Clinical Experiences with Slot Radiography using SONIALVISION safire II, and Its Utility – Lower Limb Region–

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1. Introduction

This hospital is located approximately in the center of Chuo-ku, Sapporo, near Odori Park. It is a regional core hospital offering 18 outpatient departments in six centers and 301 clinical beds. It provides a large part of the municipal and regional medical services.

Construction work on the new hospital building started in 1999. It recommenced operation in September 2002, providing the first electronic medical procedure ordering system in Hokkaido. The Department of Radiology strove toward filmless operation early on and commenced filmless X-ray radiography operations in 2004. Due to the increasing number of artificial joint replacements performed by the Orthopedics Department, the Joint Replacement Center was launched in 2005. Most diagnostic imaging equipment was upgraded along with the reconstruction work. However, the existing X-ray R/F system was moved to the new facility and was subsequently replaced by a Shimadzu SONIALVISION safire II system in 2006 **(Fig. 1)**. In this paper, we introduce our experiences using this system for slot radiography of the lower limbs, which is one important application of the system for examinations in the orthopedics field, and we discuss the utility of the system.

Photo 1 NTT East Corp Sapporo Hospital

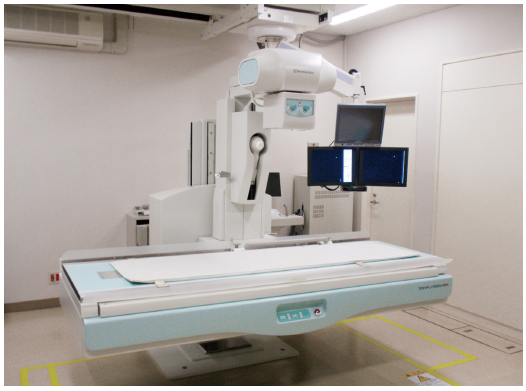

Fig. 1 SONIALVISION safire II External Appearance

2. Sequence of Events Leading Up To the Introduction of the System

This hospital conducts some 2,000 X-ray fluoroscopy examinations per year. In descending order of frequency, these include examinations of the upper gastrointestinal tract, nonvascular IVR, examinations of the lower gastrointestinal tract, and orthopedic-related examinations. Before the R/F system replacement, we carefully checked for the new functions we expected from the system (see below). We visited facilities inside and outside Hokkaido and checked the spatial resolution and quality of images produced by existing equipment from multiple manufacturers to compare the systems. The superiority of the Shimadzu direct-conversion flat panel detector (FPD) was obvious from its superb image quality and stability. In addition to this detector, the great future potential and comprehensive range of applications of the SONIALVISION safire II, including tomosynthesis and slot radiography, led us to introduce a Shimadzu SONIALVISION safire II system.

・ Functions we expected from the new X-ray R/F system:

(1) Incorporates an FPD to permit further future developments in image quality and applications.
(2) Multifunctional system to handle IVR and orthopedics as well as the core gastrointestinal tract examinations.
(3) Easy-to-use system with excellent operability and practicality.

3. Principle and Features of Slot Radiography

Slot radiography with this system uses an X-ray beam thinly collimated into a slot shape that continually scans in the S-I direction to make repeated exposures. Adjacent slot images are subsequently synthesized into one long image with just 1 cm overlap between them. **Fig. 2** shows the principle of slot radiography.

