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Research article

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Chest X-ray imaging after chest tube removal in children undergoing congenital heart surgery: May be life-saving in redo patients

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Ethics Committee Approval
The Ethical Committee of Clinical Researches (Ethics Committee of İzmir Tepecik Training and Research Hospital) granted permission for this study with the decision number 2018/22-06-112. All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Abstract

Background/Aim: Parallel to the developments in congenital heart surgery, the number of children undergoing resternotomy (redo) heart surgery is increasing. In this specific group of patients, post-operative pneumothorax (PTX) and atelectasis are preventable respiratory complications. However, in the literature, pediatric data are still limited. In this study, we draw attention to the frequency and importance of PTX, a post-operative respiratory complication in redo patients. We investigate the necessity for routine chest X-rays to detect PTX following chest tube removal after closed or open-heart operations for congenital heart disease.

Methods: A total of 554 consecutive pediatric patients who underwent cardiac surgery were analyzed. The study was designed as a retrospective cohort study. The patient's demographic data, clinical characteristics with chest tube removal, and pathologies detected by chest X-ray were recorded. Patients were divided into non-redo and redo groups or subgroups. Patients who developed PTX (n = 24) were divided into subgroups: asymptomatic or symptomatic and large or small. Data analysis and statistical comparison between the groups were performed with independent-samples t-test or Mann-Whitney U test.

Results: In 24 (4.3%) of the 554 patients included in the study, PTX was detected in the post-operative evaluation after chest tube removal. Of the PTX cases, 15 (62.5%) were small, and nine (37.5%) were large. Ten (41.6%) patients were symptomatic, while nine patients had large PTX, and one patient with small PTX was identified. There were significantly more cases of large PTX in redo cases than in non-redo cases (P = 0.038). PTX was significantly more symptomatic in redo patients than non-redo patients (P = 0.031).

Conclusion: In patients undergoing cardiac surgery for the first time, a detailed clinical assessment reduces the likelihood of post-procedure PTX and makes routine chest X-ray imaging unnecessary. Conversely, clinical follow-up of these patients in terms of PTX should be essential for possible complications. However, clinical signs of late PTX development in the first 24–48 h after chest tube removal in patients undergoing redo cardiac surgery should be followed carefully by the clinician, and chest X-ray imaging should be routinely performed.

Keywords: Chest tube, Complication, pneumothorax, Redo, Radiography

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Introduction

Mediastinal and pleural tubes are routinely placed following cardiothoracic surgery to provide drainage from the chest for air, blood, fluid, or pus [1]. Chest X-rays (CXRs) have been used routinely following a chest tube's removal to detect early post-operative pathology, particularly pneumothorax (PTX). It is also essential to repeat CXRs following the chest drain insertion to confirm the tube's positioning, check the extent of lung re-expansion, and exclude the possibility of complications after removal of the chest drain [1, 2]. However, some studies have suggested that the routine use of CXRs is unnecessary for a significant portion of cardiac surgery patients [1–3].

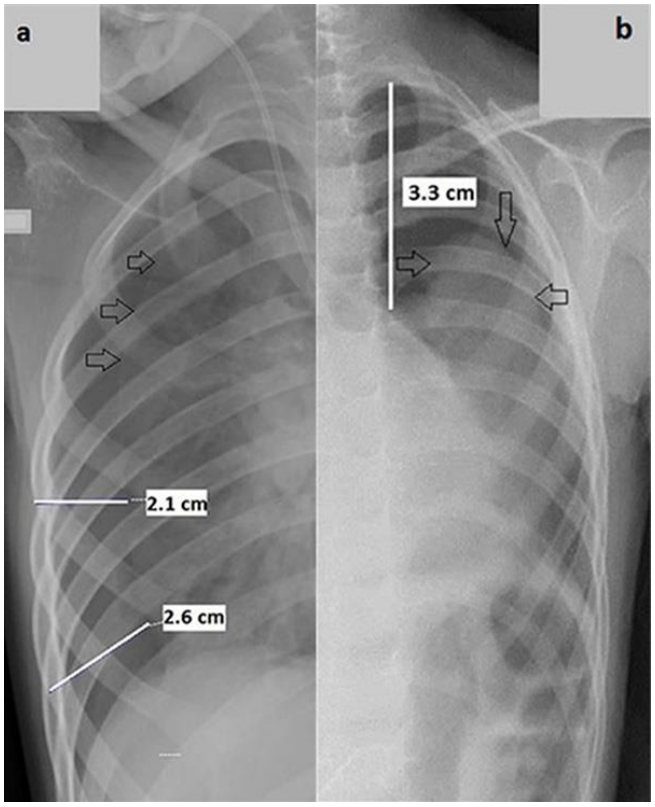
This study aims to determine if routine CXR is necessary to detect PTX following chest tube removal after closed or open-heart operations for congenital heart disease or which patients need routine CXR.

