RAD

Universal Tomosynthesis Imaging with UT-Station

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1. Introduction

Tomosynthesis is a medical term created from the words tomography and synthesis that refers to a technology for reconstructing tomographic images from multiple, consecutive radiographic images. Tomosynthesis mainly finds use in orthopedic medicine for detailed observation of fracture lines and follow-up after joint replacement surgery. Current products from Shimadzu that can perform tomosynthesis are the SONIALVISION G4 (R/F system) and the RADspeed Pro EDGE package (general radiography system). Aiming to expand the usefulness of tomosynthesis and make the technology easier to use, we have developed UT-Station, a program that realizes “universal tomosynthesis imaging” and enables tomographic images to be acquired on various radiographic imaging systems by imaging a patient together with a specially designed phantom then processing the images on a dedicated workstation. This article briefly describes universal tomosynthesis imaging with UT-Station.

2. Background

With tomosynthesis, images can be acquired without overlapping bones and tissue and allowing good confirmation of fracture lines difficult to visualize by radiography alone. Conventional tomosynthesis image reconstruction requires a flat panel detector (FPD) that can accommodate consecutive imaging and a precision mechanical control mechanism to move the imaging system in precise accordance with positional information calculated in advance based on the operational settings of the radiography system. These requirements limit which systems are capable of performing conventional tomosynthesis imaging. In universal tomosynthesis imaging, geometric positional information about the imaging system is detected from the images to be used in tomographic image reconstruction, making it possible to perform tomosynthesis imaging even on radiography systems that are not designed with a dedicated mechanical control mechanism.

3. Characteristic Features of Universal Tomosynthesis Imaging

Universal tomosynthesis imaging requires three things: (1) the UT-Station program designed for radiographic diagnostic system workstations, (2) a computer installed with UT-Station to be used as a workstation to view images and reconstruct tomographic images, and (3) a UT-phantom to

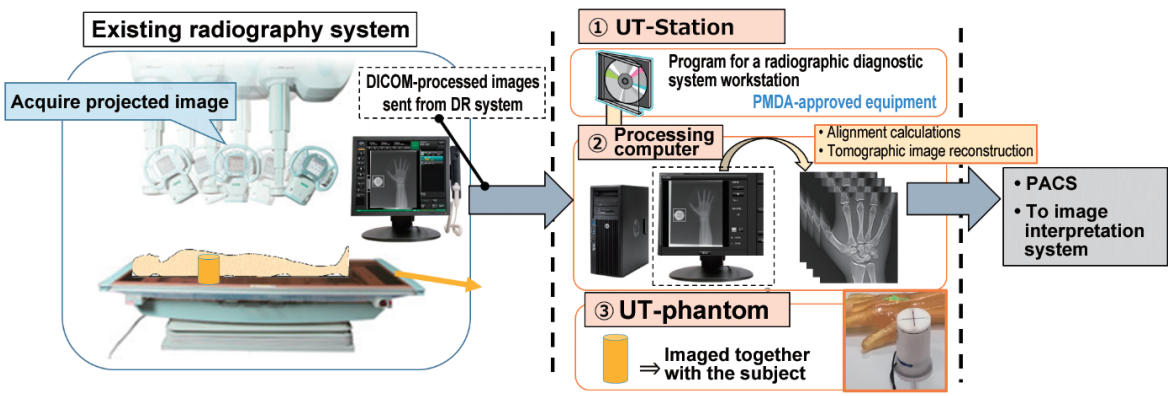


Fig.1 Overview of universal tomosynthesis imaging

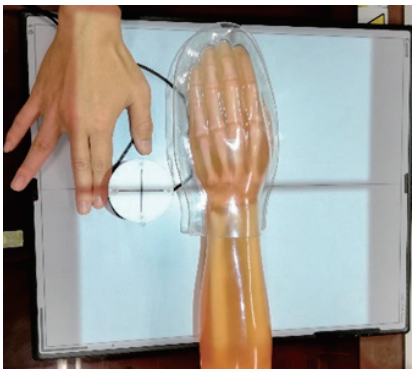
obtain geometric positional information about the imaging system from acquired images. Each of these things works independently of the radiography system, so each is easily combined with an existing radiography system. An overview of universal tomosynthesis imaging is shown in **Fig. 1**. First, the UT-phantom is placed next to the subject and 5–7 radiographic images are acquired at different irradiation angles. These radiographic images are sent to the computer installed with UT-Station, and using a tomographic reconstruction function for universal tomosynthesis imaging, UT-Station performs automatic alignment calculations and tomographic image reconstruction processing. The main target of this study is the evaluation of fractures in the extremities and hip joints. The characteristic features of universal tomosynthesis and conventional tomosynthesis are shown in **Table 1**

3.1 Imaging the Subject and the UT-Phantom

For universal tomosynthesis, the FPD is mounted on the table or in the bucky and remains immobile while imaging is performed by moving the X-ray tube. The UT-phantom must be within the projected image for the entire series of acquired images, so the lines printed on the top surface of the UT-phantom are used as a guide and placed within the irradiation field as shown in **Fig. 2(a)**. As also shown in **Fig. 2(b)** and **(c)**, the base of the UT-phantom has a suction cup design and stays firmly in place on the table surface or FPD surface even during imaging in an upright position. After setting the UT-phantom in place, about 5–7 projected images are acquired with the X-ray tube system in different positions. About 1–2 minutes of imaging time is normally needed to acquire these images with a general radiography system, so immobilizing the subject with sandbags or support apparatus is more important during universal tomosynthesis imaging than during conventional tomosynthesis. Furthermore, the irradiation dose per image acquisition is smaller than normal radiography, and the total dose for an examination is as small as around 1.5–2 times a general radiography examination. Positional information about the imaging system is calculated automatically from the projected image, which means the X-ray tube does not need to be positioned precisely between each image acquisition. The RADspeed Pro (general radiography system) also has an auto-positioning function (optional) that can position the X-ray tube by remote control.

