Normal radiologic findings and detection of complications in Hip Resurfacing Arthroplasty (HRA).

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Learning objectives

Although total hip arthroplasty (THA) has shown good results in the treatment for degenerative osteoarthritis, hip resurfacing arthroplasty (HRA) is a less aggressive method of hip reconstruction that maintains anatomy, articular biomechanics and stability in selected patients. However, it needs clinical and radiologic specific follow-up because it is associated with adverse periarticular soft tissue reactions (metalosis, pseudotumors, ALVALS) and elevated serum levels of metal ions -metallosis-, even in asymptomatic patients.

In this review, we will:

- recognize the **position of the components of the normal HRA** with conventional radiographs.

- learn and recognize **specific** as well as non-specific **complications of HRA**.

- review the different **available radiologic techniques to evaluate HRA** and the **most indicated** one for each possible complication (CT, US, MRI).

- given that **MRI** is the most adequate imaging method to **evaluate adverse periarticular soft tissue reactions**, we will learn the most appropriate **techniques** to perform the study and avoid artifacts.
Background

**TOTAL HIP ARTHROPLASTY (THA) VS. HIP RESURFACING ARTHROPLASTY (HRA)**

Hip arthroplasty is the definite treatment for degenerative osteoarthritis.

Total hip arthroplasty (THA) has shown good results, but unsatisfactory long-term survival of metal-on-polyethylene (MoP) devices in younger, active, higher-demand patients with good bone stock, gave place to second-generation metal-on-metal (MoM) prosthesis, including hip resurfacing arthroplasty (HRA).

**CONVENTIONAL TOTAL HIP ARTHROPLASTY (fig.1).**

*It involves surgical excision of the head and proximal neck of the femur, acetabular cartilage and subchondral bone.*

Consists of (fig.2):

- a femoral stem
- a femoral head
- metal acetabular cup (cemented or not - press fit-).

**HIP RESURFACING ARTHROPLASTY (HRA) (fig.3)**

*Conserves native head and femoral neck.*

It has a short metaphyseal stem for alignment, not to support load.

Hybrid: cemented femoral component and non-cemented acetabular component.

It is a metal on metal device, allowing synovial fluid to lubricate prosthetic surfaces (fig.4).

Prosthetic metal components: Cobalt (~65%), chromium (25-30%) and molybdenum (6-8%)

**HRA ADVANTAGES**

It preserves femoral bone stock, facilitating simple revision surgery on the femoral side.

It has less fail secondary to polyethylene wear and osteolysis.
This prosthesis shows a reduced implant-bearing surface wear.

The larger femoral head sizes increase stability and reduce the risk of dislocation.

Better functional results and proprioception are recognized.

**HRA LIMITATIONS**

THA is superior in terms of implant survival

In patients with low femoral head-neck ratio, removal of acetabular bone may be needed.

It is not possible to adjust limb length and femoral offset.

A Body mass index (BMI)<35 Kg / m² is recommended.

The surgical technique is much more demanding.

There is a possibility of adverse host reactions to metal ion debris (pseudotumors in periprosthetic joint space).

The elevation of serum metal ions is of uncertain significance.

**CONTRAINDICATIONS**

- Deficient bone stock or deformity in femoral head / neck and acetabulum (hip dysplasia, trauma, cystic degeneration (>1cm), osteonecrosis of the femoral head >50%).

- Advanced age and osteoporosis.

- Skeletal immaturity.

- Discrepancies in limb length > 1 cm or with low horizontal femoral offset.

- Vascular, muscular, or neuromuscular disease severe enough to compromise implant stability or postoperative recovery.

- Impaired renal function.

- Known metal hypersensitivity.

- Females of child-bearing age due to unknown effect on the fetus of metal ion release.

**INDICATIONS**
Initially, patients with very different pathological entities, even previously operated, were treated with HRA, but this lack of selection caused a high index of prosthesis failure. After changes were made in the indications and technique, the overall complication rate decreased (femoral neck fracture reduced from 7.2 to less than 1%).

