Possible Errors in Pin Insertion Positions Using the C-Arm

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Abstract
In order to measure errors in pin positions, a tibia with referenced pin insertions was radiographed in various locations using a mini C-arm. Changes in pin position locations up to seven millimeters and twelve degrees were found. To minimize these errors, limbs should be centered and parallel to the plane of the imaging screen of the C-arm. If possible, pin insertions should be made in this plane. Magnification due to the distance from the screen should be determined for precise pin positioning.

Pin insertion using the C-arm is a common procedure. In many cases a specific pin position is desired and there are often neurovascular or other structures such as the epiphyseal plate or joint surface that are to be avoided. Positioning of the patient with respect to the C-arm can be confounded by drapes and the patient’s orientation or amount of fat. Although distortions of lengths and angles with standard x-rays due to object position are well known and quantified, these relations have not been examined in detail with the C-arm. This study sought to determine these factors and if they are of sufficient concern for the surgeon to readjust the position of the patient or C-arm unit.

Materials and Methods
An OEC 6600 C-arm (GE Medical Systems, Schenectady, N.Y.) was used. A Sawbones® (Pacific Research Labs, Vashon, WA) tibia with three fixator pins inserted at specific orientations and locations was used as the model. With the tibia oriented parallel to the base plane of the C-arm image intensifier screen, one pin (C in Fig. 1) was inserted parallel to the tibial axis at a 45° superior angle to the tibia, a second pin (A in Fig. 1) at 90° to the tibial axis (orthogonal insertion), and the third pin (B in Fig. 1) inserted at 45° to the tibial axis and at a 45° superior angle to the tibia (oblique insertion). These positions indirectly represent a normal pin insertion (A), an insertion with the tibia tilted (C), and with the tibia rotated and tilted (B). The tibia was held in the clamp of a ring stand so that the distance of the tibia and its orientation could be controlled with respect to the center of the circular base screen of the C-arm. Radiographs were taken with the insertion points of the pins in the tibia centered 2.5 and 5 centimeters to the left and right and at the same distances up and down from the center point at heights of 0 (resting on C-arm base screen) and 5, 10, and 15 centimeters (Fig. 1). Measurements of distances and angles between pins, the width of the tibia, and the distances between the ends of the pins and the nearest inner cortex were made using a ruler and protractor. Values were obtained from an average of three separate measurements.

Results
The angle between the orthogonal (A) pin and the tibia axis did not vary; however, the angle between the oblique (B) pin varied approximately ten degrees larger or smaller depending on the left or right location of the tibia as seen in Table 1. A similar result was noted for forward and backward movement of the tibia. The angle between the orthogonal pin (A) and pin C did not change with forward or backward displacement but did change similar to the pins A and B for left to right displacement, but to a lesser extent.

Distances measured from the images varied as the height of the tibia was changed as seen in Table 2. Using the tibial width measurements, a linear relationship between height and apparent tibial diameter was determined; the magnification of the center images increased approximately 15%...
for each 5 cm increase in height. The left and right images at the same height were approximately 5% larger than the center image.

Discussion

If the image produced by the C-arm is misaligned, the surgeon can attempt to adjust the C-arm or patient for better centering. In this study we were interested in those cases where this was difficult or impossible and wanted to determine the effects of position on clinical measurements. In an x-ray apparatus, the x-rays fan out from the source through the object and produce the image on film or intensifier screen. The short distance between source and screen with a C-arm means that there can be appreciable magnification of the object in the image depending on the object’s distance to the screen. For objects in the center of the screen, the relative distances do not change (e.g., a pin halfway through the bone is also halfway on the image). If the object is not centered, this is not true due to the spreading of the x-ray beam that causes increased distortion the farther the object is moved from the center position. As a result, a bone with parallel cortices appears slightly hourglass shaped. This also means that pins that are inserted not in the plane of the object are subject to both magnification and distortion. Both these factors account for the finding that the pin angle changes are negative when the pins are centered and the bone offset to one side and positive when the bone is offset to the other side and the pins even more offset. These results are consistent with the findings of other investigators.1,2

Conclusion

Limbs should be centered and parallel to the imaging screen of the C-arm; a laser indicator can facilitate this positioning. Pin insertions should be made parallel to the plane of the C-arm screen if possible. Magnification due to distance should be determined by using a known sized, radiopaque marker at the level of the bone (taped to leg).

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References