# An Online Learning Tool to Obtain, Optimize, and Interpret Radiographs During Total Hip Arthroplasty

John P. Livingstone MD; Makoa Mau BS; Jeffery K. Harpstrite MD

## Abstract

*Total hip arthroplasty (THA) is a common orthopedic procedure which has been growing in popularity with the elderly population. With more surgeons completing anterior THAs, intraoperative radiographs have become commonplace. Unfortunately, there is a lack of education in regard to obtaining, optimizing, and interpreting these radiographs. The purpose of this study was to develop and test the efficacy of an online learning tool that medical students, residents, and C-arm technicians could use to improve their understanding of THA radiography. The learning tool taught users how to obtain an optimal AP pelvis radiograph and how to interpret radiographs so THA components could be placed in their optimal position. This learning tool was sent to medical students, orthopedic surgery residents, and C-arm technicians along with a pre-test, post-test, and feedback survey. Twenty users (eleven medical students and nine orthopedic surgery residents) completed the learning tool. Post-test scores (M=96.4%, SD=2.9%) were significantly greater than pre-test scores (M=68.3%, SD=23.9%) for all users (t=5.5069, P<.0001). The user's level of training was positively correlated with pre-test scores. Surveys from the users revealed that the learning tool provided significant learning opportunities, was relatively easy to understand, but was slightly too long. Users felt that this learning tool would be best suited for senior medical students, junior orthopedic surgery residents, and C-arm technicians. With the positive results of this study, the authors hope to further develop this learning tool for widespread adoption and to develop similar learning tools in the future.*

## Abbreviations

*3D = three-dimensional*
*AP = anteroposterior*
*MS = medical student*
*PGY = post-graduate year*
*SD = standard deviation*
*THA = total hip arthroplasty*

## Introduction

Total hip arthroplasty (THA), often referred to as total hip replacement surgery, is a common surgical procedure in orthopedics that continues to grow in popularity as the elderly population increases.[1,2] All orthopedic surgery residents are expected to be able to perform a THA by the end of their residency and a significant portion of their residency is dedicated to learning this procedure. Since anterior THAs have become more prevalent in recent years,[3] intraoperative radiographs have become a standard part of THAs. There is an abundance of literature on how surgeons can utilize these radiographs to optimize the positioning of the acetabular and femoral components, but there seems to be a lack of education in regard to obtaining and interpreting these radiographs.

The importance of proper component positioning has been emphasized in the literature since Lewinneck first described his safe zones in 1978.[4] Even though the optimal positions of these components are still debated to this day,[5,6] the surgeon cannot accurately determine the position of these components without optimal radiographs. Optimal radiographs can be difficult to obtain and maintain during surgery due to patient specific anatomy and positioning[7,8] in addition to difficulties communicating with C-arm technicians. There have been six publications since 2009 proposing different universal C-arm languages to improve this communication deficit,[9-14] but to the authors' knowledge, none of these have become standardized in orthopedic education. Studies have shown that fluoroscopy time during anterior THAs decreases by greater than 50% as new surgeons complete their first 40-100 cases.[15,16] When reviewing the available resources for orthopedic surgery residents, there is a paucity of information in regard to obtaining optimal radiographs for total hip arthroplasty. This may explain why new surgeons have greater fluoroscopy times.

The purpose of this study was to develop a freely available, interactive, online learning tool that residents, medical students, and C-arm technicians could utilize to obtain, optimize, and interpret radiographs during THAs. The learning tool would provide users with educational content followed by multiple choice questions to test their understanding of the previous topic. The first chapter would teach users how to obtain an optimal anteroposterior (AP) pelvis by maneuvering the C-arm or operating table. This chapter would emphasize the importance of communicating with the C-arm technician or anesthesiologist in control of the operating table. The second chapter would teach users about the optimal positioning of the acetabular component and what maneuvers are required to obtain this position. The users would be tested on their ability to identify and correct mispositioned acetabular components and to estimate the anteversion and inclination of a given acetabular component. The final chapter would teach users about the optimal positioning of the femoral component and how leg positioning can affect femur radiographs. The users would be tested on their ability to identify and correct leg length and femoral offset. To assess the efficacy of this learning tool, a pre-test and post-test would be given to all learning tool users.

