Constructing a 3-D vertebral body adaptation model with 2-D images using an ART

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Introduction

Osteoporosis leads to an increasing number of bone fractures every year, predominantly occurring in the spine, wrist, and hip. Current techniques for assessing severity of osteoporosis include dual x-ray absorptiometry (DXA), quantitative computed tomography (QCT) and quantitative ultrasound. These techniques, which only evaluate bone density, have shown limited ability to judge fracture risk. Finite element models constructed from CT scans take into account bone geometry and bone density distribution, and exhibit increased ability to predict fracture. However, the main substrate of fracture risk studies is the elderly population, for whom longitudinal evaluation would be beneficial, and frequent CT scans may be prohibitively expensive or unavailable. This study explores the feasibility of using two-dimensional images to update the density information of a vertebral finite element model initially created using a CT scan, thereby constructing an up-to-date model with less expensive and more widely available hardware.

Methods

In this preliminary study, CT scans of individual vertebral bodies from a previous study were used. All image manipulations were performed in MATLAB. The original data was projected (summed) in each of 3 radial directions, 45 degrees apart, forming three discrete 2-D images. Random noise with varying distributions was added to the original data to create another dataset called the perturbed data, which represents the dataset of the old model to be updated; the more noise added, the more bone lost to reach the current state. The original data itself was not used in the algorithms; it was used as the gold standard to which we compared our estimations. The reconstruction process involved the use of a simplified algebraic reconstruction technique (ART) to modify the perturbed density data to fit the current projections. The new density estimates were then used to assign material properties to a pre-existing mesh. A series of custom programs in C and Fortran were used to organize and prepare the data for analysis in Abaqus. Data were collected from these programs, including average bone density, elastic modulus, and vertebral stiffness. The effectiveness of the reconstruction method was evaluated by comparing quantities obtained from the original CT data, the perturbed data, and the reconstructed data.

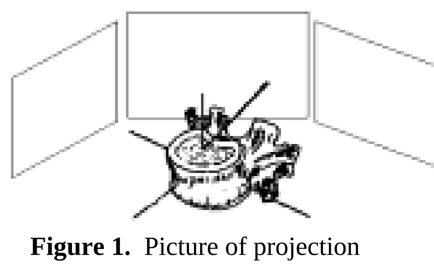

Figure 1. Picture of projection planes with respect to single vertebral body.

Results and Discussion

Initial results show that, independent of the amount of noise added, the values from the reconstructed data differs from the original data by at least 90 percent less than the perturbed data. These results show that the ART applied to two-dimensional projections can effectively decrease the noise added to the three-dimensional density data, reinforcing the feasibility of successfully constructing a new model using old CT data and current projections. Future work will predominantly involve the development of more accurate and stable reconstruction algorithms.