R/F

Use of Tomosynthesis at the Aizawa Hospital

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1. Introduction

The Aizawa Hospital is located in Matsumoto City, in the Chushin area of Nagano Prefecture, and was certified as a regional medical care support hospital in August 2001. As such, we serve a central role in coordinating medical services in the region. Furthermore, in April 2003, we were certified as a designated clinical training hospital. In April 2005, we were designated as a new emergency care center for the Chushin district. Therefore, as a central hospital responsible for acute medical care in the Chushin district, we accept all emergency patients 24 hours a day, 365 days a year, and aim to help create a region where citizens can live without worrying about emergency medical care. In 2008, we celebrated our 100 year anniversary and that same year was designated as the regional coordinating hospital for cancer treatment in February and as a social medicine provider highly beneficial to society and concerned with the common good in December. The 502-bed Aizawa Hospital contributes to society by providing high quality medical and related services **(Fig. 1)**.

Fig. 1 Aizawa Hospital

2. Use of Tomosynthesis at the Aizawa Hospital

We are currently using a SONIALVISION safire series R/F table system **(Fig. 2)** that was introduced in March 2011. The fluoroscopy room is used for a variety of examinations, such as urinary, surgical, orthopedic, and internal medicine examinations, and endoscopic examinations in the afternoon. The R/F table system recently acquired from Shimadzu is capable of tomosynthesis, which we planned to utilize effectively as a new examination tool and improve the operating efficiency of the R/F table system. However, first we needed to have orthopedic physicians request tomosynthesis, so when the system was being introduced, we held a workshop within the hospital to study the advantages of tomosynthesis based on clinical examples of imaging. The technologists actively discussed their views with the physicians about the potential of tomosynthesis and the areas where tomosynthesis is likely to have an advantage over plain radiography. In turn, the physicians also offered their views on areas where they thought tomosynthesis might be useful. As a result, the number of tomosynthesis cases gradually increased. To confirm and maintain the precision level of examinations, we collect physicians' diagnostic comments from electronic medical records for examinations performed. This information is then shared among relevant personnel. In addition, internal email is used as a method of communicating with physicians to exchange views.

Fig. 2 Currently Used System

Fig. 3 shows the number of cases using tomosynthesis during a one-year period from April 2011 to March 2012, broken down by month. All 114 cases were for orthopedic examinations. The number of cases varied depending on the month, suggesting that the use of tomosynthesis is not fully established. Next we need to analyze the number of cases for each physician to obtain the views of physicians with low usage rates and resolve any issues they may have. In general, examinations are ordered on a reservation basis, but unscheduled same-day examination requests are also accommodated.

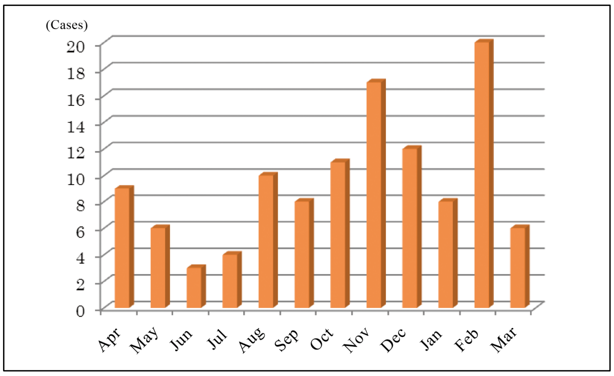

Fig. 3 Number of Tomosynthesis Cases by Month (FY 2011)

Fig. 4 shows a breakdown by target imaging area, with 16 elbow cases being the most common and the spine the next most common. We surveyed the orthopedic physicians to determine why there were so many cases of using tomosynthesis for the elbow. Responses included that though the elbow joint is small, it has a complicated structure that makes it difficult to evaluate olecranon fractures or synostosis using plain radiography images. Also, tomosynthesis is especially effective in evaluating trabeculae and synostosis near K-wires and metal objects used to secure implants and is also useful for evaluating synostosis while bones are still secured by a cast.