Materials and methods

Hospital records of 554 consecutive pediatric patients who underwent open-heart surgery with median sternotomy due to congenital heart disease between November 2017 and January 2019 and at Izmir Tepecik Training and Research Hospital Congenital Heart Surgery Clinic were reviewed. The exclusion criteria for the study consist of patients older than 18 years of age, those with intraoperative lung injury, air leakage from the thoracic tube in the post-operative period, those who underwent cardiopulmonary resuscitation, and those who underwent revision surgery due to hemorrhage. We used polyvinylchloride or silicone chest tubes (Bıcakcilar®, Istanbul, Turkiye) between 12 Fr and 32 Fr, depending on the patient's size. Thoracic tube drainage was sufficient in patients with a pleuro-pericardial window created intraoperatively for pericardial-pleural passage since mediastinal drainage would be sufficient for the pleura. Therefore, mediastinal tubes were not placed in these patients. Data were collected, including demographic characteristics (age, sex, and body surface area), perioperative data (cardiac complexity score [RACHS], type of surgery [redo or non-redo], position, number and duration of the drain, and number of CXR), and outcomes (duration of hospital stay, number, and size of PTX). Patients with dyspnea, tachypnea, or increased oxygen demand were symptomatic. The need for oxygen support was determined according to the patient's oxygen saturation (SaO_2) level. If the SaO_2 level was 90% and below, oxygen support was given to these patients. All patients underwent CXR in the pediatric cardiac unit after admission to the intensive care unit (ICU) and within 4 hours after chest tube removal.

A plain CXR was utilized for the quantification of the size of PTX. The British Thoracic Society guidelines divide PTX into small and large, based on the distance from the visceral pleural surface (lung edge) to the chest wall. If the PTX is greater than 2 cm, it is classified as a large PTX occupying approximately 50% of the hemithorax (Figure 1) [4]. A large PTX is an objective indication for drainage [5]. The PTX is assessed using the Picture Archive Computer Communication System. In our clinic, most patients with chest tubes removed are taken to the semi-ICU. The remaining patients are followed for one more day in the intensive care unit and then taken to the patient ward. All patients are re-evaluated with CXR imaging before admission to the patient ward.

Figure 1: (a, b) Chest X-ray images show quantification of large PTX size in different patients–the classic appearance of PTX with readily apparent visceral pleural line (black arrows). Interpleural distance at the level of the hilum (a) >2 cm represents a large PTX, and the distance from the lung apex to the cupola (b) >3 cm represents a large PTX.



The criteria for chest tube removal was less than 5 ml/kg/day drainage from the pleural space. Before removing the chest tube, it was confirmed that no PTX was observed in the CXR taken on the same day. Chest tubes were checked at the patient's bedside for fluctuation and the presence of air leaks. PTX was not detected in patients with CXR performed within 2 h after tube removal. The same surgical team removed the drains as per unit protocol. The use of ketamine is standard care in our unit for procedural sedation. The patients who received the dexmethothymidine infusion in ICU continued before and after removing the tube. Chest tubes were removed at the end of inspiration. After tube removal, patients were monitored closely for any signs of respiratory distress or cardiovascular compromise, and the drain entry area was covered with vaseline gauze to prevent air leakage in the early period.

Written informed consent was obtained from the parents of all patients. The study was conducted in accordance with the Declaration of Helsinki principles and was approved by the ethics committee. Ethics committee approval (June 22, 2018) decision number 2018/22-06-112 was obtained by the University of Health Sciences Tepecik Training and Research Hospital Clinical Research Ethics Committee.

Statistical analysis

Statistical analysis of the data was performed using SPSS 16. Mean (standard deviation) was used to summarize numerical data, whereas frequency (n) and percentage (%) distributions were used to summarize categorical data. The distribution of numerical data was evaluated using the Kolmogorov-Smirnov test. In addition, normally distributed numerical data in two independent groups was analyzed using

the independent-samples t-test, and the distribution of non-normally distributed numerical data in two independent groups using the Mann-Whitney U test at 95% confidence with a significance of $P < 0.05$.

Results

The clinical characteristics of all patients who underwent congenital cardiac surgery are shown in Table 1. The mean age of the patients was 4.1 (3.3) years, and 265 (47.8%) were males. Twenty-four patients (4.3%) developed PTX, of which 15 were small PTX while nine were large PTX. In patients with large PTX, seven (77.7%) were redo surgery patients. Twenty-six (4.69 %) were followed up as intubated while the chest tube was removed. However, PTX did not develop in any of these patients after chest tube removal.

Table 1: Demographic and clinical characteristics of patients.

