrow edema	30	0	5	138	85.7	100.0	100.0	96.5	97.1
(b) Reference Modality – DECT; Test Modality – MRI										
1.	Osteosclerosis	34	0	14	125	70.8	100.0	100.0	89.9	91.9
2.	Bony erosion	79	0	25	69	76.0	100.0	100.0	73.4	85.5

4. DISCUSSION

In present study, except for one patient having involvement of one joint, all the others had involvement of two or more joints. Overall, a total of 173 joints were affected in 45 patients, thus averaging almost 4 joints in each patient. In fact, majority of patients (51.1%)

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

had involvement of five or more joints. The patients of RA are typically known to present with multiple joint involvements.[14] In different studies reviewed by us, multiple joint involvement has been quite common. Døhn *et al.* in their study of 17 patients with RA reported involvement of 77 joints for the finding bone erosion, thus showing involvement of approximately 4.5 joints in each patient.[8] Regensburger *et al.* who focused only on the MCP 2 and 3 and wrist joints only reported 126 bone erosions in 103 RA patients, thus showing an average of 1.22 joints of the hand only.[15] In the study by Jans *et al.* in 20 patients with RA, as many as 400 joints were assessed and 67 joints were found to be affected, thus showing involvement of an average of 3.35 joints.[10] In present study, we carried out evaluation of all the joints where clinical symptoms were described and hence the average number of joint involvement is higher as compared to their study.

In present study, we considered MRI as the reference for evaluation of inflammatory changes, tenosynovitis, cartilage destruction, meniscus destruction and bone marrow edema whereas for bony erosion and osteosclerosis, DECT was considered as gold standard. This selection was done to provide a level ground for both the diagnostic modalities to be compared against each other with the better one of two taken as gold standard for different radiological features as already established.[7,15,16] In present study, inflammatory changes were diagnosed in all the 173 involved joints using MRI, however, DECT could detect only them in only 161 (93.1%). Thus the underdiagnosis rate of DECT as compared to MRI was 6.9%. Statistically, this difference was significant. Despite Dual Energy CT providing a better visualization of inflammatory changes as compared to conventional CT, has certain limitation in evaluating the same in comparison with MRI. Fukuda *et al.* in their study also found that DECT could not detect 20/92 (21.7%) inflammatory changes in hand psoriatic arthritis patients, thus showing an under diagnosis rate of 21.7%.[17] Compared to their study, the underdiagnosis rate was much lower in present study, primarily owing to the fact that present study involved RA cases. In another study, Kuno *et al.* also reported a higher sensitivity of MRI as compared to DECT in detection of inflammatory changes.[18] The findings of present study also show that DECT was less sensitive as compared to MRI in detection of inflammatory changes.

In present study, there was a substantial and significant agreement between MRI and CT for the diagnosis of tenosynovitis, however, it was moderately significant for diagnosis of meniscus tear, near perfect for the diagnosis of bone marrow edema, fair slight and significant for diagnosis of cartilage destruction and non-significant and slight agreement for diagnosis of joint effusion. For different radiological features where MRI was considered as the gold standard, the sensitivity of DECT ranged from 51.3% (Cartilage destruction) to 94.5% (Tenosynovitis) while specificity ranged from 62.5% (Tenosynovitis) to bone marrow edema (100%). The positive predictive value ranged from 90.9% (Cartilage destruction) to 100% (inflammatory joints and bone marrow edema). The negative predictive value ranged from 24.7% (Tenosynovitis) to 96.5% (Bone marrow edema). The order of accuracy for different MRI features in ascending order was Cartilage destruction (75.7%) followed by Joint effusion (83.8%), Meniscus destruction (86.7%), inflammatory joints (87.3%), Tenosynovitis (93.1%) and bone marrow edema (97.1%) respectively.

ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

In present study, DECT was only 68.3% sensitive in diagnosis of joint effusion. Traditionally, CT is considered to have a low sensitivity for evaluation of joint effusion.[19] Although DECT has been found to hold a high accuracy in case of joint effusion in cases of gout where it is visualized owing to urate crystal deposition at the site,[20-22] however, in case of rheumatoid arthritis, DECT was unable to visualize the joint effusion as effectively as MRI could. No previous study among different studies on rheumatoid arthritis reviewed by us, has shown the parity of DECT with MRI in evaluation of joint effusion.

