ABSTRACT

THE USE OF IN VIVO BONE MINERAL DETERMINATION
TO PREDICT THE STRENGTH OF BONE

by

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The importance of bone to the health of an individual is well known. However, in many instances there is a failure of the skeleton to provide adequate structural support throughout life. A progressive deterioration in skeletal integrity begins after maturity with the most serious loss of strength occurring in the femoral neck and the spine. Fractures in these areas associated with minimal trauma and often called "spontaneous" increase markedly with age. The primary factor in the increased fragility of the skeleton is the reduction in the total amount of bone present due to cortical thinning of the long bones and the increased rarefication of the vertebrae. A determination of the amount of bone in the areas of clinical interest, i.e. the hip and spine, may provide an estimate of the strength of the bone in these areas and a measure of the risk of fracture. The bone mineral content, BMC, determined by the University of Wisconsin mono-energetic photon absorption technique, of 29 different locations on the long bones and vertebral columns of 24 skeletons were measured. Compressive tests were

made on bone from these locations in which the maximum load and maximum stress were measured. Also the ultimate strain, modulus of elasticity and energy absorbed to failure were determined for compact bone from the femoral diaphysis and cancellous bone from the eighth through eleventh thoracic vertebrae. Correlations and predictive relationships between these parameters were examined to investigate the applicability of using the BMC at sites normally measured in vivo, i.e. radius and ulna in estimating the BMC and/or strength of the spine or femoral neck.

It was found that the BMC at sites on the same bone were highly correlated r = 0.95 or better; the BMC at sites on different bones were also highly interrelated, r = 0.85. The BMC at various sites on the long bones could be estimated to between 10 and 15 per cent from the BMC of sites on the radius or ulna. Also the BMC of the thoracic vertebrae could be estimated from the BMC at a site on the radius and age with a standard error of estimate of about 17 per cent. The maximum compressive stress of bone from the vertebral column was found to be closely related to the mass of bone mineral per unit volume of the vertebra. The maximum compressive stress and bone mineral per unit volume of the vertebral bone tissue declined with age at rates of about 17 and 8 per cent per decade respectively. It was found to be possible to estimate the maximum compressive stress of bone of the vertebra qualitatively from the radial BMC, age and the dimensions of the vertebra. The radial BMC was highly related to the mineral content of the femoral neck, r = 0.88, and the femoral neck mineral content could be estimated with a standard error of estimate of 15 per cent. It was found that the femoral necks of all skeletons with a radial BMC of less than 0.68 gm/cm were significantly weaker than those with a radial BMC greater than this value.

The relation between the BMC and the maximum compressive load of specimens of compact bone was examined. The maximum load borne by the bone was found to be more closely related to the BMC of the specimen than to the total area. The maximum compressive stress of compact bone tissue was found to decrease about 7 per cent per decade after age 35. There was also a decline in the bone mineral per unit volume of compact bone tissue of about 3.3 per cent per decade. A model in which bone is considered a porous material was developed. The model was able to mathematically describe the age related changes in the maximum stress and the bone mineral per unit volume of compact bone.

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