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High resolution imaging of scaphoid fracture with Herbert screw treatment: comparative findings on a cadaveric wrist with digital tomosynthesis, CT, CT with iterative reconstruction and cone beam CT

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Learning objectives

- To understand the technical differences between digital tomosynthesis, fan beam CT and cone beam CT image acquisition
- To understand the challenges of imaging osteosynthesis material in 3D at high spatial resolution
- To illustrate the value of iterative reconstruction in metal artifact reduction

We illustrate the objectives and performance of these techniques in a comparative experimental study on a cadaveric forearm.

Background

Imaging techniques of the wrist

Trauma to the wrist affects all population groups and constitutes a significant public health issue because of the likelihood of fractures and ligament ruptures [1]. Radiography remains the standard imaging tool but lacks sensitivity and specificity, and can lead to unnecessary wrist immobilization, particularly in patients with suspected scaphoid fracture. CT is more efficient but sometimes less available and can miss trabecular fractures [1]. New imaging techniques have emerged that might be useful in the diagnosis of wrist injuries: digital tomosynthesis and cone beam CT (CBCT). The first is a pseudo-3D technique that is, today, mainly used in breast imaging [2]. Cone beam CT (CBCT) is a fully 3D technique which recently became one of the standards in dentomaxillofacial imaging [3]. Recent studies reported the additional value and opportunities of both technologies for the diagnosis of wrist pathology [1,4-6].

Imaging principles: 2D, pseudo-3D and 3D

Compared to 2D radiography, tomosynthesis is technique that improves the ability to visualize structures without the confusion of overlapping tissue. It is not a fully 3D technique as CT, but instead uses several radiography projections to reconstruct a **pseudo-3D** image in one direction. During the acquisition, multiple (20-40), low-dose projection images of the wrist are acquired at different angles, which are then reconstructed to produce a series of thin slices (Fig. 1a). Reviewing the wrist slice-by-slice with tomosynthesis reduces the confusion of superimposed tissue complexities as on a standard digital radiograph.

Compared to tomosynthesis, multislice computed tomography (CT) is a **fully 3D** technique which allows to reconstruct the area of interest in multiple planes. There is no confusion from superimposed tissue as with radiography and tomosynthesis. A high number of projections are reconstructed to a 3D image volume. CT uses a fan beam acquisition with multiple rotations at high speed (Fig. 1b). Different from CT, a CBCT acquisition involves a lower number of projections with a large cone shaped beam in a single, slow rotation, and uses a flat panel detector as in digital radiography (Fig. 1c). As with CT, the projection data are reconstructed to a 3D image volume. Due to their different technical characteristics, CT and CBCT images fundamentally result in images of different quality. The following four are key:

1. **High contrast resolution**
   The main benefit of CBCT is that it results in high resolution images with nearly isotropic voxel sizes (x,y,z) of 150 µm. This is achieved by a combination of specific hardware characteristis: limited scan field of view, small focal spot size and high resolution detector. High resolution CT typically results in 350 µm voxels that are not isotropic.
2. **Scatter effects**
   Due to its large cone beam and imaging volume during one rotation, CBCT is much more susceptible to scatter radiation. Scattered photons that are not detected by the small CT detector are now detected by the large flat panel detector with CBCT. Detected scatter-to-primary radiation ratio's dramatically increase from about 0.2 with CT up to 0.4-3.0 with CBCT, depending on the imaging volume and beam energy. These higher scatter fractions will impair the image contrast capabilities of CBCT.

3. **Beam hardening**
   The phenomenon of beam hardening is the continuous shift of photon energy when the x-ray beam penetrates the body. This results in a shift of CT values (HU) for equal tissue type and possibly also in streak artifacts. Beam hardening is more pronounced in CBCT due to lower kilovolt and the higher heterogeneity of the x-ray beam.
4. **Acquisition speed**
   The slow tube rotation with CBCT (10-30s) compared to CT (<0.3s) limits its capabilities for dynamic studies and makes it more susceptible for moving artifacts.

The quality of 3D imaging of the scaphoid with osteosynthesis material is typically impaired due to a combination of lower spatial resolution and by the presence of metal which violates the reconstruction process (Fig. 2). Recent iterative reconstruction methods and the introduction of acquisition techniques with cone beam CT might help to improve 3D quality.

Images for this section:

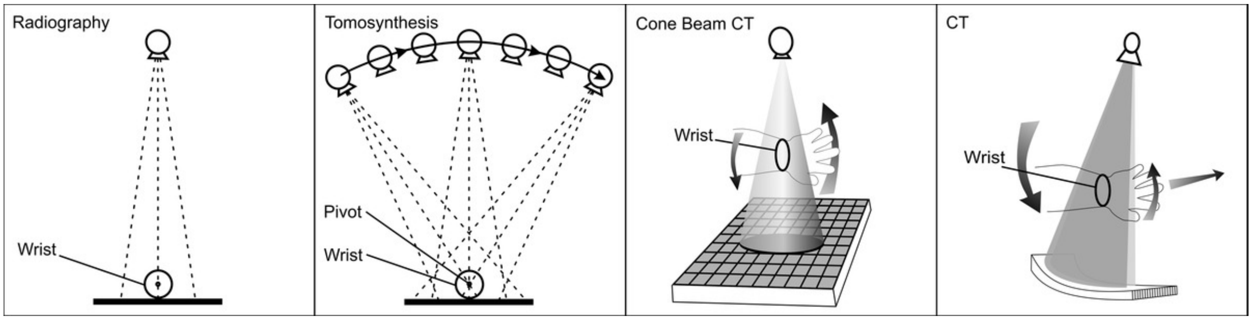

Fig. 1: Acquisition principles of radiography, digital tomosynthesis, Cone beam CT and CT.

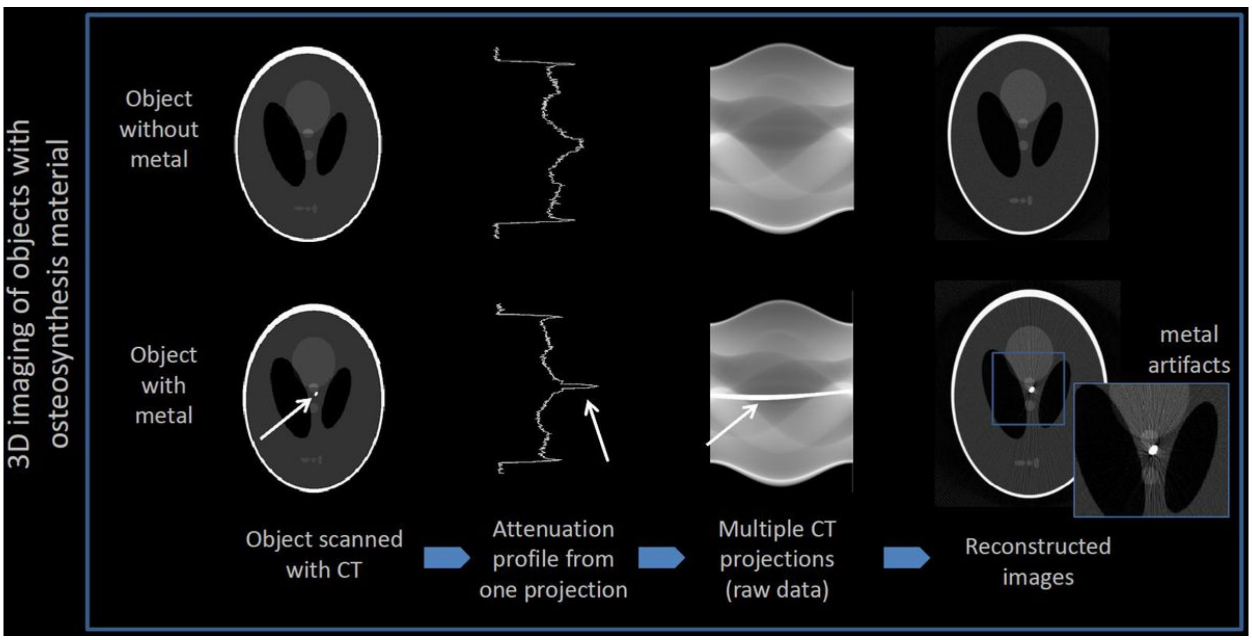

Fig. 2: Impact of metal (down) in the 3D CT acquisition and image reconstruction process. Figure illustrates from left to right: the object, attenuation profile of one projection, sinogram (raw data) and reconstructed image.