## Methods

The online learning tool was developed using Google Forms™, a freely available online survey generator. This software was chosen since it is easy to use, free, and one of the most popular survey generators that users would be familiar with. The opinions of the authors of this study in addition to current literature on the subject were used to develop the content of this learning tool.

Users would be shown suboptimal AP pelvis radiographs, acetabular component positions, and femoral component positions in each of the three chapters of this learning tool. They would then be asked to identify how the radiograph or components were suboptimal and what steps were needed to make a correction. In order to generate these images, three-dimensional (3D) models of the pelvis, femur, and THA components were either obtained from freely available online sources such as thingiverse.com or created by one of the authors of this paper. These models were merged together in a freely available 3D software called AutoDesk Fusion 360˚. Digital joints were created between the femur and pelvis so the femur could be internally/externally rotated, adducted/abducted, or extended/flexed into any position. Likewise, the acetabular and femoral components could be adjusted to any position to simulate mis-positioned components. To generate a realistic radiograph, this 3D model was rendered in a frosted glass material with a black background and specific lighting. The virtual camera used to look at this 3D model could then be moved into various positions to show how patient positioning and C-arm positioning can affect the simulated radiograph (See Figure 1).

The pre-test, learning tool, and post-test were sent to medical students, orthopedic surgery residents, and C-arm technicians. Their email addresses were collected as necessitated by the software to prevent a user from repeating either the pre-test or post-test. The learning tool consisted of 82 individual pages divided into three chapters. Following each teaching topic, users were tested with multiple-choice questions. If a wrong answer was chosen within the learning tool, the user would be shown the question slide again until the question was answered correctly. When the correct answer was chosen, the user would be taken to a review slide for additional explanations and topic review.

The first chapter taught the user about the radiographic signs of an optimal AP pelvis (see Figure 2). It then taught the user about how the motions of the operating table and C-arm will change the radiograph of the pelvis. Initially, users were tested on a single C-arm or operating table motion. After progressing through questions on individual motions, several motions were then combined. The questions would increase in difficulty by initially providing the user with answer choices containing images of the C-arm or operating table motions in addition to their written descriptions (see Figure 3). This was designed to help users associate the motions with their descriptors. As the questions advanced, the user would have to choose from descriptors only. This was designed to replicate the conditions of the operating room where the surgeon has to rely on using these descriptors to communicate the desired movements of the C-arm or operating table to staff.

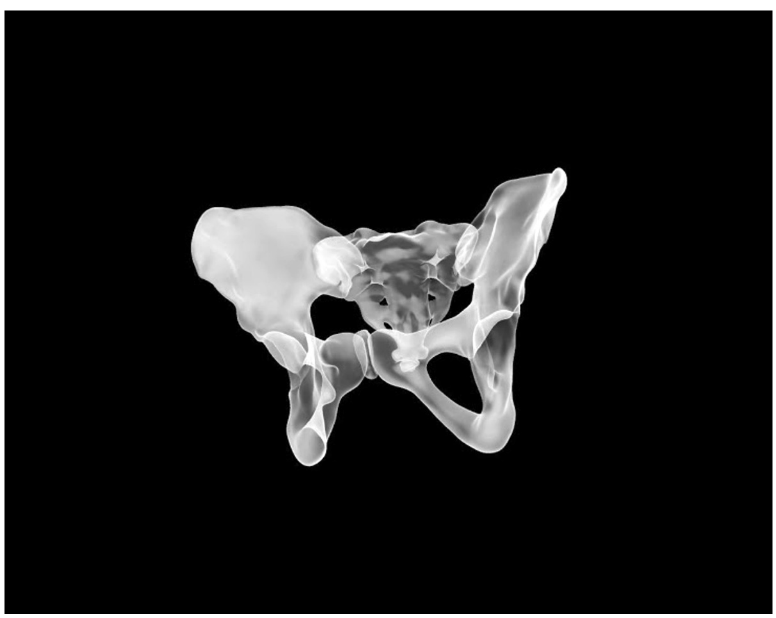

Figure 1. A simulated radiograph of a suboptimal AP pelvis.

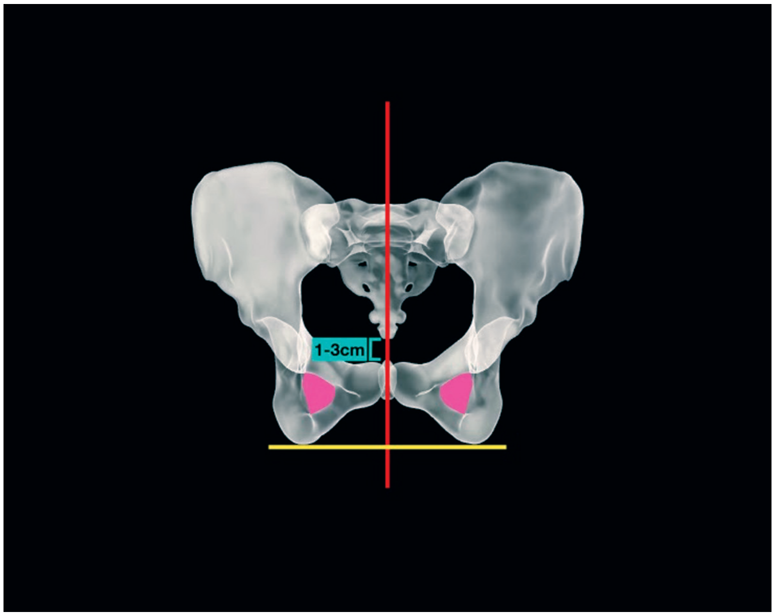


Figure 2. A simulated radiograph demonstrating the radiographic signs of an optimal AP pelvis.

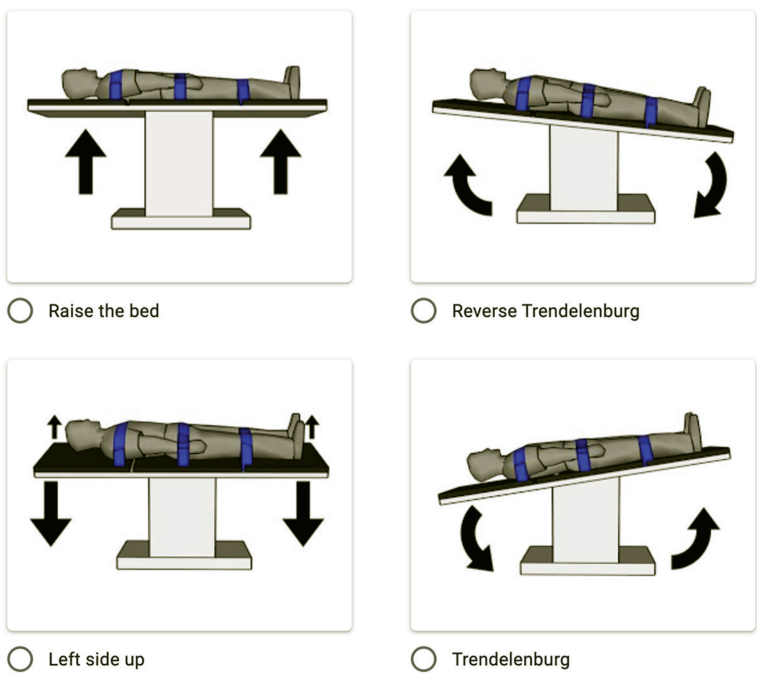


Figure 3. An example of the answer choices available in the early section of the first chapter where operating table motions and their descriptors were shown as answer choices. Later in the chapter, the questions became more difficult and only descriptors would be given as answer choices.

The second chapter focused on acetabular component positioning. Inclination and anteversion were explained using examples of mispositioned acetabular components (see Figure 4). Users were then taught about how to change the amount of anteversion or inclination by moving their hand relative to the patient as if they were holding the insertion device for the acetabular component. Since there is still a lack of consensus on optimal acetabular component positioning, an inclination of 40° and anteversion of 20° based on an AP pelvis were chosen to be optimal for this learning tool. These values are within Lewinneck's safe zone and are common amongst arthroplasty surgeons, including the senior author of this study. Users were then given questions which asked them to correct mispositioned acetabular components by moving their hand in a certain direction. Finally, users were asked to estimate the amount of inclination or anteversion. A brief discussion of parallax and distortion were included in this chapter since these phenomena can have a significant impact on acetabular component positioning.

