



Imaging evaluation of polyethylene liner dissociation in total hip arthroplasty

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Abstract

Objective To describe the imaging findings of polyethylene liner dissociation in total hip arthroplasty.

Materials and methods Retrospective search of our institution's radiology database identified 12 patients with polyethylene liner dissociation of a total hip arthroplasty. Clinical and operative notes were reviewed. All radiological studies were reviewed independently by two radiologists.

Results Among 12 patients (seven females/five males; mean age: 67 years; median interval after surgery at diagnosis: 8.5 months) with polyethylene liner dissociation, 11 had radiographs, six had CT, seven had MRI, and two had arthrography. “Bubble sign” and “crescent sign” on radiography were insensitive, seen only in three patients, but all showed abrupt eccentric positioning of the femoral head. CT identified the dislocated liner in five of six patients but failed to identify one liner, which was partially associated with the acetabular cup. MRI identified the dislocated liner in all seven patients, with the MAVRIC (multiacquisition variable resonance image combination) sequences either increasing the diagnostic confidence relative to the routine pulse sequences or being the sole sequences in which the liner can be identified if the liner remained partially associated with the acetabular cup. Arthrography identified the dislocated liner in one of two patients.

Conclusions Previously described radiographic signs of polyethylene liner dissociation are insensitive, but abrupt eccentric positioning of the femoral head in the correct clinical context is highly suggestive of the diagnosis. MRI and CT can accurately localize the displaced liner. MAVRIC is particularly helpful if the dislocated liner remains partially associated with the acetabular cup.

Keywords Total hip arthroplasty · Dual-mobility arthroplasty · Polyethylene liner · Intraprosthetic dislocation · MAVRIC

Introduction

Polyethylene liners are commonly used in total hip arthroplasties. They have historically been popular as part of a modular construct in which the polyethylene liner locks into the metallic acetabular cup, allowing flexibility in component selection intraoperatively [1, 2]. In addition, dual-mobility systems have been developed in which motion occurs at two interfaces, at the articulation between the femoral head and polyethylene liner as well as at the articulation between liner

and acetabular cup, to increase range of motion while reducing the incidence of component dislocation [3]. However, the presence of the polyethylene liner introduces another interface in which component dissociation can occur, and isolated dislocation of the polyethylene while the remainder of the components in dual-mobility systems articulate has been termed “intraprosthetic dislocation” [4, 5]. With intraprosthetic dislocation and in polyethylene liner dissociation in general, the liner can remain partially associated with the acetabular cup, or it can displace or migrate away from the cup (Fig. 1).

As most polyethylene liners are completely radiolucent, the integrity of the liner is indirectly inferred radiographically by the position of the metallic femoral head with respect to the metallic cup. For example, although the polyethylene liner is difficult to visualize radiographically, progressive superolateral migration of the femoral head in the acetabular cup, usually occurring over many years, is a sign of liner wear. However, a less common cause of eccentric positioning of the femoral head component in the acetabular cup, occurring

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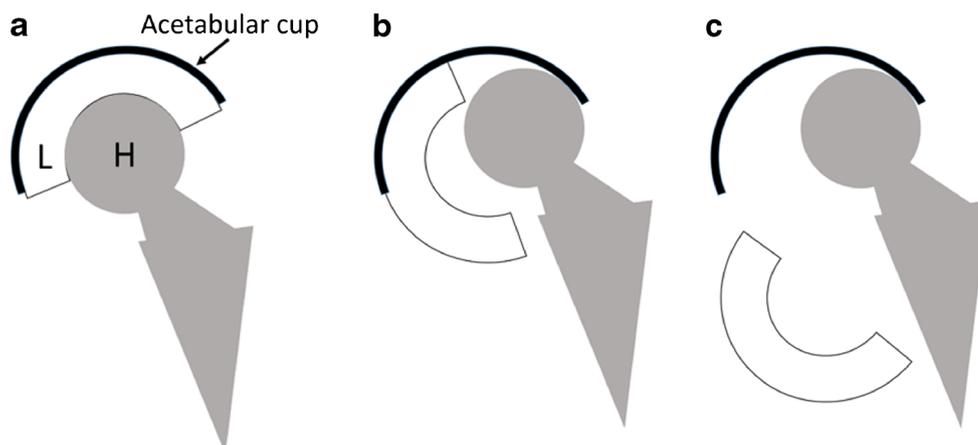


Fig. 1 Schematic diagram of **a** normal total hip arthroplasty with polyethylene liner (L) articulating with the head (H) of the femoral component, **b** liner dislocated but partially associated with the acetabular cup, and **c** liner dislocated and displaced away from the cup

acutely, is polyethylene liner dissociation. The displaced polyethylene may infrequently be visible on radiographs as a radiolucent crescent or ring in a background of soft tissue density, known as the “crescent sign” or “bubble sign,” respectively [1, 3], but the reliability of these signs is unknown [6].