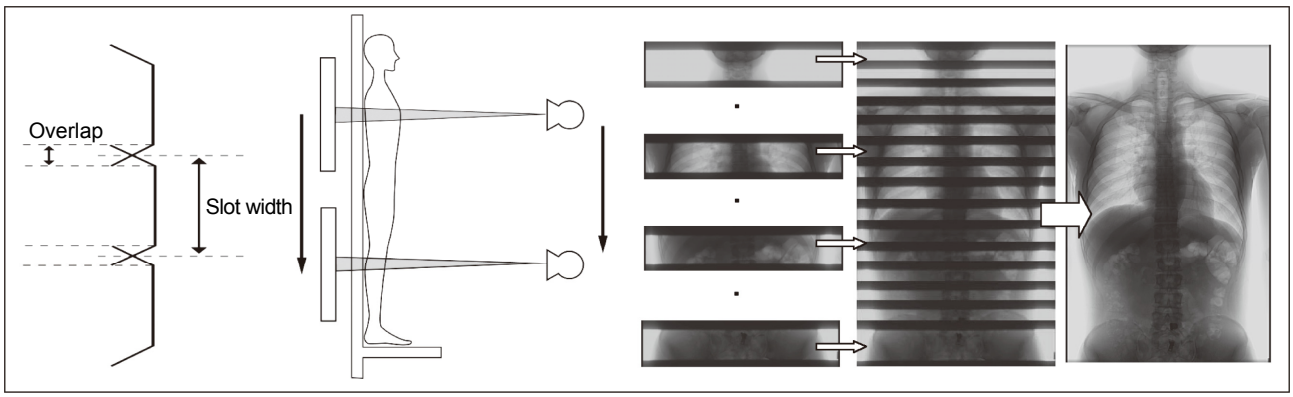

Fig. 2 Principle of Slot Radiography

Features of Slot Radiography.

1) Extremely low image distortion in the S-I direction due to imaging by parallel movements in the S-I direction.
2) Distortion-free enlarged images in the R-L direction can be obtained by designating the height above the tabletop at the target area during image reconstruction.
3) Permits radiography in the standing and supine positions without moving the patient.
4) Greater efficiency than CR long-length imaging, without the need for reading and image synthesis after filling and exposing imaging plates.
5) Approximately one-quarter the multiple X-ray exposure dose of conventional CR long-length imaging.

Two slot radiography modes are available: HS (High Speed) and HQ (High Quality). The difference between these two modes is the slot width (HS mode: 4 cm, HQ mode: 2 cm) and the speed of movement of the imaging chain (HS mode: 15 cm/s, HQ mode: 7.5 cm/s). Select either F (Frontal) with the standard radiography height set to 10 cm or L (Lateral) with the standard radiography height set to 25 cm. F (Frontal) was used for all radiography of the full lower limbs presented in this paper. Three 14" × 14" films were used for conventional CR long-length imaging, permitting approximately 90 cm coverage in the S-I direction. Slot radiography across this range takes approximately 6 sec in HS mode or 12 sec in HQ mode. The frame rate is 3.75 fps for all radiography modes. **Table 1** shows the slot radiography modes and the radiography conditions.

Program name	Function	Imaging chain speed	Slot width
HS F	HS mode, Frontal	15 cm/sec	4 cm @ 10 cm radiography height
HS L	HS mode, Lateral	15 cm/sec	4 cm @ 25 cm radiography height
HQ F	HQ mode, Frontal	7.5 cm/sec	2 cm @ 10 cm radiography height
HQ L	HQ mode, Lateral	7.5 cm/sec	2 cm @ 25 cm radiography height

Table 1 Slot Radiography Modes and Parameters

4. Operating Environment for Slot Radiography

This hospital uses slot radiography for radiography of the full spine or full lower limbs. Recently, full-limb radiography has been conducted frequently. The main purpose of full-limb radiography is to measure the alignment (angle between femur and tibia, etc. [1]) before and after total knee arthroplasty (TKA). Radiography may be conducted in the standing or supine posture, depending on instructions from the orthopedic surgeon.

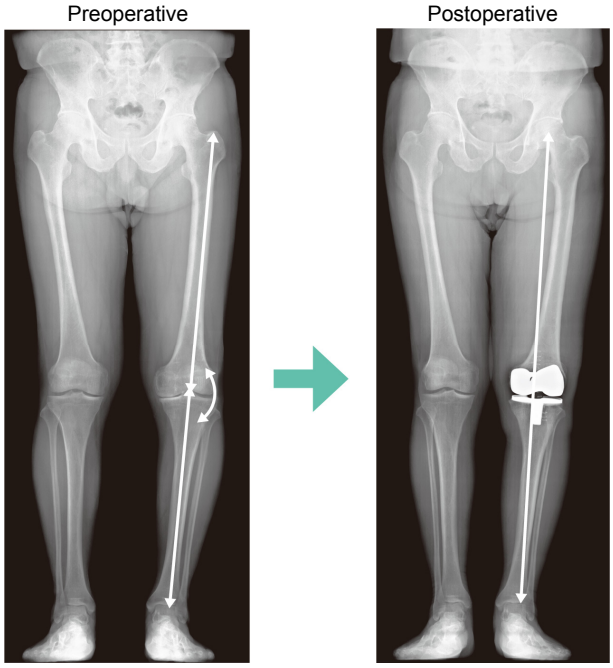

Fig. 3 Measurement of FTA and Functional Axis for Slot Radiography
Preoperative: FTA (Femorotibial Angle) measurement
Postoperative: Confirmation that the functional axis intersects the center of knee prosthesis

Due to the effort required for post-processing with conventional CR long-length imaging, it takes approximately 20 minutes from setup to synthesizing the three images and transfer to PACS, for the standing posture only. However, the SONIALVISION safire II system can complete the imaging in both the standing and supine postures in about five minutes. When we first started using slot radiography, we had to temporarily cancel the slot radiography mode

when switching from the standing to supine position, so that the imaging area had to be set up twice. However, after making a request to Shimadzu, they made software modifications to allow examinations to proceed even quicker.

