Vertebral Fracture Initiative

Part II

Radiological Assessment of Vertebral Fracture

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EXECUTIVE SUMMARY

Vertebral fractures are powerful predictors of future spine and hip fractures, so accurate diagnosis and clear, unambiguous reporting are essential.

There is considerable evidence that vertebral fractures are under-reported, and when present appropriate intervention may not occur.

The purpose of this document is to raise awareness of the relevance and importance of identification of vertebral fractures, be it on spinal radiographs or fortuitously from other images (lateral chest radiographs, mid-sagittal spinal reformations from multi-detector computed tomography [MDCT] of thorax and abdomen, magnetic resonance imaging [MRI] and radionuclide scans [RNS]).

Methods to differentiate vertebral fractures from other causes of vertebral deformities are outlined. The aim is to improve the diagnosis and management of osteoporosis and so reduce fractures and suffering.
1. INTRODUCTION

Osteoporosis-related vertebral fractures have important health consequences for older women, including disability and increased mortality (1). As further fractures can be prevented with appropriate medications, recognition and treatment of these high-risk patients is warranted. Hence the early and accurate diagnosis of vertebral fractures is an important factor in optimizing the clinical management of patients with osteoporosis.

Although osteoporotic vertebral fractures are common in men and women, and the presence of these fractures indicates that patients are at substantially increased risk for new fractures of the spine and hip (2), there is strong evidence of widespread under-diagnosis of vertebral fractures (3-6). In particular, clinicians often fail to recognize or report mild and moderate vertebral fractures, or use terminology that is not specific for fracture. There is therefore an urgent need to improve evaluation of patients who have vertebral fracture.

The purpose of this document is to emphasize the importance of appropriate diagnosis of vertebral fractures in osteoporosis, and to provide a basis for standardization of radiographic acquisition and radiological interpretation that require no specialized equipment and can be performed by any appropriately trained clinician. Improved and accurate diagnosis of vertebral fractures will enhance patient evaluation and the ability to target appropriate therapeutic intervention to those patients who would benefit most, and so reduce the risk of future fracture.
2. INDICATIONS FOR SPINAL RADIOGRAPHS

Clinical indications for spine radiographs, in the absence of trauma or malignancy, include acute back pain, focal tenderness, loss of height and known, or suspected, cases of osteoporosis, either primary or due to secondary causes (7). Spinal radiographs, and dual energy X-ray absorptiometry (DXA), would also be appropriate in patients over 50 years of age who have other radiographic features suggesting osteoporosis (thinned cortices, reduced density [radiographic osteopenia], reduced number of trabeculae) in any skeletal site (8-10).

3. ACQUISITION OF SPINAL RADIOGRAPHS

A. Ideal Radiographic Technique

For the initial assessment of vertebral osteoporotic fracture, spinal radiographs are still the most common imaging technique used. Separate antero-posterior (AP) and lateral radiographic views of the thoracic and lumbar spine are used. For follow-up examination lateral thoracic and lumbar spine radiographs generally suffice. Radiographs of the thoracic and lumbar spine should be acquired using a standardized protocol so that there is consistent technique and good quality radiographs are obtained (11, 12). The focus-to-film distance (FFD) is generally 100 cm. Thoracic radiographs are centered at T7 and the lumbar radiographs at L3.
Antero-posterior (AP) spinal radiographs

AP views of the spine are used to accurately define the number of vertebrae present and may aid in the detection of vertebral fracture. On the AP views, all the relevant vertebrae should be clearly visible on the radiograph; for the thoracic spine vertebrae C7-L1, and for the AP lumbar spine T12 to S1, should be visible (Fig 1a and b). For the thoracic spine the top of the X-ray cassette is placed 5 cm (2 inches) above the shoulders. For the lumbar spine the natural lumbar lordosis has to be reduced so that the spine is flat on the X-ray table. This is achieved by flexing the hips and knees, with a small supporting pad being placed under the knees. The vertebral levels are accurately identified by counting down from the top of the thoracic spine. With this method, anomalies in the number of thoracic and lumbar vertebrae can be identified.

Adequate collimation of the X-ray beam is important so that radiosensitive organs such as the breast and thyroid are not unnecessarily irradiated (13), and the radiation dose to the patient is kept to a minimum (Table 1). Adequate collimation also reduces scattered radiation and thus improves contrast. For the AP thoracic view, the collimation should not be too narrow; if cervical ribs or vestigial ribs at T12 are present, they should be clearly visible (Fig 1a).
Table 1. Typical patient effective radiation doses: from spine, chest and other radiographic examinations. The average effective doses from the annual natural background radiation and from a return transatlantic flight are given for comparison.

