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.

There is evidence that vertebral fractures are under-reported, and when present appropriate intervention may not occur. Improvement in the diagnosis and management of osteoporosis will reduce future fracture risk and suffering.

Relevant references:
- Delmas PD et al. (2005) Underdiagnosis of vertebral fractures is a worldwide problem: the IMPACT study *J Bone Miner Res* 20(4): 557-63

Radiographs are still the most common imaging technique used for vertebral fractures identification, but need to be of good technical quality to avoid artefactual appearances which might mimic vertebral fractures.

This particularly applies to lateral views in which the divergent X-ray beam, poor positioning or scoliosis may result in biconcave endplates which must not erroneously be interpreted as vertebral fractures.

In the breath-hold technique in the thoracic spine, rib margins may obscure vertebral endplates. This may be overcome by the breathing, or long exposure, technique which results in movement blurring of the overlying ribs and lung parenchyma, so that vertebral bodies are more clearly visualized. This technique may be difficult in elderly patients (have to remain still for longer exposure time [2-4 seconds]), and is not possible on X-ray equipment with automatic exposure time.

For lateral spinal radiographs it is essential to ensure that the spine is parallel to the X-ray table/film, by careful positioning of the patient, and that the X-ray beam is appropriately centred (T7 for thoracic spine; L3 for lumbar spine).

This avoids the ‘bean can’ effect when the X-ray beam is not parallel to the vertebral endplates which therefore appear biconcave and may simulate vertebral fractures.

In severe scoliosis it may be impossible to position the patient to avoid apparent biconcavity of endplates.
- X-ray exposure must be appropriate so as not to under- or over-expose area being radiographed, as this may cause apparent increased (osteosclerosis) or decreased (osteopenia) bone density.
- Patient size also effects X-ray penetration, causing bones to artefactually appear increased in density in large and over-weight patients, and falsely osteopenic in thin patients.

- Typical patient effective radiation doses: from spine, chest and other radiographic examinations. The average effective doses from the average annual natural background radiation and from a return transatlantic flight are given for comparison.

**Relevant references:**

**Vertebral fracture shape recognition**

- A key to visual identification of fractures and non-fracture deformities is an in depth knowledge of the normal range and variation in vertebral shape and appearance of normal endplates.

- Normal vertebrae are usually rectangular in shape with well define (crisp) cortical endplates.
A standardized approach to the diagnosis of vertebral fractures is desirable for accuracy and consistency. The semi-quantitative (SQ) method of Genant et al 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.

Relevant reference:

Using the Genant et al. SQ method, the approximate degree of height reduction determines the assignment of grades to each vertebra.

Unlike other approaches, the type of deformity (wedge, biconcavity or compression [crush]) is no longer linked to the grading of a fracture in this approach.

Using the Genant et al 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);
- mildly deformed (grade 1: approximately 20-25% reduction in anterior, middle, and/or posterior height and 10-20% reduction of the projected vertebral area);
- moderately deformed (grade 2: approximately 25-40% reduction in anterior, middle, and/or posterior height and 20-40% reduction of the projected vertebral area);
- severely deformed (grade 3: approximately 40% or greater reduction in anterior, middle, and/or posterior height and in the projected vertebral area).

Mildly deformed grade 1: approximately 20-25% reduction in anterior, middle, and/or posterior height and 10-20% reduction of the projected vertebral area. There is less consistency, and more debate, in diagnosis of mild (grade 1) fractures, than with moderate (grade 2) and severe (grade 3) fractures.

Relevant references:
• Mildly deformed grade 1: approximately 20-25% reduction in anterior, middle, and/or posterior height and 10-20% reduction of the projected vertebral area.

• Severely deformed grade 3: approximately 40% or greater reduction in anterior, middle, and/or posterior height and in the projected vertebral area.

• Subtle incident fractures are generally easily identified by comparison with previous radiographs.

• Grade 2 (moderate) incident fractures are easily identified by comparison with previous radiographs.

• Grade 2 (moderate) and grade 3 (severe) incident fractures are easily identified by comparison with previous radiographs.
Radiographic osteopenia or osteoporosis and differential diagnosis

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- There are numerous etiologies which result in vertebral fractures or deformities.

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- Features may depend on radiographic technique. If there is spinal osteopenia, thinned cortex and/or prominent vertical trabecular striations (due to loss of transverse trabeculae) in the vertebrae, these features are strongly suggestive of osteoporosis.
- It would be appropriate in the report to suggest central DXA bone densitometry (hip and lumbar spine) should be performed to confirm or refute whether the patient has osteoporosis.

Relevant reference:

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- Features may depend on radiographic technique. If there is osteopenia, thinned cortex and/or prominent vertical trabecular striations, these features strongly suggestive of osteoporosis, one must be suspicious of osteoporosis and therefore suggest central DXA.

Relevant reference:

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- Postmenopausal bone loss following the early years (maximum bone loss occurs during first four years after the menopause) can lead to fractures in later life, particularly in sites of the skeleton rich in trabecular bone (spine, wrist, hip).
- Vertebral fractures are the most common of osteoporotic fractures and tend to occur at an earlier age than other such fractures.
• In osteomalacia there is reduced mineralisation of osteoid (qualitative abnormality of bone) and the bone is soft and bends; this results in increased smooth curvature of the endplates (‘cod fish’ vertebrae).

• Large doses, or long-term therapy with glucocorticoids is a secondary cause of osteoporosis and tends to particularly affect sites of the skeleton rich in trabecular bone (spine, wrist and hip).

• In vertebral fractures marginal condensation of the endplates from impaction, and exuberant callus formation, may be seen in extreme cases.

