Morphometric X-ray absorptiometry in the assessment of vertebral fractures in renal transplant patients

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Abstract

Background. Bone mineral density (BMD) is widely employed to evaluate the risk of fractures, but more than mineral content is bone quality that accounts for bone strength. In fact, occasionally, subjects with normal or only mildly reduced BMD also experience pathologic fractures. In metabolic bone disease, like renal transplantation, the agreement between fractures and BMD is less predictable. We assessed the prevalence of vertebral fractures by means of a new, DEXA-based method (morphometric absorptiometry, MXA) and compared its concordance with the two mostly employed radiological techniques (Visual semi-quantitative, SQ, and morphometric radiography, MRX) in an asymptomatic population of transplanted patients. Moreover, the association of bone fractures with low BMD values was examined.

Methods. Fifty-three renal transplant patients underwent spinal radiographs and BMD measurements by DEXA. In order to obtain a morphometric assessment, a lateral DEXA scan was performed.

Results. Patients with vertebral fracture were 17/53 (32%) with both SQ and MRX, and 12/53 (23%) with MXA ($\chi^2 = \text{n.s.}$). A single fracture was detected in 9/53 patients (17%) with SQ and MRX, and in 4/53 (7.5%) with MXA; multiple fractures were 8/53 (15%) with any technique. With SQ as the standard reference, predictive indexes were excellent with MRX (invariably 100%) and quite good with MXA (sensitivity 70.6%; specificity 100%). Of the total of 689 vertebrae, 49 were fractured with SQ, 54 with MRX and 41 with MXA. Mild deformities were present in 21 (SQ), 26 (MRX) and 13 (MXA) vertebral bodies, respectively, while moderate-severe deformities were 28 with any technique. Again, with SQ as standard reference, predictive indexes were good (MRX: sensitivity 100%, specificity 99.2%; MXA: sensitivity 83.7%, specificity 100%). When we classified patients according to BMD T-score values, SQ and MRX recognized fractures in 4/18 normal (22%), 10/22 osteopenic (45%) and 3/13 osteoporotic (23%). With MXA 3/18 (17%) normal, 6/22 (27%) osteopenic and 3/13 (23%) osteoporotic were fractured. The lower performance of MXA was very likely due to the poor quality of images from the upper thoracic spine of obese subjects.

Conclusions. Prevalence of vertebral fractures in renal transplant patients is quite high and randomly associated with reduced BMD. A surveillance of the spine by Rx, implemented with vertebral morphometry, is therefore warranted to recognize the disease. (MXA is a reliable alternative technique, especially in more severely affected individuals.) MXA, although less sensitive than the conventional techniques because of possible technical biases, is very specific, and can be proposed for follow-up purposes in this population of patients.

Keywords: bone mineral density; dual energy X-ray absorptiometry; renal transplantation; vertebral fractures; vertebral morphometry

Introduction

Patients with kidney transplant are known to have a high prevalence of decreased bone mineral density (BMD) [1,2] and the most widely employed technique to evaluate this condition is through dual energy X-ray absorptiometry (DEXA). According to diagnostic criteria obtained from a general population, when BMD values are $< -2.5$ SD compared to a race and sex matched young normal group (T-score), a condition of osteoporosis is diagnosed, bearing an 8× increased risk of fracture [3]. Moreover, it is accepted that the risk approximately doubles for each standard deviation reduction in bone mass [4]. Transplanted patients with
decreased BMD, in comparison, have been reported to experience a fracture rate between 9 and 44% of the cases [2,5]. However, in recent years, it has been highlighted that BMD is not the sole parameter apt to evaluate bone strength, i.e. the weight bearing capacity of bone before fracturing. In fact, elasticity, spatial trabecular disposition and concentration, collagen quality and other still unknown factors are also responsible for bone strength [6]. In agreement, in the general population, bone fractures, as evaluated by conventional radiological techniques, have been evidenced also in the presence of normal or only slightly reduced BMD [7].

In this context, vertebral fractures seem to have a special importance because they are frequent and mostly asymptomatic. Currently available methods to detect these fractures include visual semi-quantitative (SQ) analysis of spine radiographs [8] and the quantitative assessments based on either morphometric radiography (MRX) [9] or morphometric X-ray Absorptiometry (MXA) [10]. The last method, introduced more recently, has been reported to agree, like MRX, with the standard visual SQ analysis in the identification of vertebral deformities in postmenopausal osteoporosis [11]. From a clinical point of view, it is useful to emphasize that all of these techniques are intended to recognize mild deformities that could be missed by a routine examination, and that, if significant, are diagnosed as fractures.

Compared to a normal population, the association between low BMD values and vertebral fractures in renal transplantation seems less predictable because of the presence of both pre-existent and/or persistent secondary hyperparathyroidism and of the use of immunosuppressive drugs (steroids in particular, that are known to negatively affect trabecular bones, like vertebrae). The aims of the present study are: to compare the new DEXA-based vertebral morphometry with conventional radiographic images in the identification of fractures in our renal transplant patients, and to evaluate the correspondence between prevalent vertebral fractures and BMD.

Subjects and methods

Subjects

We studied a total of 53 patients (45±12 years old; 31M/22F), transplanted since 6.7±5.5 years, who were on standard triple or double immunosuppressive therapy. They were asymptomatic for fractures and in a stable clinical condition. Only a minority (8/53) assumed vitamin D (calcitriol 0.38±0.25 µg/day), and even a lower number received calcium supplements (2/53; 1.5 g/day) or bisphosphonates (3/53; Alendronate 70 mg/week). Of the 22 females, 7 were postmenopausal since 4.2±7.1 years. In all, laboratory data, spinal radiographs, scan images and bone mineral density (BMD) measurements by Dual Energy X-Ray Absorptiometry (DEXA) technique were acquired on the same day.

Laboratory

Fasting blood samples were obtained for the following biochemical assays: serum creatinine, calcium, phosphate, bone alkaline phosphatase and parathyroid hormone. Creatinine (kinetic alkaline picate), calcium (creosolphalein complexone) and phosphate (ammonium molibdate) were measured by standard automated techniques. Bone alkaline phosphatase was an immunoassay utilizing a monoclonal antibody (Metra Biosystem, USA). Normal ranges are between 12 and 43 U/l. Parathyroid hormone was an IRMA, with a double antibody against the intact molecule (Inestar Stillwater, USA). Normal values are 10–55 pg/ml, with intra- and interassay variations, respectively, of 6.5 and 9.8%.

Spinal radiography

Thoracic and lumbar radiographs in the antero-posterior and left lateral projections were acquired following a standardized protocol [12]. For the lateral views, subjects were positioned in their left side with knees and hips flexed. Tube-to-film distance was set at 115 cm and films were centred at T7 and L3 for the thoracic and lumbar views, respectively.

Spinal DEXA images

Two lateral scans of the vertebrae from T4 to L4 were acquired using a QDR-4500A DEXA machine (Hologic Inc., Bedford, MA, USA), leaving the patient in the supine position (with the C-arm of the scanner rotated through 90°). The spine fan-beam DEXA images were performed using the single-energy (SE) and the dual-energy high-definition (HD) scan modes.

BMD measurements

Using the same machine, QDR-4500A, postero-anterior scans of the lumbar spine (from L1 to L4) and left hip were also acquired to measure BMD. On the basis of their bone mass, patients were classified as normal, osteopenic or osteoporotic, according to the WHO criteria [3].

Visual semiquantitative assessment (SQ)

Conventional radiographs were examined first for quality and then for fractures by an experienced skeletal radiologist (D.D.). According to Genant et al. [8], reductions in the anterior, middle or posterior vertebral heights were classified as mild (20–25% reduction), moderate (25–40% reduction), or severe (>40% reduction).

Vertebral morphometry

MRX was made by a physician skilled in diagnosing osteoporosis, using a computerized image analysis system (Morphorad, QR, Verona, Italy). Lateral spinal radiographs were digitalized by means of a scanner and then processed. The ‘edge detection’ method employed allows a sharper definition of vertebral endplates, rendering the points placement easier [13]. MXA, which is based on the lateral DEXA images, was similarly performed by a trained operator, using the standard...
semi-automatic analysis with software supplied by the manufacturer [14]. The marking and quantitative analysis was performed on the single-energy scans, using high-definition images to aid placement of vertebral markers.

According to Hurxthal criteria [15], for both MRX and MXA, six measurement points were selected in each vertebra between T4 and L4, corresponding respectively to the four corners and the mid-points of the endplates. From these points, the software automatically measures anterior (Ha), middle (Hm) and posterior (Hp) heights and calculates the following ratios: Ha/Hp (wedge), Hm/Hp (biconcavity) and Hp/Hp+1 or Hp/Hp−1 (crushing or compression), where Hp+1 and Hp−1 indicate the posterior height of the vertebra above or below the one under examination, respectively.

**Morphometric definition of vertebral fractures**

MRX and MXA reference ranges for the vertebral height ratios and their SDs derive from a healthy population of 300 premenopausal women and of 100 young adult men. A vertebra is considered fractured if any of the three ratios of vertebral body heights (Ha/Hp, Hm/Hp, Hp/Hp+1 or Hp/Hp−1) is < 3 SD but > 4 SD (grade 1 deformity) or < 4 SD (grade 2 deformity) below the gender-specific reference mean ratio [16].

**Vascular calcifications**

We also searched for aortic calcifications on lateral X-ray of the spine to rule out their possible interfering role on lumbar BMD measurements. According to the criteria adopted by Kauppila et al. [17], calcific lesions ahead of vertebral bodies, from L1 to L4, were scored from zero (no evidence) to 24 (posterior and anterior wall of the aorta extensively and longitudinally calcified).

**Statistical analysis**

Data were analyzed by means of a personal computer implemented with dedicated software (SPSS 11.5), to obtain mean ± SD values, correlation matrix, Student’s t- and/or χ² tests, as appropriate. The level of significance was settled at <5%, as usual. Moreover, to evaluate the agreement between the three techniques, we calculated the concordance index [18], while to define the diagnostic reliability of MRX and MXA, as compared to SQ, the diagnostic indexes [sensitivity, specificity, positive (PPV) and negative (NPV) predictive values] were calculated.

**Results**

Clinical, biochemical and DEXA mean values (±SD) of the population under study are reported in Table 1. Patients had moderate reduction in renal function (serum Cr = 1.8 ± 0.7 mg/dl, with a calculated clearance of 48.8 ± 17.1 ml/min) and mild degree of persistent secondary hyperparathyroidism (PTH: 137.2 ± 125 ng/ml; BALP: 29.7 ± 21 U/l), with serum levels of Ca (9.7 ± 1.0 mg/dl) and P (3.4 ± 0.9 mg/dl) averaging the normal range. DEXA BMD values, at both lumbar and femoral sites, averaged slightly reduced mean values.

Prevalence of patients with any vertebral fracture was 17/53 (32%) with both SQ and MRX, and 12/53 (23%) with MXA. Accordingly, concordance index was perfect between SQ and MRX (k = 1), and quite high between MXA and either SQ or MRX (k = 0.766). As a further piece of evidence of agreement, shown in Table 2, both with SQ and MRX, 9/53 patients (17%) had a single and 8/53 (15%) had multiple vertebral fractures. On the contrary, with MXA, a single fracture was evident in only 4/53 (7.5%), while multiple deformities were confirmed in 8/53 (15%). No statistical difference in the prevalence of fractures among the three techniques was evident (χ² = n.s.) and, considering SQ as the standard reference, predictive indexes were excellent with MRX (invariably 100%) and quite good with MXA (sensitivity 70.6%; specificity 100%; PPV 100%; NPV 87.8%) (Table 4, left side).

As shown in Table 3, of the total of 689 vertebræ examined in our study, 49 were fractured with SQ, 54 with MRX and 41 with MXA. When we considered

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**Table 1.** Mean (±SD) clinical, biochemical and DEXA values of the population under study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>45</td>
<td>12</td>
<td>23</td>
<td>68</td>
</tr>
<tr>
<td>BMI</td>
<td>24.2</td>
<td>3.6</td>
<td>17</td>
<td>31</td>
</tr>
<tr>
<td>TPX, years</td>
<td>6.7</td>
<td>5.5</td>
<td>0.5</td>
<td>20</td>
</tr>
<tr>
<td>Cr, mg/dl</td>
<td>1.8</td>
<td>0.7</td>
<td>0.7</td>
<td>4.8</td>
</tr>
<tr>
<td>CCr, ml/min</td>
<td>48.8</td>
<td>17.1</td>
<td>11</td>
<td>93</td>
</tr>
<tr>
<td>Ca, mg/dl</td>
<td>9.7</td>
<td>1.0</td>
<td>7.8</td>
<td>12.8</td>
</tr>
<tr>
<td>P, mg/dl</td>
<td>3.4</td>
<td>0.9</td>
<td>1.0</td>
<td>6.0</td>
</tr>
<tr>
<td>BALP, U/l</td>
<td>29.7</td>
<td>21</td>
<td>8.5</td>
<td>87.0</td>
</tr>
<tr>
<td>PTH, ng/ml</td>
<td>137.2</td>
<td>125</td>
<td>1.9</td>
<td>665.6</td>
</tr>
<tr>
<td>BMD, Lg/cm²</td>
<td>0.953</td>
<td>0.169</td>
<td>0.605</td>
<td>1.363</td>
</tr>
<tr>
<td>T-score, L</td>
<td>-1.029</td>
<td>1.468</td>
<td>-4.00</td>
<td>2.50</td>
</tr>
<tr>
<td>T-score, N</td>
<td>-1.290</td>
<td>1.286</td>
<td>-3.40</td>
<td>3.20</td>
</tr>
</tbody>
</table>

**Table 2.** Number of patients diagnosed as having none, one or multiple vertebral fractures with the three different techniques

<table>
<thead>
<tr>
<th>Method</th>
<th>No fracture</th>
<th>1 Fracture</th>
<th>&gt;1 Fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ</td>
<td>36 (68%)</td>
<td>9 (17%)</td>
<td>8 (15%)</td>
</tr>
<tr>
<td>MRX</td>
<td>36 (68%)</td>
<td>9 (17%)</td>
<td>8 (15%)</td>
</tr>
<tr>
<td>MXA</td>
<td>41 (77.3%)</td>
<td>4 (7.5%)</td>
<td>8 (15%)</td>
</tr>
</tbody>
</table>

**Table 3.** Number of fractured vertebrae and severity of the lesion assessed by the three different techniques

<table>
<thead>
<tr>
<th>Method</th>
<th>Normal Any fracture</th>
<th>Mild deformity &amp; grade 1</th>
<th>Moderate-severe &amp; grade 2</th>
<th>Not analysed</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ</td>
<td>640</td>
<td>49</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>MRX</td>
<td>635</td>
<td>54</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>MXA</td>
<td>628</td>
<td>41</td>
<td>13</td>
<td>28</td>
</tr>
</tbody>
</table>

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Vertebral morphometry in renal transplantation

Table 4. Diagnostic agreement of morphometric techniques with the standard SQ method on a ‘per patient’ or a ‘per vertebra’ basis

<table>
<thead>
<tr>
<th>Indices</th>
<th>Per patient</th>
<th>Per vertebra</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MRX</td>
<td>MXA</td>
</tr>
<tr>
<td>Agreement (%)</td>
<td>100</td>
<td>91</td>
</tr>
<tr>
<td>k-score</td>
<td>1</td>
<td>0.77</td>
</tr>
<tr>
<td>95% CI</td>
<td>1</td>
<td>0.74-0.86</td>
</tr>
<tr>
<td>Sensitivity (%)</td>
<td>100</td>
<td>70.6</td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>100</td>
<td>99.2</td>
</tr>
<tr>
<td>PPV</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>NPV</td>
<td>100</td>
<td>87.8</td>
</tr>
</tbody>
</table>

Table 5. Number of patients with fractures, with the three different techniques, in the three T-score categories

<table>
<thead>
<tr>
<th>T-score</th>
<th>SQ</th>
<th>MRX</th>
<th>MXA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>4/18</td>
<td>4/18</td>
<td>3/18</td>
</tr>
<tr>
<td>Osteopenic</td>
<td>10/22</td>
<td>10/22</td>
<td>6/22</td>
</tr>
<tr>
<td>Osteoporotic</td>
<td>3/13</td>
<td>3/13</td>
<td>3/13</td>
</tr>
</tbody>
</table>

the severity of the deformity, mild (SQ) or grade 1 (MRX and MXA) deformities were present in 21, 26 and 13 vertebral bodies, respectively, while moderate-severe (SQ) or grade 2 (MRX and MXA) deformities were invariably 28 with any technique. The table also shows that 20/689 (2.9%) vertebrae could not be analyzed with MXA because of the poor quality of the images; these were pertinent to five patients and were invariably restricted to the upper part of the thoracic spine (T4–T6).

In the right side of Table 4, agreement and predictive indexes, again obtained with SQ as the standard reference, are reported. MRX had 100% sensitivity, 99.2% specificity, 90.7% PPV and 100% NPV in detecting the fractured vertebrae identified by SQ, while MXA showed sensitivity 83.7%, specificity 100%, PPV 100% and NPV 98.7%.

Finally, we examined the distribution of fractured subjects within the three standard categories identified by BMD values. According to the lower T-score obtained in either lumbar or femoral site in each subject, we recognized 18/53 normal (34%), 22 osteopenic (41.5%) and 13 osteoporotic (24.5%) patients. As shown in Table 5, SQ and MRX perfectly agreed in recognizing fractures in 4/18 normal (22%), 10/22 osteopenic (45%) and 3/13 osteoporotic (23%) patients; on the contrary with MXA, fractures were evident in 3/18 normal (17%), 6/22 osteopenic (27%) and 3/13 osteoporotic (23%). Noteworthy, only 3/13 osteoporotics had indeed a vertebral fracture, while 14/40 subjects (35%) with normal or osteopenic BMD values were fractured. With any method, no correlation existed between BMD values or T-score classes and the presence or number of fractures.

As reported earlier, 7/22 females were postmenopausal and 3/7 (42.8%) had vertebral fractures, a prevalence not significantly different from the lower value obtained in premenopausal patients (3/15; 20%; $\chi^2 = $ n.s.).

Lateral X-ray of the spine also evidenced aortic calcifications in 28/53 subjects (52.8%), with a severity score averaging a mild 7.1±6.0. Patients with calcifications were older (51.1±9 vs 38.9±12 years; $P < 0.0001$), but had similar BMD values both at lumbar (0.967±0.181 vs 0.926±0.146 g/cm²; $P =$ n.s.) and neck sites (0.747±0.180 vs 0.739±0.172 g/cm²; $P =$ n.s.) as compared to 25 patients without calcifications. The number of cases classified as normal, osteopenic or osteoporotic, based on lumbar T-score, were not different between patients with (respectively, 13/28, 9/28 and 6/28) or without calcifications (12/25, 9/25 and 4/25; $\chi^2 =$ n.s.). Similarly, values obtained with neck T-score (normal = 11/28 vs 10/25; osteopenic = 11/28 vs 12/25; osteoporotic = 5/28 vs 3/25; $\chi^2 =$ n.s.) were not different between the two groups. Since the severity of vascular calcifications could be more relevant than any positivity, we also compared lumbar BMD values in three different groups selected according to the score of vascular calcification (we considered: 0 = none; 1–8 = mild; 9–24 = moderate-severe), but again no difference was observed among the groups (data not shown).

Discussion

Mechanical competence of bone results not only from its mineral content (amount of mineral in a given volume) but also from other factors (elasticity, trabecular disposition and concentration, collagen quality, etc.), and it has been evaluated that in normal subjects, BMD accounts for approximately two-thirds of bone strength [19]. However, a change in this relative contribution is predictable (but not still demonstrated) in the presence of metabolic bone disease, like renal transplantation. Accordingly, it has been recommended that the term ‘osteoporosis’, especially if not supported by bone histology, is not used in renal patients [20].

Nonetheless, BMD measurement by DEXA remains the most widely employed technique to evaluate the risk of fracture in normal individuals, even though we are now aware that subjects with normal or slightly reduced BMD can also experience pathologic bone fractures [21]. In this context, single vertebral fractures that are common in the general old population and mostly asymptomatic are of interest also because they bear a 5-fold increase risk of further, symptomatic fractures [22]. Their prevalence in renal transplantation may vary between 1.8% if searched for by routine medical records [23] and 38.5% if searched for systematically and by means of vertebral morphometry [24].

The most simple and standardized approach to detect such fractures is semi-quantitative visual assessment of each vertebral body height by Rx (SQ). With this method, an excellent agreement among trained observers has been reported in the diagnosis of prevalent and incident vertebral fractures.
DEXA T-score, only a minority of patients with SQ fractures and low BMD values. In fact, based on the new MXA, the employment for clinical diagnostic purposes.

The most recent introduction of morphometric assessment by DEXA lateral spine images (MXA) offers a potential alternative to conventional radiographs, with substantial reduction of the radiation dose to the patient [26]. This technique is certainly interesting, but data about its clinical reliability are still scanty [27], especially in renal patients.

In our study, we obtained a prevalence of fractured patients (one or more vertebral deformities) of 32% with SQ and MRX but of 23% with MXA. Both values are high if we consider the young age of the patients (45 ± 12 years) and if we compare them to the older general population of the EVOS study, showing a prevalence of 12% [28], but are in line with the prevalence of 38.5% observed by Nam et al. [24] in asymptomatic renal transplant patients, similar to us, evaluated by MRX. As for the lower prevalence obtained with MXA, this was due to the negativity of the test in five patients who had a single vertebral deformity; nonetheless, it is noteworthy that in all the cases with multiple fractures the three techniques perfectly overlapped.

When we considered the absolute number of fractured vertebrae and the severity of the lesion, we again observed some discrepancies in the case of mild or grade 1 deformities, and perfect agreement when moderate-severe or grade 2 fractures were present. As for MXA, the lower performance was linked to the poor technical quality of the images obtained from the upper thoracic spine (T4–T6) in five patients (the same with a single, undiagnosed fracture) showing a combination of increased BMI and low bone density. In this condition, the increment of soft-tissue thickness results in very noisy DEXA images not allowing a clear distinction of vertebral endplates and inter-vertebral spaces. This possible source of error with MXA, which is less of a concern with conventional radiography, can be regarded as the only possible cause of borderline deformity and definite mild fracture can be difficult and sometimes arbitrary.

In an effort to improve the objectivity of the diagnosis, quantitative, computer-assisted morphometric assessment of vertebral deformities on conventional spinal radiographs (MRX) has been brought into practice [9]. The distinction of vertebral endplates and inter-vertebral spaces. This possible source of error with MXA, which is highly specific, can be employed for the follow-up and, in case of poor quality images, integrated with SQ or MRX evident fractures (3/17, 18%) were indeed classified as ‘osteoporotic’ and then at increased risk of fracture, while most of them (14/17, 82%) had normal or only ‘osteopenic’ BMD values. In this respect, it could be argued that the possible presence of aortic calcifications may modify the true BMD of the vertebral bodies, thereby resulting in misclassifications. Data from the literature suggest minimal [29] or no effect [30,31] of vascular calcifications on BMD, but are referred to subjects with normal renal function. Indeed, data from our patients, who showed a very high prevalence of calcifications despite their relative young age, suggest no significant interference on lumbar BMD values or T-score classification. Additionally, for the purpose of the present study, we used also neck T-score values, which are reliable and not influenced by calcifications. Other possible explanations for the discrepancy rely on the above-mentioned concept of bone quality that could be significantly modified in the patients, independently of mineral content. Alternatively, it is conceivable that lower BMD values (and then bone fractures) might have been experienced previously, during dialysis or early after transplantation. In this last condition, a significant reduction in BMD is frequently described peaking at 6–12 months after surgery [32]. However, all of our fractured patients, who were asymptomatic, must be considered at increased risk of further fractures and most likely to benefit from preventive or therapeutic measures.

On practical grounds, based on the available knowledge, it would be hard to decide if it is better to have a normal BMD with some fractures or no fracture with a significantly reduced BMD; rather it seems wise to consider at increased risk both those with fracture and those with very low BMD. Therefore, systematic surveillance of the vertebrae, by means of any of the morphometric techniques here employed, seems necessary in our patients. MXA, with a perfect diagnostic agreement with the other two techniques in the presence of multiple and more severe deformities, represents a reliable and X-ray sparing alternative to the well-established SQ or to the more renowned MRX, at least employable as a screening test. On practical grounds, and considering our results, it seems wise to include in the first evaluation of each patient a conventional, radiology-based vertebral morphometry. MXA, which may suffer technical problems in obese subjects but is highly specific, can be employed for the follow-up and, in case of poor quality images, integrated with SQ or MRX.

In conclusion, there is a high prevalence of vertebral fractures in renal transplant patients independently of BMD values obtained with DEXA. A surveillance of the spine by Rx, implemented with morphometry, is warranted to recognize those with vertebral deformities. MXA, although less sensitive than the standard techniques, appears to be very specific, and then can be proposed for follow-up purposes in this population of patients.
Conflict of interest statement. None declared.

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