<table>
<thead>
<tr>
<th>Type of exposure</th>
<th>Effective Dose (mSv)</th>
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<tbody>
<tr>
<td>Thoracic spine</td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>0.4&lt;sup&gt;1,2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.3&lt;sup&gt;1,2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>0.7&lt;sup&gt;1,2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.3&lt;sup&gt;1,2&lt;/sup&gt;</td>
</tr>
<tr>
<td>PA Chest</td>
<td>0.02&lt;sup&gt;1,2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pencil beam DXA (spine)</td>
<td>&lt;0.001&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fan beam DXA (spine)</td>
<td>~ 0.01&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Quantitative computed tomography (QCT): spine</td>
<td>0.06&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>Annual natural background radiation (NBR)</td>
<td>2.4&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Return transatlantic flight (16 hours total flight time)</td>
<td>~0.07&lt;sup&gt;7&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> Wall BF, Hart D 1997 Revised radiation doses for typical X-ray examinations Report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB. National Radiological Protection Board. Br J Radiol;70(833):437-9
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Lateral spinal radiographs

Because the lateral views of the thoracic and lumbar spine are the most important for assessment of osteoporotic fracture, time and attention should be taken to correctly position the patient (Fig 2a and b). The important factor is to have the patient in the true lateral position with the spine parallel to the X-ray table to avoid rotation or scoliosis, as the latter will cause ‘tilting’ of the vertebrae causing biconcavity of the endplates (‘bean can’ effect) (Fig 3a and b). Visualization of the thoraco-lumbar junction on the lateral thoracic radiograph is useful to identify the vertebral levels. Accuracy in marking the vertebral levels at the thoraco-lumbar junction is aided by visualization of the posterior spinous processes, which change shape at the levels of T12 and L1, and also by confirmation of the presence and size of the lower ribs on the AP thoracic view.

For the lateral thoracic spine the cassette is positioned with the top 5 cm (2 inches) above the patient’s shoulders (Fig 2a). The important factor is to have the patient in the true lateral position with the spine parallel to the X-ray table to avoid rotation or scoliosis. With the patient’s shoulders, hips, knees and ankles superimposed, and with padding between the elbows and knees, this position can be maintained. With the spine parallel to the film/X-ray table the vertebral endplates are vertical to the film and parallel to the X-ray beam which avoids the parallax effect of the divergent X-ray beam. The latter falsely causes apparent biconcave endplates which must not be erroneously identified as endplate fractures (Fig 3a). A radiolucent pad may be required under the lumbar spine at waist level to straighten the lower thoracic spine so that it is parallel to the X-ray table and avoids sagging of the spine.
towards the film at the waist. If this cannot be achieved due to fixed scoliosis, then angulation of the X-ray tube towards the head may be used (11).

To visualize the upper thoracic vertebrae, the arms should be raised so that the scapulae are not superimposed on the vertebra. If the arms are raised too high above the head, the scapulae may be superimposed on the upper thoracic vertebral bodies, making it difficult to visualize the vertebral endplates. This can be overcome by placing the patient’s arms at right angles to the body.

With the breath-hold technique in the thoracic spine, the margins of the ribs may obscure the vertebral body endplates. This may be overcome by the breathing, or long exposure, technique. This causes movement blurring of the overlying ribs and lung parenchyma so that the vertebral bodies are more clearly visualized. This technique may be difficult in elderly patients, as the patient has to remain still during the longer exposure time (usually 2-4 seconds) associated with this technique. This technique is not possible on X-ray equipment that relies on automatic exposure time. The radiation dose is a little higher when the breathing technique is used (Table 1). The quality of the radiograph is improved further by placing a sheet of lead rubber on the X-ray table posterior to the spine so that backscatter is reduced.

For the lateral lumbar spine view, T12 to S1 should be visualized on the radiograph in the true lateral position without rotation or obliquity (Fig 2b). The presence of the last 12th rib and the lower thoracic vertebrae on the lateral lumbar spine view help to accurately define
the vertebral levels. This is especially so in cases of lumbarization of S1 or sacralization of L5, where the identification of T12 is important.

As with the lateral thoracic view, it is imperative that the shoulders, hips, knees and ankles be superimposed, and padding should be used between the elbow, knees and ankles to assist in maintaining the true lateral position without rotation. The lumbar spine must also be parallel to the film to avoid the biconcave endplates (‘bean can’ effect) due to tilting of the vertebrae (Fig 3b). With the patient in the lateral decubitus position, the long axis of the lumbar spine tends to run obliquely in direction from L1 to L5. This can be corrected by placing radiolucent pads under the upper part of the lumbar spine. Alternatively, the X-ray tube can be angled toward the feet so that the X-ray beam is perpendicular to the spine.

**B. Technical Problems**

The thickness of the shoulders overlying the upper thoracic vertebrae makes it difficult for the X-ray beam to penetrate through the shoulder girdle. The upper lateral thoracic region is one of the most difficult regions of the body to radiograph successfully (11). Fortunately isolated osteoporotic fractures rarely occur at levels T1-3 (14, 15). Similarly, L5 can sometimes be difficult to see on the lateral view because of the thickness of the pelvis (13). Furthermore, because of the parallax effect, L5 may be difficult to visualize clearly in the lateral position, and a coned view may be useful (16).
Because of the differences in shape of the chest and the presence of the radiodense heart overlying the lower thoracic spine, it may be difficult to visualize the whole of the thoracic spine on the AP position. This effect is a particular problem in large or kyphotic patients.