Table 1 Comparison of universal tomosynthesis and conventional tomosynthesis

	Universal tomosynthesis	Conventional tomosynthesis
FPD	Continuous imaging function not needed	FPD capable of continuous imaging
Mechanical control	Unnecessary	High-precision automatic control mechanism
Number of projected images	5–7 images (20 degrees)	20–74 images (20–40 degrees)
Imaging flow	Auto-positioning function/Manual operation	1 switch (setup → exposure)
Imaging time	Around 1–2 minutes	Around several seconds to several tens of seconds
Imaging sites	Sites with little body movement (extremities or hip joints)	No restriction
Cost	Cheaper than standard	Standard



(a) Preparing irradiation field

(b) Ready for decubitus imaging

(c) Ready for upright imaging

Fig.2 Preparing the UT-phantom

3.2 Position Detection by UT-Station

Projected images sent to UT-Station from the radiography system are selected for reconstruction processing. The UT-phantom contains multiple metal markers in a prescribed positional relationship. Before reconstruction processing can commence, preprocessing automatically analyzes the position of the UT-phantom in each image and the arrangement of each metal marker in the UT-phantom, thereby calculating the position of the X-ray focal point relative to the FPD. Evaluation of three factors: accuracy of tomographic image display height, accuracy of the calculated angle of X-ray incidence in the center of the FPD, and spatial resolution of tomographic images, has verified that the position detection performed by UT-Station is equivalent in performance to tomographic images acquired by conventional tomosynthesis. Results from UT-phantom detection in each image can also be checked in UT-Station and adjusted manually **(Fig. 3)**.

3.3 UT-Station Reconstruction Algorithm

Universal tomosynthesis is based on the assumption that projected images will be acquired using an FPD for general radiography. Therefore, UT-Station has an algorithm that can handle image reconstruction from a small number of images. When tomosynthesis reconstruction is performed from a small number of projected images, the edges of cortical bone and other structures that display a large difference in luminance (high-contrast structures) cause a ripple artifact to appear on slices outside the original tomographic imaging plane. The image reconstruction algorithm used by UT-Station applies successive approximation to reduce this ripple artifact. **Fig. 4** shows images reconstructed from seven projected images using a conventional algorithm and the algorithm used by UT-Station. These images show the ripple artifact is less apparent in images reconstructed by UT-Station compared to images reconstructed using the conventional algorithm. During reconstruction, UT-Station also checks the geometric position of the imaging system based on the positional relationship of metal markers in the UT-phantom and notifies the user of errors during position detection such as might be caused by movement of the UT-phantom during imaging.

Fig.3 UT-phantom detection

4. Clinical Images

Universal tomosynthesis images created using Shimadzu's RADspeed Pro are shown in **Fig. 5**. In both images, fracture visibility is improved over radiography and even fine fracture lines are visible.

5. Conclusion

This article briefly describes universal tomosynthesis imaging. Universal tomosynthesis imaging can produce tomographic images even from radiography systems with no tomosynthesis function by determining the position of the radiographic imaging system from radiographic images. This article also describes UT-Station; a program that performs universal tomosynthesis image reconstruction and is intended

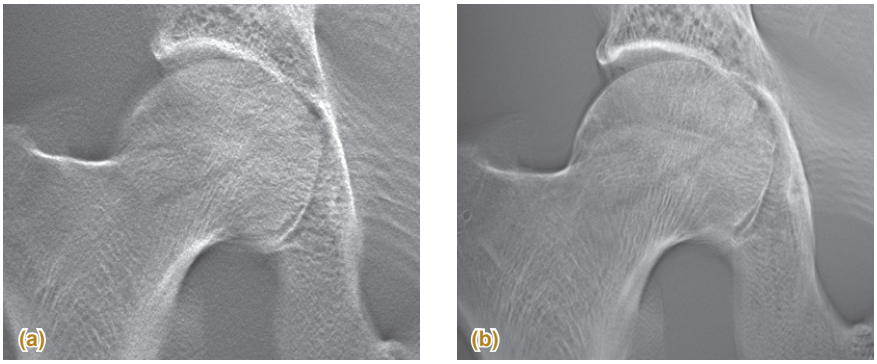


Fig.4 Ripple artifact suppression
(a) Tomographic image obtained using conventional algorithm
(b) Tomographic image obtained using UT-Station

Fig.5 Clinical case images
(a) Fracture of the right ulna
(b) Fracture of the left distal radius

for radiographic diagnostic system workstations. We look forward to being able to introduce even more new functions and applications in the future that will contribute towards more accurate diagnoses. Finally, we would like to take this opportunity to offer our sincere thanks to Yoshitami Murayama R.T., Rie Sonobe R.T., and all others involved at the Department of Radiology, Nippon Koukan Hospital for their considerable help in providing images and in clinical evaluation of universal tomosynthesis imaging, and to Takayuki Baba R.T. of the Department of Diagnostic Imaging, Imamura General Hospital for valuable advice in considering immobilization methods for imaging and in helping to create prototypes.