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Original Article

Vertebral Morphometry

Sharon H. Chou,[1] and Tamara Vokes*,[2]

[1]Division of Endocrinology, Diabetes, and Hypertension, Brigham and Women's Hospital, Boston, MA, USA; and [2]Section of Adult & Pediatric Endocrinology, Diabetes, Metabolism, The University of Chicago, Chicago, IL, USA

Abstract

There is as yet no agreement about the criteria by which to arrive at an imaging diagnosis of a vertebral fracture. Because high-grade fractures result in alterations in vertebral shape, 1 possible avenue of diagnosis has been to quantitate changes in vertebral shape. The result has been a variety of methods for the relative and absolute measurements of vertebral dimensions. Such measurements have also lent themselves to automated computed analysis. The number of techniques reflects the absence of any consensus about the best. The semiquantitative technique proposed by Genant has become the most widely used and has served the field well for comparative purposes. Its use in higher grade fractures has been widely endorsed, if some concepts (e.g., short vertebral height—vertebrae) are at variance with lower grades of fracturing. Vertebral morphometry may be the only recourse in high volume epidemiological and interventional studies.

Key Words: Vertebral fractures; quantitative morphometry; semiquantitative morphometry.

Introduction

The diagnosis of vertebral fractures is often based on changes in shape due to a compressive force along the superior—inferior axis resulting in a fracture of the vertebral end plate. However, due to the nature of the changes, there is no consensus about the definition or grading of fractures. Broadly, the methods for diagnosing vertebral fractures can be classified as qualitative, quantitative, and semiquantitative (SQ).

Qualitatively, a radiologist or other trained observer inspects the spine image(s) and decides whether a given vertebra is fractured. The diagnosis of vertebral fracture by this method is based on several factors such as changes in shape including deformity of the end plate, buckling of cortices, and loss of vertebral height. SQ methods, of which the method of Genant et al *(1)* has been the most widely used, rely on visual identification of abnormal vertebral shape and comparison of its appearance to a chart (Fig. 1). Quantitative morphometry (QM) methods involve actual measurement of vertebral dimensions with the most commonly used method being 6-point morphometry. In addition to the latter, there are other methods based on the shape of the vertebral body *(2,3)*. More recently, QM by parametric modeling of vertebral bodies in 3 dimensions has been developed *(4)*. In this article, we will focus on 6-point morphometry as most of reported studies have used this method.

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*Address correspondence to: Tamara Vokes, MD, Section of Adult & Pediatric Endocrinology, Diabetes, Metabolism, The University of Chicago, 5841 South Maryland Avenue, MC 1027, Chicago, IL 60637. E-mail: tvokes@medicine.bsd.uchicago.edu

Technique: Six-Point Morphometry

On lateral spine images (radiographs or dual-energy X-ray absorptiometry spine images, termed vertebral fracture assessment [VFA]), points are manually or digitally placed on each of the 4 corners of the vertebral body, and 2 additional points are placed in the center of the upper and lower end plates (Fig. 2A). These 6 points are used to determine the anterior, mid, and posterior vertebral heights of each vertebra (Fig. 2A). Using these points, each vertebra is then assigned a type and grade (severity) of fracture. The type of deformity is based on lower than expected ratio of particular vertebral heights: wedge for decreased ratio of anterior-to-posterior heights (Fig. 3A), biconcave for decreased ratio of mid-to-posterior heights, and compression (or crush) for decreased ratio of posterior height to the posterior height of

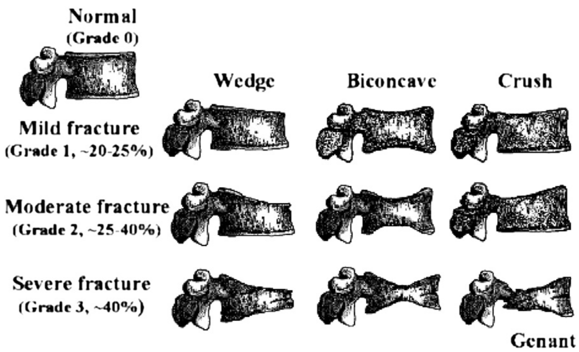

Fig. 1. Genant semiquantitative scale.

adjacent vertebrae (Fig. 3B). However, there is normal variation in the shape of vertebral bodies: mid-thoracic vertebrae may be slightly wedge shaped, and normal lumbar vertebrae may have a biconcave shape *(5)*. How to define what degree of deformity constitutes a fracture and how to assign it a grade are a matter of debate with several methods studied (see in the following section) but no consensus reached.

