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INFLUENCE OF SPECIFIC METASTASIS MECHANICAL PROPERTIES ON THE PREDICTED FAILURE LOAD OF METASTASIZED FEMUR

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Introduction

Osteolytic bone metastases are responsible for long bone fracture leading to restricted mobility or surgery [1]. Based on quantitative computed tomography (QCT), patient-specific finite element (FE) models assessing the strength of metastasized femurs can help predict bone fracture [2]. In these models, Young's modulus of each element is assigned based on its grey levels-based density. Bone microarchitecture is altered in the metastasis, and assigning specific mechanical properties to the metastasis can have an effect on both the predicted failure load and fracture location [3]. However, segmenting bone metastasis is challenging and highly operator dependent [4]. The aim of this study was to assess the influence of specific metastasis mechanical properties on the predicted failure load (and fracture risk) of metastasized femurs, and the inter-operator variability due to lesion segmentation.

Materials and methods

Femurs of five patients with lytic lesions were scanned using QCT (Mekanos cohort, Lyon). FE analyses were performed for each femur using the method described in Sas *et al.* [5,6]. Segmented femurs were meshed with 2 mm sized voxel elements. Each element was assigned a nonlinear constitutive law based on its density. Femurs were loaded in axial compression and their failure load (maximal reaction force) was computed. Then, two independent operators segmented the lesion. For each segmentation, elements of the FE model contained in the segmented volume were assigned a density of 0.001 g/cm³, corresponding to an elastic modulus of 40 kPa [7]. FE analyses were performed for each femur and each segmentation, and the failure loads were computed. For each metastasized femur, the relative difference between the failure loads obtained with and without specific metastasis mechanical properties was calculated. Moreover, the relative difference between the failure loads obtained following segmentation of the lesion by two independent operators was calculated. To assess the influence of segmentation and metastasis specific mechanical properties on the predicted fracture risk, the BOS score, defined as the failure load divided by patient's body weight, was calculated [5]. A BOS score less than 8.9 is associated with a high fracture risk.

Results and discussion

Assigning specific mechanical properties to the metastasis resulted in a lower predicted failure load, and

BOS score (Figure 1). The relative differences compared to the model without lesion segmentation ranged between 6% and 53% for operator 1 (green), and between 9% and 30% for operator 2 (orange). The mean relative difference between the failure loads obtained by both operators is 9.7% (SD: 29%), highlighting the high inter-operator variability due to lesion segmentation. A change in metastasis mechanical properties in the FE model and lesion segmentation can modify the fracture risk prediction (Figure 1). Therefore, this uncertainty should be taken into account for the fracture risk prediction. Further investigation on the influence of metastasis mechanical properties depending on lesion size and location will be conducted. The variability due to lesion segmentation also show the influence of lesion size on the fracture risk. Segmenting the lesion could allow fracture risk prediction after metastasis progress (e.g., growth), following probable clinical scenarios.

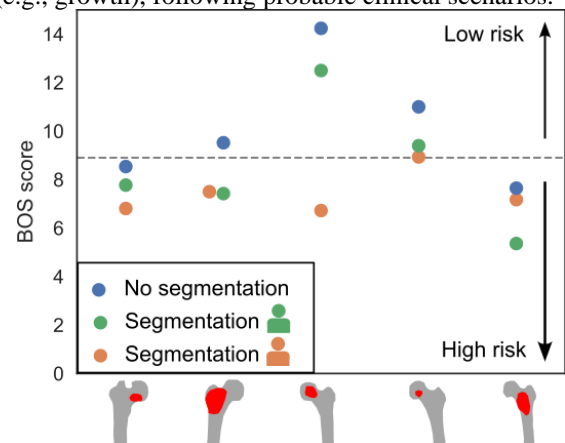


Figure 1: BOS score (failure load predicted by FE models of metastasized femurs divided by patient body weight), when the metastasis (colored in red) is not segmented (blue), segmented by operator 1 (green) or segmented by operator 2 (orange). BOS score less than 8.9 (dot line) corresponds to a high fracture risk.

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