With mild scoliosis, it may be useful to obtain the radiograph as the patient lies on the side of the convexity of the scoliosis. With the scoliotic curvature of the spine away from the X-ray table and with the use of the parallax effect, the vertebral bodies and inter-vertebral disc spaces may be seen more clearly.

4. VERTEBRAL FRACTURES

Clinical Identification of Vertebral Fractures

Although vertebral fractures are common in postmenopausal women, they are difficult to identify clinically (i.e. without spinal radiographs). Large-scale prospective studies indicate that only about one in four vertebral fractures are clinically recognized (17), and it is relatively uncommon for patients to be referred for radiographs in the course of investigation of osteoporosis. The lack of clinical recognition of fractures is due to both the absence of symptoms and difficulty in determining the cause of symptoms, which may have a variety of origins. For example, it has been estimated that less than 1% of episodes of back pain are related to vertebral fractures (18). As a result, vertebral fractures are not commonly suspected in patients reporting back pain, unless the back pain is associated with trauma. Trauma-related fractures are not considered classical (atraumatic) osteoporotic fractures. Height loss, another indicator of vertebral fractures, is also difficult to assess clinically. Some height loss
is expected with ageing due to the dessication and compression of intervertebral discs, and postural changes. Studies have concluded that height loss is an unreliable indicator of fracture status until it exceeds 4 cm (19). Unfortunately, a loss of 4 cm could also be due to multiple vertebral fractures, by which time significant and irreparable damage may have occurred.

The quantitative definition of a vertebral fracture is also contentious, and in epidemiology and pharmaceutical efficacy studies a variety of morphometric measurements have been used (Fig 4). In these six points are placed on the vertebral body: at the anterior, middle and posterior point of the upper and inferior endplates. These points define reductions in the anterior (wedge) and mid (endplate) vertebral heights in relation to posterior heights to determine change in vertebral shape, or posterior height in relation to such height in adjacent vertebrae to determine degree of crush fracture, or variations of these parameters (Appendix) (20,21). However, in a clinical setting more simple methods for the accurate diagnosis and classification of vertebral fractures are required. Also, if six-point morphometry alone is used to define vertebral fractures then other pathologies which change the shape of vertebra (e.g. Scheuermann’s disease, spondylosis, etc) will erroneously be classified as fractures (22).

**a) Radiographic Identification of Vertebral Fractures**

Because it is often unsuspected clinically, the diagnosis of vertebral fracture relies upon accurate radiographic detection and a succinct, unambiguous radiographic report of fracture (23). Yet in a single-center retrospective study of hospitalized elderly women, 50% of radiographic reports failed to report the presence of moderate or severe vertebral fractures
and many patients (over 90%) remained untreated (3). There is other evidence that vertebral fractures are under-reported (4-6).

Clinicians who interpret spine radiographs generally analyze radiographs of the thoracolumbar spine in the lateral projection to identify vertebral fractures. Vertebral fractures usually cause change in shape of the vertebrae, but not all vertebral deformities are due to fractures. To differentiate fracture from deformity the interpreter takes into account not only shape but also other features, such as the appearance of the endplate (24-28). The interpretation can be aided by additional radiographic projections such as oblique views, or by complementary examinations such as CT, MRI, or radionuclide scans (25). As with other fractures, vertebral fractures have characteristic features that allow description and classification, e.g. gradations in severity, the permanent nature of the deformity and the possibility of a refracture at the same vertebral level from serial radiographs. However, there is lack of standardization of radiologic assessment of vertebral fractures in routine clinical practice, especially when attention is not focused specifically on the issue of fracture identification. In this setting, the interpreting clinician often fails to recognize or report many mild, and some moderate, fractures, or uses terminology that is non-specific and does not adequately alert the referring clinician to the presence of a vertebral fracture and its consequent importance in osteoporosis diagnosis and management.

**Standardized Approach**

Among the diagnostic protocols to diagnose vertebral fractures, the method proposed by Genant et al (29) seems to be the most suitable for clinical applications, since the severity of
all vertebral fractures is assessed in a semi-quantitative fashion. The severity of a fracture is assessed solely by visual determination of the extent of vertebral height reduction and morphological change, and vertebral fractures are differentiated from other, non-fracture deformities. The approximate degree of height reduction determines the assignment of grades to each vertebra. Unlike the other approaches, the type of deformity (wedge, biconcavity or compression) is no longer linked to the grading of a fracture in this approach.

