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REVIEW / *Musculoskeletal imaging*

Tomosynthesis in musculoskeletal pathology

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KEYWORDS
Tomosynthesis;
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Abstract Tomosynthesis is an imaging technique that uses standard X-ray equipment with digital flat panel detectors to create tomographic images from very low-dose projections obtained at different angles. These images are parallel to the plane of the detector. Filtered back-projection or iterative reconstruction algorithms can be used to produce them. Iterative reconstruction used with a metal artifact reduction algorithm reduces metal artifacts, and therefore, improve image quality and in-depth spatial resolution. The radiation dose is lower compared to that of computed tomography and is two to three times the dose of a standard radiography. Tomosynthesis is intended for the analysis of high-contrast structures and especially for bones. It is superior to projection radiography when bone superimpositions are important or when metal structures hide regions of interest. The high in-plane resolution and its ability to perform exams in weight-bearing positioning are some of the main advantages of this technique. The impossible production of perpendicular multiplanar reconstruction and a limited contrast resolution are its main limitations. Tomosynthesis must be considered as an extension or an addition to standard radiography, as it can be performed in the same diagnostic step. The purpose of this article was to describe the principles, advantages and limitations, and current and future applications in musculoskeletal pathology of tomosynthesis.

Standard radiography has evolved considerably in recent years thanks to the use of digital flat panel detectors (FPD). They improve image quality, reduce radiation exposure, improve productivity, and generate new applications such as tomosynthesis, stitching, and dual-energy subtraction radiography [1—9]. Tomosynthesis provides a set of section planes

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from multiple projections obtained at various angles in a single scan of the studied volume [9,10]. In general, it improves the performance of standard radiography with a very low level of radiation exposure.

Interest has been expressed in breast imaging applications. However, tomosynthesis has also applications in pulmonary and musculoskeletal pathologies. These are areas for which standard radiography remains generally the first diagnostic step [9,11—15].

The arrival of this imaging technique in a field hitherto reserved for computed tomography (CT), obviously raises the question of its relevance to various diagnostic strategies, but also of its positioning within a technical platform. At a time when the price difference between a radiology room and an entry-level scanner is almost zero, is the minor additional cost of tomography sufficient to justify its use? Does it have a future in France given that CT licenses are increasing in number, that the exposure of CT has been considerably reduced and that it is unlikely that tomosynthesis would be covered by default health insurance? Manufacturers seem to believe so, as most of them are offering this technique in their portfolio [16].

The purpose of this article was to describe the principles, advantages and limitations and current indications of tomosynthesis in musculoskeletal pathology.

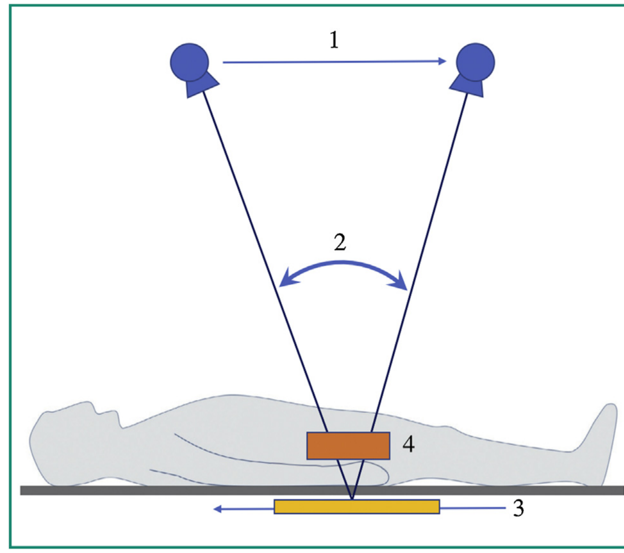

Fig. 1. Tomosynthesis principles. The x-ray tube performs a linear and angular displacement (sweep), and during this sweep, 25 to 76 shots (projections) are acquired [1]. The angular amplitude of the sweep varies between 8° and 40° [2]. During this acquisition process and depending on the tables, the detector is either stationary, or it can move in the opposite direction [3]. The size, the depth and the thickness of the target determine the choice of the acquisition and reconstruction parameters [4].

Tomosynthesis technique

General considerations

Tomosynthesis is an imaging technique that uses standard X-ray equipment with digital flat panel detectors (FPD) to create tomographic images from very low-dose projections obtained at different angles of a given anatomical region in a single sweep. Presented as a technological innovation in breast imaging, it has been used since the beginning of the 2000s [9,10].

Acquisition parameters

Tomosynthesis is available in some digital radiography rooms, as well as digital radiography and fluoroscopy systems (R/F systems). Depending on the manufacturer and the equipment, acquisition and reconstruction parameters may differ. The x-ray tube performs a linear and angular displacement (sweep), and during this sweep, 25 to 76 shots (projections) are acquired. The angular amplitude of the sweep varies between 8° and 40°. During this acquisition process, the detector is stationary with digital radiography room while it moves in the opposite direction with R/F systems (Figs. 1 and 2).

Patients can be installed in various positions, including upright, supine, and prone, which is potentially relevant to musculoskeletal pathology. In addition to standard radiography coronal and sagittal acquisitions, oblique acquisitions can also be made.

The specific acquisition parameters are the sweep angle, the sweep direction, the depth of the region of interest, the acquisition time, and the number of projections. These parameters are interdependent. They impact the clinical image quality and need to be taken into careful consideration to be optimized.

The sweep angle is in principle symmetrical. The projections are acquired at regular intervals during a continuous motion of the X-ray tube. This interval (for example every 1°) defines the number of projections. The step-and-shoot mode is not available on marketed products.

The equipment allows only one scanning axis, but certain anatomical regions, in particular for the limbs, can be positioned in different ways in order to optimize the direction of the sweep when metallic objects are present. The acquisition time varies between 2.5 and 12 seconds. The total sweep time lasts 1 to 2 seconds longer to allow for acceleration and deceleration of the tube.

Image reconstruction

The images produced are parallel to the plane of the detector (Fig. 2). It is possible to choose between three reconstruction algorithms, shift-and-add (SA), filtered back-projection (FBP), and iterative reconstruction.

With the SA method, the projection images are shifted according to the orientation of the tube and the depth of reconstruction, and then they are added together to produce the tomosynthesis images. This algorithm is no longer used because it generates many artifacts.

The FBP algorithm bears similarities to the one used in cone-beam CT. It differs, in particular, by the smaller number of projections, the less freedom in the angle of acquisitions, and the plane of the detector which remains parallel to that of the table. Using 3D filtered back-projection, the acquired projection image data is automatically reconstructed to form tomographic sections through the imaged object, with each section parallel to