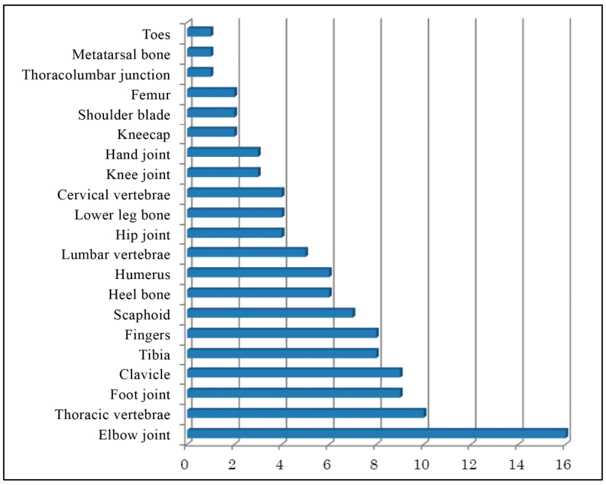

Fig. 4 Number of Tomosynthesis Cases by Target Area

3. Usefulness of Tomosynthesis

Because tomosynthesis is especially effective in reducing metal artifacts and is able to render even trabeculae, in about 90 % of the cases, tomosynthesis is used for evaluating synostosis **(Fig. 5)**. It is next most commonly used to determine the presence of bone fracture lines.

Fig. 6 shows the number of cases with an implant or other metal object in the target area. If an implant is present when trying to evaluate synostosis, the metal artifact will affect CT scans and other diagnostic imaging methods, making it difficult to evaluate the synostosis, but tomosynthesis is able to minimize the effects of metal artifacts. Therefore, it is preferred for such cases. Also, in cases with implants or other metal objects, tomosynthesis uses filtering to provide two types of images, Metal4 and Thickness++ images. This is because Metal4 allows reducing artifacts around metals more than Thickness++, but edge enhancement is weaker than Thickness++. Therefore, the characteristics of both images are considered.

Physician diagnoses were collected from electronic medical records and sorted into positive, false-positive, and no-record categories **(Fig. 7)**. Diagnoses were recorded in 80 % of the cases. This indicates that tomosynthesis results were reflected in physician diagnoses.

It has been one year since we started operating the tomosynthesis system, and cases where tomosynthesis is used for follow-up examinations have started to increase **(Fig. 8)**. The reasons for the increase include that though it is used for a variety of target areas, it is more useful for diagnosing synostosis than are plain radiographs, it uses lower exposure levels and is more effective for diagnoses that involve implant artifacts than CT, and its insurance point cost is lower, which enables short-term follow-ups.

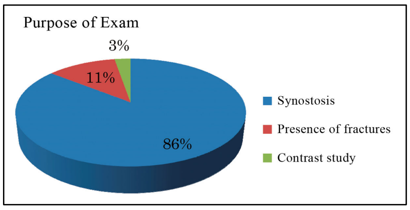

Fig. 5

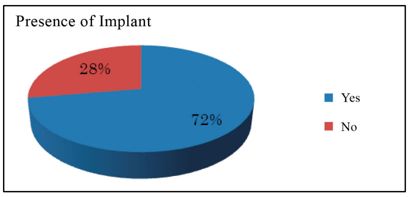

Fig. 6

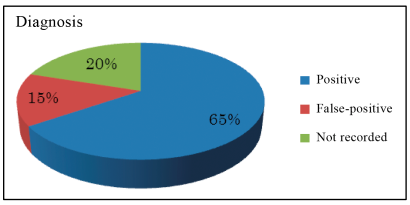

Fig. 7

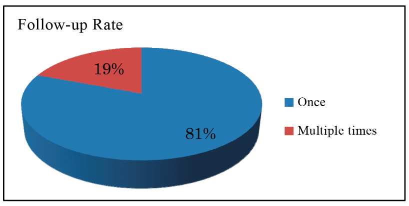

Fig. 8

4. Case Studies

4.1. Case 1 – 57-year-old male

Main complaint: Back pain

Case history: Fell down stairs. Upon hearing a sound, the patient was found fallen at the bottom of stairs with 12 steps. Patient was secured with a backboard and neck collar, and transported to our hospital by ambulance.

Imaging: CT scans of head, face, and neck, contrast-enhanced CT of chest/abdomen, and MRI of thoracic vertebrae
Hematoma in forehead, fracture of right 7th rib, burst fracture of 6th thoracic vertebra, and suspected compression fracture of 5th and 9th thoracic vertebrae **(Fig. 9)**

Treatment strategy: Since dorsal column components were retained from the burst fractured 6th vertebra, a body cast was applied for conservative therapy, followed up with tomosynthesis imaging (6 days later). A spinous process fracture was indicated **(Fig. 10)**.

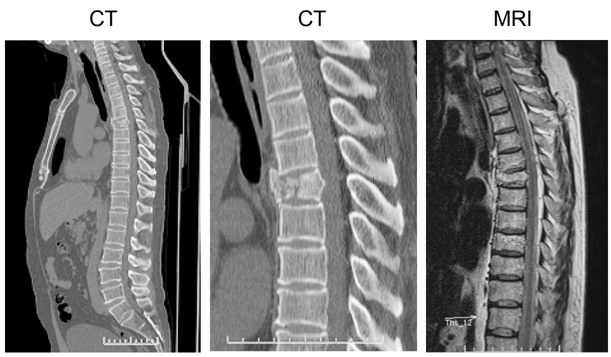

Fig. 9

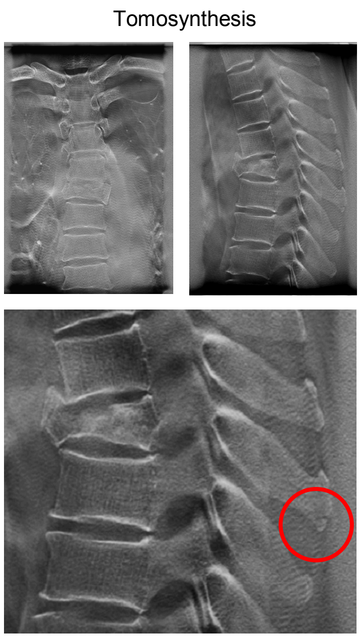

Fig. 10

X-ray parameters: 100 kV, 5 mAs
Tomographic angle: 40 deg.
Exposure time: Slow (5 s)
Resolution: High (15 fps)
Slice pitch: 2 mm
Reconstruction method: FBP
Filter: Thickness++

Compression fracture of the 5th thoracic vertebra was negative.

4.2. Case 2 – 86-year-old female

Main complaint: Right femoral pain

Case history: Hannson pin fixation of right femoral neck fracture in December 2008. In October 2011, patient experienced severe pain in right femur when waking up. Pain increased and walking became difficult, so she went to the ER.

Current symptoms: Tenderness in femoral triangle. Rotation, bending, or extension of hip joint causes pain.

Imaging: Tomosynthesis was added due to suspected right epiphysis fracture line in hip joint plain radiography **(Fig. 11)**.

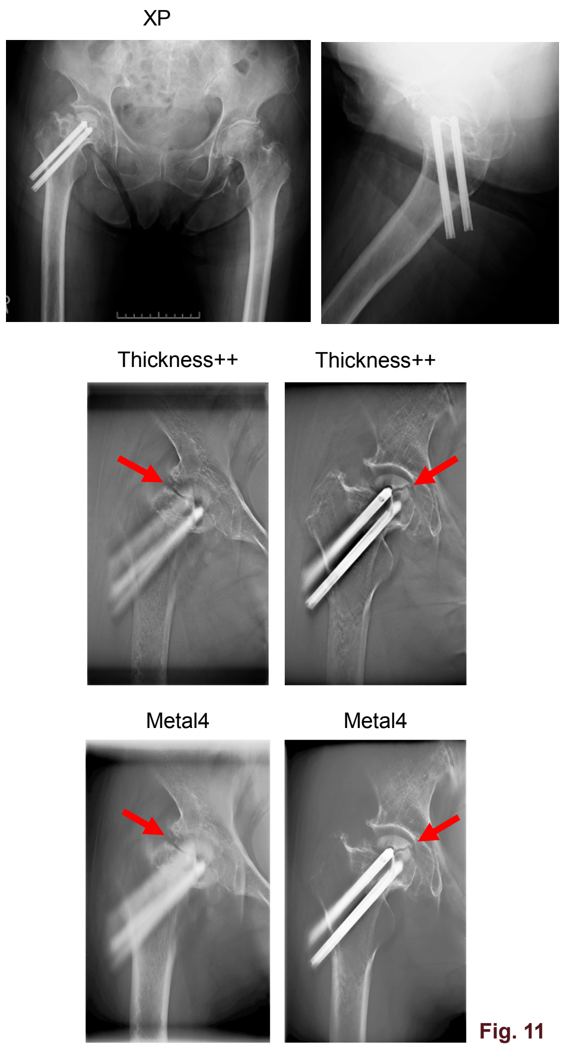

Fig. 11

X-ray parameters:	80 kV, 2.5 mAs
Tomographic angle:	40 deg.
Exposure time:	Slow (5 s)
Resolution:	High (15 fps)
Slice pitch:	2 mm
Reconstruction method:	FBP
Filters:	Thickness++, Metal4

4.3. Case 3 – 66-year-old male

Main complaint: Neck pain

Case history: Fell about 2.5 meters from a step ladder at 7:25 a.m. in October 2011 and hit his head and back. After he was unconscious or his consciousness was impaired for about one minute, an ambulance was called. When emergency medical technicians arrived, he was sitting and able to walk.

