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Diagnostic value of whole-body low-dose computed tomography (WBLDCT) in bone lesions detection in patients with multiple myeloma (MM)

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ABSTRACT

Purpose: To assess the role of whole-body low-dose computed tomography (WBLDCT) in the diagnosis and staging of patients with suspicion of multiple myeloma (MM).
Materials and methods: A total of 138 patients (76 male and 62 female; mean age 63.5 years, range 50–81 years), with early MM, underwent WBLDCT protocol study, performed on 16-slice scanner (Brilliance, Philips Medical System, Eindhoven, The Netherlands): tube voltage 120 kV; tube current time product 40 mAs. Diagnosis of osteolytic lesions was performed on the basis of axial and multiplanar reformatted images, whereas the assessment of spinal misalignment and fracture was done by using multiplanar reformatted images. The overall dose delivered to each patient was 4.2 mSv. Every patient gave personal informed consent, as required by our institution guidelines.
Results: The diagnosis was established either by histopathology or imaging follow-up (size increase of over a period time). In all 138 patients, image resolution was diagnostic, enabling correct classification of multiple myeloma patients. WBLDCT showed a total of 328 pathologic bone findings in 81/138 patients. CT scanning resulted in complete evaluation of the bone lesions in these areas of the skeleton: skull (42), humerus (15), femur (20), ribs (7), scapulae (13), pelvis (35), clavicle (13), sternum (10), cervical (39), dorsal (65), lombar (48) and sacral rachis (21). In 40/81 bone involvement detected by CT was the only CRAB criterion present. Furthermore, WBLDCT demonstrated pleuro-pulmonary lesions in 20 patients (11 infective, 9 as MM localizations) and 1 renal neoplasia.
Conclusion: WBLDCT, detecting bone marrow localizations and demonstrating extra-osseous findings, with a fast scanning time and high resolution images, is a reliable imaging-based tool for a proper management of MM patients.

1. Introduction

Multiple myeloma (MM) is a hematological disease characterized by the abnormal proliferation of monoclonal plasma cells in the bone marrow and accounts for about 2% of cancer-related deaths [1,2]. Generally MM presents de novo but it is preceded by an asymptomatic monoclonal gammopathy of undetermined significance (MGUS) phase in virtually all patients [3].

The diagnosis is obtained using the International Myeloma Working Group (IMWG) criteria, which distinguish between MM and MGUS according to: serum M-protein levels, percentage of neoplastic plasma cells in the bone marrow and presence or absence of myeloma-related organ and tissue impairment (ROTI), a damage directly related to the plasma cell proliferative process. Particularly, a patient is defined as symptomatic and deserving treatment if at least one of the following criteria (CRAB) is present: increase serum calcium levels, renal insufficiency, anemia and bone lesions [2,4–7]. Therefore, the detection of bone involvement, either as focal or diffuse pattern, has a critical value in the management of these patients. Moreover, the presence of osteolysis represents a surrogate parameter for tumor cell mass and this can affect both patient's stage and overall survival [8–10].

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MM is usually multifocal and can potentially affect every skeletal segment. Hence, for a correct evaluation of the extent of disease a whole-body imaging technique is required. Conventional radiographs still represent the "gold standard" approach in dealing with MM as baseline imaging tool, being widely available and cost-effective [2]. However, radiographic survey is inadequate for the depiction of small lytic lesions [11], with a rate of false negatives of 30–70%. Moreover, the positions required for plain radiographs are painful [12].

Multidetector computed tomography (MDCT) represents a feasible and widely used imaging tool that has demonstrated a diagnostic capability superior to conventional radiographs in detecting both lytic bone destruction and bone marrow cavities involvement. MDCT also allows a better evaluation of extramedullary lesions and areas of instability with a higher risk of fractures [13,14]. Whole-body MDCT (WBMDCT) was introduced, providing high-resolution images of cortical and trabecular bone with a fast scanning time (about 1 min) and demonstrating high efficacy in detecting osteolytic lesions <5 mm, especially in the spine (73%) [15,16]. Unfortunately, the radiation dose is higher (about 35 mSv) than that one delivered with radiographic surveys [12]. To overcome this drawback, Whole-body low-dose computed tomography (WBLDCT) was introduced in the clinical practice by Horger et al. [17] showing that even the low-dose protocol is appropriate for the diagnosis of lytic lesions [12]. Moreover WBLDCT can be further on implemented in the assessment of MM, being able to depict simultaneously all the three established categories of myeloma manifestations: lytic bone destruction throughout the whole skeleton (in a similar but more confident fashion than conventional X-ray); diffuse bone marrow involvement (especially in the appendicular skeleton) evident as osteopenia and osteoporosis; and extraosseous localizations [14,17–19].