Before TKA at this hospital, we now more frequently take X-ray images in the Epicondylar View [2] to measure the rotational alignment, in addition to frontal, lateral, and axial patella views of the knee. This radiography method has become widely adopted since it was announced in 2003. It can be added before or after slot radiography using the cubic hard cushions which we prepared by ourselves. At this hospital, we continually strive to use this system to complete the entire series of X-ray examinations before the TKA operation.

Fig. 4 Epicondylar View by SONIALVISION safire II

5. Comparison of Image Distortion in Slot Radiography and CR Long-Length Imaging

Slot radiography is said to produce no image distortion in the S-I direction unlike CR long-length imaging. However, to properly compare these images, we made a punched metal phantom made of aluminum in collaboration with Shimadzu Corporation.

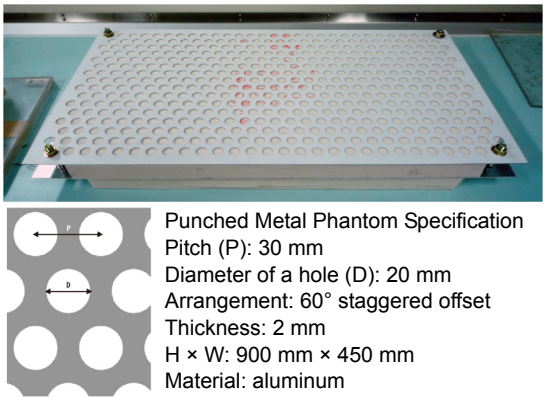

Fig. 5 Photograph of Punched Metal Phantom

The punched metal sheet is 90 cm × 45 cm with many 2 cm-diameter holes punched in a zigzag pattern. The phantom was made by sandwiching a 5 cm-thick piece of low-absorption material between two sheets of punched metal. The principle of measurement of the image distortion is as follows. Incident X-rays perpendicular to the holes in the front surface of the phantom pass through the low-absorption material and then through the holes in the rear punched metal, so that single holes appear in the image. However, when the incident X-rays are oblique to the phantom front surface, shadows of these holes fall on the rear punched metal, such that the holes are separated in the image. **Fig. 6** shows images of this phantom by slot radiography and CR long-length imaging.

Single holes are visible only near the vertical and horizontal center of the CR long-length image; image distortion is apparent concentrically as the distance from the center of the image increases. Consequently, image distortion in a CR long-length image is greatest at the corners. However, with slot radiography, almost no image distortion could be confirmed in the S-I direction and the image distortion in the R-L direction was constant along the S-I axis.

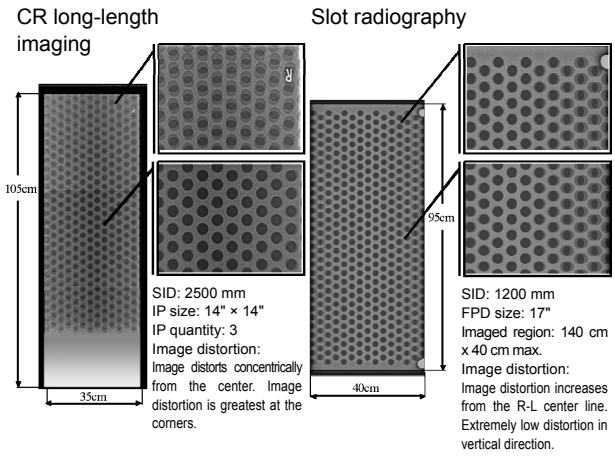

Fig. 6 Comparison Images of Punched Metal Phantom

6. Relationship between Slot Radiography and Digital Filter Conditions and the Image Quality

Initially, after comparing slot radiography images with CR long-length image, orthopedic surgeons requested improvements of the contrast between bone and surrounding soft tissue and between the knee prosthesis and its surroundings after the TKA operation. We investigated the radiography conditions and post-processing conditions to achieve improvements in the HS and HQ modes. The difference between the HQ and HS mode is that the imaging chain speed for radiography in HQ mode is half the speed in the HS mode. This suppresses blurring and reduces the angles of

incidence in the overlapping portions during image reconstruction. It achieves relatively higher image quality, although the imaging time is longer. However, there is no difference in accuracy when slot images are used for FTA measurements. Currently, we use the HQ mode and achieve quite satisfactory images. We believe that applying digital filtering continuously and smoothly from the hip joint to knee joint in images of the full lower limbs could further improve their utility in the future. **Fig. 7** shows sample frontal slot radiography images of the full lower limbs and the radiography conditions.