Past history: Surgery for spinal stenosis

Imaging: CT scan of head and plain radiography, CT, and MRI scans of cervical vertebrae indicated fracture lines in 6th and 7th cervical vertebrae and anterior surface of 1st thoracic vertebra.

Epidural hematoma **(Fig. 12)** was also present. Plain radiography and tomosynthesis in follow-up exam (2 months later) clearly showed grafted bone in tomosynthesis image **(Fig. 13)**.

X-ray parameters:	80 kV, 1.25 mAs
Tomographic angle:	40 deg.
Exposure time:	Slow (5 s)
Resolution:	High (15 fps)
Slice pitch:	2 mm
Reconstruction method:	FBP

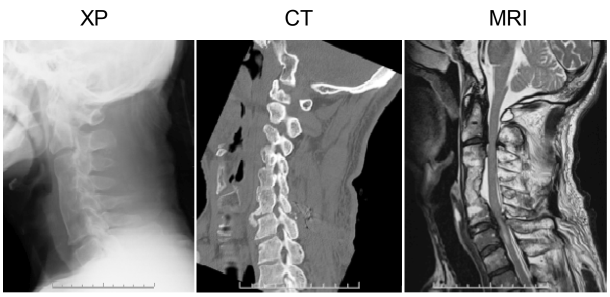

Fig. 12

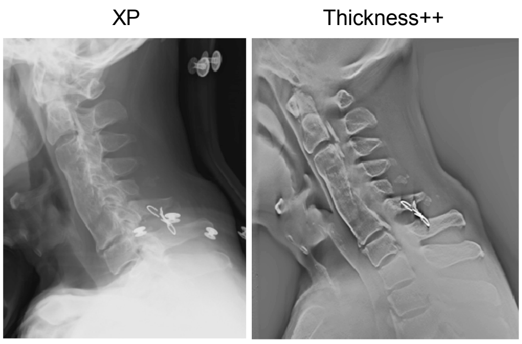

Fig. 13

Filter: Thickness++

Images taken in sitting position. Grafted bone identified in 6th cervical vertebra

4.4. Case 4 – 57-year-old male

Main complaint: Precordial chest and back pain

Case history: Fell forward during motocross bike practice. Pain in left precordial chest and back. Transported by ambulance. He was wearing a helmet.

Imaging: Performed plain radiography of chest and thoracic vertebrae and CT scans of head and thoracic vertebrae, then obtained MRI images of thoracic vertebrae the next day **(Fig. 14)**. Burst fracture of 2nd thoracic vertebra, fractured sternum, and lung contusion

Treatment strategy: Posterior fixation of 7th cervical to 4th thoracic vertebrae and autogenous bone graft performed. Plain radiography **(Fig. 15)** performed 7 days after surgery. While the lateral view, obscured by shoulders, did not allow comparison with the post-surgical image, the front view showed no movement in screws or other changes.

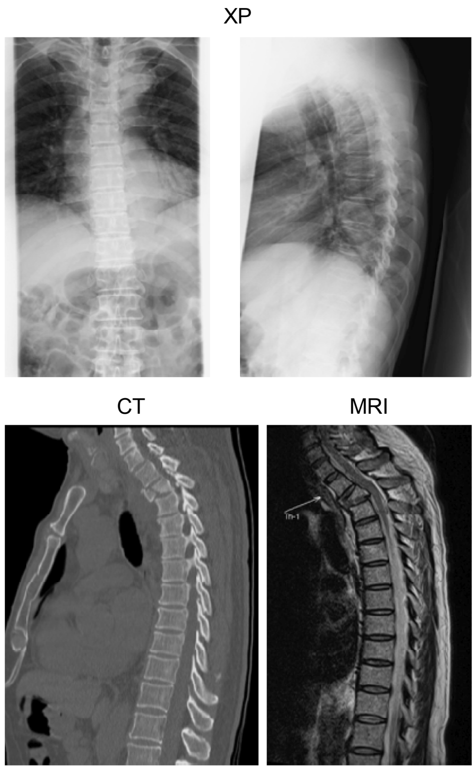

Fig. 14

XP (Day 7)

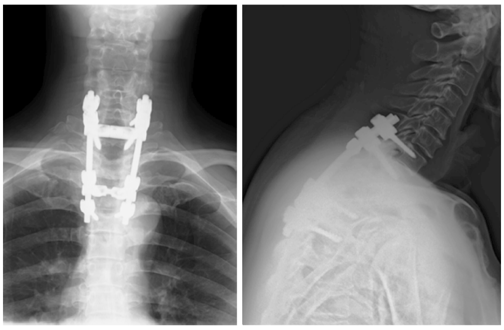

Fig. 15

CT scan **(Fig. 16)** performed 12 days after surgery. Fracture was mostly reintegrated and protrusions on posterior surface of vertebrae disappeared.
Tomosynthesis **(Fig. 17)** performed 1 month after surgery

X-ray parameters:	100 kV, 5 mAs
Tomographic angle:	40 deg.
Exposure time:	Slow (5 s)
Resolution:	High (15 fps)
Slice pitch:	2 mm
Reconstruction method:	FBP
Filter:	Thickness++

CT (Day 12)

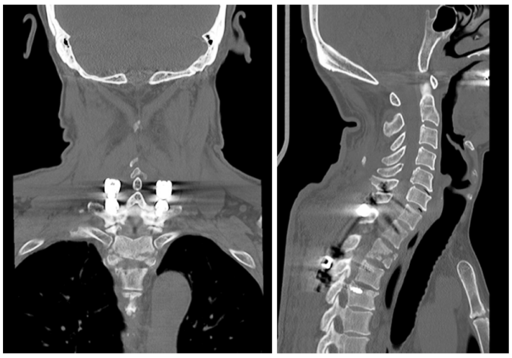

Fig. 16

Tomosynthesis

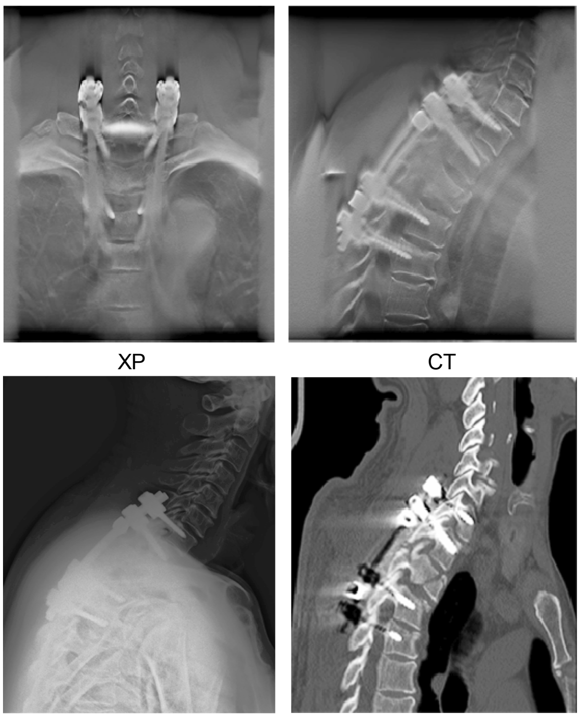

Fig. 17

In this case, the physician thought that tomosynthesis was more useful than plain radiography for determining alignment from examination images **(Fig. 17)**. Tomosynthesis was the most effective in judging screw loosening, followed by CT and plain radiography, in that order. However, CT was more effective than tomosynthesis for diagnosing synostosis.

5. Summary

Tomosynthesis is offered as additional functionality on SONIALVISION safire series R/F table systems. Because fluoroscopy can be used for positioning, images can be obtained in positions optimized for diagnosis. Tomosynthesis requires lower exposure levels and has a wider dynamic range than CT, which makes it superior for minimizing metal artifacts. In the case of scaphoid bones, it also allows diagnosing whether synostosis is progressing from the palmar or dorsal side. According to the orthopedic physicians at our hospital, CT is preferred for diagnosis during initial evaluation of bone contusions (to determine overall status and form of bone fractures and so on), but tomosynthesis is preferred for diagnosis in follow-up examinations due to evaluation of synostosis.

Issues include undershooting from implants affecting the determination of synostosis and difficulty in evaluating fracture lines when they are parallel to the direction of X-ray tube movement during exposure. Improvements are required on these issues by using reconstruction filters or by using positioning techniques that use fluoroscopy to consider the orientation of implants that minimizes effects on fracture lines. Though other facilities use tomosynthesis for many other applications, such as in respiratory, otolaryngologic, and dental applications, at Aizawa Hospital it is currently only used for orthopedic examinations. Therefore, we hope to expand the range of applications by educating the various departments.

Tomosynthesis has progressed to become an essential part of diagnostic imaging. We look forward to further major advancements in the future as well, such as those that use successive approximation methods for reconstruction. After becoming more familiar with the features of our current system, we hope to utilize the system in new application fields.