R/F

Experiences Using SONIALVISION safire and the Utility of Tomosynthesis

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1. Introduction

The hospital is located in the east of Saitama Prefecture. It is a regional core hospital that offers 723 beds with 20 clinical departments and an advanced shock trauma center. It handles an average of approximately 2,000 outpatients per day. It is a relatively new hospital that opened as Dokkyo Medical University Koshigaya Hospital in 1985. Since 2002, general radiography became fully digital and PACS was introduced in 2006 and treatments switched to monitor diagnosis.
Conventional tomography was frequently requested for orthopedic surgery at this hospital. However, after the tomography system broke down, a SONIALVISION safire incorporating tomosynthesis was introduced in October 2007. This system is normally used for fluoroscopic examinations but about 35 requests for tomosynthesis are received each month. Originally, most requests for tomosynthesis were received from the Orthopedics Division, but requests for chest tomography from the Respiratory Medicine Division are now increasing. In this paper, I will introduce metal artifact reduction for tomosynthesis in orthopedics and the use of tomosynthesis for bronchoscopic examinations for respiratory medicine.

2. Basics of Tomosynthesis

I will describe the fundamentals of tomosynthesis before introducing how it is used and its utility at our hospital.
Two reconstruction methods are used with tomosynthesis: filtered back projection (FBP) and shift-and-add (SA). Each has its own characteristics and precautions during use. The shift-and-add method (**Fig. 1-b**) shifts each pixel according to the offset to determine the tomographic plane. The FBP method (**Fig. 2**) performs 3D back projection on 74 views in slow mode and 36 views in fast mode at swing angles 40°, 30°, 20°, and 8° to reconstruct the tomographic plane. The exposure time is 5 seconds in slow mode or 2.5 seconds in fast mode. The slice thickness is determined by restricting the band frequency (**Fig. 3**).
At this hospital, we employ the wire method and bead method. The effective slice thickness was measured with each reconstruction filter type at 40° swing angle, while changing the wire thickness or metal bead diameter. **Table 1** shows the results. The results indicate a minimum slice thickness of 4 mm.

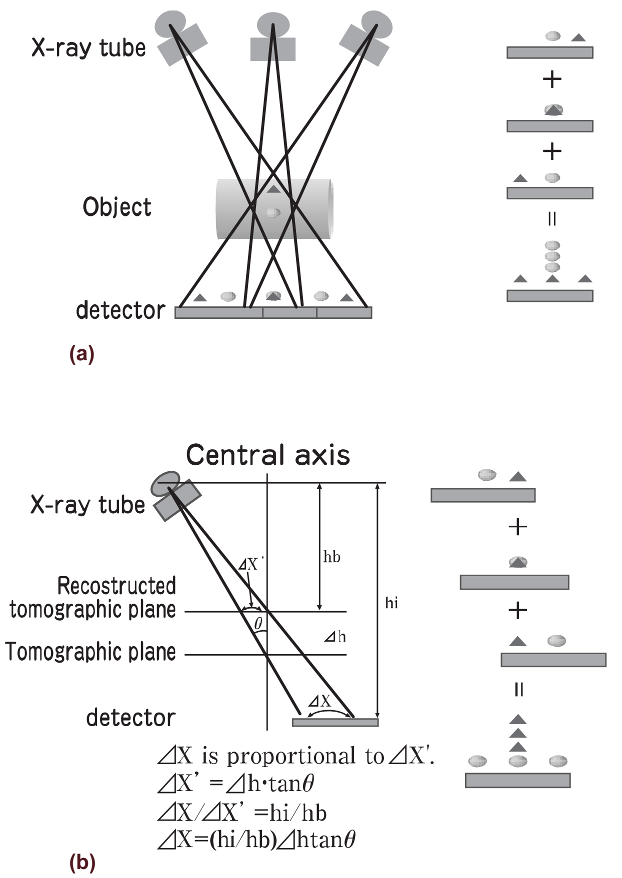

Fig. 1 **(a)** Principle of Tomography and **(b)** Shift-and-Add Method

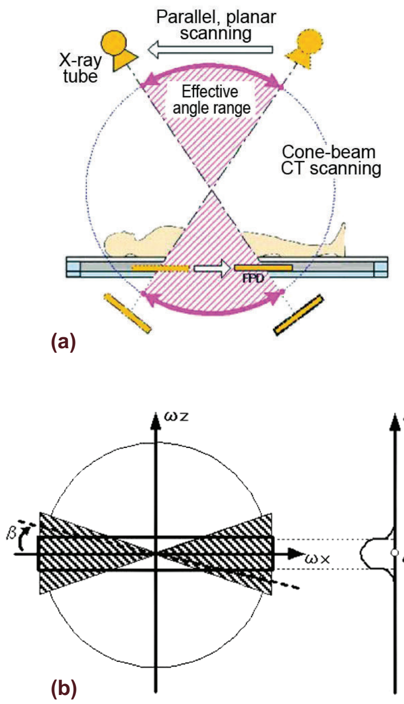

Fig. 2 **(a)** Image Reconstruction by FBP Method and **(b)** Band Limitation

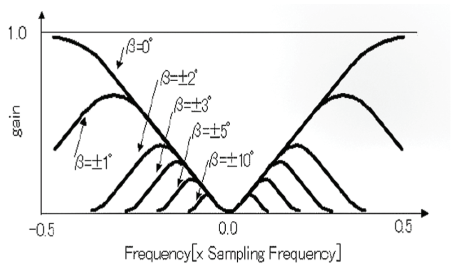

Fig. 3 Differences in Cut-Off Frequency According to X-Ray Tube Swing Angle

(Units: mm)

Reconstruction Method	Reconstructed Site	Wire Method		Bead Method	
		0.05mm	0.5mm	0.25 ϕ	0.5 ϕ
FBP	− −	4	6	4.3	6
	−	4.5	7.2	4.8	7.8
	− +	7.5	9.5	7.8	9.8
	+	10	11	10	11.8
	+ +	12	13	12	14.2
Shift-and-Add		3	4	3	4

Table 1 Effective Slice Thickness Measurements Due to Differences in Cut-Off Frequency at 40° Swing Angle

3. Use of Tomosynthesis at This Hospital

Of the approximately 400 requests for tomosynthesis received during the past year, 300 were for orthopedic surgery and 100 were for chest tomography by the Respiratory Medicine Division. In addition, tomosynthesis was performed 40 times for confirmation during transbronchial tumor biopsies (TBTB).

4. Tomosynthesis in Orthopedic Surgery

A conventional tomography system was used in orthopedics for follow-up observations of bone formation after fractures or spinal fusion surgery. After this system broke down, we started using CT for follow-up observations. However, due to the extended wait times, as our two CT systems perform approximately 100 examinations per day, we started using tomosynthesis for orthopedic follow-up observations. This allows the examination to be performed on the day, without a reservation. It leads to a reduction in patients' wait times, as tomosynthesis completes the examination within ten minutes, compared to over 30 minutes with the previous tomography system.

Metal artifacts due to metal external fixators at a fracture location, artificial joint implants, or screws for spinal fusion cause problems with CT radiography. We use the filtered back projection (FBP) method for tomosynthesis reconstruction at this hospital. As tomosynthesis artifacts are generated in a different direction in images including metals implants, tomosynthesis is extremely effective for observations of some areas (**Fig. 4**).

Tomographic imaging is performed after myelography for spinal canal stenosis in some cases. Injecting the contrast medium permits easy observations of the cauda equina. CT must be performed in the supine posture. However, tomosynthesis is possible while the patient is sitting, which allows its use to be matched to clinical symptoms. The information in the slice-thickness direction is predetermined for each slice for a CT scan, such that no information is displayed away from that slice thickness. Conversely, tomosynthesis includes some thickness information for each slice, permitting depth observations in each image (**Fig. 5**). Comparison of CT multiplanar reconstruction (MPR) images and tomosynthesis images confirms that the resolution differs according to the detector used, even when the same FBP method is applied for image reconstruction. While CT achieves superior contrast between tissues, tomosynthesis seems to offer better resolution (**Fig. 6**). We believe that images with higher diagnostic capacity can be obtained by dividing the use of CT radiography and tomosynthesis according to the type of examination and disease.

