

# Potential of tomosynthesis as a new modality for evaluating and treating painful shoulders



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## 1. Introduction

Due to advances in modalities such as MRI and ultrasound systems, the use of conventional arthrography of the shoulder joint and the subacromial bursae is becoming less common. This is presumably due not only to the relatively low diagnostic accuracy of conventional arthrography but also to its other disadvantages, such as allergic reactions to the use of contrast media and exposure to radiation. However, arthrography is still often used as a diagnostic and treatment procedure in clinical settings because of its strong capability for dynamic evaluation while simultaneously providing pain relief through the use of local anesthesia. The most important advantage of the SONIALVISION safire series is its high-resolution tomosynthesis capability. When used in combination with the T-smart function, which eliminates metal artifacts, the SONIALVISION safire series allows the use of arthrographic examinations to perform higher quality pathological evaluations than were possible previously and is even capable of reducing artifacts caused by contrast media. Tomosynthesis combined with contrast medium enables the visualization of the anatomy and pathology of bone, cartilage, tendons, and synovial tissue simultaneously, which is not possible with MRI and ultrasound systems. Assuming that this would be especially useful for evaluating and treating the shoulder joint, which has a ball-and-socket structure, we started using this modality mainly for patients with painful shoulders in 2013. The following report describes our experience using this system.

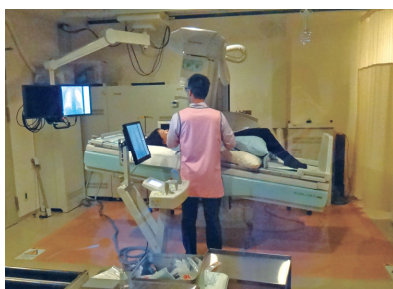


Fig. 1 Basic Limb Positioning in the Supine Position

## 2. Patient selection

In general, good candidates are middle-aged and older patients with painful shoulders due to rotator cuff tendinitis, rotator cuff tears, calcific tendinitis, synovitis, and cuff tear arthropathy. Younger patients (especially in athletes who perform extensive overhead activities) with shoulder pain are also prone to find out, SLAP injuries, pulley lesions, internal and external impingement and so on. Contraindications to the use of this system include renal insufficiency, asthma or contrast media allergies.

Due to adhesions and soft tissue contractures, visualization of the gleno-humeral joint and the subacromial bursa is difficult in patients with severe frozen shoulder or significant diabetic adhesions; however, consistent characteristic imaging findings (narrower gleno-humeral joint space, tightly strained capsule and rotator cuff, flow of contrast medium from the subacromial space to behind the clavicle) are useful for detecting the pathology to support a particular diagnosis, and pain relief can be achieved even in such cases. Therefore, patients with frozen shoulder and adhesive capsulitis are also thought to be candidates for this system. However, we tend not to use the system in cases of shoulder joint instability, dislocation, or fractures because we think that the effectiveness of the contrast media is inadequate due to loose soft tissue that routinely requires excessive use which exaggerates artifacts.

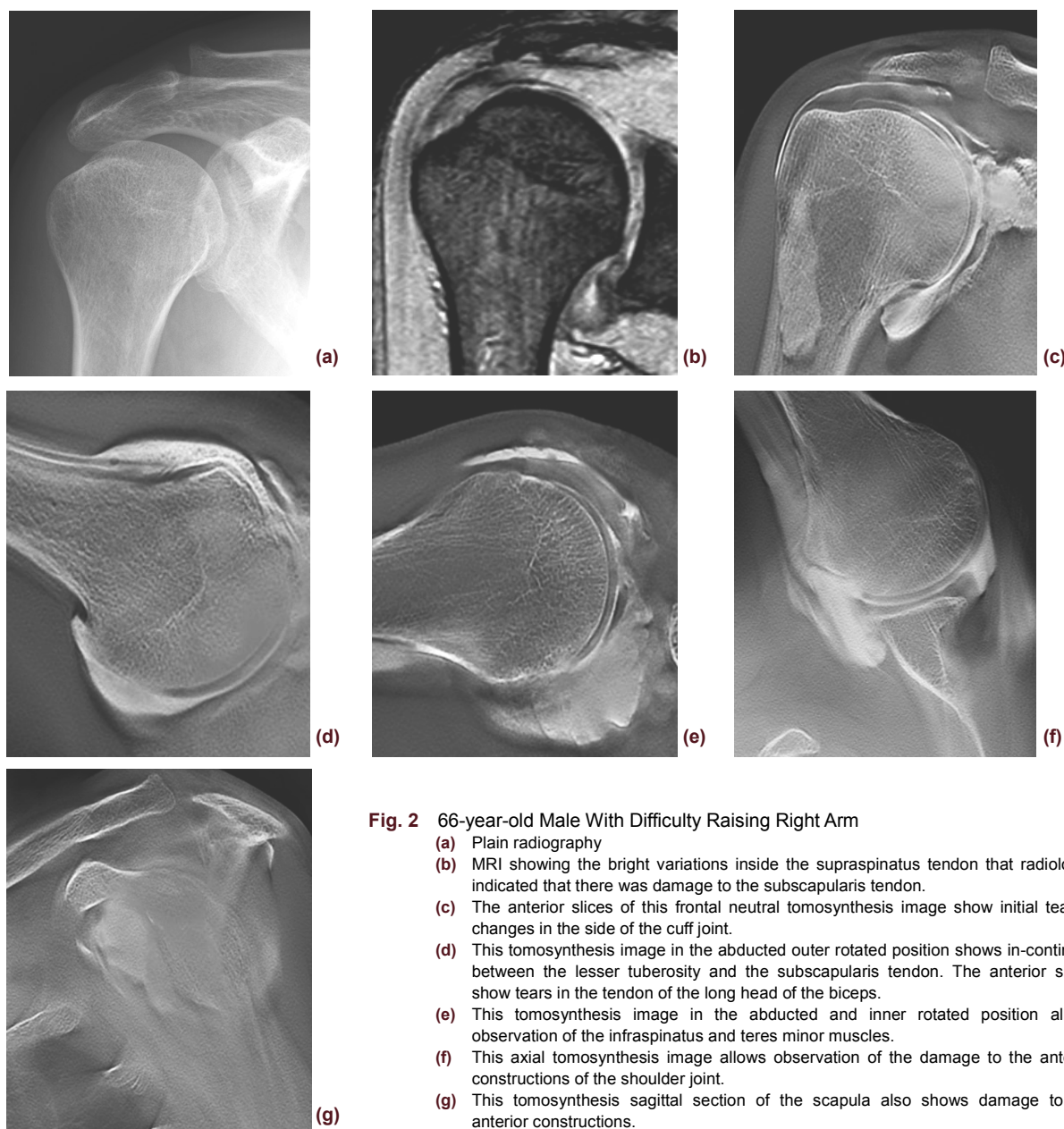
## 3. Posture—Limb Position

The most significant advantage of tomosynthesis is the ability to evaluate cross sections in multiple positions, which is beneficial for physicians. However, the scapula position can vary significantly between individuals and is affected by the positional relationship between the trunk and the upper arms.

Therefore, even if good tomographic images are obtained, it is sometimes difficult to determine the anatomical position to evaluate the images. Consequently, physicians must carefully determine the scapula position during this procedure. First, for basic limb positioning, coronal images in the supine position are used; however, as mentioned, because the scapular axis is not parallel to the table, we insert a mat under the back and hips of the patient and tilt the R/F table slightly so that the patient's head is tilted down toward the table before obtaining the images (**Fig. 1**). Second, attention needs to be paid to the arm position because soft tissues around the humerus move in three dimensions as the axis of the humerus rotates as the humeral head is rotated around its center of the rotation. We think that a slightly externally rotated arm position from a suspended neutral position is appropriate as the basic position. Minor shifts in the angle, especially the rotation

angle of the humerus can be addressed using reconstruction functions in this system. To use the advantage of tomosynthesis, we scan cross sections of the shoulder in neutral, abducted with internal rotation, or abducted with external rotation positions or zero position in the supine position (**Fig. 2**).

Generally, the supraspinatus and infraspinatus tendons can be evaluated based on the coronal images in the supine position, and the long head of the biceps can be evaluated by tracing the groove with the upper arm in the raised (abducted and slightly rotated outward, so called zero) position (**Fig. 3**). Evaluating the subscapularis muscle can be difficult in the supine position, so we obtain images with the patient in the prone position with the affected limb flexed and internally rotated, with the unaffected side resting on a pillow followed by confirming that the scapula is in the axial position using fluoroscopy (**Fig. 4**).



**Fig. 2** 66-year-old Male With Difficulty Raising Right Arm

- (a) Plain radiography
- (b) MRI showing the bright variations inside the supraspinatus tendon that radiologist indicated that there was damage to the subscapularis tendon.
- (c) The anterior slices of this frontal neutral tomosynthesis image show initial tearing changes in the side of the cuff joint.
- (d) This tomosynthesis image in the abducted outer rotated position shows in-continuity between the lesser tuberosity and the subscapularis tendon. The anterior slices show tears in the tendon of the long head of the biceps.
- (e) This tomosynthesis image in the abducted and inner rotated position allows observation of the infraspinatus and teres minor muscles.
- (f) This axial tomosynthesis image allows observation of the damage to the anterior constructions of the shoulder joint.
- (g) This tomosynthesis sagittal section of the scapula also shows damage to the anterior constructions.



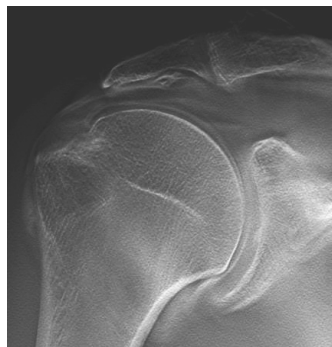
**Fig. 3** Coronal Image of 72-year-old Male with a full thickness tear of the supraspinatus tendon. Tomosynthesis was performed after confirming lesser tuberosity in the abducted externally rotated position. It shows compensatory hypertrophy of the LHB and tear was not demonstrated in all slices.



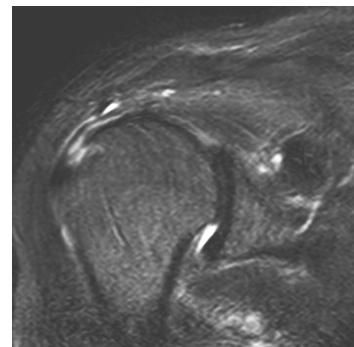
**Fig. 4** 70-year-old Male with Frozen Shoulder  
Tomosynthesis was performed with the patient positioned prone on the R/F table in a lateral decubitus position with affected side on the table and the affected limb was flexed and rotated inward, so that the scapula was set in an axial position for fluoroscopy and the lesser tuberosity was visualised anterior. The figure shows osteophytes on the tuberosity and tension on the anterior constructions, but it does not show any tearing of the subscapularis tendon. Due to the contracture, flexion range of the humerus is restricted.



(a)



(b)



(c)

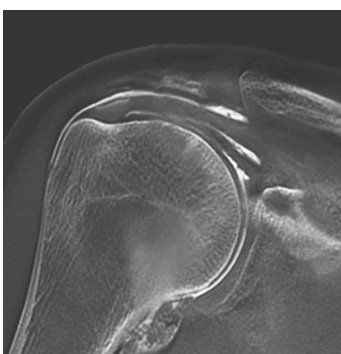
**Fig. 5** 74-year-old Male with Right Shoulder Joint Pain  
(a) Tomosynthesis image immediately after injecting contrast medium in neutral position.  
(b) Tomosynthesis image of the same limb position before completion of the examination. The outflow of contrast medium to the articular side of supraspinatus tendon indicates the partial tear.  
(c) MRI (eSTIR longTE) image that matches the tear observed on the articular side.

#### 4. Procedure

Before the examination, a 10-mL syringe, 23-gauge Cathelin needle, a local anesthetic (1 % Xylocaine), and contrast medium (Urografin) were prepared. The contrast medium was inserted in two steps: into the gleno-humeral joint in the first step and into the subacromial bursa as the second step. In each step, we performed an induced pain test to evaluate pain relief and measure the range of motion. If the contrast medium flows into the subacromial bursa after injection into the gleno-humeral joint (in cases of full thickness tears), we do not perform the second injection. We normally use a 1:1 ratio of contrast medium to xylocaine. The quantity of the contrast medium varies depending on the intra-articular pressure of the gleno-humeral joint; typically, we

use approximately 8 mL for males and 6 mL for females into the gleno-humeral joint, and approximately 4 mL for males and 3 mL for females into the subacromial bursa.

In cases of frozen shoulders, the amount of the contrast medium is decreased because of elevated intra-capsular pressure of the gleno-humeral joint. The contrast medium can be injected without significant resistance in patients with supple soft tissues, but injecting an over dose can cause prominent overshooting (artifacts) in the tomosynthesis images, even if a thin slice thickness is specified. Therefore, we only use a maximum of 4 mL of contrast medium. We do not pump or inject air for double-contrast purposes because they can reduce image quality or increase the risk of air emboli. Care should be taken not to inject even



(a)



(b)

**Fig. 6** 49-year-old female after 3 months of right shoulder joint pain caused by a partial tear in the articular side with an findings of MRI. However, tomosynthesis (a) showed small amount of pooling in the bursal side of supraspinatus and around the bicep tendon at the articular side.

small amounts of air bubbles, which was visualized acutely as low-density areas in multiple tomosynthesis slices. If we perform multislice scanning immediately after the injection, infiltration of the contrast medium is not sufficient for properly visualizing the detailed damage or the cuff profile. Then, we obtain tomosynthesis images just before finishing the examination after assessing the pain level and the final range of motion in each position.

### 5. Results of the use of tomosynthesis

The use of tomosynthesis for patients with painful shoulders has increased in our hospital. In contrast, the use of MRI of the shoulder joint has been decreasing due to physician preference. This trend has presumably decreased the number of hospital visits and medical expenses. However, for patients with planned surgery or whose pain level does not improve within two months of starting rehabilitation, we perform MRI examinations to rule out other lesions that may not have been detected with tomosynthesis.

To assess the diagnostic accuracy, we compared the use of tomosynthesis versus MRI for the treatment of 30 shoulder joints (M20 and F10) that are suitable for comparison; these cases involved 27 patients, with an average age of 64.6 (16 to 81), who were treated at our hospital between June and October 2013. The examination accuracy was investigated by using an MRI diagnosis as the control and endoscopic observation as the control for the 12 cases that received endoscopic treatment. The results indicated that the accuracy of the use of tomosynthesis to diagnose a full thickness tear was equivalent to that of the MRI control: 87 % for arthrography (86 % sensitivity and 89 % specificity) and 83 % for tomosynthesis (86 % sensitivity and 78 % specificity). For partial tears, the accuracy was 61 % for arthrography (59 % sensitivity and 100 % specificity) and 78 % for tomosynthesis (77 % sensitivity and 100 % specificity), which confirmed that tomosynthesis is useful for evaluating partial tears that are difficult to diagnose. In the cases with endoscopy control, the accuracy was 78 % for arthrography and 92 % for tomosynthesis. To determine the validity of the use of tomosynthesis imaging, five tear classifications (normal, partial tear, and small, medium, and large full tears) were used and evaluated twice by two evaluators. The resulting intra- and inter-rater reliability was  $\kappa = 0.70$  ( $p < 0.05$ ) and  $\kappa = 0.58$  ( $p < 0.05$ ). We think that the differences between the evaluators may be caused by translation of irregularities in the synovial membrane and the surface of the rotator cuff or by differences in the

evaluators' judgment of the initial lesions, such as the minimum articular side tear, that arise from differences in their level of experience in interpreting the images and in their anatomical understanding of the shoulder (Fig. 6).

The approximate total X-ray exposure dose was estimated based on the exposure time by placing a probe with 12-inch SID on a phantom shoulder surface and measuring the fluoroscopy incident surface exposure dose. The exposure dose is 2.3 mGy for the average fluoroscopy time of 98 seconds, 0.9 mGy for the average 6.2 spot radiography exposures, and 1.2 mGy for 2.8 tomosynthesis exposures. The use of tomosynthesis does not significantly increase the radiation exposure levels. We think that the appropriate use of tomosynthesis may be able to reduce the fluoroscopy time, which effectively reduces the total exposure to radiation. Considering the server capacity and cost, tomosynthesis should most likely be limited to 2 or 3 exposures for each examination.

### 6. Summary

#### • Advantages

1. By creating multi-slice high-resolution images from conventional contrast radiography examinations of the shoulder, available information was dramatically increased.
2. Using T-smart to reduce contrast media artifacts was beneficial for evaluating the shoulder joint.
3. Compared with ultrasound images, a broader area can be observed with tomosynthesis, while simultaneously evaluating bone properties. Compared with MRI, limb positioning is more flexible with tomosynthesis. The use of tomosynthesis in combination with existing modalities improves the diagnostic accuracy of shoulder joint disorders and injuries.

#### • Challenges

1. Due to the complicated anatomy and the three dimensional movement, an examiner needs to be careful with body and limb positioning when acquiring images. Therefore, physicians have to perform the examinations by themselves and become familiar with interpreting the images.
2. Tomosynthesis will be even more useful if it can be applied to reference images, 3D, VR, MPR, and other technologies.

Future studies should compare tomosynthesis to endoscopic imaging to verify the diagnostic accuracy with respect to various limb positions and anatomical locations as the number of case studies increases.