The majority of publications on the imaging diagnosis of polyethylene liner dissociation are in the orthopedic literature, focusing on radiography. In the orthopedic literature, the use of computed tomography (CT) for diagnosing this entity is limited to case reports with single cases each [5, 7–10]. To our knowledge, there is only one description of the use of CT [6] in diagnosing polyethylene liner dissociation in the radiology literature, while the use of magnetic resonance imaging (MRI) is limited to a single case report [4] and briefly in two review articles [11, 12]. We suspect that there is limited knowledge of this entity among radiologists; therefore, the purpose of this retrospective study was to describe the imaging features of polyethylene liner dissociation diagnosed at a large tertiary care orthopedic hospital that has been performing over 4500 primary and revision hip replacements per year over the past 10 years (Institutional unpublished data).

Materials and methods

Patient selection

After obtaining study approval and waiver of need for informed consent from the Institutional Review Board (IRB), a search was performed in our radiology report database using a combination of the keywords “polyethylene,” “liner,” “dislocation,” “dissociation,” “displacement,” and “migration” to identify all cases of polyethylene liner dissociation during the 10-year period from 2009 to 2018. All relevant radiological studies, including CT and MRI, were

reviewed and all available clinical notes and operative reports were reviewed. Those with dislocation of the femoral component with respect to the acetabular cup but without any subsequent studies showing polyethylene liner dissociation without dislocation of the femoral component from the acetabular cup were excluded.

Imaging

Radiographic views obtained for the hip varied based on the ordering physician or surgeon but typically included either an anteroposterior (AP) view of the entire pelvis or AP view of the hip and either a frog lateral or cross-table lateral view of the hip. CT scans were obtained using a 64-channel multidetector scanner (Philips Healthcare, Andover, MA) with data acquired at 0.625-mm slice thickness and reconstructed at 1.25-mm slice thickness. Sagittal and coronal reformations were obtained at 1.2-mm slice thickness. Metal artifact reduction software (MARS) was used for CTs performed in and after 2017. MRIs were obtained on a 1.5-T system (GE Healthcare, Waukesha, WI, USA) with the following pulse sequences routinely obtained for hips with arthroplasties: coronal multiacquisition variable resonance image combination (MAVRIC) inversion recovery and fast spin echo (FSE) sequences of the entire pelvis, axial intermediate weighted FSE of the entire pelvis, and sagittal, coronal, and axial intermediate-weighted FSE sequences of the affected hip. Two patients underwent arthrography as part of a fluoroscopy-guided arthrocentesis to exclude infection; 15–20 ml of iohexol 300 mg/ml was injected to opacify the joint as standard protocol.

Image analysis

All images were reviewed independently by two board-certified musculoskeletal radiologists with 9 and 4 years of

subspecialty experience. Each radiologist assessed the radiographs for the presence of eccentric positioning of the femoral head component of the arthroplasty with respect to the acetabular cup, and for the presence of either the “crescent sign” [1] or the “bubble sign” [3]. CT, MRI, and arthrograms were also assessed for visualization of a displaced polyethylene liner.

Statistical analysis

Descriptive statistics were performed and reproducibility of image interpretation between the two radiologists was assessed for each modality using the Cohen’s kappa statistic (κ) (Microsoft Excel 2016).

Results

Twelve patients with polyethylene liner dissociation were identified based on a search through our radiology report database. Demographic information of the patients is listed in Table 1. Five patients had standard acetabular cups and seven had dual-mobility acetabular cups. Clinically, dislocation of the femoral and acetabular components was discerned by the patient prior to seeking medical attention in six cases, a twisting injury or popping sound was noted but without a definite subjective sense of a dislocation in two patients, and presence/absence of a sensation of dislocation was not provided in four patients.

