UPDATE IN RADIOLOGY

Dual energy X-ray absorptiometry: Fundamentals, methodology, and clinical applications


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Abstract Dual-energy X-ray absorptiometry (DXA; DEXA) is the technique of choice to diagnose osteoporosis and to monitor the response to treatment. It is also useful for measuring body composition. In recent years, new applications have been developed, including vertebral morphometry through the study of the lateral spine, prosthesis integration in orthopedics, and lipodystrophy in HIV+ patients, although its use in these cases is not well established. DXA densitometry is accurate and precise. It is essential to optimize each step of the diagnostic process, taking care to ensure the best acquisition, image analysis, and interpretation of the results. Thus, to obtain the greatest utility from DXA, radiologists need to know the technique, its indications, and its pitfalls. This article reviews the fundamentals, modalities, methods, and clinical applications of DXA.

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Absorciometría con rayos X de doble energía. Fundamentos, metodología y aplicaciones clínicas

Resumen La absorciometría con rayos X de doble energía (DXA o DEXA) es la técnica de elección para diagnosticar la osteoporosis y monitorear la respuesta al tratamiento. Además, es útil para estudiar la composición corporal. En los últimos años han surgido nuevas aplicaciones como la morfometría vertebral, estudiando la columna en visión lateral, la integración de prótesis en ortopedia, o la lipodistrofia en los pacientes con infección por VIH, aunque su utilización en estos casos no está bien consolidada. En el estudio de la osteoporosis, densitometría es precisa y exacta. Para ello, es imprescindible optimizar cada etapa del proceso diagnóstico, cuidando la adquisición, el análisis de imágenes y la interpretación de los resultados. Por ello, para obtener la máxima utilidad para el clínico y el paciente, el radiólogo debe conocer la técnica, sus

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Introduction

Dual X-ray absorptiometry (DXA), also known as densitometry or dual energy X-ray absorptiometry (DEXA), can distinguish different body structures. Axial bone densitometry of the lumbar spine and hip is the modality most commonly used in clinical practice. This technique is useful for measuring the bone mineral density (BMD), and from these data the risk of fracture can be estimated, therapeutic decisions can be taken and the response to treatment can be assessed.1

On the other hand, DXA, the least known method for whole body imaging, allows us to assess the total body composition. This is particularly useful in patients with weight disorders secondary to endocrine diseases and in pediatric patients with delayed growth.2 Whole body DXA can also be useful to assess lipoatrophy associated with retroviral infections,3 in the monitoring of arthroplasties4 or to determine the cardiovascular risk.5

DXA is still little known among radiologists, who consider this technique to be more typical of other specialties. Moreover, DXA tends to be wrongly considered as a routine and automated technique, unlikely to be optimized and not requiring a radiological report. This is far from the truth. DXA, like any other diagnostic modality, requires an adequate indication, careful methodology and precise interpretation, which is only possible with appropriate training and interaction between technicians and radiologists.

As a consequence, our aim is to examine the current status of DXA, particularly emphasizing its fundamentals, main modalities, methodology and clinical applications.

Fundamentals and modalities of dual energy X-ray absorptiometry

DXA is based on the variable absorption of X-ray by the different body components and uses high and low energy X-ray photons. Depending on the equipment used, these photons can be obtained using two mechanisms.6 In some cases, the generator emits alternating radiation of high (140 kVp) and low (70-100 kVp) kilovoltage while moving across the surface of the body to be examined. In others, the generator emits a constant beam while a rare-earth filter separates high energy (70 keV) from low energy (40 keV) photons.

The available DXA systems include different types of hardware (filters, collimators, detectors) and software (analysis algorithms).7 The X-ray source can emit a pencil beam (pinhole collimator), which is registered by a single detector, or a fan beam (slit collimator), which is registered by a multiple detector.8 The latter system reduces the acquisition time and improves image quality.9 At the same time, the analysis algorithm discriminate bone from soft tissue in a variable way.10

The main modalities of DXA in clinical practice are axial bone densitometry with stationary scan table, the modality of choice to measure the BMD, and whole body densitometry, used to assess body composition.

Bone densitometry with dual energy X-ray absorptiometry

Historical perspective

Axial DXA of the lumbar spine and hip is at present the technique of choice to study osteoporosis,11 although other imaging techniques are potentially useful to assess and measure the bone structure and study its quality.5,12 (Table 1).

Plain radiography is useful to assess bone structure, although it cannot measure BMD. Some authors have tried to apply digital radiography with dual energy to obtain an estimated measurement of the BMD.

Quantitative computed tomography (QCT) of the lumbar spine (central QCT) is performed using conventional computed tomography (CT) systems. QCT of radius or tibia (peripheral QCT) can be performed using less sophisticated equipment. QCT provides volumetric acquisitions from which BMD can be estimated. Central QCT has advantages over DXA, since it allows us to differentiate between cortical and trabecular bone, assess the geometry of the vertebrae, and estimate the BMD volumetrically, expressed in g/cm3. The disadvantages of central QCT are the radiation dose and the lack of validated diagnostic criteria.13

High resolution magnetic resonance (MR) imaging may be used for assessment of the trabecular structure of peripheral bones (calcaneus, distal radius and phalanx).14 The bone architecture studied using CT or MR, quantified in terms of scale, shape, anisotropy and connectivity, allows for the assessment of bone strength without considering the BMD. Advanced MR techniques such as diffusion, perfusion and spectroscopy will most likely provide useful additional information in the future.

Quantitative ultrasound (QUS) is used for measuring BMD in the peripheral skeleton, generally at the calcaneus.

Photonic absorptiometry with iodine-125 (I-125) was initially used to study the peripheral skeleton (radius and calcaneus). It was subsequently replaced by dual photonic absorptiometry that uses gadolinium-153 and may be employed to study the axial skeleton (hip, spine and whole skeleton).15

These modalities were later on substituted by X-ray based technology, initially by plain X-ray and subsequently by DXA, which allowed for the measurement of the axial skeleton.
Table 1  Densitometry modalities.

<table>
<thead>
<tr>
<th>X-ray</th>
<th>Plain X-ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>QCT</td>
<td>Quantitative computed tomography</td>
</tr>
<tr>
<td>MR</td>
<td>Magnetic resonance</td>
</tr>
<tr>
<td>QUS</td>
<td>Quantitative ultrasound</td>
</tr>
<tr>
<td>SPA</td>
<td>Single photon absorptiometry</td>
</tr>
<tr>
<td>DPA</td>
<td>Dual photon absorptiometry</td>
</tr>
<tr>
<td>SXA</td>
<td>Single X-ray absorptiometry</td>
</tr>
<tr>
<td>DXA/DEXA</td>
<td>Dual X-ray absorptiometry/Dual energy X-ray absorptiometry</td>
</tr>
<tr>
<td>X-ray CT</td>
<td>X-ray (CT)</td>
</tr>
<tr>
<td>MR</td>
<td>Magnetic resonance</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Radioisotope 125-I</td>
<td>Radioisotope Gd-153</td>
</tr>
<tr>
<td>X-ray</td>
<td>X-ray</td>
</tr>
</tbody>
</table>

Equipment

Peripheral DXA performed with portable units (such as AccuDXA) focuses on the study of phalanxes. It is not very accurate, but its cost is also low. AccuDXA can be used to select patients likely to be assessed with central DXA on stationary table or as a substitute where central DXA is not available.

Axial DXA of the lumbar spine and femur (central DXA) is the preferred technique to measure BMD because of its good resolution and reliability, rapid acquisition and little radiation. Several devices are commercially available (Lunar, Hologic, Norland) with different characteristics. This fact makes it advisable to perform the follow up of each patient always in the same unit. The accuracy of bone densitometry performed on a DXA system with stationary table is high, with a margin of error of 1–2%.

Indications

The main use of DXA is the diagnosis of osteoporosis. It may also predict the risk of fractures, help determine the treatment, and monitor the response to treatment. Its indications are set out in the official guidelines of the International Society for Clinical Densitometry, which are revised every two years (Table 2).

Osteoporosis is the "reduction in bone mass and increase of bone fragility which in turn increases the risk of fracture". Osteoporosis is a common, often silent disease that can lead to an increased risk of fractures, sometimes atraumatic. Osteoporosis poses a serious problem to public health because of its prevalence and the cost associated with its comorbidity. According to the National Osteoporosis Foundation (NOF), osteoporosis affects 10 million Americans, but another 34 million are at risk of developing the condition. It is estimated that approximately 50% of women over the age of 50 will suffer an osteoporotic fracture during their lives. In Europe, the International Osteoporosis Foundation (IOF) collects data and promotes initiatives in every country. In Spain, approximately two million women have osteoporosis (26.1% prevalence in women ≥50 years).

In 1994, the WHO introduced the measurement of BMD with DXA as the reference standard to quantify osteoporosis. Based on a study performed on postmenopausal white women that revealed a correlation between BMD and risk of fracture, osteoporosis was defined as a "T-score of −2.5". Other values of reference for potentially useful parameters were also determined (Table 3). Thus, axial DXA became the reference standard for osteoporosis.

Methodology

The methodology of bone densitometry with axial DXA requires optimization and careful execution. The importance of each step to obtain good results must be highlighted.

Preparation

In order to properly plan the study, detailed patient information is required, and both the medical report provided by the referring physician as well as the preliminary questionnaire completed in the diagnostic center. The request form must include the indications for the study, so the areas to be examined can be determined. Bone diseases that might alter the shape or density of the bone, such as osteoporosis or ankylosing spondylitis, need to be ruled out. Previous fractures or joint replacements that might alter the planning must also be ruled out. Contraindications to DXA include pregnancy, recent (<5 days) oral administration of a contrast agent, and a recent (<2 days) isotopic study. The patient does not require any specific preparation except for the removal of any metal items located on the body area to be imaged.

Areas of study

For most adult patients, the DXA examination should include the lumbar spine and proximal femur; the forearm can also be included when hip or spine cannot be measured. In children and adolescents (younger than 20 years), the measurement is only performed in the lumbar spine.

Table 2  Indications for bone densitometry.

<table>
<thead>
<tr>
<th>Females</th>
<th>Males</th>
<th>Both sexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older than 65 yrs</td>
<td>Younger than 65 yrs</td>
<td>Unexplained fracture</td>
</tr>
<tr>
<td>Younger than 65 yrs (postmenopausal or perimenopausal)</td>
<td>Older than 70 yrs</td>
<td>Diseases or chronic treatments</td>
</tr>
<tr>
<td></td>
<td>Younger than 70 yrs with risk factors of fracture</td>
<td>Any patient to whom possible treatment is considered and to monitor the response to treatment</td>
</tr>
</tbody>
</table>

Table 3  Indications for bone densitometry.

<table>
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<tr>
<th>Females</th>
<th>Males</th>
<th>Both sexes</th>
</tr>
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<tbody>
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<td>Unexplained fracture</td>
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<tr>
<td>Younger than 65 yrs (postmenopausal or perimenopausal)</td>
<td>Older than 70 yrs</td>
<td>Diseases or chronic treatments</td>
</tr>
<tr>
<td></td>
<td>Younger than 70 yrs with risk factors of fracture</td>
<td>Any patient to whom possible treatment is considered and to monitor the response to treatment</td>
</tr>
</tbody>
</table>
The final result of the densitometry would be the lowest value of the two regions studied.

The postero-anterior (PA) scan of the lumbar spine includes the vertebral bodies of L1–L4, from which a mean BMD of these four vertebrae is obtained. Vertebrae with changes due to fracture or focal lesions will be excluded. To assess the lumbar spine, at least two evaluable vertebrae are required.

The study of the femur can indistinctly be performed on the right or left hip, although it is useful to become used to studying always the same side. Hips with changes due to fracture, focal lesions or replacements will be excluded. The total proximal femur or the femoral neck are used, whichever is lowest.

The study of the non-dominant forearm is performed when hip or spine cannot be measured (in order to have a second measurable region), to obese patients (to bypass technical difficulties), and to patients suffering from hyperparathyroidism (since forearm bones change before the axial skeleton).

**Patient positioning**

Optimization of the patient’s position on the DXA table is essential. Incorrect positioning is one of the main causes of errors in the estimation of BMD. In the PA study of the lumbar spine, the patient lies supine on the table with the legs flexed over a support pad that reduces the lumbar lordosis and approaches the spine to the table (Fig. 1).

For the study of the hip, the patient lies supine with legs slightly in abduction in order to maintain the femoral axis straight and in internal rotation (15–30°), in a way that the lesser trochanter is not visible on the image (Fig. 2).

In the study of the forearm, the patient is seated, side against the table with the arm resting on the tabletop with the palm of the hand downwards patients sit beside the table and with their forearm resting on it, with the hand in pronation and strapped (Fig. 3).

The field of view must include 1–2 cm above and below the area to be imaged. The bone must be straight and centered.

**Acquisition**

For most patients, the DXA includes PA projections of the lumbar spine and proximal femur. The lateral spine is not used in a standard osteoporosis study, but it is used in vertebral morphometry. In those devices with mobile scanning arm, measurements can be done with the patient lying supine, whereas in systems with stationary arm measurements can only be done in lateral decubitus.

Regarding the scanning time, the first densitometers with pencil-beam scans took around 5 min per scan, but now the images can be obtained in less than one minute. According
DXA uses low radiation doses and generally most of these devices do not require lead shielding of the room or special protection measures for the technicians. In the DXA units using pencil-beam scans, the equivalent surface dose for spine and hip examinations is approximately 20–100 μSv per examination, and the equivalent effective dose is 1–5 μSv per examination. For fan beam DXA, the dose is slightly higher, approximately 56 μSv for the hip, 59 μSv for the spine, and 75 μSv for whole body. The disperse radiation that the technician would receive being 1 m away from the table using a fan beam unit, performing 4 hip studies and 4 spine ones per hour would be of around 4 μSv.

Analysis

Once the image is acquired, the assessment is carried out by selecting different regions of interest (ROI). Inadequate placement of the ROIs is another important source of errors. Although the equipment automatically proposes specific areas, both the technician and the radiologist must validate them and, given the case, rectify them.

In the study of the lumbar spine, the ROIs are placed on the L1–L4 vertebral bodies (Fig. 4). It must be remembered that D12 is usually the last vertebra connected to a rib (although this is not always the case), and that L3 usually has the longest transverse process.

In the study of the hip, the ROI must be placed at the femoral neck, avoiding superimposition of the ischiopubic ramus and the greater trochanter (Fig. 5). The system measures automatically the inclination of the femoral axis and the rest of the ROIs.

In the forearm, the area of analysis is set at the distal radius, with the line of reference at the urnal styloid process (Fig. 6).

Screening of the causes of error

The radiologist must try to detect all those artifacts that might be possible causes of error in the acquisition, analysis and interpretation of the study (Table 4). Once the possible sources of error are identified, they must be excluded when performing the analysis and subsequent interpretation.

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**Figure 3** Dual energy X-ray absorptiometry of the forearm. Patient’s positioning.

**Figure 4** Dual energy X-ray absorptiometry image of a PA lumbar spine. The study includes the L1–L4 vertebral bodies.

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**Table 4**

<table>
<thead>
<tr>
<th>Region</th>
<th>BMD (g/m²)</th>
<th>Young-Adult (%)</th>
<th>Young-Adult T-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>0.987</td>
<td>87</td>
<td>-1.2</td>
</tr>
<tr>
<td>L2</td>
<td>0.930</td>
<td>78</td>
<td>-2.2</td>
</tr>
<tr>
<td>L3</td>
<td>1.053</td>
<td>86</td>
<td>-1.2</td>
</tr>
<tr>
<td>L4</td>
<td>0.961</td>
<td>80</td>
<td>-2.0</td>
</tr>
<tr>
<td>L1-L4</td>
<td>0.983</td>
<td>83</td>
<td>-1.6</td>
</tr>
<tr>
<td>L2-L4</td>
<td>0.982</td>
<td>82</td>
<td>-1.8</td>
</tr>
</tbody>
</table>
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Left Femur Bone Density

Figure 5  Dual energy X-ray absorptiometry of the left hip. The lesser trochanter must not be visualized. The area of analysis (ROI) is placed on the femoral neck.

Figure 6  Dual energy X-ray absorptiometry of the forearm. The line of reference is placed at the ural styloid.

Table 4  Sources of error in densitometry.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Patient’s positioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artifacts</td>
<td>Movement</td>
</tr>
<tr>
<td></td>
<td>Region of interest (ROI) placement</td>
</tr>
<tr>
<td></td>
<td>Foreign bodies</td>
</tr>
<tr>
<td></td>
<td>Bone diseases</td>
</tr>
<tr>
<td>Sources of error in densitometry.</td>
<td>Surgical material</td>
</tr>
<tr>
<td></td>
<td>Calcifications</td>
</tr>
<tr>
<td></td>
<td>Contrast media</td>
</tr>
<tr>
<td></td>
<td>Spondyloarthrosis</td>
</tr>
<tr>
<td></td>
<td>Fractures</td>
</tr>
<tr>
<td></td>
<td>Lytic or sclerotic lesions</td>
</tr>
</tbody>
</table>
Figure 7  On the left, dual energy X-ray absorptiometry of the spine. Dense image superimposed on the L3 vertebral body (arrow). On the right, the plain abdominal radiograph shows a calcified mesenteric lymph node (arrow).

First, the correct positioning of the patient and absence of movement during the scanning must be checked. Artifacts caused by superimposition of dense structures (including surgical material, calcifications or contrast agents) must be ruled out (Fig. 7). Bone lesions may also alter the analysis and must be mentioned in the report.

The condition that most frequently distorts the analysis is spondyloarthrosis, which is associated with bone proliferation (osteoephytes, endplate sclerosis) and morphologic changes (Fig. 8). Vertebral fractures (Fig. 9), lytic or sclerotic lesions (Fig. 10), metastases, lymphomas, bone islets, Paget’s disease, or hemangiomas. In cases of unknown suspected bone lesion, complementary radiological studies are required. It must be remembered that in patients with severe osteoporosis, the DXA scan might simulate a lytic lesion (Fig. 11).

Parameters evaluated in bone densitometry
Following the acquisition and analysis of DXA, the system calculates various parameters (Table 3). The BMC is the quantity of calcium estimated by the energy absorbed by it in a specific region. The BMD, much more relevant, is evaluated for each of the regions, expressed in g/m² (g/cm²), after adjusting for age and gender. The T-score and Z-score are used to compare the DXA result with the normative data (Table 3).

Table 3  Densitometric reference: L1-L4

<table>
<thead>
<tr>
<th>Region</th>
<th>BMC (g/m²)</th>
<th>Young adult T-score</th>
<th>Adj. to age Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>0.883</td>
<td>81.4</td>
<td>89.0</td>
</tr>
<tr>
<td>L2</td>
<td>0.911</td>
<td>83.4</td>
<td>85.5</td>
</tr>
<tr>
<td>L3</td>
<td>1.326</td>
<td>111.1</td>
<td>113.1</td>
</tr>
<tr>
<td>L4</td>
<td>1.217</td>
<td>101.0</td>
<td>104.4</td>
</tr>
</tbody>
</table>

In the analysis, the bone mineral density (BMD) in L3 and L4 is higher than in L1 and L2. Exclusion of both vertebrae shows a T-score L1-L2 = −1.9 (L1-L4 = −0.5).

Figure 8  Dual energy X-ray absorptiometry image of spine. The increase of density in the radiography (arrow) corresponds to an L3 and L4 sclerosis. In the analysis, the bone mineral density (BMD) in L3 and L4 is higher than in L1 and L2. Exclusion of both vertebrae shows a T-score L1-L2 = −1.9 (L1-L4 = −0.5).
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Figure 9  Above, dual energy X-ray absorptiometry of spine. Increased density of the L2 vertebral body (arrow) that corresponds to a fracture (arrow) on the radiograph below. Both images show a calcification (arrowheads) that is not superimposed to the spine (not affecting the analysis).

Figure 10  Dual energy X-ray absorptiometry and AP radiograph of spine (right). Increased density in the pedicle of right L1 (arrow) corresponding in the radiography to a dense pedicle. The vertebra must be excluded from the analysis.
Dual energy X-ray absorptiometry of spine in a patient with severe osteoporosis. The image simulates a defect of L3 and L4 (arrows), not confirmed by the radiographies.

The mean quantity of mineral per unit area. It is calculated dividing the BMC by unit area (g/cm²). The values used for diagnosis (T- and Z-score) are obtained by comparison with the reference database.

The T-score is the value used to diagnose osteoporosis in postmenopausal women and in men aged 50 and over. T-score is the number of standard deviations the patient's BMD above or below the mean for the young adult reference population of the same sex. A T-score >−1.0 is considered normal, osteopenia when the T-score is between −1 and −2.5, and osteoporosis is a T-score <−2.5.

The Z-score is used in premenopausal women, in men younger than 50 years, and in children and adolescents (up to 20 years). Z-score is the number of standard deviations the patient's BMD above or below the mean for the reference population of the same race, sex and age. A Z-score <−2
standard deviations is defined as "below the expected range for age".38

Reporting
The report should be tailored to the particular characteristics of each center, but in general it must comply with some minimum requirements. In addition to the patient’s personal details, the report must include the date of examination, the type of DXA system used, as well as the protocol followed. It must also specify if any region of analysis has been excluded and the reasons, and the possible presence of artifacts or suspected lesions.

The report must also include the scans obtained for each region of study, with a graph showing the patient’s data and then related back to the reference curve, the numerical values of the BMD, T- and Z-scores, and finally, a diagnostic category based on WHO criteria. The value considered most useful to diagnose a particular patient must be specified. In some cases, an estimation of the risk of fracture is also included. In general, the risk of fracture doubles for each standard deviation reduction in BMD. The study’s conclusion should be global, taking into account the lowest value of the areas studied. In patients with previous studies, any possible changes should be reported.

Estimation of the body composition using dual energy X-ray absorptiometry
Several techniques have been used to assess the composition and quantification of the body fat, mostly anthropometric methods such as the waist circumference, the waist-to-hip ratio, and the skin fold thickness.39 Among the imaging studies, CT stands out to measure visceral fat, but with some drawbacks such as radiation, among others. Bioimpedance techniques and isotope dilution have also been used.40

Whole body DXA allows for an easy and rapid measurement of body composition. It provides an estimate of body fat, and when needed, it may also estimate the BMD of the whole body. DXA is very accurate, with a margin of error of 2–6% for body composition.18 Unlike anthropometric methods, DXA has advantage of providing regional and whole-body measurements. DXA is increasingly being used; for many clinicians it is a common tool and for some authors it is the reference standard.

Indications
Whole body DXA is used in eating disorders, especially those where there might be a hormonal disorder or cardiovascular risk factors. It is also used in gastrointestinal diseases, hepatobiliary disorders, advanced renal failure, in endocrinological diseases, bone disorders such as Paget’s disease or osteoporosis, lung diseases and various chronic treatments.18 DXA may also help design the diet in patients with malnutrition and in the follow-up of patients with eating disorders.

Methodology
Patient’s positioning. The patient lies supine, centered on the table with the arms along sides of the body, hands
facing the legs without touching them and the thumbs up (Fig. 12). If the patient is wider than the width of the DXA table, a half-body scanning is performed (including the neck and head, one whole side with their corresponding arm and leg). In this case, the patient lies supine but is positioned off the center line of the table to ensure that one side is completely included in the scan field.

**Analysis.** As in BMD studies, the correct positioning and absence of motion artifacts must be verified. Following the acquisition, two images of the whole body are obtained, one of bones and other of soft tissues (Figs. 13 and 14).

The system places the ROIs automatically. The technician revises the ROIs and, if necessary, modifies them, although it is advisable to manipulate them as little as possible. The changes performed on an image are automatically introduced on the other. The ROIs correspond to anatomic regions: the head up under the chin; arms separated from the body with the cut lines passing through the armpits; forearms separated from the body, legs separated from the arms and the medial cut lines located between both legs; the limits of the spine are adjacent to it, on both sides; pelvis: the upper cut line located immediately above the pelvis and cut lines through the femoral neck without touching the pelvis.

![Whole body dual energy X-ray absorptiometry](image)

**Figure 15** Whole body dual energy X-ray absorptiometry. The patient is wider than the width of the table so the system performs half-body scanning (left). The left side is completely included in the scan field, and a contralateral estimation is performed.
In patients wider than the width of the scan field where only a half-body is scanned, the ROI is placed as explained and the system provides a total estimation (Fig. 15).

**Interpretation.** The system provides various parameters (Table 3) such as the body mass index (BMI), quantification of body fat, distribution of the abdominal fat, or values obtained from these data such as the android/gynoid ratio (A/G ratio) in the abdominal fat.

The BMI is an anthropometric indicator designed for adult males and non-pregnant females, but it does not distinguish between fat and muscle and therefore cannot be assessed in athletes. The BMI is a number calculated from a person’s weight and height and is measured in kg/m². The distribution of body tissues is expressed as percentages for the whole body and per regions: percentage of fat (fat mass), of soft parts and muscle (lean mass) and of body (BMD). Several studies have calculated curves that can be used as a reference for different populations.41-44

In addition to the composition by anatomic regions, it calculates the distribution of fat in predefined regions in the pelvic area: android (central, the lower limit is the pelvis and the lateral limit is the arms) and gynoid (hip and thighs, the lateral limits are the outer part of the legs) (Fig. 16).

The android/gynoid (A/G) ratio of the fat is the relation between the fat percentage of the android and the gynoid region. The excess of abdominal fat (android) is associated with a number of cardiovascular risk factors.45

The determination of the A/G ratio using DXA is an easy and useful tool to assess the distribution of pelvic fat. This ratio may have a role in evaluating the cardiovascular risk in overweight or underweight patients.3

BMD values of the whole body are useful to estimate mineralization, but not to diagnose osteoporosis (it is necessary to study the spine and hip in order to compare the results with the reference curves to reach a diagnosis).

**Other applications of dual energy X-ray absorptiometry**

Over the time, other potential clinical applications using DXA are being proposed. DXA systems now offer the possibility of creating personalized analysis areas to perform composition measurements. There are also studies in the field of orthopedics that investigate implant integration by assessing the regional mineralization.4 Moreover, its use in lipodystrophy and lipoatrophy is being studied, especially in HIV patients.3

**Conclusion**

DXA is a fast and reliable technique with little radiation exposure. It is the technique of choice in the diagnosis and monitoring of osteoporosis since it objectively measures the most relevant parameters. Moreover, it is useful to measure the whole body composition and its distribution by regions. There are other less common applications in potential expansion. Knowledge of the technique, its indications, methodology and applications are key issues to optimize its results and streamline its use.
Authorship

1. Responsible for the integrity of the study: RMLR.
2. Conception of the study: RMLR.
3. Design of the study: RMLR and JAA.
4. Acquisition of data: RMLR, JAA and NAG.
5. Analysis and interpretation of data: RMLR, AMH, JMGG and JGM.
6. Statistical analysis: RMLR.
7. Bibliographic search: RMLR and JAA.
8. Drafting of the paper: RMLR.
9. Critical review with intellectually relevant contributions: RMLR, JAA, NAG, AMH, JMGG and JGM.
10. Approval of the final version: RMLR, JAA, NAG, AMH, JMGG and JGM.

Conflicts of interest

The authors declare not having any conflicts of interest.

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