Using the Genant et al (Fig 5) (29) semi-quantitative (SQ) method, thoracic and lumbar vertebrae are graded on visual inspection of lateral spinal images and generally without direct vertebral measurement as normal (grade 0) (Fig 6a); mildly deformed (grade 1: approximately 20-25% reduction in anterior, middle, and/or posterior height and 10-20% reduction of the projected vertebral area) (Fig 6b); moderately deformed (grade 2: approximately 25-40% reduction in anterior, middle, and/or posterior height and 20-40% reduction of the projected vertebral area) (Fig 6c); and severely deformed (grade 3: approximately 40% or greater reduction in anterior, middle, and/or posterior height and in the projected vertebral area) (Fig 6d). There is less consistency in diagnosis of mild (grade 1) fractures, than with moderate (grade 2) and severe (grade 3) fractures (30, 31).

In addition to height reductions, careful attention is given to alterations in the shape and configuration of the vertebrae relative to adjacent vertebrae and expected normal appearances. These features add a strong qualitative aspect to the interpretation and also render this method less readily definable as either qualitative or quantitative. Jiang et al (26) have described an algorithm-based qualitative (ABQ) method in which the vertebral endplate
is scrutinized for features which are useful in the differentiation of fractures from other causes of vertebral deformities.

Assessing the severity of the deformation as the reduction of vertebral height has the effect (especially for the interpretation of incident fractures) that refractures of pre-existing vertebral fractures can be assessed using the SQ method. This is an advantage of the SQ method over the other standardized visual approaches, since it considers the continuous nature of vertebral fractures and enables a meaningful interpretation of follow-up radiographs.

Visual qualitative assessment of vertebral fractures using standardized grading schemes has been found to be more reproducible than inspection of radiographs without specific criteria for fracture diagnosis. Thus, standardized approaches have been found to be valid research tools in epidemiological research and in clinical therapeutic trials. In contrast to the purely morphometric analysis using digitization techniques, a visual assessment considers the differential diagnosis of vertebral deformities. This is of great importance for the reliability of prevalence and incidence data of vertebral fractures.

With respect to incident fractures a reader can, for example, adjust for magnification effects or different centering of the X-ray beam, whereas these technical effects may actually have a negative influence on assessments that are based solely on morphometric analysis of the vertebral dimensions.
Ensuring the reliability of interpretation of incident vertebral fractures on serial radiographs requires close attention to the radiographic procedure used. Serial radiographs of a patient should always be viewed together in temporal order so as to accomplish a reliable analysis of all new fractures.

The strength of standardized visual approaches is their use of a reader’s expertise in the interpretation of vertebral deformities to differentiate fracture from non-fracture deformities, or technical artifacts. However, this also constitutes their potential weakness, since there is room for subjectivity in the interpretation. The reader’s training and experience are therefore of utmost importance for valid use of standardized visual techniques; with trained, experienced readers it has been shown that SQ grading of vertebral fractures can be applied reliably (29, 32, 33).

5. FORTUITOUS DIAGNOSIS OF VERTEBRAL FRACTURES

Fortuitous diagnosis of vertebral fractures merits special attention. These vertebral fractures, although frequently asymptomatic, still increase the risk of future vertebral and hip fractures. They may also be used as an indication for further patient evaluation with DXA bone densitometry and clinical investigation. In some cases patients may be candidates for pharmacologic therapy to reduce future fracture risk, based on these fractures. For these reasons it is important that reports from such diverse imaging studies as lateral chest radiographs (Fig 7a), abdominal radiographs, barium studies, CT scans (Fig 7b), MRI studies, and radionuclide scans include the presence of incidental vertebral fractures. With
multi-detector computed tomography (MDCT) of the thorax and abdomen, which are examinations that are widely performed for various clinical indications, it is useful for midline sagittal reformations to be obtained routinely, particularly in women over 65 and men over 70 years. Vertebral fractures will be identified on the sagittal reformations which are not evident on the transverse axial images and which may be clinically silent (34-37) (Fig 7b).

6. DIFFERENTIAL DIAGNOSIS

There are various normal variants, congenital abnormalities, degenerative changes, fractures and other pathologies which can change the shape of vertebrae (Table 2). Differential diagnosis of vertebral fractures includes all types of osteoporosis, both primary and secondary, trauma, infection and malignancy (pathologic fractures).

