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The value of chest radiography after chest tube removal in nonventilated trauma patients: A post hoc analysis of a multicenter prospective cohort study

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BACKGROUND: Chest tubes are commonly placed in trauma care to treat life-threatening intrathoracic injuries by evacuating blood or air from the pleural cavity. Currently, it is common practice to routinely obtain chest radiographs between 1 to 8 hours after chest tube removal, while the necessity of it has been questioned. This study describes the "ins-and-outs" of chest tubes and evaluates the value of routine postremoval chest radiography in nonventilated trauma patients.

METHODS: A post hoc analysis of a multicenter observational prospective cohort study was performed in blunt chest trauma patients admitted with multiple rib fractures to two level 1 trauma centers between January 2018 and March 2021 and treated with one or more chest tubes. Exclusion criteria were mechanical ventilation during chest tube removal, missing reports of postremoval chest radiography, transfer to another hospital, or mortality before chest tube removal. Descriptive analyses were performed to calculate the number of findings on postremoval chest radiographs and reinterventions.

RESULTS: A total of 207 patients were included for analysis of whom 14 underwent bilateral chest tube placement, resulting in 221 chest tube removals investigated in this study. The mean ± SD age was 58 ± 17 years, 71% were male, 73% had American Society of Anesthesiologists scores of 1 or 2, and the median Injury Severity Score was 19 (interquartile range, 14–29). In 68 of 221 chest tube removals (31%), postremoval chest radiography showed increased or recurrent intrathoracic pathology (i.e., 13% pneumothorax, 18% pleural fluid, and 8% atelectasis). Only two (3%) of these patients underwent a same-day reintervention based on these findings, of whom one had signs or symptoms of recurrent pathology and one was asymptomatic.

CONCLUSION: It seems safe to omit routine use of postremoval chest radiography in nonventilated blunt chest trauma patients and to selectively use imaging in those patients presenting with clinical signs or symptoms after chest tube removal. (*J Trauma Acute Care Surg.* 2024;96: 623–627. Copyright © 2023 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Diagnostic Tests/Criteria; Level IV.

KEY WORDS: Trauma; chest tube; postremoval chest radiograph.

Chest tubes are commonly placed in acute trauma care to treat life-threatening intrathoracic injuries by evacuating blood or air from the pleural cavity.[1] Despite the regularity of this procedure, there are still several risks attached to chest tube placement, mainly described as insertional, positional, infective, or postremoval complications.[2]

Postremoval complications include the recurrence of a pneumothorax or hemothorax and the development of empyema. These complications potentially lead to the need for a reintervention and may triple the hospitalization costs.[3] Because recurrent intrathoracic pathology may require an early reintervention, it is common practice to take chest radiographs between 1 and 8 hours after removal.[4] However, as previous studies reported, these recurrent reintervention-requiring conditions are rare, provided the patients were not mechanically ventilated during chest tube removal.[4] Two studies showed that all nonventilated trauma patients with significant recurrence of their intrathoracic pathology after chest tube removal demonstrated clinical signs or symptoms.[5,6] Even though the evidence is limited, their findings suggest that the routine use of this diagnostic may be unnecessary for asymptomatic patients. A recent systematic review of studies on cardiothoracic surgery patients also suggested that omitting the postremoval chest radiograph is safe.[7]

As of yet, there is still no consensus on the routine use of chest radiographs in nonventilated trauma patients or if selective use in symptomatic patients would suffice. Reducing unnecessary radiographs inevitably leads to less radiation exposure, less costs, and less workload. Therefore, this study evaluates the

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need for routine chest radiography after chest tube removal in nonventilated trauma patients, by assessing findings on postremoval chest radiographs, clinical signs or symptoms, and reintervention rates.

PATIENTS AND METHODS

This study was written in accordance to the STrengthening the Reporting of OBservational studies in Epidemiology statement (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/D184).[8]

Study Design and Participants

This study is a post hoc analysis of a multicenter observational prospective cohort study on nonoperative versus operative treatment of multiple rib fractures in adult blunt trauma patients (18 years or older) admitted to level 1 trauma centers between January 2018 and March 2021.[9] Eligible patients were prospectively included in the study database after informed consent was obtained, and patients with cognitive impairment, nontraumatic rib fractures, and rib fractures as a result of cardiopulmonary resuscitation were excluded.

The present study included blunt chest trauma patients admitted to the University Medical Center Utrecht (UMCU) or University Medical Center Groningen (UMCG) and treated with one or more chest tubes. Exclusion criteria were as follows: mechanical ventilation during chest tube removal, missing report of postremoval chest radiography, transfer to another hospital, or mortality before chest tube removal. Additional data needed for the current study were retrospectively collected. Approval from the institutional review boards of both participating trauma centers was obtained.

Chest Tube Management

The two participating level 1 trauma centers used comparable chest tube removal protocols. If there was no air leakage, the chest tubes were put on water seal. In the UMCU, the chest tubes were removed if air leakage was absent for 24 hours and the fluid production was below 150 mL per 24 hours. In the UMCG, the same protocol was used regarding air leakage, but the maximum fluid production threshold was 200 mL per 24 hours. In both trauma centers, the chest tubes in nonventilated patients were removed during expiration. In all included patients, the postremoval chest radiograph was routinely taken approximately 3 hours after chest tube removal.

Explanatory Variables

Baseline characteristics were age, sex, American Society of Anesthesiologists score, mechanism of trauma, maximum Abbreviated Injury Scale score per body region, Injury Severity Score, Glasgow Coma Scale score, first arterial blood pH, and base excess measured within an hour of admission to the emergency department. The following chest tube management parameters were collected: number and side(s) of chest tubes, indication for initial chest tube placement, and total duration of ipsilateral chest tube treatment. In case the patient had multiple ipsilateral chest tubes, the last removed chest tube outcomes were used for analysis.

Response Variables

Outcome measures were abnormal findings on the postremoval chest radiograph, defined as an increase or recurrence of ipsilateral pathology on the postremoval chest radiograph, as compared with the findings on preremoval chest radiography. This pathology included pneumothorax, pleural fluid (e.g., hemothorax, pleural effusion, or empyema), and atelectasis. Clinical signs and symptoms of recurrent pathology within 24 hours after chest tube removal were increased dyspnea, tachypnea (>20/minute), and increased oxygen demand compared with the demand before chest tube removal. The endpoint of the study was the first reintervention after the last chest tube removal. Reinterventions performed on the same day as chest tube removal were described primarily, as this reintervention may directly result from findings on the postremoval chest radiograph. Secondarily, delayed reinterventions after chest tube removal up to 3 months after the initial trauma were also described. Because no other routine follow-up chest radiographs were made after the postremoval chest radiograph, these delayed reinterventions were all indicated by findings on selective chest radiographs, performed by clinical indication, in patients demonstrating symptoms of increased or recurrent pleural pathology.

Statistical Analysis

Baseline characteristics and outcome measures were presented as means ± SD for parametric continuous variables, medians with interquartile range (IQR) for nonparametric continuous and ordinal variables, and numbers with proportions for categorical variables. All descriptive analyses were performed using Stata 13.0 (StataCorp LP, College Station, TX).

RESULTS

Between January 2018 and March 2021, 221 nonventilated patients were admitted to the UMCU or UMCG with multiple rib fractures and intrathoracic injuries requiring one or more chest tubes. After excluding seven patients who were transferred to other hospitals, five patients who died before chest tube removal, and two of whom data on the postremoval chest radiograph were missing, 207 patients were included for analysis. Of the included patients, 155 were admitted to the UMCU and 52 were admitted to the UMCG.

The included patients had a mean ± SD age of 58 ± 17 years, and 71% were male (Table 1). The majority (73%) had little or no comorbidities, as scored with an American Society of Anesthesiologists scores 1 or 2. The mechanisms of injury were mainly falls (33%), motor vehicle accidents (24%), or bicycle accidents (22%). The median Injury Severity Score was 19 (IQR, 14–29), and the median Glasgow Coma Scale score was 15 (IQR, 14–15).

Among the 207 included patients, 14 underwent bilateral chest tube placement, resulting in 221 chest tube removals investigated in this study (Table 2). In 31 (14%) of these, 2 ipsilateral chest tubes were inserted, and 1 patient (0.5%) had 3 ipsilateral chest tubes in situ. Indications for initial chest tube placement were pneumothorax (54%), tension pneumothorax (7%), hemothorax (11%), hemopneumothorax (16%), and as routine care postsurgery (12%). Patients were treated with chest tubes for a median of 5 days (IQR, 3–7 days).

Postremoval chest radiography showed increased or recurrent intrathoracic pathology after 68 chest tube removals (31%): a pneumothorax in 13%, pleural fluid in 18%, and atelectasis in 8% (Table 3). A total of 27 patients (12%) demonstrated any

TABLE 1. Baseline Characteristics

Variable	Total Patients N = 207
Age, mean ± SD, y	58 ± 17
Male, n (%)	146 (70.5)
Comorbidity ASA, n (%)	
1–2	150 (72.8)
3–4	56 (27.2)
Mechanism of trauma, n (%)	
Motor vehicle accident	49 (23.8)
Motor cycle accident	12 (5.8)
Bicycle accident	45 (21.8)
Fall	68 (33.0)
Pedestrian	11 (5.3)
Other	21 (10.2)
AIS score, median (IQR)	
Head	0 (0–2)
Thorax	3 (3–4)
Abdomen	0 (0–1)
Spine	0 (0–2)
Extremities	2 (0–2)
ISS, median (IQR)	19 (14–29)
GCS score, median (IQR)	15 (14–15)
Blood pH, median (IQR)	7.36 (7.31–7.40)
Base excess, median (IQR)	−1 (−3 to 1)

AIS, Abbreviated Injury Scale; ASA, American Society of Anesthesiologists; GCS, Glasgow Coma Scale; ISS, Injury Severity Score.

clinical signs or symptoms pointing toward intrathoracic pathology within the first day after removal, and 3 patients (1.4%) underwent reinsertion of a chest tube within this time frame. Of these three patients, one had bilateral chest tubes. A visual overview of the reintervention rates shows that, among the 68 cases (31%) with abnormal findings on the postremoval chest radiograph, only 2 (2.9%) underwent a reintervention based on these findings (Fig. 1). One of these two (50%) had signs or symptoms of recurrent pathology, and one (50%) was asymptomatic. The postremoval chest radiograph from the asymptomatic patient showed a recurrent pneumothorax, indicating the need for reintervention. Among the patients with negative postremoval chest radiographs (n = 153 [69%]), one (0.7%) chest tube reinsertion was performed on the day of removal, which was exclusively indicated by symptoms.

TABLE 2. Chest Tube Management Characteristics

Variable	Chest Tubes n = 221
Bilateral chest tubes, n (%)	14 (6.3)
No. ipsilateral chest tubes, n (%)	
1	189 (85.5)
2	31 (14.0)
3	1 (0.5)
Indication for chest tube placement, n (%)	
Pneumothorax	119 (53.9)
Tension pneumothorax	15 (6.8)
Hemothorax	25 (11.3)
Hemopneumothorax	36 (16.3)
Postsurgery	26 (11.8)
Duration of chest tube treatment, median (IQR)	5 (3–7)

TABLE 3. Outcome Measures After Removal of the Chest Tubes

Variable	Chest Tubes N = 221
Ipsilateral pathology on postremoval chest radiograph, n (%)	68 (30.8)
Pneumothorax	29 (13.2)
Pleural fluid	39 (17.7)
Atelectasis	17 (7.7)
Signs or symptoms <24 h after removal, n (%)	27 (12.2)
Increased dyspnea	6 (2.7)
Tachypnea >20/min	8 (3.6)
Increased oxygen demand	17 (7.7)
Chest tube reinsertions, n (%)	17 (7.7)
On the day of chest tube removal	3 (1.4)
One or more days after chest tube removal	14 (6.3)

After the first day of chest tube removal, an additional 14 reinterventions (6%) were performed. All were primarily indicated by clinical signs or symptoms and, in most cases, confirmed by chest radiography or other imaging. Delayed reinterventions were performed in 5 of 68 patients (7.3%) with abnormalities and in 9 of 153 patients (5.9%) without abnormalities, on the initial postremoval chest radiograph. Reinterventions were performed after a median of 2 days (IQR, 1–6 days).

DISCUSSION

In the present post hoc analysis of a multicenter observational prospective cohort study, the value of postremoval chest radiography was assessed in nonventilated trauma patients. After removing 221 chest tubes, almost a third of the chest radiographs (31%) showed increased or recurrent intrathoracic pathology. Two (2.9%) of the patients with abnormalities on postremoval chest radiography underwent a reintervention, and one (50%) of these already showed symptoms of recurrent pathology. The findings of this study suggest that it may be safe to omit the routine use of postremoval chest radiographs in trauma patients and to selectively use chest radiography in cases of symptoms or other clinical suspicions of recurrent pathology.

Only one asymptomatic patient underwent chest tube reinsertion, which was indicated by a recurrent pneumothorax on the postremoval chest radiograph. Because the reintervention was performed directly after chest tube removal, it remains unknown whether this patient would eventually have developed any symptoms that indicated the need for chest radiography or, perhaps, an immediate reintervention.

