NEW RADIOGRAPHIC IMAGE ANALYSIS METHOD FOR EVALUATING TRABECULAR BONE MASS OF THE HIP

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INTRODUCTION
The diagnosis of osteoporosis is currently primarily based on the bone mineral density (BMD) measurements by dual-energy X-ray absorptiometry (DXA). However, DXA-based BMD measurements have been shown to lack predictive ability of the individual risk of fracture [1], and most fractures occur in individuals without osteoporosis as defined by DXA [2].

Trabecular bone architecture dynamically varies with the loading conditions and with age. Resorption of trabecular bone occurs in osteoporosis leading to increased risk of fracture. Thus, evaluation of the changes in trabecular bone mass and structure might be valuable in fracture risk assessment.

Several techniques for the assessment of trabecular bone have been described including ultrasound, high-resolution computed tomography, and magnetic resonance imaging. Texture analysis of radiographs has also been proposed as an alternative, since standard X-ray imaging is easily available at low cost. However, the intensity variation between radiographs is a significant source of error in the image analysis. Thus, reliable differentiation of trabecular pattern is needed before applying radiographs for analysis.

The principal aim of the current study was to develop image processing method independent of intensity for evaluating bone mass from the plain radiographs of the hip. The preliminary results with 37 samples will be presented here.

MATERIALS AND METHODS
The study was performed using radiographs of excised femurs (N = 37), digitized along with a calibration scale by a scanner with a resolution of 900 dpi. A rectangular region of interest (ROI) was selected to represent trabecular bone at the greater trochanteric area. Noise was reduced from the image using a median filter, followed by morphological top and bottom hat operations. The local gradients of the original image were calculated (Eq. 1), and a new gradient-based binary image was constructed.

\[
\nabla F = \frac{\partial F}{\partial x} + \frac{\partial F}{\partial y}
\]

An estimate for trabecular bone mass was defined from the gradient-based binary image of the ROI by calculating the area of trabecular bone divided by the total ROI area (TrA/TotA). Pearson’s correlation coefficient \(r\) between TrA/TotA and standard DXA-based total BMD was calculated. Image processing and analyzing was performed using Matlab® software, version 7.0.1 (The MathWorks, Inc.).

RESULTS
A typical original radiograph and the corresponding gradient-based binary image from a trabecular ROI at the trochanteric area are shown in Figure 1. The correlation coefficient \(r\) between TrabA/TotA and BMD was 0.819 (\(p < 0.001\)).

DISCUSSION
We developed here a gradient-based method for the assessment of trabecular bone mass from radiographs. According to the preliminary results, bone mass estimated by the current method explained 67 % of the variation in DXA-based BMD. Thus, even if measured only from a limited ROI, it appears to represent a reasonable estimate of total femur BMD. The current method might even give some structure related information additive to BMD which might be clinically important, since BMD has been shown to be insufficient in predicting individual fracture risk [1].

The strength of the gradient-based image processing method is that it is insensitive to intensity variations between images. Thus, it might also be suitable as an image enhancement method for trabecular structure analysis from clinical radiographs.

The preliminary evaluation was made on radiographs of excised femurs. It is not known how the soft tissue and orientation affect the results. The optimal selection of the ROI is also not yet known. The sample size was also too small for final conclusions.

In future studies, structural parameters should be included in the radiograph-based estimation of trabecular bone at the hip. It remains to be seen how this method works in the evaluation of clinical hip fracture risk.

REFERENCES

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Figure 1. (Left) Original radiographic image from the trabecular bone at the trochanteric area of femur. (Right) Same image processed with the gradient-based method.