Table 2. Differential diagnoses of changes in shape of vertebral bodies

<table>
<thead>
<tr>
<th>Vertebral fractures</th>
<th>Vertebral deformities</th>
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<tbody>
<tr>
<td><strong>Osteoporotic</strong> (low trauma)</td>
<td>Developmental</td>
</tr>
<tr>
<td><strong>Traumatic</strong></td>
<td>(short vertebral height, ‘butterfly’ vertebra and other abnormalities of spinal segmentation, ‘block’ vertebrae)</td>
</tr>
<tr>
<td><strong>Pathological</strong></td>
<td><strong>Normal variants</strong></td>
</tr>
<tr>
<td>(neoplastic, hemopoietic diseases and infections)</td>
<td>(‘cupid’s bow’, anterior step deformity)</td>
</tr>
<tr>
<td></td>
<td><strong>Scheuermann’s disease</strong></td>
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<tr>
<td></td>
<td>(juvenile osteochondritis)</td>
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<td></td>
<td><strong>Spondylosis</strong></td>
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<tr>
<td></td>
<td>(degenerative disc disease)</td>
</tr>
<tr>
<td></td>
<td><strong>Metabolic</strong></td>
</tr>
<tr>
<td></td>
<td>(osteomalacia, Paget’s disease)</td>
</tr>
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</table>
Deformities can be related to developmental anomalies (e.g. short vertebral height Fig 8a; cupid’s bow Fig 8b; anterior step deformity), Scheuermann’s disease (Fig 8c); degenerative disc disease (spondylosis Fig 8d) which changes the modeling of the vertebra and Schmorl’s node (Fig 8e). The ABQ method suggests a pathway (Table 3) aimed at assisting the interpreting clinician in differentiating fractures from deformities (26). This is accomplished by careful scrutiny of the endplate; in vertebral fracture the endplate is irregular, with texture change adjacent and below, due to micro-fractures, whereas in non-fracture deformities the endplate is more distinct with characteristic abnormalities (Fig 8a-e). In congenital anomalies the endplate is generally distinct (Fig 8a and b). In Scheuermann’s disease there is endplate irregularity and slight wedging of several adjacent vertebrae, most commonly in the mid and lower thoracic spine (Fig 8c). In spondylosis there is slight wedging and elongation (increase in AP diameter of the vertebral body) with narrowing of the disc space and marginal osteophytes (Fig 8d). Schmorl’s nodes, in which there is prolapse of disc material into the vertebral body, there are bone defects with sclerotic margins in the anterior and posterior aspect of the vertebra adjacent to the endplate (Fig 8e).

In pathological fractures related to such etiologies as bone metastases or myeloma (Fig 9a and b) there is often cortical destruction and bulging into the spinal canal of the posterior vertebral margin, and other imaging techniques such as MRI (Fig 9c) are required for diagnosis (25).
Table 3. Algorithm-based Qualitative (ABQ) Assessment of vertebral fracture
(Drawn from reference 26)

7. REPORTING

a) Clear and accurate terminology must be used

If there is a fracture, then the term ‘fracture’ must be used, and terms such as ‘collapse’ and others should be avoided (23). It is relevant to give the grades (1-3; mild, moderate or severe) (29) and number of fractures present, as the more severe the grade, and the more vertebral fractures which are present, indicate that the patient is at higher risk of future fracture (38). Even mild fractures must be clearly identified as they are determinants of
Further fracture risk (39), and combined with BMD can enhance prediction of fracture risk (40).

Other features to suggest spinal osteoporosis (prominent vertical trabecular striations, as the horizontal trabecular are lost preferentially; thinned cortices, radiographic osteopenia) should also be commented upon (8-10). The report should indicate if the fracture is osteoporotic, traumatic or pathological in origin, and suggest further appropriate imaging, if relevant. If the change in vertebral shape is not due to fracture, then the term ‘deformity’ should be used and the cause of the deformity suggested (normal variant, congenital anomaly, Scheuermann’s disease, spondylosis, Schmorl’s nodes, etc).

**b) Importance of WHO FRAX® calculator**

In 1994 the World Health Organization (WHO) defined osteoporosis in postmenopausal women, in terms of bone mineral densitometry (BMD) as performed by DXA in the lumbar spine (L1-L4), proximal femur and distal forearm. A T-score (standard deviation [SD] score related to mean BMD of young [20-29 years] normal Caucasian women) equal to, or below, -2.5 was defined as osteoporosis in postmenopausal women (41). However, this was never a satisfactory BMD level for intervention as age is such a strong and independent determinant of fracture. In 2008 the WHO published a tool (FRAX®) to calculate 10-year fracture risk for individual patients aged between 40 and 90 years using clinical risk factors (with or without femoral neck DXA BMD) (42,43). The clinical risk factors used in the calculator include age, gender, height, weight, previous low trauma fracture over age 50, parental hip fracture, oral glucocorticoid therapy (for more than 3 months at a dose 5mg daily or more), rheumatoid arthritis, current smoking, alcohol consumption (more than 3 units per day) and
secondary causes of osteoporosis (including type I [insulin dependent] diabetes, osteogenesis imperfecta in adults, untreated long-standing hyperthyroidism, hypogonadism or premature menopause (<45 years), chronic malnutrition, or malabsorption and chronic liver disease). Subsequently national guidelines for appropriate treatment interventions were launched in several countries (44,45). The presence of vertebral fracture therefore influences the calculation of fracture risk in the FRAX® tool and consequently affects management of patients. However, FRAX® underestimates the risk when more than 1 vertebral fracture is diagnosed; both severity and number of vertebral fractures are strong determinants of risk of further fractures (46) Fracture risk prediction is also enhanced by combining vertebral fracture status and BMD. Thus FRAX® may not be useful in patients with spinal osteoporosis with multiple and severe vertebral fractures.

c) Suggest referral for central DXA

If a low trauma vertebral fracture is present on imaging studies then the report must include advice to consider further relevant investigation (e.g. performing central DXA) and management to referring clinicians. This should be compatible with national guidelines, which may vary between countries.

This would ensure that patients found to have vertebral fractures on imaging studies are further evaluated, resulting in reduction in the suffering related to osteoporotic fractures.
8. CONCLUSIONS

Vertebral fractures are the most common consequence of osteoporosis, occurring in a substantial proportion of post-menopausal women and elderly men. Most vertebral fractures, however, are not clinically recognized and can occur and accumulate silently. It is established that the presence of a vertebral fracture is a strong risk factor for subsequent osteoporotic fractures, and that patients with low BMD and vertebral fractures are at highest risk. Large-scale clinical trials have demonstrated that osteoporosis therapies can increase BMD (by 4-12%) and reduce fracture rates (vertebral fractures can be reduced by 40-70%) (47,48). These benefits are most pronounced in patients with low BMD and vertebral fractures. Clinical guidelines promulgated by the International Osteoporosis Foundation, National Osteoporosis Foundation, and others around the world, recognize the importance of vertebral fractures, along with BMD, as key risk factors for use in patient evaluation. However, while BMD is widely used in patient evaluation, radiologic assessment of vertebral fractures is not commonly performed, or if performed, is inadequately standardized and interpreted. By understanding the clinical principles of osteoporosis diagnosis and management provided in this document, by adopting the radiological guidelines for assessing vertebral fractures provided herein and by clearly indicating “vertebral fracture” in the patient’s report clinicians worldwide can contribute substantially to reducing the consequences of osteoporosis.
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FIGURES:

Figure 1: Good technique for spinal radiography: AP views
a) thoracic spine: the levels from C7 to at least L1 need to be visualized; centering at T7, and field of view wide enough to include first (or cervical) and 12th ribs, to enable accurate counting of vertebral bodies
b) lumbar spine: levels from at least T11 to sacrum need to be visualized; centering L3. Spine needs to be as flat as possible to the X-ray table, without rotation.
Figure 2: Good technique for spinal radiography: lateral views

a) thoracic spine: the arms are positioned so as to rotate the scapulae off the upper thoracic spine and centering at T7; the levels from at least T4 to L1 should be assessable

b) lumbar spine: the levels from at least L11 to L4 should be assessable; centering is at L3. For both views it is essential that the spine is parallel to the X-ray film/table so as to avoid tilting of the vertebrae which causes apparently biconcave endplates.
Figure 3: Technical problems: because of the divergent X-ray beam if centering is not ideal, the spine is not parallel to the X-ray table or if there is a spinal scoliosis then the vertebrae appear tilted and have apparently biconcave endplates as illustrated in lateral a) thoracic and b) lumbar spine radiographs, and which must not be erroneously diagnosed as vertebral fractures.
**Figure 4: Six point vertebral morphometry:** this is a quantitative method of assessing vertebral shape by placing a) six points on the superior and inferior endplate at the front, mid and posterior margins. From these can be measured the b) anterior (A), middle (M) and posterior (P) heights and various ratios calculated.
Figure 5: Semi-quantitative (SQ) assessment of vertebrae classifying them as normal or graded: 1 mild, 2 moderate and 3 severe vertebral fractures according to the degree of change in shape of the vertebra (Drawn from reference 29).
**Figure 6: Vertebral fractures:** a) normal appearance b) grade 1 mild upper endplate fracture c) grade 2 moderate vertebral fracture d) grade 3 severe vertebral fractures
Figure 7: Fortuitous diagnosis of vertebral fractures: a) vertebral fractures may be evident on lateral chest radiographs as evident in the lower thoracic spine; b) MDCT of the thorax and abdomen are frequently performed in radiology department. With routine reformatting of mid line sagittal images through the spine, particularly in women over 65 and men over 70 years of age, will demonstrate vertebral fractures which are not visible on transverse axial sections and which may be asymptomatic and so not clinically suspected (upper endplate grade 2 moderate fracture of L1).
**Figure 8: Vertebral deformities:** etiologies other than vertebral fractures can change the shape of vertebrae. Developmental anomalies such as 
a) short vertebral height, as evident in two of these lower thoracic vertebrae; the endplate is crisp excluding fracture as cause; 
b) ‘cupid’s bow’ is a normal variant depicted by a smooth concavity in the posterior, inferior endplate as illustrated in the lumbar spine 
c) Sheuermann’s disease (juvenile osteochondritis) affecting several, adjacent thoracic vertebral endplates which are irregular, with slight wedging and elongation of the vertebral bodies 
d) spondylosis in which there has occurred remodeling of the vertebral body due to degenerative disc disease as evident by anterior marginal osteophytes 
e) Schmorl’s nodes in the endplates of T8 which may simulate fractures. These tend to occur in the anterior and posterior endplates and have sclerotic margins.
Figure 9: Pathological vertebral fractures: multiple myeloma: a) lateral thoracic spine radiograph and b) sagittal spine reformation from MDCT showing diffuse lytic areas with vertebral fractures and destruction of cortical margins, a sinister feature in vertebral fractures c) multiple bone metastases: T2 weighted sagittal MR scan showing heterogenous signal intensity of vertebral bodies and a pathological fracture of T11. The latter has posterior bulging of its posterior margin, another sinister feature in vertebral fracture.
10) APPENDICES