All but one patient had radiographs at the time of diagnosis. In all radiographs, the femoral head component of the prosthesis was eccentrically aligned along the superolateral portion of the acetabular cup, similar to an arthroplasty with polyethylene liner wear, according to both radiologists ($\kappa = 1.00$). Unlike polyethylene liner wear, however, this eccentric positioning was abrupt and new when compared to the prior radiographs. Most likely because of the abruptness of the radiographic findings, liner dissociation was suggested on the radiography report in four patients. In another five patients, liner dissociation was also suggested on the radiography report,

although either a CT or MRI had been available at the time of the radiography evaluation. Both reviewers noted a radiolucent ring (“bubble sign” [3]) on the AP radiograph immediately above the acetabular cup in one patient (Fig. 2a), and a subtle radiolucent ring superimposed on the femoral neck in another patient in retrospect (Fig. 3a), although the latter was not prospectively reported. In a third patient, a subtle radiolucent crescent was visible medial to the femoral neck (“crescent sign” [1]) (Fig. 4a) to both reviewers. By reassessing the radiographs after the CT or MRI showing the dissociated liner was reviewed, one of the reviewers felt that the “crescent sign” was seen in three additional patients and the “bubble” sign seen in one additional patient; the second reviewer was not in agreement regarding these last four cases ($\kappa = 0.35$).

Out of the six patients who underwent a CT scan, a cup-shaped hypodense structure representing the polyethylene liner which had migrated away from the acetabular cup and into the posterior joint recess/greater trochanteric bursa was seen in five patients according to both of the radiologists ($\kappa = 1.00$) (Fig. 3b). The dislocated liner could not be identified in one patient as it was still partially associated with the acetabular cup and the region was obscured by beam-hardening artifact (Fig. 5a). In this last patient, subsequent MRI confirmed the presence of a dislocated liner (Fig. 5b).

Among the seven patients who underwent an MRI, the dislocated polyethylene liner was identified in all cases by both radiologists ($\kappa = 1.00$); in the three patients in which the liner had dislocated and migrated, the liner was identified as a cup-shaped hypointense structure in the posterior joint recess/greater trochanteric bursa. In the four patients in which the liner had dislocated but was still partially associated with the acetabular cup, the liner could be discerned as having malrotated relative to the acetabular cup, with its inferior edge protruding more laterally and overlapping with the femoral neck on the coronal images (Fig. 4b). Albeit not as conspicuous as in the coronal plane, the malrotated liner could also be seen in the axial (Fig. 4c) and sagittal (Fig. 4d) planes as well. Upon retrospective review of the images, this was discernible on the routine pulse sequences in three

Table 1 Demographics of patients

Gender	7 females/5 males
Laterality of arthroplasty	8 right/4 left
Patient age at diagnosis of intraprostatic dislocation	39–93 years (mean 67)
Time between surgery and diagnosis	3 weeks–24 years (median 8.5 months)
Arthroplasty type (manufacturer)	7 dual-mobility (4 Stryker MDM; 3 Zimmer Biomet Dual Mobility) 5 standard (1 Depuy modular system, 4 unknown manufacturer)
Imaging performed for the hip at time of diagnosis	Radiographs: 11 MRI: 7 CT: 6 Arthrogram: 2
Position of the dislocated liner	Migrated away from the acetabular cup: 7 Partially associated with the acetabular cup: 5

