

Efficacy of Chest X-Rays after Drain Removal in Adult and Paediatric Patients Undergoing Cardiac and Thoracic Surgery: A Systematic Review

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October 5, 2022

Abstract

Background: Chest X-rays are routinely obtained after removal of chest drains in patients undergoing cardiac and thoracic surgical procedures. However, a lack of guidelines and evidence could question the practice. Routine chest X-rays increase exposure to ionising radiation, increase healthcare costs and lead to overutilisation of available resources. This review aims to explore the evidence in the literature regarding the routine use of chest X-rays following the removal of chest drains. **Materials & Method:** A systematic literature search was conducted in PubMed, Medline via Ovid, Cochrane central register of control trials (CENTRAL) and ClinicalTrials.gov without any limit on the publication year. The references of the included studies are manually screened to identify potentially eligible studies. **Results:** A total of 375 studies were retrieved through the search and 18 studies were included in the review. Incidence of pneumothorax remains less than 10% across adult cardiac, and paediatric cardiac and thoracic surgical populations. The incidence may be as high as 50% in adult thoracic surgical patients. However, the re-intervention rate remains less than 2% across the populations. Development of respiratory and cardiovascular symptoms can adequately guide for a chest X-ray following the drain removal. As an alternative, bedside ultrasound can be used to detect pneumothorax in the thorax after the removal of a chest drain without the need for ionising radiation. **Conclusion:** A routine chest X-ray following chest drain removal in adult and paediatric patients undergoing cardiac and thoracic surgery is not necessary. It can be omitted without compromising patient safety. Obtaining a chest X-ray should be clinically guided. Alternatively, bedside ultrasound can be used for the same purpose without the need for radiation exposure.

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Conclusion: A routine chest X-ray following chest drain removal in adult and paediatric patients undergoing cardiac and thoracic surgery is not necessary. It can be omitted without compromising patient safety. Obtaining a chest X-ray should be clinically guided. Alternatively, bedside ultrasound can be used for the same purpose without the need for radiation exposure.

Keywords: Chest X-ray, Chest Drain, Chest Tube, Cardiac surgery, Thoracic surgery

INTRODUCTION

Chest drains are widely used in cardiothoracic surgery. They are left in place after surgery for evacuation of air and fluids accumulated in the thoracic cavities. It has been a standard practice to obtain a routine chest X-ray once the chest drain is removed. There is no clear guidance regarding the necessity and timing of the chest X-rays after removal, yet they are rather empirically obtained.¹⁻³ American College of Radiology does not support the routine use of chest X-rays after the removal of chest drains.⁴

Undifferentiated routine use of chest X-rays has several disadvantages. It increases false-positive rates, overall costs and leads to overutilisation of the healthcare resources.^{5,6} Furthermore, it increases the exposure to ionising radiation in patients, especially important in children because of the cumulative risk of malignancy later in life.^{3,7} In addition, routine use of chest X-rays does not influence mortality rate, length of intensive care stay or hospital stay.⁵ This review aims to explore the evidence in the literature regarding the routine use of chest X-rays in patients, both adults and children, undergoing cardiac and thoracic surgical procedures.

MATERIALS & METHODS

This systematic review follows the 2020 updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline.⁸

Literature search

We conducted a systematic literature search of studies investigating the effectiveness of routine chest X-rays after drain removal in patients undergoing cardiothoracic surgery in Pubmed, Medline via Ovid, Cochrane central register of control trials (CENTRAL) and ClinicalTrials.gov. There was no limit on the publication year of the studies, and the last search was performed on 17 April 2022. The keywords used in combination with Boolean operators include “cardiac surgery”, “thoracic surgery”, “cardiothoracic surgery”, “chest drain removal”, “chest tube removal”, “chest X-ray” and “chest radiograph”. The references of the included studies and relevant reviews are also manually screened for identifying potentially eligible studies.

Inclusion and exclusion criteria

Original research studies reporting the incidence of pneumothorax and chest X-ray findings after the chest drain removal in both adult and paediatric patients undergoing cardiac and thoracic surgery procedures were included. The exclusion criteria included case reports, case series, reviews and studies on chest X-rays after drain removal on the trauma patients exclusively.

Study screening, data extraction and outcome measures

Two authors (KPPH, KEH) independently reviewed the included studies and performed data extraction. Disagreements between the authors were resolved by consensus or by escalating to another author (MST). The following set of data was extracted: (i) study characteristics including study design, (ii) patient population characteristics, (iii) incidence of pneumothorax after removal of drain, (iv) clinical signs and symptoms following the removal of chest drain, and (v) re-intervention (re-insertion) of chest drain. The primary outcome measure is the incidence of pneumothorax, whereas, the secondary outcomes include the need for re-intervention following the removal of the chest drain, and signs and symptoms after chest drain removal.

Quality assessment

The quality of the included studies was independently assessed by two authors (KPPH, KST) using the Methodological Index for Nonrandomized Studies (MINORS).⁹ All included studies are moderate-quality studies with a global score ranging from 8-12 out of 16.

RESULTS

A total of 375 studies were retrieved through our search, and 80 duplicates were removed. The titles and abstracts of the remaining 295 studies were screened to identify potentially eligible 22 studies. After the full-text screening, 18 studies were included in the systematic review. Eleven studies were conducted in the United States of America^{1-3,7,10-16}, four studies in the United Kingdom¹⁷⁻²⁰, one in the Netherlands⁵, one in Germany²¹ and one in Iran⁶ (Table 1). No other studies were identified through manual screening of references of the included studies and relevant reviews. PRISMA flow diagram is demonstrated in Figure 1. Adult patients refer to patients at least 18 years of age, and paediatric patients refer to patients under the age of 18 in the studies. Re-intervention is defined as the re-insertion of a chest drain.

Cardiac surgery adult patients

One simple randomised trial⁶, three prospective cohort studies^{5,11,19} and one retrospective cohort study¹⁸ evaluated the efficacy of routine chest X-rays constituting a total of 2,080 adult patients undergoing cardiac surgery procedures, which includes coronary artery bypass grafting (CABG), valve surgery and atrial septal defect repair, either as isolated procedures or in combination. The mean duration of chest drain before removal is 1.4-1.8 days^{11,18,19}, and a routine chest X-ray is obtained within 3-4 hours after the removal.^{6,19}

If a chest X-ray is obtained after the removal, the incidence of pneumothorax ranges from 1.3-9.3% with up to 1.3% of patients developing respiratory symptoms or haemodynamic changes and re-intervention was required in 0.5-1.3% of the patients.^{5,6,11,18,19} If no routine chest X-ray was performed after the drain removal, 5.0-11.8% of the patients developed respiratory symptoms or haemodynamic changes, of which 0.7-2.5% would require re-intervention.^{6,18}

Cardiac surgery paediatric patients

Two prospective cohort studies^{10,20} and two retrospective cohort studies^{7,14} have examined the incidence of pneumothorax and the efficacy of chest X-rays after the chest drain removal. It includes a total of 12,171 paediatric patients undergoing congenital cardiac surgery operations. The mean age of the patients ranges from 0.2-2.7 years. The mean duration of chest drain varies from 1-6.4 days after the procedure, and a chest X-ray is performed within 2-6 hours after the removal of the drain.^{7,10,14,20}

The incidence of pneumothorax after chest drain removal is 0.21% in a study with 11,651 patients⁷ and goes as high as 13.6% in other studies.^{10,14,20} Clinical symptoms developed in 0.1-1.87% of the patients, and 0.1-1.6% of patients would eventually undergo re-intervention for the pneumothorax.^{7,14}

Thoracic surgery adult patients

Three prospective studies^{15,17,21} and two retrospective studies^{1,2} including 921 patients explored the effectiveness of routine chest X-rays in adult patients undergoing thoracic surgical procedures, which include both video-assisted thoracoscopy (VATS) and open surgery. The patients have a mean age of 60-64 years in the studies and had the chest drains for an average duration ranging from 1-4 days. A chest X-ray is usually performed 2-4 hours after the removal of the chest drain.¹

The incidence of pneumothorax on the chest X-ray after removal of the drain varies greatly from 4 to 48%.^{1,2,15,17,21} Nonetheless, only up to 0.5% of patients need a subsequent intervention after the positive radiographic findings.^{1,2,17} The incidence of pneumothorax in asymptomatic patients is approximately 32.8%, but none of the patients required re-intervention. They only had clinical observation and repeated the chest X-rays.¹

Thoracic surgery paediatric patients

Four retrospective studies with a total of 708 paediatric patients investigated the necessity of performing routine chest X-rays after the removal of chest drains.^{3,12,13,16} The mean age of patients in the studies ranges from 7.5 to 9.4 years. The patients underwent various thoracic surgical procedures including VATS and open surgeries. The average length of the chest drain is 3.7-7.2 days before removal, and the chest X-rays are obtained within 2-6 hours after the removal of the drain.

In the post-drain removal chest X-rays, the incidence of pneumothorax is 3.1-3.9%^{3,12} with a re-intervention rate is 0.7-1.7%.^{12,13,16} Clinical symptoms were present in all patients who required re-intervention. In asymptomatic patients, the incidence of pneumothorax is 1.8%¹³, of which 0.4-0.9% of the asymptomatic patients would undergo further re-intervention.^{13,16}

Bedside ultrasound versus chest X-ray after removal of chest drain

There are two prospective observational studies with combined 173 patients, which evaluated the role of bedside ultrasound in comparison to using chest X-ray after removal of a chest drain to detect pneumothorax, predominantly in the thoracic adult surgical population.^{15,21} The overall sensitivity of the bedside ultrasound is 32%, however, the sensitivity is increased to 100% in detecting pneumothoraces of 3 cm or larger, and the specificity is 85%.²¹ There is a strong association between ultrasound and chest X-ray with a therapeutic agreement of 97%.²¹ There is perfect agreement between the two methods with a κ statistics value of 1.000.¹⁵

DISCUSSION

Studies in the literature recommend that there is no need to routinely perform a chest X-ray after the removal of a chest drain following cardiac or thoracic surgery. Diverse patient populations undergoing

different cardiac and thoracic surgeries have demonstrated the incidence of pneumothorax that requires intervention after removal of chest drain is low and it is highly correlated with the development of clinical symptoms. Approximately 1-2% of patients would require re-intervention after the chest drain removal, with the exception of the adult thoracic surgical population, which may be up to 10% of the patients. The high incidence could possibly be contributed by the preexisting pulmonary pathology and complex physiological changes within the pleural space associated with the thoracic surgical procedures.¹

It was previously thought the paediatric population might develop a higher rate of pneumothorax occurrence since young children are unlikely to be able to follow breathing commands during the chest drain removal.²⁰ However, it is not the case when a large study with more than 11,000 paediatric patients in cardiac surgery demonstrated the incidence of pneumothorax as less than 1%.⁷ Nevertheless, a good removal technique is essential to reduce the rate of complications.²⁰

Current literature agrees that performing a chest X-ray is only necessary if a patient develops respiratory or cardiovascular symptoms after the removal of the chest drain given that most clinically significant pneumothorax will eventually develop clinical symptoms. Omitting a chest X-ray will significantly reduce the healthcare cost^{1,12,14,18,19}, as well as radiation exposure in paediatric patients.¹² Moreover, routine chest X-rays lead to additional subsequent chest X-rays without the further need for intervention.^{2,14,18}

On the other hand, a clinically significant pneumothorax might develop after the removal of the chest drain despite the lack of symptoms. Especially in very young patients, who are not able to communicate, it could be concerning that a moderate or large pneumothorax may not exhibit clinical symptoms in the context of a lack of good respiratory or cardiovascular physiological reserve, despite very few of them requiring subsequent intervention.⁷ Assessment of clinical symptoms solely might not be sufficient, and subgroups of patients with risk factors should be identified to acquire chest X-rays following the removal of the chest drain.^{5,7} Nonetheless, a greater majority of studies reinforce the fact that routine use of chest X-rays can be eliminated without compromising patient safety.

An alternative to obtaining a chest X-ray after the removal of a drain is bedside ultrasound. Despite overall low sensitivity and specificity compared to X-rays, the bedside ultrasound is highly accurate in identifying a clinically significant pneumothorax.²¹ It is safe, has no ionising radiation, has lower cost compared to X-rays, and has rapid instant interpretation compared to ordering, obtaining and interpreting a chest X-ray. It is reproducible and requires minimum experience to detect pneumothorax, with the benefit of detecting further diagnoses such as pleural effusion and pericardial effusion.¹⁵ Yet, the use of ultrasound could be limited by subjective interpretation of findings depending on the experience of the operator, postoperative surgical dressings, and anatomical and physiological changes, especially after thoracic surgery. In spite of the limitations, an overall low incidence of pneumothorax after chest drain removal would further favour the use of bedside ultrasound instead of chest X-rays.

