**POSTER 21**

## Mechanical Effects of Virtual Prophylactic IMN Fixation in Femurs with Metastatic Disease

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BACKGROUND: Metastatic disease of bone (MDB) is a common and costly condition, with only moderate agreement amongst surgeons regarding when and what surgical treatment is needed in these medically compromised patients.[1] Many patients with femoral metastases undergo prophylactic intramedullary nailing (IMN) fixation for impending pathologic fractures. The question of whether to use IMN fixation or when is IMN fixation not enough, remains to be answered.

QUESTIONS/PURPOSES: Our goals were to use patient-specific finite element (FE) modeling to 1) computationally evaluate the effects of simulated IMN fixation on the mechanics of femurs affected with MDB, and 2) determine when the mechanical gains of IMN fixation in femurs affected by MDB appear most beneficial.

PATIENTS AND METHODS: With Institutional Review Board approval, computed tomography (CT) scans were collected retrospectively from 48 patients (54 femurs) with proximal femoral metastases (64±13 years; 23/31 females/males). There were 24 lytic, 19 mixed, 6 diffuse, and 5 blastic metastases in the cohort. The CT scans were used to create patient-specific, voxel-based FE models of the entire femur.[2] The FE models incorporated inhomogeneous CT-Hounsfield density-based material properties, and nonlinear post-yield behavior.[3] Compressive displacement applied at the femoral head and patient-specific proximal muscle forces applied at muscle insertion locations were used to simulate the instant of peak joint contact force during normal level walking[4] while the femur was physiologically constrained.[5] FE analyses of the same femurs were repeated after incorporating virtual IMN fixation (Smith and Nephew, TRIGEN INTERTAN). Placement of the IMN surfaces within each femur model was verified by a board-certified surgeon, then the voxel-based representations of the IMN components were tied to the bone at appropriate locations to adequately simulate load transfer. Failure strength (peak resultant reaction force at the femoral head; higher failure strength indicates stronger femur) and load-to-strength ratio (LSR = patient-specific contact force/failure strength; lower LSR indicates lower fracture risk) were compared between the with and without IMN conditions using comparison of means and percentile analysis. Paired t-test (normal data) or Wilcoxon signed-rank test (non-normal data) were used for comparison of whole-cohort means while Kruskal-Wallis test (non-parametric one-way ANOVA) was used for comparison of multiple means. An alpha level of 0.05 was defined as statistically significant.

RESULTS: Most femurs (71%) were determined to be at relatively low fracture risk (LSR≤0.5) at the time of CT evaluation. IMN fixation resulted in a very modest average 10% increase in mechanical strength ($p<0.001$), which was associated with a 7% reduction in fracture risk ($p<0.001$). However, these whole-cohort averages do not adequately reflect the considerable variation in the reduction in fracture risk across femurs (0.13-50%; Fig. 1). Reduction in fracture risk appeared preferential ($p=0.073$) based on the type of metastases (Fig. 2), with greater reductions observed in femurs with lytic (10%) and diffuse (9%) metastases, compared to femurs with blastic (5%) and mixed (4%) metastases. In femurs with the largest reduction in fracture risk (>10%; Fig. 1), IMN fixation hardware directly passed through a considerable section of that femur's metastatic lesion, whereas the lesions in femurs with the smallest reduction in fracture risk were minimally spanned by the IMN fixation.

CONCLUSIONS: We only observed modest mechanical gains with virtual IMN fixation in terms of increased femoral strength and reduced fracture risk. Given the mechanically strong baseline condition of most femurs in this cohort, evident by the low fracture risk at the time of CT scanning, the relative increase in stiffness with the addition of the IMN hardware may not make a substantial contribution to overall mechanical strength in many cases. Femurs with blastic metastases, which are characterized by abnormal bone *formation*, are intuitively expected to not be as

mechanically compromised as those with lytic metastases. This could explain the lower mechanical gains associated with IMN fixation in the blastic and mixed (combined blastic, lytic) type lesions. The mechanical gains of IMN fixation in femurs affected by MDB appear most beneficial so long as the hardware stabilizes an adequate section of the lesion. In this work, we focused on a common physiologic activity - walking, which provided a low fracture risk for most femurs. Mechanical effects of IMN fixation may vary based on the activity modeled (e.g. stair ascent, sideways fall), particularly for loading mechanisms the IMN hardware was not designed to resist.

CLINICAL RELEVANCE: Femurs with lytic and diffuse lesions that are directly spanned by some element of the IMN fixation hardware are most likely to benefit mechanically from prophylactic IMN fixation.

REFERENCES: [1] Nazarian A et al. Clin Orthop Rel Res. 2016; 474(3):652-9. [2] Johnson JE et al. J Biomech. 2020; 106:109825. [3] Keyak JH et al. Clin Orthop Rel Res. 2005; (437):219-28. [4] Bergmann G et al. J Biomech. 2001; 34(7):859-71. [5] Speirs AD et al. J Biomech. 2007; 40(10):2318-23.

Figure 1

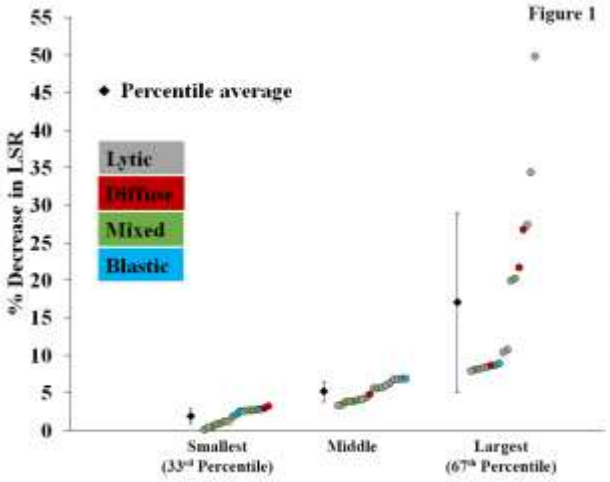


Figure 2