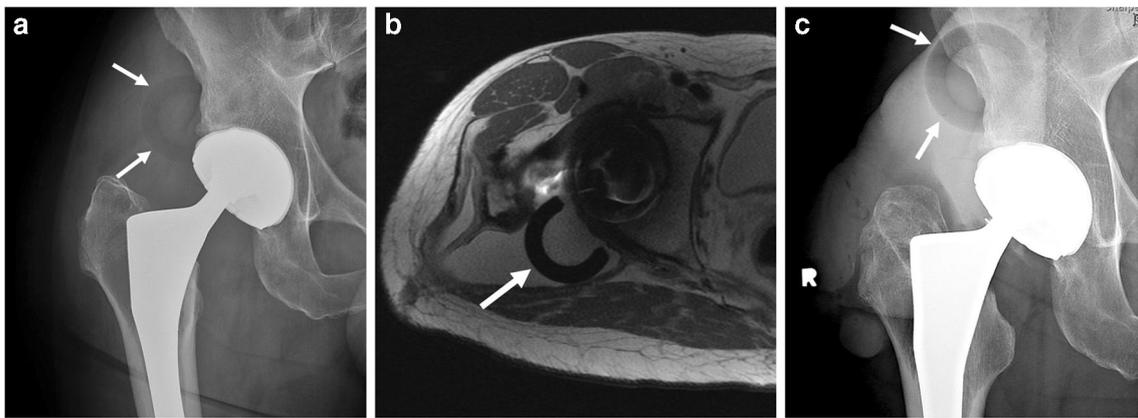


Fig. 2 A 39-year-old male with recurrent dislocation events of the right hip since total hip arthroplasty was revised to a dual-mobility system 4 months prior. **a** AP radiograph shows eccentric positioning of the head of the femoral component relative to the acetabular cup and a hypodense ring above the prosthesis, described as a “bubble sign” (arrows). **b** Axial

intermediate-weighted FSE MRI without MAVRIC shows the displaced liner (arrow) in the posterior recess of the joint. **c** Arthrogram during fluoroscopy-guided arthrocentesis clearly demarcates the displaced liner (arrows)

patients, but in the two patients in which MAVRIC sequences were performed, the MAVRIC sequences increased the diagnostic confidence relative to the routine pulse sequences. In the fourth patient in which the liner had dislocated but was partially associated with the acetabular cup, the MAVRIC sequences but not the routine pulse sequences revealed the dislocated liner (Fig. 6).

Fluoroscopy-guided arthrocentesis was performed on two patients to exclude a prosthetic joint infection. As standard protocol at our institution, an arthrogram was performed as part of the arthrocentesis, which revealed the migrated liner as a ring-shaped filling defect in one patient (Fig. 2c) while it failed to demarcate the liner in the second patient according to both radiologists ($\kappa = 1.00$). In the latter, the polyethylene liner was dislocated but still partially associated with the acetabular cup.

Eleven of the 12 patients underwent revision surgery, which confirmed the diagnosis of polyethylene liner dissociation. One patient had not yet undergone revision surgery at the time of this writing but his imaging studies clearly showed the dislocated and displaced polyethylene liner.

Discussion

Polyethylene liner dissociation is a well-known entity among orthopedic surgeons that perform hip replacements, but only a few studies have been published on this subject in the radiology literature [6, 13]. None among the latter clarifies the fact that the imaging appearance of polyethylene liner dissociation will differ based on whether the liner remains partially associated with the acetabular cup or has migrated away from the cup. Radiologists, particularly musculoskeletal radiologists, must be familiar with this entity and its imaging appearance, as polyethylene liner dissociation must be treated urgently and surgically [7, 14].

The purpose of the current study was not to make a statement on the incidence, but polyethylene liner dissociation is a very rare complication, seen in 12 patients over a 10-year period from 2009 to 2018 at our institution. Given approximately 4500 primary and revision hip replacements performed per year at our institution, this translates to less than three cases per 10,000. Although the true incidence is likely higher

Fig. 3 A 65-year-old female with recent dislocation event after right dual-mobility total hip arthroplasty placed 2 months prior. **a** AP radiograph shows a very subtle “bubble sign” (arrows) which was visible only in retrospect. **b** Sagittal reformation from a CT scan shows the displaced liner (arrows) posterior to the femoral component

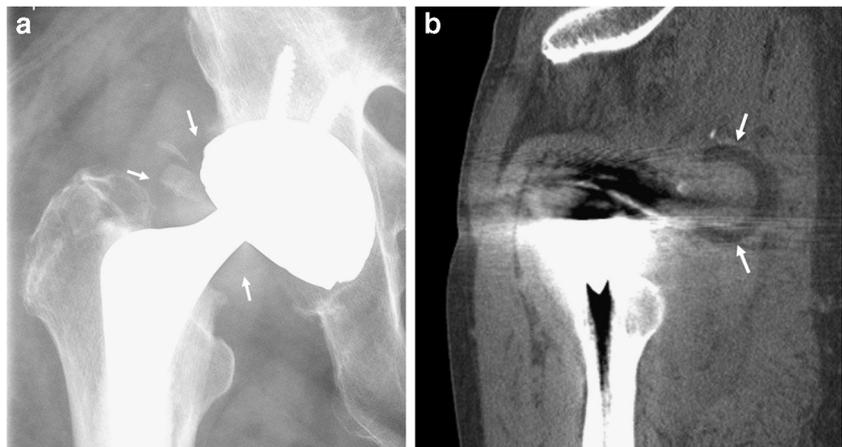
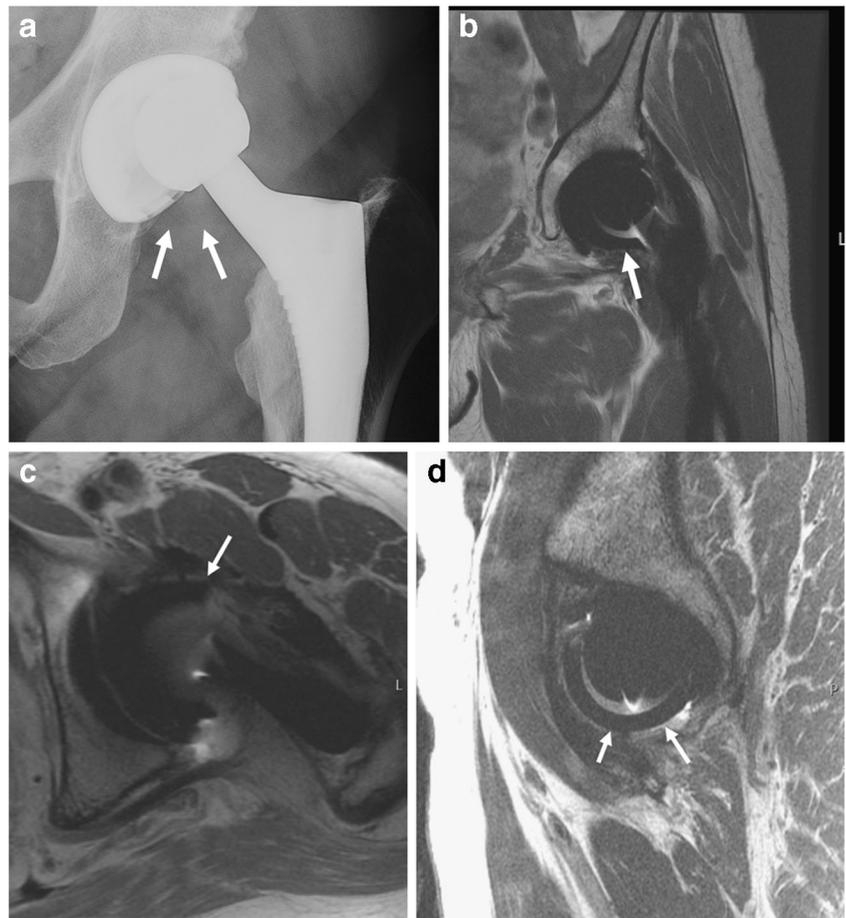


Fig. 4 A 73-year-old female with left total hip arthroplasty placed 6 years prior and recent onset of pain. **a** AP radiograph shows eccentric positioning of the head of the femoral component with respect to the acetabular cup and a subtle crescentic hypodensity (*arrows*) medial to the femoral neck, known as the “crescent sign.” **b** Coronal intermediate-weighted FSE MRI without MAVRIC shows the crescentic hypointense structure (*arrow*) extending medially from the inferior portion of the acetabular cup, representing the dislocated liner, the “MR crescent sign.” **c** Axial and **d** Sagittal intermediate-weighted FSE MRI without MAVRIC also show the abnormal positioning of the liner (*arrows*)



than this as our search method would not have identified those with the diagnosis made by clinical history only, liner dissociation is nevertheless an extremely rare complication.

Polyethylene liner dissociation can occur with both mono-articular and dual-mobility total hip arthroplasties, and the imaging appearance differs depending on whether the dislocated liner remains associated with the acetabular cup

or has displaced away from the cup. On radiography, it manifests as the femoral head component being eccentrically positioned within the metallic acetabular cup, similar to polyethylene liner wear [1]. Signs specific to polyethylene liner dissociation on radiography have been described; the “crescent sign” is a crescentic radiolucency seen medial to the femoral neck representing the liner that has malrotated relative to the

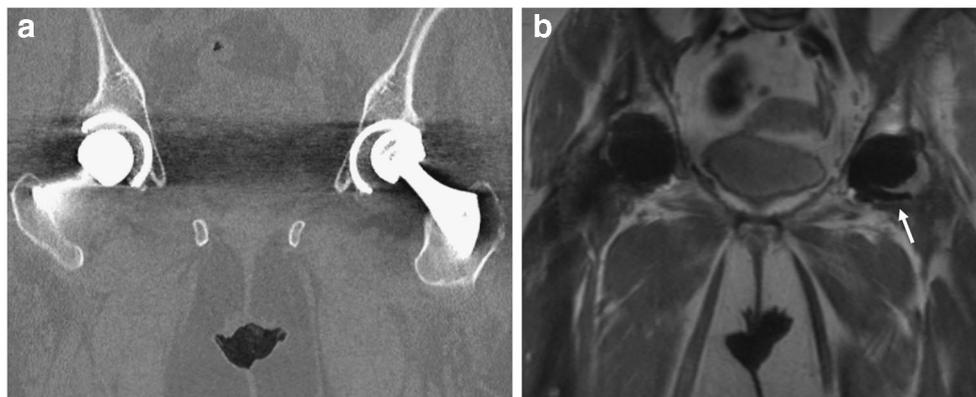
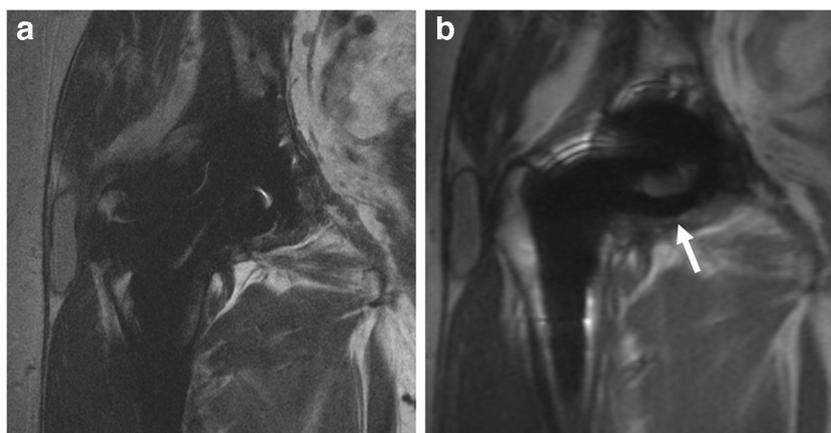


Fig. 5 A 61-year-old female with left total hip arthroplasty revised 11 months prior and pain since feeling a “pop” of the left hip. **a** Coronal reformation of CT scan shows the eccentric positioning of the head of the femoral component of the total hip arthroplasty but does not

reveal the dislocated liner. The right hip has also been replaced. **b** Coronal MAVRIC FSE MRI shows the “MR crescent sign” of the dislocated liner (*arrow*), which remains partially associated with the acetabular cup

Fig. 6 A 73-year-old female with right total hip arthroplasty placed 24 years prior and pain since a twisting injury to the hip. **a** Coronal intermediate-weighted FSE MRI without MAVRIC fails to reveal any abnormality due to susceptibility artifact. **b** Coronal MAVRIC FSE MRI reveals the “MR crescent sign” (arrow) representing the liner dislocated from but partially associated with the acetabular cup



acetabular cup, present in nine of nine patients according to one study [1]. The “bubble sign” is a ring-shaped radiolucency seen in the periprosthetic soft tissue representing the disassociated and displaced liner [3], not to be confused with another radiographic “bubble sign” due to metallosis from the arthroplasty [15]. In our study of 12 patients, 11 of whom had radiographs, both of these signs were insensitive for the detection of polyethylene liner dissociation, with a subtle bubble sign being present in two patients and crescent sign being present in only one patient. We also found only fair agreement ($\kappa = 0.35$) [16] between the two reviewers in the identification of these two radiographic signs; one of the reviewers thought either a bubble sign or crescent sign was seen in four additional patients only after he reviewed the CT or MRI, while the other reviewer did not agree. Albeit a small sample size, our study suggests that not only are “bubble” and “crescent” signs insensitive for diagnosing liner dissociation, there is also only fair inter-observer reliability in interpreting radiographs for these signs.

Among the 11 patients with radiographs, all had abrupt eccentric positioning of the femoral head with respect to the acetabular cup compared to recent prior radiographs. It is important to note that, even without the presence of either the “bubble” or “crescent” sign, this abrupt eccentric positioning of the femoral head should be diagnostic of polyethylene liner dissociation, and if the patient provides a reliable history, cross-sectional imaging is not necessary for the diagnosis.

Our study shows that both CT and MRI more reliably localized the position of the polyethylene liner compared to radiography, proving liner dissociation. When the liner was dislocated and displaced away from the acetabular cup, CT easily identified the liner as a cup-shaped hypodense structure in all five patients. However, in the one patient in which the dislocated liner was still partially associated with the cup, CT was not able to identify the liner because of beam hardening artifact. In this particular case, MARS was not used as MARS software became available on our CT scans only recently; it is possible that the partially associated liner would have been

visible had MARS been utilized. Jang et al. reviewed seven patients with a liner that had dislocated but was still partially associated with the cup, and they were able to see the radiolucent crescent medial to the femoral neck, which they termed the “CT crescent sign,” in five patients [6]. Although there have been a few case reports of CT being used to diagnose polyethylene liner dissociation [5, 7–10], these are mostly in the orthopedic literature, only described one patient each, and did not differentiate liners that were still associated with the acetabular cup from those that had displaced away from the cup. To our knowledge, we are the first to report the CT appearance of dislocated and displaced polyethylene liners in multiple patients.

In our study, MRI was able to identify all seven liners with polyethylene liner dissociation, including three that were dislocated and migrated and four that were still partially associated with the cup. We found that the cup-shaped hypointense liner is easily visible when it has displaced away from the cup even without relying on the MAVRIC sequences. However, when the dislocated liner is not completely dissociated from the cup, it appears as a hypointense crescent adjacent to the neck of the femoral component, analogous to the “CT crescent sign” as described by Jang et al. [6], which may be difficult to discern on routine pulse sequences. The conspicuity of the “MR crescent sign” is improved on the MAVRIC sequences, and in one case, the diagnosis of a liner dislocation could not have been made without MAVRIC. Although the specific metal artifact reduction technique used on our MRIs was MAVRIC, as it is a proprietary sequence of GE Healthcare and all of the magnets at our institution are GE, we believe that other metal artifact suppression techniques such as WARP and SEMAC (Siemens Healthcare) [17] should also allow detection of these partially associated dislocated liners by demonstrating the “MR crescent sign”.

One case report in the orthopedic literature [4] and two review articles in the radiology literature [11, 12] show an image of an MRI with the dislocated and displaced polyethylene liner, but our study is the first to specifically describe the

MRI appearance of the dislocated liner, either as a cup-shaped hypointense structure if it is displaced away from the acetabular cup or “MR crescent sign” if still partially associated with the cup.

In all of our patients in which the polyethylene liner had dislocated and migrated away from the acetabular cup, the migrated liner was noted in the posterior joint recess/greater trochanteric bursa, likely because this is the most dependent part of the hip joint. However, it is important to note that the loose and dissociated liner can potentially migrate to any anatomic region that is an extension of the hip joint. For example, the liner can travel into the pelvis or retroperitoneum via the iliopsoas bursa [5].

An abrupt eccentric positioning of the femoral head relative to the acetabular cup on radiographs should be diagnostic of liner dissociation. Nevertheless, MRI or CT may still play a role in preoperative planning even if the diagnosis is clear; it would be useful for the surgeon to know where the dissociated liner is located, especially in those rare cases in which the liner has migrated into the pelvis or retroperitoneum. The choice of MRI versus CT would depend largely on the availability of metal artifact reduction for each modality. With the availability of optimal metal artifact reduction sequences, an MRI would be preferred, as it may be more likely to identify the liner that is dislocated but still partially associated with the acetabular cup compared to CT. MRI also has the advantage of being able to detect concomitant soft tissue injuries that CT would not.

There are some limitations to our study. It is retrospective, thus it is subject to selection bias, as we may not have identified all cases of polyethylene liner dissociation; it is possible that there may be other patients who only had radiographs at our institution who subsequently underwent surgical revision without further imaging as the diagnosis of polyethylene liner dissociation was clear clinically. A more accurate analysis of sensitivity and specificity would have required a review of the operative reports of all revision surgeries of hip arthroplasties at our institution, which would not have been feasible given the lack of a registry of hip arthroplasty revisions.

In conclusion, we have shown that an eccentrically seated femoral head component within the acetabular cup on radiography is not specific to polyethylene liner wear, and if abrupt, is highly suggestive of liner dissociation even in the absence of the “bubble sign” or the “crescent sign”. Both CT and MRI can be useful for accurate localization of the dissociated liner. Metal artifact reduction sequences such as MAVRIC can be helpful in identifying the “MR crescent sign” of a dislocated liner which is still partly associated with the acetabular cup.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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