Interpretation of osteoporotic vertebral deformity on frontal view radiographs of the chest and abdomen: a pictorial review

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Abstract: Osteoporotic vertebral fracture (OVF) has high prevalence in the elderly population. It affects at least one-fourth of all postmenopausal women and is commonly seen among women approximately one decade after menopause. A vertebral fracture, after minor trauma, is a hallmark of osteoporosis. Many fractures and associated complications, including secondary fractures and mortality, can be prevented by routine osteoporosis screening in older people and timely treatment initiation in at-risk individuals. Depending on the technical condition of the radiographs, a substantial portion of moderate to severe grades OVFs in mid-thoracic and lower thoracic spine as well as lumbar spine can be detected on a frontal view digital radiograph of the chest or abdomen. Radiologists should pay attention to the potential existence of an OVF while reading chest and abdominal radiographs of elderly female subjects. In this pictorial review, we describe our experience in evaluating the normal shaped and deformed vertebrae on chest and abdominal radiographs.

Keywords: Osteoporosis; vertebral fracture; radiograph; chest; abdomen; vertebral deformity.

Osteoporosis is a systemic skeletal disease characterised by a reduction in bone mass and qualitative skeletal changes that cause an increase in bone fragility and higher fracture risk. Primary osteoporosis is considered to have two etiologic variants. Type I affects postmenopausal women and is related to rapid loss of bone after menopause, whereas type II affects individuals over 70 years old and involves age-related loss of bone or senile osteoporosis. Secondary osteoporosis is loss of bone caused by an agent or disease process such as corticosteroids, endocrine disorders, or an inflammatory process. Fragility fractures may occur in almost all skeletal segments, but the preferential locations are the vertebral column, the proximal ends of the femur and humerus, and the distal end of the radius (Colles

fracture). Trauma due to a fall is by far the most frequent cause of fractures affecting long bones, while it is more difficult to determine the cause and the exact time of fragility fractures of the vertebral body, which often go undiagnosed. Osteoporotic vertebral fracture (OVF) has high prevalence in the elderly population. It affects at least one-fourth of all postmenopausal women and is commonly seen among women approximately one decade after menopause. A vertebral fracture, after minor trauma, is a hallmark of osteoporosis. The detection of OVF in women suggest that the patient's bone strength is compromised, and the risk of future fracture is substantially increased, both for further OVF and non-vertebral fragility fracture including the hip (1-5). Hip fractures have highly detrimental and

very costly individual and social repercussions; in women over 55 years and older, they are responsible for more hospitalisations than heart attacks, strokes, and breast cancer combined (6). OVFs can be associated with decreases in trunk extension torque, spinal motion, functional reach, mobility skills and walking distance, and may also influence mortality because their association with chronic back pain, immobility and postural change (7). Multiple and more severe grades of OVFs are associated with an even greater fracture risk (1,2,8).

Advances in understanding the biology of osteoporosis have resulted in several medications that have been demonstrated to reduce fracture risk, both vertebral and nonvertebral, including hip, fractures (9-13). Nonpharmacologic approaches to manage osteoporosis, the combination of weight-bearing and resistance training, and adequate calcium and vitamin D intake and physical activity, can positively affect bone mass. Coupled with preventing falls and limiting modifiable risk factors, such as smoking and alcohol use, these measures can help reduce a person's risk for osteoporotic fractures (14,15). An early detection of an OVF can lead to further investigation and appropriate therapy that decreases the risk of future fractures, critically to target pharmaceutical treatment to the patents aged 65 years or older with a hip or vertebral fracture (16). Many fractures and associated complications, including secondary fractures and mortality, could be prevented by routine osteoporosis screening in older people and timely treatment initiation in at-risk individuals.

Despite its importance, many patients with OVF and at high risk for further fracture remain undetected and untreated. OVF may often be relatively asymptomatic clinically, it is expected that less than 1/4 radiographic OVFs are diagnosed as clinical incident fractures (17,18). Among women at high risk for fracture, defined as those over 65 years of age and having at least 2 other fracture risk factors, only about one third in USA reported treatment with osteoporosis medication (19). Many guidelines suggest women with age ≥60 or ≥65 years should have osteoporosis screening (3,5,20-23). The International Society for Clinical Densitometry recommends DXA (dual-energy X-ray absorptiometry) assessment for all women and men aged ≥65 and ≥70 years, respectively (24). However, this measure is still not commonly taken by individuals. On the other hand, in clinical practice, frontal radiograph (FR) of the chest is often taken for patients suspected of respiratory

diseases, pleural diseases, as well as to assess heart and big vessels, while chest lateral radiograph (LR) is taken less often for these purposes. FR of abdomen is taken in patients with abdominal pain, for assessing urinary stone, gastrointestinal gas etc. Based on the analysis of digital spine radiograph which allows convenient adjustment of brightness and contrast of the images, we reported that moderate to severe vertebral deformities (VDs, i.e., with >25% vertebral height loss) at mid-thoracic and lower thoracic spine as well as lumbar spine are mostly identifiable on the FR, with a small proportion of ambiguous cases further clarified by additional lateral view imaging (25). Moreover, some mild VD and endplate and/or cortical fracture (ECF) are also visible on FR (25). It can be envisaged that, depending on the technical condition of the radiographs, a substantial portion of moderate to severe grades VDs can also be detected on FRs of the chest and abdomen. VD is the appearance of OVF (though not necessarily every VD is an OVF). Opportunity exists for detecting OVFs on digital chest/abdominal FR for high-risk osteoporotic patients (such as elderly females >65 years) when they are X-rayed for other indications. Radiologists should pay attention to the potential existence of an OVF while reading chest and abdominal RFs of elderly subjects. Once an OVF is identified, to prevent secondary fracture, a multidisciplinary case management approach that takes the form of a fracture liaison service (FLS) can be established, which has been shown to be the most effective organizational approach (26). Patient should also receive education to encourage live a healthy lifestyle, to raise self-awareness about the disease and to become involved in self-care management (27,28).

FRs of chest are mostly commonly taken posterior-anteriorly (PA), i.e., the anterior chest wall is closed to the X-ray detector. Since the spine is at the back of the chest, compared with spine RFs which are taken with the spine close to the X-ray detector, the vertebrae are magnified on FR to some extent and the borders are blurrier. Moreover, FRs of chest are mostly used for detecting lung diseases. Since lung, filled with air, absorbs much less X-ray than abdominal organs, chest FRs are commonly taken with much less mAs (milli-Ampere-seconds) than that of the abdominal FR and spine FR. On the other hand, FRs of abdomen are mostly commonly taken on anterior-posteriorly (AP, mostly in a supine position), i.e., the lower back is closed to the X-ray detector. Thus, the vertebral

borders on abdominal FR are usually sharp. The most frequent site of OVF involvement is the thoracolumbar junction, with the second most frequent region being the mid-thoracic spine (29,30). One of the difficulties of reading spine on FR of chest and abdomen is that the site of highest prevalence of OVF, i.e., the thoracolumbar junction, is usually 'off-centre' to the X-ray beam. In our experience, this is more a problem for chest FR, where the focus of the X-ray beam is toward mid-thoracic region; T12, L1, and L2, when included in the field of view, may not be well displayed. Till further evidences are available, it is probably prudent that we emphasize the specificity of our interpretation of OVF, and minimised 'false alarm' or 'over-call' for patients when the primary indication for the radiographs is not OVF screening (25). X-ray cone-beam may cause geometric distortion of vertebrae located at extremities of the scans, and the accuracy of diagnosis of VCFs can also be reduced at the upper thoracic levels. Upper thoracic spine is also often associated with physiological kyphosis; however, it has been known that OVF at levels above T6 is less common (29,30).

For OVF high risk patients with suspected VDs or definite VDs on FR, additional LR or DXA imaging based VFA (vertebral fracture assessment, or other imaging modalities such as CT/magnetic resonance imaging when indicated) should be recommended. This can not only confirm (or refute) the suspected VFs on FR, lateral imaging also helps to grade the OVF and detect possible additional VF(s) missed on FR. Multiple OVFs is a strong indication for initiation of anti-osteoporosis treatment. In assessing a vertebra, there are usually three stepwise questions: (I) does a VD exist? (II) is this VD likely a compressive VD? (III) can this compressive VD be called OVF? Currently, the differentiation of what is compressive VD and what is OVF has not been well defined. Some investigators choose to call VDs of Genant semi-quantitative (SQ) grade-2 and above (i.e., those compressive VD with ≥25% height loss) as OVF, while call SQ grade-1 compressive VD as osteoporotic VD. Some authors suggest that OVD is OVF only when diagnosed on the basis of evidence or findings of endplate, cortical, or trabecular damage (31,32). It should also be noted that to exclude VDs of non-osteoporotic causes can be difficult in practice, particularly for mild deformities caused by degeneration and old trauma. A 'golden' radiological standard to separate osteoporotic and non-osteoporotic deformities in every case does not exist till now. The age group with high prevalence of OVF is also the age group with high prevalence of spine metastatic tumors. Differentiating between OVD and metastatic deformity can be sometimes difficult by sole radiograph (33). MRI is the preferred imaging technique for differential diagnosis purpose.

To expand our previous report on spine RF assessment of VD (25), we further evaluated the normal shaped and deformed vertebrae of spine on chest and abdominal radiographs and describe our experience in the current pictorial review (*Figures 1-31*). To facilitate understanding the VD appearance on FR, a number of spine radiographs are also included in this article. All the VD gradings on LR were based on the extended semi-quantitative (eSQ) criteria, where in addition to a qualitative diagnosis of osteoporotic VD, minimal grade, mild grade, moderate grade (mod/m), moderately-severe (mod/s) grade, severe grade, and collapsed grade OVDs have vertebral height loss of <20%, 20–25%, >25%–1/3, >1/3–40%, >40%–2/3, and >2/3, respectively (35). We do not offer grading on FR.

In conclusion, as the clinical management can be improved by opportunistic detection of OVF, radiologists should be trained and sensitized in VD identification in FR. This pictorial review provides 28 examples with VD demonstrated on FR. The best way for radiologists to acquire the skill of interpreting VD on FR is to read lots of examples. In clinical practice, PA + lateral chest radiographs are commonly taken, so radiologist have lots of opportunities to practice, by reading FR images and the results confirmed by LR. For abdominal radiograph, LR is usually not simultaneously obtained. Since the demonstration of lumbar vertebrae on abdominal FR is similar to spine radiograph, radiologists can practice reading lumbar VD on spine FR (spine LRs are usually taken simultaneously). Readers are also encouraged to refer to the 19 illustrative cases in our previous article (25). The importance of OVF in East Asian men for predicting further osteoporotic fracture risk remains unknown (36,37). We reported that existing severe OVFs in elderly Chinese males were only weakly associated with higher further vertebral fracture risk at year-4 follow-up (37). However, compressive VD commonly occur in men with bone mineral density defined osteoporosis (36,38). After old traumatic deformity, degenerative deformity and other non-osteoporotic deformities are excluded, radiographic compressive VD is a strong indicator that the patient has osteoporosis.
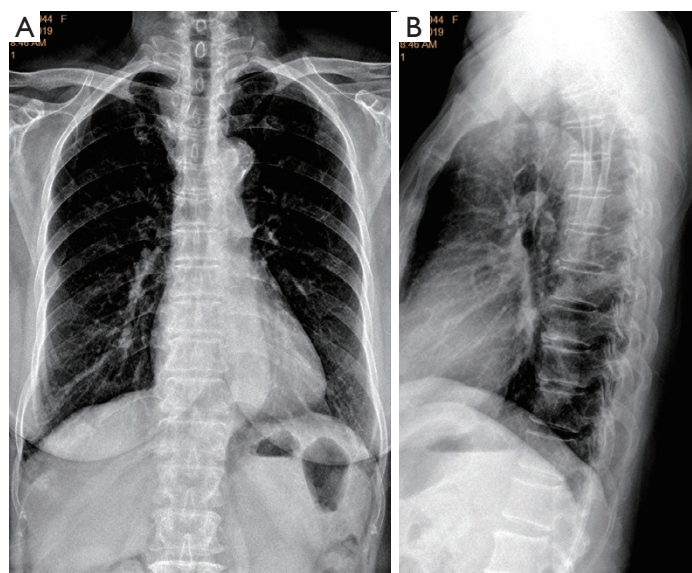
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Figure 1 Chest radiographs of a female aged 76 years (A: FR, B: LR). Mid- and lower thoracic vertebrae and L1/L2 vertebrae are displayed on FR with no deformity. Note, compared with AP (anterior to posterior) spine radiograph (see *Figures 2-5* below), vertebral body's borders can be slightly blurry due to PA (posterior to anterior) filming when the anterior chest wall is close to the X-ray detector. FR, frontal radiograph; LR, lateral radiograph.
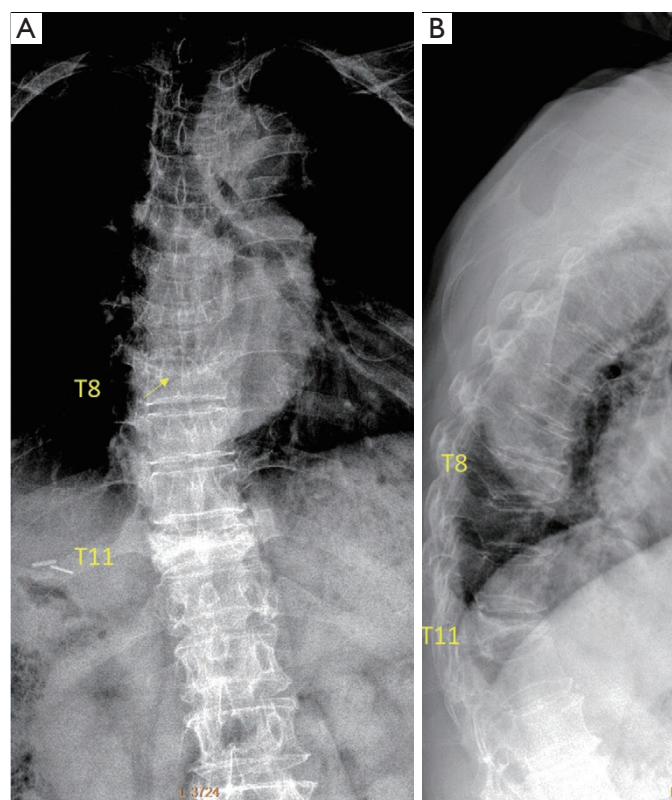
