DXA: state of the art

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Summary

Nowadays, dual X-ray absorptiometry (DXA) is the most widely used technique for the measurement of bone density.
In this article technical characteristics of DXA densitometers and their ways of functioning are reviewed.
Radiation dose to the patient is considered.
Finally, findings of DXA densitometry and their interpretation are assessed.

KEY WORDS: osteoporosis, DXA.

Introduction

Dual x-ray absorptiometry (DXA) was introduced in 1987 (1) and, to date, it still represents the most widely used technique for the diagnosis of osteoporosis in the clinical practice. The World Health Organization (WHO) has defined the threshold levels for the diagnosis of osteopenia and osteoporosis using DXA technique.
DXA machines consist of a mobile source of X-rays, a patient couch, a detection system on which fall the radiations emerged from the bones under examination. The x-ray source is under the couch and moves together with the detection system which is located opposite to it over the body of the patient.
The main characteristic of DXA lies in the fact that it uses an x-ray beam composed of two different photon energies.
The method used to produce the two photon energies may be either constant or pulsed. In the first case it is produced a beam which is constant in intensity and voltage and is filtered by a filter made of cerium or samarium (rare earth) in order to obtain two distinct beams with different energies.
The pulsed method produces an alternant emission of beams with different energies with a frequency of 60 Hz/sec.
The energy used (70-140 kV Hologic; 40-70 kV Lunar; 45-80 kV Norland) is conveniently chosen to compensate the different attenuation coefficients of mineralized bone and soft tissue. Practically, the intensity of high energy photons and low energy photons is analyzed separately after they have passed through bones and soft tissues.
Using a particular computing algorithm, the attenuations of soft tissues are subtracted, obtaining in this way the attenuation values of bone.
The attenuation of the skeleton is related to its bone mineral density by comparing the values obtained with standard values determined on phantoms of known density (higher attenuation-higher density).
Attenuation values of low energy photons are also used to produce the image, as they are computed pixel by pixel (indirect matrix) and transformed into a grey-scale map.

Machine used

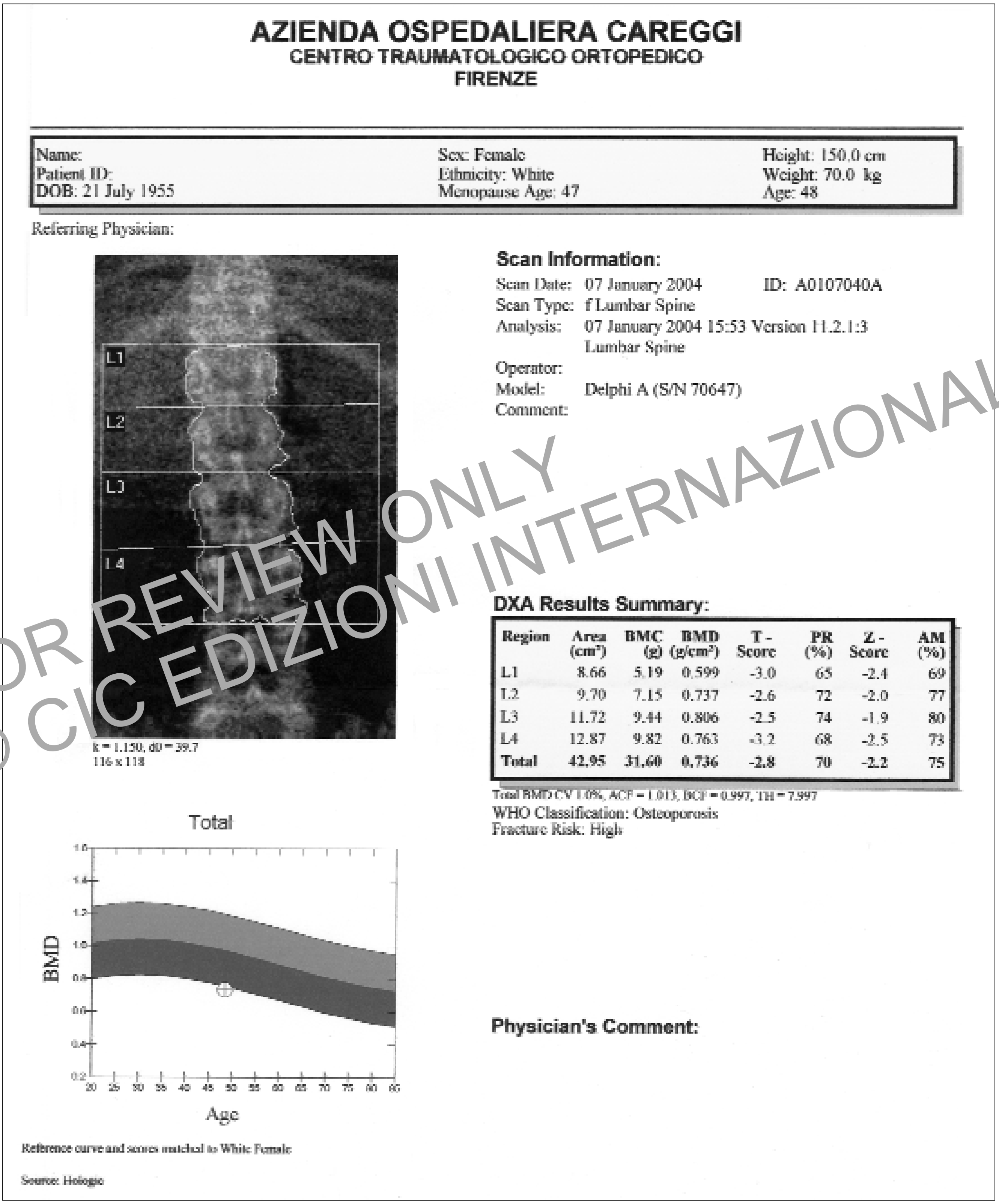
DXA densitometers have undergone remarkable technological improvements both in the process of x-ray emission and x-ray absorption.
These facts have allowed a shorter scan time, increased diagnostic accuracy (accuracy of density measurements) and a reduction of the dose to the patient (2-4).
In first generation DXA densitometers the x-ray beam is extremely thin (pencil beam), as it is obtained by means of a narrow collimation.
Given the dot-like morphology of the beam, the scans of the x-ray source are characterized by repeated passages separated by few millimeters over different positions of the longitudinal axis of the patient.
The detection system is usually represented by a phosphor crystal.
A further generation of densitometers (second generation machines) is represented by the use of a fan beam rather than pencil beam technology.
Fan beam machines employ wider beams that permit more rapid scanning and a spatial resolution of 0,5-0,7 mm. There have also been employed new detection devices made of arrays of solid detectors.
Obviously, such improvements have significantly shortened the scanning times, that are less than one minute for the spine and around five minutes for a “total body” study.
Newer machines have now the capacity to perform lateral scanning. This is permitted by a C-arm structure on which the x-ray tube is mounted and that can be rotated along 90°.
Lateral scanning increases measurement accuracy avoiding the superimposition of vertebral posterior elements, marginal osteophites, vascular calcifications that may artificially increase bone density in the postero-anterior measurements of the lumbar spine.
Lateral images of vertebral bodies have a good definition, are obtained with the patient in a supine position avoiding the artefacts that are commonly found when the patient lies on his/her flank and may be very useful for vertebral morphometric evaluation using a specific software (5).
These statements are acceptable only in case of patient with a straight spine; when scoliosis or kiphosis is present the examination becomes difficult to perform and less reliable (6), as supine position does not permit enough compensation for the curvatures.
Moreover, updated machines are now supplied with specific softwares for the evaluation of periprothesic bone (hip, knee)

