

# Using the 320-Multidetector Computed Tomography Scanner for Four-Dimensional Functional Assessment of the Elbow Joint

Yin Peng Goh, MBBS, and Kenneth K. Lau, MBBS, FRANZCR

## Abstract

As described in this case report, the use of the 320-Multidetector Computed Tomography scanner (Aquilion One, Toshiba Medical Systems, Japan) to produce continuous 3-dimensional images in real time, over a distance of 16 cm in the z-axis, proved to aid in the diagnosis of a patient's restrictive elbow joint. This state-of-the-art scanner allows fast and noninvasive dynamic-kinematic functional evaluation of the elbow joint in vivo. It will also be applicable to kinematic studies of other joints.

Clinical examination has the primary role in assessing musculoskeletal conditions. Imaging, on the other hand, is an important investigational tool in the diagnosis of joint disorders. Conventional imaging is the first-line approach to bone and joint conditions. Plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI), however, may fail to diagnose the cause of a restrictive joint condition. Experimental studies have demonstrated joint kinematics through periodic CT and MRI scanning of the joint in static positions, which then allowed 4-dimensional (4D) evaluation of joint motions.<sup>1-3</sup> However, these modalities involve longer total scan time, increased radiation exposure, tedious positioning of the joint during scanning, and have not led to widespread clinical application.

As described in this case report, the use of the 320-Multidetector Computed Tomography (320-MDCT) scanner (Aquilion One, Toshiba Medical Systems, Japan) to produce continuous 3-dimensional (3D) images in real time (4D), over a distance of

16 cm in the z-axis, proved to aid in the diagnosis of a patient's restrictive elbow joint. This state-of-the-art scanner allows fast and noninvasive dynamic-kinematic functional evaluation of the elbow joint in vivo. It will also be applicable to kinematic studies of other joints. The patient provided written informed consent for print and electronic publication of this case report.

## CASE REPORT

A 50-year-old Bangladeshi woman with a past history of malunited supracondylar fracture of the right distal humerus was referred to the orthopedic outpatient clinic for assessment of persistent pain and stiffness of the elbow joint that resulted in marked functional disability. On physical examination, she had disproportionate pain on movement of the joint and severe restriction of movement in all directions.

A radiograph of the right elbow showed malunion of the distal humeral metaphyseal fracture with a spur-like bone density overlying the anteromedial aspect of the distal humerus (Figure 1). The pain was managed conservatively, with stellate ganglion block and physiotherapy. The patient achieved limited improvement in range of motion of the elbow joint over the next 12 months: 20° to 60° flexion/extension arc of motion, 40° supination, and 90° pronation.

Given the very slow improvement in restrictive elbow joint motion over the 1-year period, we performed dynamic-kinematic CT<sup>4</sup> using the 320-MDCT scanner to further elucidate the cause of this restriction. Several 320-MDCT



**Figure 1.** Radiograph of right elbow showed malunion of supracondylar fracture of humerus resulting in a spur-like bony projection (arrow) at the anteromedial aspect of distal humerus.

Dr. Goh is Diagnostic Imaging Registrar, Monash Medical Centre, Southern Health Care Network, Victoria, Australia.

Dr. Lau is Radiologist and Head of Computed Tomography, Monash Medical Centre, Southern Health Care Network, and Adjunct Clinical Associate Professor, Faculty of Medicine, Nursing and Health Sciences, Monash University, Melbourne, Victoria, Australia.

Address correspondence to: Kenneth K. Lau, MBBS, FRANZCR, Department of Diagnostic Imaging, Monash Medical Centre, Clayton Road, Clayton, Victoria, Australia, 3168 (tel, 613-9594-2200; fax, 613-9594-6029; e-mail, ken.lau@southernhealth.org.au).

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**Figure 2.** Dynamic cine-mode imaging using 320-Multidetector Computed Tomography scanner (Aquilion One, Toshiba Medical Systems, Japan) confirmed the spur-like projection at the anterior aspect of medial epicondyle of distal humerus (arrow) impinging the coronoid process of ulna and restricting further flexion movement of elbow joint at 55°.

findings were not evident on conventional imaging. First, the spur-like bony projection was found to be impacted on the coronoid process of the ulna, preventing flexion beyond 55° (Figure 2). Second, on elbow extension at 18°, the olecranon impacted on a posteriorly angled distal humeral fracture fragment, preventing further extension (Figure 3).

Open surgery on the elbow confirmed these imaging findings. A 5-mm anteromedial osteophyte (corresponding to the “spur-like bony projection” on the scan) and a 5-mm lateral osteophyte at the distal humerus (corresponding to the posterior angulation of the distal humeral fragment) were excised. Three months later, pain relief was complete, and functional improvement was marked: 0° to 110° flexion/extension arc of motion and full range of supination/pronation motions.

#### Image Acquisition Protocol

The 320 detectors in the 320-MDCT scanner allow 16-cm coverage in the z-axis without table movement. Scans were acquired dynamically, allowing visualization of the joint motion in real time over the full 16 cm. Scanning parameters used in this acquisition were 80 kilovolt peak (KVp), 70 mA to 100 mA, and 0.35 second interval time. Effective patient radiation doses were 0.51 mSv and 1.32 mSv for flexion/extension and supination/pronation acquisitions, respectively. Thirty-six time points, covering 1 complete motion cycle of flexion/extension and supination/pronation movements of the elbow joint, were acquired. Total image acquisition time was 12.6 seconds.

#### 320-MDCT Scanning Technique

The patient was positioned standing next to the gantry with her right arm extended through the aperture of the scanner. She was asked to perform flexion/extension and



**Figure 3.** Dynamic cine-mode imaging using 320-Multidetector Computed Tomography showed moderate posterior angulation of distal fracture fragment (arrow). This restricted further extension of elbow joint at 18°.

supination/pronation motions without fixations to allow natural movements of the elbow joint. She rehearsed the movements several times until she could consistently reproduce them with a steady “jerk-free” motion. The scan acquisition was then manually started, and she began the required motions when audibly cued. Acquisition was manually terminated when the motions were completed.

#### Image Reconstruction Technique

Multiplanar images were reconstructed at 1-mm intervals, and 3D images were generated using a volume-rendering technique. The images were displayed over time in cine mode showing the motions of the joint in 4D.

#### DISCUSSION

Supracondylar fractures of the adult humerus are uncommon and often difficult to manage due to the complexity in the anatomy of the elbow joint that allows for motion in multiple planes.<sup>5</sup> In a series of 50 patients with supracondylar humeral fractures, comminuted fractures were best managed conservatively, with closed reduction and traction, to allow good functional outcome of the elbow joint.<sup>5</sup> Poor outcomes of conservative management, however, are debilitating. Patients with poor outcomes often report severe limitations of arc motion resulting in functional disability and persistent pain, which are secondary to fracture malunion or nonunion.<sup>6</sup> In our patient’s case, persistent pain and limitation in elbow movements were secondary to malunion of the supracondylar fracture.

In the initial evaluation of chronic posttraumatic elbow pain and limitation of arc motion, plain radiography of the elbow is the most appropriate imaging modality because of its availability and low cost.<sup>7-9</sup> In cases in which radiographs are nondiagnostic, CT or MRI can be useful in diagnosing posttraumatic joint pathologies.<sup>7,9</sup>

Kinematic imaging allows visualization of the interactions between various parts of a joint in real time, and thus, provides the clinician with another dimension of information. Experimental studies have evaluated the kinematics of joint motions using various modalities. Tay and colleagues<sup>2</sup> studied the kinematics of wrist joint motion in a cadaveric model using modified 64-slice cardiac gated CT. However, the temporal resolution of that modality is insufficient and produces mid-motion artifacts. It also requires repeated, periodic motions over multiple acquisitions, limiting its clinical application. Crisco and colleagues<sup>1</sup> described using multiple static CT volume image data sets acquired at various positions to simulate joint motion. The main limitation of this method is that motion is simulated rather than being directly visualized. Other modalities described as overcoming the limitation of serial static images in the assessment of complex elbow joint disorders are lateral fluoroscopy with CT registration<sup>10</sup> and fusion of radio-stereometric analysis with spiral CT dataset<sup>11</sup> to evaluate joint motions. These modalities involve tedious and complex data processing.

MDCT allows image acquisition in high spatial and temporal resolution for superior anatomical information.<sup>4</sup> MDCT was also reported in a large study to be the gold standard for adequate evaluation of structures in the assessment of complex joint fractures.<sup>8</sup> However, most standard MDCT scanners (4-MDCT, 16-MDCT, 64-MDCT) do not yield kinematic information during joint scanning. The 256-MDCT scanner described by Kalia and colleagues<sup>4</sup> allows excellent dynamic-kinematic assessment of joints, though, in comparison with the 320-MDCT scanner described in our study, it holds the slight disadvantage of a narrower scan field of view, 12.8 cm in the *z*-axis—the result of having fewer detector rows.

The recently introduced high-resolution 320-MDCT scanner offers an improved imaging technique that enables dynamic-kinematic viewing of structures over 16 cm in the *z*-axis without table movement. Its current clinical application is scanning an entire functioning organ, such as the heart, brain, or larynx, in a single motion cycle.<sup>12-14</sup> Similarly, it enables scanning of the entire elbow joint in a single motion cycle, and therefore, allows brilliant visualization of the complex joint motion in real time that cannot be observed with traditional helical CT scanners or experimental kinematic CT. This is possible because of the increased number of detector rows with faster acquisition times, which translate into better temporal resolution with less radiation exposure to the patient.

In our patient's case, the 320-MDCT scanner provided anatomical and functional information that cannot be illustrated on conventional imaging—including the osteophytes and the posteriorly angled distal humeral

fragment that reduced the flexion/extension arc of motion to 18° to 55° (Figures 2, 3). Clinical improvement in joint function after surgery further substantiated the accurate diagnosis demonstrated by the 320-MDCT scanner. This dynamic-kinematic modality has provided valuable insight into the diagnosis and management of a restrictive elbow joint.

## CONCLUSION

The 320-MDCT scanner enables multiplanar visualization of joint motions in real time. With use of this dynamic-kinematic modality, vivid images of joint structures can be viewed under physiologic conditions, allowing for functional assessment of a complex joint and identification of the cause of its dysfunction, which are not possible with conventional imaging.

## AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest in relation to this article.

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