Another problem area where DECT was found to be less sensitive was cartilage destruction where its sensitivity was as low as 51.3% only. However, it was highly specific (95.8%). Although a high specificity with reasonable sensitivity of DECT has been shown in evaluating cartilage morphology and changes,[18,23] however, in present study, though we achieved a high specificity yet could not find it to be reasonably sensitive. Thus, despite improvisations, cartilage destruction assessment still remains to be an area where DECT lags behind MRI.

As far as high efficacy of DECT in evaluation of tenosynovitis is concerned, it is particularly based on a better visualization through the help of iodine contrast.[12,24] However, this also resulted in loss of specificity. In present study we found the specificity of DECT in evaluation of tenosynovitis to be 62.5% only. Thus showing that increased sensitivity for tenosynovitis as rendered by DECT led to a higher false positive rate too. No doubt, administration of contrast helps to increase the sensitivity of CT for detection of tenosynovitis as also observed by Polster *et al.* who also found a high agreement between post-contrast CT and MR imaging for identification of tenosynovitis.[25]

In present study, for evaluation of meniscus destruction, DECT was found to be highly specific (96.6%) and reasonably sensitive (76.2%). However, VandeBerg *et al.* in two different studies reported DECT to hold both high sensitivity as well specificity (both >90%) in detection of meniscal destruction among patients being evaluated for anterior cruciate ligmament tear.[26,27] In present study, the evaluation was being done in cases of RA, where unlike ACL tear, both soft tissue as well as bony changes are taking place and are often overlapping. This overlapping resulted in some loss of visualization resulting in loss of sensitivity, however, the specificity could be retained well.

In present study, DECT had both high sensitivity (85.7%) as well as specificity (100%) in evaluation of bone marrow edema. Overall rendering a high accuracy (97.1%). As far as evaluation of bone marrow edema is considered, DECT has emerged as a useful imaging modality for evaluation of bone marrow edema and has been reported to be highly accurate.[10,11] DECT fills the gap of conventional computed tomography in visualization of bone marrow edema.[10] The findings in present study are in agreement with the observation made by Jans *et al.* who observed DECT to have an agreement with MRI on 97.5% joints evaluated by them.[10] In present study, we also found this accuracy to be 97.1%.

In present study, for the two features – osteosclerosis and bony erosion, CT was considered as gold standard and sensitivity & specificity of MRI as found to be 70.8 & 100% and 76% & 100% respectively. Thus showing a high specificity of MRI but with an average to good sensitivity. Compared to present study, Regensburger *et al.* while comparing the MRI

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against HR-pQCT for detection of osteosclerosis and bone erosions found MRI to be only 24% sensitive and 97% specific.[15] They were of the view that MRI rarely detects osteosclerosis. In present study, though we found MRI to be 100% specific which is comparable to 97% reported by them, however, we did not find the sensitivity of MRI to be that poor. In another study, Døhn *et al.* similar to present study found bone erosion detection rate to be lower in MRI as compared to CT.[9] They reported detection of bone erosion in MRI to be 19.5% lesser than CT. In present study too, we found bone erosion detection rate to be 24% lesser in MRI as compared to DECT.

Given the complex pathophysiology and presentation of rheumatoid arthritis which involves the soft tissue, cartilage, meniscus and bone at locations complex to be accessed directly, it requires an imaging modality that could accomplish the all, however, between DECT and MRI, both the modalities have certain limitations. Nevertheless, in present study we found that DECT has a definite edge over MRI in evaluation of osteosclerosis and bony erosions, while at the same time it was highly sensitive in evaluation of inflammatory joints, tenosynovitis, meniscus destruction and bone marrow edema which were traditionally considered to be the domains where MRI had an edge over conventional computed tomography. The findings in present study, thus show that in a resource-restricted facility where Magnetic resonance imaging is not available, DECT could be used as an alternative for the most of the features, otherwise considered to be diagnosable only by MRI while at the same time offering better imaging for osteosclerosis and bony erosion. In order to get a more comprehensive information, use of both the modalities is recommended wherever such facilities are available.

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ISSN: 0975-3583, 0976-2833 VOL11, ISSUE4, 2020

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