and for distal and ultradistal radius (4).

Dosimetry

DXA examination has always involved low radiation dose both to patients and operators.

With modern machines the dose to patients varies from 20 to 100 micro Sv, according to different exam typology; at these exposures, operators distant more than 2 meters from the x-ray



AZIENDA OSPEDALIERA CAREGGI
CENTRO TRAUMATOLOGICO ORTOPEDICO
FIRENZE

Name: Sex: Female Height: 150.0 cm
Patient ID: Ethnicity: White Weight: 70.0 kg
DOB: 21 July 1955 Menopause Age: 47 Age: 48

Referring Physician:

Scan Information:

Scan Date: 07 January 2004 ID: A0107040A
Scan Type: f Lumbar Spine
Analysis: 07 January 2004 15:53 Version 11.2.1:3 Lumbar Spine
Operator:
Model: Delphi A (S/N 70647)
Comment:

DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T - Score	PR (%)	Z - Score	AM (%)
L1	8.66	5.19	0.599	-3.0	65	-2.4	69
L2	9.70	7.15	0.737	-2.6	72	-2.0	77
L3	11.72	9.44	0.806	-2.5	74	-1.9	80
L4	12.87	9.82	0.763	-3.2	68	-2.5	73
Total	**42.95**	**31.60**	**0.736**	**-2.8**	**70**	**-2.2**	**75**

Total BMD CV 1.0%, ACF = 1.013, BCF = 0.997, TH = 7.997
WHO Classification: Osteoporosis
Fracture Risk: High

Physician's Comment:

Reference curve and scores matched to White Female

Source: Hologic

Figure 1 - Graphic representation of DXA findings.

source do not need any protection.

The vast majority of machines are now equipped with an automatic device for the optimization of scanning parameters according to patient morphologic characteristics and exam typology.

Quality control and autocalibration

All updated machines need a daily quality control procedure to be performed on a phantom for the assessment of reproducibility of bone density (BMD) measurements.

Such controls are very important for the verification of long term machine stability, so as to be able to accurately detect slight bone density variations.

Some newer machines are equipped with an autocalibration device which operates continuously during the examination interposing through the beam tissue-equivalent materials for both bone and soft tissue.

Exam results

DXA examination is a monoplanar bone density evaluation and the densitometric findings (BMD) are expressed as gram/cm^2 (planar density).

BMD results are expressed as standard deviation (SD) by means of T-score and Z-score.

In details: T-score describes the difference between the BMD of the patient under examination and the BMD of a standard young adult population (20-30 years) and refers to the peak bone mass.

The Z-score shows the patient's results as the difference from the mean of age and sex-matched controls. Z-score is particularly important for patients aged 75 or more.

The World Health Organization has defined osteopenia T-score values between -1 and -2,5 SD, osteoporosis T-score values equal or lower than -2,5 SD and severe osteoporosis T-score values lower than -2,5 SD associated with radiologic evidence of one or more fractures (7).

DXA results are reported both as numeric values of T-score and Z-score and by a graphic curve normalized for sex and age (Fig. 1).

DXA is the most widely used technique for diagnosis and follow-up of patients suffering from osteoporosis or considered at risk for such disease.

Lumbar spine and proximal femur are the sites most commonly examined; less common is the evaluation of the distal radius which is performed in particular conditions such as hyperparathyroidism or when the evaluation of other sites is impossible (dedicated machines).

To date, total body DXA examination is only indicated for the assessment of the relative body percentage of fat and muscle.

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