Although QM is intended to be quantitative, point placement is subjective and not always straightforward. Osteophytes, Schmorl nodes, and the uncinate process at the posterosuperior border of the thoracic vertebrae should be excluded for point placement *(6*; Fig. 4A*)*. Point placement may be challenging for images with these non-fracture deformities and for those with projectional variations resulting from radiographic technique (Figs. 2B and 4B).

Despite subjectivity and difficulty with point placement, the accuracy and precision of QM are reasonably good for well-trained observers. Accuracy was assessed in a small ex vivo study using 9 cadaveric vertebral columns *(7)*. Anterior, mid, and posterior vertebral heights were assessed by direct measurement and by QM performed on radiographs, as well as on dual-energy X-ray absorptiometry images. Both QM approaches were strongly correlated ($r^2 = 0.99$) with direct measurements. Reproducibility of QM was also found to be good in 400 postmenopausal women with low

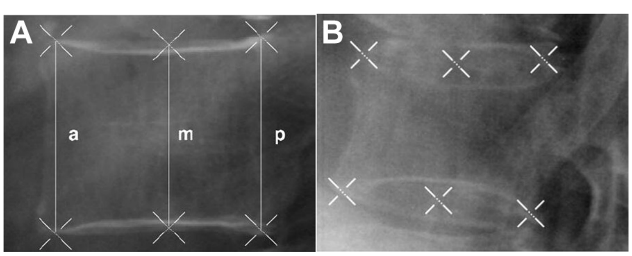

Fig. 2. Placement of morphometric points in a vertebra with orthogonal projection (**A**) and one with obliquity (**B**). Vertebral heights: anterior (a), mid-vertebral (m), and posterior (p). From http://www.advances-in-medicine.net/2011/12/conventional-x-rays-in-the-diagnosis-of-osteoporosis-morphometric-vertebral-fracture-analysis.html.

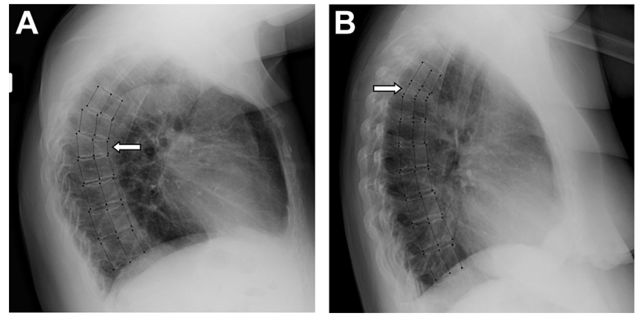

Fig. 3. Examples of spine radiographs with fractures as indicated by the white arrows: wedge fracture at T7—anterior height is lower than posterior height (**A**); crush fracture at T5—posterior height of T5 is lower than the posterior heights of T4 and T6 (**B**). Crush fractures typically have decreased vertebral heights throughout the vertebra. Please note that point placement can be debated in these examples, exemplifying some of the uncertainties in vertebral morphometry.

bone mass and at least 1 vertebral fracture with coefficients of variation of 2%–4% for both intraobserver and interobserver comparisons of vertebral heights *(8)*.

Defining Prevalent Vertebral Fractures

There is no consensus about defining vertebral fractures by QM. Vertebral fractures can be defined as a reduction in vertebral height compared with other heights within the vertebra or to a normal height as determined by a reference population. Furthermore, height differences that constitute a fracture can be based on percent reduction or standard deviation (SD) from the norm.

The Melton Method defined a vertebral fracture as any ratio of anterior-to-posterior height, mid-to-posterior height, or posterior-to-posterior height of adjacent vertebrae that is less than 0.85 *(9)*. To account for natural variations in vertebral shape and size at each level, the individual's ratio may be

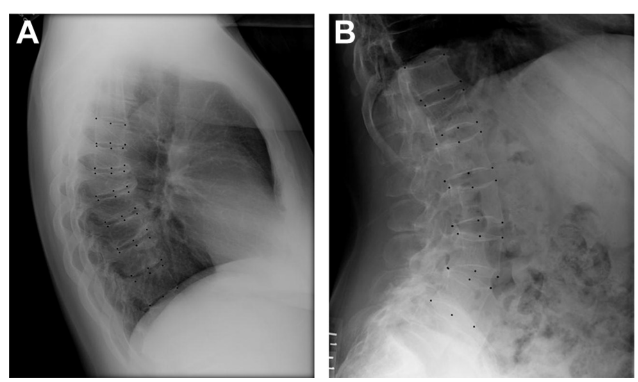

Fig. 4. Challenges to point placement on spine radiographs: avoidance of labeling osteophytes (**A**) and difficulty (subjectivity) of point placement with obliquity (**B**). Please note that point placement in these examples are debatable.