Patients, n	554
Non-Redo surgery, n (%)	469 (81%)
Redo surgery, n (%)	85 (19%)
Mean age (years), mean (SD)	4.1 (3.32)
BSA (m²), mean (SD)	0.5 (0.65)
Male (%)	265 (47.8%)
RACHS score, mean (SD)	2.3 (0.75)
Drains	
Mediastinal, n	381
Pleural, n, right/left/bilateral	68/98/45
Mean duration of a drain (days), mean (SD)	2.12 (0.9)
Number of chest drains, mean (SD)	1.7 (0.3)
Mean number of CXRs, mean (SD)	2.68 (0.55)
Hospital LOS (days), mean (SD)	6.56 (1.27)
Number of PXT, n (%)	24 (4.3%)
Small, n (%)	15 (62.5%)
Large, n (%)	9 (37.5%)

BSA: body surface area, CXR: chest X-ray, LOS: length of stay, PTX: pneumothorax.

The findings and outcomes in the patients with PTX after chest tube removal are shown in Table 2. In the ten (41.6%) patients with PTX who had clinical signs or symptoms, we identified nine (37.5%) patients with large PTX and one (4.1%) patient with small PTX. The patient with a small PTX became symptomatic and had interstitial lung disease. Fourteen patients with PTX were identified to have no clinical signs or symptoms. A total of nine patients (eight with large PTX and one with small PTX, which enlarged later) underwent considerable interventions.

Table 2: Findings and outcomes in patients with PTX.

	n	%
Patients	24	4.3
Number of PXT		
Large (L)	9	37.5
Small (S)	15	62.5
Clinical findings		
Asymptomatic (L/S)	14 (0/14)	58.4
Symptomatic (L/S)	10 (9/1)	41.6
Subcutaneous emphysema	7 (3/4)	40
Tachypnea	9 (6/3)	45.8
Increased oxygen requirement	10 (8/2)	41.6
Other pathology detected on CXR		
Atelectasis	6	25
Pulmonary congestion	3	12.5
Pleural effusion (minimal, <10 mm)	10	41.6
Intervention following CXR		
Clinical observation, no drain	15	62.5
Drain reinsertion	9	37.5
Outcome		
Dissolved spontaneously	15	62.5
Drain removed on day 2	9	37.5

CXR: chest X-ray, PTX: pneumothorax.

The drains were removed on days 2–4 in all patients with PTX, and no patient needed reintervention. The clinical observation was continued in 15 patients with small PTX, and no symptoms were observed. Large PTX in redo cases was statistically significantly more than in non-redo cases ($P = 0.038$, 7 *vs.* 2 patients). In addition, the PTX of patients who underwent redo surgery was statistically more symptomatic ($P = 0.031$, 8 *vs.* 2 patients). A comparison of surgery type groups (redo and non-redo) in patients with PTX is shown in Table 3, and a comparison of PTX size and symptom status is shown in Table 4.

Table 3: Comparison of surgery type groups in patients with PTX.

	Non-Redo	Redo	*P*-value
Asymptomatic (n = 14)	9 (64.3%)	5 (35.7%)	0.064
Symptomatic (n = 10)	2 (20%)	8 (80%)	0.031
Small PTX (n = 15)	9 (60%)	6 (40%)	0.086
Large PTX (n = 9)	2 (22.2%)	7 (77.8%)	0.038

PXT: pneumothorax.

Table 4: Comparison of PTX size and symptom status.

	Small PTX	Large PTX	*P*-value
Asymptomatic (n = 14)	14 (100%)	0 (0%)	<0.01
Symptomatic (n = 10)	1 (10%)	9 (90%)	<0.01

PXT: pneumothorax.

Discussion

The current value of using CXRs following chest drain removal remains controversial [1–3]. In our clinic, as in most centers, routine CXRs are the parts of a standard practice following chest drain removal in patients undergoing cardiothoracic surgery to eliminate PTX or collection in the thoracic cavity. Although the first CXR image after chest tube removal was normal in this study, PTX was detected in 4.3% of patients on the radiograph taken 24 h later. A literature review revealed six studies detecting pathology in routine CXR ranging from 2% to 40% compared to 79% in clinically indicated CXRs [1, 6–9]. Furthermore, the incidence of therapeutic intervention requirements was about 1.5% [1–3]. In our study, the intervention rate following CXR after chest tube removal was 1.6% (9 patients), and seven were redo cases.

In most patients, clinical assessment helps recognize PTX cases where routine CXRs are not required [8, 10, 11]. Several studies have shown that routine CXRs are unnecessary regardless of whether pleural and mediastinal tubes are used [1, 7–12]. Clinical symptoms vary and may range from no symptoms to severe dyspnea depending on the PTX size, although some common signs include tachypnea, dyspnea, cough, and tachycardia [4, 5]. In addition, the patient's respiratory capacity can affect the manifestation of symptoms. In our study, at least one of the signs and symptoms of PTX was present in all patients with large PXT. The most common symptom of patients with PXT was increased oxygen requirement (10 patients, 41.6%) and tachypnea (11 patients, 45.8%).

Cardiac surgery requiring redo is technically challenging due to adhesions, scars, and previous graft placements and carries a higher intraoperative and post-operative risk. Nevertheless, redo operations are more common in pediatric patients [13]. In patients who underwent redo cardiac surgery, adhesions between the pleura, chest wall, and mediastinal structures may have caused iatrogenic lung injury. The main factors leading to the development of PTX in redo patients are the minimal injuries associated with the dissection of pleural adhesions and the disruption of respiratory function due to pain [14]. The increased respiratory capacity following clinical recovery can lead to air escaping through the lung tissue at points where the pleural adhesions are damaged. Therefore, increased respiratory capacity following the clinical improvement in redo cases, starting from the post-operative first day, can increase

PTX complications, and substantial complications may be prevented following routine CXRs in patients undergoing redo surgery. In addition, there may be areas of micro-damage in the lung tissue during mediastinal exploration and dissection of the planes in redo patients. Air leaks associated with areas of micro-injury in the lung parenchyma may be overlooked during the bedside air leak assessment. There was no considerable air leak in redo patients who developed PTX before removing the thoracic tube. A potential reason for this is that there could have been air leaks that were too small to be seen with the naked eye. Hence, we believe that routine CXR effectively increases the probability of identifying PTX in patients who underwent redo cardiac surgery due to lung injuries associated with pleural adhesions.

A higher rate of large PTX was detected in redo cases in our study, and a statistically significant difference was found. However, PTX was observed to be more symptomatic in redo cases, and also, in this respect, a statistical difference was found. Therefore, the use of routinely appropriate X-ray imaging generally outweighs the risk of possible complications or disease detection in redo cases. Therefore, the routine use of CXR should be considered in the presence of redo cardiac surgery.

In a prospective, observational study including a total of 214 consecutive patients undergoing cardiac surgery and routine CXRs within 24 hours of drain removal, Tolsma et al. [9] reported that, for the majority of the patients, it seemed reasonable to reduce the number of routine CXRs within the first 24 hours of ICU stay. However, the optimal timing for performing CXRs remains unclear [8, 9, 12]. In our study, PTX was diagnosed in all patients between post-operative days 1 and 2. Thus, these were explicitly post-operative redo cases that required intervention.

As with our study results, CXR imaging is predominant in redo patients. Children with congenital heart disease are exposed to increased amounts of low levels of ionizing radiation with each CXR, computed tomography, and cardiac catheterization procedure that they undergo, and there are risks associated with using X-ray imaging. Because the number of safe exposures to ionizing radiation is unknown, efforts should be made to minimize this risk by reducing unnecessary exposure to ionizing radiation. In addition, these patients should be protected from any unnecessary radiographs [15]. Further to the risks associated with increased exposure to ionizing radiation, routine CXRs utilize radiology, medical and nursing resources and interrupt nursing care.

Based on our results, we believe that careful observation for developing PTX is required in patients undergoing redo heart surgery. Suppose tachypnea, desaturation, and an increase in oxygen demand are observed in the post-operative follow-up of redo patients. In that case, PTX that may develop in the period after chest tube removal should be considered. Interpreting the symptoms in favor of atelectasis and applying non-invasive positive pressure ventilation to the patient may aggravate PTX. According to our results, we can say that the conventional CXR imaging after chest tube removal in the patient group undergoing non-redo cardiac surgery is unnecessary, as stated in previous publications. However, in patients with respiratory symptoms, it is undoubtedly necessary to exclude PTX with CXR in addition to other lung pathologies.

Although this research has fulfilled its aims, there were some unavoidable limitations, such as this being a single-center retrospective study and limited by the number of patients enrolled to participate. Therefore, the sample size in redo cardiac surgery was not large enough to make a definitive conclusion. Also, the size and classification of PTX were problematic in the pediatric patient group because chest size varies according to the age and physical size of the patient. While there are many methods to calculate PTX size with CXR in adult patients, there are still no cut-off values related to age and weight in the pediatric age group [16]. This topic should therefore be addressed in future studies.

Conclusions

In patients undergoing cardiac surgery for the first time, a thorough clinical assessment before chest tube removal reduces the likelihood of post-procedure PTX and makes CXR unnecessary. However, clinical follow-up of these patients in terms of PTX should be essential for possible identifying complications. According to the results of our study, the use of CXR after chest tube removal in patients who underwent surgery for the first time should be decided according to clinical indications. Based on our study results, we conclude that routine CXR should be used after chest tube removal in patients who have undergone redo cardiac surgery. When respiratory symptoms develop in the late post-operative period, especially in children who have undergone redo surgery, a possible PTX should be excluded by performing a new CXR.

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