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Basic Science

Is Ultrasound As Useful As Metal Artifact Reduction Sequence Magnetic Resonance Imaging in Longitudinal Surveillance of Metal-on-Metal Hip Arthroplasty Patients?

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ABSTRACT

Background: Current guidelines recommend longitudinal monitoring of at-risk metal-on-metal (MoM) arthroplasty patients with cross-sectional imaging such as metal artifact reduction sequence (MARS) magnetic resonance imaging (MRI) or ultrasound. During follow-up evaluations, the clinical focus is on the relative interval changes in symptoms, radiographs, laboratory tests, and cross-sectional imaging modalities. Although MRI has the capacity for the detection of adverse local soft tissue reactions (ALTRs), the potential disadvantages of MARS MRI include the obscuration of periprosthetic tissues by metal artifacts and the cost. The aim of this study was to evaluate the diagnostic accuracy of ultrasound in comparison with MARS MRI in detecting ALTR in MoM patients during consecutive follow-up.
Methods: Thirty-five MoM patients (42 hips) were recruited prospectively to evaluate the sensitivity and specificity of the ultrasound for detecting ALTR in relation to MARS MRI during 2 longitudinal follow-up scans. The agreement between ultrasound and MARS MRI in ALTR grade, size, and size change was calculated.
Results: At the initial evaluation and at the subsequent follow-up, ultrasound had a sensitivity of 81% and 86% and a specificity of 92% and 88%, respectively. At the follow-up evaluations, ultrasound was able to detect the "change" in the lesions size with -0.3 cm^2 average bias from the MARS MRI with higher agreement ($k = 0.85$) with MARS MRI compared to the initial evaluation in detecting any "change" in ALTR size or grade.
Conclusion: Ultrasound detected the interval change in the ALTR size and grade with higher accuracy and higher agreement with MARS MRI compared with the initial evaluation, suggesting ultrasound is a valid and useful.

Since the introduction of the current-generation metal-on-metal (MoM) bearing surfaces, over 1.5 million MoM hip arthroplasties have been implanted worldwide [1]. In the early 2000s, MoM bearing articulations represented 35% of all total hip arthroplasties (THAs) performed annually, in the United States [2]. However, the national registries reported unexpectedly high early failure of these prostheses, 2- to 3- fold higher than the contemporary THA systems [3]. Adverse local tissue reactions (ALTRs) to wear-related metal debris have emerged as an important reason of failure in MoM patients [4]. Current consensus guidelines recommend longitudinal surveillance of "moderate" risk stratification MoM hip prostheses patients with cross-sectional imaging [5].

Both metal artifact reduction sequence (MARS) magnetic resonance imaging (MRI) and ultrasound (U/S) scanning have been recommended as useful cross-sectional imaging modalities in the clinical evaluation of MoM patients. U/S is not affected by metal artifacts and can discriminate solid from cystic lesions. However, the operator-dependent nature of U/S and its inconsistency in

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evaluating the deep structures, especially in obese patients, are potential disadvantages [6]. MARS MRI is a highly sensitive modality for the detection of solid and cystic soft tissue reactions, including both small and posterior lesions [7,8]. The potential disadvantages of MARS MRI include the increased scan time, the obscuration of periprosthetic tissues by metal artifacts, and the cost. MRI has a significantly higher cost than U/S. In the United States, the cost of U/S and MARS MRI has been reported to be approximately USD 800 and USD 1500, respectively [9]. Therefore, for a single follow-up of 500,000 MoM patients, the potential cost differential between these modalities would be approximately USD 350 million [9].

Most MoM patients with “low” and “moderate” risk stratifications may need follow-up cross-sectional scans during longitudinal surveillance. During follow-up evaluations, the clinical focus is on the relative interval changes in symptoms, radiographs, laboratory tests, and cross-sectional imaging modalities. Although few studies have evaluated the diagnostic accuracy of U/S in ALTR detection at initial evaluation [9-11], data regarding the validity of U/S in the setting of consecutive follow-up of MoM patients would be of importance. The aim of this study was therefore to prospectively compare the diagnostic accuracy of U/S to MARS MRI during longitudinal surveillance in detecting ALTR in a cohort of MoM arthroplasty patients who have elected to be treated nonoperatively.

Methods

Patients

In this institutional review board–approved study, all study patients were identified from a multidisciplinary, tertiary referral MoM center specializing in the evaluation and treatment of patients with MoM hip arthroplasty. Thirty-five patients (21 men, 14 women) with 42 hip arthroplasties were recruited for prospective MRI and U/S follow-up. These were “low” and “moderate” systematic risk stratification patients electing nonoperative treatment with surveillance [5]. Patients' demographics are summarized in Table 1 and Table 2. All patients were re-evaluated at the minimum 1-year follow-up (mean, 14 months; range, 13-18 months) with both MARS MRI and U/S performed on the same day using standardized imaging protocols.