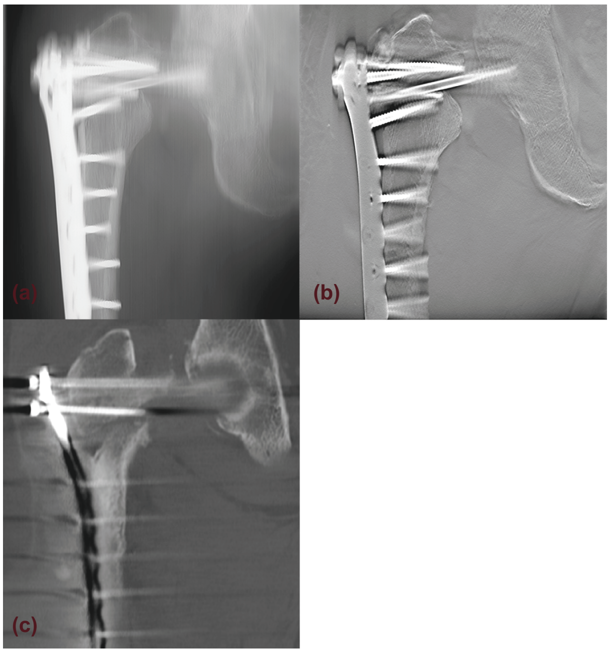

Fig. 4 Differences in Artifacts Due to Reconstruction Method
(a) SAA **(b)** Tomosynthesis **(c)** CT MPR

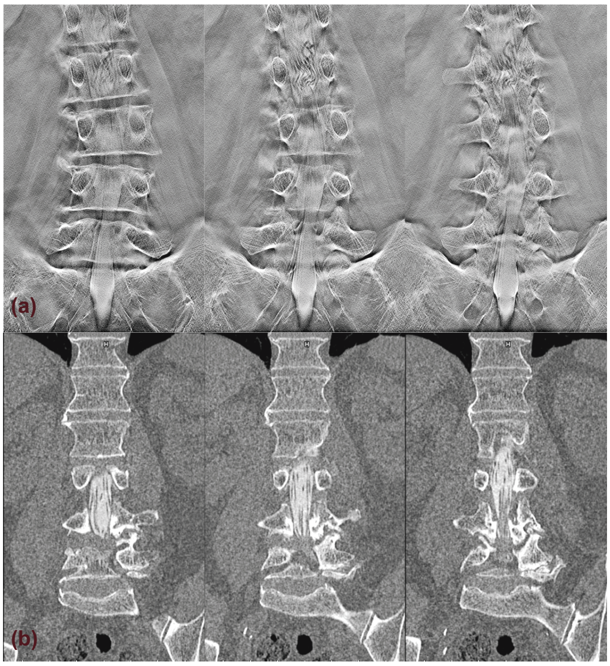

Fig. 5 Comparison of **(a)** Tomosynthesis and **(b)** CT MPR

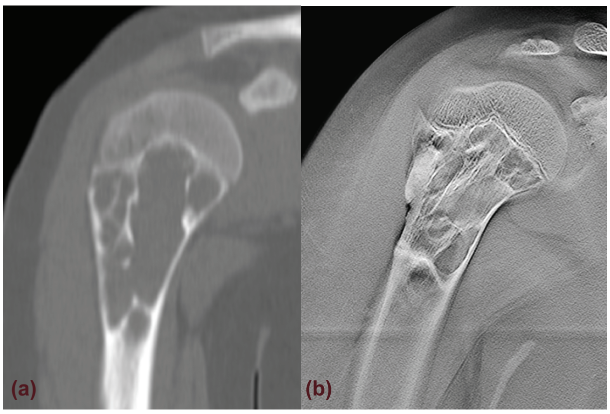

Fig. 6 Differences in Resolution of **(a)** CT and **(b)** Tomosynthesis

5. Metal Artifact Reduction

Reconstruction by the FBP method results in problems with overshoot and undershoot artifacts. One method of alleviating the artifacts around metals is to shift the cut-off frequency in the low-frequency direction (from –– reconstructed site to ++ reconstructed site). This method reduces metal artifacts and permits clearer image observations around metals, but results in a greater effective slice thickness. Conversely, artifacts can be reduced by increasing the proportion of the direct-current (DC) component as a new reconstructed site (**Fig. 7**). Adding a direct-current (DC) component enhances the contrast and reduces the effects of overshoot and undershoot artifacts, without changing the effective slice thickness, to facilitate observations of the bone structure around implants (**Fig. 8**).

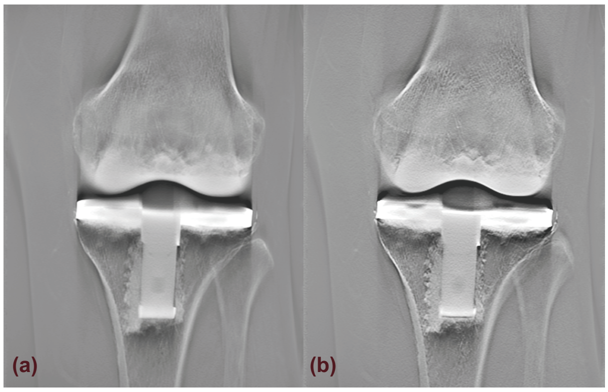

Fig. 7 Changes in Image Due to Metal Artifact Reduction
(a) ++ Reconstructed Site
(b) –– Reconstructed Site

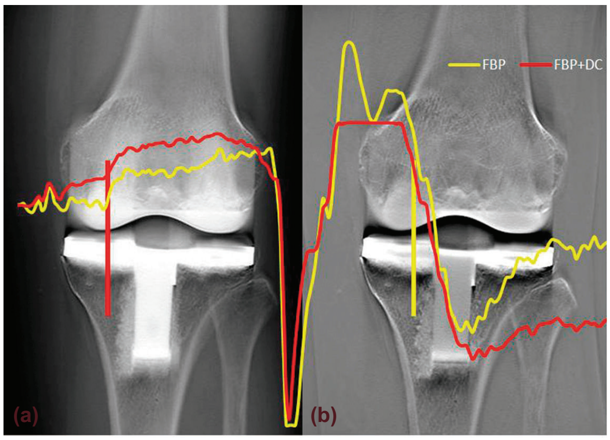

Fig. 8 Image and Profile Curve Before and After Adding DC Component
(a) After **(b)** Before

6. Utility of Tomosynthesis for Transbronchial Tumor Biopsy

This hospital performs 200 bronchoscopic biopsies per year under fluoroscopic guidance. However, lung lesions can be difficult to confirm using fluoroscopy. It can also be unclear whether the bioptome has securely grasped the lesion. Therefore, at this hospital, we use tomosynthesis to confirm that the bioptome has reached the biopsy position at the site of the lesion during bronchoscopic examinations such as transbronchial tumor biopsies (TBTB). Before the examination, we use CT images to check the slice height of the target lesion to determine the tomographic plane for the bronchoscopic procedure. Enlarged image reconstruction of the target site is performed using the fast mode at 30° swing angle in order to minimize breath-holding time (the patient has to hold their breath during the bronchoscopic examination), reduce exposure dose to the operator, and provide images rapidly. The images can be displayed in approximately 1 to 2 minutes. As tomosynthesis images can confirm that the bioptome has reached the lesion and can select the bronchial tube, biopsies are possible on tissue at other positions (**Fig.9-1**). Previously, the side station images could be displayed on the console monitor only during bronchoscopic examinations. However, the monitor switching function can display these images on monitors in the examination room, to present realtime tomosynthesis images to the operator. Images with DC component addition to eliminate metal artifacts also increase the contrast for chest tomography to close to a conventional tomographic image. These are clear images with reduced artifacts at the lesion (**Fig. 9-2**). They also clearly display the position of the bioptome (**Fig. 9-3**). A new method to understand the running direction of bronchial tubes in the lung field in advance is to perform radiography with the patient in the same posture as during chest tomosynthesis, and reconstruct images at 0.5 mm reconstruction pitch. Free software is then used to confirm the running direction of bronchial tubes in simple MPR images. Tomosynthesis manages tomographic images as DICOM DIR files, such that 3D data can be acquired to display MPR images. This permits three-dimensional observations of the running direction of bronchial tubes in the same status as during the examination, and is used at this hospital for the MPR display of 3D data for cases in which the running direction of the bronchial tubes is difficult to confirm (**Fig. 10**).

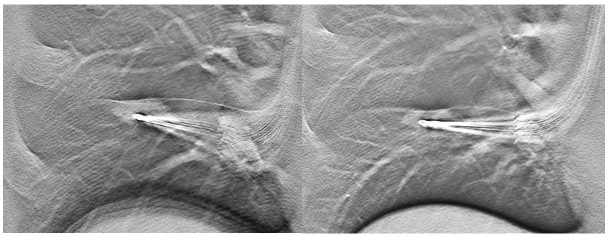

Fig. 9-1 Tomosynthesis Image to Confirm TBTB Bioptome Position

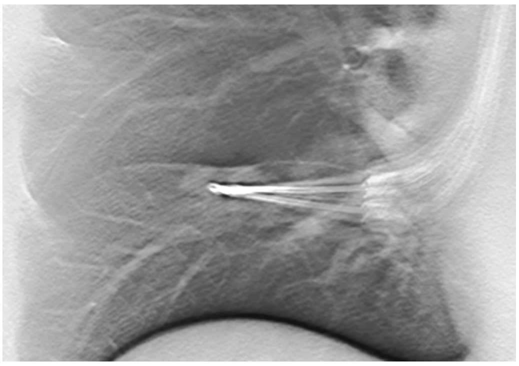

Fig. 9-2 Tomosynthesis Image to Confirm TBTB Bioptome Position (with DC Component)

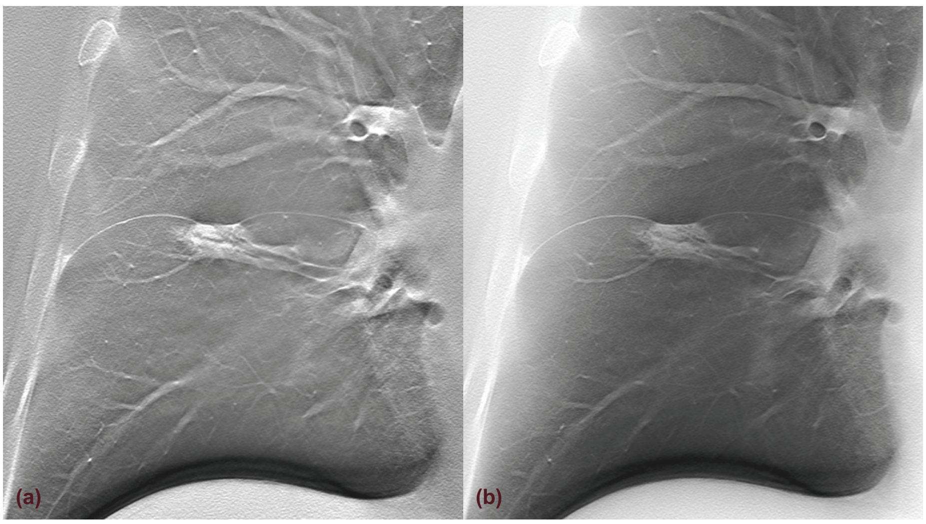

Fig. 9-3 Chest Tomographic Images With and Without DC Component
(a) No DC component **(b)** With DC component

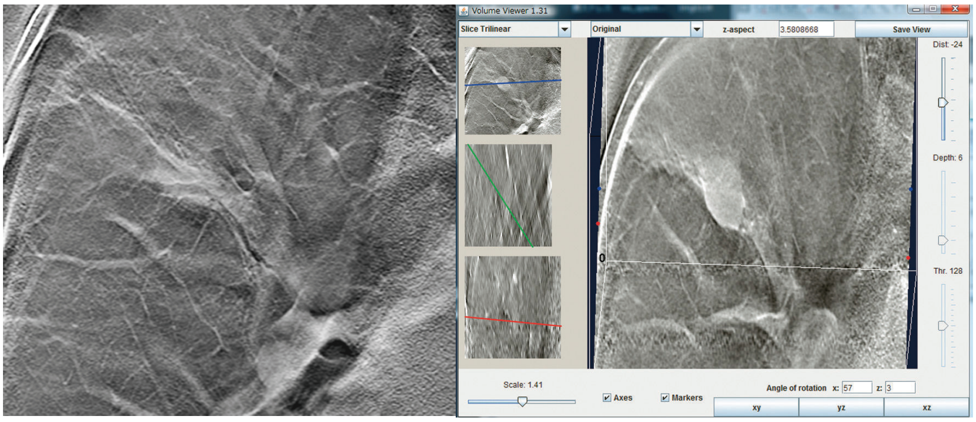

Fig. 10 MPR Display from 3D Viewer

7. Conclusions

We described the use of tomosynthesis only for orthopedics and bronchoscopies in respiratory medicine at this hospital. However, we also use tomosynthesis to confirm the bile duct during DIC and for ERCP. The current system incorporates an R/F table but it is desirable to use the system for general radiography. New programs, such as dual-energy tomosynthesis, being developed for the SONIALVISION safire should expand the scope of application of the system and increase clinical requirements for it in the future.

Reference

Takeshi Shiomi : The principle and clinical application of Tomosynthesis, Medical Imaging and Information Sciences Vol 24, No 2 (2007) Special Lecture Article