Multiple studies following outcomes of total hip arthroplasty (THA) have shown the critical importance of accurate acetabular component position.1-4 Proper cup position affects postoperative function and prevents the development of complications related to instability, component impingement, accelerated polyethylene wear, and consequent need for revision surgery.4

The multiple surgical approaches available for THA have advantages and disadvantages, and the direct anterior approach exhibits several unique benefits.5 Due to the use of intermuscular planes and avoidance of damage to the abductor musculature, patients report better postoperative pain scores and shorter hospital stays after the procedure.5 Although all approaches for THA can use intraoperative radiography, the direct anterior approach requires the use of intraoperative imaging, exposing the patient and surgical team to radiation. The authors hypothesized that calculation of the preoperative pelvic tilt angle and communication of this value with the fluoroscopy technician may result in a decrease in intraoperative fluoroscopy use. The study also examined total radiation exposure during the procedure to ensure that it was within safe limits. The pelvic tilt was calculated preoperatively for 100 consecutive patients undergoing THA by the direct anterior approach. The fluoroscopy technician was blinded to the value of pelvic tilt for the first 50 cases (control group), with the angle being communicated for the following 50 cases (test group). The total duration of fluoroscopy use for each case was recorded. The values were compared for the 2 experienced technicians involved in the study. The surgeon was blinded to the duration of fluoroscopy use in all cases. Mean fluoroscopy time was 28.65 seconds in the control group and 23.61 seconds in the test group (P=.033). No significant difference in duration of fluoroscopy use was found between the 2 fluoroscopy technicians. The control group and the test group were within safe limits of radiation exposure to both the patient and the surgical team. Preoperative pelvic tilt calculation significantly decreases the amount of imaging used during THA by the direct anterior approach. Although it was a statistically significant reduction, both groups were within safe limits for both the surgical team and the patients, and thus the clinical significance is unknown. [Orthopedics. 2016; 39(5):e962-e966.]
phy to guide component placement, the direct anterior approach for THA allows the patient to be in a supine position on a radiolucent table, thus improving ease of image acquisition. This facilitates the use of fluoroscopy to accurately determine the acetabular component position intraoperatively.6

Appropriate cup placement can be difficult to determine on plain radiographs without the use of anatomic referencing. The position of the cup, specifically version and inclination, is affected by the pelvic tilt.7 Anteversion is also affected by patient position, with the value increasing when the patient moves from a supine to a standing position.3 An increase in the amount of posterior pelvic tilt has been shown to relate to an accelerated rate of polyethylene wear.3 The use of standing anteroposterior (AP) pelvic radiographs can be used to mitigate the effects of the changes in pelvic position during cup placement, but an intraoperative reproduction of the standing AP radiograph is necessary for optimal cup position. The only reliable method for reproducing this image is trial and error, which increases the amount of radiation exposure to the patient and the surgical team and prolongs operative time.

Radiation exposure to the surgical team is becoming increasingly important as minimally invasive procedures such as the direct anterior approach for THA gain popularity.8-10 Intraoperative imaging is being used in increasing amounts during orthopedic operative procedures, thus placing the surgeon and surgical team at greater risk of the detrimental effects of chronic radiation exposure, including increased rates of malignancy and eye complications.10-12 Strategies to decrease duration of fluoroscopy use could limit these complications in the orthopedic surgeon.

The goal of the current study is to determine whether a preoperative measurement of standing pelvic tilt can be used to decrease the intraoperative fluoroscopy time required to reproduce the standing AP radiograph of the pelvis after the direct anterior approach for THA.

**MATERIALS AND METHODS**

A prospective study was designed to investigate whether the use of preoperative measurements of standing pelvic tilt can decrease the intraoperative fluoroscopy time with the direct anterior approach for THA. Research ethics board approval at the authors’ institution was granted for completion of this study.

One hundred consecutive patients undergoing THA by the direct anterior approach performed by a single surgeon (B.A.L.) with experience with the technique were enrolled in the study. Informed consent was obtained from all study participants. Patients were grouped into the control group, which consisted of the first 50 patients, and the test group of the next 50 patients (Figure 1). Preoperative standing AP and lateral pelvis radiographs were taken, and the pelvic tilt was calculated for each patient (Figure 2). Pelvic tilt was defined as the angle formed between a line connecting the center of the femoral head to the center of the superior endplate of S1 and a reference vertical line. Two experienced fluoroscopy technicians provided imaging for all of the cases. For the control group, the fluoroscopy technician providing imaging for the case was blinded to the calculated pelvic tilt. For the test group, the fluoroscopy technician was given the value for each patient’s pelvic tilt, which was used for the initial tilt of the image intensifier of the fluoroscopy machine prior to image acquisition. Duration of fluoroscopy use was recorded for each case after the completion of imaging. Both the surgeon and the fluoroscopy technician were blinded to the fluoroscopy time for the duration of the case.

Mean intraoperative fluoroscopy time between the 2 groups was then compared using a 2-tailed Student’s t test, with a P value less than .05 considered statistically significant. The radiation doses to the patient and primary surgeon were then estimated based on the duration of fluoroscopy use and published values for deep radiation exposure.11,13

**RESULTS**

The demographics of the control and test groups were compared in the areas of age, sex, operative side, body mass index (BMI), intraoperative complications, preoperative diagnosis, and pelvic incidence. The 2-tailed Student’s t test was performed, and the groups were not

**Figure 1:** Study protocol. Abbreviations: DA, direct anterior; THA, total hip arthroplasty; XR, x-ray.

**Figure 2:** Calculation of pelvic tilt angle based on preoperative standing radiographs.
statistically significantly different in demographic composition ($P > 0.05$) and were thus directly comparable for the purposes of this study. The results of this analysis are summarized in the Table. Mean intraoperative fluoroscopy time was 28.65 seconds in the control group and 23.61 seconds in the test group (Figure 3). The result was calculated using the 2-tailed Student’s $t$ test and showed a statistically significant decrease ($P = 0.033$) in intraoperative fluoroscopy use in the test group.

The fluoroscopy time was also recorded for 2 experienced fluoroscopy technicians to assess the learning curve to determine whether this was also a factor in the decreased radiation exposure time in the test group, which was the second cohort of the 100 patients. The results are shown in Figure 4. No obvious correlation for a learning curve for the 2 technicians was found.

### DISCUSSION

The use of preoperative pelvic tilt calculation to decrease fluoroscopy time in THA by the direct anterior approach has been proposed. With knowledge of the bony anatomy of the patient’s pelvis, the fluoroscopy technician requires fewer trial-and-error images to recreate a perfect AP image. Although the results show statistical significance for decreased duration of imaging in favor of the test group, the clinical significance to the patients and the surgical team may not be clinically relevant. Given acceptable levels of radiation exposure to both patients and the surgical team, a 5-second decrease in fluoroscopy may not result in clinical benefit.

Mehlman and DiPasquale\(^\text{13}\) reported that the primary surgeon is exposed to 20 mrem per minute of deep radiation exposure with the use of intraoperative fluoroscopy. In the current study, patients in the control group would result in a cumulative radiation exposure of 1405 mrem per year to the primary surgeon, but the addition of communication of the pelvic tilt to the fluoroscopy technician decreases this to approximately 1150 mrem per year. Each case of direct anterior approach THA without a preoperative pelvic tilt calculation therefore results in the exposure of approximately 1.7 mrem of radiation, which, for a surgeon performing 150 cases of direct anterior approach THA per year, results in 255 mrem of additional radiation exposure annually. In this study, both groups were well below the recommended annual deep radiation exposure level of 5000 mrem.\(^\text{11}\) Based on the average annual number of cases performed by the senior surgeon in this study, the procedure is safe and does not expose the surgeon to a dangerous level of radiation. It would take approximately 3000 THA cases performed by the direct anterior approach without communication of the pelvic tilt...

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Control Group</th>
<th>Test Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Age, mean, y</td>
<td>65.14</td>
<td>66.68</td>
</tr>
<tr>
<td>Sex, No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>Male</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Side, No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Left</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>Body mass index, mean, kg/m$^2$</td>
<td>27.7</td>
<td>28.2</td>
</tr>
<tr>
<td>Intraoperative complications, No.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Preoperative diagnosis, No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>45</td>
<td>49</td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Developmental dysplasia of the hip</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pelvic incidence</td>
<td>62.63°</td>
<td>60.81°</td>
</tr>
</tbody>
</table>

**Figure 3:** Mean total intraoperative fluoroscopy time for the control and test groups.

**Table**

**Control and Test Group Demographics**
to reach an unsafe level of exposure for the primary surgeon. However, this calculation assumes that the primary surgeon is not performing any other surgical procedures requiring fluoroscopy, which is not the case for many orthopedic surgeons, who also have a trauma practice.

The radiation exposure to the patient during the procedure is more significant because he or she is not wearing protective equipment and is positioned directly within the radiograph beam. The direct exposure to the patient provides up to 4000 mrem per minute of fluoroscopy use.\textsuperscript{11} Patients in the control group were exposed to an average of 1866 mrem during the procedure, as compared with 1533 mrem in the test group. Assuming the patient has 2 or fewer direct anterior approach THA procedures annually, no other major pelvic radiation exposure from other sources, such as pelvic or abdominal computed tomography scans, and no nonarthroplasty surgery requiring the use of imaging, the 5 seconds of decreased fluoroscopy exposure does not appear to be clinically significant based on these values.

This study has several limitations. This was not a randomized trial, and because the groups were sequential, it may have been affected by the learning curves of both the surgeon and the fluoroscopy technician. Previous studies examining the learning curve for THA performed through a direct anterior approach have reported that it is not significant after the first 100 cases, which would have minimized the effects of a learning curve, given the experience of the primary surgeon in this series.\textsuperscript{6} The fluoroscopy time for the 2 fluoroscopy technicians used in the case also did not show significant variation with the number of cases performed. The fluoroscopy time varied within the groups, likely due to the technical difficulty of the cases. Because the groups were similar in age, sex, operative side, and diagnosis, this is unlikely to significantly confound the data.

Although the decrease in radiation exposure to the surgical team may be minimal, long-term studies regarding the effects of radiation exposure on the orthopedic surgeon during a several-decades-long career do not exist. The majority of studies examining long-term outcomes from radiation are from nuclear bomb survivors, and the effects of chronic low-dose exposure related to surgery are unknown.\textsuperscript{11} Small increases in malignancy and cataract formation have been seen; thus, reduction in exposure during a common procedure may have benefit for the career surgeon.\textsuperscript{10,12,14} Although calculation of the pelvic tilt preoperatively aids in reducing duration of fluoroscopy, it will not have a significant effect on component position because the final image under which component implantation is performed does not change.

Possible future directions include the use of dosimeters during direct anterior approach THA to improve the accuracy of radiation measurement for the surgical team, possible associations between patient BMI and fluoroscopy duration, and quantifying the learning curve for fluoroscopy technicians.

CONCLUSION

The results of this study show a statistically significant decrease in the amount of fluoroscopy time required for a THA performed through the direct anterior approach when the preoperative value of the pelvic tilt angle is known to the fluoroscopy technician. Although the decreased fluoroscopy time is unlikely to be clinically significant for the patient, the long-term effects of chronic low-dose radiation on the surgical team are currently unknown, and reductions in exposure may become important for a surgeon using this approach over a several-decades-long career.

REFERENCES