U/S Scanning Protocol

U/S examination was performed using a GE E9 machine and a 6-MHZ convex traducer (Toshiba Medical Systems, Zoetermeer, Netherlands). Three separate real-time clips of the hip using a 6- to 15-MHz linear array probe were obtained. The scanning technique was systematically performed for all patients, over the anterior (Fig. 1), lateral (Fig. 2), and posterior (Fig. 3) periprosthetic soft tissues. The first clip was a sweep centered on the anterior hip beginning inferior to the hip joint and extending in an axial fashion cranially to the anterior inferior iliac spine. A lateral sweep was obtained in a coronal plane from posterior to anterior through the greater trochanter. The final sweep was obtained posteriorly beginning at the ischiofemoral space and extending superiorly in the axial plane to the posterior acetabulum. Still images of all abnormalities were recorded for review.

Table 1
Summary of Patient Characteristics.

Patient Characteristics	
Patients (hips)	35 (42)
Gender	M, 21; F, 14
Age (y)	60.5 (43-84)
Height (m)	1.63 (1.57-1.90)
Weight (kg)	78.3 (49.0-113.4)
BMI (kg/m^2)	26.6 (19.4-40.3)
Follow-up after index surgery (mo)	65.2 (21.6-132)
Implant type	MoM THA, 29; MoM hip resurfacing, 13
Harris Hip Score	66 (34-100)
Metal ion levels (μg/L)	Co, 2.8 (0.6-44.0); Cr, 2.2 (0.5-53.7)

BMI, body mass index; F, female; M, male; MoM, metal on metal; THA, total hip arthroplasty.

Table 2
Summary of MoM HR and THA Implants.

Type of MoM Implant	Side	Manufacturer	Implant	Femoral Head Size (mm)	Femoral Head Offset	Acetabular Cup Size (mm)
HR	Right	Smith and Nephew	Birmingham	48	0	56
HR	Left	Smith and Nephew	Birmingham	46	0	52
HR	Left	Smith and Nephew	Birmingham	42	0	48
HR	Right	Smith and Nephew	Birmingham	50	0	58
HR	Left	Smith and Nephew	Birmingham	50	0	56
HR	Left	Smith and Nephew	Birmingham	50	0	58
HR	Right	Stryker	Cormet	48	0	54
HR	Left	Stryker	Cormet	50	0	56
HR	Right	Stryker	Cormet	46	0	52
HR	Left	Stryker	Cormet	48	0	54
HR	Left	Stryker	Cormet	50	0	56
HR	Right	Stryker	Cormet	50	0	58
HR	Right	Wright Medical	Conserve plus	50	0	60
THA	Right	Depuy	Pinnacle Sector II	36	+3	56
THA	Right	Depuy	Pinnacle Sector II	36	0	50
THA	Right	Depuy	Pinnacle Sector II	40	−2	56
THA	Left	Depuy	Pinnacle Sector II	36	0	52
THA	Right	Depuy	Pinnacle Sector II	28	+3	52
THA	Left	Depuy	Pinnacle Sector II	44	0	62
THA	Left	Depuy	Pinnacle Sector II	36	0	50
THA	Left	Depuy	Pinnacle Sector II	36	0	52
THA	Right	Depuy	Pinnacle Sector II	36	+3	52
THA	Left	Depuy	Pinnacle Sector II	36	0	56
THA	Left	Depuy	Pinnacle Sector II	36	0	54
THA	Right	Depuy	Pinnacle Sector II	40	+12	56
THA	Left	Depuy	Pinnacle Sector II	36	0	50
THA	Right	Depuy	Pinnacle Sector II	36	+6	50
THA	Left	Depuy	Pinnacle 100	36	0	60
THA	Right	Depuy	Pinnacle 100	36	0	58
THA	Left	Depuy	Pinnacle 100	40	0	58
THA	Left	Depuy	Pinnacle 100	36	0	60
THA	Left	Depuy	Pinnacle 100	40	0	56
THA	Left	Depuy	ASR	45	0	50
THA	Left	Depuy	ASR	51	+2	58
THA	Left	Depuy	ASR	47	0	54
THA	Left	Depuy	ASR	45	0	52
THA	Left	Depuy	ASR	43	0	48
THA	Right	Depuy	ASR	45	0	50
THA	Right	Depuy	ASR	43	0	48
THA	Left	Smith and Nephew	Birmingham	46	0	52
THA	Right	Smith and Nephew	Birmingham	46	0	52
THA	Left	Stryker	Cormet	46	0	54

ASR, articular surface resurfacing; HR, hip resurfacing; MoM, metal on metal; THA, total hip arthroplasty.

MARS MRI Protocol

MRI scans were acquired using a 1.5-T clinical superconducting magnet (Sigma; GE Medical Systems, Milwaukee, WI) using 5