METHODS USED TO DEFINE CHANGE IN VERTEBRAL SHAPE

A) STANDARDIZED METHODS FOR FRACTURE ASSESSMENT

The first quantitative method to assess vertebral deformities was Fletcher’s “index of wedging” in which normal variations in anterior heights were compared with posterior heights (1). Barnett and Nordin used a “biconcavity index” in which the biconcavity of a vertebra was measured as a quotient of the middle vertebral height and the anterior vertebral height (2). This quotient was assessed from only one lumbar vertebra, and a value of less than 0.8 was regarded as an indication of osteoporosis. Hurxthal was the first to describe in detail the measurement of vertebral heights for the purpose of assessing anterior wedge fractures (3).

Since then many epidemiologic studies and clinical trials have used various morphometric methods to identify fractures (4-6). Melton’s method defined vertebral fractures using percentage reductions in ratios of anterior, middle or posterior heights of vertebral bodies compared with normal values for that particular vertebral body (5). Eastell et al. modified this method, defining fractures on the basis of standard deviation reductions instead of fixed percentages (7). McCloskey et al. modified Eastell/Melton methods by including the use of predicted posterior heights (8). The Minne et al. method compared vertebral heights that have been normalized for body size by dividing all values by the corresponding values of T4 and comparing the results to values in healthy young women (6). Other groups have also used different approaches to vertebral morphometry (9-11).
B. SEMI-QUANTITATIVE (SQ) METHOD

In addition to morphometric methods, semi-quantitative (SQ) methods for detecting vertebral fracture have been used in various research settings. In these approaches there is the assignment of numeric scores to vertebral fractures, or their assignment to distinct categories, according to their shape or type and their severity, in a definable and reproducible manner without making measurements of vertebral dimensions. Several SQ methods have been used.

The first standardized approach was proposed by Smith and colleagues (12). Like the biconcavity index of Barnett and Nordin (2), the method grades only the vertebra with the most severe deformity on the radiograph (12). In contrast to Smith et al., Meunier graded each vertebra according to its shape (13). Grade 1 is assigned to a normal vertebra that has no deformity; grade 2 to a biconcave vertebra; and grade 3 to an endplate fracture or a wedged or crushed vertebra (14). Kleerekoper et al. modified Meunier’s method and introduced the “vertebral deformity score” (VDS) (15). In the VDS each vertebra from T4 to L5 is assigned an individual score from 0 to 3, depending on the type of deformity. This grading scheme is based on the reduction of the anterior, middle, and posterior vertebral heights (ha, hm, and hp respectively). A vertebral deformity (graded 1 to 3) is present when ha, hm, or hp is reduced by at least 4 mm or 15% (15).

C. GENANT SEMI-QUANTITATIVE (SQ) METHOD

The strength of a Genant SQ method is that it makes use of the entire spectrum of visible features that are helpful in identifying vertebral fractures (16,17). In addition to changes in dimension, vertebral fractures are detected visually by the presence of endplate
abnormalities, lack of parallelism of the endplates, and general alterations in appearance when compared with neighboring vertebrae (Fig. 5, 6b-d). These visual characteristics may not be captured by the six digitized points used in morphometric methods (Fig. 4). Subtle distinctions between a fractured endplate and deformity associated with Schmorl’s nodes can be made visually only by an experienced observer (Fig. 8e). The same is true for the wedge-shaped appearance caused by remodeling of the vertebral bodies in degenerative disc disease (spondylosis) (Fig. 8d).

As with prevalent fractures, most incident fractures are easily identifiable on sequential radiographs. The inevitable variation in positioning of patients and parallax effect of the divergent X-ray beam may result in differences in point placement on follow-up radiographs. This can result in the morphometric detection of an incident fracture that would be interpreted visually as simply an alteration in radiographic projection. These sources of false-positive or false-negative interpretations are particularly common when parallax problems arise due to poor radiographic technique or improper patient positioning.

The reproducibility of Genant’s SQ method has been assessed in various studies (16,18-21). In one study inter-observer agreement was 94% (kappa score 0.74) for the diagnosis of prevalent fractures and 99% (kappa score 0.80) for the diagnosis of incident fractures (16). In another study Li et al. (18) reported the inter-observer agreement was about 94% for the dichotomous fracture/non-fracture diagnosis (the respective kappa scores were 0.80 to 0.81). The agreement between the two readers using the whole grading scale to rate fractures was 90.6%, with a corresponding kappa score of 0.69. Wu et al. reported on the agreement of the
Genant SQ method for the assessment of incident vertebral fractures (21,22). Kappa scores ranged from 0.80 to 0.84.

