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Making VFA Part of Standard Clinical DXA Assessment for Osteoporosis Care: Recommendations From the International Working Group on DXA Best Practices

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Abstract

Fracture risk is strongly dependent on the presence of previous fractures, especially vertebral. In this paper, we focus on the use of vertebral fracture assessment (VFA) with dual-energy x-ray absorptiometry (DXA), as vertebral fractures can be clinically silent, and their identification is critical for optimal bone health management. Our tool was to inform health care professionals about the clinical utility of accurate recognition and classification of vertebral fractures. A comprehensive narrative review was conducted on the clinical relevance of diagnosing vertebral fractures, the technical aspects of optimal methodology for VFA, image interpretation and scoring methods, and pitfalls in evaluating VFA. Proposals for standardization on methodology and indications for VFA were discussed and iterated after comments from 15 international societies to achieve consensus recommendations. Vertebral fracture assessment should ideally be performed in all patients in whom a DXA–bone mineral density measurement is indicated. However, when there are limitations to DXA access or reimbursement, VFA should be obtained in patients at high risk for fractures, such as those with a low bone mineral density T-score (<−1.0) and one or more of the following: oral glucocorticoid use, prior vertebral fracture, loss of height, and advanced age (International Society for Clinical Densitometry criteria). If VFA is not available on the DXA system software, conventional lateral spine radiographs can also be used as an alternative option to identify vertebral fractures. Although several scoring systems exist, the semiquantitative Genant score and the algorithm-based qualitative scoring system seem to be among the best, with the Genant score being the easiest to apply in clinical practice.

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Osteoporotic fractures are common, particularly in the elderly, with one in two women and one in five men suffering from a fragility or low trauma fracture after 50 years of age.[1-3] Fragility fractures commonly occur in patients with osteoporosis, a systemic disease characterized by low bone mineral density (BMD) and structural deterioration in bone tissue making bones less able to

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withstand forces.[4,5] Osteoporosis, defined as a T-score less than or equal to −2.5, is diagnosed clinically by assessing BMD with central dual-energy X-ray absorptiometry (DXA), as recently discussed by our multidisciplinary International Working Group on BMD.[6,7] The diagnosis of osteoporosis is important to identify patients at high fracture risk who will benefit from lifestyle and pharmacologic interventions to reduce fracture risk.[1,2,8-10]

Although an individual's future fracture risk can be estimated by clinical risk factors in combination with measurement of BMD by DXA,[1,2,4,9,11] one of the strongest predictors of fractures is the presence of preexisting vertebral fractures (VFs), which can be diagnosed with good accuracy by vertebral fracture assessment (VFA), previously known as instant vertebral assessment or lateral vertebral assessment, at the time of BMD measurement by DXA.[12-24] This is clinically relevant as most VFs are not recognized based on patient symptoms alone.[12,14-17,21,22,25-31] Identification of VFs may change the diagnostic classification of metabolic bone disease, estimation of future fracture risk, and treatment decisions.[12-15,17-19,21,22,32] Compared with standard radiography of the thoracic and lumbar spine, VFA is less expensive, involves less ionizing radiation, images vertebrae with less obliquity or parallax than standard radiographs, and is more convenient because it can be performed at the same visit as DXA BMD measurement.[12,13,17,20,29,33] This report will review the technical aspects of performing VFA with DXA; the optimal interpretation, grading, and scoring methods; and the potential pitfalls involved. It is intended to inform health care professionals who are not experts in the care of patients with skeletal diseases to achieve a better understanding of strategies to diagnosis osteoporosis and assess fracture risk.

ARTICLE HIGHLIGHTS

- In daily practice, fracture risk is usually estimated based on clinical risk factors and bone mineral density (BMD).
- Performing a vertebral fracture assessment (VFA) in addition to dual-energy x-ray absorptiometry (DXA) is important because the majority of vertebral fractures are clinically silent; and vertebral fractures are strong predictors of both vertebral fractures and nonvertebral fractures.
- When there is an indication for DXA—bone mineral density, there is also an indication for DXA-VFA.
- The finding of previously unrecognized vertebral fractures may change diagnostic classification and estimation of fracture risk.
- Pre-existing vertebral fractures may influence the choice of initial treatment or treatment sequence.
- Baseline VFA is useful to monitor patients who may subsequently develop an incident vertebral fracture.

METHODS

This is another paper of the multidisciplinary international working group for best practice; the first paper on DXA-BMD has been recently published in *Mayo Clinic Proceedings*.[6] Briefly, the working group consists of representatives of 15 organizations, was co-chaired by two authors (AAK and RHJAS), and met virtually every 2 months and once yearly at the American Society for Bone and Mineral Research annual meeting.

We conducted a comprehensive narrative review of the literature to explore the clinical significance of diagnosing VFs, focusing on optimal methods for VFA, image interpretation, scoring systems, and common diagnostic challenges. The first versions of the five subchapters were initiated by one of two experts.

The review compared available VFA scoring systems, including the semiquantitative (SQ) Genant score and the algorithm-based qualitative (ABQ) scoring method.

We searched PubMed, Embase, Google Scholar, and the Cochrane Library using the following key terms: "vertebral fracture," "vertebral fracture assessment," "VFA," "Genant score," "semiquantitative Genant score," "ABQ score," "osteoporosis," "DXA," and "spinal imaging." The search was performed in January 2024. Hand searching reference lists for relevant articles was also conducted.

To ensure relevance and clinical applicability, we reviewed recent position statements and practice recommendations from international bone health and radiology societies. Feedback from 15 professional societies was incorporated to achieve consensus on VFA standardization proposals.

CLINICAL RELEVANCE OF VFs

Vertebral fractures are the most common fractures among men and women older than 50 years of age.[9,12-15,17,20,26,28-31,33-38] It has been estimated that only one of three VFs result in symptoms sufficient to come to medical attention, usually as new or worsening back pain.[16,17,25,26,30,38,39] Thus, most VFs are silent and may be subsequently identified on imaging for evaluation of height loss or back pain. One of the reasons for the large percentage of asymptomatic fractures is that, in contrast to a peripheral fracture, usually characterized by acute and severe pain after a fall or trauma, VFs usually occur without trauma during normal activities such as climbing stairs, bending, twisting, or lifting.[15,40] Back pain is also very common in adults, and may not be associated with a fracture due to the mild nature of the discomfort.[41] Importantly, back pain and functional limitations are more common among women than in men with an asymptomatic VF.[42]

The clinical relevance of VFs is that they are strong predictors for future fractures, independent of BMD.[38,43,44] In patients with VFs, the risk of future VFs and nonvertebral fractures (including hip fractures) is elevated two- to five-fold.[18,19] The risk of incident VFs and nonvertebral fractures is strongly related to the number, severity, and recency of prevalent VFs.[18,19] Vertebral fractures that are present on routine imaging of the spine are commonly under-reported, representing missed opportunities to diagnose VFs and intervene to reduce the risk of future fractures. For example, in a study in 2451 postmenopausal women, 32% had at least one VF but 34% of these were falsely reported as normal or described with equivocal terminology.[16] In a US study of 934 postmenopausal women, only 50% of VFs were adequately diagnosed by the radiologist, representing a false negative rate of 50%, whereas only 25% were reported in the medical records.[28] It is therefore important to explore strategies for the detection and reporting of VFs in those already suspected of being at higher fracture risk.

The rationale for performing a DXA-VFA in addition to DXA-BMD includes the following: (1) The finding of a previously unrecognized VF may change diagnostic classification and estimation of fracture risk; (2) Pre-existing VF may influence the choice of initial treatment or treatment sequence. And (3) baseline VFA is useful to monitor patients who may subsequently develop an incident vertebral fracture.

PERFORMING VFA

The correct acquisition of VFA on a DXA scanner requires that the operator has the knowledge, skills, and competency in scanner-specific patient positioning, anatomy, and correct analysis techniques.[45] Most DXA scanners have VFA software pre-installed or available for installation. Each DXA scanner has a VFA measurement protocol that may require the use of positioners for optimization of scan quality. Regardless of which scanner is used, the spine area of interest should include the lowest lumbar vertebral body and include the entire thoracic spine. In an optimal VFA scan, the fourth thoracic vertebra through the fifth lumbar vertebra are imaged and valid for fracture recognition. Because of overlying lung tissue, the upper one-third of the thoracic spine is often poorly visualized. Difficulties in positioning may arise in patients who have mobility challenges, kyphosis, or scoliosis. In these patients, repositioning (reverse the side of the lateral position to straighten the curve) or use of lumbar and thoracic radiographs may be required.

Correct patient positioning for the VFA is essential for obtaining a good quality diagnostic scan. In general, most individuals have five lumbar vertebrae, with the iliac crests at the level of the L4/L5 disc. However, in some individuals there may be four, or

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more often six lumbar-like vertebral bodies, and it is common that some of the upper thoracic vertebral bodies are not adequately visualized.[13,46] Fortuitously, this is not a major limitation of VFA imaging because the majority of VFs occur between vertebral levels T6 through L4.[47] We recommend labelling vertebrae from the bottom upwards, starting at L5 or L6. A review of 542 VFA scans has shown that 55% had one or more and 25% had three or more vertebrae deemed unsuitable for evaluation, whereas 90% required manual adjustment for quantitative assessment.[13]

Different methods are available to aid the analysis of the images in research and practice, including the Genant SQ visual assessment technique[28,29,48] and the ABQ assessment method[47,49-51] These are discussed in more detail in the next section. The use of an automated analysis is discouraged because the placement of software 6-point markers (sometimes 8-point markers) is variable and not always accurate.

Individuals who interpret VFA must be familiar with standard scanning procedures to determine whether the image is valid for recognition of VFs. Knowledge of anatomy and variants in vertebral bodies is essential to interpret the VFA. Vertebral levels not adequately visualized should not be included in the analysis and should be noted as exclusions in the report. Artifacts, discussed later under the heading "Common Pitfalls With VF Diagnosis by VFA," should be described. Automated vertebral morphology, if performed, must be validated by the interpreter. When possible, individuals should use existing previous VFA or radiographic studies to confirm whether a VF is old or new. When there is doubt regarding the diagnosis of a VF or an atypical-appearing vertebral body, consideration of additional imaging to exclude other pathologic processes should be recommended.

Each DXA manufacturer provides specific instructions for how to perform VFA scans with their technology. Ideally, the scan should start using the protocol to ensure that L5 is identifiable. When the VFA image is also intended to detect abdominal aortic calcification, which is associated with cardiovascular disease[52] and fractures,[53] then including 4 cm of soft tissue anterior to the lumbar spine is required.

Most modern DXA scanners use fan beam systems with linear array detectors, allowing for rapid acquisition time compared with pencil beam systems that have a longer scan time and are more demanding for patients. Most studies validating diagnostic accuracy have been conducted with newer fan beam/narrow fan beam systems. Some scanners require repositioning of the patient to obtain VFA images, which can be time-consuming and difficult, whereas one (Hologic) offers a built-in rotating C-arm which can perform the scan with the patient maintaining their position, saving time and potential discomfort.

Daily quality assurance procedures for DXA BMD testing should be performed; however, there is no standard quality assurance requirement for VFA. Regular auditing of image quality by a second qualified interpreter is advisable. Lateral spine BMD measurements are not recommended for diagnostic classification.

INTERPRETATION AND REPORTING OF VFA

In recent decades, methods of VF ascertainment on lateral spine images have evolved considerably. Radiologists' subjective assessments historically had poor inter-rater reliability; hence, fully quantitative morphometric methods were developed in the 1980s and 1990s[45,51,54] to improve accuracy and reliability of VFAs. These methods adjudicate a vertebra to be fractured if the posterior, middle, or anterior height(s) in the sagittal plane are reduced beyond a certain cut-off point as defined by the specific morphometric method. However, these methods do not distinguish vertebral fractures from nonfracture deformities that are also associated with height loss. Moreover, applying the six relevant markers to each vertebra to calculate all these height ratios

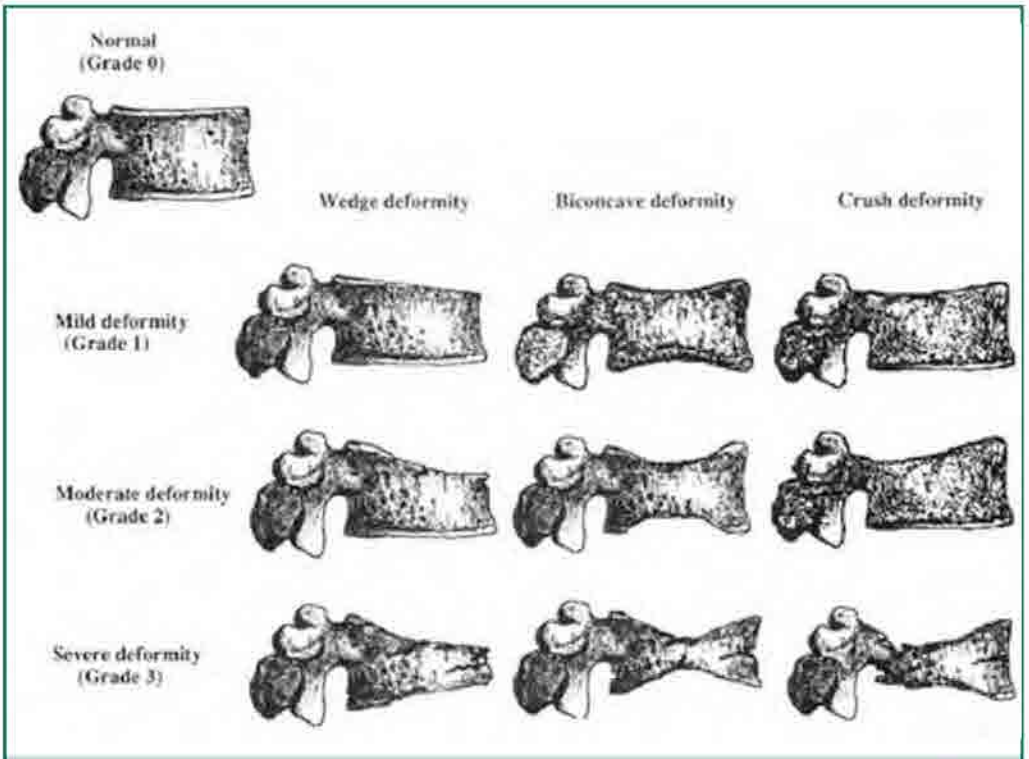

FIGURE 1. Genant-score of vertebral fractures. Reproduced with permission from Genant et al.[48]

is time-consuming and a somewhat tedious process.

To address these concerns and take advantage of the qualitative characteristics that distinguish fractured from nonfractured vertebrae, the SQ method of VF diagnosis was introduced by Genant in 1993.[48] Semiquantitative VFs are diagnosed primarily based on changes in vertebral shape (wedge, biconcave, or crush) (Figure 1). Vertebrae T4-L4 were graded on visual inspection as normal (grade 0), mildly deformed (grade 1, approximately 20% to 25% reduction in anterior, middle, and/or posterior height and a reduction of area 10% to 20%), moderately deformed (grade 2, approximately 25% to 40% reduction in any height and a reduction in area 20% to 40%), and severely deformed (grade 3, approximately 40% reduction in any height and area) (Figure 1).

Identification of both the number and severity of VFs is important, as both are independent predictors of incident fractures.[18,19] Additionally, the sum of the grades of VFs from T4 through L4 inclusive (spinal deformity index) is monotonically associated with an increased risk of both incident vertebral and nonvertebral fractures, after accounting for age and BMD.[18] Although the Genant SQ method does not explicitly state criteria by which VFs should be distinguished from nonfracture deformities associated with vertebral height loss,[49] Genant emphasized in his original publication the importance of qualitatively assessing if features of such deformities (such as degenerative disc disease and Scheuermann disease) might explain the observed shape change.[4,48]

The ABQ method of VF diagnosis was introduced in 2004,[55] postulating that broad endplate depression in the sagittal plane (from posterior to anterior cortex) is the morphologic feature that defines a VF and distinguishes it from nonfracture deformities.[56] The original ABQ method did not include any criteria for grading severity of fracture. A modified ABQ (mABQ) method was proposed in 2018, whereby fractures are adjudicated using the ABQ method, but

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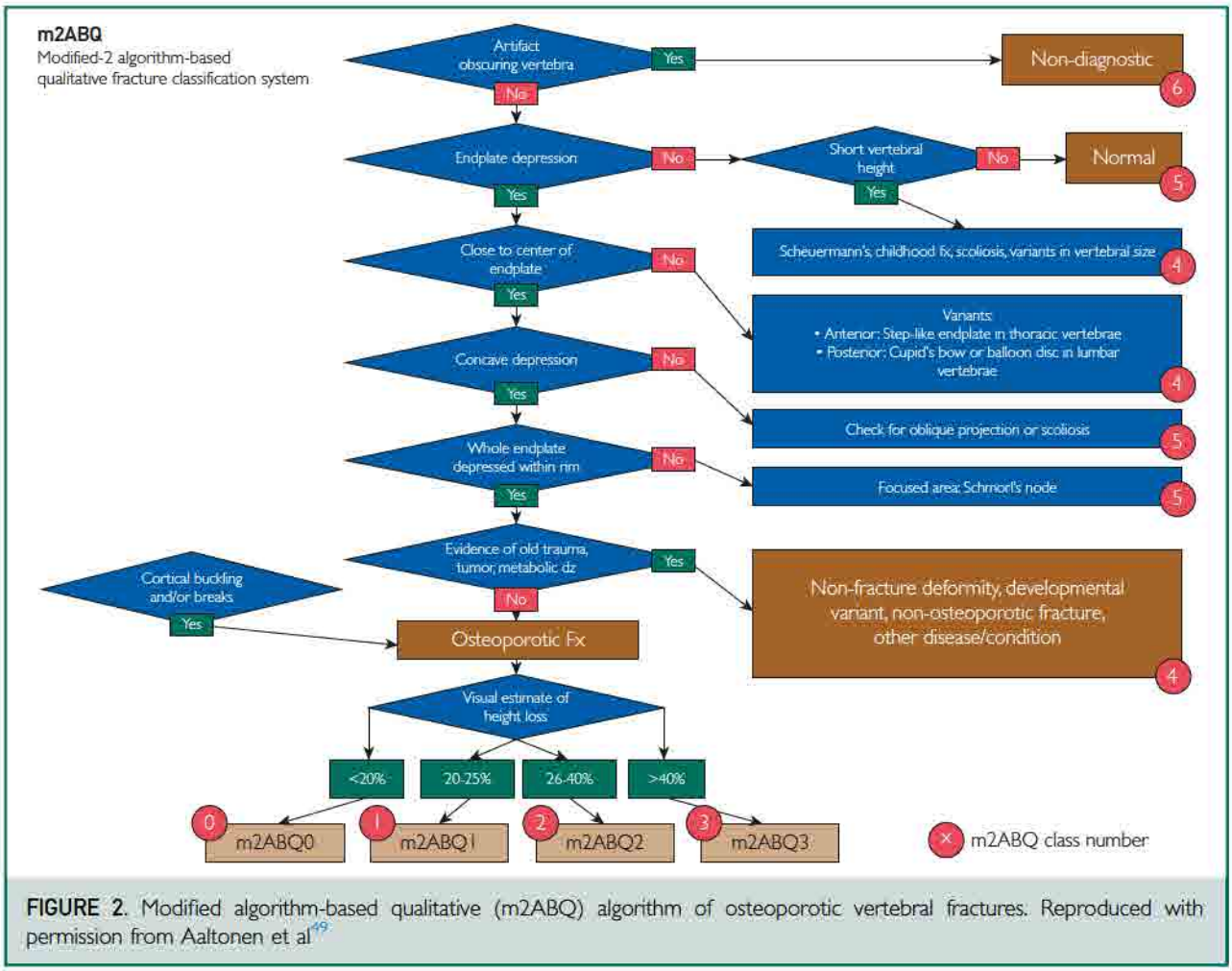

FIGURE 2. Modified algorithm-based qualitative (m2ABQ) algorithm of osteoporotic vertebral fractures. Reproduced with permission from Aaltonen et al[49]

are then graded according to the same height loss criteria used in the Genant SQ method.[47] In recent years, it has been recognized that anterior cortex fracture and buckling can infrequently/rarely occur in the absence of recognizable endplate depression[49] particularly on standard radiographs or DXA/VFA.[57] Hence, the mABQ method includes anterior cortical disruption or buckling as a separate criterion for diagnosis of VF (Figure 2).

Several studies have directly compared the mABQ method with the Genant SQ method or a fully quantitative morphometric (QM) method. These show that the prevalence of VFs is substantially higher in the thoracic region using either the Genant SQ[47,58] or a full QM method[59] compared with mABQ and that it is modestly higher in the lumbar region. This discrepancy may be greater in men compared with women.[58] Individuals with one or more VFs that meet the mABQ definition have lower BMD than those with VFs that meet the Genant SQ definition.[47,58] The presence of one or more mABQ VFs are more strongly associated with incident VFs and nonvertebral fractures compared with the presence of one or more Genant SQ VFs,[47] and mABQ VFs are more strongly associated with incident hip and VFs than QM VFs.[59] The inter-rater reliability of mABQ and Genant SQ methods is similar for grade 2 and grade 3 fractures but substantially better for mABQ compared with Genant SQ for grade 1 fractures.[47] On the other hand, the Genant SQ method is more easily performed, has been used in most clinical trials

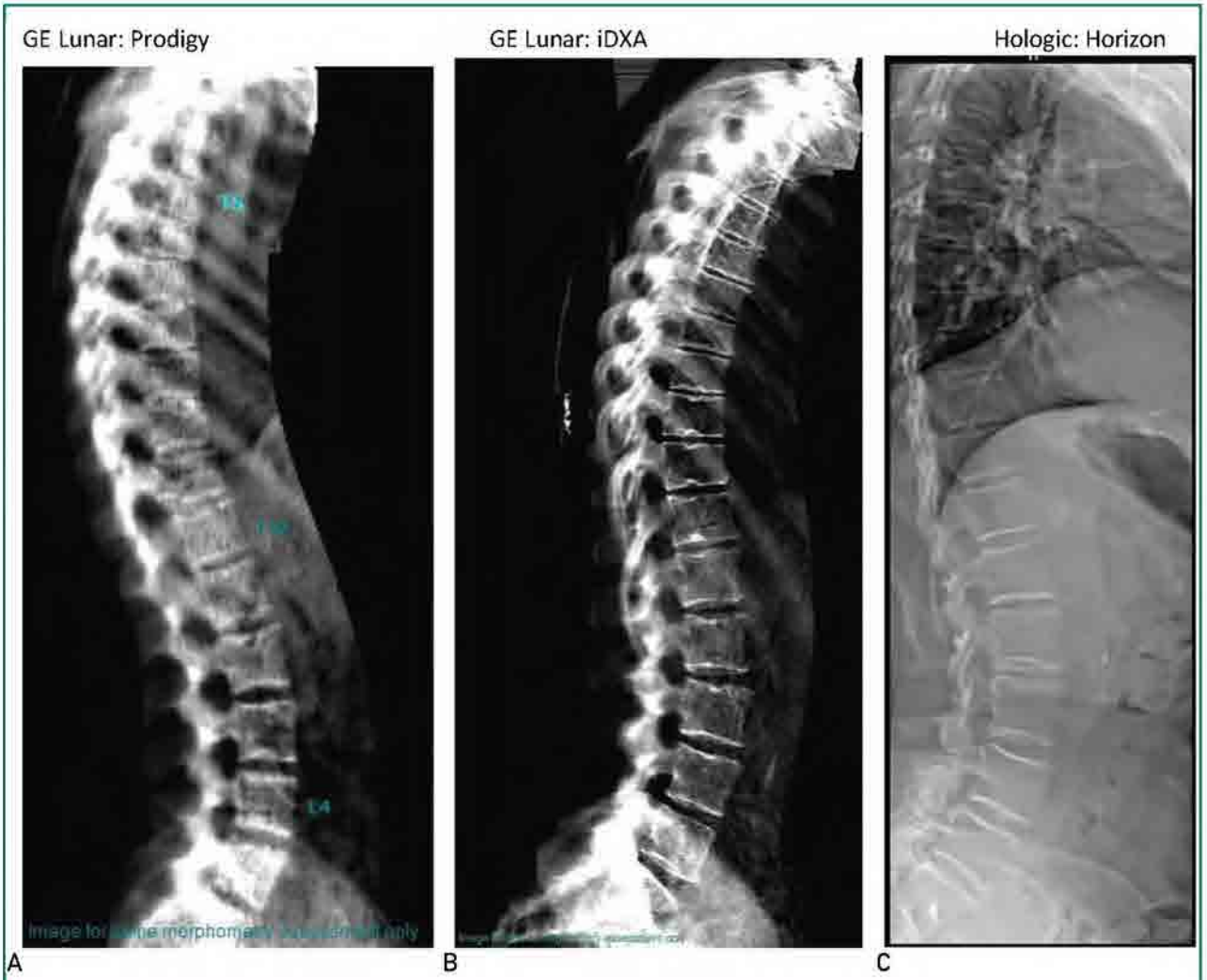

FIGURE 3. Three examples of modern technology show high quality vertebral image acquisition in patients without vertebral fractures. Image courtesy of John J. Carey, John Schousboe, and Neill Binkley.

evaluating osteoporotic drug therapies, and is commonly used in epidemiological studies estimating the prevalence of VFs.[35]

Prospective studies have now shown that prevalent VFs identified by VFA are associated with incident fractures using either the mABQ method[36] or the Genant SQ method.[20,33] One of the studies using the Genant SQ method required endplate depression and/or cortical discontinuity to consider grade 1 deformities to be fractured.[22]

A recent systematic review of 12 studies found that the sensitivity of VFA for identifying one or more prevalent VFs on a per patient basis compared with standard radiography ranged from 0.65 to 1.00, whereas the specificity ranged from 0.74 to 1.00.[36] When analyzed for individual vertebrae, the accuracy of VFA compared with conventional radiographs had a sensitivity ranging from 0.70 to 0.79 and a specificity ranging from 0.95 to 1.00. Additionally, the accuracy of VFA for the detection of Genant SQ grade 1 fractures was lower than for grade 2 or 3 fractures.[20,33] Another meta-analysis showed that the pooled sensitivity of VFA vs conventional radiographs on a patient level for a VF Genant SQ grade greater than or equal to 2 was 0.84 (95% CI, 0.72 to

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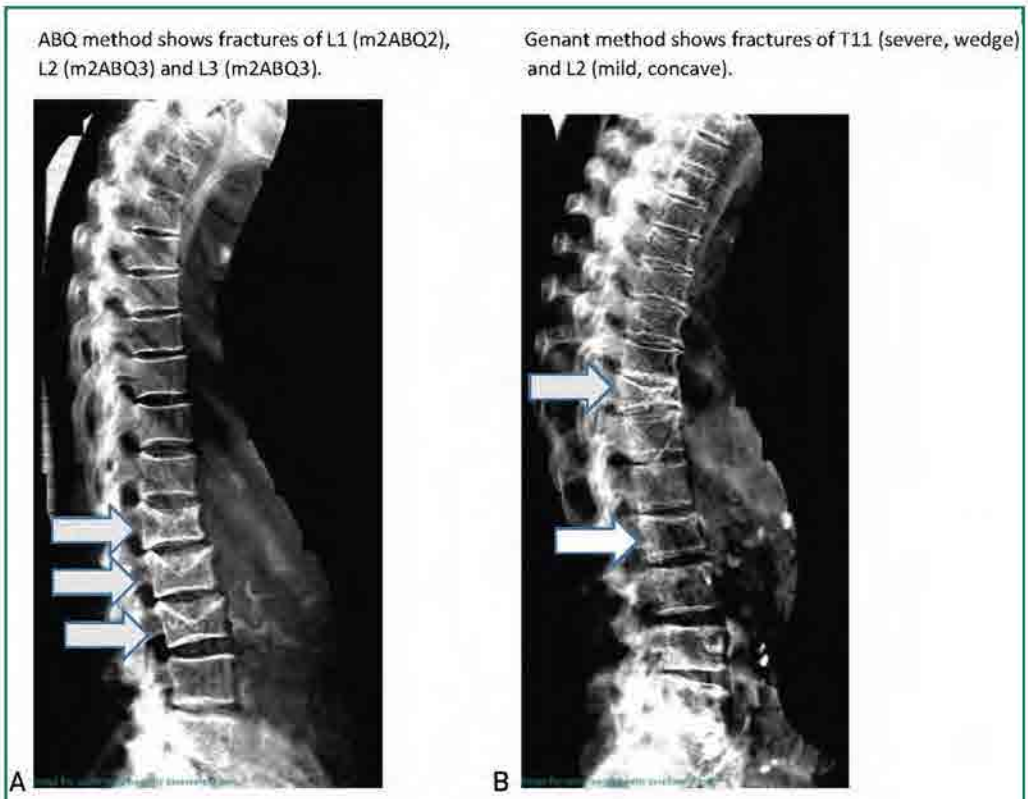

FIGURE 4. GE Lunar vertebral fracture assessment images showing examples of vertebral fractures (white arrows) from two different patients identified using the modified algorithm-based qualitative (m2ABQ) algorithm (A) and Genant (B) methodology. Note presence of vascular calcifications. Image courtesy of Neill Binkley.

0.92) and the specificity 0.90 (95% CI, 0.84 to 0.94).[13] One reason for the differences in sensitivity and specificity between VFA and conventional radiographs is related to the poor visualization above the seventh thoracic vertebrae with VFA due to lower resolution obtained from DXA images.[56]

COMMON PITFALLS WITH VF DIAGNOSIS BY VFA

Modern technology has greatly enhanced the ability to obtain excellent VFA images, which have very good sensitivity and specificity when compared with plain radiographs in the detection of VFs as outlined already.[13,28,29,36,46,60] Despite these advances, recognition and documentation of VFs remain problematic, with numerous publications describing the failure to diagnose fractures when present, discordance of interpretation with different interpreters for mild VFs, need for expertise in the methodology, problem of comparison between imaging modalities, and the lack of an absolute set of diagnostic criteria.[16,28-30,50,61-64]

It is important to appreciate that vertebral deformities that appear to be VFs may sometimes be due to other conditions. Distinguishing VFs from nonfracture pathologies can be challenging.[31,35,48,61,63] A number of congenital anatomic variants are well described,[63,65] whereas other pathologies can have a similar appearance[61,63,64,66-71] or may co-exist with VFs (Table).[59-61,64,71] The prevalence of vertebral deformities varies according to vertebral level (highest in lower thoracic vertebrae), sex (more common in women than men), and geography (more common in some countries than others), and is highly dependent on the VF

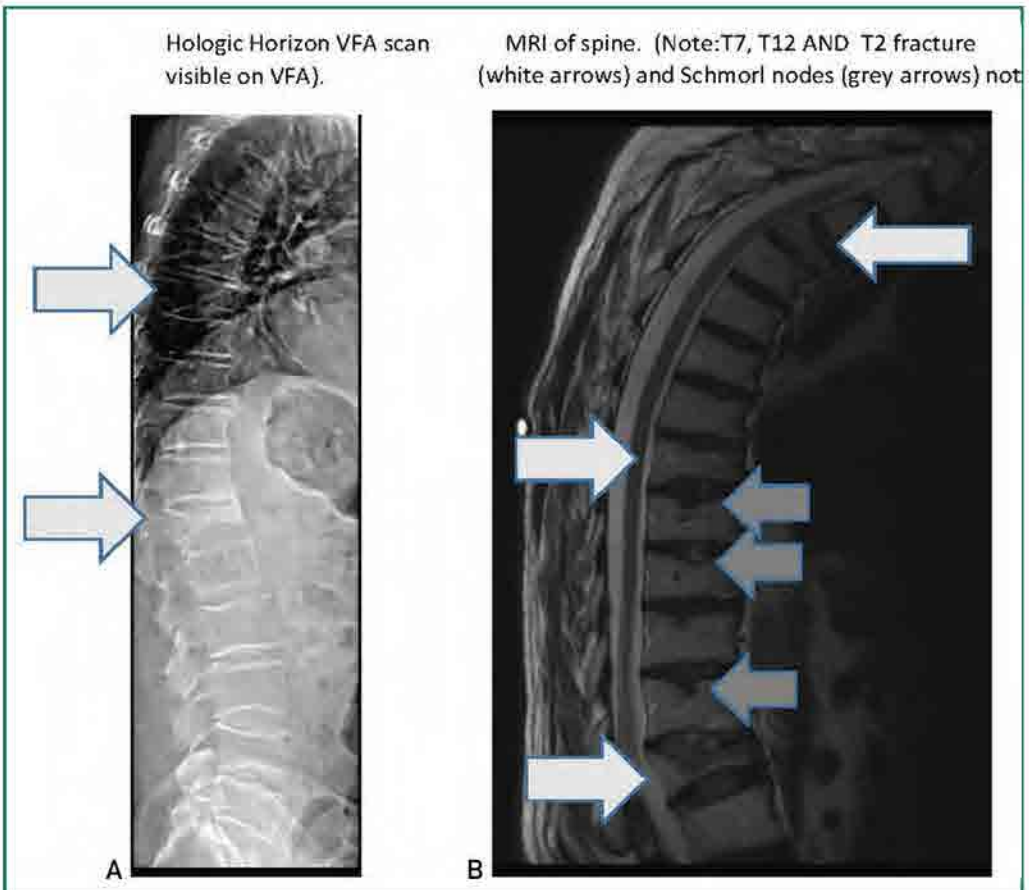

FIGURE 5. Hologic vertebral fracture assessment (VFA) image showing (A) vertebral fractures (white arrows) of T7 (inferior endplate grade 2) and T12 (grade 3) and (B) additional vertebral fracture on magnetic resonance imaging (MRI). Image courtesy of John Schousboe.

classification method.[12,30,34,50,62] There is a critical need for clearer definitions and terminology, including the appropriate use of the word "fracture" in reports, consensus, education, and training related to VF diagnosis (with VFA).[16,28,29,31,50,61-63]

The prevalence of spinal deformities ranges from 5% or 6% to 80% or 90% depending on the population studied, particularly with respect to age, criteria applied, and imaging modality used,[50,62,64,68] with many non-VF deformities also associated with back pain and stiffness.[66] Additionally, postural abnormalities such as scoliosis and kyphosis are common in children[72,73] and adults,[74-76] making the interpretation of images in these patients difficult. Because VFs are associated with a continuum of vertebral height loss and anatomical deformities, very mild VFs can easily be confused with other abnormalities or missed.[16,28,29,61] Among the most confound factors for interpretation of VFs are osteoarthritis,[66,69-71] diffuse idiopathic skeletal hyperostosis, and Scheuermann disease.[67,68] Physiological variations in vertebral height and shape are also very prevalent.[63] Congenital disorders such as spina bifida and scoliosis are frequent,[65,73] whereas less common pathologies in children and adults may occur. Finally, metal implants such as artificial discs or osteosynthesis materials may interfere with VFA interpretation.

Characteristic and distinguishing features greatly enhance the interpretation of images including additional clinical, qualitative, and quantitative information, some of which is outlined in the Table. Although osteoporotic fractures are strongly associated with

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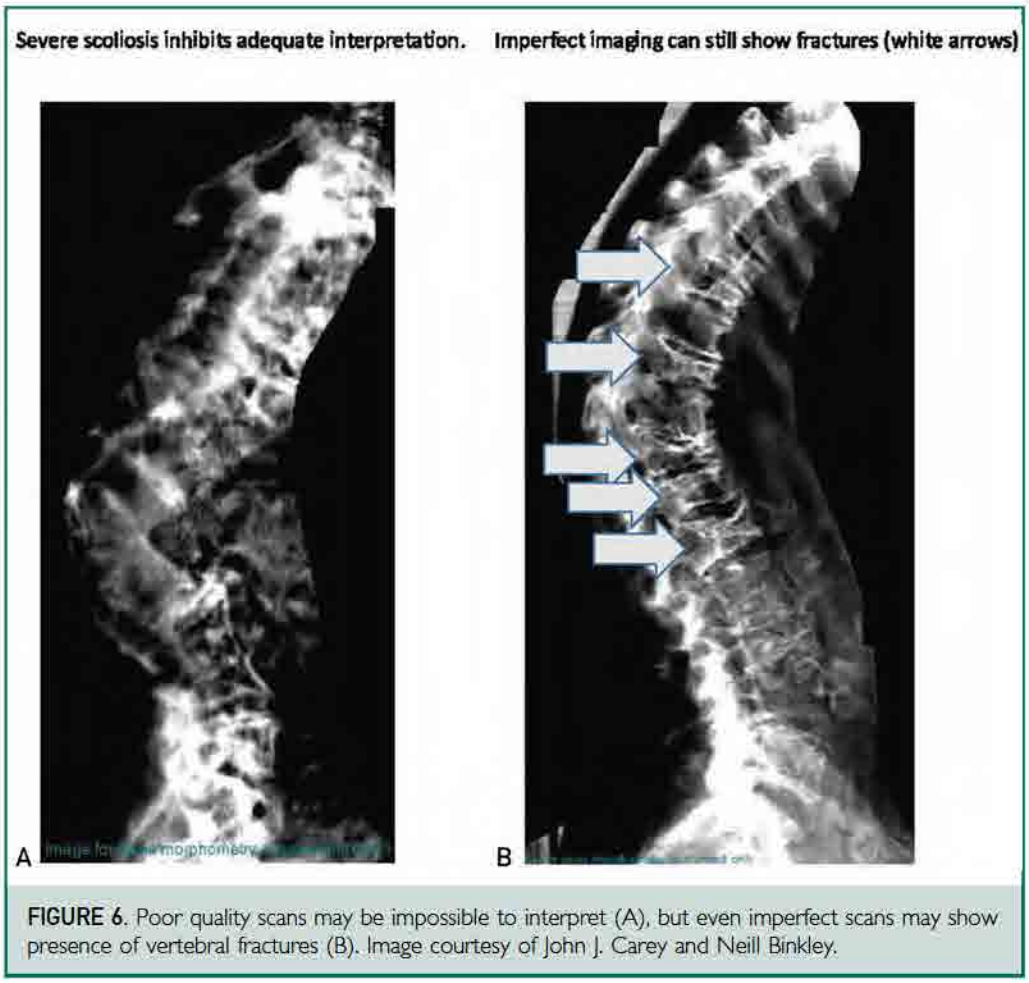

FIGURE 6. Poor quality scans may be impossible to interpret (A), but even imperfect scans may show presence of vertebral fractures (B). Image courtesy of John J. Carey and Neill Binkley.

low BMD (T-score <−1.0), the mean T-score of the total hip in the US NHANES III (Third National Health and Nutrition Examination Survey) population with prevalent VFs by VFA was −0.7.[35] Although pain, kyphosis, height loss, and other symptoms may be an indication to consider imaging of the spine, these features are not specific to fragility fractures.[35,38,43,44,66-68,77] Correct diagnosis is critical as the implications are very different.[12-14,61,77] Training courses with expert clinicians and musculoskeletal radiologists are offered by the International Society for Clinical Densitometry and the European Calcified Tissue Society. These address many of the anatomic variants and fracture mimics and provide those interpreting images with a good foundation of knowledge.[78,79] When uncertainty exists, liaising with an expert musculoskeletal radiologist and considering the need for additional imaging as subsequently outlined is crucial. The thoracic vertebrae may appear slightly wedged and the lumbar vertebrae may appear slightly concave while still falling in the normal variance spectrum.[28,29,38,48,50,56,63]

Errors in DXA acquisition, reporting, and interpretation are common and can have a profound impact on patient care.[78,79] There has been a substantial increase in the insertion of various artificial grafts, stents, and substances over the past 30 years or more such that many patients today may have an array of items which can falsely increase BMD. These include surgical devices, vascular grafts and stents, pumps, and transplanted organs and tissues; some examples are shown in Figures 3-11 (Table).

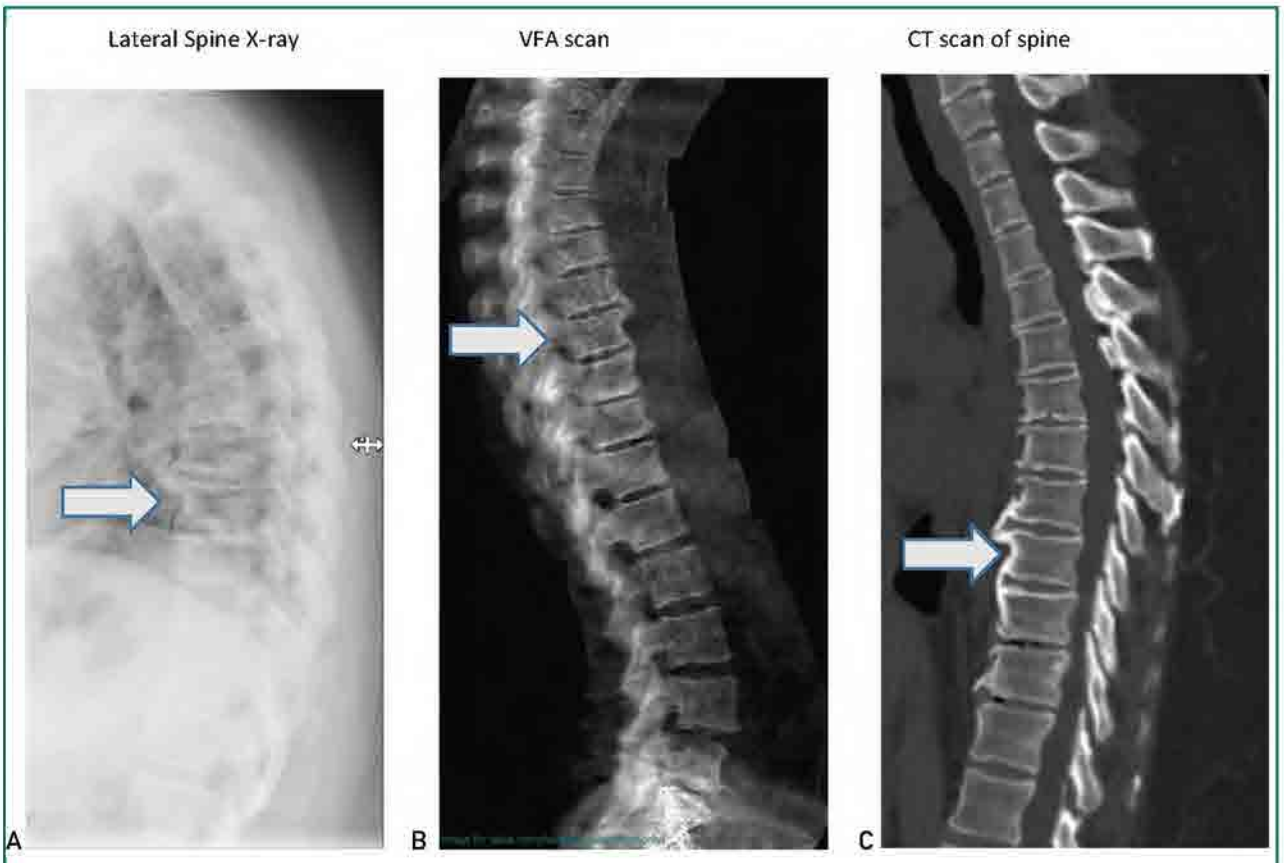

FIGURE 7. Osteoarthritis can mimic fractures, and additional imaging may help clarify the correct diagnosis. A patient with back pain had a lateral spine x-ray (A) reported as showing a T8 vertebral fracture (white arrow). Subsequently, a dual-energy x-ray absorptiometry–vertebral fracture assessment (VFA) scan (B) was requested that did not clearly show a fracture. A follow-up computed tomography (CT) scan (C) confirmed this to be osteoarthritis rather than a vertebral fracture (note the large osteophytes). Image courtesy of Neill Binkley.

OTHER IMAGING TECHNIQUES FOR DIAGNOSING VFs

The lower diagnostic accuracy of VFA in comparison to conventional radiographs for levels above T7 must be considered. Additionally, when the diagnosis of a VF is unclear or if there are remaining concerns with VFA, additional imaging may be warranted for confirmation. Historically, conventional radiography was regarded as the gold standard[20,33,36]; today, magnetic resonance imaging (MRI) (when available) is considered the gold standard for correct identification of vertebral fractures.[80-82] Additional benefits to MRI include the ability to identify other pathologies, information about the acuteness of the fracture (eg, by the presence of edema) and presence of damage to surrounding tissues, and lack of radiation.[80-82] Computed tomography (CT) scans (regular or low-dose) are also useful, in particular when MRI is not available or not suitable. Novel methods, such as dual-energy computed tomography and combined CT scanning with MRI, are showing promise and greater sensitivity to diagnose recency of fracture.[80,81] Discussion with a local expert musculoskeletal radiologist is the key to optimizing the use and benefits of further imaging.

DISCUSSION

This report is a consensus of 15 national and international societies dedicated to advancing excellence in skeletal assessment and fracture risk evaluation providing

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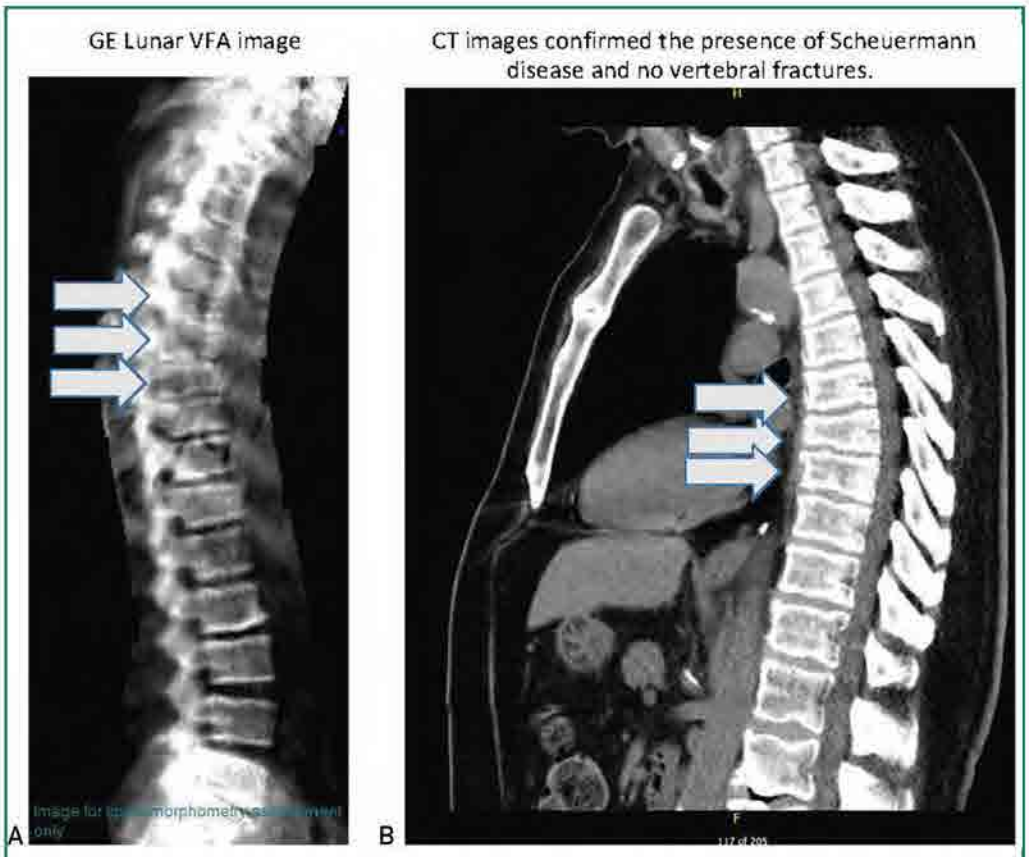

FIGURE 8. Scheuermann disease (white arrows) can mimic vertebral fractures and may be indistinguishable on vertebral fracture assessment (VFA) imaging. Image courtesy of John J. Carey. CT, computed tomography.

guidance on best practice in the use of VFA technology because diagnosing VFs has important clinical consequences. The result of VFA is positive when one or more VFs were diagnosed grade greater than or equal to 2 (and otherwise negative), and in case of one VF grade greater than or equal to 2, there is an independent risk factor for future fractures, and clinicians should make decisions about treatment based on BMD, clinical risk factors, and the presence of VFs. Because there are a number of osteoporosis medications which have proven efficacy in preventing fractures, in particular in patients with VFs,[8] it is important to diagnose those individuals at high risk for fracture who may benefit from pharmacologic intervention, including early use of anabolics.[83]

High fracture risk is estimated by integrating BMD with clinical risk factors and the presence of VFs using validated fracture risk algorithms, such as FRAX.[1,2,12,38] Vertebral fractures are the most common type of fragility fractures and are strong predictors of future fractures.[1,2,12,30,34,38] An individual with a VF is five times more likely to suffer another VF and up to three times more likely to have another major osteoporotic fracture.[14,18,21] Moreover, the majority of patients with VFs do not come to clinical attention, highlighting the need for strategies to identify silent VFs.[25,26] The development of DXA/VFA has created an opportunity to diagnose VFs as a part of standard clinical care in patients screened and monitored for osteoporosis/poor bone health. Vertebral fracture assessment is an

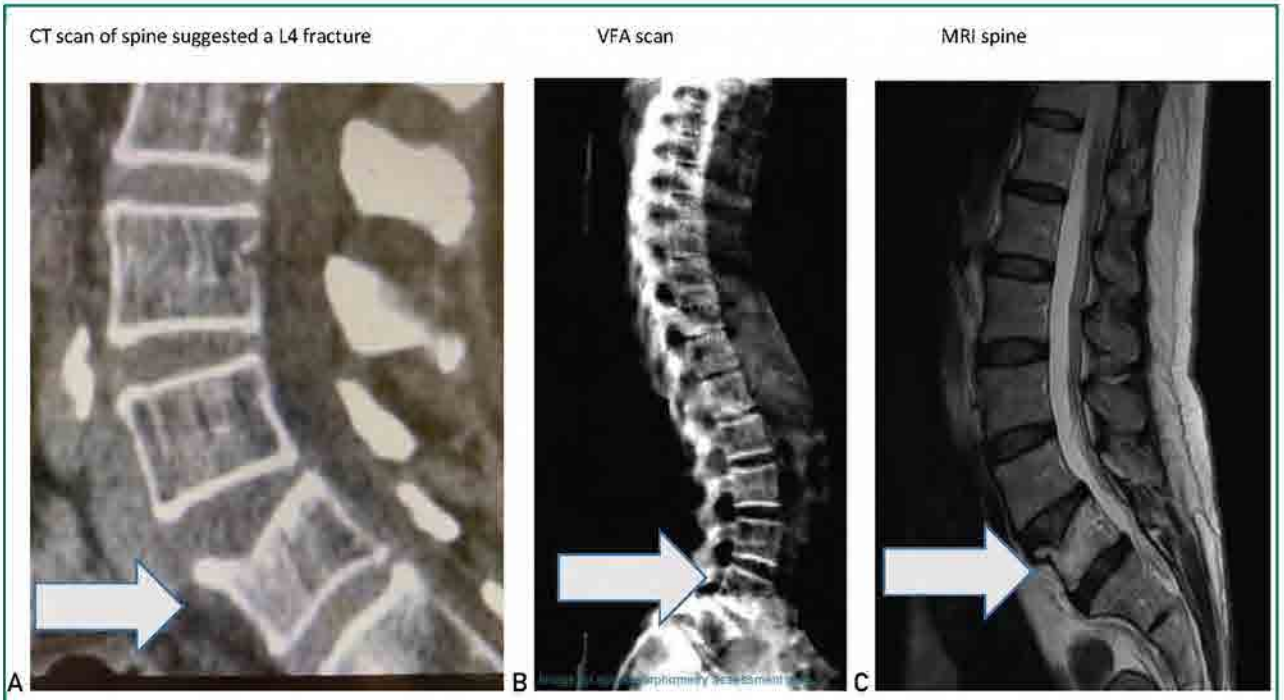

FIGURE 9. Schmorl nodes can mimic fractures. Additional imaging and radiology review can help. (A) A patient with back pain and an L4 fracture (white arrow) on a computed tomography (CT) scan was referred for a dual-energy x-ray absorptiometry (DXA) scan. (B) The DXA vertebral fracture assessment (VFA) scan showed no vertebral fracture, but the patient had low bone mineral density (T-score: −2.2). (C) A magnetic resonance imaging (MRI) scan showed a large subacute Schmorl node but no vertebral fracture. Image courtesy of John J. Carey.

inexpensive and reliable method for the assessment of VFs, particularly moderate-to-severe VFs, and available on most modern DXA systems. Vertebral fracture assessment has several advantages over other imaging modalities, including point-of-service convenience in association with DXA BMD testing, having much lower effective radiation dose compared with conventional spine x-rays (0.7 mSv for the standard lumbar spine radiograph vs 0.002 to 0.05 mSv for VFA of the whole thoracolumbar spine), and lower cost.[12,20,38]

Osteoporosis is one of the most prevalent noncommunicable diseases worldwide. There are many effective and available medications worldwide, some for almost 30 years, which lower subsequent vertebral and nonvertebral fracture risk. Today, we have good evidence that some medications are more effective than others in reducing fracture risk.[8] Osteoanabolic agents are superior to antiresorptive drugs for reducing fracture risk, especially VFs, in women at very high risk for fracture, including those with a low T-score who have moderate to severe VF(s).[1,84,85]

Vertebral fracture assessment can help to identify patients in need of osteoanabolic drugs. Changes in BMD with osteoporosis medication are very reflective of treatment efficacy,[10] but monitoring VFA should be considered, especially among those with prior VF, or when medication has been stopped, particularly denosumab.[86] Thus, VFA should ideally be performed in all patients in whom a DXA-BMD is indicated, both at baseline and additionally to subsequent measurements, which has the opportunity to diagnose both prevalent and incident VFs.

However, including VFA in all patients having BMD measured by DXA is associated with additional time and effort, identification of previously unrecognized VFs with VFA

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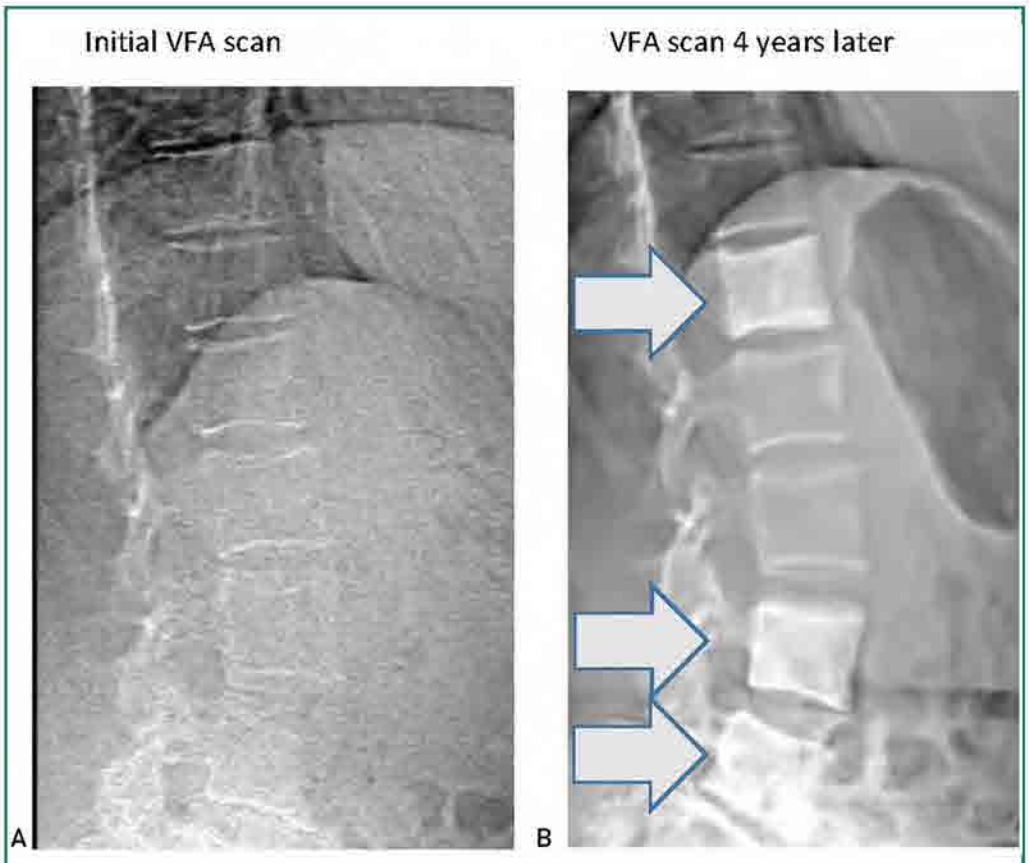

FIGURE 10. Dual-energy x-ray absorptiometry vertebral fracture assessment (VFA) imaging warrants careful attention for other pathologies. (A) A patients initial scan showed no significant abnormality; however, a repeat scan (B) 4 years later showed metastatic breast cancer at L1, L4, and L5 (white arrows). Image courtesy of John Schousboe.

may lead to treatment that might not have otherwise been given, and a reduction in personal and societal costs of fragility fractures. In settings where financial or staffing resources are inadequate to perform both VFA and BMD measurement in all patients or limited by insurance payment or legislation, VFA should be targeted at patients at greater risk. According to the International Society for Densitometry (ISCD), lateral spine imaging with standard radiography or VFA by DXA is indicated when T-score is less than −1.0 and of one or more of the following is present: women 70 years of age or older or men age 80 years of age or older, height loss greater than 4 cm (>1.5 inches), self-reported but undocumented prior vertebral fracture, glucocorticoid therapy equivalent to greater than or equal to 5 mg of prednisone or equivalent per day for greater than or equal to 3 months.[38]

Financial limitations can also play a role in services where there are inadequate funds to purchase VFA software, particularly in low- and middle-income countries, where access to DXA is often severely constrained or not available.[87-89] In those situations, performing a conventional radiograph of the thoracolumbar spine can be an alternative in the subgroup of patients with a very high fracture risk, particularly the elderly and patients with height loss. A possible disadvantage of this strategy is the lack of information against which to judge whether VFs found subsequently are incident or prevalent.

The lower diagnostic accuracy of VFA in comparison to conventional radiographs,

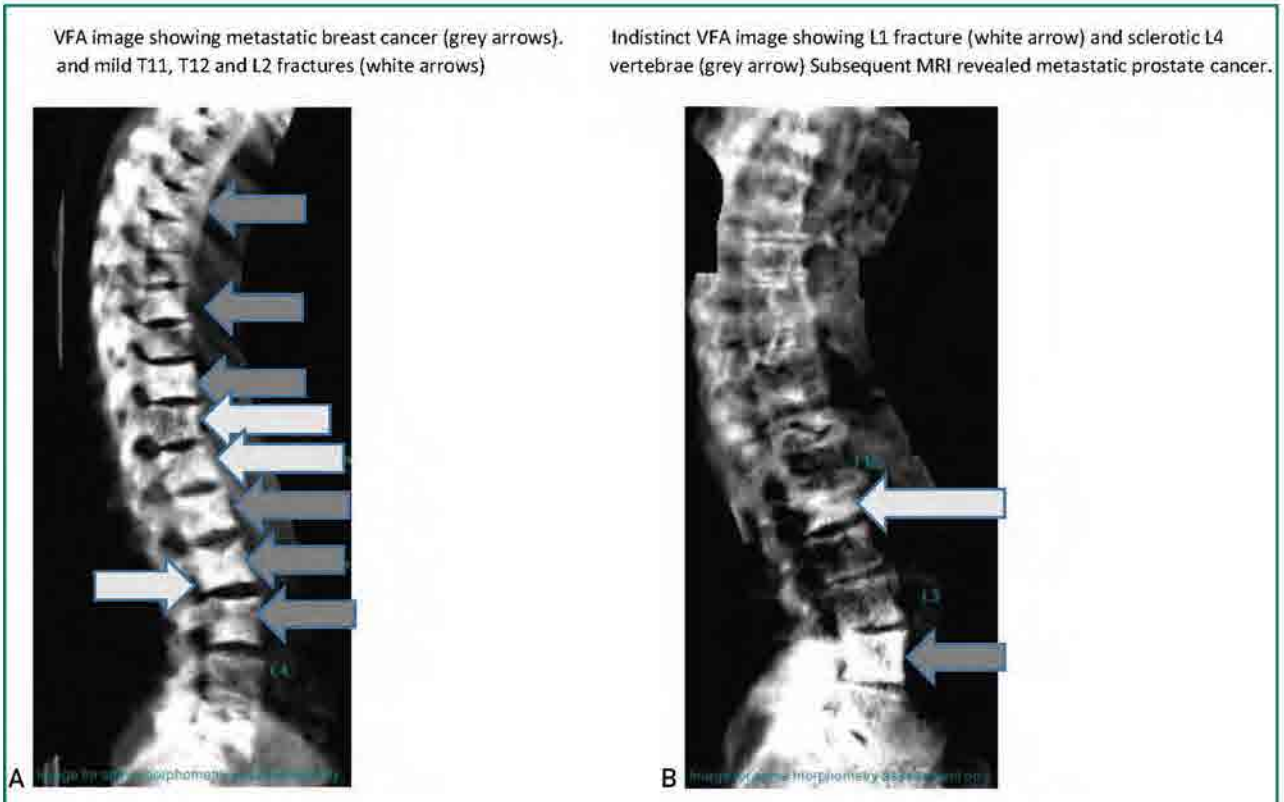

FIGURE 11. Vertebral abnormalities can be due to vertebral fractures, but other pathologies may co-exist such as metastatic disease. Image courtesy of John J. Carey. VFA, vertebral fracture assessment.

particularly above T7, must be considered. However, the sensitivity and specificity for VFs according to Genant grade greater than or equal to 2 is substantially higher. Because most VFs occur between T7 and L1, and as the increased subsequent fracture risk is related to the severity of the VF, both limitations (poor visualization in upper thoracic spine and not scoring Genant grade 1 VFs) may be less relevant in daily practice.

Health professionals engaged in the performance, interpretation, and reporting of VFA should have access to up-to-date information on best use of their technology and adequate training and knowledge in which artificial intelligence can be very helpful to provide accurate and reliable information to referring clinicians.[90] Underreporting of VFs is a global problem and radiology or VFA reports can be suboptimal.[16,45,51,54] Adequately reporting the number, type, and severity of VFs, whether using the Genant or ABQ method, is even more important for clinicians who base their diagnostic decisions and treatment strategies on the presence or absence of fractures that are grade 2 or more. An important point is that there is always a risk of incidental findings or doubt whether there is a VF or not, potentially leading to the use of new imaging techniques (CT, MRI). However, we mentioned that the sensitivity and specificity of grade 2 or more VFs is substantially higher than for grade 1; thus, when only focusing on the much easier to recognize grade 2 VFs, the number of extra imaging techniques will be much lower than for VF grade 1. Adequate care must also be taken to differentiate VFs from other abnormalities, such as Scheuermann disease, osteoarthritis, and other fracture mimics as they have direct and critical impact on clinical decision making for patient management.

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TABLE. Differential Diagnoses of Vertebral Fractures

Disorder	Characteristics	Population prevalence	Association with low bone mass
Scoliosis, kyphosis and positioning problems[72-76]	Usually obvious on antero-posterior and lateral images. More severe forms can make distinguishing fractures from positioning difficult. See notes from those performing the scan.	Prevalence rises with age from <10% of children to >30% of older adults	Variable
Congenital anomalies[65]			Variable
Osteoarthritis[66,68,70,71]	Endplate changes and spurs (osteophytes) may take on the appearance of mild fractures.	3%-95%	Variable
Diffuse idiopathic skeletal hyperostosis[69]	Hyperostosis and spurs may give a more rectangular appearance suggestive of mild fracture	10%-35%	No
Scheuermann disease[67]	Endplate irregularities, Schmorl nodes, kyphosis. Usually seen in several adjacent vertebrae so a pattern of abnormal vertebrae are seen.	1.4%-13.5%	No
Schmorl nodes	Round defect in middle or anterior vertebral endplate with or without sclerotic rim.	7%-30%	No
Short vertebral height	Reduced vertebral height without evidence of endplate depression. Associated with older age and greater weight. Usually associated with multiple similar shaped vertebrae.	20%-40%	No
Artifacts	Usually obvious on antero-posterior and/or lateral images. Vertebral fracture assessment can be very helpful in this regard as shown in examples below.	Very common	Variable
Spondyloarthropathies	Vertebrae with syndesmophytes; may interfere delineation of the contour detection of the vertebra.	1%	Yes
Malignancy	Sclerotic or lytic bone lesions which may be present in multiple bones.	<1%	Variable

Finally, the implementation of VFA in addition to DXA is a difficult issue; it can be limited by barriers and accelerated by facilitators in clinical practice.[91,92] Adequate implementation of VFA is limited by lack of knowledge, technology and/or staff, and/or inappropriate recognition that VFs may well be present with very few or mild symptoms or even none at all. Many patients do not understand the significance of a high VF risk; sometimes patients and even physicians are not aware of the prognostic importance of VFs as it relates to future fracture risk. A promising new development is artificial intelligence, diagnosing a VF on an earlier imaging technique.[90] We will emphasize that using opportunistic imaging may lead to earlier diagnosis of a VF and may be clinically relevant. Nevertheless, performing a VFA in the same setting as DXA provides information on the current presence or absence of the number and severity of VFs. Nevertheless, performing a VFA in the same setting as DXA provides information on the current presence or absence of the number and severity of VFs. However, successful implementation of DXA/VFA is feasible, as shown in a Dutch study in which a comparison was made of the percentage of performed VFs and diagnosed VFs (grade 2) at the fracture liaison service before and after a national guideline in which VFA was advocated in addition to DXA (4.7% to 97.1% and 0.9 to 14.7%, respectively).[93] In line with that, Schousboe et al[94] have shown that the systematic introduction of VFA following DXA influences the prescription of medication to treat osteoporosis (52.3% vs 28.4% in patients with a positive VFA vs a negative VFA).

CONCLUSION

We advocate considering VFA in all patients in whom a DXA is indicated. When VFA is

adequately performed and reported using a grading according to Genant or ABQ, with appropriate VF differentiation from other abnormalities, the identification of these fractures can lead to improvement in patient care with reductions in morbidity and mortality but also relief from the high economic costs of treatment of osteoporotic fractures.

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POTENTIAL COMPETING INTERESTS

The authors report no competing interests.

Abbreviations and Acronyms: **ABQ**, algorithm-based qualitative; **BMD**, bone mineral density; **DXA**, dual-energy x-ray absorptiometry; **mABQ**, modified algorithm–based qualitative; **QM**, quantitative morphometric; **SQ**, semiquantitative; **VFA**, vertebral fracture assessment; **VF**, vertebral fracture

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