Figure 2 Spine radiograph (A: FR, B: LR). T11 vertebral body is collapsed. T9 and T10 are of normal shape, while T8 (arrow) had a height loss (eSQ mod/m VD). T7 eSQ mod/m VD is not well recognised on FR. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
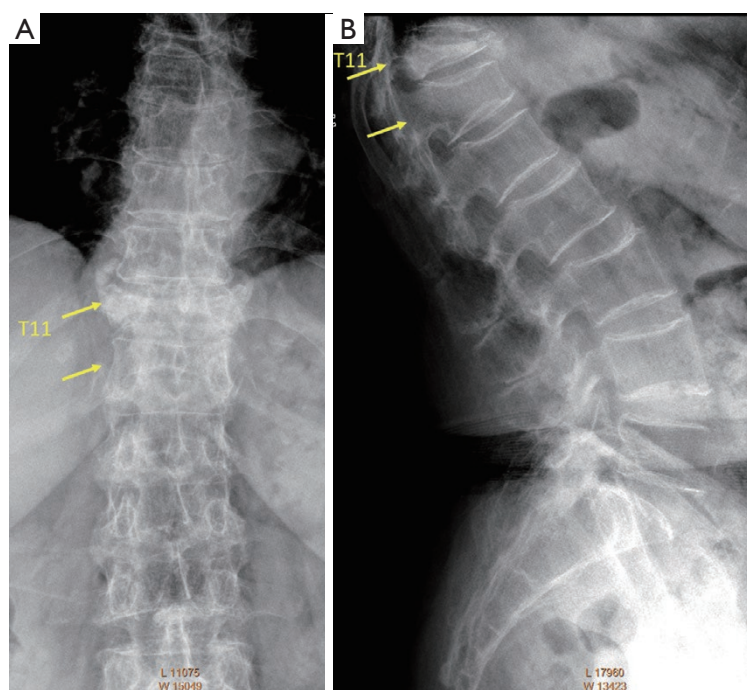
Figure 3 Spine radiograph. T11 vertebral body is collapsed. T12 has eSQ mod/m VD with endplate depression. T11 (arrow) and T12 (arrow) OVF induced local kyphosis. Due to the altered projection of X-ray relative to the L1 and L2 (B), L1 and L2 are poorly displayed on FR (A). OVF, osteoporotic vertebral fracture; FR, frontal radiograph; VD, vertebral deformity.
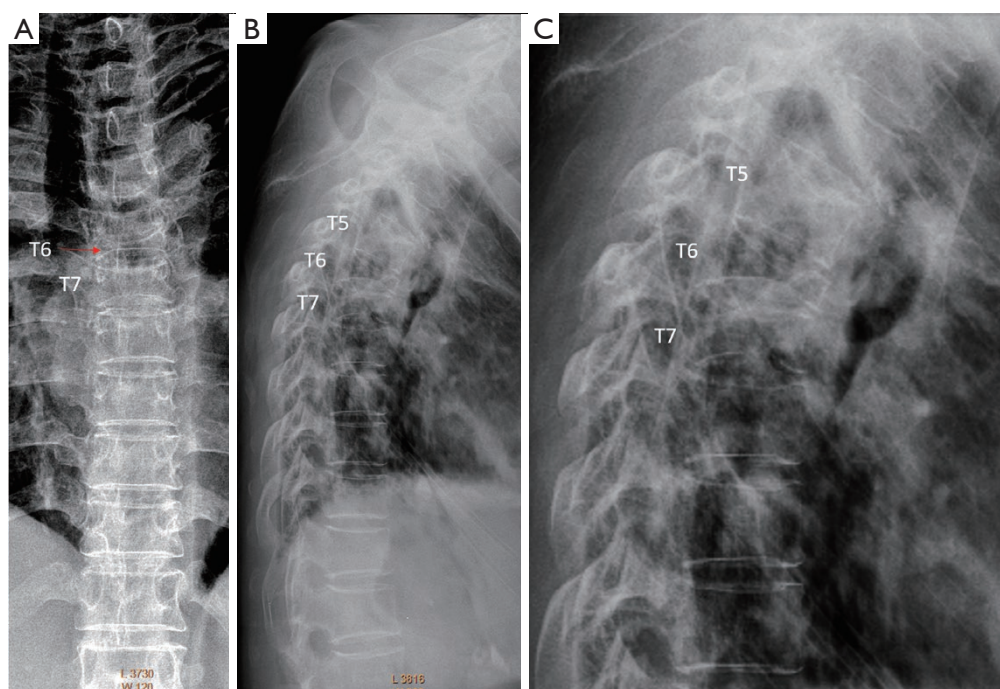
Figure 4 Spine radiograph (A: FR, B/C: LR). T6 vertebral body (arrow) is collapsed which is demonstrated on FR. T7 has VD which is confirmed on LR (eSQ grade mod/m). T5 mild deformity cannot be assessed on FR. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
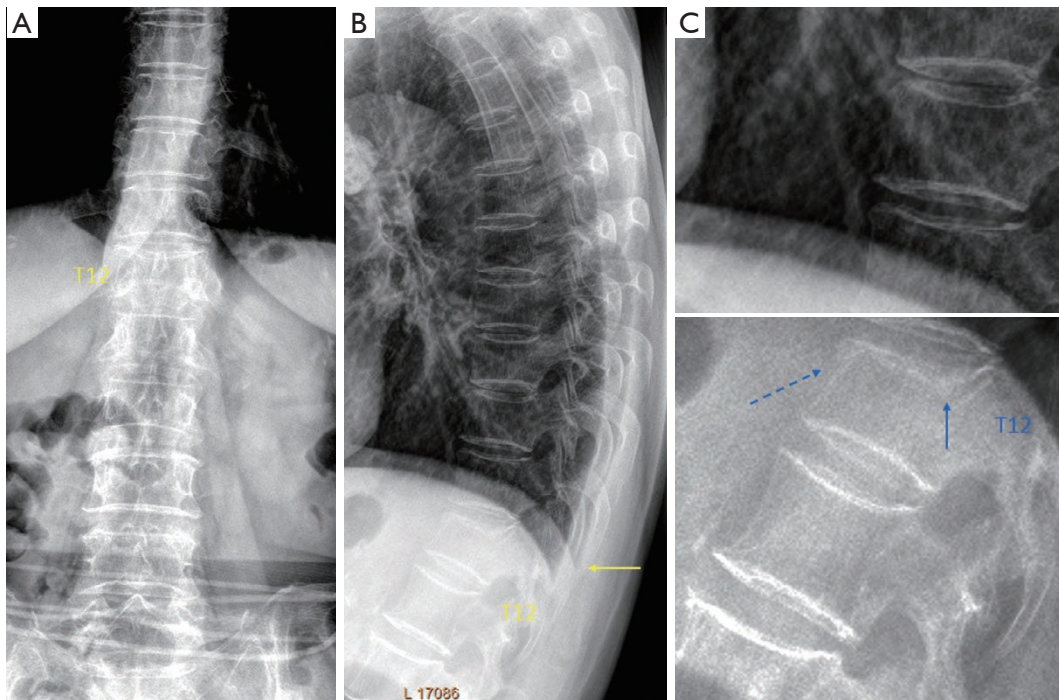
Figure 5 Spine radiographs show T12 VD. FR (A) show T12 has a height loss, and the vertebral upper border is depressed. These changed can be appreciated by comparing with the regular shape of T11. LR (B) show kyphosis around T11/T12 level (arrow), which might be due to T12 VD. (C) is a zoomed-in image of lateral spine at T12 level. T12 has positive ECF sign with upper endplate collapse (blue arrow) and anterior cortex fracture (dotted arrow). Reproduce with permission from reference (25) supplementary materials. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
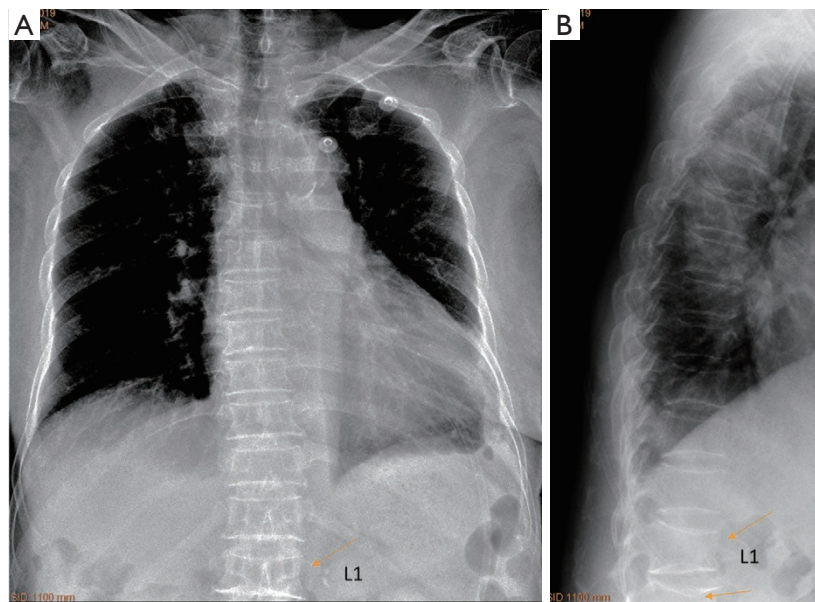
Figure 6 Chest radiographs a female aged 84 years (A: FR, B: LR). FR shows L1 VD (arrow, note both upper and lower endplates depression), which is confirmed by LR showing L1 eSQ mod/m VD (arrow). L2 upper endplate depression is shown on LR (arrow). FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
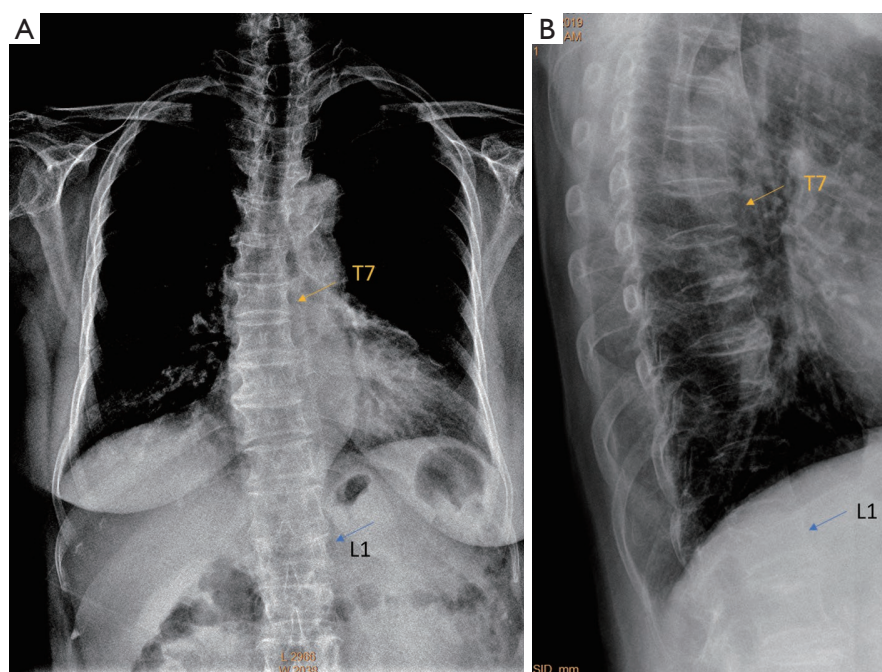
Figure 7 Chest radiographs of a female aged 84 years (A: FR, B: LR). FR shows L1 VD (blue arrow), which is apparent when comparing the normal appearing T12 and L2. L1 VD is confirmed on LR. T7 (orange arrow) has a minimal grade VD which cannot be seen on FR. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
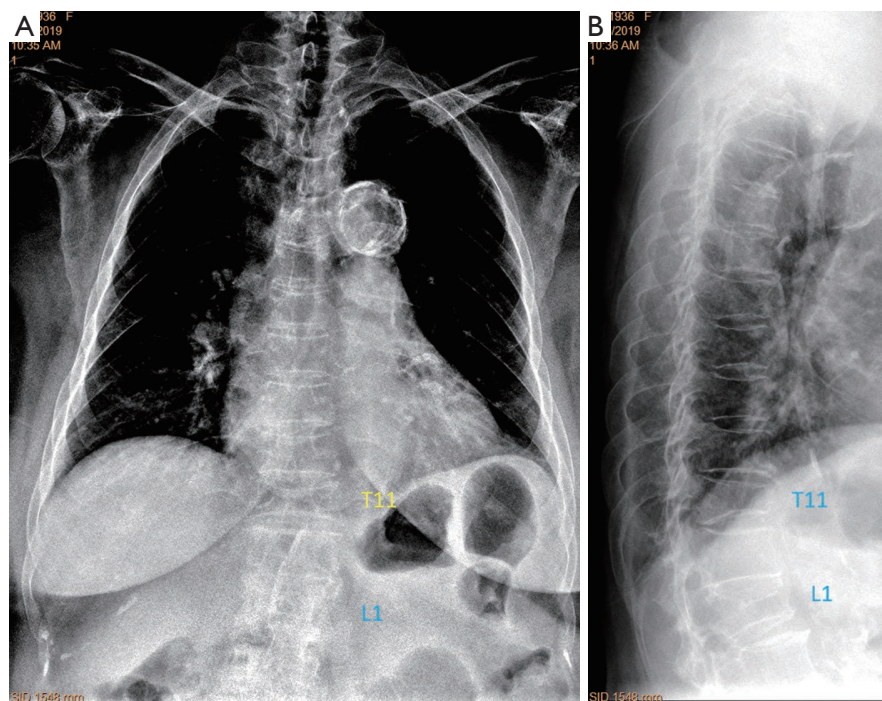
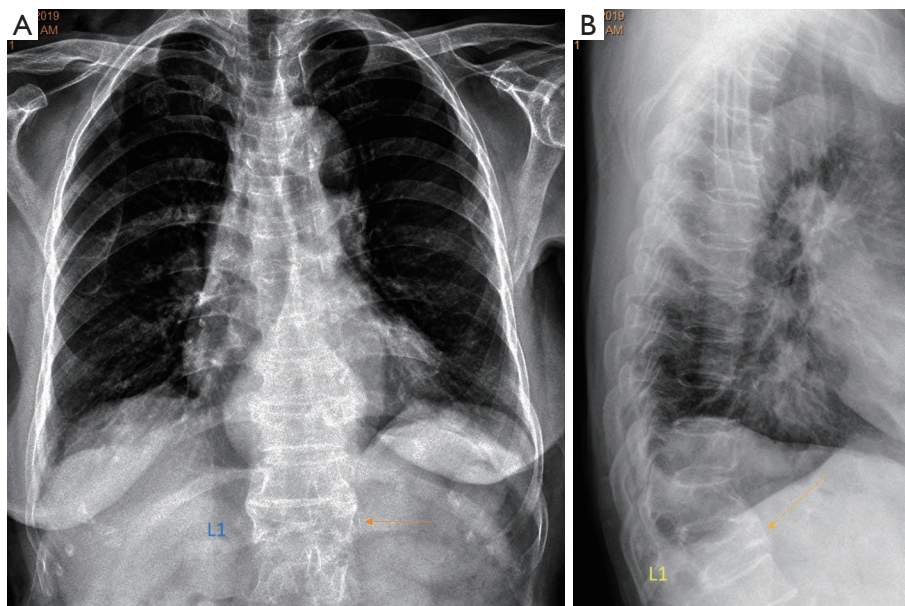**Figure 8** Chest radiographs of a female aged 84 years (A: FR, B: LR). FR shows T11 VD, which is apparent when comparing the shape of T10. FR confirmed T11 to be eSQ mod/s grade. FR also suspect L1 VD (with increased density), FR confirmed L1 eSQ severe grade. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
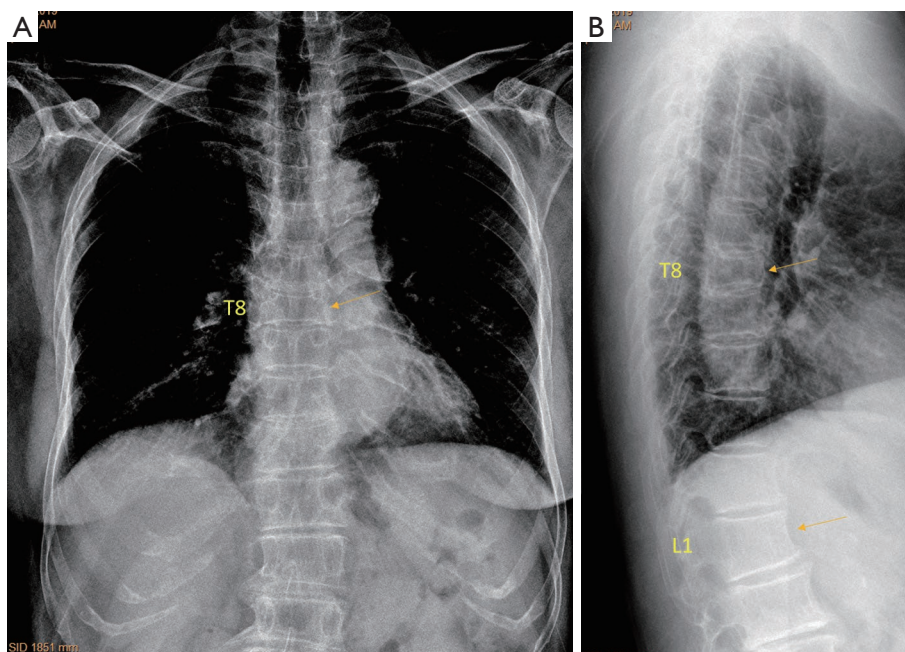
Figure 9 Chest radiographs of a female aged 77 years (A: FR, B: LR). FR shows T8 VD (arrow), which is apparent by comparing the shape of T7 and T9. FR confirms T8 to be eSQ mild VD. LR also suggests L1 eSQ minimal grade VD (arrow) which cannot be seen on FR. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.

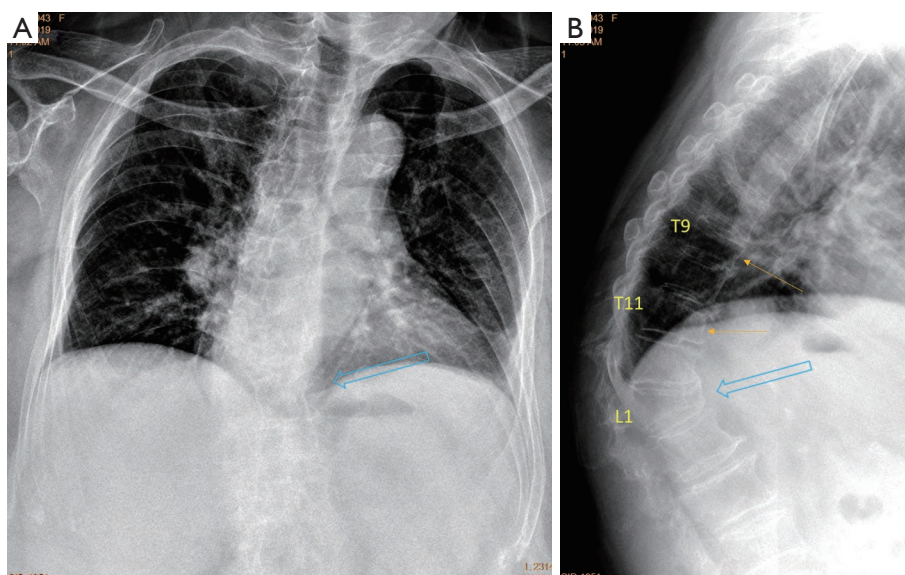**Figure 10** Chest radiographs of a female aged 83 years (A: FR, B: LR). FR shows L1 collapsed deformity (arrow) which is confirmed on LR. FR, frontal radiograph; LR, lateral radiograph.
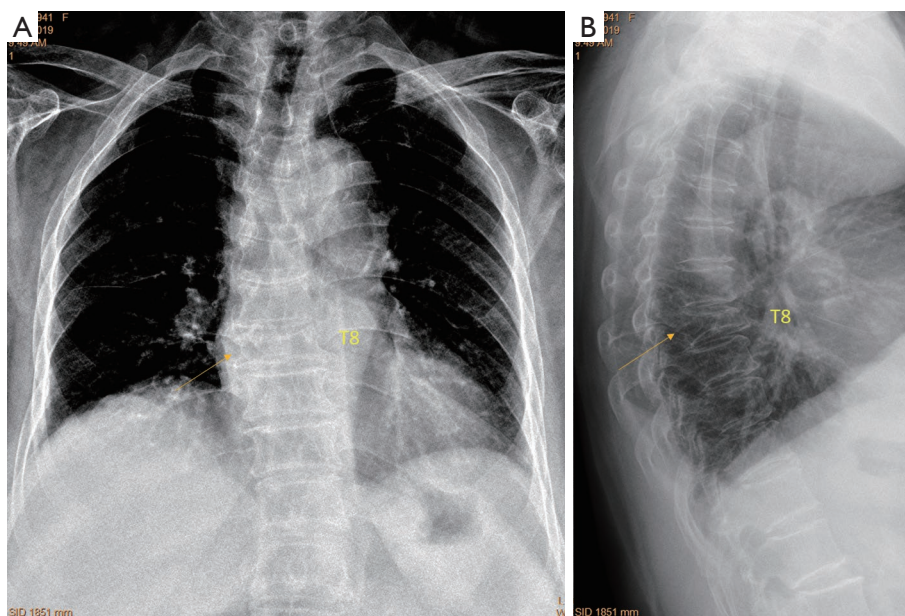
Figure 11 Chest radiographs of a female aged 79 years (A: FR, B: LR). FR show T8 deformity (arrow) which is also shown on LR (eSQ severe grade). FR, frontal radiograph; LR, lateral radiograph.
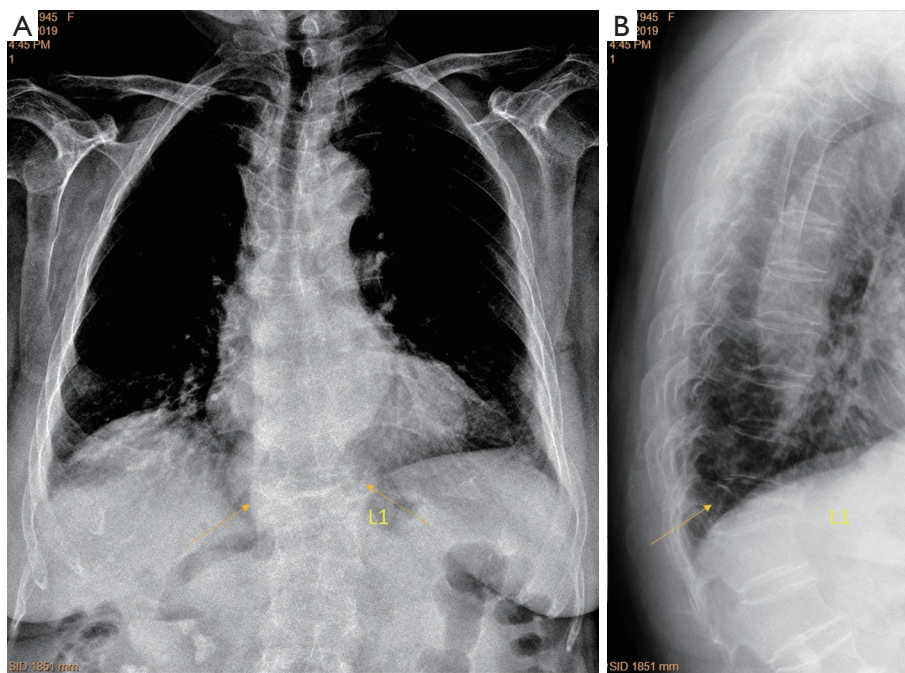
Figure 12 Chest radiographs of a female aged 75 years (A: FR, B: LR). FR shows L1 collapse (arrow) which is also shown on LR. FR, frontal radiograph; LR, lateral radiograph.
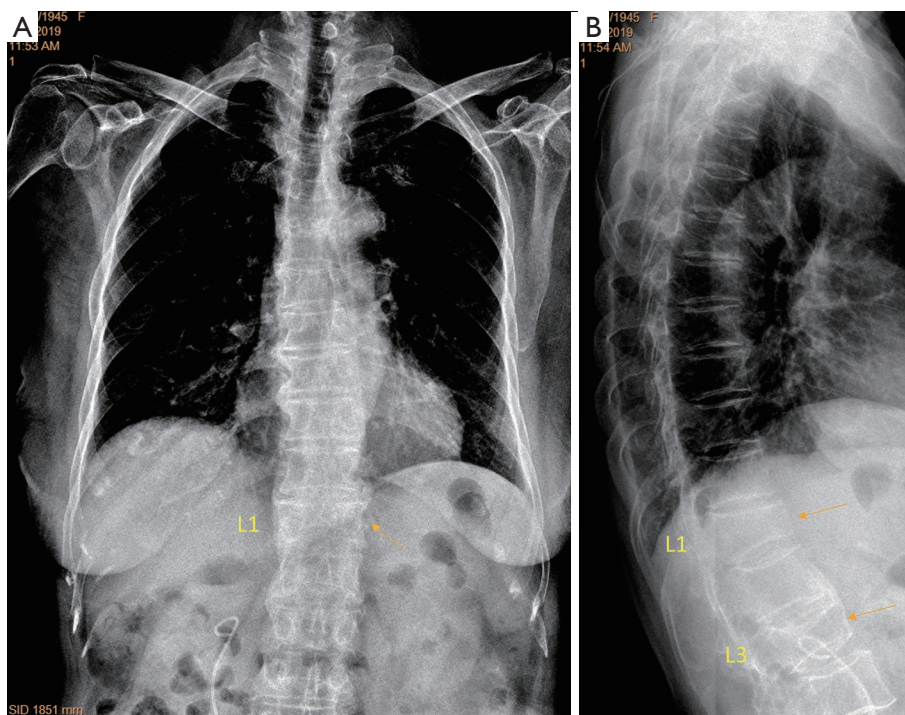
Figure 13 Chest radiographs of a female aged 75 years (A: FR, B: LR). FR shows suggested L1 VD (arrow) which is confirmed on LR (mod/ m deformity). LR shows L3 eSQ mod/s VD (arrow) which cannot be assessed on FR. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.

Figure 14 Chest radiographs of a female aged 77 years (A: FR, B: LR). Individual vertebrae are not well shown FR. However, a scoliosis with an angle formation (blue arrow) strongly suggest severe VD. LR shows L1 severe deformity, T9 (orange arrow), T11 (orange arrow) eSQ mod/s and mod/m deformity. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
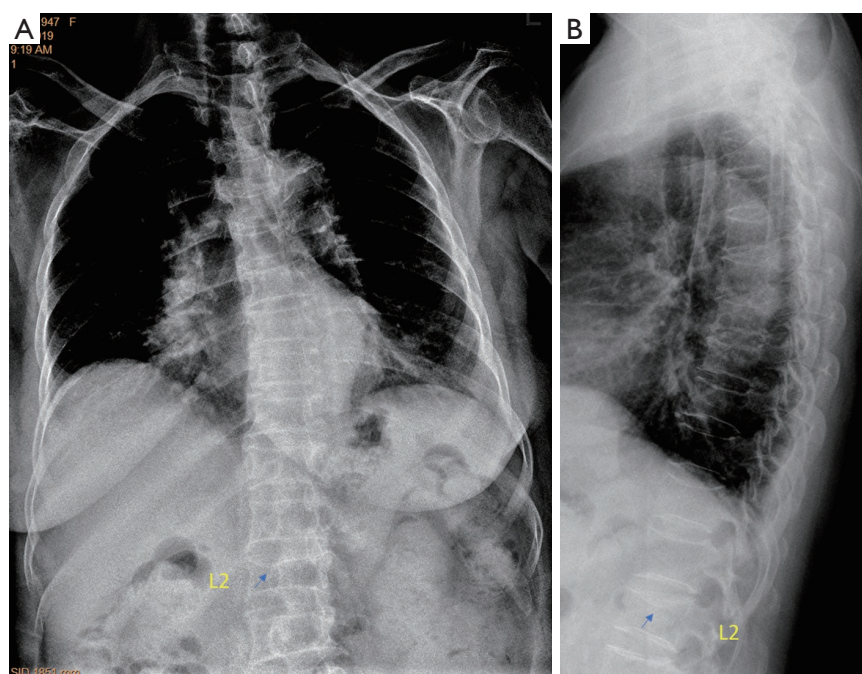
Figure 15 Chest radiographs of a female aged 73 years (A: FR, B: LR). L2 VD (arrow) is noted on FR. LR shows L2 eSQ mod/m VD with upper endplate fracture. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
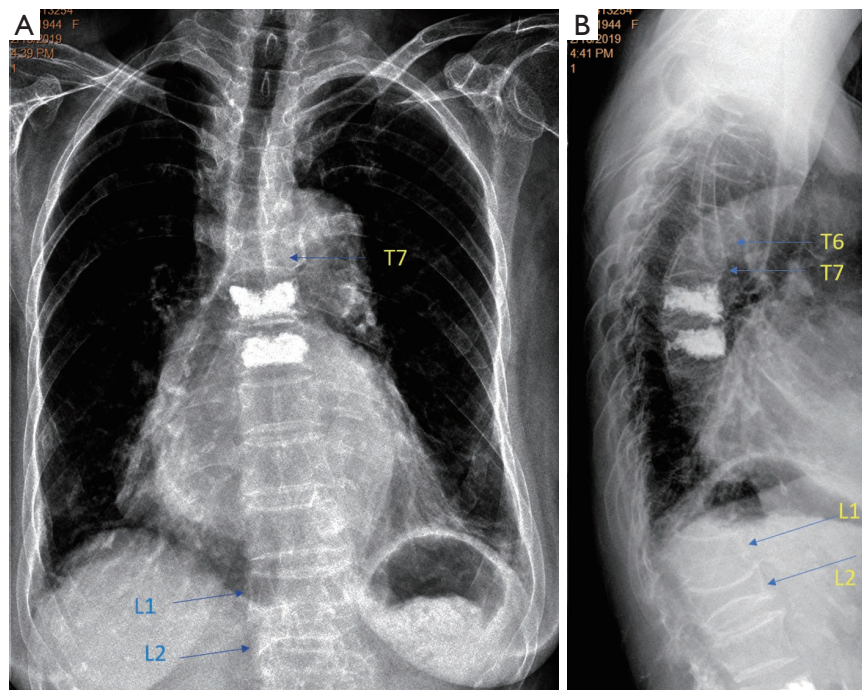

Figure 16 Chest radiographs of a female aged 76 years (A: FR, B: LR). VD of T7 (arrow), L1 (arrow) and L2 (arrow) are noted on FR, with LR confirmed eSQ T7 severe VD (arrow), L1 mod/s VD (arrow), and L2 severe VD (arrow). Injected cement (after vertebroplasty or kyphoplasty) is shown inside T8, T9 and L4 vertebral bodies. T6 VD, which is shown as eSQ mod/m grade VD on LR (arrow), cannot be evaluated on FR. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
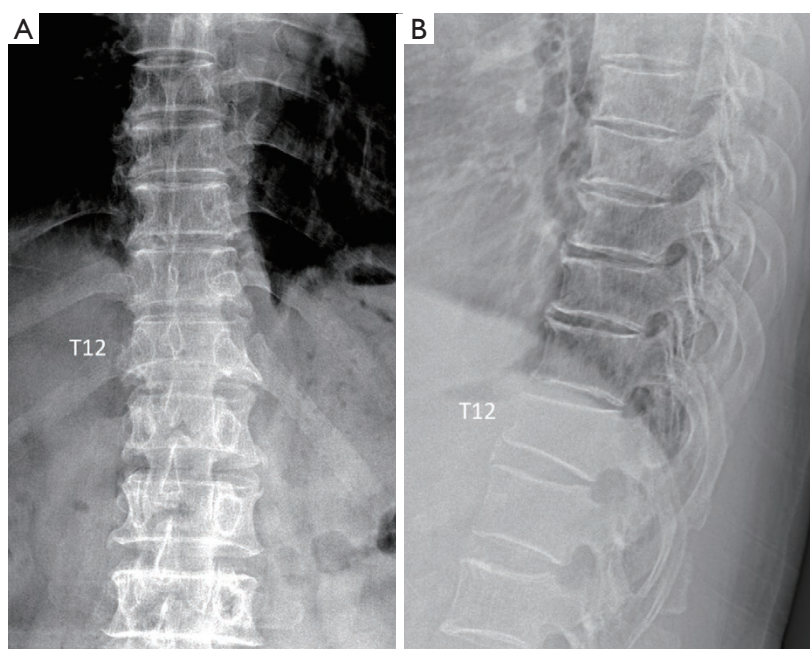
Figure 17 Spine radiograph (A: FR, B: LR). LR shows T12 eSQ mild VD. T12 VD is barely recognisable on FR by comparing it with the normal appearance of T11 and L1. It is expected that this mild VD could not be reliably evaluated on chest FR indicated for lungs. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
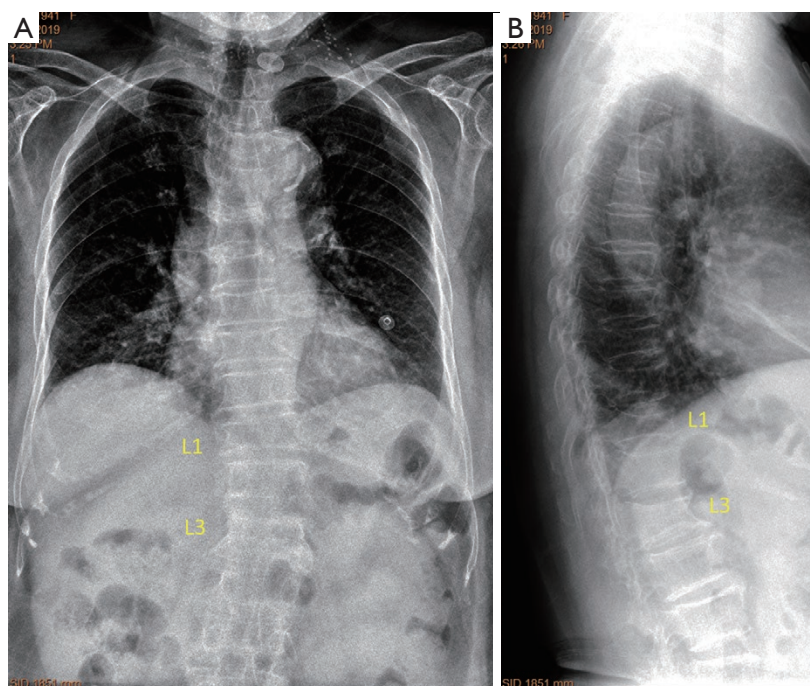

Figure 18 Chest radiographs of a female aged 79 years (A: FR, B: LR). VD of L3 can be highly suspected on FR with possible deformed shaped and higher density (suggesting collapsed bone). VD of L1 can be highly suspected on FR by comparing its shape with those of T12 and L2. This case illustrates the importance of comparing the shape and density of a suspected VD with those of its adjacent vertebrae. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
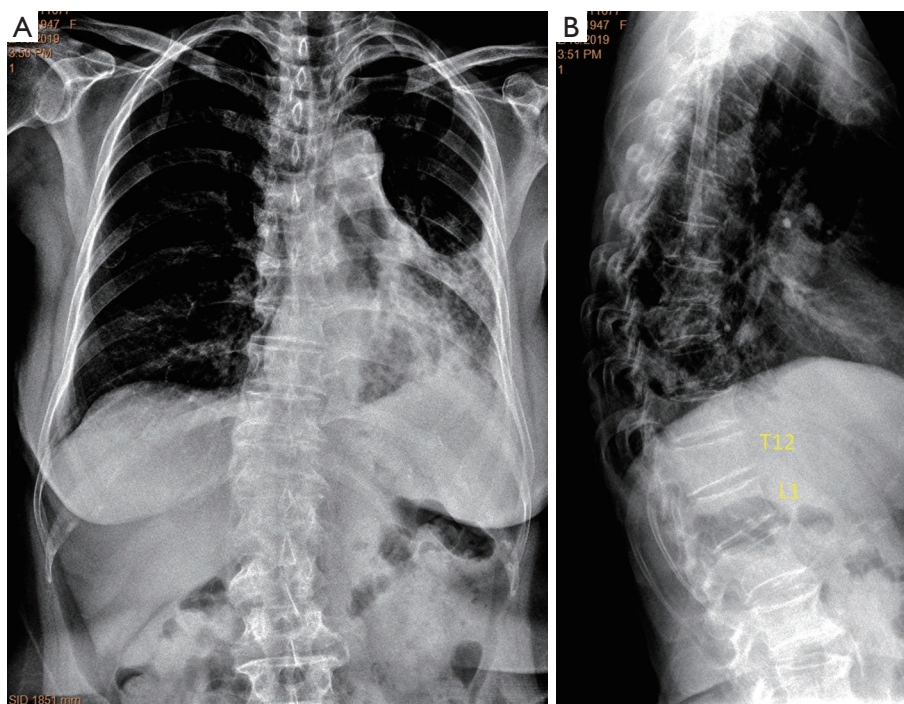
Figure 19 Chest radiographs of a female aged 73 years (A: FR, B: LR). LR shows T12 and L1 minimal grade VD, which cannot be evaluated on FR. In the meantime, L2 and L3 are poorly displayed on FR, misinterpretation of them as VD should be avoided. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
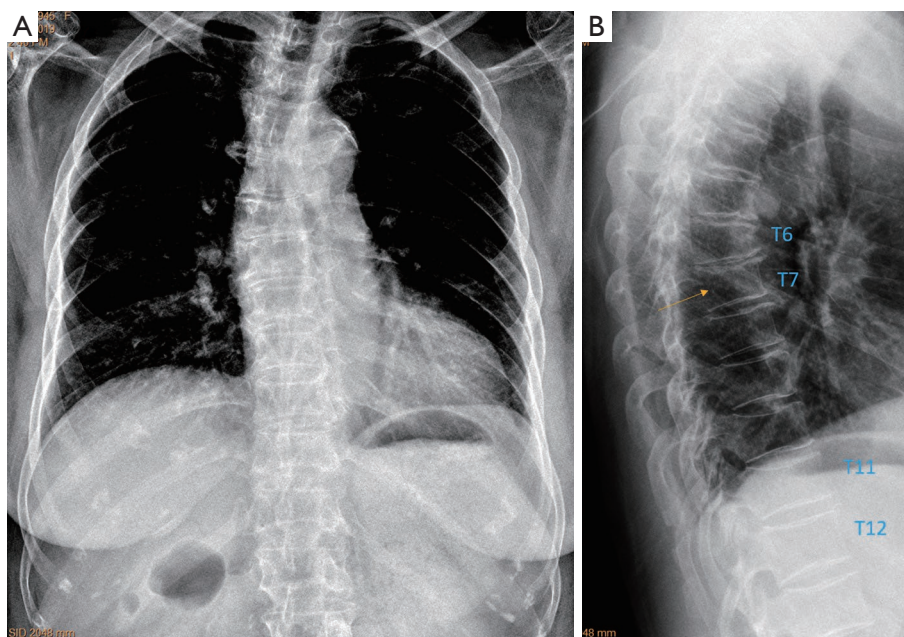

Figure 20 Chest radiographs of a female aged 75 years (A: FR, B: LR). FR shows there is eSQ minimal grade VD for T6, T7 (arrow), T11, T12. These VDs cannot be properly evaluated on FR. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
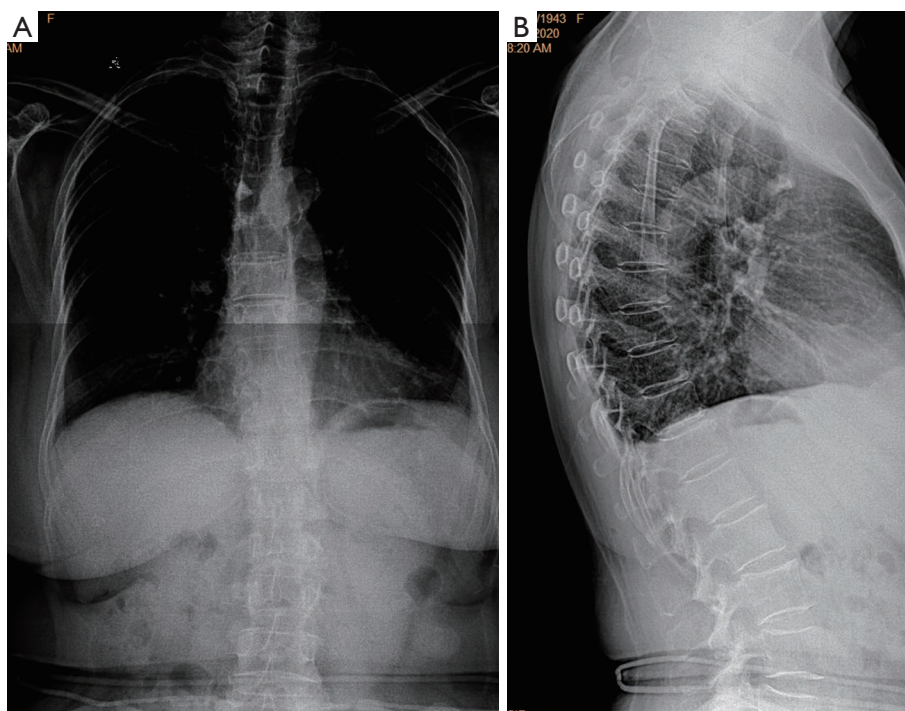
Figure 21 Chest radiographs of a female aged 77 years (A: FR, B: LR). LR shows there is no there is no VD observed. While mid-thoracic vertebral bodies show normal shape on FR, the thoracolumbar region's vertebrae are very blurred due to X-ray projection. Over-call of VD at thoracolumbar region should be avoided for such a case. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
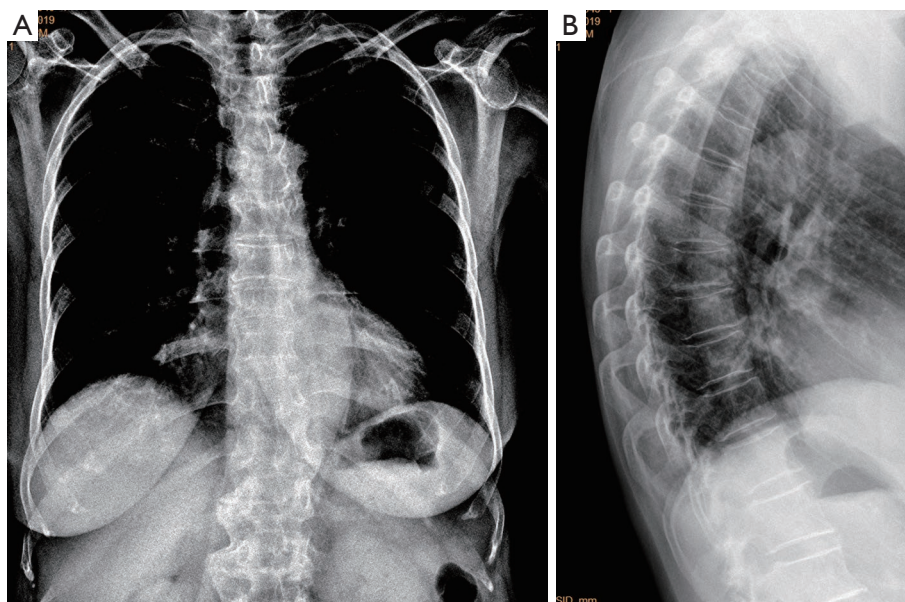

Figure 22 Chest radiographs of a female aged 75 years (A: FR, B: LR). LR shows there is no VD observed. Mid-thoracic vertebral bodies show normal shape on FR. Due to X-ray projection, the thoracolumbar region's vertebrae cannot be evaluated individually on FR. Over-call of VD at thoracolumbar region should be avoided for such a case. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
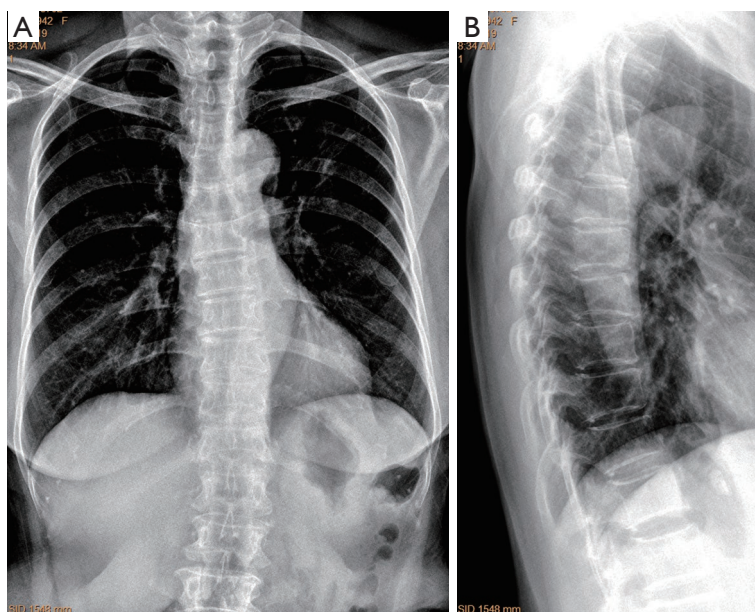
Figure 23 Chest radiographs of a female aged 78 years (A: FR, B: LR). Due to X-ray projection, there is a risk that T12 may be mislabelled as VD. Note T11 and T12 vertebral bodies have similar shape. Over-call of VD at thoracolumbar region should be avoided for such a case. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
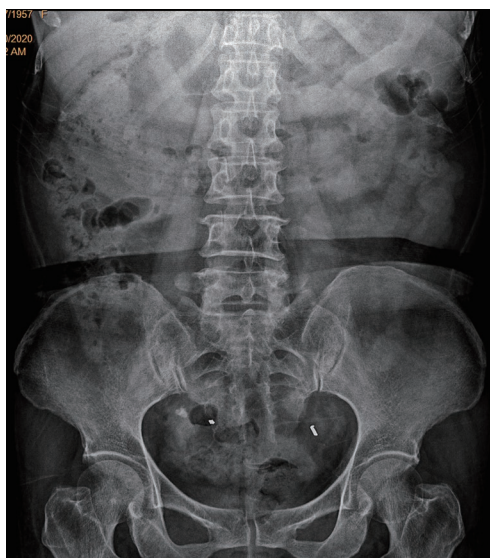

Figure 24 Abdominal FR of a female aged 63 years. L1-L5 vertebrae are well displayed with no deformity noted. LR confirmation was not obtained for this patient. FR, frontal radiograph; LR, lateral radiograph.
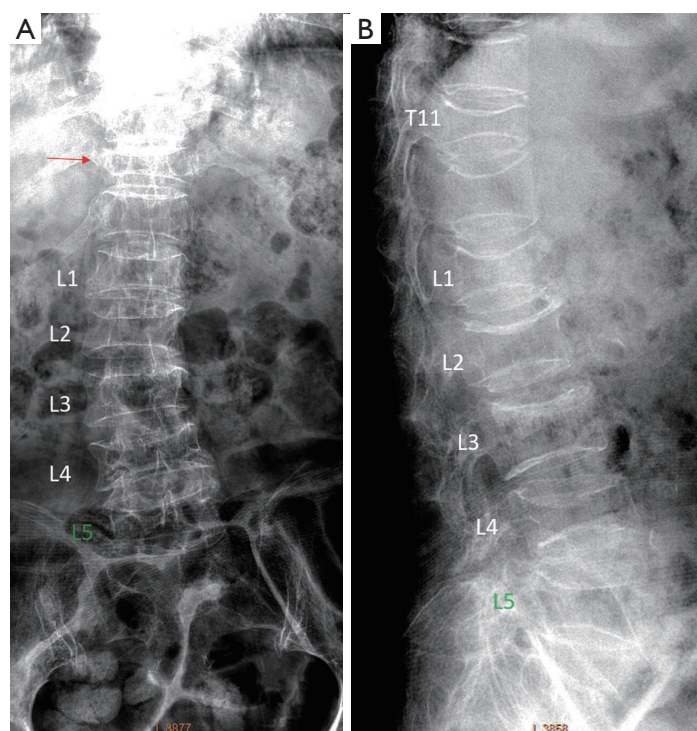
Figure 25 Spine radiograph (A: FR, B: LR). In addition to T11 eSQ severe VD (arrow), L1-L5 shows multiple deformities with endplate depression. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
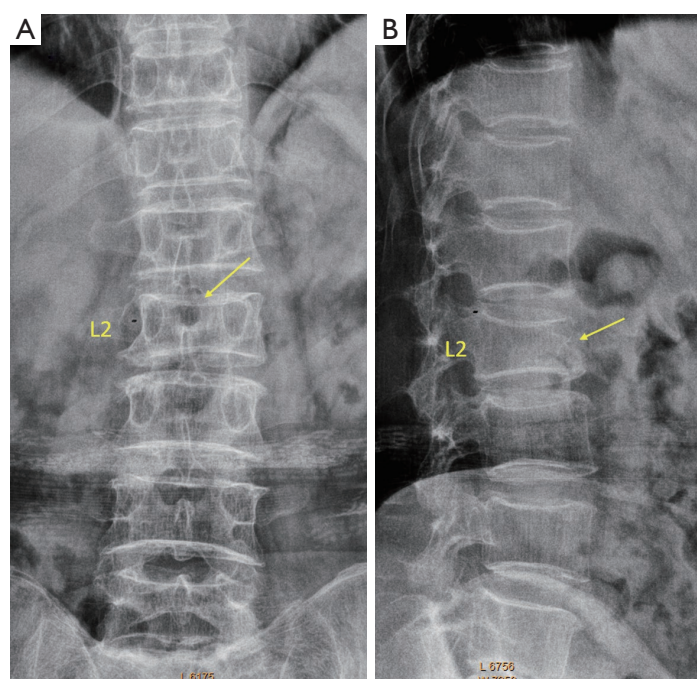

Figure 26 Spine radiographs show L2 VD. FR (A) show L2 height loss and as well as endplate depression (arrow), which is also well shown on LR (B). (B) also shows additional anterior cortex fracture (arrow). Reproduce with permission from reference (25) supplementary materials. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
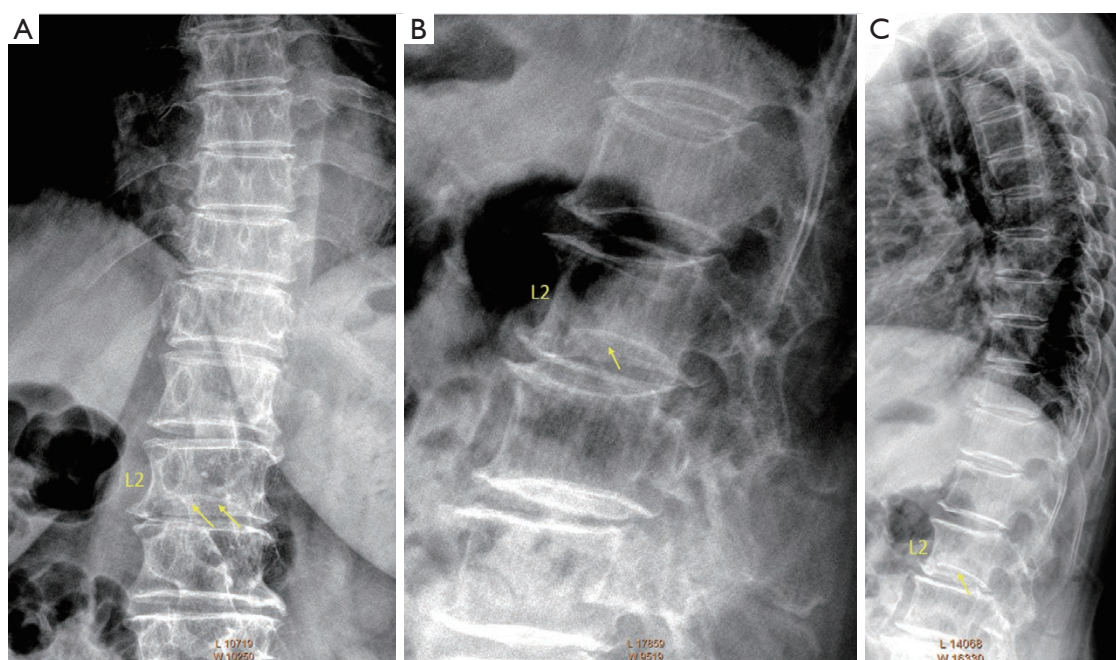
Figure 27 Spine radiographs show L2 lower endplate fracture with minimal vertebral height loss. FR (A) show L2 lower endplate fracture (arrows). This can be appreciated by comparing the normal-appearing lower endplates of L1 and L3. LR (B,C) shows apparent endplate fracture (arrow). (B) shows a zoomed-in image of L2. Reproduce with permission from reference (25) supplementary materials. FR, frontal radiograph; LR, lateral radiograph.
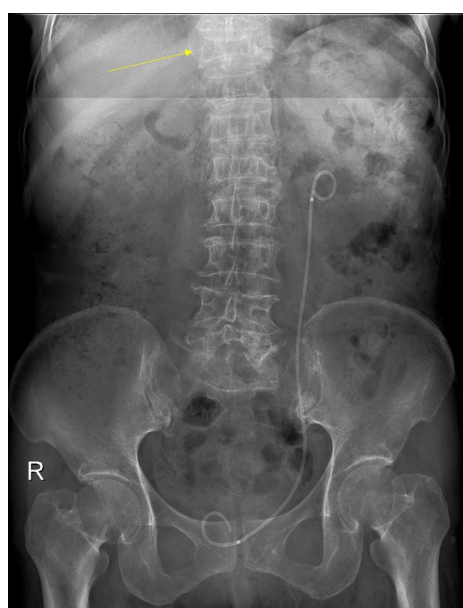

Figure 28 Abdominal FR of a 71 years old female, compressive VD of T10 is noted (arrow). A left urinary tract drainage catheter can be seen. LR confirmation was not obtained for this patient. Reproduced with permission from reference (34). FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
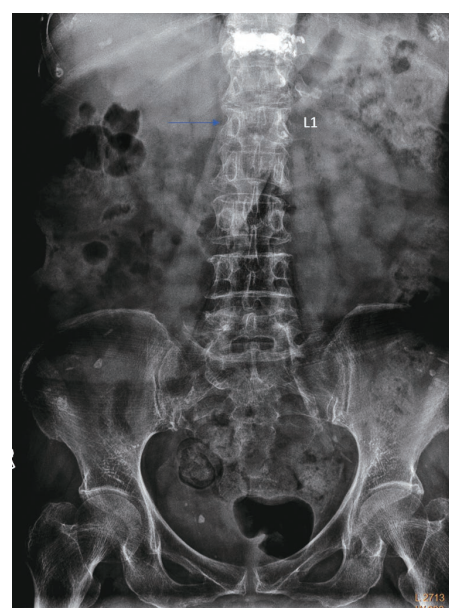

Figure 29 Abdominal FR of a female aged 78 years. T11 shows injected cement after vertebroplasty or kyphoplasty. Arrow shows VD of L1. LR confirmation was not obtained for this patient. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.

Figure 30 Standing abdominal FR of a female aged 90 years with bowel obstruction. Thoracolumbar junction has kyphosis and scoliosis. Double arrows indicate injected cement after vertebroplasty or kyphoplasty. Thin arrow indicates a definite VD. Thick dotted arrow suggests a vertebra with severe or collapsed deformity. LR confirmation was not obtained for this patient. FR, frontal radiograph; LR, lateral radiograph; VD, vertebral deformity.
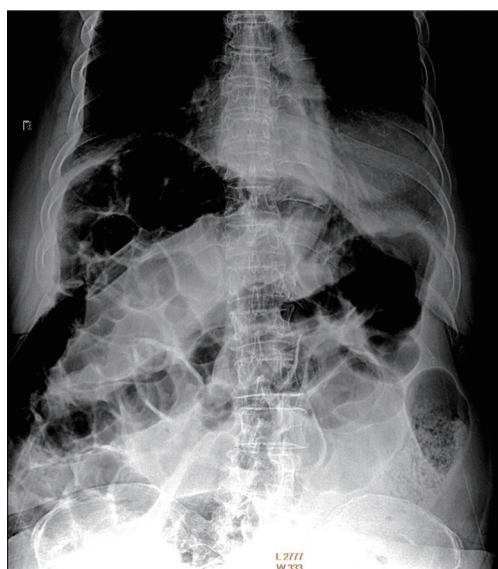

Figure 31 Abdominal FR of a female aged 70 years. T5-L4 vertebrae are displayed with no deformity observed. Bowel distention and extensive gas collection are noted. LR confirmation was not obtained for this patient. FR, frontal radiograph; LR, lateral radiograph.

Footnote

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