Several different approaches have been used to define vertebral fracture. The traditional qualitative method diagnoses vertebral fracture based on individual readers’ experience. Approaches using quantitative morphometry (QM) and the semi-quantitative (SQ) method were developed to overcome the subjectivity of traditional visual diagnosis, and these methods identify vertebral deformity based on measured (QM) or visual (SQ) estimation of height reduction. A new visual approach, the algorithm-based qualitative (ABQ) method, diagnoses osteoporotic vertebral fractures based on endplate depression alone, regardless of vertebral height reduction.

Osteoporotic vertebral fracture results in vertebral deformity; however, vertebral deformity can result from many conditions other than osteoporotic fracture. QM is unable to exclude deformities that are not caused by fracture, while the SQ method can be difficult to apply. Furthermore, visually estimated height reduction may be in conflict with radiological differential diagnosis. This may explain the finding that the SQ method identifies more ‘fractures’ than QM, particularly at the middle thoracic spine.

The ABQ method was devised by Guirong Jiang to improve accuracy in diagnosing vertebral fracture. The method was developed through examination of the radiological characteristics of incident vertebral fracture. Incident vertebral fractures are more likely to represent true fractures, because they cannot be attributed to normal variation or non-fracture deformities.

Definition of vertebral fracture using ABQ

The principle of the ABQ method for diagnosing vertebral fracture is to detect endplate depression, irrespective of height reduction (see Table 1). The process leading to classification is further described by an algorithm (see Jiang et al and Ferrar et al), which lists various fracture-like appearances that need to be checked and eliminated.

The normal endplate

When examining a spinal image, it is important to understand the radiological anatomy of the vertebral endplate. The endplate is the superior or inferior surface within the stronger edge ring, or vertebral ring. In the absence of vertebral fracture, the endplate is not visible as a separate structure when viewed on a radiological image. When the projection is not oblique, the endplate simply overlays the ring line. When the projection is oblique, two ring lines are visible. The ‘inner’ ring line is projected against the vertebral body and, therefore, appears denser. Whether the nearer or further aspect of the ring appears as ‘inner’ or ‘outer’ depends on the orientation and centring of the projection (see Figure 1; in this example both the superior and inferior endplates lie between the inner and outer.

| Table 1. Endplate depression and height reduction in fracture assessment |
|-----------------|-----------------|
| Fracture        | Endplate depression | Height ‘reduction’ |
| Fracture        | ✓                | ✓ or ✗             |
| Non-fracture deformity | ✗                | ✓                 |
| Normal          | ✗                | ✗                 |
ring lines). This is similar to a ‘bean can’ effect, where the lid represents the endplate. The cortex is the side of the ‘bean can’. The vertebral ring is the thick edge around the lid.

Osteoporotic fracture
Extensive examination of the radiological characteristics of incident fractures found that osteoporotic fracture always involves endplate depression, with or without fracture of the cortex or edge ring. Endplate depression creates an extra line beneath the ring lines, often seen as a smooth concave line (concave fracture; see Figure 2a). When the anterior or lateral cortex also fractures, the vertebra becomes wedged, but concave depression at the central endplate is still seen (wedge fracture; see Figure 2b). When the posterior cortex fractures, as well as the anterior and lateral cortex, the vertebra is crushed (crush fracture; see Figure 2b). In a sense, all ABQ fractures are, therefore, concave fractures.

Height reduction is not necessary to identify a vertebral fracture using the ABQ method, although it may indicate severity. Severity is irrelevant to diagnosis, however, with the ABQ approach, because any fracture that is detected is a true fracture, regardless of the extent of deformity. Assessing severity becomes important only when the ABQ approach is compared with other methods, as the majority of ‘mild fractures’ detected by those methods may not be true fractures.4 With the ABQ method, mild fracture alone has a similar predictive value for subsequent fractures to that of ‘more severe’ fractures.7

Identifying incident vertebral fracture with the ABQ approach also differs from the height reduction criterion used by other methods. For an incident new fracture (in a vertebra without previous fracture; lumbar vertebra L2 in Figure 3), endplate depression is the only criterion, without any minimum threshold for height reduction, as long as true endplate depression is present. An existing fracture could progress to any of:

- A fracture at the opposite endplate to the previous fracture (L3 vertebra in Figure 3)
- Worsening at the same endplate but with a change in type (from a concave to a wedge or crush fracture, or from a wedge to a crush fracture)
- Further height reduction.
Variation in shape, conditions that mimic fractures, and non-osteoporotic fractures

The normal human spine has four curves in the sagittal plane, with a slightly kyphotic thoracic spine and a slightly lordotic lumbar spine; therefore, at the middle thoracic spine, vertebrae are often slightly wedged anteriorly, while at the lower lumbar spine, they are often slightly wedged posteriorly. These vertebrae are normal variants with no endplate depression and are, therefore, not fractures according to the ABQ method, but could be defined as such with methods that use height reduction as the primary criterion. With the ABQ approach, these vertebrae are labelled as short vertebral height, or SVH.4

Congenital or developmental disorders, such as hemi-vertebrae, bone dysplasia and Scheuermann’s disease, can also result in SVH. Vertebrae can be short as well as elongated (increased anterior–posterior width), with a waving or irregular endplate. These vertebrae may have marked height 'reduction' (>40%), but are not fractured, as concave endplate depression is not present.