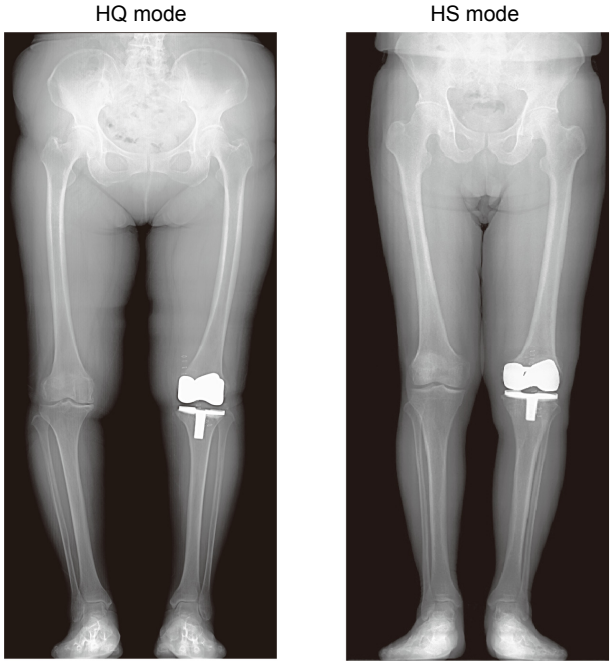

Fig. 7 Frontal Slot Radiography Images of Full Lower Limbs and the Radiography Conditions
HQ mode: 70 kV, 500 mA, 10 ms, 7.5 cm/sec,
imaged length: approx. 90 cm,
imaging time: approx. 12 sec
HS mode: 85 kV, 400 mA, 4 ms, 15 cm/sec,
imaged length: approx. 90 cm,
imaging time: approx. 6 sec

7. Precautions Regarding Slot Radiography

As described above, slot radiography is convenient and easy to operate and can take long-length images in a short time. Entering the height of the target area above the tabletop during image reconstruction produces images with low distortion that permit highly accurate measurements. However, as slot radiography is a new method, some new precautions must be followed. During image reconstruction after slot radiography, a large difference between the height of the target area above the tabletop and the Reference Height reconstruction parameter may result in discontinuous images in the S-I direction or compression or stretching of the image in the R-L direction. The compression or stretching of the image in the R-L direction is the same phenomenon observed in CT scanograms. However, as these phenomena result from the software configuration that links the radiography technology and reconstruction parameters, no major errors are expected if the default settings are used. [3)]

8. Conclusions

We explained how we mainly use the slot radiography function of the SONIALVISION safire II X-ray R/F system for radiography of the full lower limbs and described the knowledge we gained by comparing these images with CR long-length images. Magnification errors are low in principle in the S-I direction and setting the height of the target area for image reconstruction can correct for image stretching in the R-L direction. Consequently, the system can make accurate measurements in the field of orthopedic surgery. The workflow is superior to CR long-length imaging and examinations in both the standing and supine postures can be completed rapidly. The Department of Radiology at this hospital offers 23 diagnostic imaging and treatment systems. These are operated on rotation by 15 radiological technologists, which demands convenient operation and efficient examinations for each modality. Slot radiography is extremely useful from this viewpoint. To further enhance examination efficiency, we strive to use this system for all radiography examinations, including Epicondylar View. Slot radiography is applicable not only to the full lower limbs but is also effective for full spine radiography for the examination of scoliosis. We anticipate that this application will increase in the future.

References:

1) Everything You Need to Know about Total Knee Arthroplasty (TKA) for Safe and Effective Surgery. Edited by Suguro and Inoue, Medical View Co., Ltd. 2007
2) K. Kanekasu et al. Epicondylar View in Total Knee Arthroplasty. Kansetsu Geka (Journal of Joint Surgery) Vol.22, No.8. 2003
3) SONIALVISION safire Series Clinical Manual (Slot Radiography). Medical Systems Division, Shimadzu Corporation. MMLS-0004. Rev.1.0. 2008