R/F

Introduction of R/F SONIALVISION G4: Tomosynthesis Operational Performance and Usage Experience

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1. Introduction

In February 2022, our hospital introduced the SONIALVISION G4 (manufactured by Shimadzu Corporation) in our R/F room. The reasons behind this introduction included the aging of the previously used equipment and a request from orthopedic surgeons to perform Tomosynthesis imaging for follow-up examinations after total hip arthroplasty (THA). After more than a year of consideration, we decided to adopt the SONIALVISION G4. In addition to the standard features, the system's specifications included the Side Station i3 (T-smart compatible image processing workstation), an area dosimeter, an auxiliary tabletop, and other accessories necessary for fluoroscopy examinations. Options such as Tomosynthesis and Slot Advance (long view radiography function) were also added.

2. Operational Methods

In our operations, regular fluoroscopy examinations are scheduled in 30-minute slots. However, Tomosynthesis imaging does not have specific reservation slots and can be ordered at any time. Since Tomosynthesis imaging can be completed in about 5 to 10 minutes once the technique is mastered, it can be performed between regular fluoroscopy examinations. Additionally, when there is a long waiting time for general radiography examinations or when Tomosynthesis and general radiography examinations are ordered together, general radiography examinations for orthopedic orders are also conducted using the SONIALVISION G4. For general radiography examinations performed with the SONIALVISION G4, considering the operational limits and safety of the tube and detector, we limit the procedures to two directions and two body parts in either standing or supine positions. The target regions are restricted to the cervical spine, thoracic spine **(Fig. 1)**, lumbar spine, clavicle, shoulder joint, humerus, pelvis, hip joint, femur, and knee joint. Additionally, in fluoroscopy, it is possible to record fluoroscopic images as DICOM images with up to 1,000 frames per series (approximately 1 minute at 15fps), with no restriction on the number of series. This allows for examinations such as swallowing studies **(Fig. 2)** and dynamic shoulder joint examinations. We utilize pulsed fluoroscopy at 7.5 fps by default. thanks to the motion tracking and noise reduction functionality, which minimize motion lags, and object extraction enhancement that provides highly visible images. Before updating the equipment, we used 15 fps, but the current pulse rate still receives positive feedback from physicians **(Table 1)**.

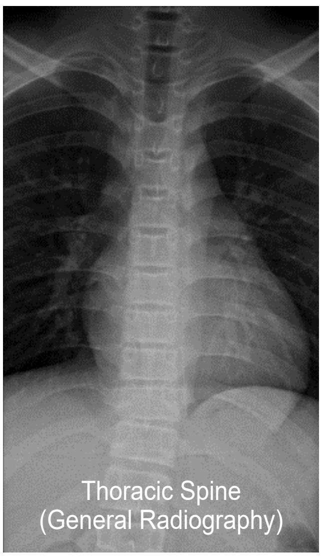

Fig.1

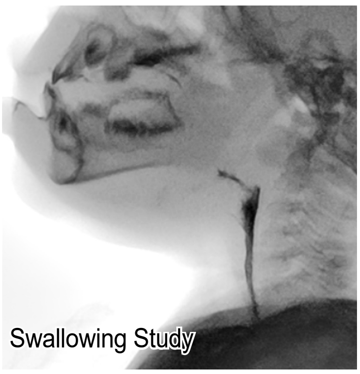

Fig.2

Table 1

General fluoroscopy examinations	7.5fps
Barium enema examinations	3.75fps
Orthopedic fluoroscopy examinations	7.5fps
Pediatric VCU	3.75fps
Tomosynthesis	3.75fps
Swallowing studies and shoulder dynamics	15fps

3. Operational Performance

Of the total 2,929 fluoroscopy and Tomosynthesis examinations performed after the SONIALVISION G4 system was introduced (from April 2022 to October 2023), excluding cases involving radiography, Tomosynthesis imaging was used for 36% of the cases, as shown in **Fig. 3**. Initially, Tomosynthesis imaging was introduced to capture follow-up images after total hip arthroplasty (THA). However, once system operations commenced, there was increasing demand from orthopedic surgeons to capture four regions (4R) including functional assessments of the spine post-surgery. **Fig. 4** breaks down the Tomosynthesis imaging cases, revealing that 71% involved the spine, 18% shoulder joints, and 3% hip joints, with most requests being postoperative cases involving implanted devices. Contrary to expectations, the number of hip joint imaging cases did not significantly increase. On average, approximately 13 Tomosynthesis imaging procedures were performed weekly.

The reasons for preferring Tomosynthesis imaging include:

- Obtaining images with fewer metal artifacts (T-smart: iterative reconstruction)
- Lower radiation dose compared to CT
- Same-day imaging possible without a reservation (imaging can be done anytime the equipment is available)
- Functional imaging, which is difficult with CT, can be easily performed in standing or supine positions with Tomosynthesis
- General radiography examinations can also be performed with the same equipment
- Ability to evaluate subtle changes and fractures

These factors contributed to the increase in the number of examinations.

4. Imaging Range and Limitations of Tomosynthesis Imaging

Due to the limited stroke distance of the X-ray tube, Tomosynthesis imaging cannot be performed at the edge of the examination table. To clarify the imaging range, we have marked the allowable field sizes on the table as shown in **Fig. 5**. For areas that do not fit within the imaging range, an extension tabletop is used in seated or supine positions as depicted in **Fig. 6**. It is also important to note that it is not possible to specify a tomographic center height setting exceeding 25 cm from the tabletop.

5. Clinical Utility of Tomosynthesis Imaging

As previously mentioned, approximately 70% of Tomosynthesis imaging cases at our institution involve spinal examinations, with the most frequent being four-directional spinal imaging that includes functional imaging. The aim of functional imaging is to evaluate bone fusion between vertebrae post-surgery under stress and to check for loosening of pedicle screws. **Fig. 7** demonstrates examples of frontal, lateral, lateral flexion, and lateral extension lumbar spine images in the standing position. They show no loosening, no instability of the fused vertebrae and cage, and bone fusion was deemed successful.

Furthermore, postoperative Tomosynthesis imaging of the lower cervical to upper thoracic spine has

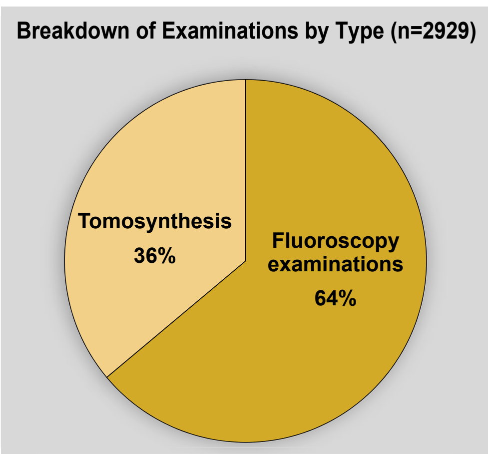

Fig.3

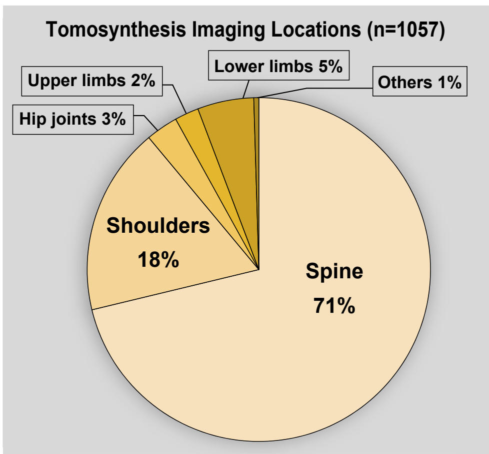

Fig.4

been highly praised by orthopedic surgeons. In general radiography, imaging the lateral view of the lower cervical to upper thoracic spine is particularly challenging due to overlapping shoulders and the increased body thickness. However, Tomosynthesis imaging can produce better images than general radiography by slightly increasing the exposure conditions. **Fig. 8** and **Fig. 9** show examples of good quality Tomosynthesis images of the lower cervical to upper thoracic spine. For some physicians, Tomosynthesis imaging is the first choice for postoperative evaluation of the lower cervical to upper thoracic spine.

