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CASE REPORT

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Utilization of ultrasound for the detection of pneumothorax in the neonatal special-care nursery

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Abstract Pneumothorax is a potentially life-threatening condition in the setting of the neonatal special-care nursery (SCN) that may result in rapid deterioration and death. The familiar appearances associated with pneumothorax on AP supine chest radiograph are highly specific, but limited in sensitivity. In this case report, we describe the theory and technique of thoracic ultrasound for detection of pneumothorax in the SCN, providing a viable alternative to the cross-table lateral radiograph without ionising radiation, with highly accurate results, and with minimal patient positioning.

Keywords Ultrasound · Pneumothorax · Neonatal special-care nursery

Introduction

Pneumothorax is a potentially life-threatening condition in the setting of the neonatal special-care nursery (SCN) that may result in rapid deterioration and death. The presence of pneumothorax within the neonatal population receiving mechanical ventilator support and positive end-expiratory pressure has been reported to be as high as 33% [1]. Although new ventilation techniques have decreased the relative incidence of pneumothorax, it remains a common occurrence in the ventilated neonate. In addition to the acute cardiac and respiratory insult associated with pneumothorax, the hypoxemic consequences as a result of underventilation have been established as a causative factor in the development of intraventricular haemorrhage [2].

The familiar appearances associated with pneumothorax on AP supine chest radiograph are highly specific, but limited in sensitivity [3]. Within the SCN, the cross-table lateral radiograph has been shown to increase sensitivity; however, it requires both repositioning and manipulation of support tubes and lines and subjects the patient to further ionising radiation. Furthermore, a subtle pneumothorax may not be detected on cross-table lateral radiograph owing to artefact, technique, or positioning [4].

The ability of ultrasound to detect even small pneumothoraces has been well documented in the adult literature [5, 6, 7, 8]. We describe a case in which this application has been expanded to include the diagnosis of pneumothorax within the neonatal special-care nursery (SCN).

Case report

A premature neonate was admitted to the special-care nursery (SCN) because of respiratory distress following delivery that developed into hyaline membrane disease and bronchopulmonary dysplasia. A patent ductus artery clip was placed during the second week of life.

On day 38 of life, it was noted that the neonate had increasing FiO_2 and pressure- support requirements. The patient demonstrated increased crackles at the left lung base; however, the remainder of the physical examination was otherwise non-contributory. An AP supine chest radiograph was interpreted by the clinician as showing a hyperinflated left hemithorax with a focal area of consolidation along the left upper lung zone (Fig. 1) with a low clinical suspicion of pneumothorax. As a result, no further radiographs were obtained, and the neonate was observed without further intervention or investigation.

Following a routine abdominal ultrasound (to assess the kidneys for hydronephrosis), the thorax was ultrasonographically interrogated using a 10-MHz linear transducer to exclude pneumothorax (Acuson 128 XP Mountain View, Calif.). The right hemithorax demonstrated normal comet tail artefact and lung sliding. The left hemithorax demonstrated absence of lung sliding and comet-tail artefacts along the left anterior chest, findings consistent with a left-sided pneumothorax (Fig. 2). Owing to the fact that this technique had not been previously described in the paediatric population, a cross-table lateral radiograph was obtained, which confirmed the left anterior pneumothorax (Fig. 3).

A chest tube was subsequently introduced into the left hemithorax, which resulted in a gush of air and the expulsion of a small amount of serous fluid, confirming the presence of pneumothorax,