Findings and procedure details

Experimental setup and imaging sessions

In this experimental study (Fig. 3), we performed image acquisition on a cadaveric forearm with four techniques: digital tomosynthesis (Definium 8000, GE Healthcare), high resolution CT, CT with iterative reconstruction (both Discovery 750HD, GE Healthcare) and cone beam CT with a supine scanner (Newtom 5G, QR, Verona).

Prior to the first imaging session, an orthopaedic surgeon induced a controlled transverse osteotomy of the scaphoid. A second imaging session was performed after reduction of the osteotomy with placement of a Herbert screw. Obtained images are qualitatively assessed for: detail, bony delineation, beam hardening and metallic artifacts.

Findings

Both radiography and tomosynthesis images clearly depict fracture of the scafoid (Fig. 4 left, white arrow). After placement of the Herbert screw, dark bands appear at the boundary of the metal in case of the tomosynthesis images (Fig. 4 right, black arrows). This artefact is caused by the reconstruction process.

The fracture of the scaphoid can also be readily visualised on high resolution CT with and without iterative reconstruction as well as on the cone beam examination (Fig. 5). When comparing the high resolution CT images with those reconstructed by means of iterative techniques, the cortical bone appears clearly sharper on the iteratively reconstructed images. This way the fracture of the scaphoid becomes much more obvious. The cortical bone delineation however becomes somewhat irregular, most clearly visible at the distal surface of the radius and the lateral surface of the capitate. This staircase artifact feature can best be seen on the magnification views of the scaphoid (black arrows). This reconstruction artefact also propagates in the radio-scaphoid and the scaphocapitate joint space respectively. Comparing these two convential CT studies with the cone beam study, the latter images show an even better resolution. The cortical bone aswell as the trabecular pattern are more delineable and the fracture of the scaphoid is equally discernible compared to the iteratively reconstructed CT images. In contrast to the CT images with iterative reconstruction, the distal surface of the radius appears much smoother on the magnification views of the scaphoid on the cone beam study.

When looking at the studies of the wrist taken after placement of the Herbert screw, it becomes obvious that the metal artefacts present on the high resolution CT can be greatly diminished by use of iterative recontruction algorithms (Fig. 6). However streak artefacts are still clearly recognizable on the CT images with iterative reconstruction, whereas they are virtually non-existent on the cone beam study.

Images for this section:

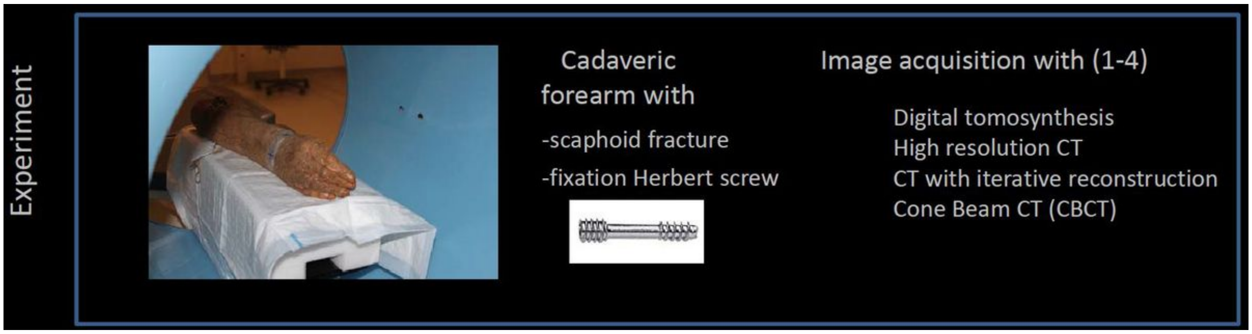

Fig. 3: Experimental setup

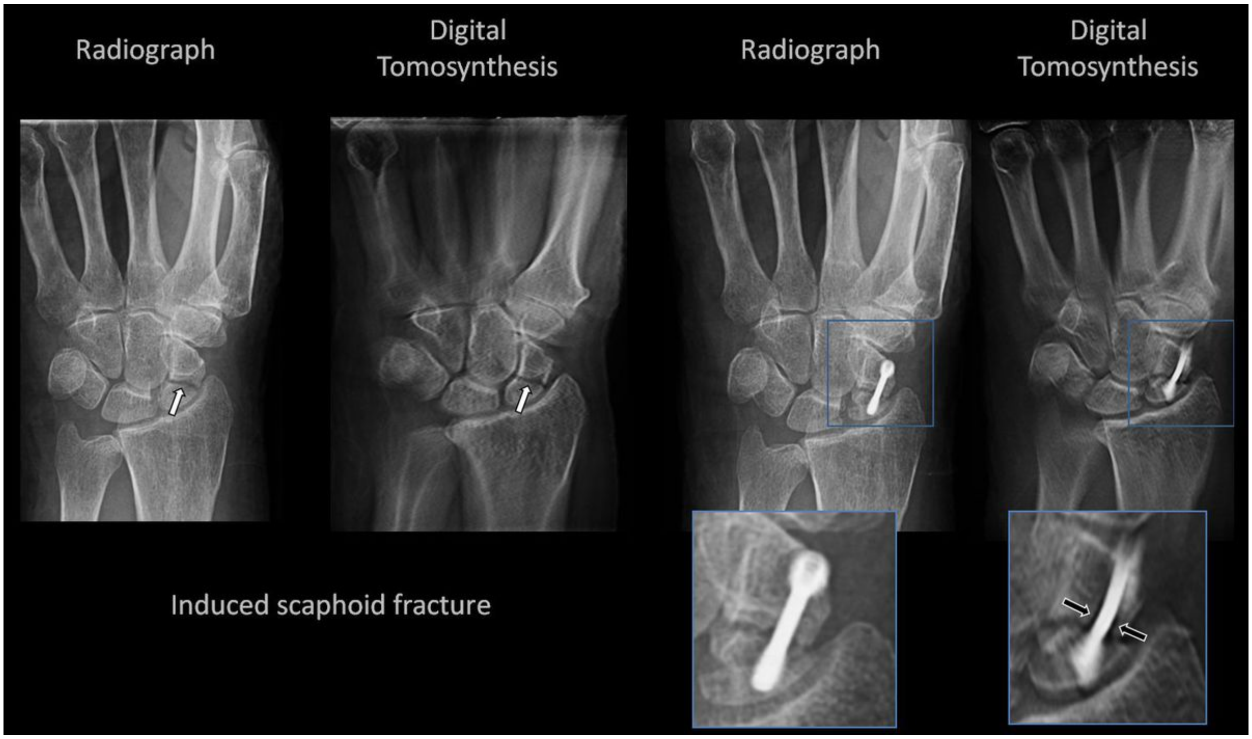

Fig. 4: Radiograph and tomosynthesis images of scafoid fracture (left) and Herbert screw fixation (right).

