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Should Patients Be Weight-Bearing When Obtaining Preoperative Radiographs of the Hip and Knee?

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Question 9: Should patients be weight-bearing when obtaining preoperative radiographs of the hip and knee?

Response/Recommendation: Current literature supports the use of weight-bearing radiographs in the preoperative evaluation of patients undergoing hip and knee arthroplasty. This approach not only provides a more accurate representation of anatomical considerations such as the degree of joint space narrowing, lower extremity alignment, and other radiographic parameters, but also provides additional information on the affected joint in functional positions. This allows the formulation of a comprehensive preoperative plan, potentially leading to better surgical outcomes.

Level of Evidence: Moderate.

Expert Vote: Agree 89.8%; Disagree 5.7%; Abstain 4.5%.

Rationale

Knee

Determination of joint width is an important part of the evaluation of degenerative joint disease as it constitutes the basis for surgical decision-making. In the context of knee osteoarthritis, it is well-established that arthritis does not uniformly involve each of the three compartments of the knee. When the disease is limited to one compartment, surgical options include unicompartmental knee arthroplasty or high tibial osteotomy as opposed to total knee arthroplasty. As the choice between these procedures and their surgical outcomes depends on the status of the unaffected compartment(s), it is imperative that surgeons thoroughly evaluate the extent of disease in each compartment preoperatively. Although magnetic resonance imaging (MRI) has been shown to be the most sensitive tool for assessing articular cartilage [1,2], plain radiography remains the most widely available and least costly modality [1,2]. Standing knee radiographs are now the standard imaging tool for evaluating the presence and degree of joint space narrowing and bone attrition in knee arthrosis, offering higher precision compared to ultrasonography and MRI [3]. Optimizing the information from radiographs could therefore decrease the need for more costly alternative imaging techniques.

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Variations in radiographic measurements may occur based on the weight-bearing status of the patient [4,5]. The knee osteoarthritis severity scale initially proposed by Kellgren and Lawrence was widely criticized because it was derived from non–weight-bearing projections and overemphasized the presence of osteophytes, which some argue are a natural occurrence with aging and not always pathologic [6]. In contrast, joint space narrowing is only a gross descriptor in the Kellgren-Lawrence grading system. Blackburn et al. attempted to correlate the radiographic Kellgren-Lawrence scale with arthroscopic findings; not surprisingly, the authors found that the scale underestimated the articular cartilage damage [7].

It is important to note that conventional weight-bearing radiography may still underestimate the extent of cartilage wear. In an analysis of 34 patients who had knee osteoarthritis, Wiedow et al. found that the degree of underestimation in patients who had medial arthrosis was small and acceptable. However, in patients who had lateral arthrosis, more pronounced discrepancies were found [8]. The flexion view knee radiograph first described by Holmblad [9] and Resnick et al. [10] showed that a standard tunnel view was more sensitive to joint space narrowing than standing antero-posterior (AP) projections. This assertion was subsequently supported by biomechanical data demonstrating that peak articular stresses at the femoro-tibial articulation occurred at 28° flexion because of the diminished contact area [11]. Rosenberg et al. investigated the accuracy of the 45° postero-anterior (PA) weight-bearing projection in a consecutive series of 53 patients who underwent arthroscopy [12]. Using a minimum difference of 2 mm in joint space width between the medial and lateral compartments as a criterion for predicting articular cartilage ulceration or erosion on arthroscopy, they found a greater sensitivity with the 45° PA projection (80 to 85%) compared to standing AP radiographs (25 to 30%) and there were no false positives for either the medial or lateral compartments in their study [12]. In accordance with the preceding studies, Dervin et al. found that the 45° PA was superior for detecting lateral compartment cartilage wear, but offered no advantage on the medial side [13]. There were 12 patients who were categorized as having severe lateral compartment articular chondropathy (grade IV) at the time of arthroscopy. The lateral joint space height averaged 1.0 ± 1.7 mm on the 45° PA radiograph compared to 2.7 ± 1.1 mm on the three-foot standing AP view. Using a cut-point of 2 mm or less to predict grade IV chondral changes, the 45° PA view was more sensitive than the standing AP view (83 versus 42%) at correctly detecting the most severe chondropathy. The authors hence proposed that the 45° PA view be the screening radiograph of choice in evaluating any patient for osteoarthritis of the knee.