• If there is rapid onset and/or extensive generalised osteopenia, particularly if there is evidence of localised lucent areas in the skeleton, consider multiple myeloma, in which there will be a monoclonal paraprotein in serum or urine.

Other imaging methods or analysis

• 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 endplates.

• The interpretation can be aided by additional radiographic projections such as oblique views, or by complementary examinations such as CT, MRI, or radionuclide scans.

Relevant reference:
Six point vertebral morphometry is a quantitative method of assessing vertebral shape by placing six points on the superior and inferior endplate at the front, mid and posterior margins. From these can be measured the anterior (A), middle (M) and posterior (P) heights and various ratios can be calculated.

**Relevant reference:**

The quantitative definition of a vertebral fracture is contentious, and in epidemiology and pharmaceutical efficacy studies a variety of six point morphometric measurements have been used.

- In these six points are placed on the vertebral body: at the anterior, middle and posterior point of the upper and inferior endplates.
- An alternative approach is to apply six-point video-assisted quantitative morphometry using electronic imaging.
- 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.
- Although quantitative, the limitations of six point morphometry are that the measurements may be affected by technical factors (magnification, parallax effect of divergent X-ray beam and others) and will not differentiate between vertebral fractures and deformities.

Multi-detector computed tomography (MDCT) of the thorax and abdomen 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 as vertebral fractures will be identified on the sagittal reformations which are not evident on the transverse axial images and which may be clinically silent.

In pathological fractures, related to such etiologies as bone metastases or multiple myeloma, there is often cortical destruction and bulging into the spinal canal of the posterior vertebral margin, and other imaging techniques, such as MRI may be required for diagnosis.

- In multiple myeloma radiographs may show generalised osteopenia, but MRI will show diffuse infiltration and pathological fracture with diffuse low signal intensity in T1-weighted images and high signal intensity in T2-weighted images.
• **Relevant references** for value of midline sagittal reformations for incidental diagnosis of vertebral fractures on MDCT:

• Vertebral fractures may also be evident on lateral chest radiographs, barium studies, intravenous urograms, MDCT and MRI performed for other clinical reasons, but are often overlooked.

**Relevant references:**

• The differential diagnosis between osteoporotic and malignant pathological fractures may be difficult, but the presence of a soft tissue mass, osseous destruction and fractures and retro-pulsion of the posterior margin of the affected vertebra are features of sinister pathology.
• CT and MRI may be helpful in differentiation.

• **MRI is particularly useful in visualizing bone marrow pathology.**
• Osteoporotic fracture of L5 which shows marrow edema (low signal on T1-weighted image; high signal on T2-weighted image and low signal on diffusion weighted image).

Relevant reference:

• This summarises the features of malignant pathological vertebral fractures.

Relevant reference:

• Pathological fracture of L5 which shows marrow tumor (low signal on T1-weighted image; high signal on T2-weighted image and high signal on diffusion weighted image) and retro-pulsion of posterior vertebral margin.

Relevant references:

• This illustrates the features in MRI which indicate features of multiple metastases.

Relevant reference:
Differential diagnosis between fractures and deformities

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- It is important to scrutinise carefully the shape of the vertebra and features of the endplate to differentiate vertebral fractures from deformities.

Relevant reference:

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- It is important to scrutinise carefully the shape of the vertebra and features of the endplate to differentiate vertebral fractures from deformities.

Relevant references:

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- Abnormal shape of the endplate can be due to developmental anomalies and must be differentiated from the endplate changes of vertebral fracture.

Relevant reference for spinal developmental anomalies:

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- Sheuermann’s disease (juvenile osteochondritis) affecting several, adjacent thoracic vertebral endplates which are irregular, with slight wedging and elongation of the vertebral bodies.
- 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.
- Spondylosis in which there has occurred remodeling of the vertebral body due to degenerative disc disease as evident by anterior marginal osteophytes.
- In spinal hemangiomas there is a coarse and sparse trabecular pattern.

**Relevant review:**

- There are 3 pathways that lead to the 3 alternative outcomes of osteoporotic vertebral fracture, non-fracture deformity, developmental variant, non-osteoporotic fracture or other condition, and normal.
- The starting point of the algorithm is “is there depression of the vertebral endplate?” If the answer is yes, there are then further criteria to satisfy before the observer arrives at the diagnosis of osteoporotic vertebral fracture.
- If there is no depression of the endplate, or the other criteria in this pathway are not satisfied, the observer is directed to the non-fracture deformity pathway and from there to the non-fracture deformity or normal outcome.

- It is vital that clinicians search for, and recognise, vertebral fractures, on whatever imaging is available and being reviewed (spinal radiographs, lateral chest radiographs, barium studies, MDCT of thorax and/or abdomen [and midline sagittal reformats], MRI and RNS).
- It is relevant to differentiate between change in vertebral shape as due to vertebral fractures or deformities.
- If a vertebral fractures differentiate between old/new, osteoporotic/traumatic, benign/malignant.
- Provide a clear and unambiguous report and suggest further imaging and management, if appropriate.

**Relevant review:**
• In 1994 the World Health Organization (WHO) defined osteoporosis in postmenopausal women, in terms of bone mineral densitometry (BMD) by DXA in the lumbar spine (L1-L4), proximal femur and distal forearm as 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.

• 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). The clinical risk factors used 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. 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 one vertebral fracture is diagnosed; both severity and number of vertebral fractures are strong determinants of risk of further fractures. 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.

Relevant reference:
- http://www.who.int/chp/osteoporosis.pdf
- WHO publication - Kanis JA, on behalf of the World Health Organisation Scientific Group. Assessment of osteoporosis at the primary health care level. WHO Collaborating Centre for Metabolic Bone Diseases, University of Sheffield 2007