Fluoroscopy use and radiation exposure in the direct anterior hip approach

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Abstract: The direct anterior approach to the hip is an increasingly common approach for a total hip replacement. Fluoroscopic guidance can help evaluate bone preparation and component positioning. Traditional landmarks for establishing acetabular component position can be variable and lead to placement of the acetabular component outside Lewinnek's safe zone. Fluoroscopic imaging has been shown to increase accuracy in acetabular cup position. Fluoroscopic imagining during the direct anterior approach has been shown to be safe and can be viewed as an advantage of the anterior hip approach.

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The direct anterior approach (DAA) to the hip is an increasingly common approach for a total hip replacement (1,2). Fluoroscopic guidance is frequently used to evaluate bone preparation, check component positioning, and measure leg length and offset during the surgery (3,4). Accurate acetabular cup placement is felt to be critical for long term success of hip replacements (5). Traditional landmarks for establishing acetabular component position can be variable and lead to placement of the acetabular component outside Lewinnek's safe zone (6,7). Fluoroscopic imaging has been shown to increase accuracy in acetabular cup position and is viewed as an advantage of the anterior hip approach (8).

Importance of acetabular cup position

Accurate placement of the acetabular cup inclination and anteversion may be critical for the long-term success of total hip arthroplasty (THA) (5). Lewinnek *et al.* (9) defined the ideal acetabular component position as 15° (±10°) of anteversion and 40° (±10°) of abduction. Multiple studies demonstrate increased dislocation rates (10) and higher biomechanical stresses (11,12) when acetabular components were placed outside the "safe zone". Jolles *et al.* (10) found that acetabular cups positioned outside Lewinnek's zone had an increased dislocation rate. Patil *et al.* (11) demonstrated cups positioned outside Lewinnek's zone experienced increased biomechanical force which may lead to higher rates of polyethylene wear and osteolysis. Wera *et al.* (13) reviewed 75 THA revisions for instability and determined the most common etiologies were cup malposition (33%) and abductor deficiency (36%). Moskal *et al.* (12) showed that poor acetabular cup position may cause increased dislocation rates and component impingement. Poor acetabular position leads to increased bearing surface wear and higher revision surgery rates.

Despite the acceptance of these safe zones to describe accurate placement of acetabular components, recent studies suggest there may be more complexity to pelvic alignment targets (8,14,15). Lewinnek's safe zone was defined under controlled parameters and therefore does not account for the unpredictability and fluid nature of true pelvic orientation (8). Intra-operative positioning does not determine final acetabular component position. Polkowski *et al.* (15) established that the patient's operative position impacts evaluation of cup position after surgery. DiGioia *et al.* (14) also demonstrated that there are normal differences in pelvic orientation when evaluating a patient's lateral, standing, and supine pelvic X-rays. Final acetabular component orientation is ultimately dependent on both functional pelvic tilt and sagittal plane balance.

Decreased accuracy of acetabular cup position using traditional landmarks

Traditional methods of establishing acetabular component position include the use of mechanical guides. Anatomic reference points include the anterior superior iliac crest and pubic symphysis (9) and transverse acetabular ligament (16,17). Unfortunately, different factors such as body habitus and use of minimally invasive techniques diminish accuracy of mechanical guides and anatomic landmarks (18,19). A surgeon's perception of the patient's position on the operating directly influences component position as well.

Several studies have demonstrated decreased accuracy in placement of acetabular components using traditional landmarks (6,7). Barrack *et al.* (6) evaluated 1,549 hip replacements. They showed that only 88% of cups remained in a target range of anteversion 5°–35° and abduction 30°–55°. Callanan *et al.* (7) studied 1,823 total hip replacements and found that 38% fell within a target range of anteversion 5°–25° and abduction 30°–45°.

Potential benefits of fluoroscopic guidance in acetabular cup placement

Fluoroscopic guidance decreases variability in acetabular component positioning (3,20,21).

Rathod *et al.* (3) evaluated 825 THAs (453 direct anterior THAs with X-ray guidance and 372 posterior THAs without X-ray guidance). Specialized software was used to evaluate cup inclination and anteversion on a standardized pelvic X-ray. Decreased variability of acetabular cup anteversion was found when intra-operative fluoroscopy was used on patients in the supine position. They felt the direct anterior hip approach facilitated use of intra-operative fluoroscopy.

Beamer *et al.* (20) found that the chances of inserting a cup in Lewinnek's safe zone for anteversion and abduction were 2.3 times greater with the use of fluoroscopy (95% CI, 1.2–5.0; P=0.03). They evaluated a series consisting of 109 successive patients who had either a primary THA, a conversion of a preceding hip operation to THA, or a revision THA during a 2-year period. Acetabular components placed without fluoroscopic guidance were implanted in the preferred range of anteversion (5°–25°) and range of abduction (30°–45°) 44% of the time. Under X-ray guidance, implantation in the Lewinnek's safe zone for anteversion and abduction notably improved to 65%.

Use of fluoroscopy in the DAA to a total hip replacement

Matta *et al.* (21) described a single, tissue sparing anterior approach to total hip replacements. This approach permitted placement of the stem and cup implants without removing or splitting any of the muscles or tendons surrounding the hip. They evaluated 494 primary total hip arthroplasties performed with an anterior approach using fluoroscopy. They found that the average abduction angle of was 42° and the average cup anteversion was 19°. 96% of the THAs were in the range of 35° to 50° abduction. 93% of the THAs were within the target range of 10° to 25° cup anteversion. Three patients had hip dislocations (overall dislocation rate of 0.61%). None of these patients needed revision surgery for dislocations.

Slotkin *et al.* (8) felt that the supine positioning during DAA THA facilitated the use of fluoroscopy to enhance cup positioning. They retrospectively reviewed 780 surgeries performed by two surgeons over a 36-month period. They used a range of abduction 30°–50° and version 5°–25° as their target cup position. They found that 92% of acetabular cups were placed within the targeted abduction range. Ninety-three percent of acetabular cups fell within the targeted anteversion range. 88% of acetabular cups fulfilled both criteria. They also discovered that the accuracy of cup placement for combined abduction and anteversion improved every year (79.2% in 2011, 90.9% in 2012, and 95.6% in 2013). They attributed the improved cup placement to greater consistency with the supine position utilized with anterior hip approaches. They also suggested that using fluoroscopy in DAA THA helped re-produce pre-operative pelvic orientation and provided instantaneous feedback for accurate acetabular placement.

Fluoroscopic imaging done in the supine position are more accurate when compared to standing post-operative images than images taken in the lateral position. Ji *et al.* (22) showed that performing the DAA in the supine position facilitated reproducible X-ray images and therefore improved accuracy of cup implantation. They evaluated a retrospective, comparative study of 60 THAs done with X-ray guidance (30 in posterior approach group and 30 in DAA group). They found that when fluoroscopic images were used in the DAA THA they achieved improved intra-operative evaluation of cup orientation. This led to a less variability of acetabular implant anteversion when compared to the posterior approach.

Jennings *et al.* (23) retrospectively evaluated 199 patients (fluoroscopy group, 98; non-fluoroscopy group, 101) who had DAA THA with and without C-arm X-ray direction over a 6-month period. Mean cup abduction and anteversion angles were 43.4° (range, 26.0°–57.4°) and 23.1° (range, 17°–28°) in the X-ray cohort. Mean acetabular cup abduction and anteversion angles were 45.9° (range, 29.7°–61.3°) and 23.1° (range, 18°–29°) in the group without the use of fluoroscopy. Use of the C-arm was attributed to improved abduction angles (P=0.002), but there was no statistically significant improvement in version angles. They noted that 80% of implants were within the combined safe zone when X-rays were used. Only 63% of the implants were within the safe zone in the non-X-ray group.

Risks of radiation exposure with fluoroscopic imaging

Radiation exposure during medical procedures potentially impacts both patients and health care workers. Mastrangelo *et al.* (24) found a fivefold increase in lifetime cancer rates in orthopedic surgeons who used fluoroscopy routinely. The Radiation Effects Research Foundation suggested a potential threshold of 0.8 Gy (800 mGy) for developing cataracts (25).

Different methods such as distance from and source and lead aprons have been used to decrease risk of exposure. Many facilities embrace the ALARA (as low as reasonably achievable) philosophy (4). Surgeons typically remain relatively close to the X-ray beam. Giordano *et al.* (26) reported that as a surgeon doubles the distance between themselves and the X-ray, the radiation exposure reduces by a factor of 4. Unfortunately, surgeons normally cannot use distance as a means of diminishing radiation dose during fluoroscopy. However, a 0.55-mm-thick lead apron used during X-rays does reduce 99% of radiation exposure (27).

The degree of radiation contact to both the surgeon and to the patient is concerning. Acceptable levels are still unknown. McArthur *et al.* (4) measured the patient and surgeon exposure during a consecutive series of 51 primary DAA THA's performed by a single surgeon using fluoroscopic guidance. Surgeon exposure was recorded with a dosimeter. Gray (Gy) is a unit of measure of ionizing radiation defined as 1 J of energy absorbed by 1 kg of matter (27). The dose-area product (DAP) (Gy-cm^2) was 0.716 Gy-cm^2 (range, 0.251–1.81 Gy-cm^2). Mean fluoroscopic time was 0.59 minutes. DAP and fluoroscopic times were similar to reported levels for other fluoroscopically guided hip operations. They felt this information may aid in setting reference dose levels for this procedure.

Curtin *et al.* (27) evaluated 157 fluoro-assisted DAA THAs by a single fellowship-trained arthroplasty surgeon. They found that the total patient radiation contact was similar with earlier reported levels for a screening mammogram (3 mGy) and 4 times less than that of a normal chest CT (13 mGy).

McNabb *et al.* (28) evaluated 45 patients undergoing DAA THAs by placing radiation dosimetry badges at the sternal notch and pubic symphysis. They found that the mean patient entrance surface dose at the pubic symphysis and the sternal notch was not measurable in most patients. The mean patient exposure in their study during DAA THAs was 178 mrem. This is lower than a single pelvic X-ray (600 mrem). No surgeon in their study had a measurable radiation entrance surface dose. They felt that both patients and surgeons are at relatively low radiation exposure risk with use of fluoroscopy during a DAA THA.

Senior author's technique for use of fluoroscopy during DAA THA

The senior author uses fluoroscopic spot checks for assessment of pre-operative leg length, offset, final cup position after impaction, femoral broach position and final implant position. He does not use fluoroscopy to assist with acetabular reaming or femoral preparation. Live fluoroscopy is not utilized during any portion of the surgical procedure. During placement of the acetabular cup, he does not step away from the patient. While measuring leg lengths, he stands at that foot of the table to simultaneously clinically visualize the patient's leg lengths.

Conclusions

Fluoroscopic imagining has been shown to improve accuracy in DAA THAs in regard to acetabular cup position, offset, and leg length. Multiple studies demonstrate low radiation exposure risk to both the surgeon and the patient.

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Footnote

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