INTRODUCTION: In adults, a spontaneous, atraumatic avulsion of the lesser trochanter is considered a strong indicator of metastatic involvement of the proximal femur. However, the relatively rare occurrence of this type of fracture has led to a dearth of research, limited mainly to clinical case studies of its significance. As a result, the structural effect of metastases in the lesser trochanter on the strength of the proximal femur is unclear, and recommendations for treatment of such a fracture are based on sparse anecdotal evidence. To elucidate this issue, we used CT scan-based finite element (FE) models to compute reductions in proximal femoral strength due to simulated metastatic lesions at various locations at the level of the lesser trochanter, including within the lesser trochanter itself.

METHODS: Twelve cadaveric proximal femora were obtained from 12 female donors and CT scanned (GE CTi, calcium hydroxyapatite phantom, 0.674-mm pixels, 80 kVp, 280 mAs, 3-mm slices). A three-dimensional FE model of each femur was generated from the CT scan data. The boundary conditions represented a single-limb stance-type loading to failure, with incremental displacement applied to the femoral head at 20° to the shaft within the coronal plane. Abductor muscle forces were applied. The FE-predicted fracture load, FFE, was defined as the maximum total reaction force at the femoral head.

To model the effect of metastatic lesions, in-house software was used to alter the CT scan data to create a 20-mm-diameter spherical void at various locations at the level of the lesser trochanter (Fig. 1). Initially, FE models of one randomly selected femur were generated to determine the effect of a defect placed tangent to the periosteal surface at each of 12 locations (Fig. 1). Eight additional FE models were created to study the effect of a defect centered at the periosteal surface, creating an approximately hemispherical defect (Fig. 1). FFE of each model with a simulated defect was divided by FFE of the intact FE model to obtain a measure of the strength remaining after introduction of the defect, %intact. A paired t-test was used to determine if %intact for the tangent defects was significantly different than %intact for the centered defects.

Based on the results of this initial analysis, further investigation focused on the effect of simulated defects tangent to the anterior-medial corner of the bone. For each of the 12 femora, 9 FE models (108 total models) were generated, each with a defect 1.5 mm and 3 mm posterior and/or lateral to the anterior-medial corner (Fig. 2). %intact was calculated for each model by dividing FFE of each model with a simulated defect by FFE of the corresponding intact FE model. At each of the 9 locations, the mean and standard deviation of %intact were determined and a t-test was used to determine if %intact was significantly different than 100%. A paired t-test and signed rank test for non-normally distributed data were used to determine if %intact for each defect along the anterior cortex was significantly different than %intact for the defect along the medial cortex at the same distance from the anterior-medial corner.

RESULTS: For the analysis of defects around the perimeter of the femur, the defect in the anterior-medial corner resulted in the largest reduction in %intact (54.1%), while the defect in the lesser trochanter had almost no effect (%intact=99.8%, Fig. 1). %intact for the 8 defect locations at the periosteal surface (Fig. 1) were not significantly different than their corresponding tangent defects (p=0.99). For all 12 femora, %intact rapidly increased with distance from the anterior-medial corner of the bone (Fig. 2). %intact for each defect along the anterior cortex was significantly different than %intact for each defect along the medial cortex at 1.5 mm (p=0.01) and 3 mm (p=0.03) from the anterior-medial corner.

DISCUSSION: This study has shown that an isolated defect in the lesser trochanter has almost no effect on proximal femoral strength, whereas a defect in the anterior-medial corner of the bone at this level results in a substantial strength reduction. The effect of defects in the anterior-medial aspect of the bone is extremely sensitive to defect location, with defects in the medial cortex slightly more destructive than defects in the anterior cortex. Thus, the risk of fracture from metastatic defects at the level of the lesser trochanter is highly variable. Although these results apply only to single, 20-mm-diameter spherical defects with well-defined borders, the trends reported here can be useful for interpreting the significance of metastatic lesions in this region.

An avulsion of the lesser trochanter may be accompanied by extensive metastatic involvement in other regions of the femur. Thus, the treatment for an avulsion fracture of the lesser trochanter must take into account the extent of metastatic involvement in the critical load-bearing regions of the femur. These regions include the anterior-medial corner at the level of the lesser trochanter and the inferior-medial cortex of the neck, as reported previously. Based on the results of this study, prophylactic fixation of the proximal femur after avulsion of the lesser trochanter may not always be necessary. These findings contrast with conventional wisdom regarding metastases in this region, in which an avulsion of the lesser trochanter is usually considered a sign of high risk of additional fracture and, therefore, an indication for prophylactic internal stabilization. Further investigation with the aid of FE analysis would be useful for developing clinical guidelines for assessing fracture risk.


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