CONCLUSION

A routine chest X-ray following chest drain removal in adult and paediatric patients undergoing cardiac and thoracic surgery is not necessary. It can be omitted without compromising patient safety. Obtaining chest X-rays should be guided by the development of respiratory and cardiovascular symptoms. An alternative to the chest X-ray is to perform a bedside ultrasound, which is rapid, safe, cost-effective and accurately identifies pneumothorax without ionising radiation. Further research is required to identify the asymptomatic patients with a clinically significant pneumothorax, who may need subsequent intervention.

REFERENCES

1. Zukowski M, Haas A, Schaefer EW, et al. Are Routine Chest Radiographs After Chest Tube Removal in Thoracic Surgery Patients Necessary? *J Surg Res.* 2022;276:160-167. doi:10.1016/j.jss.2022.02.046
2. Porter ED, Fay KA, Hasson RM, Millington TM, Finley DJ, Phillips JD. Routine Chest X-Rays After Thoracic Surgery Are Unnecessary. *J Surg Res.* 2020;250:188-192. doi:10.1016/j.jss.2019.12.030
3. Johnson B, Rylander M, Beres AL. Do X-rays after chest tube removal change patient management? *J Pediatr Surg.* 2017;52(5):813-815. doi:10.1016/j.jpedsurg.2017.01.047
4. Suh RD, Genshaft SJ, Kirsch J, et al. ACR Appropriateness Criteria® Intensive Care Unit Patients. *J Thorac Imaging.* 2015;30(6):W63-W65. doi:10.1097/RTI.0000000000000174
5. Tolsma M, Kröner A, van den Hombergh CL, et al. The clinical value of routine chest radiographs in the first 24 hours after cardiac surgery. *Anesth Analg.* 2011;112(1):139-142. doi:10.1213/ANE.0b013e3181fdf6b7
6. Mandegar M, Shafa M, Ghazinoor M. Efficacy of routine chest X-ray after chest tube removal in patients undergoing cardiac surgeries. 2007;7(4):686-689.
7. LaGrasta C, McLellan M, Connor J. Clinical descriptors of pneumothorax following chest tube removal in paediatric cardiac surgery. *Cardiol Young.* 2021;31(1):121-124. doi:10.1017/S1047951120003467
8. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* Published online March 29, 2021:n71. doi:10.1136/bmj.n71
9. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (MINORS): development and validation of a new instrument: Methodological index for non-randomized studies. *ANZ J Surg.* 2003;73(9):712-716. doi:10.1046/j.1445-2197.2003.02748.x
10. Woodward CS, Dowling D, Taylor RP, Savin C. The routine use of chest radiographs after chest tube removal in children who have had cardiac surgery. *J Pediatr Health Care.* 2013;27(3):189-194. doi:10.1016/j.pedhc.2011.09.003
11. Eisenberg RL, Khabbaz KR. Are chest radiographs routinely indicated after chest tube removal following cardiac surgery? *AJR Am J Roentgenol.* 2011;197(1):122-124. doi:10.2214/AJR.10.5856
12. McGrath E, Ranstrom L, Lajoie D, McGlynn L, Mooney D. Is a Chest Radiograph Required After Removal of Chest Tubes in Children? *J Pediatr Health Care.* 2017;31(5):588-593. doi:10.1016/j.pedhc.2017.04.014
13. Kanamori LM, Guner Y, Gibbs D, Schomberg J. Are routine chest X-rays following chest tube removal necessary in asymptomatic pediatric patients? *Pediatr Surg Int.* 2021;37(5):631-637. doi:10.1007/s00383-020-04809-7
14. Pacharn P, Heller DN, Kammen BF, et al. Are chest radiographs routinely necessary following thoracostomy tube removal? *Pediatr Radiol.* 2002;32(2):138-142. doi:10.1007/s00247-001-0591-5
15. Saucier S, Motyka C, Killu K. Ultrasonography versus chest radiography after chest tube removal for the detection of pneumothorax. *AACN Adv Crit Care.* 2010;21(1):34-38. doi:10.1097/NCI.0b013e3181c8013a
16. Cunningham JP, Knott EM, Gasior AC, et al. Is routine chest radiograph necessary after chest tube removal? *J Pediatr Surg.* 2014;49(10):1493-1495. doi:10.1016/j.jpedsurg.2014.01.004
17. Whitehouse MR, Patel A, Morgan JA. The necessity of routine post-thoracostomy tube chest radiographs in post-operative thoracic surgery patients. *Surgeon.* 2009;7(2):79-81. doi:10.1016/s1479-666x(09)80020-6
18. McCormick JT, O'Mara MS, Papasavas PK, Caushaj PF. The use of routine chest X-ray films after chest tube removal in postoperative cardiac patients. *Ann Thorac Surg.* 2002;74(6):2161-2164. doi:10.1016/s0003-4975(02)03982-6

19. Khan T, Chawla G, Daniel R, Swamy M, Dimitri WR. Is routine chest X-ray following mediastinal drain removal after cardiac surgery useful? *Eur J Cardiothorac Surg.* 2008;34(3):542-544. doi:10.1016/j.ejcts.2008.05.002
20. Stather P, Cheshire H, Bogwandas H, Peek G. Pneumothorax post paediatric chest drain removal. *Thorac Cardiovasc Surg.* 2011;59(5):302-304. doi:10.1055/s-0030-1250357
21. Galetin T, Defosse J, Schieren M, et al. Sensitivity of chest ultrasound for postoperative pneumothorax in comparison to chest X-ray after lung resecting surgery. *Eur J Cardiothorac Surg.* 2020;57(5):846-853. doi:10.1093/ejcts/ezz332

TABLES

Table 1: Study characteristics included in the systematic review

Author	Year	Study design	Patient population	Number of patients
Pacharn et al	2001	Retrospective cohort	Cardiac surgery, paediatric	374
McCormick et al	2002	Retrospective cohort	Cardiac surgery, adult	1,000
Mandegar et al	2007	Randomised controlled trial	Cardiac surgery, adult	315
Khan et al	2008	Prospective cohort	Cardiac surgery, adult	151
Whitehouse et al	2009	Prospective cohort	Thoracic surgery, adult	74
Stather et al	2010	Prospective cohort	Cardiac and thoracic surgery, paediatric	93
Saucier et al	2010	Case control	Thoracic surgery, adult	50
Eisenberg et al	2010	Prospective cohort	Cardiac surgery, adult	400
Tolsma et al	2011	Prospective cohort	Cardiac surgery, adult	214
Woodward et al	2011	Prospective cohort	Cardiac surgery, paediatric	53
Cunningham et al	2014	Retrospective cohort	Thoracic surgery, paediatric	146
Johnson et al	2017	Retrospective cohort	Thoracic surgery, paediatric	179
McGrath et al	2017	Retrospective cohort	Thoracic surgery, paediatric	281
Galetin et al	2019	Prospective cohort	Thoracic surgery, adult	123
Porter et al	2019	Retrospective cohort	Thoracic surgery, adult	241
LaGrasta et al	2020	Retrospective cohort	Cardiac surgery, paediatric	11,651
Kanamori et al	2021	Retrospective cohort	Thoracic surgery, paediatric	102
Zukowski et al	2022	Retrospective cohort	Thoracic surgery, adult	433

FIGURES

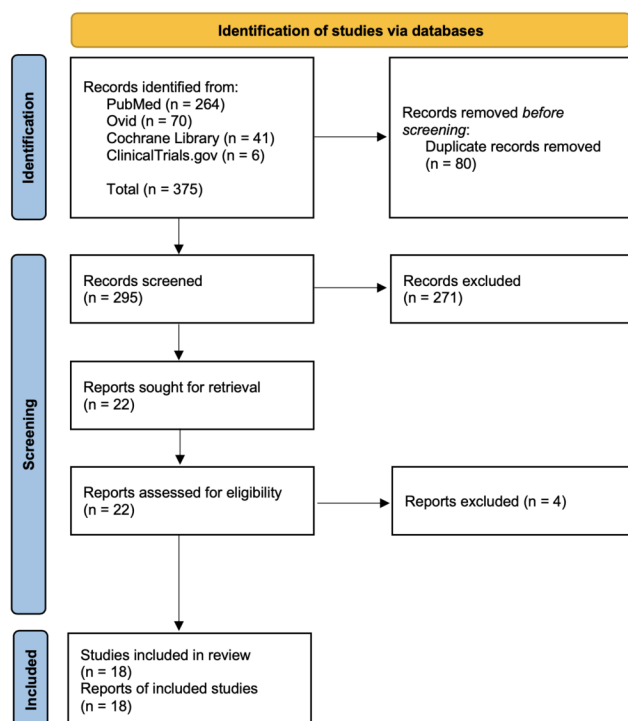


Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Diagram