There are limitations of the Genant SQ method that may also apply to other standardized approaches. For example, from morphometric data in normal subjects vertebrae in the mid-thoracic spine and in the thoraco-lumbar junction are slightly more wedged than in other regions of the spine (short vertebral height) (Fig. 8a) (8,23-25); consequently normal variations may be misinterpreted as mild vertebral deformities (8,26,27). This may falsely increase prevalence results for vertebral fractures from visual readings in the specific anatomical regions. The same applies, to a lesser extent, in the lumbar spine, where some degree of biconcavity is frequently seen (normal variants e.g. ‘cupid’s bow) (Fig 8b). Accurate diagnosis of prevalent fractures, which requires that the reader distinguish between normal variations and the degenerative changes resulting from true fractures, still depends on the experience and training of the observer.

It has been argued that the diagnosis of mild vertebral fractures in particular may be quite subjective, and that these fractures may be unrelated to osteoporosis (8). However, mild grade 1 fractures detected with the SQ method are also associated with a lower BMD than normal, and they also predict future vertebral fractures, although to a lesser extent than do moderate (grade 2) or severe (grade 3) fractures (28).

For the diagnosis of incident fractures, other limitations may apply. Generally, incident fractures are easily identified qualitatively on serial spinal radiographs, since a direct
comparison with baseline radiographs is possible. Using the Genant SQ method for the assessment of incident fractures, however, the reader may sometimes feel that even though a further height reduction is evident in a vertebra, it may not justify assigning a higher grade to the incident fracture in comparison with the pre-existing prevalent fracture, since some degree of settling or remodeling of the vertebral shape generally occurs following a fracture. Therefore, in general, serial radiographs of a patient should be viewed together so that incident fractures can be readily identified. Only those progressive changes that lead to a full increase in deformity grade or an increase from a questionable deformity (grade 0.5) to a definite fracture constitute designation as an incident fracture.

D. COMPARISON BETWEEN GENANT SQ METHOD AND MORPHOMETRIC TECHNIQUES

Quantitative morphometric assessment of vertebral fracture was developed to obtain an objective and reproducible measurement, using rigorously defined point placement and well-defined algorithms for fracture definition. However, such an approach has some limitations. In general, a substantial number of mild deformities detected by SQ method are missed by morphometric methods. A significant number of false positives are found with morphometric methods owing to the choice of point placement and threshold for defining vertebral deformity. Although most moderate to severe fractures are detected by both techniques, only SQ method can detect mild and subtle fractures, and appreciate anatomic, pathologic and technical issues that influence the evaluation of fracture detection.
Leidig-Bruckner et al (29), compared Genant SQ method (16) with a morphometric approach (6) and reported a good correlation \( r=0.76 \) for baseline measurements and a moderate correlation \( r=0.57 \) for follow-up measurements. Li and colleagues compared Genant SQ method (16,17) with vertebral morphometry for the detection of prevalent fracture (18). Kappa scores for agreement with the consensus reading ranged from 0.84 to 0.87 for visual interpretations, and from 0.54 to 0.75 for the morphometric approach. Wu et al. (21,22) also compared Genant SQ method (16) with a morphometric approach for the detection of incident fracture. There was only fair to moderate agreement between quantitative morphometry and SQ method (the highest kappa score was 0.63). In a comprehensive study, Black et al. (28) compared four different morphometric techniques (6-8, 24) in 3,013 spine radiographs. In addition, Genant SQ method (16) was compared with the morphometric approach in 502 cases. The agreement between the SQ method and the quantitative approaches was moderate (kappa score of approximately 0.6). There was a high concordance between quantitative morphometry and the SQ method for fractures defined as moderate or severe by SQ method. There was, however, a significant discordance for fractures designated mild in the SQ method.

**E. ALGORITHM BASED QUALITATIVE (ABQ) ASSESSMENT**

A structured algorithm-based qualitative method, with emphasis on scrutiny of the vertebral endplates more than change is vertebral shape to differentiate between deformities and fractures has been suggested (30,31). Recently, the ABQ method has been applied to research cohorts (32-35). In one study ABQ, SQ, and morphometric methods of defining vertebral fractures were compared (33). Among elderly men participating in the MrOs study the
prevalence of vertebral fracture ranged from 10% to 13%. Agreement between diagnostic methods was moderate. Discordance related mainly to differential classification of mild thoracic deformities or ABQ definition of vertebral fractures as traumatic and short vertebral height identified by ABQ was common and not linked to low BMD. In another study (34) using both radiographic and DXA vertebral fracture assessment (VFA) the prevalence of radiographic vertebral fracture identified by ABQ and SQ was similar, but on VFA was 50% higher for SQ. Mild ABQ vertebral fracture was associated with low BMD. Inter-observer agreement for radiographic diagnosis was significantly better for ABQ than for SQ; agreement between ABQ and SQ was moderate.

F) APPENDIX REFERENCES:


