Localisation of Vertebrae on DXA VFA Images using Constrained Local Models with Random Forest Regression Voting

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Osteoporotic fractures are associated with significant morbidity, mortality and public health costs, and will increase with an ageing population. Many osteoporotic vertebral fractures (VF) present on images do not come to clinical attention or lead to fracture prevention treatment. Furthermore, DXA vertebral fracture assessments (VFA) are often reported subjectively by a radiologist or other clinician. VFA computer-aided systems offer potential advantages. Methods based on statistical shape models (e.g. active appearance models, AAMs) have been used to segment vertebrae in radiographs and DXA VFA. However, results achieved using AAMs exhibit significant numbers of large errors due to model fitting failure, particularly on more severely fractured vertebrae. We evaluate an alternative algorithm, the Random Forest Regression Voting Constrained Local Model (RFRV-CLMs), which has proved more robust and generalizable than AAMs in annotation of landmarks on various clinical images; we investigate whether this will reduce the number of fitting failures in vertebral segmentation.

320 DXA VFA images obtained on various Hologic (Bedford MA) scanners had manual annotations of 405 landmark points of vertebrae T7 to L4, with fracture classifications from an expert radiologist. RFRV-CLMs were applied to these data in a leave-1/4-out fashion. Figure 1 shows an example image with manual annotations (left; grade 3 severe and grade 1 mild fractures of L1 and L2, respectively), with automatic annotations for L1 to L3 (right). Errors were calculated as the mean, across each vertebra, of the minimum distances between the automatic annotations and a Bezier spline passing through the manual annotations. Figure 2 shows a cumulative distribution function of errors in ten vertebral levels in all 320 images, for each vertebral classification. Mean errors of <4mm were achieved for 95% of grade 3 fractures, and 100% of other classifications. Mean errors above 2mm were observed on 3.84% and 10.48% of vertebra with grade 2 and 3 fractures, respectively, compared to 10.2% and 16.5% obtained with AAMs. We conclude that the RFRV-CLM produces fewer large errors due to fitting failures than the AAM in vertebral segmentation, and so is more suitable for automatic analysis of DXA VFA.

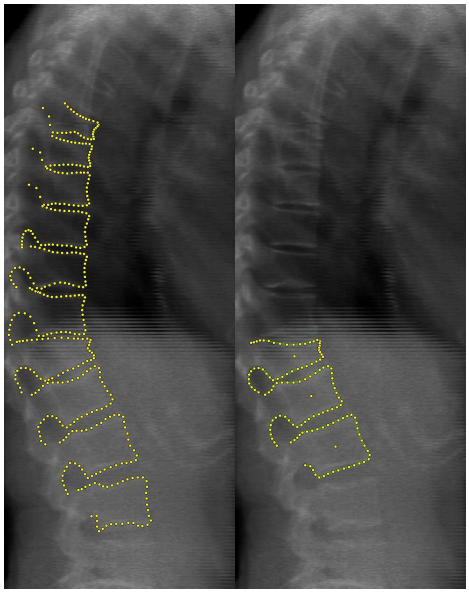

Figure 1:

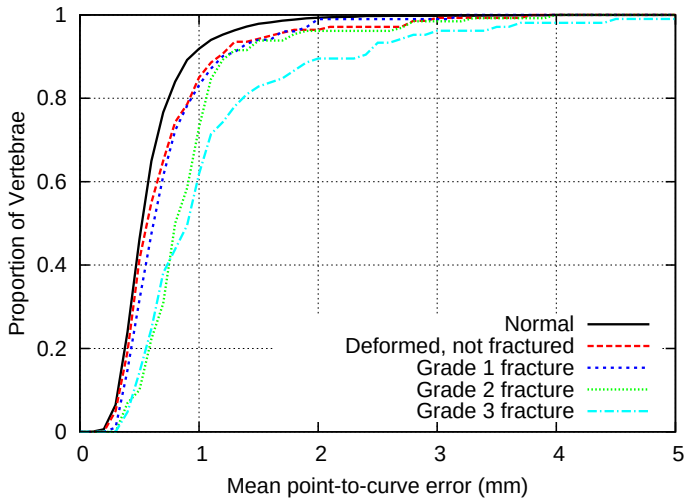

Figure 2: