Conventional X-rays in the diagnosis of osteoporosis

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Summary

Conventional X-ray examination of the spine is the most important method to diagnose vertebral fractures. Radiologists are requested to identify, characterize and quantify vertebral fractures. Based on this diagnosis, an estimation of the incident fracture risk becomes possible and an indication to treat can be discussed consequently. Standardized documentation of diagnostic results is mandatory to assess the efficiency of the treatment.

KEY WORDS: conventional X-rays, vertebral fractures.

Introduction

The WHO definition of post-menopausal osteoporosis is based on the measurement of bone mineral density (BMD) with dual X-ray absorptiometry (DXA). Low DXA-BMD of the hip as well as poor results in the trail making and chair rising tests are risk factors of equivalent magnitude (OR 1.19-1.23) for vertebral fractures (Johnell, 2004(. Consequently, more diagnostic approaches are needed to complete the diagnostic procedure. The most important method to identify spinal fractures is conventional X-ray, particularly because >50% of spinal osteoporotic fractures are not accompanied by clinical symptoms, and hence, remain unnoticed. Nevertheless, the diagnosis of vertebral fractures is important, because the prevalence of vertebral fractures is associated with an increased risk of incident fracture (Johnell, 2004; Felsenberg, 2004).

Vertebral osteoporotic fractures are characterized by buckling and sintering of trabecular structures and deformation of the vertebral bodies (cave in of vertebral end plates). Conventional X-rays are therefore the most important source of information.

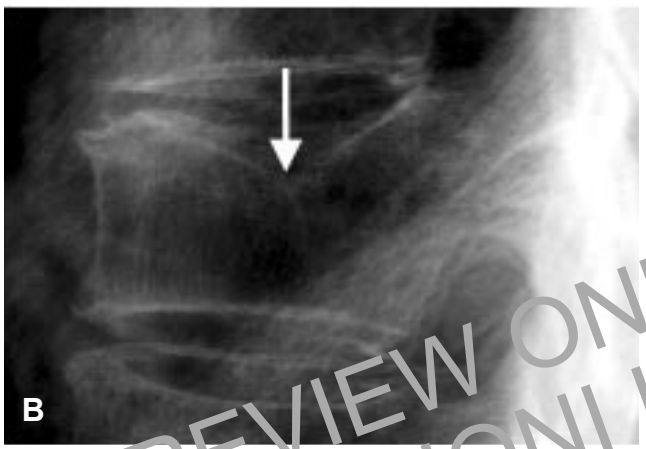
How to perform X-rays

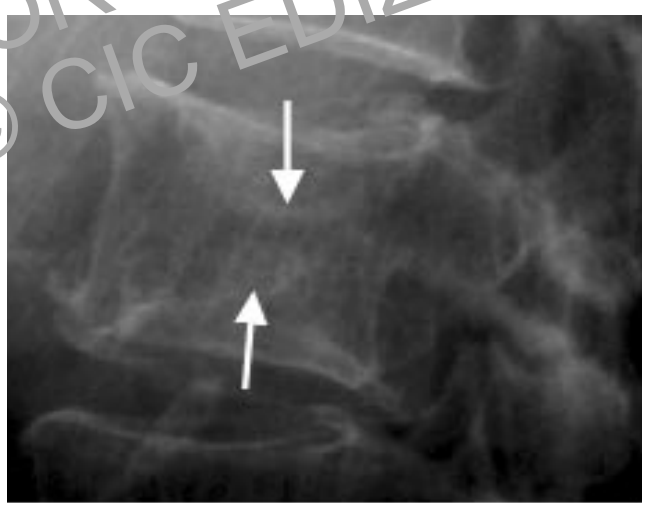
During the basic diagnostic procedure, it is mandatory to X-ray the patient's vertebral column in an anterior-posterior and lateral projection because for differential diagnostics, it is important to exclude other diseases causing vertebral deformities. In follow-up studies one can reduce X-ray examination to lateral expositions of the spine.

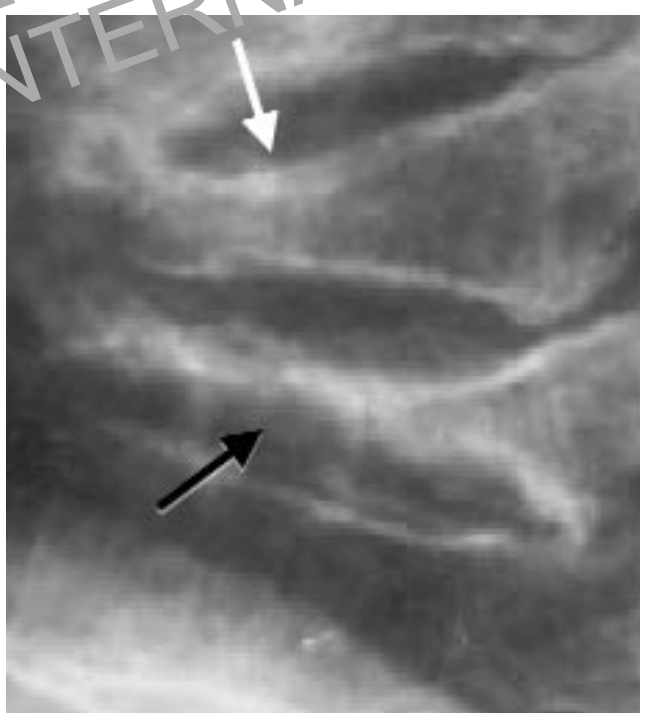
Osteoporotic vertebral fractures occur only in the dorsal and lumbar spine and are extremely rare in the cervical spine and in the upper thoracic vertebral bodies (T1-3). Therefore X-rays should depict T4-L5.

X-rays of the lateral thoracic spine are often underexposed in the cranial part, overexposed in the caudal part; whereas ribs, pulmonary structures and the diaphragm superimpose vertebral bodies. The quality of the image and consequently, the diagnostic accuracy, are badly influenced by these conditions. To avoid these influences, it is highly recommended to use breathing technique (developed by the author) and to perform the X-ray examination in a recline position. In the lateral position, scoliosis of the spine should be equalized as far as possible by using support cushions in order to expose the spine in parallel to the X-ray film (table). During X-ray exposition the patient is asked to quickly and deeply breathe in and out and without moving his or her body. The result is a tomographic effect with blurring off all moved structures like ribs, diaphragm and pulmonary structures. The problem of under- and overex-

Figure 1 - The best technique to perform high quality X-rays is the breathing technique: subject is asked to breath in and out during X-ray exposition. A) Dorsal spine without and B) with breathing technique.







position is impressively reduced.

How to diagnose vertebral osteoporotic fractures?

Osteoporotic vertebral fractures are characterized by end plate deformities of different shape. Increased activity of osteoclasts generates increased numbers of Howship's resorption lacunae on the surface of bone. Resorption first affects horizontal trabeculae leading to a deterioration of the trabecular network. This increases the risk of trabeculae buckling, and consequently, vertebral endplates fracture. Deterioration leads to different shapes: wedge, concave, biconcave, or crushed.

The diagnosis and classification of the shape of a vertebral fracture should be followed by the quantification of the fracture. Several approaches exist, but only two are important: a semi-quantitative and a morphometric analysis.

Semi-quantitative vertebral fracture analysis

Semi-quantitative analysis of vertebral fractures combines visual diagnostic with subjective estimation of the extent of the fracture. The X-ray will be compared to a list of examples of fractured vertebral bodies (Figure 3; method of Genant). Four different degrees of vertebral deformities are described: normal (Grade 0), mild (grade 1), moderate (grade 2), severe (grade 3). The semi-quantitative analysis is subjective.

Figure 2 - Shape of fractured vertebral bodies in osteoporosis. A) Wedge shaped fracture of the vertebral. B) Concave fracture of the upper endplate of a thoracic vertebra. C) Biconcave vertebral fracture. Both endplates are fractured centrally. D) Crushed (black arrow) and wedge shaped (white arrow) vertebral bodies.