The third and final chapter taught the user about femoral component positioning and the effects that femur positioning can have on component positioning. First, users were taught how to measure femoral offset and length. They were then shown various examples of how abduction/adduction, flexion/extension, and internal/external rotation will change the appearance of the femur on the radiograph. This was accomplished with both still images (see Figure 5) and video animations created in the 3D software. Users were given questions on femur offset and length prior to a brief survey. The survey asked users about their opinions on the learning tool, who they thought the learning tool was best suited for, and provided space to write comments. Likert scales from 0-5 were used to assess the learning potential, topic difficulty, question difficulty, and length of this learning tool.

A pre-test and post-test were created to assess the efficacy of the learning tool. The pre-test asked users for their level of training, experience with THAs, and if they had any formal training on C-arm language/communication. The pre-test and post-test contained 31 scored questions which were worth a total of 38 points. These were the same questions that were used in the learning tool but the order of the answer choices for each question were randomized. The data from these were collected via Google Forms and were exported into Microsoft Excel for data analysis. A paired T-test was used to calculate any significant difference between mean pre-test and post-test scores amongst all users. This statistical test was also used to calculate any significant difference between pre-test and post-test scores within each user's level of training. This would help determine which levels of training the learning tool was best suited for. All statistical tests were calculated using ©GraphPad.com.

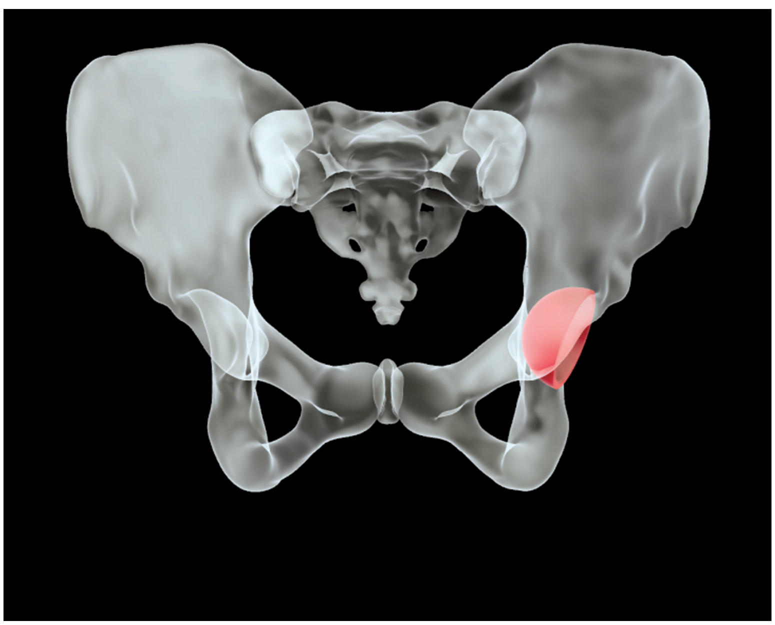

Figure 4. An example of a mispositioned acetabular component used in the second chapter of this learning tool.