It is important to qualify, however, that neither osteophytosis using the Kellgren-Lawrence grading nor joint space narrowing on weight-bearing radiographs provides an accurate assessment of osteoarthritis in patients who had the relatively early disease, as radiographs, in general, are not sensitive enough for this purpose [14]. Brandt et al. confirmed the well-recognized insensitivity of the plain radiographs in early osteoarthritis, demonstrating that joint space narrowing in standing AP radiographs was not uncommon in the presence of normal tibiofemoral articular cartilage [14]. Specifically, 32 patients (35%) had grossly normal articular cartilage in both tibio-femoral compartments on arthroscopy; however, based on Kellgren-Lawrence grading as well as a separate criterion emphasizing joint space narrowing, a radiographic diagnosis of osteoarthritis was made in 26 (81%) of these individuals.

In addition, the mechanical axis angle measured on weight-bearing radiographs can differ up to 2.0° from radiographs in the supine position [4,5]. Positioning a patient supine eliminates the ground reaction force on the knee, which can underestimate alignment deformity. The knee adduction moment, which forces the knee into varus during weight-bearing, is not captured in the supine position. Brouwer et al. analyzed 20 patients who had medial compartmental osteoarthritis and found that the mean difference between hip-knee-ankle (HKA) angles measured standing and supine was 2° (range, 1 to 3°; SD 0.45, $P < 0.001$), with more varus deviation observed in the standing position compared to the supine position [4]. Specogna et al. measured HKA angles in 40 patients who had varus knees and found that the mean difference was 1.59° (95% confidence interval (CI), 1.03 to 2.14) for single- versus double-limb standing, 1.63° (95% CI, 1.07 to 2.18) for double-limb standing versus supine, and 3.21° (95% CI, 2.49 to 3.94) for single-limb standing versus supine [5]. Wang et al. similarly showed that the mean HKA angle measured on single-leg stance radiographs was more varus (mean difference 2.1°, $P < 0.001$) than on double-leg stance radiographs, which was more varus (mean difference 1.4°, $P < 0.001$) than that on supine radiographs [15]. Mechanical axis measurements were also found to be different when comparing weight-bearing radiographs to computer-assisted navigation data or MRI [16–19], which are non–weight-bearing, three-dimensional imaging modalities that further negate the confounding effect of knee rotation or flexion. Consequently, full-length weight-bearing AP radiographs are regarded as the gold standard for determining knee joint alignment [20].

Several factors may affect the extent of an alignment discrepancy between supine and standing radiographs, which include severe soft-tissue laxity around the knee joint [5,21] as well as the difference in joint attrition [22,23]. In patients who had increased ligamentous laxity, the difference in HKA measured on standing and supine whole-leg radiographs may be even more pronounced [24]. In contrast, when the soft tissues are balanced after total knee arthroplasty, the postoperative difference in HKA measured on weight-bearing and non–weight-bearing radiographs decreases [25].

An accurate preoperative weight-bearing assessment provides valuable information on lower-extremity alignment, accounting for the loss of cartilage and ligamentous imbalance of the knee, which has been termed “functional deformity.” This will not be seen on a preoperative computed tomography (CT) scan [26] or intraoperative radiography [19]. A greater awareness of the variation in alignment between preoperative assessment, intraoperative execution, and postoperative review will allow surgeons to reliably achieve their alignment goals in knee reconstruction.

Hip

The goals of total hip arthroplasty (THA) not only include the elimination of a painful hip joint, but also the restoration of leg length, offset, center of rotation, and a mechanically stable ball-and-socket joint. To achieve these goals, component positioning needs to be optimized. Among things to consider, the risk of femoral neck impingement on the acetabular rim, polyethylene liner, or adjacent unresected bone needs to be minimized to avoid pain, edge loading, and accelerated component wear [27].

