Radiographic interpretation of hip replacement hardware. A pictorial essay.

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Purpose

"Low friction" hip joint replacements began at 1960s by Charnley J. with the pioneer use of stainless steel metal-on-polyethylene (MOP) prostheses. Since their introduction until today many variation have been designed following the basic principle of metal femoral head articulating against a polyethylene socket.

Nowadays hip joint replacements constitute one of the most common type of elective, semi-lective and trauma related orthopaedic operations, with approximately 300,000 interventions performed each year worldwide.

Radiography remains the mainstay of the initial imaging evaluation and the follow-up assessment of the prosthetic hip. The purpose of this study is to present the normal radiographic appearance of hip replacements and also to familiarise musculoskeletal radiologists with the diagnostic approach of the immediate postoperative radiograph and the potential complications of hip replacements.
Methods and Materials

This research consisted of two phases.

The first step included a review of the pertinent literature. Major databases were searched for articles related to radiographic interpretation of hip replacement hardware using the following search terms: "Hip joint replacement" , "radiographic interpretation", "postoperative complications".

At the second phase the authors performed a retrospective study of immediate postoperative pelvic radiographs of a cohort of patients treated with hip replacement during a period of 2 years (February 2011-February 2013) at a tertiary hospital.
1. Type and fixation of hip replacements

Hip replacements include two general types: hemiarthroplasty and total hip arthroplasty (THA).

Hemiarthroplasty is an operation that replace the femoral surface of the hip joint and it is generally performed for diseases related to the femoral head - such as fracture and avascular necrosis in older patients - and not the hip joint.

THA performed both for diseases that affect both sides of the hip joint resulting in an articulation between fixed prosthetic femoral and acetabular components.

The prosthetic devices may be cemented or not. Cementless methods are most frequently used in young patients. The press-fit technique is a cementless methods in which the stabilization of the implant into the femur is achieved by interference fit. The biologic ingrowth methods achieve fixation without cement and by directly attachment of remodeled bone to the coated or roughened surface prosthetic component. These special surface coatings used in modern implants are not visible on radiographs.

2. Interpretation of postoperative radiograph after hip replacements.

The diagnostic approach of the initial radiograph must be done in a systematic way. It provides information about the type, the initial position and fixation of the prosthetic device and it can be used as a reference for retrospective comparison with follow-up radiographs.

The date, the correct side, of the radiograph and the patient's identity must be assessed. The quality of the radiograph is important. The initial postoperative protocol include at least an anteroposterior (AP) supine pelvic radiograph with the x-ray beam focused on the pubic symphysis, with extension and 150 internal rotation of the hips, showing the entire hip prosthesis and cement.

For the verification of the correct placement of the prosthesis the following specific anatomical landmarks and measurements need to be evaluate:

a. Leg length: The measurement of leg length on the AP pelvic radiograph include:

A pelvic reference line that connect transversely the inferior borders of the acetabular tear drops (consist of cortical and medullary bone located at the acetabular notch, at the anteroinferior portion of the acetabular fossa by the contribution of the ishium and pubic rami).
A femoral reference line that connect the lesser trochanters.

A perpendicular line that connect the two reference lines is measured on both sides and compared. A deviation to 1cm considered acceptable (fig.1)

Leg length inequality can result in a short leg (higher position of the prosthesis) and reduced efficiency of the hip joint muscles or in a distal displaced device with increased risk of dislocation due to muscle stretching.

b. Horizontal and vertical centre of rotation:

This measurement evaluates the position of the femoral head to the socket. The vertical center of rotation is evaluated by measuring the distance between the center of the femoral head and the transischial tuberosities line (fig.2). The horizontal centre of rotation can be assessed by the measurement of the distance between the femoral head centre and the bottom of the corresponding acetabular teardrop and comparison with the normal contralateral hip (fig.3). The distances should be equal bilaterally.

