STRAIN RATIO DISTRIBUTIONS CAN ELEGANTLY DESCRIBE THE EFFECT OF LESION LOCATION AND SIZE IN FEMORAL METASTASES

Abbas Rizvi (1), Chloe Scott (2), Sohan Seth (3), A. Hamish Simpson (4), Pankaj Pankaj (1)

1. School of Engineering, The University of Edinburgh, UK;
2. Department of Orthopaedics, Royal Infirmary of Edinburgh, UK;
3. School of Informatics, The University of Edinburgh, UK;
4. Edinburgh Medical School, The University of Edinburgh, UK;

Introduction

The spread of primary cancer, in advanced disease, to distant organs such as bones, results in metastatic bone disease (MBD). Area effected by MBD transforms into abnormal tissue called lesion. These lesions in bones reduce overall load-bearing capacity and increase the risk of a fracture. The fracture risk is clinically undertaken using the Mirels' score system [1]. Recently, CT-based finite element (FE) analyses have been used to evaluate risk. The process involves developing FE models from a patient's CT scan and using the ratio of the absolute maximum principal strain in the diseased femur and the median strain in the same anatomical region of the disease-free femur [2]. These approaches do not provide a guide as to how location, size and growth of lesion, influence fracture risk. This study employs an automated process with the aim to provide a framework for holistic risk evaluation using strain ratio distribution over the entire diseased femur.

Methods

We have developed an automated process for conducting biomechanical analysis on computational models of a femur. Currently, the analyses are linear elastic and employ tetrahedral finite elements with four integration points. The nodes on the proximal condyles are linked to a single point representing Hip Joint Centre (HJC) while the nodes on the distal condyles are linked to a single point representing Knee Joint Centre (KJC). The model is subjected to varying physiological boundary conditions at HJC and KJC. Through an automated process, spherical cavities of different diameters and at different locations are created to represent a lesion. The analysis is undertaken for the disease-free femur repeated after the introduction of lesions. To reduce discretization error, identical meshes are used for both diseased and disease-free models (with the exception of the lesion). Thus the location of the integration points for both the models are identical. Equivalent strain at integration points is evaluated for both the diseased and disease-free femurs and the distribution of equivalent strain ratios (ESR) calculated at identical integration points across the femur used to describe the effect of the lesion.

Results

For the purpose of demonstration of the proposed automated process, standardized fourth generation Sawbones femur model is used with loads representing single legged stance [3]. Sample stain ratio distribution plots are shown in Figure 1 which describe their effect on femur as the location of lesion changes medial to lateral.

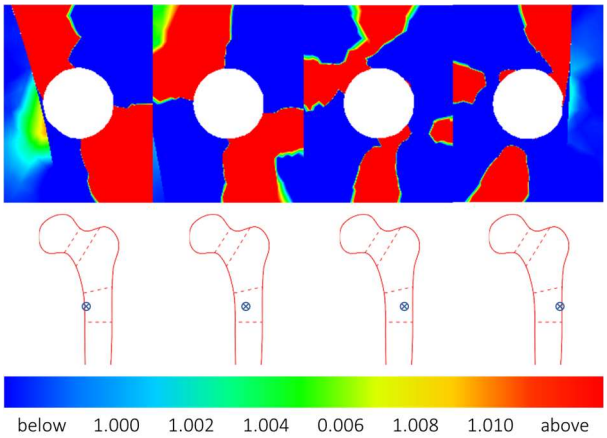

Figure 1: Strain Ratio distributions around 8mm diameter lesion with varying location, anterior view

We have also examined the effect of lesion size and cortical destruction using this automated process. We have also used the automated process to create animations of describing effects of lesion.

Discussion

The proposed automated process is capable of providing ESR distribution on the entire femur for lesion of any size and location. As strain ratios are scalar, their use appears to be more theoretically sound in comparison to recently publish work using principal strain ratios. By using this process sensitivity analysis can be conducted to evaluate the effect of lesions at different locations and of different sizes, with and without cortical destruction on entire femoral structure.

References

1. Mirels H, Clin Orthop Relat Res 1989;249:256–264
2. Sternheim et al, Bone, 2018;110:215–20
3. Levadnyi et al, Proc Inst Mech Eng 2021;235(1):17–27

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