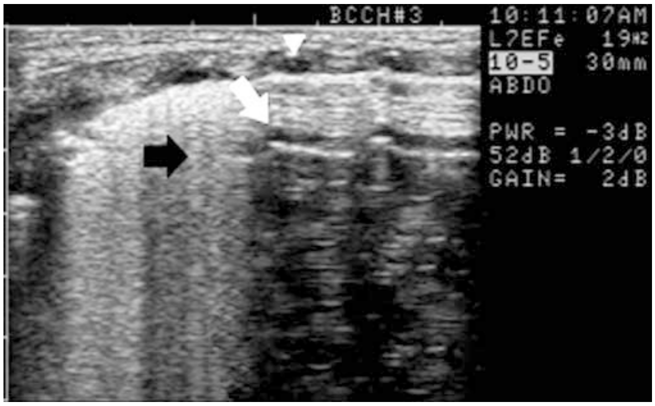

Fig. 2 Sagittal sonographic image of the left hemithorax, utilizing a 10-MHz linear probe. Four ribs (*arrowhead*) are included in the sonographic field of view. A normal comet-tail artefact is demonstrated in opposed lung (*black arrow*). The lack of comet-tail artefacts in the inferior aspect of the hemithorax (with lack of lung sliding on real-time imaging) suggests pneumothorax (*white arrow*)

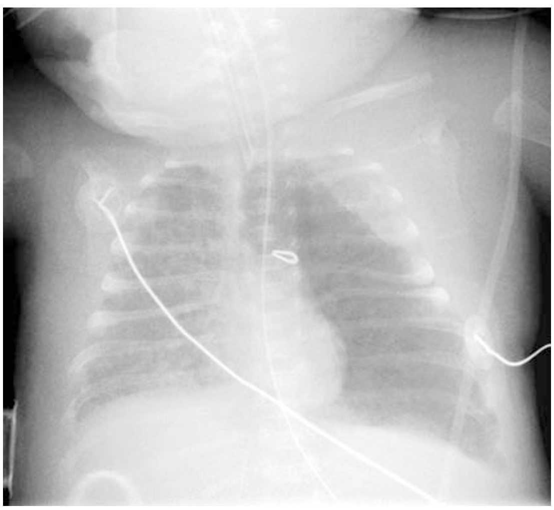

Fig. 1 A 138-day-old infant with respiratory distress: AP supine chest radiograph. The endotracheal tube, nasogastric tube, and a PDA clip are seen. Hyperinflation of the left hemithorax is evident. A region of atelectasis is present in the left apex

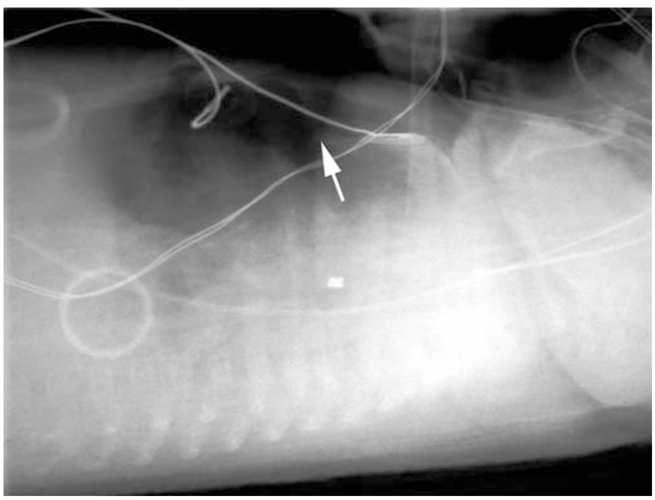

Fig. 3 Cross-table lateral chest radiograph demonstrates a moderate-sized anterior pneumothorax. The visceral pleural surface of the collapsed lung is evident (*arrow*)

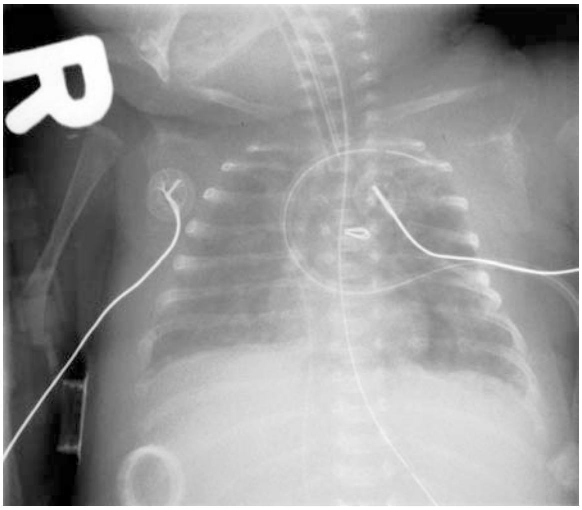

Fig. 4 AP supine chest radiograph following insertion of a tube in the left side of the chest. Resolution of hyperinflation of the left hemithorax and reaeration of the atelectatic lung in the left apex are noted. Trace residual pneumothorax is identified along the medial aspect of the left lung

with subsequent decompression of the left hemithorax (Fig. 4). The patient's ventilatory status improved shortly after chest-tube placement.

Discussion

The identification of pneumothorax within the SCN has traditionally required a combination of high suspicion, clinical examination (with transillumination) and confirmation via an AP supine chest radiograph. Although the classic findings associated with pneumothoraces are highly specific (sharp delineation of pericardial silhouette, deep sulcus sign, asymmetric lucency of the hemithoraces), they lack sensitivity, especially with subtle pneumothoraces, especially those that tend to collect along the nondependent anterior chest wall. The cross-table lateral radiograph improves the overall sensitivity in the radiographic detection of pneumothorax, but is technically more difficult, prone to artefacts because of support lines, requires proper film placement, and most importantly, subjects the patient to repositioning and manipulation of support lines [4].

A body of literature has developed from emergency radiology regarding the detection of pneumothoraces with ultrasound in the ICU and trauma settings. The technique is well described in the trauma literature and has demonstrated that the ultrasound technique has a greater sensitivity and higher negative predictive value than the conventional AP supine chest radiograph for the diagnosis of pneumothorax in the setting of blunt trauma [7, 8]. More recent studies have concluded that this novel application of ultrasound is as sensitive as CT in the emergency room setting [5]. Furthermore, the technique has demonstrated similar positive predictive values as compared to supine chest radiography in the adult ICU [6, 9].

The ultrasound technique is relatively straightforward; however, it requires real-time imaging in order to appreciate the dynamic processes within the thorax. The examination requires a high-frequency linear transducer (preferably 7 MHz or higher) that is placed along the nondependent aspect of the thorax with adjustment of the focal zone to the parietal/visceral pleural interface and overall depth set at 5–6 cm. Because of the small size of the neonatal chest, the transducer has the ability to span the entire length of the hemithorax.

Two observations have been established as reliable criteria in the exclusion of pneumothorax: the presence of motion at the parietal/visceral pleural interface, as demonstrated by the to-and-fro motion that is synchronized with respiration during real-time scanning (referred to as 'lung sliding') and hyperechoic reverberation artefacts extending from the pleural interface to the distal edge of the ultrasound image (comet-tail artefacts).

Comet-tail artefacts within the lung have been postulated to originate from the visceral pleura as a result of small fluid collections within the subplerual interlobular septae. These collections lie adjacent to alveoli, resulting in high impedance and reverberation. Similarly, lung sliding is the dynamic imaging of the movement of subpleural interlobular septae during respiration. The absence of these phenomena in patients with pneumothoraces may be due to loss of apposition of these collections with the parietal pleura, preventing through transmission to the visceral pleura.

Failure to identify the lung sliding and comet-tail artefacts with a high-frequency linear array transducer has been reported as having a 100% negative predictive value, a 100% sensitivity and 96.5% specificity for identification of non-loculated pneumothorax as compared to CT for adult patients in the ICU setting [6].

The identification and prompt management of pneumothorax in the SCN have greatly improved with newer and more advanced resuscitative techniques and with the use of the cross-table lateral radiograph. However, in situations where prompt diagnosis and minimal manipulation of the patient is required, the pragmatics of performing a radiograph during resuscitation may prove difficult.

The primary benefits to this technique are the absence of ionising radiation, the ease in which the examination can be performed, the repeatability, and the relative portability of the ultrasound. The fact that the patient need not be repositioned for the examination makes this an ideal method in determining pneumothorax in unstable patients where a high clinical suspicion of pneumothorax exists despite equivocal findings on routine AP supine views.

The ultrasonographic technique is not meant to replace the invaluable information provided by standard chest radiography, but may serve as an adjunct for the identification of pneumothorax in the setting of equivocal conventional radiographs and high clinical suspicion.

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