

INDIVIDUALISED FINITE ELEMENT MODEL PREDICTS FEMORAL FRACTURES MORE ACCURATELY THAN CURRENT CLINICAL INDICATORS

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Introduction

Individualised Finite element (FE) models from CT data are a promising tool to non-invasively assess the bone strength and the risk of fracture of bones in vivo in individual patients. In clinical practice the risk of femoral neck fracture is estimated through patient-specific clinical information using epidemiological models like the FRAX tool. But this approach does not account for the mechanical determinants of the fracture [5].

The aim of this work is to use validated FE modelling procedure [3] to prove its better accuracy to predict femoral fracture over the current clinical indicators.

Patients and Methods

In this case-control study we recruited 100 Caucasian women who were at least 5 years post menopause. The case group consisted of 50 patients who had sustained a hip fracture (37 intra-capsular and 13 extra-capsular fractures) within the previous 90 days due to low-energy trauma. Exclusion criteria comprised any history of bone metastases, hyperparathyroidism, a known confusional state or dementia as documented in hospital notes. The CT datasets were segmented (using the open-source ITK-Snap software) in order to extract the three-dimensional bone surface. Then unstructured meshes (10-node tetrahedral elements) were generated using ANSYS mesh morphing software. Each CT dataset was calibrated using the European Spine Phantom. The inhomogeneous material properties were mapped from CT datasets into the FE model with the BoneMat_V3 software [4]. Bone strength was evaluated in quasi-axial loading conditions, for a set of 12 different configurations sampling the cone of recorded in vivo hip joint reactions [2], and was defined as the minimum load inducing on the femoral neck surface an elastic principal strain value greater than a limit value [1].

Results

There were no statistically significant difference between the fracture and the control groups for age, height and weight ($p < 0.05$). All indices of areal bone mineral density (aBMD) between fractured and controls showed on average a lower value for fractured respect of the controls, with similar mean difference (17% for total femoral aBMD, 16% for femoral neck aBMD). FE-predicted strength differed between fractured and non-fractured on average for 19%. To evaluate its ability to identify patients at risk of hip fracture, FE-based strength was compared to the FRAX predictor by computing for each predictor the Receiver Operating Characteristic (ROC) curve, and then the Area Under the Curve (AUC). The individualised risk predictor based on FE bone strength was found to perform significantly better (AUC = 0.74) than FRAX (AUC = 0.65). When the FE-based strength indicator was combined with available clinical information in a logistic regression, the resulting predictor achieved in this retrospective study an excellent accuracy (AUC = 0.81).

Discussion

This study confirms that individualised, CT-based finite element models, when generated using to the state-of-the-art protocols, can provide a predictor of the risk of hip fracture much more accurate than those based on clinical data alone. In the integrated workflow developed in the VPHOP Project (FP7-ICT-223865) CT-based risk prediction is requested only for those patients for whom the clinical decision is uncertain.

References

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