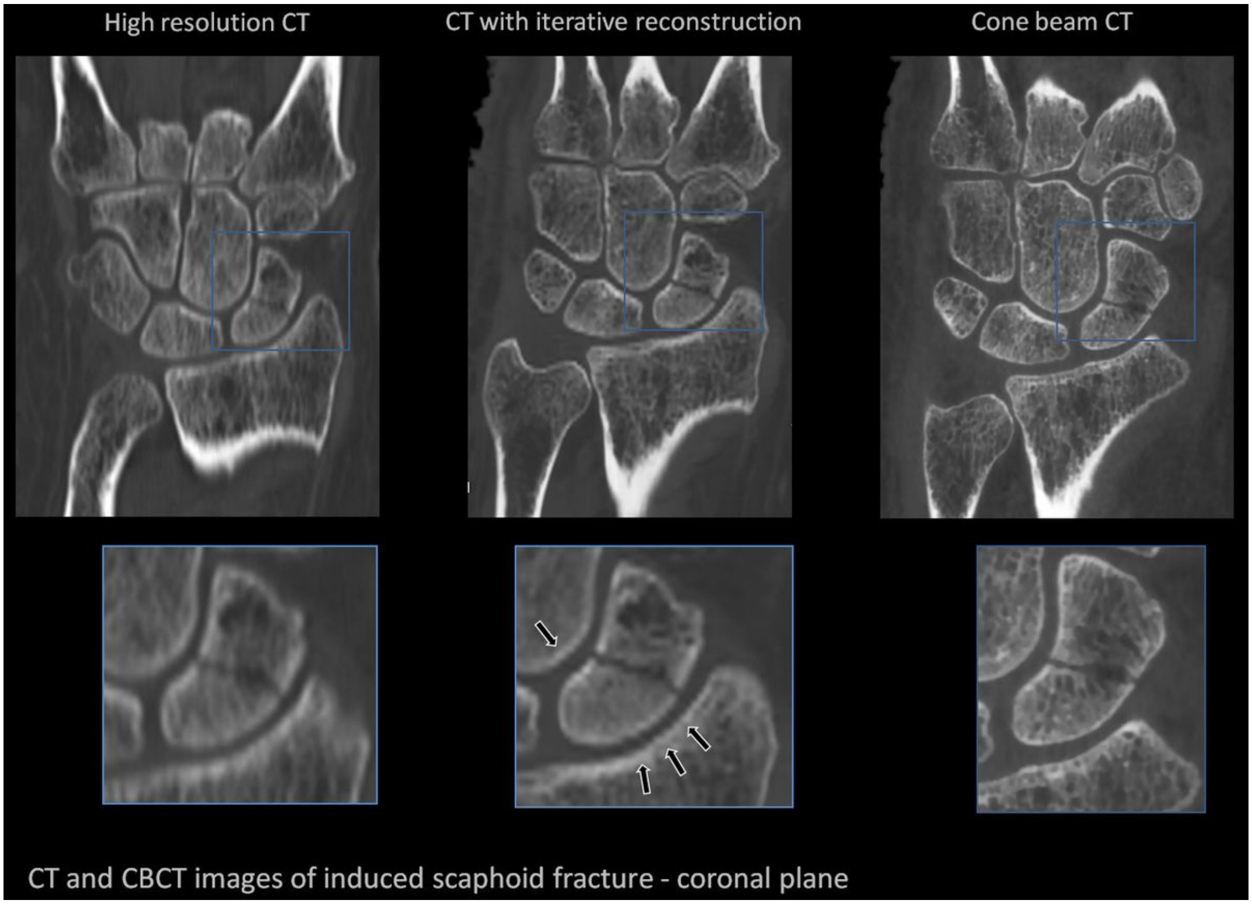

Fig. 5: High resolution CT, CT with iterative reconstruction and Conebeam CT images of scafoid fracture. Black arrows show irregular feature with iterative reconstruction.