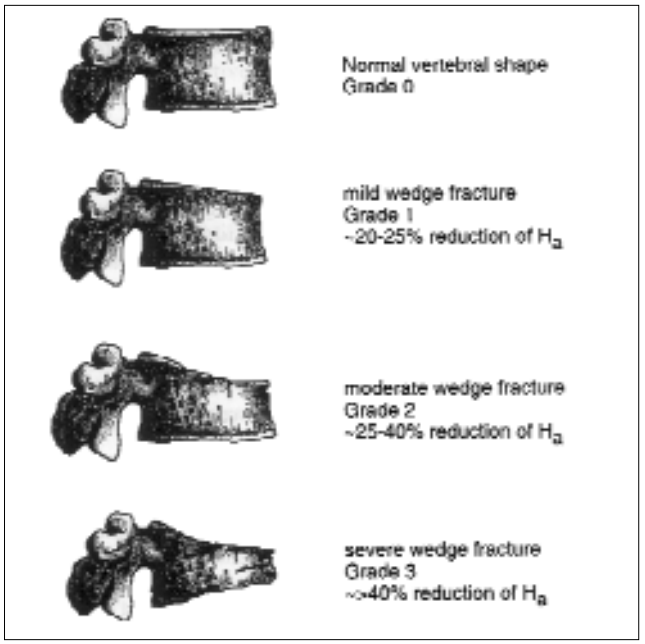


Figure 3 - Semiquantitative diagnostic of vertebral fractures (HK Genant method).

Morphometric vertebral fracture analysis

Objective quantification of a vertebral fracture can be performed with morphometric measurements. Using a ruler, you can measure the anterior, middle, and posterior heights of the vertebral bodies on a plane X-ray film or digitally on screen (Figure 4). To calculate the grade of fracture, you divide each the anterior and middle height by the posterior height and multiply them with 100. The result is the percentage of deformity. Crushed fracture is defined as a fracture in which the posterior edge of the vertebral body is almost always involved. In order to calculate a crushed vertebra you divide the posterior height with the posterior height of the adjacent vertebral body above and/or below.

A vertebral body is called fractured if the a/p, m/p or p/p height ratio is □80%. This definition was applied in nearly all big international intervention studies and in big epidemiological studies (EVOS, EPOS).

Differential diagnosis of vertebral deformities

All vertebral fractures are associated with vertebral deformity but not all vertebral deformities present fractures. To differentiate between diverse reasons of deformities, characteristics of the different deformities have to be described. In this article, only a few diagnoses will be discussed: Scheuermann's disease, osteoarthritis, bone metastases, and traumatic fractures.

Figure 4 (A-C) - Measurement of vertebral heights and calculation of height ratios. b. Positioning of measurement points in case of projection errors. c. Correct measurement of a vertebral body with a concave fracture of the upper endplate.

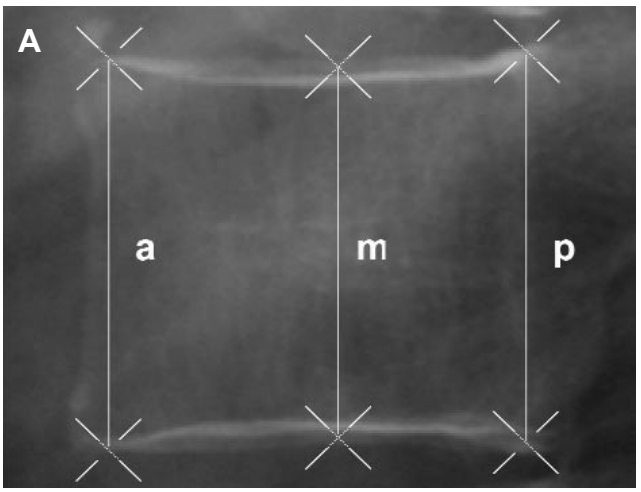


Figure 4 A) - Measurement of a/p, m/p and p_{up}/p or p_{low}/p to calculate height ratios. A height ratio x 100 □ 80% is defined as a fracture. P_{up} is the height of the vertebra above and P_{low} is the height of the vertebra below.

Figure 4 B) - In case of projection errors, endplates are not projected on one line but like an oval. This has to be differentiated from a biconcave fracture. Measurement points have to be set between the end lines. In case of a fracture, a fracture line is visible and the measurement point has to be positioned on this fracture line (Figure 4c).

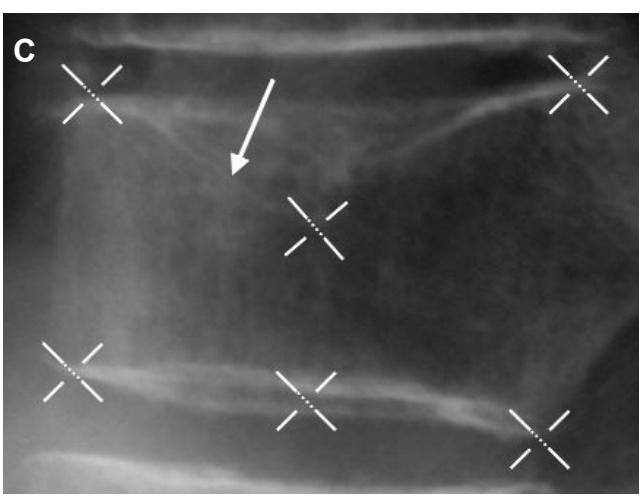


Figure 4 C) - Endplate fractures can be identified by a fracture line (white arrow). The illustrated case shows an end plate which is caved in centrally. Position the measurement point on this line.

Scheuermann's disease (Sd) is characterized by:
– Wedge-shaped deformities (most frequent at T7, T8 and L1).
– Uneven vertebral endplates caused by minimal cave-ins of the lower and upper endplates by discus material.
– Schmorl's nodes: small protrusions of intervertebral disk material caving the endplates; predominantly located in T6-T11, maximum T8. Those nodes are mostly marked by a sclerotic edge and are positioned in the anterior sections of the vertebral bodies most frequently of the thoracic spine. Sometimes it is extremely difficult to differentiate between Schmorl's nodes and recently occurred endplate cave-ins achieved by bone loss.
– Long vertebral bodies concerning anterior/posterior direction.
– Edgren Vaino Sign (pathognomonic).
– Height depression of intervertebral disk space.

It is not absolutely necessary that all signs are present to diagnose Scheuermann's disease. If two characteristics of the following three are detectable, one can diagnose Sd: wedge shaped deformity, hyperkyphosis of the dorsal spine, Schmorl's nodes or uneven end plates.

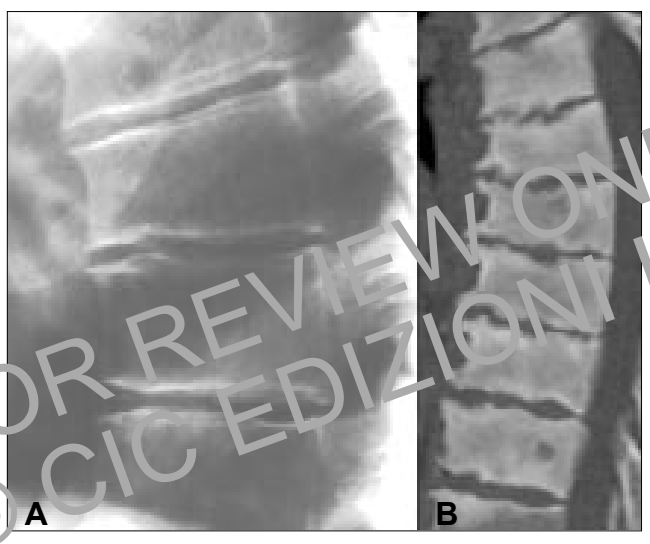


Figure 5 - A) X-ray of Scheuermann's disease with some of the typical signs: narrowed disk space, wedge shaped vertebral bodies, uneven endplates, Edgren Vaino sign. B) Spiral-CT sagittal reconstruction of a dorsal spine with extraordinary remnants of Scheuermann's disease.

Spinal Osteoarthritis

Spinal Osteoarthritis is characterized by degenerative processes in the spine (spondylosis). A large variety of different shapes can be seen on X-rays. Height reduction of the intervertebral disk space, sclerosis of the endplates, and marginal vertebral osteophytes are typical for osteochondrosis intervertebralis whereas normal disk space and submarginal spondylophytes is characterizing spinal osteoarthritis. Because of this additional bone, the shape of the vertebrae changes: wedge shape or concave shape. While degenerative processes are associated with the above described osteo- and spondylophytes as well as with height reduction of the intervertebral disc space (in case of osteochondrosis), those bone structures are usually not found in cases of osteoporotic vertebral fractures.

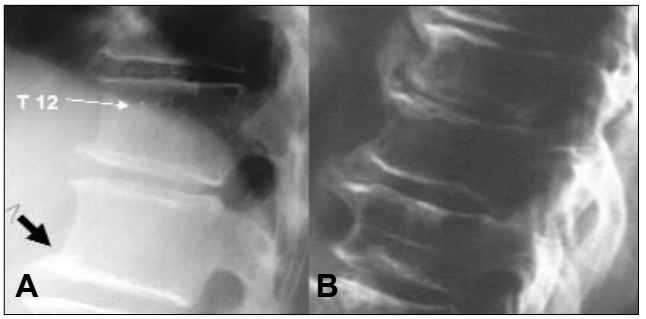


Figure 6 - A) Degenerative deformities of the T12 vertebra with slightly narrowed disk space, signs of degeneration with spondylophytes (short black arrow). The wedge shaped deformity of T12 is not based on osteoporosis. B) Spinal osteoarthritis with severe vertebral deformities.

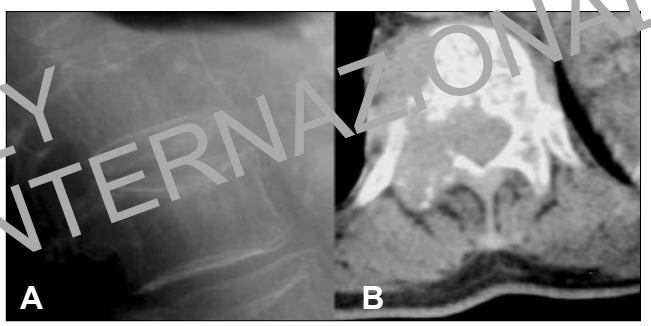


Figure 7 - Bone metastases with destruction of the vertebral body. A) X-ray with vertebral deformity. B) Corresponding CT examination illustrating the osteolytic lesion.

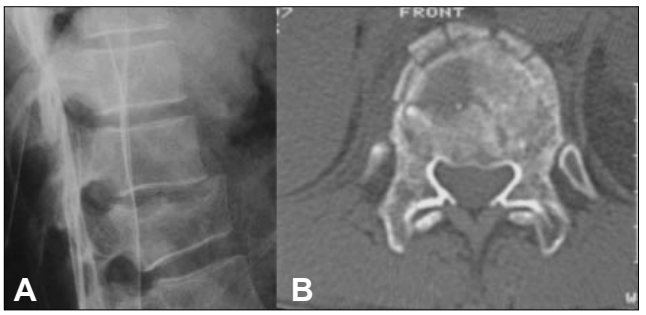
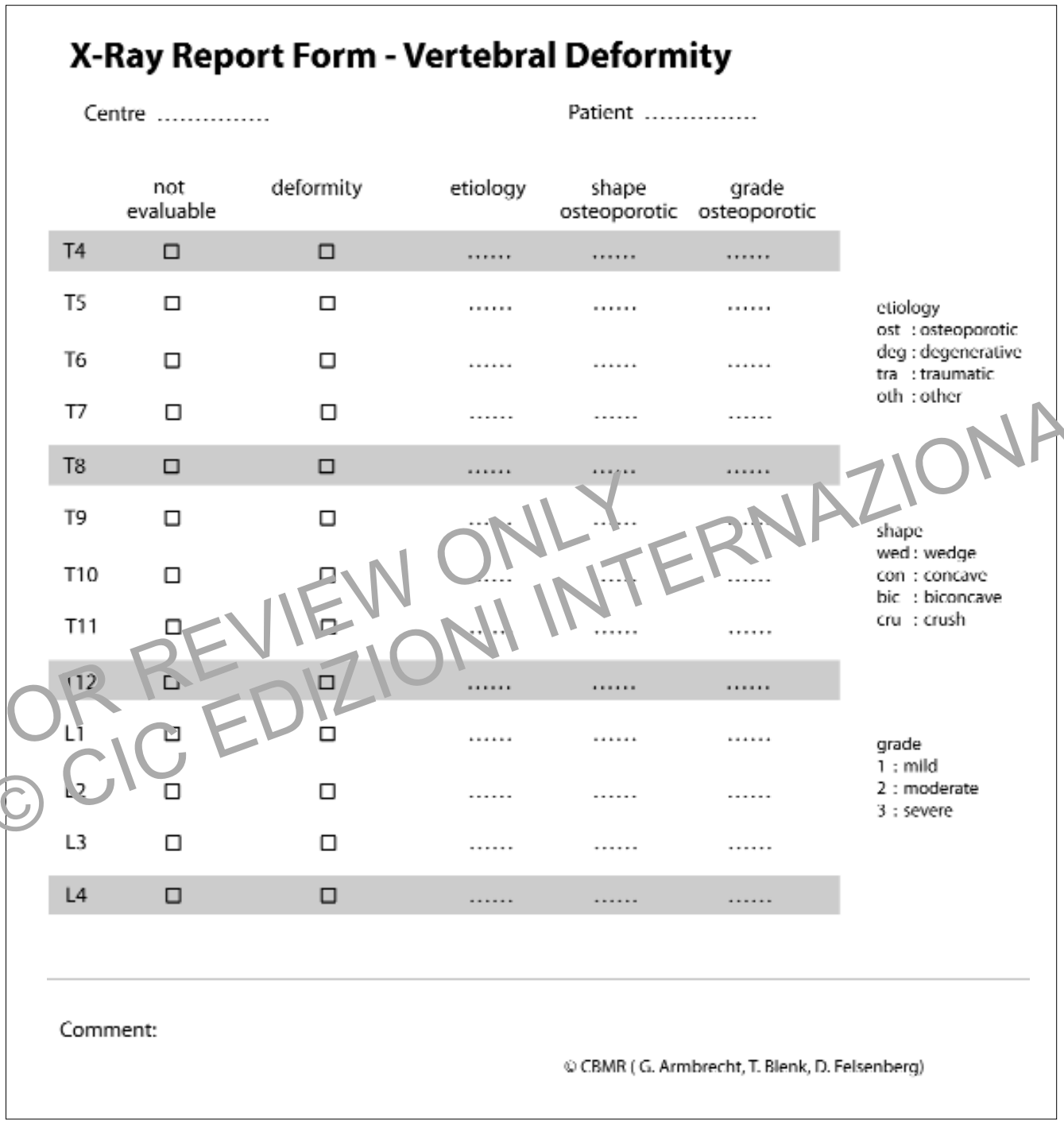


