Morphological Variations and Regional Radii of Curvature of the Femur

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Background/Purpose: Prior analyses of the femoral radius of curvature (ROC) used only a few points to represent the femur, focused on the diaphysis, and did not include the distal metaphysis where intramedullary (IM) nail anterior cortical perforation may occur, and did not compare ROC in different regions of the femur. The curvature of contemporary femoral IM implants begins at the end of the generally straight proximal body and ends at the tip of the implant, which is placed at or distal to the distal condylar flare. Therefore the purpose of this study was to determine the femoral ROC of the region of the femur spanned by a modern nail in a large population using a novel automated technique and compare the ROC between the proximal and distal halves.

Methods: The sagittal ROC of the outer and inner anterior cortical boundaries of 1629 patients (3258 femurs) obtained from PE (pulmonary embolism) protocol CT scans were analyzed with a novel custom MATLAB script that automatically determined the location of femoral landmarks, adjusted for body position, and measured the ROC of the full region of interest and proximal and distal halves. Anterior cortical boundaries were automatically detected at each axial slice with an axial resolution of 5 mm. The region of interest was selected to correspond to the curved portion of most contemporary nails, or 15% of the length of the femur (approximately 6.5 cm) distal to the tip of the greater trochanter to 10% (approximately 4.4 cm) proximal to the distal end of the condyles. The length of the femur was defined from the tip of the greater trochanter to the distal end of the condyles while the axis of the femur was defined as a line between the tip of the greater trochanter and the distal femoral sulcus. Associations between age, femoral length, and height to ROC of the full region of interest and the proximal and distal halves were determined using bivariate analysis.

Results: Mean age was 53.2 years (standard deviation [SD] 16.6). Mean height was 66.3 inches (SD 3.9). The mean outer and inner anterior ROC was 131.3 cm (SD 47.8) and 129.1 cm (SD 49.2) for the full length, 359.7 cm and 884.1 cm for the proximal half, and 1278.2 cm and 2874.6 cm for the distal half. ROC depended on location, height, and length of femur ($P < 0.001$). 10% and 54% of femurs had a lower ROC in the distal and proximal halves, respectively, than of the full length. ROC of the proximal or distal halves was not dependent on age nor length.

Conclusion: The mean femoral ROC of the anterior inner cortex of the region spanned by the curved portion of an IM nail is smaller than most contemporary nails, which are accommodated for by the medullary canal. The majority of the inner anterior cortical curvature of the femur occurs in the proximal half. 1 in 10 femurs will have a distal half that is more curved than its full length and may be at increased risk for anterior cortical perforation. The length of the femur had a significant association with ROC. When broken down by tertiles, the shorter third of femurs had a mean ROC of 119 cm and the longer third 139 cm ($P < 0.001$). However, the ROC of the proximal or distal halves of the femur did not depend on length. These findings have implications for short and long nail design.

See pages 47 - 108 for financial disclosure information.