6.1 Precautions for Tomosynthesis Imaging: Patient Movement

Tomosynthesis imaging, with a capture time of approximately 5 seconds, is highly susceptible to patient movement. **Fig. 10** shows an example where streak artifacts caused by movement resulted in blurred contours of the observation area, necessitating a repeat examination. The same applies when breath-holding is not possible. If maintaining a stable position is difficult, it is essential to use belts or other methods to stabilize the patient's position.

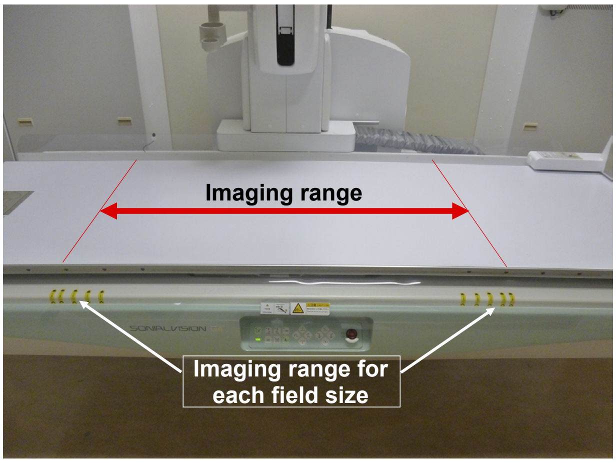

Fig.5

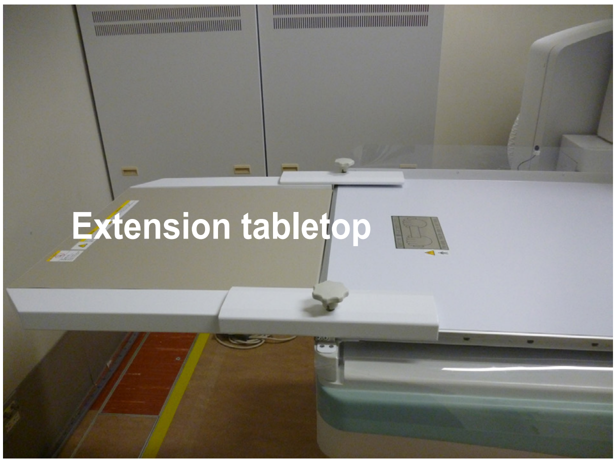

Fig.6

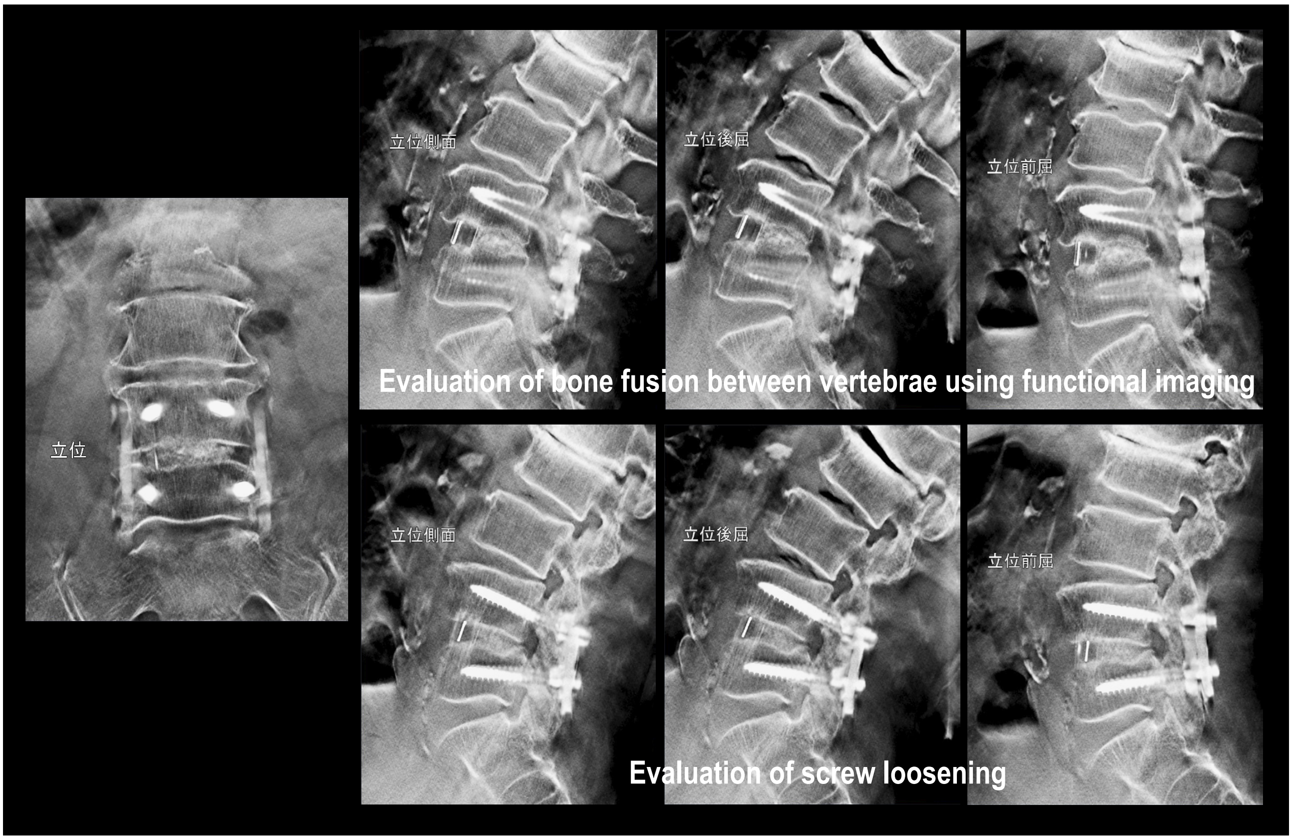

Fig.7

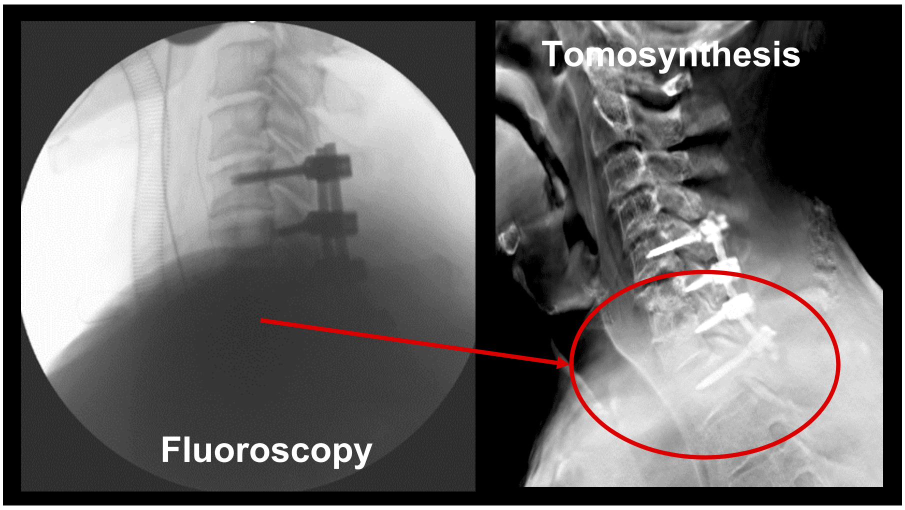

Fig.8

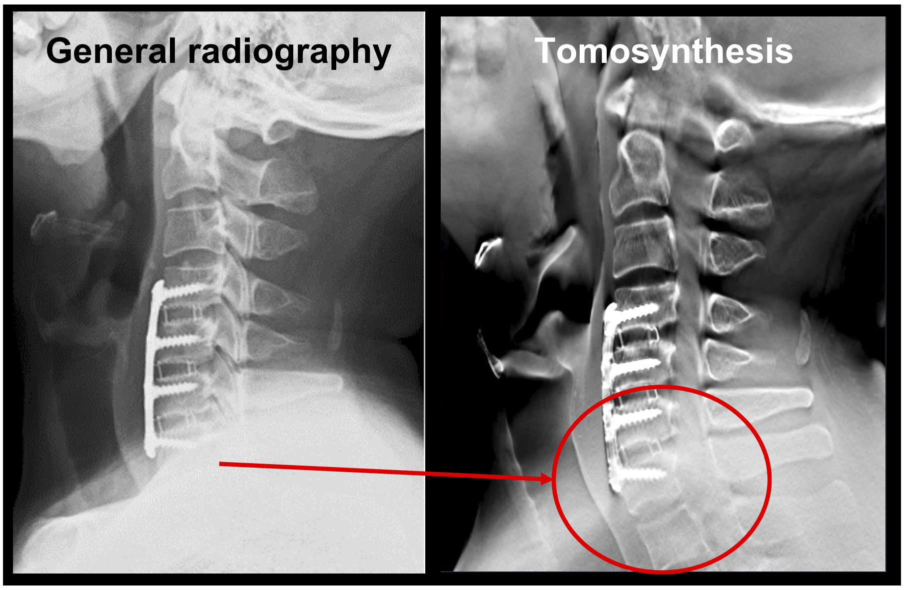

Fig.9

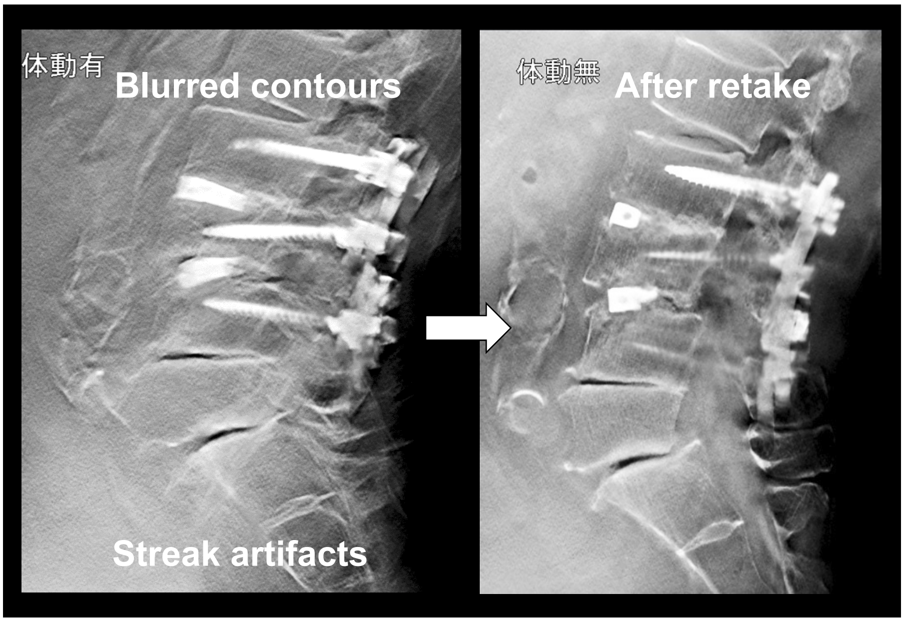

Fig.10

6.2 Precautions for Tomosynthesis Imaging: Types and Sizes of Metal and Collimation Artifacts

In the reconstruction process, the Side Station i3 (T-smart) automatically extracts metals using default metal type and size settings predefined for each procedure. If the actual metal type and size do not match the default settings, artifacts such as trabecular bone defects or undershoot may occur. **Fig. 11** illustrates an example of artifacts caused by differences in metal sizes in the L-SP Lateral (metal type) view. If the selected metal size is smaller than the actual metal, an undershoot appears as a black void, and if the selected metal size is larger than the actual metal, trabecular bone defects occur. These artifacts can interfere with the evaluation of screw loosening and bone fusion, thus requiring careful attention.

Fig. 12 shows examples of artifacts caused by different metal type differences. This comparison of metal (S/M/L) and pin wire types (S/L) show that artifacts appear with any size selection for Metal (S/M/L). However, for the pin wire size setting (S/L), the least artifacts occur when pin wire size setting L is selected, indicating the optimal metal type and size.

When metal artifacts occur, the operator must select the appropriate metal type and size for reconstruction. There is no detailed explanation regarding metal types and sizes, and the optimal selection can only

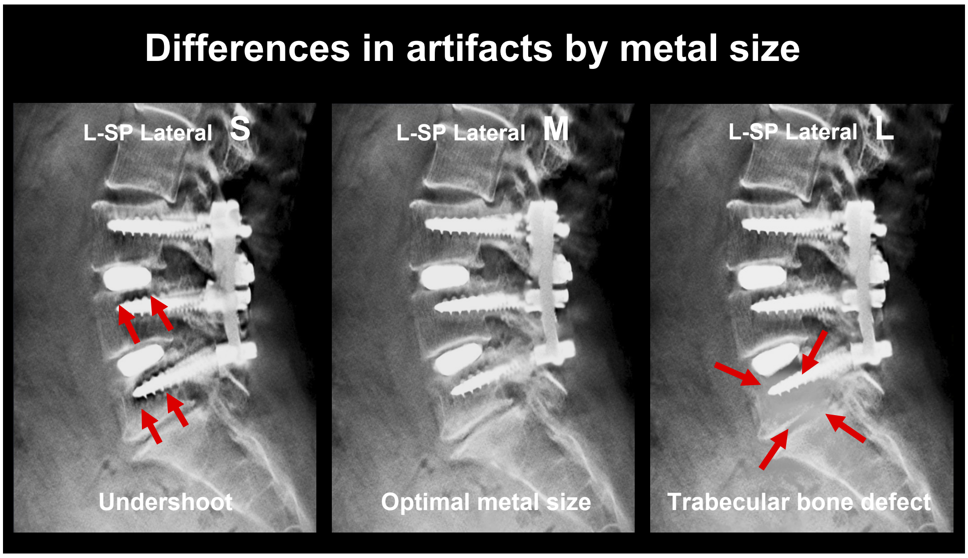

Fig.11

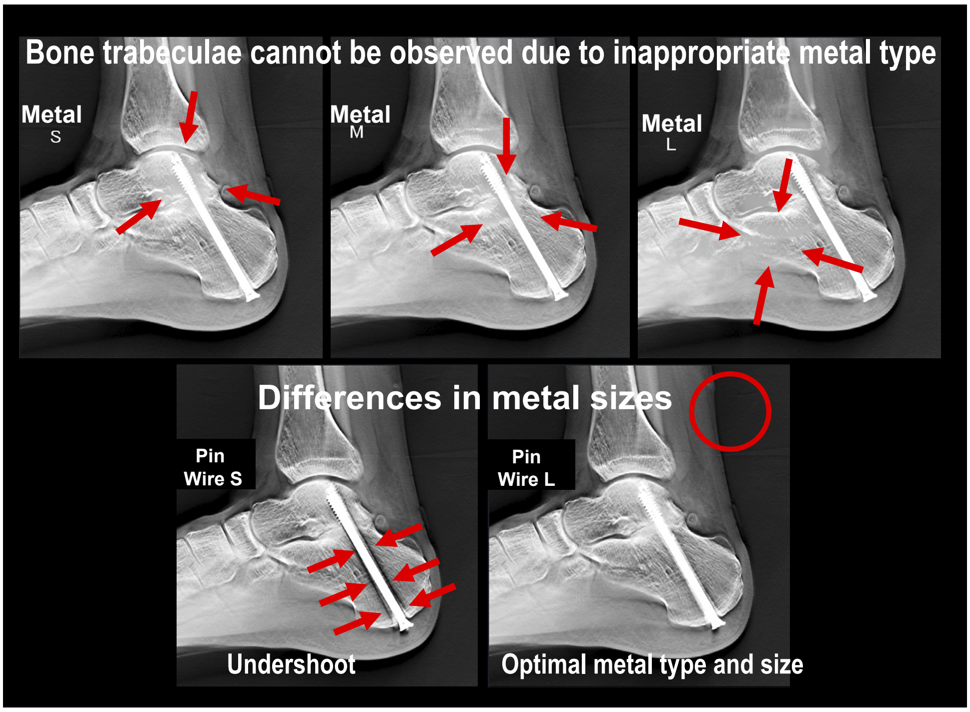

Fig.12

be determined through reconstruction trial and error. Fig. 13 illustrates the actual reconstruction process for metal types and sizes. The selection of processing options for reconstruction is based on reference materials and experience.

Additionally, when collimating the field of exposure during Tomosynthesis imaging, the collimated area may be misidentified as metal during the reconstruction process (T-smart), resulting in artifacts. If artifacts occur due to collimation, instead of reacquiring the image, it should be cropped to exclude the collimated area from the reconstruction region. Fig. 14 shows an example where artifacts appeared due to collimation, which were eliminated after cropping.
Currently, T-smart has evolved into T-smart PRO, which incorporates AI technology. It automatically sets recommended parameters regardless of the type and size of the metal, minimizing artifact occurrence during reconstruction. This advancement simplifies the parameter setting process, reducing the need for the experience and skill traditionally required, thereby improving throughput and significantly reducing the burden on healthcare professionals.

6.3 Precautions for Tomosynthesis Imaging: Imaging Conditions

Fig. 15 illustrates an example where insufficient imaging dose makes it difficult to evaluate bone fusion and implants, highlighting the need to set imaging conditions according to body type. Fig. 16 presents an example of the thoracolumbar junction, where there is a weak representation of the density difference between the lung field and the soft tissue boundary of the abdomen. If the lung field receives an excessive dose, it results in overexposure, that hinders, evaluation. Therefore,optimal imaging parameter settings and breathing methods and frequency processing that are appropriate for the target area are necessary.

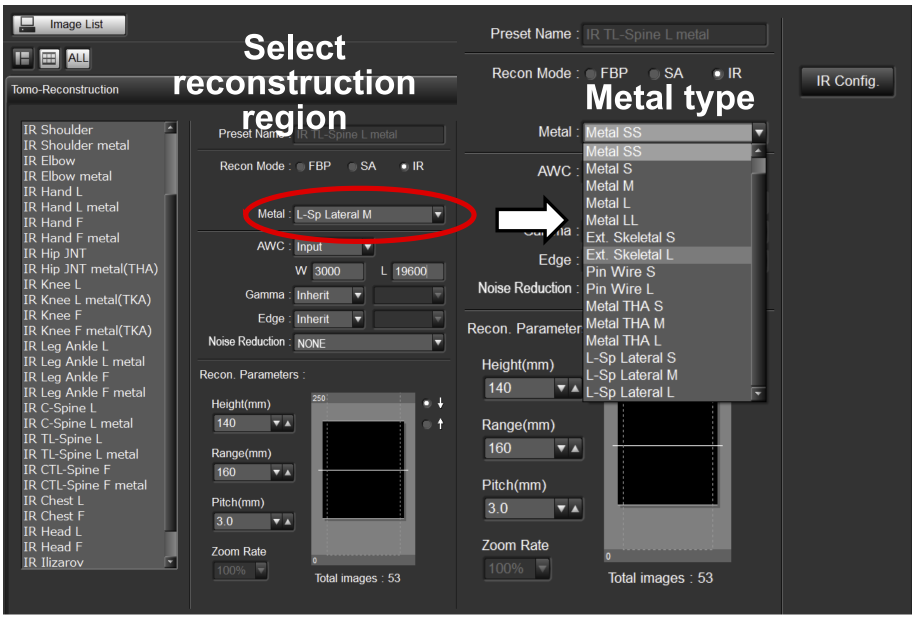

Fig.13

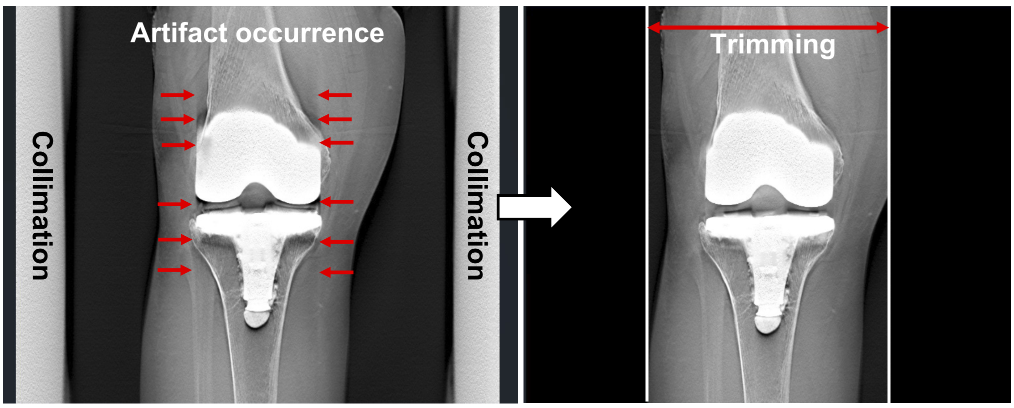

Fig.14

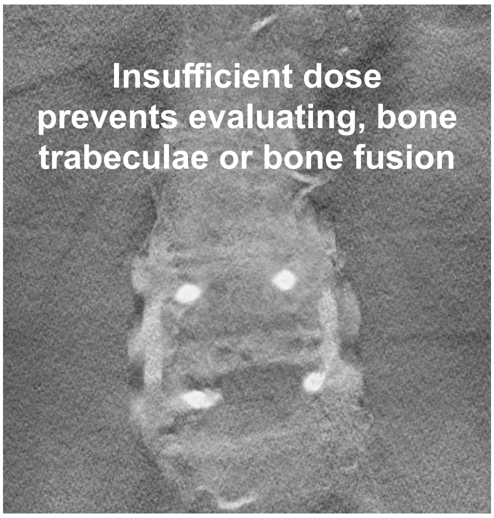

Fig.15

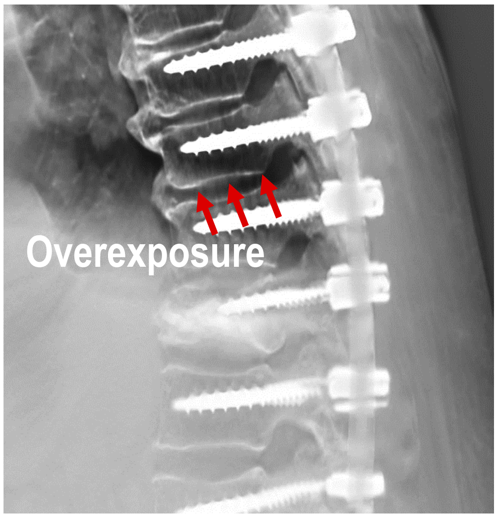

Fig.16

7. Conclusion

The SONIALVISION G4 is a versatile device capable of performing fluoroscopy, Tomosynthesis imaging, fluoroscopic recording, Slot Advance radiography, and general radiography. It offers excellent image quality and performance. Even at reduced pulse rates, fluoroscopy provides clear images with minimal ghosting, effectively reducing exposure levels. Furthermore, Tomosynthesis imaging proves to be a valuable examination method, providing images with minimal implant artifacts.

We look forward to continued advancements in Tomosynthesis image processing from Shimadzu Corporation.