Figure 8 - Traumatic vertebral fracture. A) Typically, the fragments are dislocated and increase the diameter of the vertebral body, as visible on lateral spine X-rays. The anterior parts of the vertebral bodies are out of alignment. B) Corresponding CT-examination of the fractured vertebra. No fragments are dislocated in the spinal channel.

Bone metastases

Osteolytic metastases are complications in breast cancer, bronchial cancer, hypernephroma, and other malignancies. Osteolytic lesions in vertebral bodies are frequently associated with deformations which you then have to differentiate against osteoporotic fractures. With CT- or MRI-examinations better differentiation can be achieved.



X-Ray Report Form - Vertebral Deformity

Centre ..... Patient .....

	not evaluable	deformity	etiology	shape osteoporotic	grade osteoporotic
T4	☐	☐	.....	.....	.....
T5	☐	☐	.....	.....	.....
T6	☐	☐	.....	.....	.....
T7	☐	☐	.....	.....	.....
T8	☐	☐	.....	.....	.....
T9	☐	☐	.....	.....	.....
T10	☐	☐	.....	.....	.....
T11	☐	☐	.....	.....	.....
T12	☐	☐	.....	.....	.....
L1	☐	☐	.....	.....	.....
L2	☐	☐	.....	.....	.....
L3	☐	☐	.....	.....	.....
L4	☐	☐	.....	.....	.....

etiology
ost : osteoporotic
deg : degenerative
tra : traumatic
oth : other

shape
wed : wedge
con : concave
bic : biconcave
cru : crush

grade
1 : mild
2 : moderate
3 : severe

Comment:

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Figure 9 - Standardized X-ray report for osteoporosis diagnostic concerning vertebral fractures (Felsenberg D, Armbrecht G, Blenk T).

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Traumatic fracture

The traumatic vertebral fracture is characterized by an increase in diameter in the anterior-posterior and bilateral direction as a result of a sudden high-force impact that leads to bone fragments being distributed to all directions. Unidirectional fractures with dislocation of the fragments can be observed as well but contrary to osteoporotic sintering fractures, you will always see a dislocation of fragments.

Standardized documentation of diagnostic results

Radiologists should take care to systematically identify and document all vertebral deformities. The final report should include a description of vertebral deformation, the exact number of deformations, the exact location, the differential diagnostic, and in case of a vertebral osteoporotic fracture, the grade and shape of deformations has to be noted. In order to standardize the report we recommend using the following report sheet: