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Experiences Using RADspeed Pro EDGE for Tomosynthesis



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1. Profile of Imamura General Hospital

Located in Kagoshima City, Imamura General Hospital was first opened in April 1984 as Imamura Branch Hospital, then reopened in June 2017 as Imamura General Hospital after renovation and completion of a new hospital ward (Fig. 1, 2). This renovation was taken as an opportunity for the hospital to focus on acute medical care and expand to 28 medical departments. The hospital is fully equipped for emergency cases with a helipad on its roof. A high-precision radiation therapy system (TomoTherapy) was also introduced to strengthen medical services in oncology along with highly specialized medical care for hematological diseases, kidney diseases, gastrointestinal diseases, heart diseases, stroke and orthopedic sports surgery. The recent hospital renovation also saw a renewal of almost all diagnostic imaging systems. Three of Shimadzu's radiography systems were adopted, including RADspeed Pro EDGE, and this article reports on the hospital's experience during startup and first clinical use of this system for tomosynthesis.



Fig.1 View of Imamura General Hospital



Fig.2 View of Sakurajima from the Hospital Roof

2. Background to Adoption

RADspeed Pro EDGE can include various interlocking mechanical features such as an auto-positioning feature, Bucky tracking function linked to Bucky stand and table, and field-of-view interlocking. RADspeed Pro EDGE is also compatible with the imaging applications such as long view radiography, dual energy subtraction, and tomosynthesis. Of the three units adopted by the hospital, one includes all of these features.

A major reason for adopting RADspeed Pro EDGE was for its biggest strength, which is tomosynthesis imaging. Tomosynthesis acquires multiplanar cross-sectional images of a target at 1/3 to 1/10 the radiation dose of CT, the patient also pays around half the price for tomosynthesis compared with CT, and tomosynthesis comes with no limit on the number of acquisitions performed each month. This was all good news to doctors who use CT imaging for follow-up and needed to spend time annotating insurance claims to justify this practice. Furthermore, doctors in their 50s had experience performing diagnosis with tomography and became key persons in the decision to adopt the systems.

3. Installation and Operation

The positions of the Bucky table and Bucky stand were investigated in detail prior to installation (Fig. 3). Positions were decided after a detailed investigation that simulated patient flow, radiological technologist flow, radiography on a wheelchair or a stretcher in each radiography room, as well as the positioning and ease of access to storage racks that hold imaging support tools in frequent use at our hospital (Fig. 4). We also aimed to keep the almost same operability compared with the previous system by arranging the locations of command buttons for controlling the X-ray tube support, and the direction of collimator's operation knobs.

The auto-positioning feature may be a one of most useful option of the RADspeed Pro EDGE. Once experienced it makes us not to go back to a previous system. It does the work of an assistant technologist by automating positioning from standing to supine and

axial positions among other functions. It took time and required lots of work to preset the X-ray projections with the acquisition protocols, but once set the all X-ray projection, it can be performed by remote controller, saving on technologist's labor and allowing more face-to-face time with the patient.



Fig.3 Radiography Room Layout (left) and Control Room (right)



Fig.4 Imaging Support Tools and Storage Racks

4. Experiences of Using Tomosynthesis

RADspeed Pro EDGE is capable of performing tomosynthesis on both standing and supine patients, and can acquire 60 images in 12 seconds. After acquisition is complete, the raw images are sent to a workstation dedicated to image reconstruction, where reconstruction is performed automatically based on preset reconstruction conditions.

The system's most unique technology is probably the "T-smart" reconstruction method that can reduce metal artifacts. "T-smart" separates metal region from other substances in raw images, and performs image reconstruction on the metal and other substances separately by iterative reconstruction (IR) method, then creates composite images. Though the conventional filtered back projection (FBP) method can also still be used, T-smart reconstruction is dramatically more effective for patients with metal implants.

T-smart images are not reconstructed automatically after acquisition, and require object range and other preference to be set manually before reconstruction, which itself takes more than 1 minute. However, metal artifacts that are obtained by smart are dramatically reduced than in images reconstructed with FBP. Image sharpness can also be improved with T-smart by increasing the number of iteration, and reconstruction can also be performed when metal implant is not present in the subject. We now use T-smart for all clinical study. When RADspeed Pro EDGE was first introduced at

our hospital, orders for tomosynthesis were limited to a certain number, and time was taken to complete both imaging and postprocessing before starting a subsequent order. This approach was taken to allow us to acquire the knowhow needed to obtain good images with the system.

For tomosynthesis, the image quality of the raw images affects the reconstructed images, and a number of key points must be considered during imaging. These include determining the center of the cross-section, determining the center and range of the field of view, and the relationship between cross-section direction and orientation of metal implants and pathology in the patient. Among such key points, this article describes in detail the measures our hospital has taken to reduce body motion.

4.1 Reducing Body Motion for Tomosynthesis Imaging

General radiography systems are unable to perform the successive image acquisitions at high speed performed with fluoroscopy systems due to the performance limitations of their flat panel detectors. RADspeed Pro EDGE has an image acquisition rate of 5 images/second, which allows 60 images to be acquired in an imaging time of 12 seconds. This is at the limit of what can be achieved while suppressing body motion by requesting the patient simply suspend respiration.

Body motion during image acquisition has a disastrous effect on reconstructed tomosynthesis images. To counter this, our hospital uses original support tools specially constructed to stabilize particular body positions for tomosynthesis imaging.

Imaging support tools of a variety of shapes and the other heavy objects like "sandbag" are used together to greatly reduce body motion by holding limbs and body in a position sustainable for a long period of time and in a body position appropriate for imaging the pathology. Since radiography time were reduced by sensitivity improvements over the long history of radiography, these sandbags have largely remained unused in the corner of the radiography room, but with tomosynthesis imaging we once again appreciate their utility. However, such heavy objects should probably only be used with the consent of the patient and while taking care to avoid loading the joints.

As one example, these support tools are used to create a particular body position for tomosynthesis imaging of the elbow (**Fig. 5**). A wedge-shaped support is inserted under the shoulder to prevent slumping of the shoulder joint, the forearm is raised to the appropriate position based on forward tilt of the head of radius, and sandbags are used to mitigate transmission of trunk movement to the arm.

For lateral imaging of the lumbar spine (**Fig. 6**), head pillow height is adjusted based on shoulder width, a bath towel or similar support is used to maintain a straight vertebral body, and in case of right-left lateral,

imaging support tools appropriate to body width are used to stabilize the right arm and right lower leg, and sandbags are used to mitigate minor movements. Configuring a particular body position in this way takes a little time, but when re-radiographing is not acceptable, all efforts should be spared to improve image quality.



Fig.5 Body Position for Tomosynthesis Imaging of Elbow Joint



Fig.6 Body Position for Tomosynthesis Imaging of Lateral Lumbar Spine

As well as the key points mentioned earlier, other points to consider with tomosynthesis arise from each clinical case. Our aim is to quickly establish a new tomosynthesis imaging method compatible with a variety of patients that will accurately describe pathologies.

4.2 Clinical Cases of Tomosynthesis

1. Fractured Left Navicular Bone (Fig. 7)

A 14-year-old boy developed pain with no particular causative incident during athletics (jumping) training and was diagnosed with fractured left navicular bone. The MR image obtained before surgery showed a bone fracture (Fig. 7a) and the CT image (Fig. 7b) identified the depth of the fracture. The fracture was stabilized with a cannulated cancellous screw (CCS) by an invasive surgery of foot phalanx.

The radiograph obtained after surgery (Fig. 7c) showed the fracture line only faintly. Tomosynthesis images acquired after surgery showed bone trabeculae in individual cross-sections clearer than in the CT image, and showed in detail the state of bone fracture reduction. T-smart reconstruction is also effective in visualizing the CCS (Fig. 7d) and providing a clear view of the relationship between fracture and CCS. As a post process, oblique cross-section views can be reconstructed to obtain an optimized cross-section angle for more detailed observation (Fig. 7e). Tomosynthesis is considered necessary for follow-up of this case due to the difficulty of observing the fracture line on radiographs.

2. Faulty union of Medial Malleolus Accessory Ossification Center (Fig. 8)

A 12-year-old boy developed pain after kicking a ball with the inside of the foot while playing football 1 month ago, but ignored the pain and continued to play football. The boy stopped playing football to achieve bone union, and progress was evaluated every month using tomosynthesis images to determine when the boy could

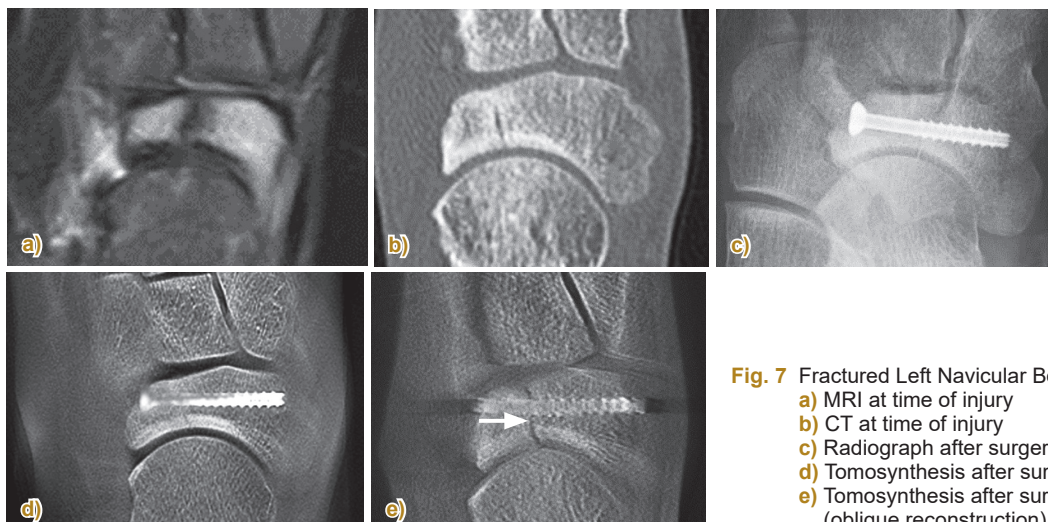


Fig. 7 Fractured Left Navicular Bone
a) MRI at time of injury
b) CT at time of injury
c) Radiograph after surgery
d) Tomosynthesis after surgery
e) Tomosynthesis after surgery (oblique reconstruction)

return to activities.

Lateral view of radiographs obtained during follow-up do not allow easy observation of the area of interest and an accurate evaluation of progress is difficult (Fig. 8a, b).

Meanwhile, tomosynthesis images can avoid overlapping of bone. Tomosynthesis at the first visit (frontal view) (Fig. 8c) is effective for determining intra-articular displacement in each cross-section view and tomosynthesis at the first visit (lateral view) (Fig. 8d) successfully shows the unique fracture line and is also useful for observing bone remodeling in fine detail. Also from a point of view of dose reduction, it is seemed that tomosynthesis is useful for follow up study of young patients.

3. Lumbar Spondylolysis (Fig. 9)

A 19-year-old pitcher in a university baseball team developed pain during pitching approximately 1 month ago. The pain gradually increased and the patient was instructed to stop sporting activities. Progress to resumption of activities was investigated with monthly tomosynthesis.

The MR image (Fig. 9a) shows a high signal intensity area at L3 and is effective for determining the stage of pathology. The CT image (Fig. 9b) allows observation from many directions in a single acquisition. The radiograph (Fig. 9c) takes little time and provides a better general understanding thanks to transmission images. Tomosynthesis images (Fig. 9d, e) are also useful for observing fine details of bone remodeling in

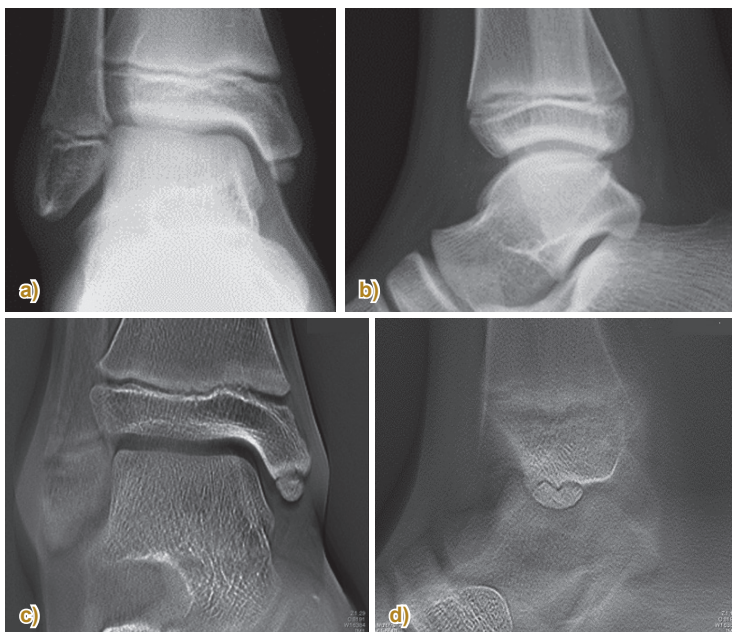


Fig. 8 Faulty union of Medial Malleolus Accessory Ossification Center
a) Radiograph during follow-up (frontal view)
b) Radiograph during follow-up (lateral view)
c) Tomosynthesis at the first visit (frontal view)
d) Tomosynthesis at the first visit (lateral view)

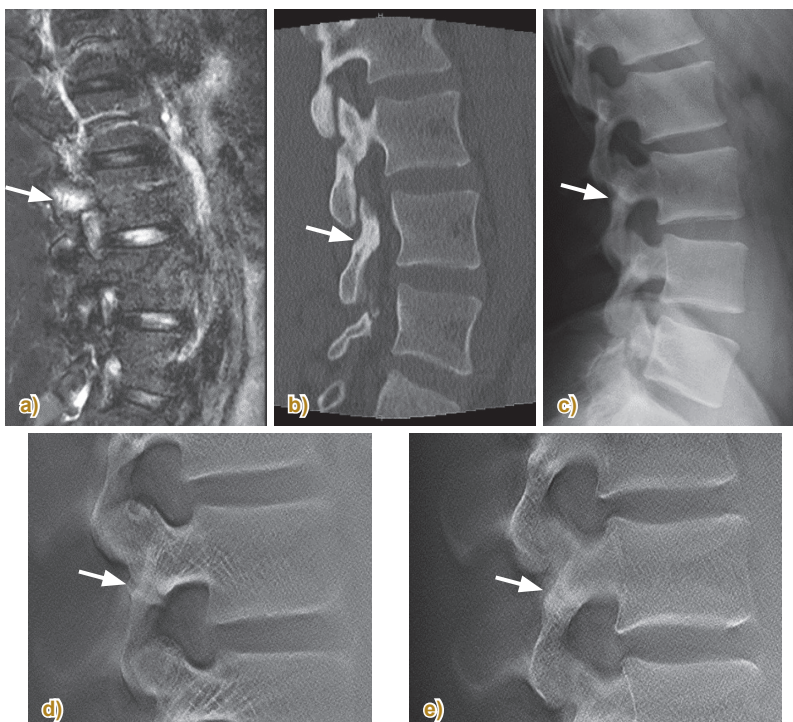


Fig. 9 Lumbar Spondylolysis
a) MRI at the first visit
b) CT at the first visit
c) Radiograph at the first visit
d) Tomosynthesis at the first visit
e) Tomosynthesis 1 month after the first visit (bone union visible)

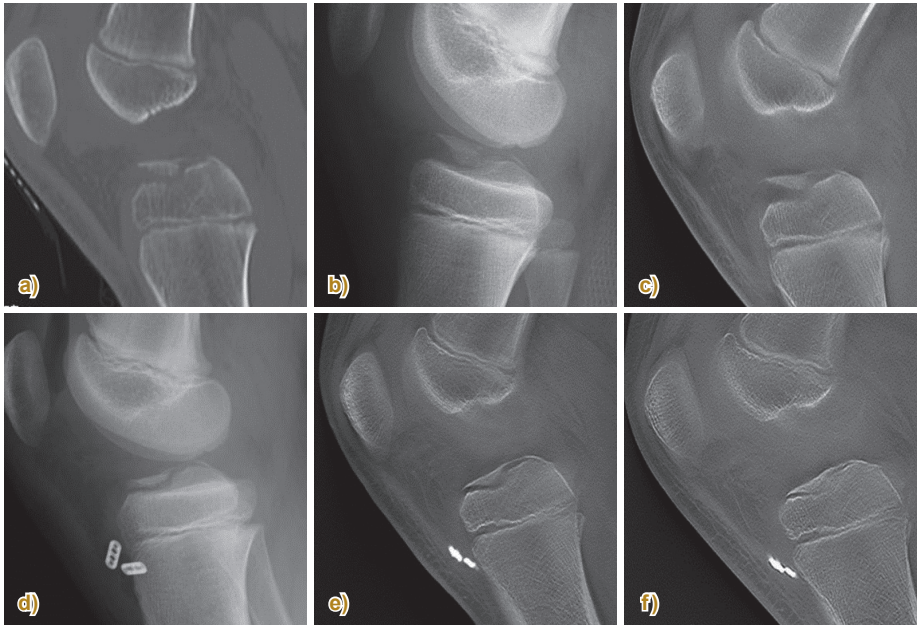


Fig. 10 Fracture of the Tibial Intercondylar Eminence
a) CT at time of injury
b) Radiograph at time of injury
c) Tomosynthesis before surgery
d) Radiograph during surgery
e) Tomosynthesis 7 days after surgery
f) Tomosynthesis 14 days after surgery

lumbar spondylolysis and are effective in determining the stage of pathology.

4. Fracture of the Tibial Intercondylar Eminence (Fig. 10)

A 9-year-old boy fell off a kick scooter and hit his knee. A Meyers type III fracture of the intercondylar eminence was diagnosed. The patient was referred from another hospital to be admitted to our hospital for surgery. There was substantial displacement of the separated fragment, and open surgery was performed on the intraarticular fracture with right knee arthroscopy. Tomosynthesis imaging was performed for a preoperative evaluation of the fracture (Fig. 10c). Bone trabeculae appear clearer by tomosynthesis than CT imaging, and tomosynthesis allows for easier determination of orientation between fragment and its original position. Tomosynthesis was performed a second time 7 days after surgery (Fig. 10e). The End button position was well displayed by T-smart reconstruction, and allowed detailed observation of the state of fragment reduction. Tomosynthesis imaging was performed a third time 14 days after surgery (Fig. 10f). Progress was steady, and a tomosynthesis image gave a detailed view of bone remodeling. Our experience has shown that tomosynthesis is effective for follow-up in cases such as this.

This case of fracture of the tibial intercondylar eminence is an example of a tomosynthesis imaging order that was received after tomosynthesis imaging has been performed a number of times and skill had been acquired in tomosynthesis imaging. When I entered

the operating room during surgery to take portable radiographies, tomosynthesis images alone were displayed on a large wall-mounted monitor and used for reference during surgery. Given the hospital also has access to CT images, MRI images, and radiographs, that tomosynthesis images were used for reference during surgery gives great pleasure to the author who was involved in introduction and initial operation of the system at our hospital.

5. Conclusions

Tomosynthesis allows medical facilities without CT systems to obtain a definite diagnosis of occult fractures and perform detailed follow-up with less dose and reduced cost to the patient. The author expects the role played by tomosynthesis in diagnostic imaging to grow in the future.

A number of variable factors must be taken into account when acquiring raw images and during image reconstruction to produce tomosynthesis images of a certain quality. Radiological technologists must have the knowledge, technique, and experience to produce tomosynthesis images with high diagnostic value. Personally, the author is excited by the rare emergence of this creative imaging modality.

The author looks forward to Shimadzu hearing the voices of its many users, understanding how its products are used in a clinical setting, and launching products even more suited to meeting the demands of clinical practice.