

# The Utility of Tomosynthesis in Emergency Examinations



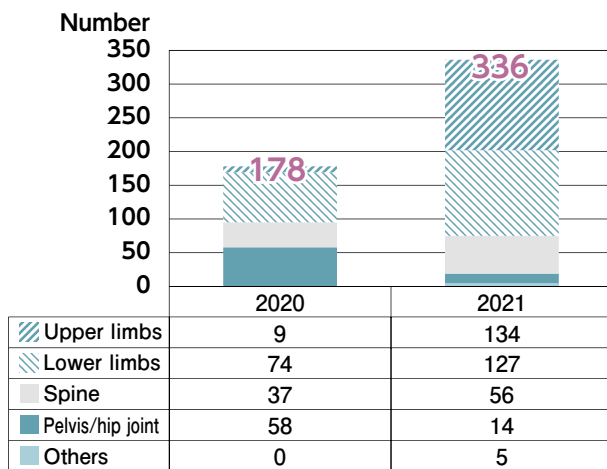
Hidehiko Fukuoka, R. T.

Radiology Department, KARIYA TOYOTA General Hospital  
**Hidehiko Fukuoka**

## 1. Hospital Introduction

Our hospital is located in Kariya City, Aichi Prefecture, and is a private medical institution operated by the Toyota Medical Corporation (comprising Kariya City, Takahama City, and eight Toyota Group companies). The hospital serves approximately 700,000 people within a 10km radius and has 704 beds. It is a certified emergency medical center, operating 24/7, 365 days a year, under the slogan "Emergency care for all." In March 2020, as part of our equipment

modernization due to aging equipment, we introduced the RADspeed Pro EDGE package in the outpatient examination room area adjacent to the emergency outpatient department. Utilizing the features of the RADspeed Pro EDGE package, a general radiography system, we also perform Tomosynthesis in the same workflow as general radiography. In the fiscal year 2020, we conducted 178 Tomosynthesis examinations, mainly in orthopedics, and 336 in 2021 (**Fig.1**).

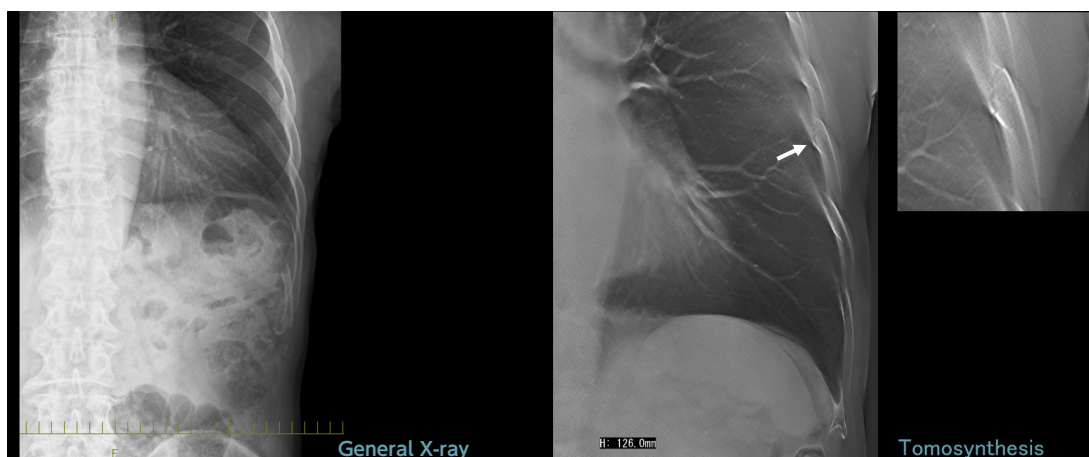


**Fig.1** Number of Tomosynthesis Examinations at Our Hospital

## 2. Tomosynthesis Applications in Emergency Cases

### 2.1 Rib Fracture (Fig.2)

A male in his 70s fell off his bicycle after colliding with a car, experiencing pain in his left chest that worsened with deep breaths. He visited our emergency outpatient department at night and underwent a general X-ray examination. No clear bone injury was diagnosed, and he was sent home. The next morning, he visited our orthopedics department and underwent chest tomosynthesis, which revealed a fracture line in the left 7th rib, leading to a diagnosis of rib fracture.



**Fig.2** Rib Fracture

Rib fractures are often missed in general X-rays. In a study by our radiological technologists, rib fractures accounted for 35% of all missed bone injuries. In cases like this, where general X-rays show no clear bone injury but a fracture cannot be ruled out, tomosynthesis proves to be useful.

### 2.2 Multiple Rib Fractures, Scapular Fracture (Fig.3)

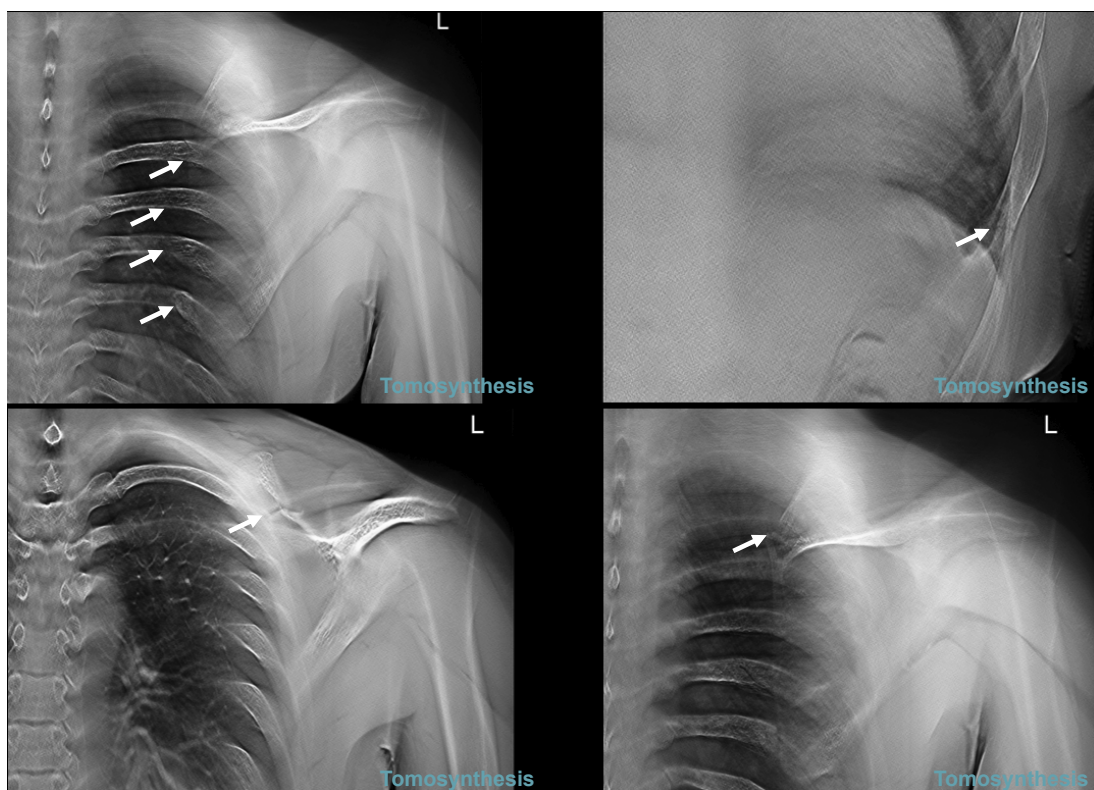
A man in his 30s fell off his bicycle, injuring his left back. He could not raise his left arm after the injury and visited our emergency outpatient department at night. No clear bone injuries were found in the general X-rays of the scapula, shoulder joint, and clavicle. An ultrasound suggested a possible fracture in the left rib back area but was deemed non-urgent. The next day, he was referred to orthopedics. Since the general X-ray from the previous day did not clearly show rib fractures, chest tomosynthesis was performed, revealing fractures in the 5th, 6th, 7th, and 8th ribs on the back side, with two fracture points on the 7th rib. The scapular fracture, missed in the previous day's general X-ray, was also identified via tomosynthesis.

In trauma cases involving the thorax or shoulder girdle, injuries from both direct and indirect forces can occur, requiring broad field of view imaging. Tomosynthesis, which allows evaluation of a wide

area in a single shot, is useful in such cases, especially for identifying severe conditions like flail chest (two or more consecutive rib fractures at two or more sites).

### 3. Preliminary Study on Tomosynthesis for Foreign Body Ingestion

Foreign body ingestion is a condition often encountered in emergency departments. Delayed diagnosis can lead to serious complications, requiring prompt and accurate diagnosis and treatment. This condition is not limited to children; adults also commonly ingest objects such as Press Through Packages (PTP), a common form of packaging for tablets, or fish bones. Generally, gastrointestinal foreign bodies that have fallen into the stomach are believed to be excreted through the anus without causing complications like gastrointestinal perforation. However, there have been cases where ingestion of sharp objects like PTP sheets or fish bones went unnoticed, leading to gastrointestinal perforation diagnosed via X-ray CT. In this context, we conducted a basic study to explore the feasibility of using tomosynthesis for the localization of ingested foreign bodies, comparing it with general X-ray images.



**Fig.3** Multiple Rib Fractures, Scapular Fracture

## 3.1 Method

### 3.1.1 Phantom Creation

To assess the detection capability of foreign bodies in general X-rays and tomosynthesis, a phantom for visual assessment was created. A uniform phantom was made using agar powder, and foreign bodies were inserted into it. The materials of the inserted foreign bodies in the agar phantom included three types of PTP sheets: polyvinyl chloride (PVC), cyclic olefin copolymer (COC), and polypropylene (PP). There were a total of six types, including those with and without enclosed tablets. Additionally, fish bones with thicknesses of  $\phi 1\text{mm}$  and  $3\text{mm}$ , a cigarette, a plastic toy, and a 1 yen coin were included (Fig. 4)."

### 3.1.2 Phantom Imaging

The agar phantom created in the previous step was imaged using both general X-rays and tomosynthesis. Additionally, the same foreign bodies were inserted into a chest phantom (manufactured by Kyoto Kagaku) for imaging. The locations of the foreign bodies were set at the lower esophageal level of the anterior part of the thoracic vertebrae and the abdominal region, as shown in Fig.5. The chest phantom was imaged in both the frontal and right anterior oblique positions. The exposure conditions



Fig.4 Agar Phantom and Layout of Foreign Bodies

are shown in Fig.6, using the default settings of our hospital.

### 3.1.3 Visual Assessment

The images obtained from the agar and chest phantoms were visually assessed by two radiological technologists with 15 and 2 years of experience. The assessment was based on a three-point scale: "○" for clearly indicating the foreign body, "△" for barely indicating the foreign body, and "×" for not indicating the foreign body. The assessment was performed using a high-resolution monitor with 1M pixel resolution, and window operations were conducted as deemed necessary by the observers.

## 3.2 Results

### 3.2.1 Visual Evaluation of Agar Phantom

The visual assessment results of the agar phantom are shown in Table 1 and Fig.7. For PTP sheets with tablets, all materials were clearly indicated in both general X-ray and tomosynthesis images. For PTP sheets without tablets, PVC was barely indicated in general X-rays but was clearly visible in tomosynthesis. Other materials were not indicated in either imaging type. The 3mm fish bone was clearly visible in both imaging types, but the 1mm bone was only visible in tomosynthesis. The

General X-ray Examination  
80kV, 2.6mAs, Additional filter: 0.2mmCu  
(Displayed Dose: 0.026mGy)

Tomosynthesis  
80kV, 2.0mAs, Swing angle: 40°, Additional filter: 0.3mmCu  
(Displayed Dose:  $0.014\text{mGy} \times 60 = 0.84\text{mGy}$ )  
Image reconstruction: Iterative reconstruction method

Fig.6 Exposure Conditions and Image Reconstruction Conditions

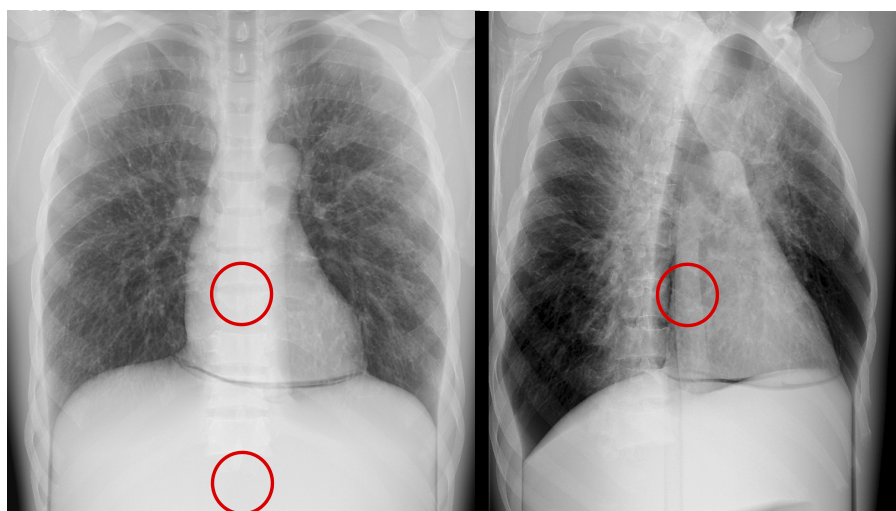


Fig.5 Location of Foreign Bodies in the Chest Phantom

cigarette and the 1 yen coin were clearly visible in both, and the plastic toy, barely visible in general X-rays, was clearly visible in tomosynthesis.

### 3.2.2 Visual Evaluation of Chest Phantom

The visual assessment results of the chest phantom are shown in **Table 2** and **Figs. 8, 9, 10**. PTP sheets with tablets were barely indicated in general X-ray images for all materials, but were clearly indicated in tomosynthesis images. PVC PTP sheets without tablets could not be indicated in the frontal tomosynthesis images overlapping with the vertebral body, but could be indicated in the

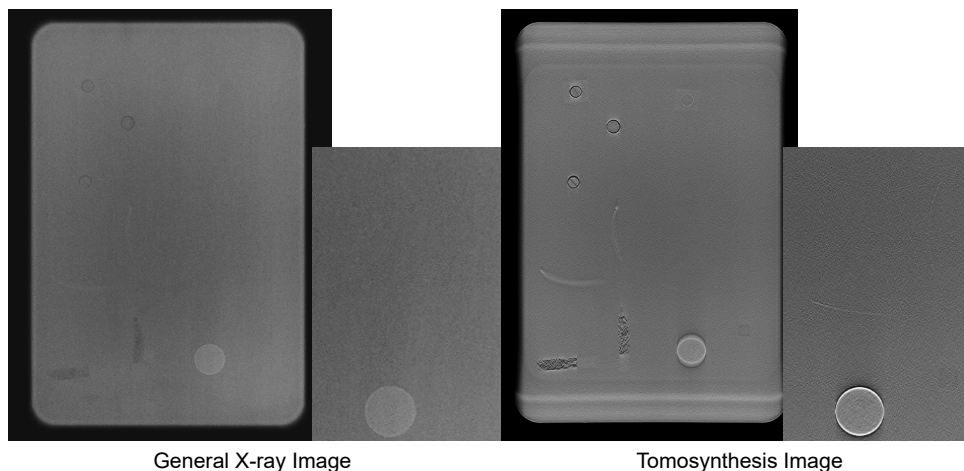
right anterior oblique and abdominal positions. COC and PP PTP sheets could not be indicated in either imaging type.

In the case of fish bones, none were indicated in general X-ray images, but the 3mm fish bones were clearly indicated in all tomosynthesis images. The 1mm fish bone could be clearly indicated in the right anterior oblique position in tomosynthesis images, but not in the abdominal region.

The cigarette was not indicated in general X-ray images, but could be barely indicated in tomosynthesis images. The plastic toy and 1 yen coin were barely indicated in general X-ray images, but were clearly indicated in tomosynthesis images. The visual assessment of the chest phantom also demonstrated that tomosynthesis was superior to general X-ray examinations in detecting foreign bodies.

**Table 1** Visual Evaluation Results of Agar Phantom

Agar Phantom	General X-ray	Tomosynthesis
PVC (With tablet)	○	○
COC (With tablet)	○	○
PP (With tablet)	○	○
PVC (Without tablet)	△	○
COC (Without tablet)	×	×
PP (Without tablet)	×	×
Fish Bone (φ 3mm)	○	○
Fish Bone (φ 1mm)	×	○
Cigarette	○	○
Plastic Toy	△	○
1 Yen Coin	○	○

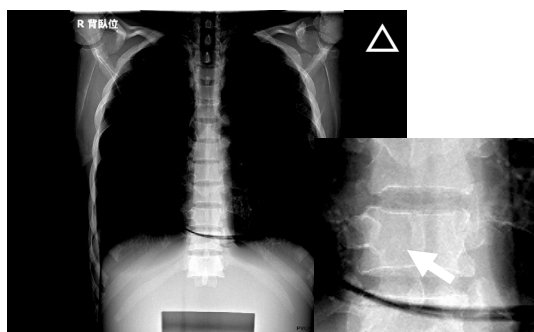


**Fig.7** Images of Agar Phantom

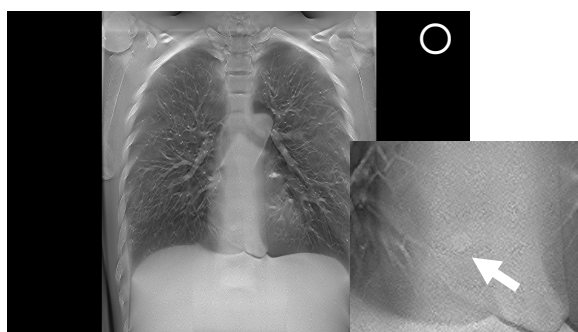
**Table 2** Visual Evaluation Results of Chest Phantom

Agar Phantom Positioning	General X-ray			Tomosynthesis		
	AP	LPO	Abdominal region	AP	LPO	Abdominal region
PVC (With tablet)	△	△	△	○	○	○
COC (With tablet)	△	△	△	○	○	○
PP (With tablet)	△	△	△	○	○	○
PVC (Without tablet)	×	×	×	×	○	△
COC (Without tablet)	×	×	×	×	×	×
PP (Without tablet)	×	×	×	×	×	×
Fish Bone (φ 3mm)	×	×	×	○	○	○
Fish Bone (φ 1mm)	×	×	×	×	○	×
Cigarette	×	×	×	△	△	△
Plastic Toy	△	△	△	○	○	○
1 Yen Coin	△	△	△	○	○	○

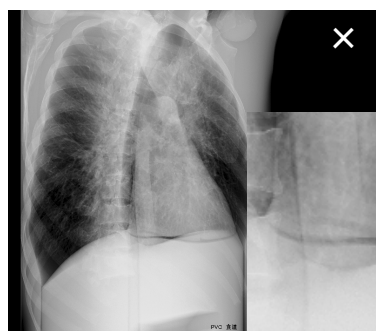




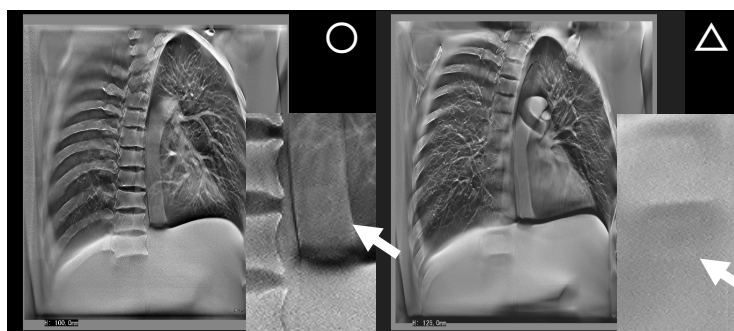
General X-ray Image PVC (With tablet)



Tomosynthesis Image PVC (With tablet)

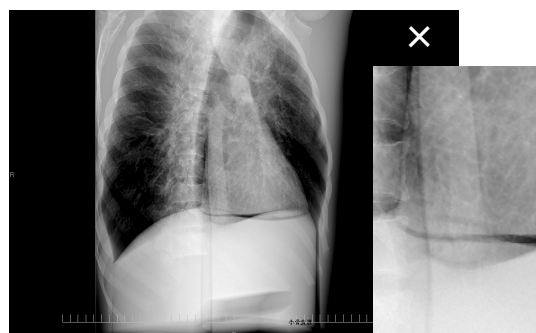


General X-ray Image PVC (Without tablet)

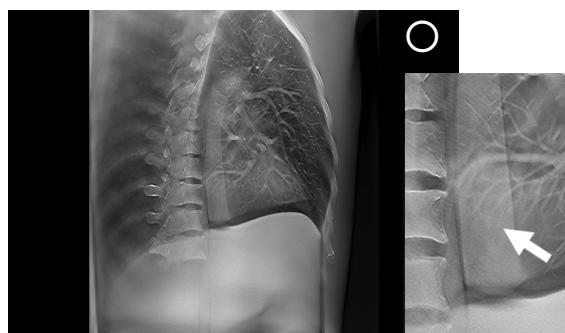


Tomosynthesis Image PVC (Without tablet)

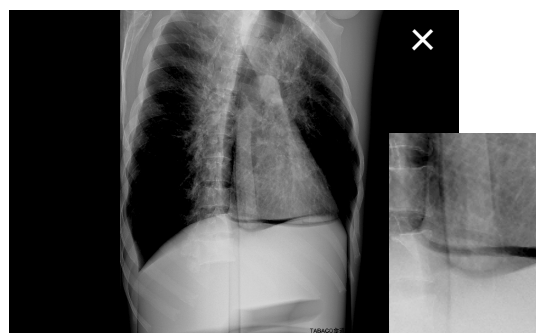
**Fig.8** Images of Chest Phantom (PTP Sheets)



General X-ray Image Fish Bone (φ 1mm)



Tomosynthesis Image Fish Bone (φ 1mm)

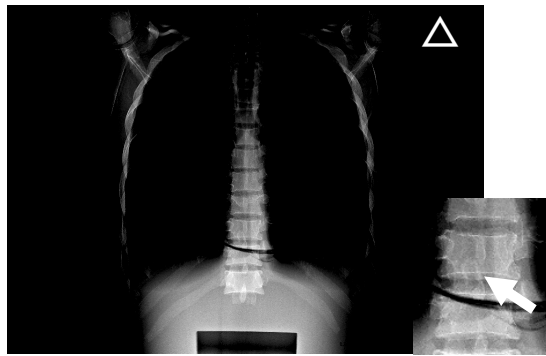


General X-ray Image Cigarette

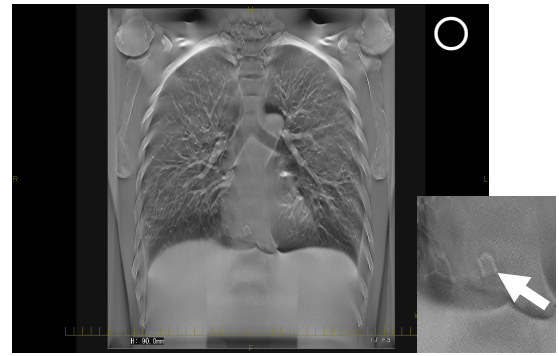


Tomosynthesis Image Cigarette

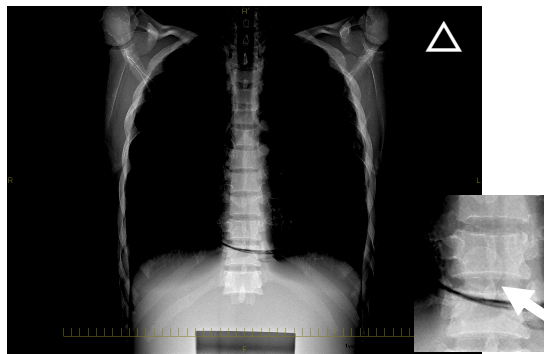
**Fig.9** Images of Chest Phantom (Fish Bone, Cigarette)



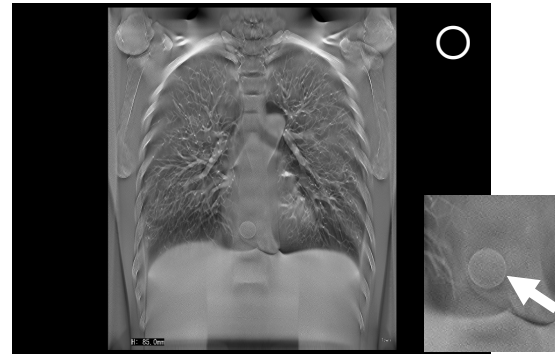
General X-ray Image Plastic Toy



Tomosynthesis Image Plastic Toy



General X-ray Image 1 Yen Coin



Tomosynthesis Image 1 Yen Coin

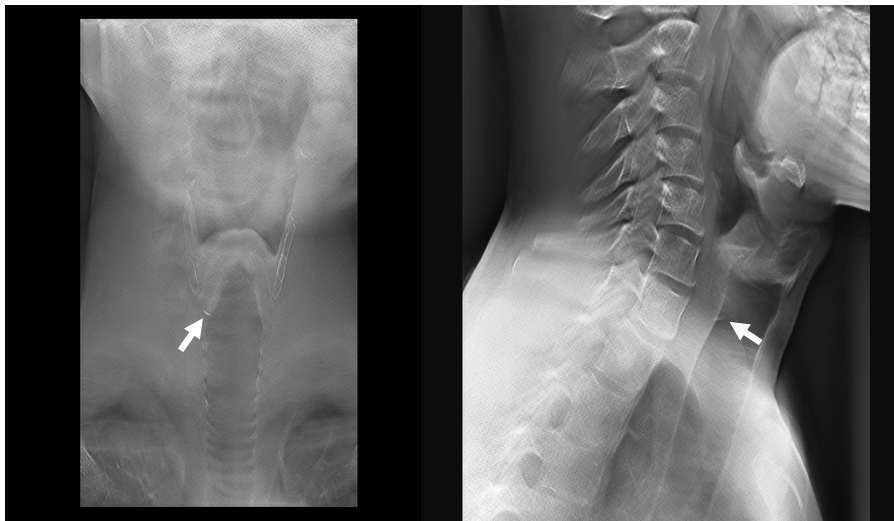
**Fig.10** Images of Chest Phantom (Plastic Toy, 1 Yen Coin)

### 3.3 Discussion

Tomosynthesis, with its multiple projection data, appears to have superior foreign body detection capabilities compared to general X-rays. While some objects were barely indicated in general X-rays, these required significant window condition adjustments and were easily missed. On the other hand, tomosynthesis clearly indicated these objects. However, PTP sheets made of COC and PP without tablets and 1mm fish bones in the abdominal region were not indicated in tomosynthesis. Thus, tomosynthesis for localizing ingested foreign bodies should be used when the episode of ingestion and symptoms are clear. Additionally, right anterior oblique imaging is useful for the thoracic esophageal region, where frontal imaging may be obscured by the vertebral body.

The exposure conditions were not examined in this study. It is believed that the detection ability of foreign objects with low X-ray absorption may be improved by using low tube voltage or energy subtraction. We would like to consider this as a future study topic along with radiation dose.

In some reported cases from other facilities, PTP sheets that could not be identified with general X-rays were successfully diagnosed using tomosynthesis, enabling early pre-endoscopic diagnosis (2). The utility of tomosynthesis, which can be performed at lower exposure and lower cost than CT, is considered to be highly useful. However, in pediatric cases with a high incidence of foreign body ingestion, motion artifacts are likely to have a significant effect on tomosynthesis with long imaging time, and it is feared that accurate diagnosis may not be achieved. Additionally, attention is needed in the cervical region, as shown in **Fig. 11**, for differentiation from the trachea. In this case, the patient experienced discomfort in the neck after eating chicken, and the bone ingestion was suspected. The trachea, which overlaps the esophagus, contains structures with relatively high x-ray absorption, such as tracheal cartilage and cricoid cartilage, and it is important to observe them while paying attention to anterior-posterior slice images and anatomic positioning to avoid misidentifying them as foreign bodies.



**Fig.11** Tomosynthesis Image of the Cervical Region (Arrow indicates the tracheal cartilage)

### 4. Conclusion

In the field of emergency medicine, we have introduced the utilization of tomosynthesis based on our experience in its use and the basic study on localization diagnosis of foreign bodies. By implementing the RADspeed Pro EDGE package in the general radiography room adjacent to the emergency outpatient area, we can seamlessly conduct examinations, which we believe is particularly useful for searching bone injuries in trauma cases

and detecting foreign bodies in cases of ingestion with clear episodes and symptoms. We aim to continue further studies and effectively utilize tomosynthesis to contribute to emergency medical care.

### References

- 1) Hiroshi Niitani, Toshiichiro Kuchi: Three cases where CT was useful for diagnosing ingested PTP, *Journal of Clinical Emergency Medicine*, 13: 664-667, 2010
- 2) Masaru Sasaki et al.: Two cases where pre-endoscopic diagnosis of ingested PTP sheet was made possible by tomosynthesis, 353rd meeting of the Japanese Society of Gastroenterology Kanto branch, 2019