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Expiratory chest radiographs do not improve visibility of small apical pneumothoraces by enhanced contrast

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ABSTRACT: Demonstration of small apical pneumothoraces is supposed to be facilitated by expiratory chest radiographs. This study aimed to analyse the assumed enhancement of visual contrast on expiratory chest radiographs in patients with small apical pneumothoraces.

Optical densities (OD) were obtained with a densitometer (X-rite 3001) on 54 paired inspiratory and expiratory chest radiographs of 22 consecutive patients with small apical pneumothoraces. The ODs were measured: at the intervertebral space between the first and second thoracic vertebrae (Area 1); at the peripheral part of the affected lung parenchyma (Area 2); and at the adjacent intrapleural space (Area 3).

Excellent correlations of OD of each area were obtained between paired inspiratory and expiratory chest radiographs. The ODs of all areas on expiratory chest radiographs were significantly higher than on inspiratory chest radiographs. Contrast between pulmonary parenchyma and intrapleural air in inspiratory and expiratory films did not differ significantly.

Expiratory chest radiographs do not improve visibility of small apical pneumothoraces by enhanced contrast between pulmonary parenchyma and intrapleural air. Expiratory chest radiographs show equally increased OD in the area of lung tissue and intrapleural air, caused by increased extrapulmonary tissue density during expiration, resulting in increased radiation exposure monitored by the ionization chambers of standard radiological equipment. If expiratory chest radiographs are really improving the visibility of apical pneumothoraces, there must be other reasons than contrast enhancement to explain this.
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Currently, it is common practice to perform chest radiographs during maximal inspiration and expiration in patients suspected of pneumothorax [1–8]. In particular, the demonstration of small apical pneumothoraces should be facilitated by expiratory chest radiographs, due to enhanced visual contrast between pulmonary parenchyma and intrapleural air [4, 8].

Recently, two studies questioned the need for expiratory chest radiographs in diagnosing pneumothoraces [9, 10]. In both studies, all types of pneumothoraces were investigated. It was unclear whether expiratory chest radiographs were especially helpful for detecting small apical pneumothoraces. If enhanced visual contrast is responsible for better detection, this should, in particular, be of value for diagnosing small apical pneumothoraces. In this study, we analysed whether the assumed enhancement of visual contrast on expiratory chest radiographs was indeed present.

Material and methods

Patients

Chest radiographs of 22 consecutive patients with small apical pneumothoraces were retrospectively studied. All patients were referred to our hospital between December 1991 and July 1994 for complaints associated with spontaneous pneumothorax. Sixteen patients were male and six female, with a mean age of 30±12 yrs. Ten patients had right-sided pneumothorax. One patient was known to have pulmonary emphysema. In none of the patients was immediate treatment with a chest tube required.

Chest radiography

A total of 54 paired upright chest radiographs in maximal inspiration and expiration was available in these patients. In three patients, more than one pair of chest radiographs was available for inspection. Chest radiographs were included if they showed a small apical pneumothorax without a detectable visceral pleural stripe near the lateral chest wall.

Chest radiography was performed with standard stationary equipment (Siemens Vertix with Polimat generator and Philips Vertical Diagnost H with M50CP generator) at 125 kVp and 2–4 mAs.

Densitometry

Densitometry was performed using a densitometer which measured the intensity of visible light transmitted through a chest radiograph after it was illuminated, expressed as optical density (OD). The range of OD which is encountered in radiography extends from 0.25 (white) up to 2.5 (black). Contrast between two points on a radiograph is defined as being equal to the difference in the OD at these points. The minimum contrast which can be detected visually is 0.02. The physics of densitometry has been described previously [12].

The ODs of 54 chest radiographs during maximal inspiration and expiration of all patients were measured with a densitometer (X-rite 3001). Three areas (surface=0.5 cm^2) on each chest radiograph were identified for measurement of OD. Area 1: the intervertebral space between the first and second thoracic vertebrae, which did not change significantly during respiration. Area 2: the most peripheral part of the affected lung parenchyma near the visceral pleura opposite the pneumothorax, without overprojection of ribs or presence of pulmonary consolidation. Area 3: the intrapleural space near the visceral pleura opposite to Area 2, without overprojection of ribs. Contrast was determined by the difference in OD of Area 2 (lung parenchyma) and Area 3 (intrapleural airspace) during maximal expiration and inspiration.

Statistics

The linear correlation coefficients (Pearson) of OD of Areas 1, 2 and 3 between paired chest radiographs were calculated. In paired chest radiographs the significance of differences in mean OD of Areas 1, 2 and 3 and also in contrast were calculated by paired samples t-tests. A p-value less than 0.05 was considered to be statistically significant.

Results

Figure 1 shows the scatterplot of OD of all areas in paired inspiratory and expiratory chest radiographs. Significant correlations of OD of each area between paired inspiratory and expiratory chest radiographs were demonstrated. The following correlation coefficients were calculated: Area 1, r=0.89, p<0.0001; Area 2, r=0.75, p<0.0001; and Area 3, r=0.81, p<0.0001.

Table 1 shows the results of the mean OD and contrast of the three different areas in the paired chest radiographs.

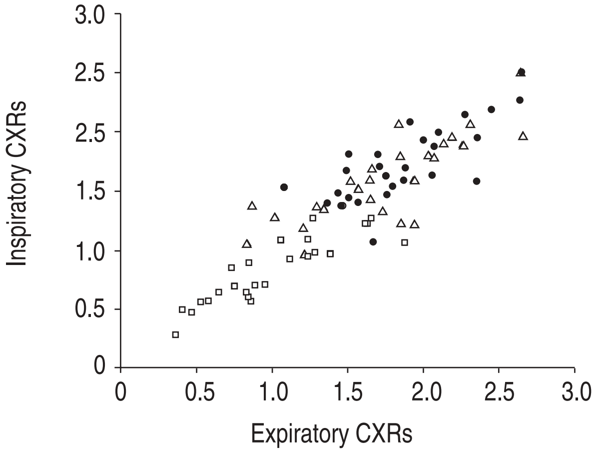

Fig. 1. – Scatterplot of optical density (OD) of all areas in paired chest radiographs (CXRs). ❑: Area 1; ●: Area 2; Δ: Area 3.

The ODs of all areas in expiratory chest radiographs were significantly higher than in inspiratory chest radiographs. Contrast between pulmonary parenchyma and intrapleural air in inspiratory and expiratory films did not differ significantly.

Discussion

The radiological diagnosis of a small apical pneumothorax can be made by identifying the visceral pleural line or by detecting air in the pleural cavity [1, 2, 4]. However, the visceral pleural line is not always easy to detect due to the ribs and clavicular shadows which may parallel the visceral pleura [6, 7]. Air in the pleural space is seen as a homogeneous zone without signs of bronchi or vessels lying over the collapsed apex of the lung. Because air is less dense than lung tissue, this results in a difference in OD of these two parts on chest radiography, which is noticed by the observer as contrast [12].

Present day standard textbooks recommend performance of inspiratory and expiratory chest radiographs in patients suspected of a pneumothorax [1–5]. We are aware of only two studies that have evaluated the routine usage of additional expiratory chest radiographs in diagnosing pneumothoraces. Both studies demonstrated that expiratory chest radiographs gave no additional clinical information than inspiratory chest radiographs [9, 10]. Less than 4% of pneumothoraces were not seen on inspiratory chest radiographs.

Table 1. – Mean OD and contrast of different areas on expiratory and inspiratory chest radiographs (n=54)

Chest radiographs	Inspiration	Expiration
Reference area (Area 1)	0.86±0.29	1.03±0.41**
Lung parenchyma (Area 2)	1.58±0.36	1.73±0.32*
Intrapleural air (Area 3)	1.73±0.49	1.87±0.40*
Contrast (ΔOD Area 3-2)	0.15±0.27	0.14±0.31

Values are presented as mean±SD. OD: optical density; NS: not significant. *: p=0.01; **: p<0.001.

Several reasons have been suggested as to why expiratory chest radiographs would result in better visualization of particularly small apical pneumothoraces. During maximal expiration, the lung volume is decreased by the vital capacity causing the intrapleural air to occupy a relatively larger part of the thoracic cavity than during inspiration, resulting in enlargement of the pneumothorax [2, 5]. The external compression of lung tissue would result in enhanced contrast between intrapleural air and pulmonary parenchyma and increased thickening of the visceral pleura [1–4, 8]. However, it has been doubted whether lung tissue density will increase during progressive collapse of the lung and increasing size of the pneumothorax. Both blood flow and air content would diminish, leaving the lung tissue density unchanged [1, 6, 11].

The difference of OD between expiratory and inspiratory chest radiographs ranged 0.14–0.17. The minimum difference in OD which can be detected visually on a chest radiograph is about 0.02 [12]. In our study, the expiratory chest radiographs had significantly higher OD in all areas, and no significant difference of contrast between intrapleural air and pulmonary parenchyma was found in either type of chest radiograph. This resulted in increased overall blackening of expiratory chest radiographs without differences in contrast compared to inspiratory films. We also demonstrated excellent correlations of OD between different areas on the paired inspiratory and expiratory chest radiographs, indicating that the differences in OD between paired chest radiographs were consistent.

The OD on radiographs is proportional to the radiation exposure [12]. The radiation exposure is determined by the milliamperage of the X-ray tube and the radiation exposure time, monitored by the ionization chamber. Two ionization chambers at both lung apices are activated during the making of a posteroanterior chest radiograph. If the lung tissue density changed during expiration, the ionization chambers would be responsible for equal OD on inspiratory and expiratory chest radiographs. However, during the expiratory manoeuvre, the intercostal muscles contract, the intercostal spaces are narrowed, and the position of the scapulae changes. This results in an increased density of extrapulmonary tissue over both lungs. This increased density means that increased radiation exposure is required before the monitoring ionization chambers receive the same number of photons as occurs with inspiratory chest radiographs. Assuming that the lung tissue density as well as the density of the tissue in the intervertebral space are not changed during expiration, this results in equally increased OD in the area of lung tissue, surrounding intrapleural air and intervertebral space, which was indeed confirmed in our study. Visual contrast was similar on both chest radiographs; indicating that lung tissue density did not alter during expiration.

In conclusion, expiratory chest radiographs do not improve visibility of small apical pneumothoraces by enhanced contrast between pulmonary parenchyma and intra-pleural air. Moreover, expiratory chest radiographs show equally increased OD in the area of lung tissue and intra-pleural air, caused by increased extrapulmonary tissue density during expiration, resulting in increased radiation exposure monitored by the ionization chambers of the radiological equipment. It remains unclear whether other reasons are responsible for the assumed improvement of detection of pneumothoraces on expiratory chest radiographs. Possibilities might be the change in position of the lung and thoracic cage, or a relative increase in size of the small pneumothorax during expiration.

For daily routine, it is unnecessary to continue obtaining inspiratory and expiratory films because most pneumothoraces are seen on inspiratory chest radiographs. The few small pmeumothoraces that might have been missed are of little clinical value, since for these patients no treatment is necessary. Only if ascertaining whether a small pneumothorax may have major consequences, for instance by preventing other expensive and invasive investigations, should one perform an expiratory film.

Addendum

In order to evaluate whether small apical pneumothoraces are better detectable on expiratory chest X-rays, two independent observers (one radiologist and one pulmonologist) evaluated, without any additional information, 78 chest X-rays in random order. These consisted of 24 normal inspiratory chest X-rays and 27 paired inspiratory and expiratory chest X-rays with small apical pneumothoraces. All pneumothoraces were confirmed by thoracic computer tomography, which was performed for the detection of bullae, sufficiently large to justify bullectomy. The percentage of misdiagnosing apical pneumothoraces was 3.8% (3/78). The pneumothoraces which were not detected were equally divided among the inspiratory, expiratory and normal chest X-rays. The interobserver agreement was 96%.

From these findings we conclude that the routine addition of expiratory chest X-rays does not sinificantly improve the diagnostic yield from inspiratory chest X-rays. Furthermore, the practice of requesting only an expiratory chest X-ray in a suspected case of pneumothorax cannot be justified from our findings. An inspiratory chest X-ray is needed to investigate other possible causes of the patient's complaints and an occasional missed small apical pneumothorax will rarely have therapeutical consequences. By abandoning the routine addition of expiratory chest X-rays in patients suspected of a pneumothorax, we can avoid unnecessary radiation exposure and reduce health care costs for the community.

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