At least 50% of QM fractures and 75% of SQ fractures from population samples are not fractures according to the ABQ method. In addition, because SVH occurs at particular regions of the normal spine, these false positives are not distributed uniformly throughout the spine. Failure to differentiate SVH from fracture may be the reason for the high frequency of vertebral fractures at the middle thoracic spine identified by the SQ method,4,6,9 and may also be the reason for the poor inter-rater agreement (kappa was 0.33 on a per-subject basis) between SQ readers.9

Some conditions can mimic endplate depression. Poor positioning or inadequate projection may result in a ‘bean can’ appearance, made by the elliptical vertebral ring lines. Overlying organs or tissues can also mimic endplate depression. This can be due to osteophytes (commonly seen at the lumbar spine), the end of the scapula (seen at the level of thoracic vertebrae, T7 or T8), or the glenoid (seen at T4 level). Developmental endplate variations, such as ‘step-like anterior endplate’ and ‘Cupid’s bow’ may mimic fractures.4 Endplate depression can also be seen in some pathological fractures and old traumatic fractures.

The differentiation between traumatic and osteoporotic fracture is a challenge. Criteria for the differential diagnosis have now been formulated and applied to several studies, one of which was presented at the National Osteoporosis Society Conference in 2007.10
Applying the ABQ method to research

The prevalence of fracture determined by the ABQ method is much lower than that determined by height reduction. Using the ABQ method, fracture prevalence was 6.7% among women (n=373, mean age 64 years) enrolled in a study in Sheffield and 7.7% among women (n=390, mean age 66 years) in a study conducted in San Diego, while a prevalence of 24% was found with the SQ method in the study in Sheffield. In a population-based cohort study of American women, aged over 65 years, the fracture prevalence with the SQ method was 32%. This was even higher than the prevalence that was determined using QM (20%), which does not allow for radiological differential diagnosis.

Men tend to have a higher prevalence but lower incidence of fractures than women. The prevalence among men (n=255, mean age 65 years) in the study in San Diego was 11.8%; the ten-year incidence was 3.5% in men, compared with 6.7% in women.

Fractures diagnosed with the ABQ method have a closer relationship with low bone mineral density (BMD) and clinical presentation for osteoporosis. The mean age-adjusted BMD Z-score at the lumbar spine for fractures detected with the ABQ method was –0.75, whereas it was –0.20 with the SQ method (p<0.05). Individuals with fractures agreed by the ABQ and SQ methods had lower BMD than those identified with the SQ approach alone.

Fractures detected by the ABQ method are most commonly at the junction of the thoracic and lumbar spine, while ‘fractures’ diagnosed with the SQ method are reported with a consistently very high frequency at the middle thoracic spine (see Figure 4). This difference in the pattern of distribution is because most SQ ‘fractures’ at the middle thoracic spine are SVH, either normal, normal variants, or Scheuermann’s disease by ABQ. The inter-rater agreement with the ABQ approach is good (kappa 0.74), even when mild fracture is included. The ABQ method has been applied to X-ray absorptiometry images (vertebral fracture assessment, or VFA) from studies with high and low frequency of fracture.

The first longitudinal study using the ABQ approach was published in January 2008, while another was presented at the 2008 Annual Meeting of the American Society for Bone and Mineral Research. Fractures identified by the ABQ method have a high predictive value for future fractures (relative risk [RR] 5.2–5.8), even the identification of mild fractures alone (RR 4.7; p<0.01). SVH, however, is not related to osteoporosis and does not predict future vertebral fracture (RR=0.8; p<0.001). Even for moderate SVH, the RR was 0.9 (p>0.05). SVH may even be associated with a reduced risk of vertebral fracture. When subjects with both SVH and ABQ fracture were also counted into the SVH group, the RR was still below 1.0 (RR=0.4; p<0.05). This could be explained by findings that developmentally wedged vertebrae become resistant to forces due to condensation of the trabeculae beneath the endplates, and that fibrous transformation in the adjacent discs reduces the hydraulic pressure against the endplates.

Applying ABQ in clinical practice

In Sheffield, the ABQ method has been used to better identify which patients have a vertebral fracture, with the aim of using this method in the routine management of osteoporosis. Appropriate training in vertebral appearance and in this method improves accuracy of diagnosis, compared with mere emphasis on height reduction,
and, therefore, provides a better service to patients. Training is necessary because a reorientation of perspective is required. For individuals with experience in examining vertebral fracture, training of a few hours, with several examples, may be sufficient to allow the application of the ABQ method.

References

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Key points

- The algorithm-based qualitative (ABQ) method diagnoses vertebral fracture based on endplate depression alone, regardless of vertebral height reduction.
- The ABQ method may be more closely aligned with clinical fracture and has a high predictive power for future fracture.
- The ABQ perspective is useful when examining routine clinical images.