Extremity imaging with cone beam computed tomography

The high resolution at relatively low radiation dose offered by cone beam computed tomography may be added to many new imaging methods in the near future. The 3D imaging already adopted by dental practices may soon emerge in medicine.

Number of extremity CT scans is increasing

The number of extremity CT scans has increased drastically within the last ten years. For example, in Finland in 2008, 2.6 times more extremity CT scans were performed than in 2005, and four times more were performed than in 2000. During the same period, the total number of CT examinations increased 58%.¹⁻³ This means that MDCT units are increasingly being used for extremity examinations that could be done faster, cheaper and with lower radiation doses.

Dedicated extremity CBCT could help to rationalise diagnostic imaging by providing similar or even better data than MDCT for radiologists and orthopaedic surgeons. In addition, there would be less need to send patients for MDCT scans and no delay in treatment planning. Rationalising the use of expensive imaging equipment can lead to more efficient utilisation, cost savings and improved patient care.

3D imaging in the X-ray room

Planmed Verity extremity CBCT scanner (Planmed Oy, Helsinki, Finland) enables 3D visualisation in general X-ray rooms in a way that has not been available before.

With 3D imaging using multi-planar reconstruction (MPR) and surface-rendering techniques, problematic cases such as the scaphoid fracture can be visualised with one scan rather than by acquiring multiple special views that are subjected to positioning errors. The patient does not necessarily have to wait for a conventional CT scan, but can be properly diagnosed and treated with minimal delay. Minimising the delay in treatment, on the other hand, can save the patient from surgery.

Töölö trauma center in Helsinki, Finland,

Dr Sami Tohka, PhD
Planmed Oy

Wrist arthrography with Planmed Verity CBCT extremity scanner. Axial and coronal on top and sagittal multi-planar reconstruction (MPR) image on bottom row. Voxel size 0.4x0.4x0.4mm
has been evaluating extremity CBCT under an investigational protocol. “We are planning to do all our operated wrist and scaphoid fractures with the extremity CBCT unit. In the future, this method will be increasingly used for acute wrist and ankle traumas,” says Docent Seppo Koskinen.

Specialised, high-resolution imaging
What makes CBCT technology intriguing is the fact that the compact and robust technology enables specialised design. It is relatively easy to produce devices that incorporate features for specific uses, such as adjustable gantry. Also, a lightweight but robust structure allows the unit to be moved around easily.

Lower extremity applications may include such functions as weight-bearing imaging, where the patient stands inside the gantry and the foot, ankle or knee can be imaged in a natural position under load. Also, patients who need elbow scans can be imaged with the arm at shoulder level with the elbow in 90 degrees flexion, a position which is challenging to achieve in MDCT. Severely injured patients or patients in postoperative control can be imaged when lying or sitting on their own hospital beds. Also claustrophobic patients can better tolerate dedicated extremity devices than whole-body MDCT scanners.

Despite the promising potential of specialised CBCT systems, the technology has its limitations and cannot totally replace whole-body MDCT systems. MDCT has higher contrast resolution and is more suitable for dynamic studies than relatively slow CBCT, whereas CBCT has better isotropic resolution (up to ±0.1 mm) compared with MDCT (typically >0.3 mm).

Implanted metal objects cause variable degrees of artifacts in both MDCT and CBCT studies. On the other hand, the total cost of ownership is clearly more for MDCT units than for dedicated extremity scanners. The systems can be installed in virtually any location that can house a low-dose X-ray system, and the installation itself is straightforward. Maintenance, power consumption and staffing costs are negligible compared with an MDCT device.

3D imaging with low dose
One of the benefits of a dedicated extremity CBCT scanner is the low radiation dose. The lower effective dose — which also prevents radiation affecting other parts of the body — is a result of several attributes, including:

- Sensitive flat-panel detector technology
- Pulsed X-ray generation
- Optimised filtration for extremity targets
- Small imaging geometry that enables use of low imaging parameters
- Single 3D scan vs multiple, repeated radiographs for special views.

The low dose is a prerequisite for routine 3D imaging. Docent Mika Kortesniemi, PhD, head physicist at Helsinki University Hospital, has extensive experience with CBCT technology in both medical and dental use.

Dr Kortesniemi has found that the effective dose observed during the use of the extremity scan corresponds to a dental panoramic X-ray scan or a single thorax posterior–anterior projection. “CBCT can reach a lower radiation dose, especially compared to non-optimised MDCT scans,” he says.

MDCT scans can deliver unnecessary doses to other parts of the body, especially when these regions cannot be protected. For example, elbow CT scan is difficult to perform without subjecting the patient to excess radiation.

Extremity CBCT complements MRI
In general, magnetic resonance imaging (MRI) is the preferred method for diagnostic imaging of soft tissues, whereas CT gives better results for calcified tissue diagnostics. CT, on the other hand, is more reliable for fracture assessment, since inflammatory processes such as bone remodeling and callus formation show up in magnetic resonance imaging (MRI) a long time after the fracture has clinically healed.

Bone tumour diagnostics utilise a combination of both CT and MRI. It is safe to say that MRI and CBCT examinations complement
rather than compete in diagnostic extremity imaging.

**New ways of imaging**

In the near future, there will be many new imaging methods and applications that utilise CBCT technology. Dental practices have already adopted 3D imaging in general use. It is not difficult to foresee a similar trend toward general use of 3D imaging in medical imaging as well. For instance, CBCT enables bone healing process follow-up without removing the cast and tackling applications that use contrast media or other specialised imaging techniques that are performed at general X-ray facilities. With the low dose and easy accessibility combined with high-quality clinical images, CBCT can completely change the way orthopaedic imaging will be practised in the future.

**Planmed Verity extremity CBCT scanner**

Planmed Verity extremity CBCT scanner utilises X-ray tube with tungsten target and 0.5mm focal spot size with 0.5mm Cu and 2.5mm Al filtration. Anode voltage range is 80–96kV at 1–12mA current. The system houses a flat-panel amorphous silicon detector with a 20x25cm active area that can reach up to 30fps image acquisition speed. Binning of isotropic pixels can be used depending on the imaging protocol (0.1, 0.2, 0.4mm isotropic resolution). Maximum field of view of one scan is up to 13x16cm, and a stitching algorithm can be used to combine two or more consecutive imaging volumes. Typical scan time is 1.8 seconds.

The reconstructed 3D volume is displayed on the accompanying 19" touch-screen display, which is used to manage image acquisition, processing and DICOM communication to hospital information systems and image archives. The system features a vertical column attached to a motorised gantry with adjustable height and tilt. With a mobile base, the system can be moved aside for storage within the X-ray room. Adjustable positioning system uses carbon fibre positioning trays to centre the target to the field of view indicated by lasers. A video camera is located inside the TearDrop®-shaped bore to assist in positioning. Soft gantry surfaces reduce patient discomfort and motion artifacts.

The Planmed Verity unit is designed for extremity CT imaging at the point of care in emergency departments, orthopaedic clinics and trauma centres. Typical users are radiologists, orthopaedic surgeons and extremity specialists such as hand and foot surgeons.

**References**


Coronal views of post-operative weight-bearing (top left) and normal (top right) ankle. Sagittal MPR view on bottom row. Voxel size 0.4x0.4x0.4mm.