Normally the socket demonstrates the inferomedial corner at about the same horizontal level as the bottom of the teardrop shadow and the medial part adjacent the lateral border of the teardrop shadow. An acetabular component placed to an insufficient medial position increase the risk of dislocation. In protrusion acetabuli the socket breaches the ilio-ischial line (a line along the medial border of the iliac wing and the medial border of the ischium).

c. Acetabular abduction angle:

This angle is subtended by a line joining the superolateral and inferomedial corners of the socket and the bi-ischial pelvic reference line (a transverse line drawn through the ischial tuberosities). The normal range of the angle should be 40°± 10 (fig.4). Less angulation results in limited abducted but stable hip - a greater angle increase the dislocation risk.

The version of the socket is an important factor for dislocation but difficult to assess in standard postoperative radiographs. The socket is projected as an ellipse and mathematical formulae for evaluating the version angle has been proposed. Normally the 2 halves of the ellipse should be overlap in the AP pelvic radiograph.

Socket anteversion is assessed on a lateral radiograph of the groin and a normal range should be measured 15°± 10.

d. Femoral stem positioning:

The prosthetic stem should be noted in a neutral position along the longitudinal axis of the femoral shaft (fig.5). If the tip of the stem rests against the medial endosteum a
valgus positioning is present. Varus positioning is considered if the proximal part of the component abuts at the medial cortex and the tip abuts at the lateral cortex (fig.9). Varus position predispose to loosening and fracture.

e. Cement mantle:

-Cemented hip arthorplasties: For better adhesion of the cement with endosteal trabeculae a metal plastic, cement plug or bioabsorbable material is presented distal to the tip of the stem.

The cement mantle thickness should be ideally 2-3mm all the way around the component to minimize the risk of cement cracking and loosening.

The fibrous pseudocapsule at the cement-bone interface is classified in 4 grades according to Barrack et al.:

Grade A: the cement mantle completely fill the medullary canal (at least 2mm thick)

Grade B: there is a surrounding thin radiolucency (<50%) at the cement-one interface.

Grade C: the radiolucency covers 50% to 99% of the bone-cement interface (C1 grade if bubbles/voids are noted, and grade C-2 if the cement mantle is incomplete (<1 mm).

Grade D: complete bone-cement radiolucency, defects in the cement mantle, absence of the cement distally to the stem tip.

Generally it is important to evaluate the bone-cement and cement-prosthesis interfaces and to assess for any gaps or lucencies.

A radiolucency greater than 2mm at either interface is a sign of loosening.

For assessing cement-bone and cement-prosthesis lucencies the Charnley-Delee system divided the acetabular cement mantle in three equal zones labeled I, II and III from lateral to medial around the periphery of the cup. Notably lucencies should not appeared in zone II or III.

According to Gruen method the femoral cement mantle in the AP radiograph is divided into 7 zones, with the first three identified from proximal to distal along the lateral aspect of the prosthetic component, zone 4 at the tip of the stem, and zones 5 to 7 identified from distal to proximal along the medial aspect of the stem. Johnston et al. described 7 additional zones surrounding the femoral cement surface in the lateral radiograph.
Cementless hip arthroplasties: The most important factor is to assess the stability of the prosthesis. A thin radiolucent band (<2 mm) delineated by a thin sclerotic margin around the rough surface of the prosthesis that remain stable after two years, provides sufficient stability. Signs of bone ingrowth include no susidense,"spot weld" at the lower part of the porous coating and calcar resorption (fig.6).

Both cenented and cementless hip arthroplasties should be checked for stress shielding phenomenon. Stress shielding is the redistribution of load (and consequently stress on the bone) that occurs when the femoral head is replaced by the femoral component of a total hip replacement. Stress on proximal 10cm of femoral cortex is reduced, because much of the load bypasses this region and is carried in the metal stem to the isthmus of the femur. Radiographic signs of stress shielding are:

- atrophy of the proximal femur is substantially greater with stiff cementless femoral components than with cemented components(fig.7 and 8).

- local disuse osteoporosis

- severe disuse osteoporosis/proximal femoral cortex can be completely resorbed

Stress shielding of proximal femur is more pronounced when a stem of large diameter has been used.