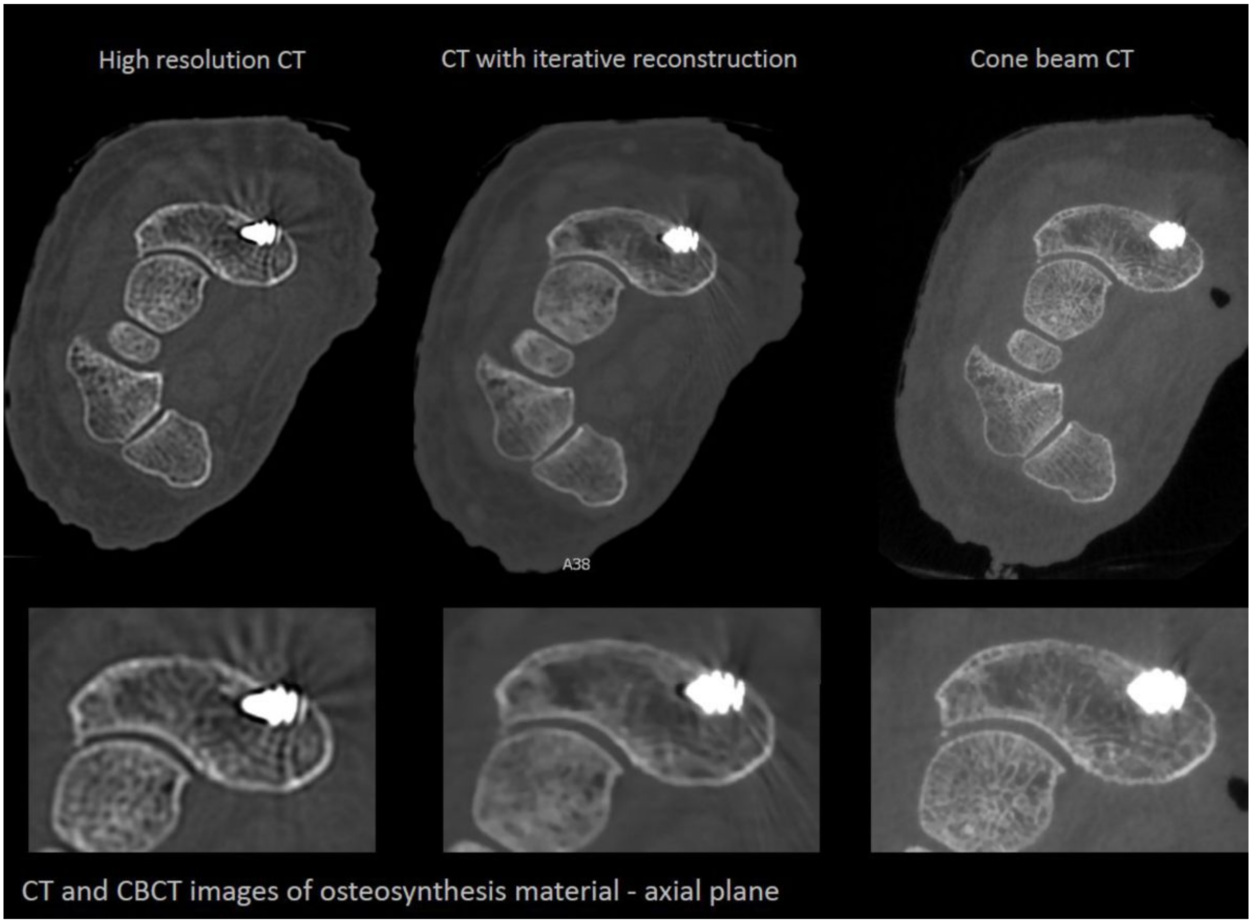

Fig. 6: High resolution CT, CT with iterative reconstruction and Conebeam CT images of scafoid fracture with Herbert screw fixation.

Conclusion

Owing to its higher intrinsic resolution and lower susceptability for metal artefacts, Cone beam CT technique clearly resulted in improved image quality compared to high resolution CT and CT with iterative reconstruction.

Images for this section:

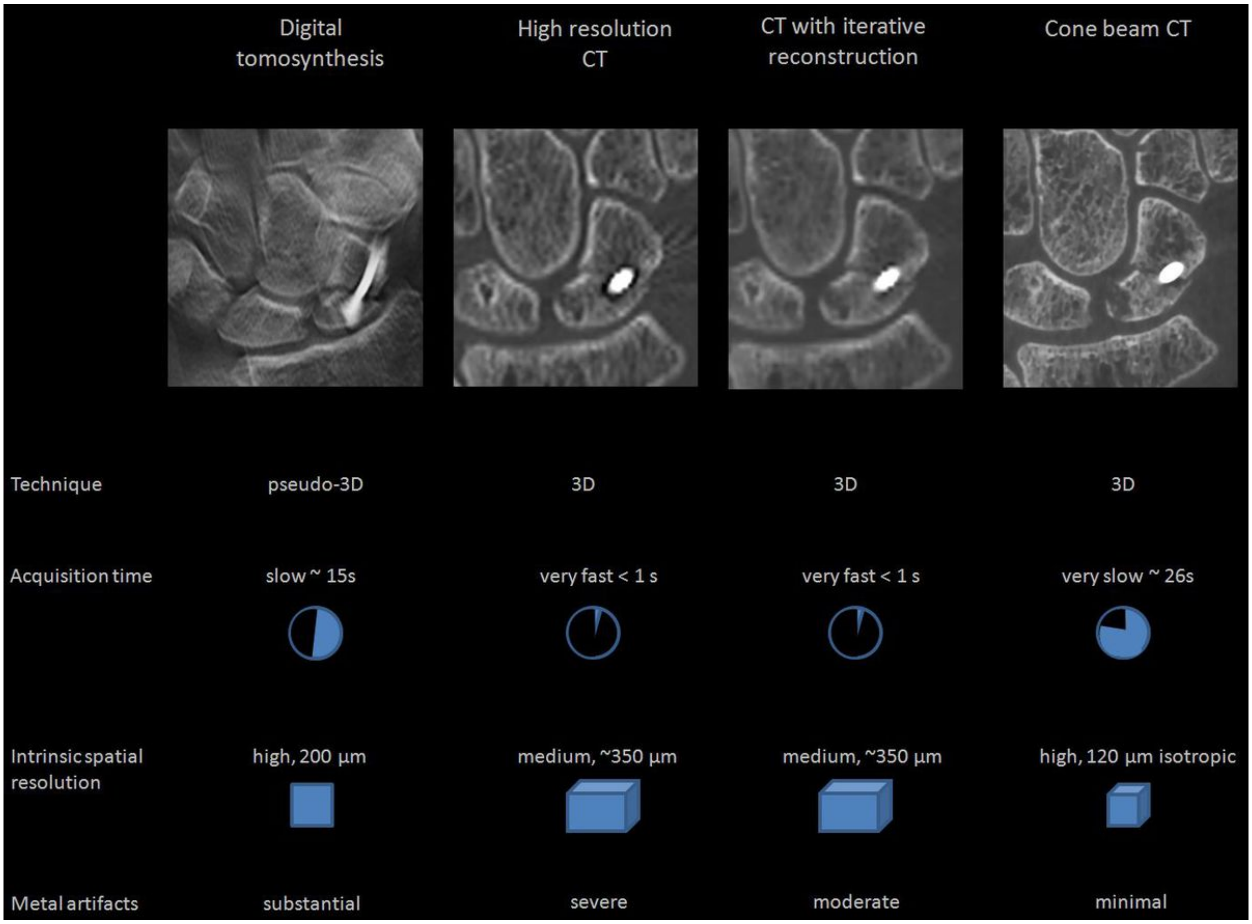

Fig. 7: Comparison of techniques with key characteristics.

Personal information

References

1. Ottenin MA, Jacquot A, Grospretre O, et al. Evaluation of the diagnostic performance of tomosynthesis in fractures of the wrist. Am J Roentgenol 2012; 198(1):180-186.
2. Skaane P, Bandos AI, Gullien R, et al. Comparison of digital mammography alone and digital mammography plus tomosynthesis in a population-based screening program. Radiology 2013; 267(1):47-56.
3. European Commission. Cone Beam CT for dental and maxillofacial radiology: evidence-based guidelines. Radiation Protection report 172. 2012
4. De Cock J, Mermuys K, Goubau J, et al. Cone-beam computed tomography: a new low dose, high-resolution imaging technique of the wrist, presentation of three cases with technique. Skeletal Radiol 2012; 41:93-96.
5. Vasilyev A, Egorova E, Blinov N, et al. Opportunities of cone-beam computed tomography in diagnostics of wrist pathology. ECR 2013; Epos Poster No C-0336
6. De Smet E, De Praeter G, Verstraete K, et al. Cone Beam Computed Tomography: Clinical applications in musculoskeletal imaging. ECR 2014; Epos Poster No C-1412