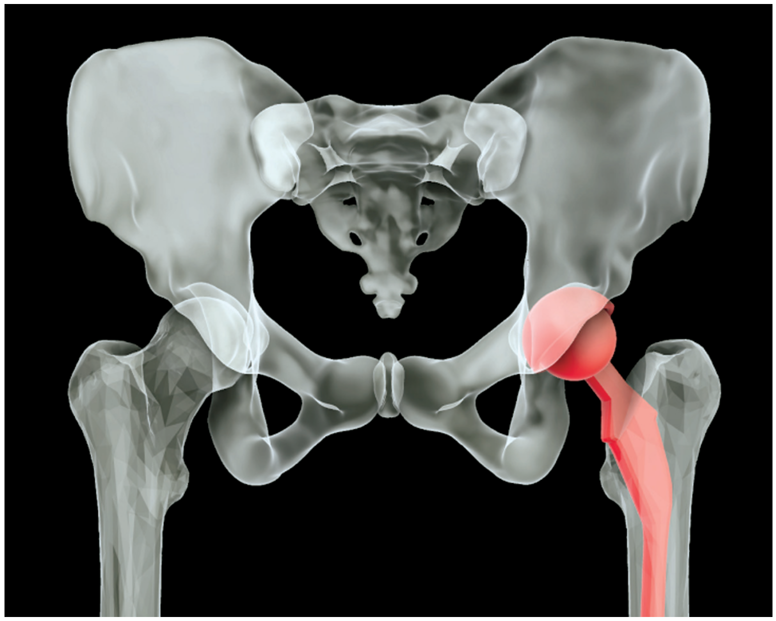

Figure 5. An example of a femoral stem with increased offset from the third chapter of this learning tool.

## Results

A total of 20 users completed the pre-test, learning tool, and post-test. Eleven of these users were medical students ranging from first year medical students (MS1) to third year medical students (MS3) and the other nine users were orthopedic surgery residents ranging from post-graduate year 1 (PGY-1) to post-graduate year 5 (PGY-5). One C-arm technician completed the pre-test but did not complete the learning tool or post-test so their data was not included in the study. Only two users, a PGY-2 and PGY-5 resident, had received any type of formal training on C-arm language. Seven users had never seen a THA, four users had only observed a THA, four users had assisted with a THA, and five users had performed a THA.

There was a significant difference in pre-test (M=68.3%, SD=23.9%) and post-test scores (M=96.4%, SD=2.9%) amongst all users (t=5.5069, *P*<.0001). When comparing scores amongst users by training levels, there was a positive correlation between years in medical training and pre-test scores. MS1s scored the lowest on the pre-test (M=46.7%, SD=18.4%) while the PGY-5 resident scored the highest at 94.7%. When comparing the pre-test and post-test scores between these groups, there was a significant improvement in scores amongst MS1s (46.7% to 95.7%, *P* <.0001) and PGY-3s (92.1% to 96.5%, *P* =.0377). Statistical significance was not found amongst the groups with two users (MS3, PGY-1, PGY-4) and could not be calculated for the single user groups (MS2, PGY-5) (see Table 1). The questions with the lowest pre-test and post-test scores were asking users to estimate the anteversion or inclination of the acetabular component in degrees without any reference. All users had completed the post-test within 24 minutes of completing the learning tool.

Table 1

| Level of training | # of users | Mean Pre-test score | Pre-test SD | Mean Post-test score | Post-test SD | Paired t-test |
|---|---|---|---|---|---|---|
| MS1 | 8 | 46.7% | 18.4% | 95.7% | 3.7% | <.0001 |
| MS2 | 1 | 50.0% | | 97.4% | | |
| MS3 | 2 | 72.4% | 16.7% | 94.7% | 3.7% | .2487 |
| PGY-1 | 2 | 78.9% | 11.2% | 97.4% | 0.0% | .2578 |
| PGY-2 | 1 | 86.8% | | 100.0% | | |
| PGY-3 | 3 | 92.1% | 0.0% | 96.5% | 1.5% | .0377 |
| PGY-4 | 2 | 90.8% | 5.6% | 96.1% | 1.9% | .2952 |
| PGY-5 | 1 | 94.7% | | 100.0% | | |
| All users | 20 | 68.3% | 23.9% | 96.4% | 2.9% | <.0001 |

In the feedback section of the learning tool, users chose an average of 4.50 on the Likert scale when asked "How much did you learn from this learning tool?" with 0 representing "nothing" and 5 representing "a lot". Users chose an average of 2.20 on the Likert scale when asked "How difficult was it for you to understand the topics in this learning tool?" and 2.40 when asked "How difficult were the questions in this learning tool?" with 0 representing "not difficult at all" and 5 representing "extremely difficult". Users chose an average of 3.45 on the Likert scale when asked "What do you think about the length of this learning tool?" with 0 representing "too short" and 5 representing "too long" (see table 2). When comparing this feedback with user training levels, the MS1s found that they learned the most with an average score of 4.75 while the PGY-5 resident learned the least with a score of 2. The rest of the feedback was relatively similar across training levels.