Historically, the preoperative evaluation of patients who had hip arthritis relied on supine plain radiographs [28]. More recently, weight-bearing presurgical THA planning has been proposed. This has been driven by the advent of modern imaging technology such as the digitization of traditional X-ray machines and full-body upright stereo radiography (EOS Imaging, Paris, France), as well as the newfound understanding that single-position static images of the pelvis cannot adequately inform the surgeon of optimal implant positioning. The hips and spine are dynamically interconnected through the pelvis, and it is now well-established that the sagittal orientation of the pelvis changes in concert with a person’s posture during activities of daily living [29]. This concept is best understood by observing two weight-bearing radiographs: a lateral radiograph of the lumbo-pelvic region in the standing position, as well as the same radiograph in the seated position with the hips and knees flexed. Based on these projections, important sagittal spino-pelvic alignment parameters have been described: lumbar lordosis, pelvic incidence, spino-pelvic tilt, and sacral slope [30]. An in-depth analysis of the hip–spine relationship will be provided in a separate section (Section L).

Hip component positioning was traditionally guided by Lewinnek's "safe zone" to prevent component impingement and decrease the likelihood of dislocation [31]. This "safe zone" was established based on the traditional radiological technique of the patient lying supine on a flat X-ray plate. Recent literature, however, has demonstrated that the concept of Lewinnek's "safe zone" is not necessarily protective of prosthetic dislocation, especially in patients who have degenerative lumbar disease, spinal fusions, and spinal deformity [32–36]. It is now established that pathologically altered spino-pelvic kinematics warrant a patient-specific acetabular component safe zone, which has been termed "functional anteversion" or "functional safe zone" based on the variation in acetabular orientation in relation to postural changes [37,38]. Importantly, the acetabular cup must be placed within a narrow range of patient-specific anteversion/inclination values, tailored specifically to one's spino-pelvic mobility and pelvic tilt (PT) in certain functional positions [39]. These values can only be determined using weight-bearing images in a standing and sitting position to assess the stiffness of the lumbo-pelvic complex and the functional position of the acetabulum [40,41]. Spinal mobility is a quantifiable risk factor, with an increased risk for dislocation conferred with less than 20° of flexibility in lumbar lordosis from the standing position to a flexed seated position [42]. The Hip-Spine Workgroup therefore advocates that four static radiographs be obtained for preoperative planning before THA: a supine AP pelvis, a standing AP pelvis, a standing lateral pelvis, and a seated lateral pelvis [29]. These images should be ideally obtained on 36-inch radiographic cassettes or by stereo radiography (EOS Imaging, Paris, France); however, in many cases, a smaller cassette can still be useful. By comparing the standing and seated lateral radiographs, the hip surgeon will be able to assess the change in PT or sacral slope. Changes to these values that are < 20 degrees from standing to sitting imply a stiff spine that will be unable to tilt posteriorly in a sitting position, increasing the risk of femoro-acetabular impingement and resultant instability or premature component wear. For these patients, the Hip-Spine Study Group made a recommendation for increasing acetabular anteversion to prevent a posterior dislocation [29]. Spino-pelvic mobility data derived from functional weight-bearing radiography not only influences alignment targets, but also influences the bearing choice at times, as some surgeons advocate for the use of a dual-mobility liners in at-risk patients in an effort to maximize stability [43]. The recommendations on the routine use of radiography to assess the spino-pelvic relationship and the use of dual-mobility liners for at-risk patients provide an in-depth description of these dilemmas (Section L).

It is clear that the biomechanics of the spino-pelvic junction must be considered in the context of acetabular component orientation, and consequently, weight-bearing imaging of the hip and pelvis should be obtained as they provide hip surgeons who had vital information to determine the optimal surgical plan.

Limb-length discrepancy (LLD) is a leading cause of litigation and occurs in up to 32% of patients following THA [44]. Accurate restoration of limb length in THA remains paramount, yet LLD is often a technical error due to insufficient preoperative planning and inaccurate surgical execution. LLD can be measured clinically or radiographically, but for the purpose of this review, only the radiographic methods will be evaluated.

The conventional method for assessing LLD on preoperative radiographs involves drawing a line through the inferior aspect of the teardrops on a weight-bearing AP pelvic radiograph, followed by measuring the vertical distance of the most prominent point on each lesser trochanter to the interteardrop line [45–47]. This measurement normalizes pelvic obliquity in favor of determining anatomical differences at hips, such as acetabular cartilage degeneration and femoral head wear. Although this method fails to evaluate other sources of LLD apart from the pelvis and proximal femur and may be limited by rotation of the lesser trochanter and adduction or abduction contractures of the hip, it is still the most widely used method at present.

The variation in LLD between supine and standing has been previously examined using supine scanograms [48,49]. Sabharwal et al. included 79 children and 32 adults in whom LLD was secondary to trauma (55%), congenital shortening (18%), Blount disease (14%), or another cause (13%). The measurement of limb length obtained from standing AP radiographs was very similar to that obtained from a scanogram, especially in the absence of substantial mechanical axis deviation. The authors thus proposed the use of a standing AP radiograph of the lower extremities as the initial imaging study for patients who had suspected LLD [48]. More recently, the variation between supine and standing radiographs was examined in AP pelvic radiographs, wherein Bhanushali et al. found that the median variation in LLD from supine to standing AP pelvis radiographs was −1.5 mm (range, 0.7 to 6.9), and no cases varied by > 10 mm [50].

In patients who had hip dysplasia, a supine AP pelvic radiograph may also overlook changes in the acetabular version and coverage in weight-bearing positions [51]. For patients undergoing hip preservation surgery, suboptimal correction can result in instability or femoro-acetabular impingement [52]. Variation between measurements made on supine and standing radiographs may render a surgeon's intraoperative correction on the supine patient inadequate for a standing posture. As such, an appreciation of this variation remains crucial to reduce the risk of complications. Bhanushali et al. analyzed the anterior coverage (AC), posterior coverage, lateral center-edge angle, acetabular inclination, sharp angle, PT, retroversion index, femoro-epiphyseal acetabular roof index, femoro-epiphyseal horizontal angle, LLD, and pelvic obliquity and found that there was significant variation in AC and PT between supine and standing radiographs in patients undergoing periacetabular surgery for hip dysplasia. It is well-established that PT decreases from supine to standing [51,53–58], with variations of between 3 and 5° reported in the literature [51,53,55,56]. A small decrease in AC was also found in several reports [51,53,59], although variations in the lateral center-edge and sharp angles remain contentious [51,58,60,61]. Nevertheless, given the aforementioned variations in radiographic parameters on weight-bearing versus supine radiographs, it is recommended that both views be routinely obtained before periacetabular, allowing surgeons to plan using a supine radiograph and adjust their correction by the variation observed between supine and standing radiographs of each individual patient.

Conclusions

Despite the limitations of conventional radiographs, they remain the most practical and readily available imaging tools for preoperative planning in patients who have hip and knee pathology. It is the consensus of this panel that weight-bearing radiographs should be obtained whenever possible, as they provide additional information on joint space narrowing, lower extremity alignment, the spino-pelvic relationship, LLD, and other radiographic parameters. Technological advancements such as the EOS imaging system could enhance the accuracy and comprehensiveness of these assessments, supporting the use of weight-bearing radiographs as standard practice.

CRediT authorship contribution statement

Graham S. Goh: Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Jesse W.P. Kuiper:** Writing – review & editing, Methodology, Investigation. **Tarek A. El Khadrawe:** Writing – review & editing, Methodology, Formal analysis. **Paul C. Jutte:** Writing – review & editing, Methodology, Formal analysis. **Fahri Erdoğan:** Writing – review & editing, Methodology, Formal analysis. **Lyes Aitelhadj:** Writing – review & editing, Methodology, Formal analysis. **Harmen B. Ettema:** Writing – review & editing, Methodology, Formal analysis. **Chahine Assi:** Writing – review & editing, Methodology, Formal analysis.

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