RESEARCH LETTER

Novel imaging detailing the origins of a pneumothorax

ABSTRACT

This is a prospective clinical study aimed at introducing a method to visualise the location of an air leak and to identify the bulla responsible on three-dimensional (3-D) cine CT. In 10 patients with spontaneous pneumothorax, dynamic 320-detector row CT was performed with injection of 0.9% saline into the affected pleural cavity via a preplaced chest tube. In eight cases, 3-D cine CT thoracography revealed the location of the air leak and the bulla responsible (7 cases: air stream sign; 1 case: repeated collapse and expansion of a bulla with the patient's breathing).

BACKGROUND

Currently, patients with pneumothorax are treated without knowing the location of the air leak or ruptured bulla.

We have previously reported a method to show the radiological signs of an air leak on CT in a patient with spontaneous pneumothorax.[1 2] However, these findings only showed still planar images of air bubbles after leaking from the lung. To accurately detect the location of the air leak, the direction of the air leak from the lung should be captured.

In this report we assessed whether three-dimensional (3-D) cine CT[3 4] can reveal the point of the air leak and the bulla responsible in patients with spontaneous pneumothorax.

MATERIALS AND METHODS

A prospective clinical study was conducted in patients who underwent chest tube placement for treatment of spontaneous pneumothorax. Patients with an air leak which was present 24 hours after drain insertion and where the air leak was present in the chest tube bottle during vocalisation were included in the study. Specific interventions for the management of pneumothorax beyond chest tube insertion were instituted after the CT study. The patients underwent surgery for a persistent air leak later if considered suitable. Endobronchial occlusion therapy and/or chemical pleurodesis were applied as non-surgical therapies for air leak.

The subjects of this study were admitted for pneumothorax to the respiratory department of the National Saitama Hospital, Saitama, Japan between 1

Table 1 Relationship of the characteristics and radiological findings of each case

Case no	Age/sex, side, primary lung disease	Trigger of air leak	Elapsed time from onset of pneumothorax to CT scan (days)	Radiological findings and location on static CT	Scanned area (patient's posture during 2nd/3rd scan)	Radiological findings on 4-D CT thoracography	Presumed location of air leak and causative lesion (lobe, segment)	Exposure radiation dose (CTDI-Vol/DL) of 4-D CT thoracography (mGy/mGy×cm)	Treatment for pneumothorax	Elapsed time from CT scan to surgery (days)	Operative findings of air leak location (confirmed location: lobe, segment)
1	80/M, R, COPD	Talking	2	Focal bullae, upper	Upper (supine)	Air stream	Upper, apical	197.9/3809	Op	8	Same as presumption
2	85/F, R, COPD	Expiration	18	Focal bullae, upper	Upper (supine)	Air stream	Lower, apical	98.8/1581	EWS	–	–
3	18/M, L, -	Talking	5	Solitary bulla, apex	Upper (supine)	Air stream	Upper, apico-posterior	157.5/2088	Op	3	Same as presumption
4	50/M, R, COPD	Talking	6	Diffuse bullae, upper	Upper (supine/lateral)	Air stream	Upper, apical	261.9/4070	Op	2	Same as presumption
5	19/M, L, –	Talking	6	Solitary bulla, apex	Upper (supine)	Air stream	Upper, apico-posterior	118.8/1302	Op	5	Same as presumption
6	85/M, L COPD	Talking	16	Diffuse bullae, whole	Upper (supine/ semi- lateral)	Collapse and expansion of bulla	Upper, apico-posterior	314.1/5510	Op	6	Same as presumption
7	22/M, L, –	Talking	5	Multiple bullae, apex	Upper (supine)	Air stream	Upper, apico-posterior	151.3/2249	Op	3	Same as presumption
8	64/M, L, COPD, IP	Talking	25	Diffuse bullae, whole	Upper (supine/lateral)	Air stream	Upper, anterior	208.3/3606	EWS and pleurodesis	–	–
Cases with no motion signs											
9	73/M, L, COPD	Talking	19	Diffuse bullae, upper	Upper (supine/lateral)	–	(Unknown)	239.2/4119	Op	4	(Lower, apical)
10	86/M, L, COPD	Expiration	14	Diffuse bullae, upper	Upper (supine/lateral)	–	(Unknown)	202.0/3231	Op	1	(Upper, anterior)

CTDIvol, volume CT dose index; DL, dose length; EWS, endoscopic bronchial obstruction using Watanabe spigots; F, female; IP, interstitial pneumonia; L, left; M, male; Op, operation; R, right.

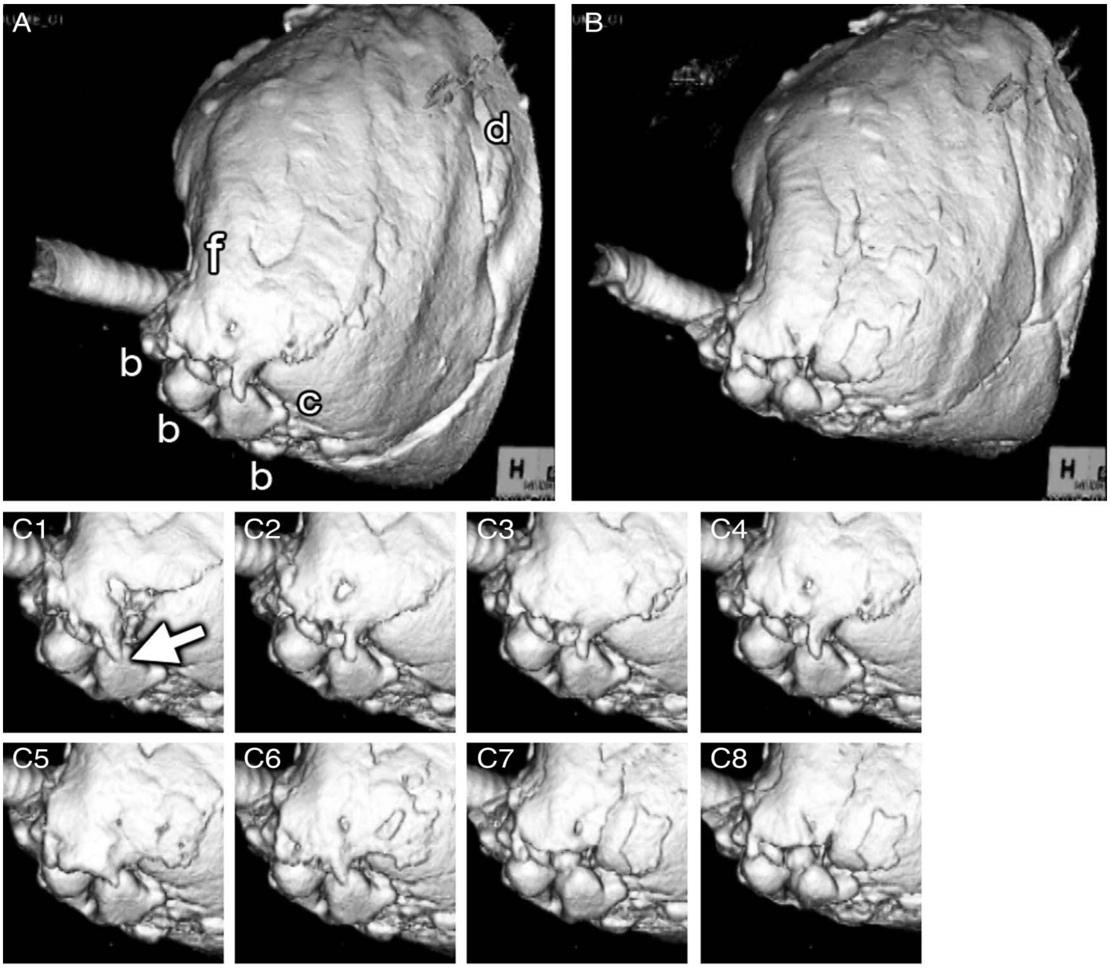

Figure 1 Motion of air on four-dimensional CT thoracographic images (case 1). (A) Maximum inspiratory time: (b) bullous lesions; (c) causative lesion of the air leak; (d) preplaced drain; (f) free pleural space of pneumothorax. (B) Maximum expiratory time. Only surfaces of air are rendered within the upper half of the right thoracic cage. The aerial areas are the airway from the trachea to the alveoli, bullous lesions, pneumothorax space and leaked air. Leaked air is shown only in (A). (C1–8) Sequential images. An aerial train connecting a bulla to a space of pneumothorax that appeared during inspiration (C1). The train spread along the lung and enlarged the pleural space (C2–C5). After changing to expiration, the funnel-shaped part of the aerial train close to the bulla disappeared. According to the expiration, the train is divided (C5–8) and the pleural space is finally shrunk. This means airflow spouting from a bulla. The leak point can be judged to be where the tip of the funnel shape of the aerial train has appeared (C1, arrow).

January and 31 December 2015. The ethics committee of the National Saitama Hospital approved the study (R2015-20).

Procedure

After 0.9% saline was injected into the affected pleural cavity via a preplaced chest tube, a dynamic scan with a 320-multidetector row CT (320-MDCT) scan apparatus was performed while the patient breathed deeply. Dense areas were extracted from the obtained data and rendered as 3-D movies. In the surgical cases, the leakage point was confirmed during surgery the following day. The details of the procedure are shown in online supplementary file 1.

RESULTS

Twenty-six patients with pneumothorax were admitted for drainage therapy during the study period. Ten of the 26 patients satisfied the study criteria and consented to participate in the study (table 1). Eight of the 10 patients underwent surgery to stop their air leak. The other two cases underwent bronchial occlusion therapy because they were a high risk for surgery.

Radiological findings in cine 3-D CT movie

Air stream in saline solution

At the beginning of the patient's inspiration, a funnel-shaped 3-D figure of air appeared on a bullous lesion in saline solution pooled in the pleural cavity (see figure 1 and videos in online supplementary files 2 and 3). The 3-D figure ran along the lung and diverged to the surface of the saline. Seven patients showed this finding, which we presumed was a direct sign of the air leak. We considered that the tip of the funnel shape of the train showed the leak point and that the closest bulla to the tip was a ruptured lesion. In all surgical cases we confirmed that our preoperative presumptions were accurate.

Shrinking bulla

In one patient the bulla collapsed at inspiration and expanded at expiration on four-dimensional (4-D) CT imaging (see video in online supplementary file 4). We confirmed that this bulla blew an air leak during surgery performed on the following day.

The other two patients showed no motion signs.

Adverse events

None of the patients showed symptoms of fever, surgical site infection, pyothorax, pneumonia or drainage failure. Adverse events caused by injection of saline solution were not observed.

DISCUSSION

In this study we directly demonstrated air leaking from a lesion of the lung and specified the leak point precisely on CT images. Leaked air was three-dimensionally depicted with dynamic motion in synchronisation with breathing. We refer to our new method as '4-D CT thoracography'.

4-D CT thoracography was useful for patients with pneumothorax with a massive air leak. The present method should be clinically applied in patients who cannot be cured by simple drainage and require another invasive therapy such as bronchial occlusion therapy[5] or thoracoscopic surgery. These treatments require a better way of locating the air leak.

Our method requires a 320-MDCT apparatus[6] but does not require skilled techniques or special materials. Only saline solution was used in this study and no adverse events occurred. Saline is safe and cheap.

This method allows observation of how bullae behave in vivo. One case showed that a ruptured bulla collapsed in the inspiration phase and then expanded in the expiration phase. These findings may be useful in the dynamic analysis of bullae in vivo.

The cause of failure in two cases without motion signs may be a shortage of injected saline solution or the wrong postural position.

To reduce exposure to radiation, a dynamic scan was performed at a low dose of irradiation. The images were then reconstructed and optimised using a full iterative reconstruction method.[7]

Currently, 4-D images still cannot be reconstructed in real time. This depends on the throughput of the image processing workstation, but development of software and hardware will solve the issue in the near future.[8]

The aim of this study was to establish a method to demonstrate the leak point accurately rather than to investigate the clinical significance of detection of a leak point. The results of this study offer a significant advance in the localisation of bullae causing pneumothorax where surgery is planned.

CONCLUSIONS

This study suggests that 4-D CT thoracography can detect the precise location of an air leak in patients with pneumothorax. This new procedure will be useful for patients who are undergoing surgery but not for the routine evaluation of a pneumothorax.

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Contributors KN takes full responsibility for the work represented in this manuscript. He performed most of the study examinations and all the surgeries. He contributed to the study concept and design, data collection, data analysis and manuscript writing. HG and TI performed examinations and surgeries and contributed to data collection and analysis. YN and SH contributed to treatment of the patients. TI contributed to manipulation of the CT scanner and reconstruction of the CT images. All authors have read and approved the final manuscript.

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Patient consent Obtained.

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