Users felt that the learning tool was most appropriate for senior medical students, junior orthopedic surgery residents, and C-arm technicians. 90% of users felt that the learning tool was best suited for PGY-1s and only 25% of users felt that it was appropriate for PGY-4s and PGY-5s (see Figure 6).

Table 2

| Training | Learning potential: 0=none 5= a lot | Difficulty understanding topics 0=not difficult at all 5=extremely difficult | Difficulty with questions 0= not difficult at all 5=extremely difficult | Length of learning tool 0=too short 5=too long |
|---|---|---|---|---|
| MS1 | 4.75 | 2.75 | 2.75 | 3.375 |
| MS2 | 5 | 1 | 1 | 3 |
| MS3 | 4.5 | 2.5 | 3 | 3.5 |
| PGY-1 | 5 | 1.5 | 2 | 3 |
| PGY-2 | 4 | 2 | 3 | 4 |
| PGY-3 | 4 | 1.666666667 | 1.333333333 | 3 |
| PGY-4 | 5 | 2.5 | 3 | 4 |
| PGY-5 | 2 | 1 | 2 | 5 |
| Mean | 4.50 | 2.20 | 2.40 | 3.45 |

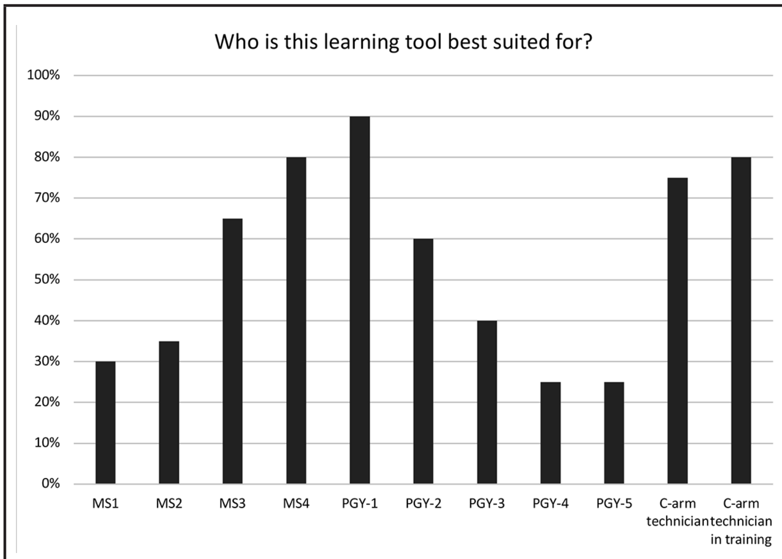


Figure 6. A bar chart of the users' opinions on who this learning tool would be best suited for.

## Discussion

This learning tool proved to be an effective method of teaching medical students and orthopedic surgery residents about optimizing and interpreting radiographs during total hip arthroplasty. This learning tool was able to teach users how to obtain an optimal AP radiograph and how to optimally place total hip arthroplasty components under fluoroscopy. To the authors' knowledge, this is the first educational tool which focuses on obtaining, optimizing, and interpreting radiographs during total hip arthroplasty.

Free online resources such as hipandkneebook.com have excellent information about component positioning and the radiographic markers of the pelvis during THA. Unlike this learning tool, however, it does not explain *how* one can obtain these optimal radiographs and component positions. This disconnection between identifying the problem (ie, a suboptimal radiograph) and educating readers on how to solve it (moving the C-arm or patient) is prevalent in published literature as well.[7,17] This connection is likely engrained in the minds of most arthroplasty surgeons but, in the author's experience, it is generally not well-established in orthopedic surgery residents. By having an intimate understanding of the 3D relationship between the C-arm, the patient's anatomy, and the components, skilled surgeons can limit radiation exposure and operating time. Gaining this understanding can require years of training and several studies have shown that surgeons have longer fluoroscopic times when they first start performing anterior THAs.[15,16]

Communication between surgeons and C-arm technicians can be difficult when performing THAs. This is often seen when C-arm technicians are not familiar with the C-arm language that is being used by the surgeon.[13] With numerous studies proposing different C-arm languages, this is not surprising.[9-14] Rather than focusing on a particular C-arm language, this learning tool used a variety of different descriptors used in the proposed universal C-arm languages. The hope was that this would familiarize the users with the most common descriptors so they could easily operate with different surgeons and C-arm technicians.