Considering this important intrinsic characteristic, in agreement with the Department of Hematology, since 2008 in our institution conventional radiography has been replaced by WBLDCT as initial imaging technique for the evaluation of MM. Hence, the purpose of our study was to assess the role of WBLDCT in bone lesions detection and in the evaluation of extra-osseous findings (including lung, abdomen and pelvic localizations), in patients with MM.

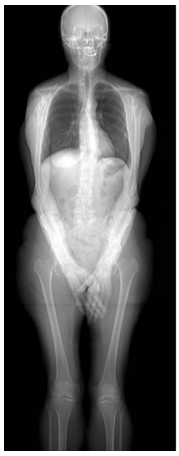
2. Materials and methods

2.1. Study population and CT protocol

From April 2008 to September 2011 a total of 138 consecutive patients (76 male and 62 female; mean age 63.5 years, range 50–81 years) with histologically proven MM underwent baseline unenhanced WBLDCT protocol study; every patient gave personal informed consent, as required by our institution guidelines.

Our study protocol was performed on a 16-slices scanner (Brilliance, Philips Medical System, Eindhoven, The Netherlands) with the following acquisition parameters: tube voltage 120 kV; tube current 40 mAs; collimation 16 × 1.5, pitch = 1; thickness 2 mm. Patients were positioned supine and head first, with the arms beside the body, in order to allow also the evaluation of the upper limbs and, additionally, to avoid beam hardening artifacts overlaps in the abdomen (Fig. 1). In 12/138 overweighed patients (≥80 kg) and in 23/138 patients with known or expected reduced bone density, the dose was increased up to 50 mAs. The advantage of a high tube current is the beneficial for the diagnosis of pathological bone changes, in particular in patients with reduced bone density.

The Field of View (FOV) was adapted to the major circumference of the patient. The scan length was stretched from the roof of the skull down to the proximal tibial metaphysis. The images were acquired in inspiratory apnea during the scanning through the thorax and the upper abdomen. Depending on patients' height, the scan lasted about 40–60 s.



Kv	120
mAs	40
Scan Length	1
Collimation	16x1.5
Thickness	2 mm

Fig. 1. Scanning protocol and patient position. The table on the right summarizes the WBLDCT protocol while the figure on the left shows the patients' placement during the execution of the CT scan, in order to avoid artifacts due to hardening of the beam in the abdomen.

Based on the high CT attenuation of the bones a low mAs setting can be used to gain a lowering of the tube current to 40 mAs, with an effective equivalent dose delivered to the patient of 4.2 mSv (Table 1).

2.2. Image analysis

The diagnosis of osteolytic bone lesions was performed on the basis of axial and multiplanar reformatted (MPR) images, whereas the assessment of spinal involvement in terms of misalignment and

Table 1
The calculation of effective dose and the dose equivalent to organs was performed using the Monte Carlo dosimetric data relating to the report of the National Radiological Protection Board SR250.

Organ	W_T	mSv	$W_T - H_T$
Gonads	0.2	3.8	0.77
Bone marrow (red)	0.12	3.5	0.42
Colon	0.12	3.9	0.47
Lung	0.12	4.8	0.57
Stomach	0.12	4.4	0.53
Bladder	0.05	4.6	0.23
Breast	0.05	3.8	0.19
Liver	0.05	4.3	0.22
Esophagus (thymus)	0.05	5	0.25
Thyroid	0.05	6.4	0.32
Skin	0.01	3	0.03
Bone surface	0.01	6.9	0.069
Remainder 1	0.025	3.5	0.087
Remainder 2	0.025	3.5	0.087
Total effective dose (mSv)		4.2	

Remainder organs	mSv
Adrenals	4.1
Brain	4.7
Upper large intestine	4.2
Small intestine	4.1
Kidney	4.5
Pancreas	4
Spleen	4.2
Thymus	5
Uterus	4.2
Muscle	3.4
$CTDI_W$ (mGy)	2.8
$CDTI_{vol}$ (mGy)	2.8
DLP (mGy cm)	295