The Surface Arthroplasty Risk Index (SARI) (Beaulé et al) is calculated based on the presence of femoral head cysts, patient weight, previous hip surgery and UCLA activity level. (Table 1)

**SARI >3 Increases 12 times the risk of early failure or adverse radiographic findings**

Only one indication:

Primary diagnosis of osteoarthritis in a patient under 50 with a femoral head > 50 mm.

**EVALUATION OF THE NORMAL HRA**

**CONVENTIONAL RADIOGRAPHS**

They are the primary imaging modality, needed to measure the femoral stem-shaft angle and cup abduction angle

**Technique**

AP view of the pelvis (fig.5) and Cross-table (shoot-through or Johnson) (fig.6) lateral view. The lateral view allows visualization of the lateral plane of the cup, position and assessment of the amount of anteversion and the presence of anterior cup overhang.

Position: patient supine and the non-operated hip flexed to 90 (so that it does not obstruct the field of view). The beam is aimed from the midline. The cassette is positioned lateral to the hip.

**How is the Femoral component position evaluated?**

**Femoral stem-shaft angle** is formed by a line along the femoral shaft and a line along the femoral stem.

It must be higher than 135°(figs.7)
How is the acetabular component evaluated?

**Cup abduction angle** (fig. 8) is formed by the lateral edge of the acetabular component relative to a horizontal reference line.

Ranges from 35°-50°.

The higher the cup angle, the greater the wear of a MOM implant.

**Anteversion of the socket** (fig. 9) is measured by the angle created from a vertical line perpendicular to the horizontal plane and the edge of the acetabular component.

Ranges from 15°-20°.

**METAPHYSEAL STEM ZONES** (figs. 10, 11)

Short femoral stem is cemented and is very useful for the detection of radiolucencies indicating the presence of osteolytic areas which precede loosening. Migration commonly occurs on the femoral side.

Amstutz and colleagues divided the bone stem in areas to analyze femoral fixation with a scoring system of 0 to 9 points. Acetabular lucencies were also evaluated and scored.

**ACETABULAR RADIOLUCENCIES** (fig. 12)

Osteointegration of the socket is recognized when bone trabeculae reach the implant interface and there are no radiolucencies.

**A radiolucency score of #7 in this rating system is substantial because it is likely to progress to component loosening overtime**

**DIAGNOSTIC ALGORITHM FOR EVALUATION AND TREATMENT OF PATIENTS WITH MOM HIP ARTHROPLASTY**

HRA needs clinical and radiologic specific follow-up because it is associated with adverse periarticular soft tissue reactions (metallosis, pseudotumors, ALVALS) and elevated serum levels of metal ions -metallosis-, even in asymptomatic patients. We will see these complications in detail in the next section. Several protocols of management for the follow-up of these patients have been proposed (Table 4).
- In painless patients with correct position of the HRA in conventional radiographs only follow up would be indicated. However, if the HRA is not well positioned, metal ions blood levels would be determined and in case of elevation of them, an MRI would be performed.

- Symptomatic patients would need both an MRI study and determination of metal ions blood levels to decide possible revision.
Fig. 1

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Fig. 2: Modular options with uncemented Total Hip Replacement

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Fig. 3: HIP RESURFACING ARTHROPLASTY. AP view, conventional radiograph.

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**Fig. 4:** Birmingham Hip Resurfacing (BHR) System

© Birmingham Hip Resurfacing (BHR) System
Fig. 5: AP view of HRA.

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Fig. 6: Lateral view of a HRA.

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Fig. 7: Femoral stem-shaft angle on AP view.

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Fig. 8: Cup abduction angle on AP view.

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Fig. 9: Anteversion of the socket on lateral view.

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| Femoral head cyst of >1 cm in size | 2 |
| Patient weight of < 82 kg | 2 |
| Previous hip surgery | 1 |
| UCLA activity level of >6 | 1 |
| Maximum score | 6 |

(Beaulé et al.)

Table 1: SURFACE ARTHROPLASTY RISK INDEX (SARI)

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Table 2: Metaphyseal stem zones.

Table 3: Acetabular zones.


0=No lucencies
1=Lucency in zone I
2=Lucency in zone II
3=Lucency in zone III
4=Lucencies in zones I & II
5=Lucencies in zones I & III
6=Lucencies in zones II & III
7=Lucencies in zones I-III (incomplete)
8=Lucencies in zones I-III (complete)
9=Migration.
Table 4: DIAGNOSTIC ALGORITHM FOR EVALUATION AND TREATMENT OF PATIENTS WITH MOM HIP ARTHROPLASTY

Findings and procedure details

Complications of HRA

There are specific and non-specific complications (Table 5).

The specific complications are femoral neck fracture and head colapse, neck narrowing, implant instability, impingement and adverse reaction to metals (pseudotumors and metallosis).

Non-specific complications may take place in any type of prosthesis, such as mechanical loosening, component failure, heterotopic ossification, dislocation, infections, bursal collections and muscle atrophy.

SPECIFIC COMPLICATIONS

Femoral neck fracture and femoral head colapse

Femoral neck fracture is the most common cause for failure of the procedure. It occurs in 1.5% of patients. Often an early complication, within the first three months after operation. It is located in the implant -neck junction (superolateral).

Common factors are found in 85% of cases: significant varus placement of the femoral component, notching of the superolateral cortex of the femoral neck at the time of surgery and technical problems (inaccurate reaming of the native femoral head).

Femoral head colapse causes implant instability.

Types of fracture (Zustin et al)

1. Acute, biomechanical (8%): It is the earliest (41-57 days post-intervention). It affects only the neck. Pathology shows no necrosis or fibrosis (fig.13).

2. Subacute, postnecrotic (51%): 149+-168 days post-operation. It is secondary to necrosis 2/3 inside the component (fig. 14).

3. Chronic, biomechanical: 179+-165 days post-surgery. Seudoarthrosis and fibrosis are found (fig.15).

Femoral neck stress fractures have also been described, in patients with acute small lesions that can repair themselves chronically (fig.16).
Neck narrowing

It only occurs in HRA. It reaches 77-90% of patients. Defined as loss of >10% of femoral neck diameter from the original postoperative radiographs (fig. 17), it is not associated with poor clinical outcome if it does not progress over 3 years. It has an uncertain meaning, most probably a form of stress shielding, caused by external pressure from synovitis or secondary to impairment of the blood supply to the femoral head.

Adverse reaction to metal

There are two recognized mechanisms of undesired reaction to metals:

1. Excessive wear of bearing surfaces causing metallic debris -METALLOSIS- and periprosthetic soft tissue deposition -PSEUDOTUMORS- . This reaction depends on the degree of metal wear (fig.18,19). Factors that cause this wear are:

- Abnormal loading in implant surfaces due to component malposition (increased acetabular abduction/inclination, poor acetabular anteversion…)

- Decreased head diameter.

2. Hypersensitivity to metal. This reaction to metal does not require substantial wear of bearing surfaces.

Metal particles can become integrated into the soft tissue surrounding the implant, leading to necrosis. An aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL) is a local immune-mediated type IV delayed hypersensitivity reaction. Often with excessive necrosis but without significant wear-induced debris.

Metallosis

Metal particles undergo corrosion, allowing metal ions to enter and circulate in blood serum. Excessive wear of prosthesis is associated with elevated cobalt and chromium levels in serum, red blood cells, urine, and joint fluid. Chromium and cobalt are markers because their concentrations in serum are proportional to degree of metal-on-metal wear.

Elevated serum chromium or cobalt even in the absence of symptoms indicate implant wear.

Pseudotumors

Fluid collections are the most common type of pseudotumors.
There is no significant difference in prevalence comparing painful (57%) and asymptomatic resurfacing prosthesis (61%). It occurs in almost 100% of symptomatic patients, according to some series.

The number of pseudotumors in symptomatic MoPoly replacements is less significant (less than 15%).

They can be detected with US, CT or MR, but only MRI can give a specific diagnosis.

MRI specific parameters for the evaluation of metal prosthesis are shown in tables 6 and 7.

Special MRI techniques are used to minimize metal artifacts, such as the MARS sequence. It is a modification of the VAT (View angle tilting) technique using a spin-echo sequence with increased strength of the slice selection gradient, increased receiver BW, and increased read frequency encoding gradient combined with VAT. The result is elimination of in-plane distortion but through-plane distortion is not corrected and the increased frequency-encoding gradient results in decreased SNR up to 50% for a 30-cm field of view.

Signal characteristics in MRI T1:

There are several patterns:

- Non-specific: Hipointense collections, similar to simple fluid (fig.20).
- More specific for reaction to metal: Hiperintense to muscle, complex collection (figs. 21).
- Most specific for metallosis: Hipointense to muscle in all sequences (fig.22, 23, 24, 25).
- Complex collections with internal debris, fluid-debris levels (fig.26).

**Ultrasound**

In patients with contraindications to perform an MRI, ultrasound can evaluate soft tissue masses adjacent to implants.

It is a cheap screening tool in asymptomatic patients to monitor for the detection of pseudotumors allowing closer monitoring for implant failure in patients with already known pseudotumors.

Types of fluid collections:

- Hipo-/ anechoic fluid collections are non-specific (fig. 27).
Mixed echogenity collections and predominantly solid masses (fig.28) are more specific of the presence of seudotumors which can persist overtime, even after revision surgery (fig. 29).

**NON-SPECIFIC COMPLICATIONS**

There are also non-specific complications (regardless of implant design): Mechanical loosening, osteolysis, component failure, heterotopic bone formation, bursal collections, muscle atrophy, infection and dislocation (very rare).

**Osteolysis**

Conventional radiographs may fail to detect or may grossly underestimate the presence of osteolysis, so CT is an appropriate image technique. (fig.30)

**Component failure and failure of integration**

Later failures are observed due to acetabular problems: very increased wear (component failure) (fig. 31) or poor cup anchorage (failure of integration) (fig. 32).

**Heterotopic ossification**

Risk is greater after resurfacing arthroplasty. It happens in 60% of patients reducing the range of motion (fig.33).

Predisposing factors are being young and male, muscle trauma, failure to use prophylactic indomethacin and a surgical technique with soft tissue damage.
Table 5: COMPLICATIONS OF HIP RESURPHACING ARTHROPLASTY

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Fig. 13: FEMORAL NECK ACUTE FRACTURE. (A) Frontal radiograph two months after HRA surgery shows a line of fracture in the superolateral neck. A few days later, while
planning the revision surgery, the patient suffered severe acute pain and limp. A frontal Rx (B) was performed where a complete neck fracture was seen. (C) Frontal Rx of the same patient after conversion to THA.

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**Fig. 14:** FEMORAL HEAD COLAPSE. AP view of a HRA shows malposition of the prosthesis. The patient presented 3 months after surgery with acute hip pain.

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Fig. 15: FEMORAL NECK CHRONIC FRACTURE. (A) AP radiograph of a 39 year old female patient who presented at the ER complaining of acute hip pain three years after arthroplasty surgery. Femoral component had tilted into varus and the picture was consistent with femoral neck partial fracture. (B) A month later, a radiograph taken right before conversion to total hip replacement shows progression of the findings with complete fracture of the superolateral femoral neck.

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Fig. 16: FEMORAL NECK STRESS FRACTURE. (A) Post-operative control AP view in a 50 year old female patient shows a well-defined intracortical radiolucency in the inner cortex of the femoral neck, which was not taken into consideration. (B) Months later, the same patient presents to the ER with severe hip pain. A small line of fracture is seen reaching the cortex. Conservative management was decided with protected weight bearing. (C) One year later, cortical sclerosis and thickening as a reparative stress reaction is seen. Patient remained asymptomatic.

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Fig. 17: FEMORAL NECK NARROWING. Serial postoperative anteroposterior and oblique lateral radiographs illustrate changes of narrowing of femoral neck. Postoperative views of a patient who underwent surgery for primary osteoarthritis. Note cystic changes in acetabular native bone. (A and B) Two years after surgery, radiographs were taken because of hip discomfort. Significant narrowing is noted (30%). Cystic acetabular changes have enlarged notoriously (C and D).

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**Fig. 18:** METALLOSIS. Intraoperative photos from a patient undergoing revision of resurfacing arthroplasty. Resected femoral head and neck with extensive metal debris around neck. Several dark appearing masses in the iliopsoas bursa that indicated metallosis were seen. Synovial fluid was black, secondary to high metal content. There was no necrosis.

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Fig. 19: METALLOSIS. Hematoxylin & eosin stain. Metal particles in macrophages from the synovium of this patient with a loose hip resurfacing arthroplasty. The cells brown and individual metal particles appear as small black cytoplasmic inclusions. Acknowledgements to Dr. Luis Cortés, Chief of Pathology.

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### Table 6

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| **METAL ARTIFACT REDUCTION IMAGING PROTOCOL. MAGNET = 1.5 TESLA. COIL = TORSO PHASED-ARRAY OR APPROPRIATE COMBINATION OF LOCAL COILS** |
|-------------------------------------------------|-------------------------------------------------|
| **B<sub>0</sub>**                                | Avoid ultra–high-field magnets (3T)             |
| **BW**                                          | Increasing receiver bandwidth (BW), TE and echo spacing can be decreased. |
| **Frequency encoding gradient**                 | Steeper amplitude of the frequency-encoding gradient diminishes the relative impact of field inhomogeneities. |
| **MATRIX**                                      | High                                           |
| **FOV**                                         | Small - Axial 240 x 340 -Coronal 200 x 200 -Sagital 200 x 200 |
| **VOXEL**                                       | Small                                          |
| **SLICE THICKNESS**                             | 4-5 mm                                         |

| **METAL ARTIFACT REDUCTION IMAGING PROTOCOL. MAGNET = 1.5 TESLA. COIL = TORSO PHASED-ARRAY OR APPROPRIATE COMBINATION OF LOCAL COILS** |
|-------------------------------------------------|-------------------------------------------------|
| **SPIN - ECHO**                                 | Less affected by susceptibility artifacts       |
| **GRADIENT -ECHO**                              | To Avoid                                       |
| **T1 TR**                                       | 500-600ms                                      |
| **T1 TE**                                       | Decrease TE and echo spacing TE<25 ms           |
| **PDTE**                                        | PD Preferable to T2 TE<35 ms                   |
| **STIR**                                        | Good fluid-sensitive secuence                   |
| **FAT-SAT**                                     | Suboptimal because local field inhomogeneities prevent homogeneous fat-saturation |

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Fig. 20: PSEUDOTUMOR. Patient with right HRA. Axial MARST1WI shows an isquiotrochanteric simple fluid collection, hipointense to muscle. Metallosis at surgery was found.
Fig. 21: METALLOSIS AND PSEUDOTUMOR. MARS Coronal T1W MRI. 40 year-old asymptomatic female patient with bilateral HRA, left inguinal soft tissue tumor and very high levels of blood cobalt. Coronal left hip T1-weighted MRI shows a big iliopsoas hiperintense bursal collection with parietal thickening and multiple signal-void hipointense nodules.

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Fig. 22: PSEUDOTUMOR. MARS Sagital T2W MRI. 40 year-old asymptomatic female patient with bilateral HRA and left inguinal soft tissue tumor and very high levels of blood cobalt. T2-weighted MARS sagital images of the left hip demonstrate a thin-walled iliopsoas collection with very low T2 signal. A revision arthroplasty was performed. Pathologic findings were consistent with extensive metallosis, and multiple groups of macrophages engulfing brown and metallic particles were seen.

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Fig. 23: PSEUDOTUMOR. MARS STIR Sagital MRI. 40 year-old asymptomatic female patient with bilateral HRA and left inguinal soft tissue tumor and very high levels of blood cobalt. MARS STIR Secuences sagital images of the left hip demonstrate a thin-walled iliopsoas collection very low signal. A revision arthroplasty was performed. Pathologic findings were consistent with extensive metallosis, and multiple groups of macrophages engulfing brown and metallic particles were seen.

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Fig. 24: METALLOSIS. Coronal T1WI MRI MARS. Bilateral HRA. Note small left peritrochanteric hipointense fluid collection deep to the iliotibial tract with signal void nodules, indicating metal deposition. There are also bilateral very hipointense iliopsoas bursal collections.

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**Fig. 25:** METALLOSIS. Coronal STIR MRI MARS. Bilateral HRA. Note small left peritrochanteric hipointense fluid collection deep to the iliotibial tract with signal void nodules, indicating metal deposition.

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**Fig. 26:** METALLOSIS AND PSEUDOTUMOR. Sagital STIR MRI demonstrates an iliopsoas bursal complex collection.

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Fig. 27: PSEUDOTUMOR. 40 year old asymptomatic female patient with bilateral HRA and left anterior soft tissue hip mass. An US was requested to rule out psedotumor vs. Inguinal hernia. (A) Transverse and (B) Sagital US of the left hip shows a periarticular iliopsoas bursal collection with anterior solid and posterior cystic components. Metal blood test levels were ordered and revealed cobalt: 485.6 microg/L (laboratory normal reference 0-1.0) and chromium 233.1 microg/L (normal value 0-2.0). A revision arthroplasty was performed.

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Fig. 28: US PSEUDOTUMOR EVOLUTION. Transverse and longitudinal ultrasound sections. Only a month after previous US, the mass is predominantly solid.

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**Fig. 29:** US PSEUDOTUMOR EVOLUTION. Longitudinal and transverse ultrasound sections. A year after revision arthroplasty of the previous patient a follow up US of the left hip shows improvement. Instead of the predominantly solid mass that was seen before, a complex collection, with development of multiple thick internal septa is identified.

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**Fig. 30:** OSTEOLYSIS. Pelvic CT performed in an asymptomatic patient with bilateral HRA to study a right ovarian teratoma (*), showed a polylobulated left lytic acetabular roof bone lesion (+), that had not been recognized in conventional Rx (arrows in (B)). Four years later, pelvic TC (C) demonstrate that osteolytic changes remained unchanged and that migration of the femoral component had not progressed. Ovarian teratoma had been removed. Cystic lesions were not seen in MRI due to metallic artifacts.

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Fig. 31: COMPONENT FAILURE SECONDARY TO MALPOSITION. (A) AP view of a left HRA with component malposition: higher than normal cup angle, and femoral component proximal migration. One year later, AP (B) view of the left HRA show periprosthetic soft tissue metallic debris deposition (arrow and circle) caused by abnormal wear of bearing surfaces.

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Fig. 32: FAILURE OF INTEGRATION. Anteroposterior (A) and oblique (B) radiographs of right HRA demonstrate radiolucency around the circumference of the acetabular component (arrowheads) sign of failure to integrate.

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**Fig. 33:** HETEROTOPIC OSSIFICATION (red arrows).

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Conclusion

1. **HRA is a less aggressive method of hip reconstruction** that maintains anatomy, articular biomechanics and stability, but **needs clinical and radiologic specific follow-up** because it is associated with adverse periarticular soft tissue reactions (pseudotumors, ALVALS) and elevated serum levels of metal ions -metalosis-, even in asymptomatic patients.

2. **CONVENTIONAL RADIOGRAPHS** are:
   - essential for the evaluation of **HRA components** and for the detection of some complications (neck fracture and narrowing, loosening, failure of components).
   - unable to detect soft tissue complications, including the presence of solid or cystic masses adjacent to the implant, described as part of the spectrum of metal hypersensitivity.

3. **CT** may detect the presence of **osteolysis**, not seen or underestimated by conventional radiographs.

4. **MRI** (PD, T1WI, MARS) are a useful tool in identification and monitoring of patients with HRA and **reaction to metal** and may help guide management including revision arthroplasty.

5. **US** is of value for the detection of **soft tissue complications** in patients with contraindications for the realization of MRI.
Personal information

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