The results of this study demonstrated that this learning tool was most effective in first year medical students and seemed to be effective in residents up to a PGY-3 level. At the authors' institution, residents complete their arthroplasty rotation during PGY-3 which is likely why PGY-3 to PGY-5 residents had significantly higher pre-test scores than all other users. These results align with the user's feedback that the learning tool was best suited for more senior medical students and junior orthopedic surgery residents. 80% of users felt that this tool would be suited for C-arm technicians in training, but there were no complete responses from C-arm technicians to validate this.

Overall, the feedback from this learning tool was positive. Most users noted that they learned a significant amount from the learning tool and that the topics and questions in the learning tool were mid-range in difficulty. Several users commented that the learning tool was too long, but the mean Likert score was 3.45/5 in this regard suggesting that most users were comfortable with the length of the learning tool.

There are several strengths to this study. The learning tool recorded the timestamps for completion of the pre-test, learning tool, and post-test and found that all users completed the post-test within 24 minutes of completing the learning tool. This reduces the chances of recall bias effecting the post-test scores. Another strength of this study is that the authors only utilized freely available software and 3D models to generate the learning tool making it easily reproducible. By generating a 3D model of a pelvis, the authors were able to avoid using radiographs from prior surgical cases or taking additional radiographs during future cases for the purposes of this project. The 3D model could generate any combination of pelvic obliquity, tilt, or component positions that would not likely be seen even in a large sample of surgical radiographs.

There are several limitations of this study as well. The authors were only able to recruit 9 orthopedic surgery residents with the remaining 11 users being medical students, mostly MS1s. The authors were also unable to recruit any MS4s or C-arm technicians to take part in this study. A larger sample size would have given us more feedback about how this learning tool can best be utilized and would have provided greater statistical power. Based on our data, a minimum of three users per academic level would be required to reach statistical significance when comparing pre-test and post-test scores. Another limitation of this study is that the real-world application of this learning tool was not tested. In an ideal study design, the authors would monitor the fluoroscopic times of residents before and after performing a THA and track their communication skills via surveys. There were some difficulties when making the learning tool via Google Forms™. As the length of the learning tool increased, the software became progressively slower which made it difficult to edit. Additionally, this software can be cumbersome when generating pathways for specific answer choices, so the authors elected to only create pathways for correct answer choices.

The use of this freely available, interactive, online learning tool improves the understanding of THA radiography and component positioning for users in a variety of stages of medical training. With the data and feedback obtained from this study, the authors plan to improve the learning tool and create a higher quality experience for users. The authors would like to collaborate with other institutions to test the next iteration of this learning tool and broaden its use in medical education. As online learning becomes more prevalent, especially since the COVID-19 pandemic, the authors hope that new, more interactive learning tools such as this one can be incorporated into many aspects of medical education, especially orthopedics. Procedures like pelvic fixation, femoral neck fixation, and intramedullary fixation could benefit from an interactive learning tool similar to the one created for this study. The authors hope that learning tools such as this one can be implemented on a widespread basis to ultimately improve the surgeon's understanding of radiographs during a THA and hopefully improve patient outcomes.

## Conflict of Interest

None of the authors identify a conflict of interest.

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## Appendix

To access the learning tools, use the following links:

**Pre-test**
For actual completion: https://forms.gle/2kcSMAb56rcCcRNf7
For prefilled pre-test: https://docs.google.com/forms/d/1X_Cjjq7jS9DjAExSEREUrUaZ3tzN622wC4UZBOHXqxI/prefill

**Learning tool**
For actual completion: https://forms.gle/J1NJmJYSJyLGV1V9A
For prefilled learning tool: https://docs.google.com/forms/d/1JJ5zjmiSfAIdAhTJwhQGQ9VwVyt7ifEroUeB6Q9eG3Q/prefill

**Post-test**
For actual completion: https://forms.gle/aVVxJjdMmCaWnvx47
For prefilled post-test: https://docs.google.com/forms/d/15dPQXBUgXEQbmHj-vX_xw8RbvD3yRBR9SNZZ3tz7E-Y/prefill