3. Complications

a. Loosening

Cemented hip arthroplasties: lucencies more than 2mm at the cement-bone interfaces surrounding the prosthesis or lucencies more than 2mm metal-cement interface that were absent in the early postoperative radiograph, progressive widening of a preexisting lucency at the cement-bone interface in the follow-up radiographs and fracture of the cement mantle.

According to Gruen method lucencies should not be appeared in the subtrochanteric regions of zones 2-6. Stable radioluencies in zone 1 may be a normal finding but an enlargement at the follow-up radiographies is indicate loosening.

The acetabular loosening is estimated by measuring the superior migration (top of cup to transishehial tuberosity line), medial migration (medial socket to teardrop or another medial landmark), and lateral inclination.

The radiological appearance of femoral component loosening is a varus or valgus shift of the stem and possible subsidence (distance between femoral component to greater tuberosity or transischial tuberosity line)
Noncemented hip arthroplasties: lucencies more than 2mm metal-cement interface that were absent in the early postoperative radiograph, progressive widening of a preexisting lucency at the cement-bone interface in the follow-up radiographs and subsidence > 1cm and/or progressive migration more than 1 year after placement.(fig.9).

Signs of socket loosening include lucencies wider than 2mm at any point. According to Charnley-Delee system lucencies should not appeared in zone II or III.

Radiographically osteolysis is suggested by the presence of focal well-defined lucencies around either the acetabular or femoral components.

b. Hardware failure

Polyethylene wear is assessed by measuring and comparing the superior (D1) and inferior (D2) distances between the femoral head and the surface of the acetabulum. This distances should be equal. A substantially smaller D1 than D2 is indicative a shift in femoral head position and a possible hardware failure.

c. Dislocation

Atraumatic dislocation due to the component malposition is the second most common reason for revision after 3 months to 5 years after surgery.

An acetabular component that is too vertically inclined (> 60°), too anteverted (>20° opening anteriorly), or retroverted (opening posteriorly) increase the risk of dislocation.

d. Infection

The radiographically distinction between an infectious from a noninfectious loosening is difficult. The presence of osteolysis with periosteal reaction and/or cortical destruction on radiograph is highly predictive of infection (fig.10).

e. Periprosthetic fracture

Periprosthetic fractures occur more common at the tip of the femoral component any time after hip replacements(fig.11). Periprosthetic fracture can be either intraoperative or postoperative. The incidence of these fracture is even higher in revision hips (4%) than primary arthroplasties (1.1%).

f. Heterotopic ossification (HO)
It is defined as abnormal formation of true bone around the hip joint extra-skeletal soft tissues. According to Brooker classification on the AP view there are four grades:

grade 0: no HO,

grade 1: one or two foci of HO <1cm each,

grade 2: ossification or osteophytes occupying less than half the space between the femur and pelvis,

grade 3: ossification or osteophytes occupying more than half the space between the pelvis and femur,

grade 4: ossification that bridges the pelvis and femur.
Images for this section:

**Fig. 1:** leg length measurement-pelvic and femoral reference lines

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Fig. 2: vertical centre of rotation

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Fig. 3: horizontal centre of rotation

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Fig. 4: acetabular abduction angle

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**Fig. 5:** normal AP view of THA for right hip osteoarthritis

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Fig. 6: Normal AP view of THA after a femoral neck fracture- immediate post operative x ray, the sutures and the drain appear

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Fig. 7: lateral view of THA for osteoarthritis treatment, stress shielding of the left proximal femur appears

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**Fig. 8:** Same patient. AP view of THA for osteoarthritis treatment, stress shielding of the proximal femur appears

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Fig. 9: loosening and mild varus position of the femoral stem

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Fig. 10: a painful septic right hip

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Fig. 11: Intraoperative fracture distal to the tip of the femoral stem

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Conclusion

This retrospective case series shows the significance of the classical pelvic radiograms for the evaluation of hip replacement hardware. Mal positioning of the femoral or the acetabular component, inefficiency cement mandle, intraoperative fracture are indicative findings that influence weight bearing status, follow up protocols, revision possibility and patients' postoperative quality of life. Low cost of radiograms and short learning curve of muscoskeletal radiologists to be familiar with the normal x ray of the hip hardware strengthen the value of our study.
References:


