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FULL PAPER

Evaluation of a new system for chest tomosynthesis: aspects of image quality of different protocols determined using an anthropomorphic phantom

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Objective: To compare the image quality obtained with the different protocols in a new chest digital tomosynthesis (DTS) system.

Methods: A chest phantom was imaged with chest X-ray equipment with DTS. 10 protocols were used, and for each protocol, nine acquisitions were performed. Four observers visually rated the quality of the reconstructed section images according to pre-defined quality criteria in four different classes. The data were analysed with visual grading characteristics (VGC) analysis, using the vendor-recommended protocol [12-s acquisition time, source-to-image distance (SID) 180 cm] as reference, and the area under the VGC curve (AUC_{VGC}) was determined for each protocol and class of criteria.

Results: Protocols with a smaller swing angle resulted in a lower image quality for the classes of criteria

“disturbance” and “homogeneity in nodule” but a higher image quality for the class “structure”. The class “demarcation” showed little dependency on the swing angle. All protocols but one (6.3 s, SID 130 cm) obtained an AUC_{VGC} significantly <0.5 (indicating lower quality than reference) for at least one class of criteria.

Conclusion: The study indicates that the DTS protocol with 6.3 s yields image quality similar to that obtained with the vendor-recommended protocol (12 s) but with the clinically important advantage for patients with respiratory impairment of a shorter acquisition time.

Advances in knowledge: The study demonstrates that the image quality may be strongly affected by the choice of protocol and that the vendor-recommended protocol may not be optimal.

INTRODUCTION

Conventional chest radiography and CT of the thorax are at present the imaging modalities most frequently used to detect and monitor lung diseases. Chest radiography is still the most common examination in radiology departments; its advantages include low radiation dose, short examination time, low cost and easy access.^{1,2} A disadvantage of chest radiography is that all tissues are overlaid in a two-dimensional image with the inherent limitation that lesions may be hidden/disguised by the surrounding tissues and therefore escape detection. CT, being a three-dimensional examination, allows detection of very small lesions, but the technique is much more expensive, less available, requires longer examination

time and exposes the patient to a considerably higher radiation dose.^{3–5}

Digital tomosynthesis (DTS) of the chest^{3–7} is a relatively recently implemented technique in which the examination procedure is similar to that of chest radiography. It is performed by using similar equipment, although the X-ray tube moves in one direction during the exposure to acquire projection radiographs from different angles. These radiographs are used to reconstruct tomographic planes at different depths, providing a three-dimensional representation of the interior of the human body. This reduces the tissue overlap problem of chest radiography while exposing the patient to only a slightly higher radiation dose as compared with chest radiography.^{8–10}

In comparisons with chest radiography, DTS has been shown to substantially increase the detection of pathology such as pulmonary nodules,^{5,11–15} mycobacterial disease,¹⁶ pleuropulmonary disease,¹⁷ and pulmonary emphysema.¹⁸ The clinical interest has also been based on the successful use of DTS as a problem-solving tool after chest radiography,^{19–21} substantially reducing the need for CT after a non-conclusive chest radiography. That the measurement accuracy of DTS has been shown to be similar to that of CT has indicated the potential of using DTS instead of CT, *e.g.* follow-up of pulmonary nodules.^{22–24} Finally, owing to the very low dose of DTS, it has been suggested as a suitable technique for lung cancer screening.²⁵

Three DTS systems for chest tomosynthesis currently exist. The studies described above were performed using the systems from Shimadzu Corporation (Kyoto, Japan) and GE Healthcare (Chalfont St Giles, UK). Fujifilm (Tokyo, Japan) is the third medical company that recently has developed a DTS system for thoracic radiology. The Fujifilm DTS system offers the possibility of changing various parameters for each DTS protocol, including the exposure parameters for each projection image, the swing angle, the number of projection images acquired and the image processing parameters. This could allow the operator to adapt the protocol to different patients and clinical questions. The purpose of the present study was to compare the quality of the images obtained with different protocols available in the Fujifilm DTS system, employing an anthropomorphic chest phantom and using visual grading of images according to the predetermined quality criteria.

METHODS AND MATERIALS

Phantom model

The multipurpose chest phantom N1 “Lungman” (Kyoto Kagaku Co. Ltd, Kyoto, Japan) can be used for both plain radiography and three-dimensional imaging (such as CT scanning). The internal components consist of the mediastinum and pulmonary vessels and are attached to an abdominal block. This abdominal block is removable, allowing for insertion of tumours and other lesions (Figure 1). In the present study, a round, 12-mm simulated tumour with an attenuation of 100 Hounsfield units was placed medially on the right to allow the evaluation of pulmonary nodule homogeneity in the image.

Figure 1. 1, Main body (chest wall); 2, mediastinum (heart and trachea included); 3, abdomen (diaphragm) block; 4, 15 variations of simulated tumours. The material of the phantom, the inserted bone structures and pulmonary, have attenuation properties and three-dimensional structures that closely replicate those of human tissues, resulting in X-ray and CT images similar to those of a real patient. Information was derived from the supplier’s catalogue, manufactured at Kyoto Kagaku Co. Ltd (Kyoto, Japan).

Imaging equipment

The phantom was imaged with an FDR AcSelerate (Fujifilm, Tokyo, Japan) chest X-ray equipment with DTS options. The system has a stationary caesium iodide (CsI) flat panel detector ($43 \times 43 \text{ cm}^2$, 2880×2880 pixels of $0.15 \times 0.15 \text{ mm}^2$). The projection images were transferred to the system’s post-processing unit, with software for DTS image reconstruction, post-processing unit v. 2.0. (Fujifilm). The algorithm of tomosynthesis reconstruction for all protocols was filtered back projection.

Digital tomosynthesis protocols

The Fujifilm DTS system has a large number of protocols [called tomosynthesis exposure identity (ID) by the vendor] that can be selected for chest DTS. They differ in source-to-image distance (SID), X-ray tube swing angle, total exposure time and the number of exposures. In the present study, protocols with an exposure time $>9 \text{ s}$ or a SID $<130 \text{ cm}$ were excluded. This resulted in nine selected protocols suitable for lung examinations. Additionally, the vendor-recommended protocol was included in the study (Table 1). The tube voltage and filtration were kept constant as described above, but the tube current (mA) was altered for each protocol to achieve a constant effective dose of 0.4 mSv for each protocol.²⁶ The dose from each single exposure thus varied, but the total dose was kept constant. Other settings, such as collimation of the X-ray tube, reconstruction condition and image post-processing parameters, were the same for all protocols.

Imaging procedures

For each protocol, nine acquisitions of the chest phantom were performed; triplicate examinations of the phantom in three different projections (posterior anterior, right and left oblique). The acquired image material for the study thus consisted of 90 examinations ($10 \text{ protocols} \times 3 \text{ projections} \times 3 \text{ repetitions}$). During exposure, the detector unit (chest unit) was fixed but the X-ray tube moved linearly in the α -direction (down to up). To prevent motion artefacts caused by the movement of X-ray tube and to increase the reconstruction accuracy, two markers were placed on the detector on both sides of the phantom (Figure 2), in accordance with the recommendation from the vendor in clinical use. The reconstructed planes were transferred to the picture archiving and communication system (PACS) (Sectra Medical Systems, Linköping, Sweden) for further evaluation.

Table 1. Exposure data for the 10 chest digital tomosynthesis protocols assessed in the study. All projection images were acquired using a source-to-image distance (SID) of 130 or 180 cm and a total filtration of 3.5 mm Al + 0.2 mm Cu. The X-ray tube moves vertically and acquired 20–60 exposures in the angular interval 10°–27° over 4–12 s, depending on the protocol. Two different grids, with aluminium interspace, were used: a grid with ratio 10/1 and a focusing distance of 140 cm for protocols with SID 130 cm and a grid with ratio 12/1 and a focusing distance of 180 cm for protocols with SID 180 cm

Tomosynthesis exposure identity	SID (cm)	Tube swing angle (°)	Total exposure time (s)	Number of exposures	Tube voltage (kV)	Tube current per projection (mA)	Projection time (s)
60	130	10	6.3	32	120	100	0.008
61	130	13	4.0	20	120	159	0.008
62	130	15	4.7	24	120	133	0.008
65	130	20	6.3	32	120	100	0.008
66	130	25	7.9	39	120	83	0.008
70	180	10	8.8	44	120	135	0.008
71	180	14	6.0	30	120	200	0.008
73	180	15	6.6	33	120	181	0.008
74	180	20	8.8	44	120	138	0.008
76	180	27	12.0	60	120	104	0.008

Image evaluation

The quality of the reconstructed images was evaluated using visual grading, an established method of image quality evaluation based on subjective assessment of criteria related to the reproduction of image components such as anatomical landmarks, pathological structures or physical characteristics.^{27,28} In visual grading, the subjective assessment is made by observers by using a rating scale that can be either absolute, meaning that the images

Figure 2. A projection radiograph of the chest phantom used in the study. The four markers (+) used to increase the reconstruction accuracy are visible at the right and left of the phantom. For all digital tomosynthesis acquisitions, 81 slices with an interslice distance of 5 mm were reconstructed, independent of protocol.

are assessed one at a time on an absolute scale, or relative, meaning that the images are compared side by side, using a relative scale and one or more images for comparison. In the present work, relative visual grading was used.

The criteria developed for the study were based on the European guidelines on quality criteria for diagnostic radiographic images^{29,30} and the quality criteria proposed for chest tomosynthesis by Asplund et al¹³ in combination with the clinical experience of the observers (Table 2). The criteria focused on eight anatomical regions of the thorax and were distributed to cover various distances to the detector and different types of structures (Figure 3). Each anatomical region in the images was marked with a letter (A–H) to simplify for the observers, but this served only as a starting point for the region to examine. Five regions included vessels, and for these regions, two criteria were used: (1) “demarcation”, *i.e.* how well the borders of the vessels were defined and (2) “disturbance”, *i.e.* how much the outlining and identification of a single vessel was disturbed by surrounding vessels. The observers were instructed to assess vessels with a diameter of approximately 1 mm, except in the centre of the right lung (Region G) where instead a vessel of approximately 3-mm diameter was chosen. Mediastinal structures were assessed by evaluating the structure of a vertebral body (cortical bone and trabeculae) in the lower thoracic spine and the carina. Finally, the 12-mm nodule inserted in the centre of the right lung was assessed for border demarcation and its internal homogeneity.

The images acquired with protocol identity (ID) 70 were used for comparison in the relative visual grading evaluation. For each comparison, the observer rated the image quality related to each criterion on a five-step scale from –2 (image quality much lower than for the comparison protocol) to +2 (image quality much higher than for the comparison protocol). The protocol for comparison was chosen for statistical reasons based on the

Table 2. The criteria developed for the present study to rate the image quality of the reconstructed digital tomosynthesis slices

Region	Structure	Criterion
A	Basal dorsal	Vessel demarcation (small vessels)
	Basal dorsal	Disturbance of vessels in front/behind
B	Spine	Definition of structure
C	Nodule	Homogeneous
	Nodule	Definition of edge
D	Peripheral vessels (upper, lateral right)	Vessel demarcation (small vessels)
	Peripheral vessels (upper, lateral right)	Disturbance of vessels in front/behind
E	Retrocardiac	Vessel demarcation
	Retrocardiac	Disturbance of vessels in front/behind
F	Carina	Definition of structure
G	Vessel round nodule	Vessel demarcation (3-mm vessels)
	Vessel round nodule	Disturbance of vessels in front/behind
H	Basal ventral	Vessel demarcation (small vessels)
	Basal ventral	Disturbance of vessels in front/behind

assumption that this protocol would be of average image quality, so that the observer would use the entire rating scale.

The DTS planes (entire stacks) were presented in random order, and images were identified only by a code unrelated to the type of protocol. They were presented in nine groups of nine stacks. The DTS to be evaluated was presented on the left screen and

the corresponding images from the comparison protocol (ID 70) on the right screen. The stacks were paired so that both stacks were of the same projection. The observers were allowed to adjust the window width and window level and to use the panning and zooming functions.

Four senior consultant radiologists, all with more than 20 years' experience, participated as observers in the study. However, only one of the observers had any significant experience from reading tomosynthesis images. The image quality was evaluated on the hospital's PACS system workstations with the image workstations used for routine clinical radiology. The monitors were two Rad-iForce®, RX340, 3 MP, Color LCD monitors from Eizo (Hakusan, Japan) for digital imaging and communications in medicine, calibrated on a yearly basis. The ratings were recorded on a paper protocol, and the data were later manually entered into a data file.

Visual grading characteristics and statistical analysis
Before the statistical analysis, the observers' ratings for the different criteria and regions were pooled to create four classes of criteria: demarcation, disturbance, structure and homogeneity in the nodule (Table 3). Since protocol ID 70 was used for comparison in the evaluation by the observers, the rating "0" was given to all criteria for this protocol. Although numerical values were used to rate image quality, they represent an ordinal scale, and, consequently, the ratings were treated as ordinal data in the statistical analysis. Furthermore, since the ratings were made relative to a fixed operating point (the same protocol was used for comparison in all evaluations by all observers), they could statistically be treated as absolute (*i.e.* belonging to a fixed ordinal scale), enabling the application of visual grading characteristics (VGC) analysis.^{27,28}

VGC analysis is a non-parametric, rank-invariant method of analysing visual grading data. In VGC analysis, the ratings for two protocols at a time are compared by creating VGC curves, similar

Figure 3. Eight anatomical regions of criteria in tomosynthesis image. Full format and enlargement. As an example three (of the eight) marked regions are seen: B, lower thoracic spine; C, peripheral vessels approximately 1mm; D, vessels around the inserted nodule approximately 3mm.

Table 3. The four classes of criteria. Demarcation consisted of the five assessments of vessel borders for each protocol. Disturbance consisted of the five assessments of disturbance from surrounding vessels. Structure was composed of the ratings for the two mediastinal structures and the borders of the nodule homogeneity in nodule simply consisted of a single criterion

Classes of criteria	Number of series	Number of observers	Number of criteria	Ratings
Demarcation	9	4	5	180
Disturbance	9	4	5	180
Structure	9	4	3	108
Homogeneity in nodule	9	4	1	36

to the receiver operating characteristics (ROC) analysis where the ratings for abnormal and normal cases are used to create a ROC curve. A VGC curve is constructed for each criterion (or class of criteria) and reflects how the proportion of images that are judged as being of higher quality than a certain threshold for one protocol (the assessed protocol, on the y axis) varies with this proportion for the other protocol (the reference protocol, on the x axis), when the threshold is altered. The VGC curve thus ranges from 0.0 to 1.0. The deviation from the diagonal is a measure of how much the two protocols differ in image quality. Normally, the area under the VGC curve (AUC_{VGC}) is used as a scalar measure of this difference.^{31,32} An AUC_{VGC} of 0.5 for a given criterion reflects similar image quality for that criterion for the two protocols. An $AUC_{VGC} > 0.5$ indicates higher image quality, and an $AUC_{VGC} < 0.5$ indicates lower image quality, for the assessed protocol than for the reference protocol.^{27,28}

As the reference for the VGC analysis, the manufacturer's recommended protocol ID 76 was used. The VGC analysis was

performed for each class of criteria using the software VGC Analyzer (in-house developed computer software, University of Gothenburg, Gothenburg, Sweden). This software determined the VGC curve averaged over observers, and a bootstrapping (resampling) technique was applied to determine the asymmetric 95% confidence interval of the AUC_{VGC} . An example of an obtained VGC curve is given in Figure 4. The p -value for the null hypothesis ($AUC_{VGC} = 0.5$) was determined using a resampling and permutation technique. The statistical analysis of the AUC_{VGC} was based on the binormal VGC curve, and the paired resampling was performed on image stacks (nine stacks for each protocol) and observers for the results to be generalizable to the population of observers and images. $p < 0.05$ was considered statistically significant. Since the rating "0" was given to all criteria for protocol 70, the actual variability for protocol ID 70 was neglected. The p -value was thus underestimated for this protocol [in the analysis of the uncertainty of the AUC_{VGC} for this protocol, only the variability of the reference protocol (ID 76) was included].

RESULTS

The AUC_{VGC} and p -values for each DTS protocol and each class of criteria, using protocol ID 76 as a reference, are shown in Table 4. In general, protocols with a smaller swing angle resulted in lower image quality for the disturbance and "homogeneity in nodule" classes of criteria but higher image quality for "structure" class of criteria. The demarcation class of criteria showed little dependency on the swing angle. Only one DTS protocol (ID 65) gave results similar to those of the protocol recommended by the vendor (the reference protocol in the VGC analysis) regardless of class of criteria. An important advantage of the protocol ID 65 was the shorter exposure time (6.3 vs 12 s). All other protocols gave significantly lower image quality than the reference protocol for at least one class of criteria.

Regarding the dependency on the SID, two protocols with a SID of 130 cm (IDs 62 and 66) yielded lower image quality than that of the reference protocol for the demarcation class of criteria, whereas protocols with a SID of 180 cm yielded images of similar quality as the reference protocol for this class of criteria. For the disturbance class of criteria, all protocols with a SID of 180 cm yielded significantly lower image quality than that of the reference, whereas two of the protocols with a SID of 130 cm (IDs 65 and 66) were similar to that of the reference protocol. Regarding the classes of criteria structure and homogeneity in nodule, no dependency on the SID was evident.

Figure 4. An example of a visual grading characteristics curve, reflecting how the proportion of images that are judged as being of higher quality than a certain threshold for protocol identity (ID) 60 varies with this proportion for protocol ID 76, when the threshold is altered, for the "structure" class of criteria.

Table 4. Area under the visual grading characteristics curve (AUC_{VGC}) and p -values for the different digital tomosynthesis (DTS) protocols for the four classes of quality criteria

DTS exposure ID	Tube swing angle (°)	Demarcation		Disturbance		Structure		Homogeneity in nodule	
		AUC_{VGC}	p -value	AUC_{VGC}	p -value	AUC_{VGC}	p -value	AUC_{VGC}	p -value
60	10	0.58	n.s.	0.05	<0.001	0.70	<0.01	0.14	<0.01
61	13	0.42	n.s.	0.12	<0.001	0.62	<0.05	0.24	<0.05
62	15	0.38	<0.05	0.20	<0.001	0.59	n.s.	0.33	0.05
65	20	0.44	n.s.	0.34	n.s.	0.53	n.s.	0.45	n.s.
66	25	0.39	<0.05	0.43	n.s.	0.44	n.s.	0.52	n.s.
70	10	0.59	n.s.	0.03	<0.001	0.74	<0.05	0.00	<0.01
71	14	0.55	n.s.	0.10	<0.001	0.70	<0.01	0.28	0.05
73	15	0.57	n.s.	0.22	<0.01	0.68	0.05	0.33	n.s.
74	20	0.54	n.s.	0.27	<0.01	0.50	n.s.	0.38	n.s.

ID, identity; n.s., non-significant.

DISCUSSION

Chest DTS visualizes anatomic structures better than chest radiography and exposes the patient to less radiation than CT. Chest DTS is less time consuming, more accessible and less expensive than CT and can provide diagnostic information superior to that provided by chest radiography. To make full use of this recently developed technology, its performance must be optimized. This study investigated how variations in the chest DTS protocols influence image quality, assessed according to the predetermined quality criteria. It was found that one protocol (ID 65) gave image quality on par with the protocol recommended by the vendor (ID 76) but with the clinically important advantage of a shorter acquisition time (6.3 vs 12 s). Many patients who are monitored because of pulmonary nodules are elderly, and they often suffer comorbidity in the form of obstructive lung disease. For these patients, it is advantageous to apply imaging protocols requiring a short breath-hold without compromising the image quality. However, protocol ID 65 uses a SID of only 130 cm, in contrast to the SID of 180 cm used for protocol ID 76. Consequently, as a SID of 130 cm is not recommended for conventional chest radiography,²⁹ a clinical study is indicated to compare the image quality provided by these two protocols for chest DTS.

Protocols other than ID 65 resulted in image quality equivalent or inferior to the vendor-recommended protocol for the demarcation, disturbance and homogeneity in nodules classes of criteria. Several protocols yielded higher image quality than the recommended protocol for the structure class of criteria. To understand these results, the protocols must be analysed in terms of their acquisition parameters. Two important parameters in tomosynthesis are the tube swing angle and the projection image density (the total number of acquired projection images divided by the swing angle). Regarding the projection image density, if this is too low, the blurring of high-contrast structures outside the reconstructed plane will turn into ripple.⁴ The projection image density needed to avoid this artefact depends on the thickness of the object. In chest DTS, a projection image density

of two (images per degree) has been recommended, as the ribs (being significant high-contrast structures) may be at a considerable distance from certain reconstructed planes,⁴ especially for larger patients. Söderman *et al*³³ who performed a study similar to the present study (an evaluation of image quality based on the reproduction of an anthropomorphic chest phantom at different acquisition protocols) on the GE chest DTS system reported an increase in image artefacts with decreasing projection image density. This was especially evident for projection image densities <1 (projection image densities down to 0.5 were investigated). For all protocols included in the present work, the projection image density was >1.5. No strong effect of ripple artefacts on the image quality was thus expected, especially as the phantom represents a relatively lean male. In fact, the recommended alternative (ID 65) uses one of the lowest projection image densities of the investigated protocols (32 projection images acquired at a swing angle of 20°, resulting in a projection image density of 1.6) and still turned out as the best alternative to the vendor-recommended protocol (using a projection image density of 2.2).

Regarding the tube swing angle, this will directly affect the depth resolution in the reconstructed planes, an increased swing angle leading to an improved depth resolution.⁴ For the protocols included in the present study, there was a considerable variation in the swing angle. The effect of this can be clearly seen for the disturbance class of criteria. This class of criteria consisted of judgements of the disturbance from surrounding vessels (in front/behind) and was thus related to the depth resolution. Table 4 shows that all protocols with a swing angle <20° resulted in a significantly lower rating than the reference protocol (swing angle 27°) for this class of criteria and that the smaller the swing angle, the lower the AUC_{VGC} . This result agrees well with Söderman *et al*³³ who reported that for a criterion related to the possibility to follow vessels through the volume all protocols with a swing angle <20° resulted in a lower image quality than their reference (swing angle 30°). For the demarcation class of criteria, on the other hand, no strong dependency on the swing angle was seen in the present

study. The lack of influence from swing angle on vessel demarcation also agrees well with Söderman et al who used four different criteria related to the in-plane reproduction of vessels. Although an indication of an increased image quality with decreasing swing angle was reported for one of the criteria, no general trend could be seen. The last comparison with Söderman et al can be made for the structure class of criteria, consisting of the ratings for the reproduction of the spine and the carina. In the present study, the AUC_{VGC} in general increased with decreasing swing angle. Söderman et al did not assess the visibility of the spine, but a criterion related to the reproduction of the trachea was included. For this criterion, they reported an increasing image quality with decreasing swing angle, similar to the present study. Although no comparison with conventional chest radiography was made in the present study or in the study by Söderman et al, the result that a larger swing angle led to worse image quality indicates that the reproduction of the large airways may not benefit from the depth resolution provided by DTS.

A prerequisite for the present study was that the DTS system allowed variations in protocol settings and parameters, including the exposure time (4–12 s). Comparisons of multiple protocol settings are best performed by repeated examination of the same object. For this, a phantom model closely resembling the human body was employed. A similar comparison in patients would have been ethically questionable. However, the clinical validity of our findings needs to be verified and additional factors such as positioning and breath-holding need to be investigated.

One of the challenges of chest DTS image acquisition is artefacts caused by breathing^{3,5,7} and by vibration of the X-ray tube. To minimize motion artefacts induced by X-ray tube vibration, the present DTS system corrects image misalignment in the DTS planes by comparing the ideal position information with the position of markers placed right and left of the object being imaged (Figure 2). This alignment correction is performed automatically before image reconstruction.

This study has several limitations. First, it is based on imaging of an anthropomorphic phantom and not humans. Management of respiratory motion artefacts is an important issue in the clinical situation, and in a patient study, these may have affected the results since the exposure time varied between protocols. Additionally, anatomic variations between patients could not be accounted for in this experimental setting. Although the anthropomorphic phantom incorporates anatomical structures that mimic the attenuation of human organs and tissues, the results may not be possible to transfer to the clinical situation.

By contrast, the lack of respiratory motion in the phantom model made it possible to detect small differences in image quality between protocols despite limited image material. The phantom is also equivalent to a lean person and, the results might be different for a larger patient. In a clinical study, chest DTS visualized 4–10 mm pulmonary nodules significantly better than chest radiography in examinations without respiratory motion artefacts, whereas if artefacts were present, the two techniques showed similar performance.⁵ Such artefacts may also lead to misinterpretation of tumour diameter, as illustrated by a study on chest DTS for follow-up of lung nodules, where tumour growth was falsely reported because of respiratory motion artefacts.³⁴ The second limitation of the present study is that not all observers had clinical experience of chest DTS image reading. However, all had long experience (more than 20 years) of radiology in a university hospital, and two are thoracic radiologists. It has been shown that experienced thoracic radiologists (more than 20 years) are quickly able to take advantage of chest tomosynthesis to detect pulmonary nodules.¹² Inexperienced observers can also perform well in this task after a short learning session with feedback.¹³ Third, because the technology is fairly new, there are no established quality criteria for chest tomosynthesis. For the present study, we therefore developed image quality criteria for DTS based on established quality criteria for chest radiography²⁹ and chest CT³⁰ and criteria proposed for chest DTS¹⁵ in combination with the clinical experience of the authors and the observers. The image quality criteria applied in the present study take into account several aspects of the effect of different sweep angles and also relate to anatomical structures throughout the chest in order to be relevant for the clinical validity of the results.

In conclusion, the present study indicates that the acquisition protocol may strongly influence the image quality in chest DTS and that different anatomical structures are differently affected by changes in, for example, tube swing angle. For the Fujifilm DTS system, a chest protocol with 6.3-s acquisition time was found to yield image quality similar to that from the vendor-recommended protocol with acquisition time 12 s. A shorter acquisition time may be clinically important for patients with respiratory impairment.

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