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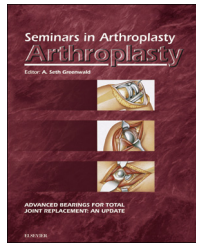

Intraoperative digital radiography: Paradigm shift in standard of care

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ARTICLE INFO

Keywords:
total hip arthroplasty
digital radiography
cup position
x-ray
pelvic tilt

ABSTRACT

Despite our best efforts, orthopaedic surgeons do not always achieve desired results in acetabular cup positioning in total hip arthroplasty. New advancements in digital radiography and image analysis software allow contemporaneous assessment of cup position in real time during the surgical procedure. Changes in pelvic tilt are accounted for based on a preoperative reference radiograph that is aligned with the patient in the lateral decubitus position. Digital radiography enables a technological and ideological paradigm shift in total hip arthroplasty based on a reliable, cost-effective, user-friendly, and familiar technology, putting the outcome directly in the hands of the surgeon.

1. Introduction

Improper acetabular component (cup) position during total hip arthroplasty (THA) is associated with early failure due to polyethylene wear and dislocation due to impingement. These two modes of failure contribute to approximately 25% of revision hip surgeries. The cost of each revision is about 150% of the cost of a primary total hip arthroplasty [1,2]. Moreover, inadequate acetabular component placement has been associated with femoral neck impingement and decreased range of motion, limb length discrepancies, and gait disturbances [3–15]. Obtaining accurate desired cup position is essential in maximizing patient satisfaction and patient outcomes while minimizing the need for revision hip surgery.

Lewinnek et al. [10] in 1978 defined the so-called "safe zone" as 30°–50° cup abduction and 5°–25° cup anteversion. In their series, meeting these parameters reduced dislocations rates. Several authors have recommended an abduction angle of 40°–45° to prevent complications [6,13,16,17], while others have achieved results similar to those of Lewinnek et al. and have found cup inclinations between 30° and 55° acceptable to assure proper function and prolong implant survivorship [15,18]. Cups positioned within this range are generally associated with greater hip stability and a reduced rate of poly wear [1,16].

Various anatomic and technological alignment guides have been developed to assist in proper cup abduction angle during surgery. Movement of the patient, especially in the lateral decubitus position, can introduce errors even with the use of such positioners. Despite their best efforts, however, orthopaedic surgeons do not always achieve the desired cup position. Successful placement of the cup at the preferred abduction angle of 30°–45° is reported only in 62% of cases,

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http://dx.doi.org/10.1053/j.sart.2015.09.005
1045-4527/

up to 85% with an angle in the range of 30°–50°, and 93–93.5%, if the range is expanded to 30°–55° [19–22].

Computer navigation systems, with or without robotics, based on computed tomography, MRI, or ultrasound, as well as imageless navigation systems, and portable intraoperative radiographs have been used to assist cup positioning during THA. Intraoperative radiographs have allowed surgeons to properly position the cup in the safe zone in 75%–90% of cases [23,24]. However, it is difficult to obtain proper and reproducible intraoperative radiographs. Use of a C-arm with fluoroscopy has been reported to achieve a 97% success rate in placing the acetabular cup in the desired position [25,26]. Similar outcomes are published when computer navigation systems, based on either computed tomography or ultrasound, and imageless navigation systems are utilized to assure correct cup placement in the majority of cases [27–35]. However, the high cost, requirement of multiple preoperative visits, time for setting up the equipment for surgery, radiation exposure, and difficulty with obese patients have limited the widespread use of these techniques.

New advancements in digital radiography and image analysis software allow intraoperative assessment of cup position in real time. Intraoperative, or "trial radiographs" with the patient in lateral decubitus position can be digitally manipulated to match preoperative radiographs obtained with patients in the supine position to enable calculation of the abduction angle in these patients. This allows the surgeon to have precise control over the cup position during the operation rather than experience disappointment and frustration while viewing the postoperative film.

Figure 1 – An example of a standard cordless, portable digital radiography unit. These units typically cost between $65,000 and $75,000 USD.

2. Intraoperative digital technique

In our patient population, a soft-tissue-sparing posterior approach with all patients in the lateral decubitus position is used [36]. The majority of patients were secured to the operating table using a pegboard with radiolucent pegs [36]. Obese patients were secured using an arcuate metal bracket to clear the protuberant abdomen and apply pressure precisely over the symphysis. The proximal position of the bracket did not obscure the relevant bony landmarks.

All THA patients had digital preoperative supine anteroposterior (AP) pelvic radiographs with the femur in 15°–20° of internal rotation, which served as the reference radiograph to assess appropriate orientation of intraoperative films. A portable digital radiography unit (Radlink, Gardena, CA) consisting of a computer, upper and lower monitors (one for preoperative reference film and one for the intraoperative trial radiograph), a cordless flat-panel detector, and a standard portable x-ray machine (Fig. 1) was used. All radiographs were taken with a source-to-image distance of 1 m with the center of the beam directed to the pubic symphysis (Fig. 2). The software (Radlink GPS) then matched the preoperative and intraoperative radiographs, correcting for magnification and minor changes in orientation. The pelvis was considered to be in neutral axial rotation if the center of the sacrum was in line with the symphysis. A line perpendicular to an interteardrop line passed through the pubic symphysis and bisected the sacrum and neutral pelvic tilt if the major and minor axis of the pelvic inlet were the same as those obtained pre-operatively (Fig. 3).

If a match was not possible (greater than 3° of axial pelvic rotation and/or pelvic tilt), films were repeated as necessary after moving the operating table forward (or back) along its long axis to achieve desired pelvic rotation. Based on our previous observation that extreme differences in the pelvic inlet view between two radiographs can alter the cup angle measurement on the AP view, an effort was made to match the intraoperative pelvic tilt to the preoperative one by moving the radiographic unit in the appropriate direction.

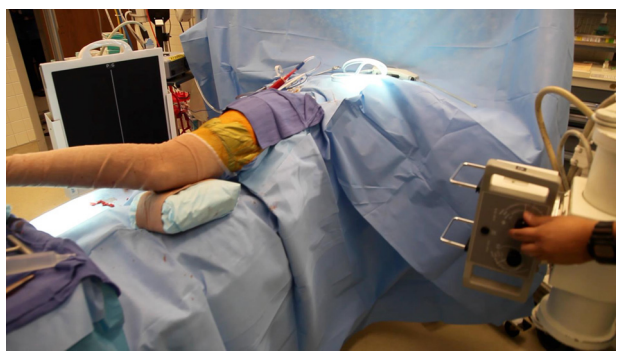

Figure 2 – The setup for an intraoperative AP pelvis with the patient in the lateral decubitus position. A cordless cassette is placed posterior to the sterile field. A standard portable x-ray machine is positioned anteriorly.