The current findings show that almost a third of all postremoval chest radiographs in trauma patients display abnormalities, which is in line with other studies on this subject in nonventilated trauma patients that reported percentages between 0% and 38%.[5,6,10–13] In 27 cases (12%), the patients demonstrated clinical signs or symptoms of their injury, which is high compared

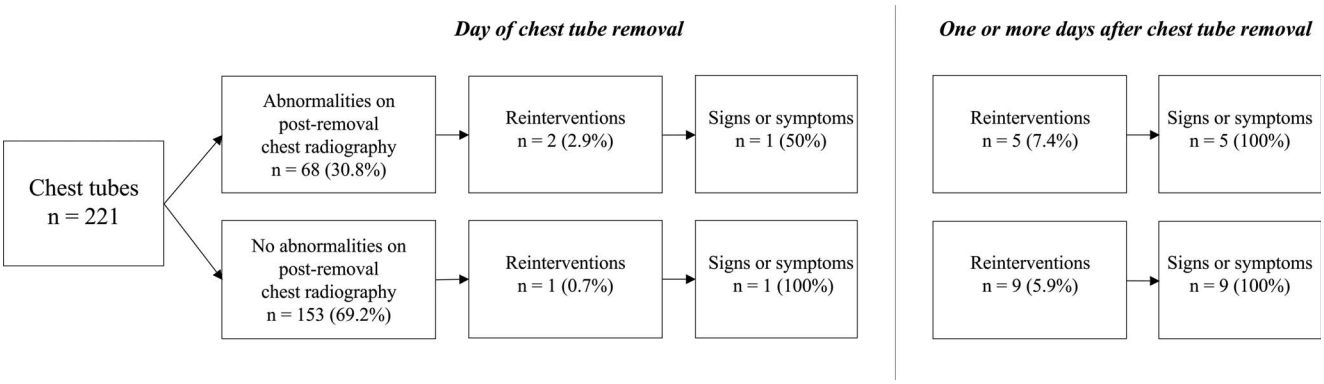

Figure 1. Visual overview of the outcomes.

with two other studies that reported symptoms in 2% and 3.8%.[5,6] When reserving chest radiography exclusively for symptomatic patients, only 12% would have undergone postremoval chest radiography, indicating a possible eightfold reduction in usage of this diagnostic. The selective use of postremoval chest radiography could lead to less use of resources and some cost reduction. Chest radiographs with insignificant recurrent pathology may even indicate longer observation and more follow-up radiographs, further increasing the costs. While it has previously been described that postremoval complications may triple hospitalization costs, it should be stated that these complications occur regardless whether a postremoval chest radiograph is obtained or not. An early recognition of recurrent pathology remains important, which is why the chest radiograph should still be selectively used in patients demonstrating symptoms. Beattie et al.[14] investigated the cost-effectivity of a strategy in which patients were only observed after chest tube removal versus a strategy in which all patients routinely underwent chest radiography, taking all clinical consequences of a positive chest radiograph into account as well in their analysis. They showed that observation is cost-effective because this resulted in an average fivefold decrease in costs compared with a routine chest radiography strategy while not lowering the effectiveness measured in quality-adjusted life years.

The reintervention rate in our cohort was 1.4% within the first day after removal and 8% when including the reinterventions performed later as well. These rates align with current literature reporting rates ranging from 0% to 6% in nonventilated trauma patients.[4] We took all delayed reinterventions into account within the first year after trauma, regardless of the timing, and reported on reinterventions performed after discharge, even up to 28 days after removal. Four chest tubes (1.8%) were reinserted after more than a week, and in none of these cases, the postremoval chest radiograph showed abnormalities.

To our knowledge, this study is the largest to retrospectively investigate the need for postremoval chest radiography in a population of prospectively included level 1 blunt chest trauma patients. For less severely injured trauma patients, it could be argued that reintervention rates might be lower, resulting in even less added value of the postremoval chest radiograph. This study adds to current evidence arguing that the routine use of postremoval chest radiography is redundant.[4] Still, more studies are needed to confirm the safety of omitting these radiographs by investigating complication rates in patients not routinely undergoing postremoval chest radiography. Ideally, this should be studied separately in ventilated and nonventilated patients. We included nonventilated patients only, as studies show that postremoval complication rates were higher among ventilated patients than nonventilated patients.[4] Nonetheless, two studies that specifically investigated the effect of mechanical ventilation on complication rates after chest tube removal showed no significant effect.[15,16] However, because ventilated patients presumably sustain more severe injuries than nonventilated patients, and any symptoms of recurrent pathology might be masked by sedation, it could be reasoned that chest tube management in these two distinct populations should be assessed separately.

This study also has its limitations. First, this study was performed as an extension of a previous multicenter prospective cohort study on the treatment of patients with multiple rib fractures. Therefore, data were not primarily collected for this study, and some additional variables were collected retrospectively. However, the necessary clinical and radiographic data were available as part of the standard of care. Second, we conducted this study in patients who sustained blunt chest trauma. The reason for this was simply that penetration chest trauma is almost nonexistent in our region. It should be noted that our results apply to blunt chest trauma patients. Third, symptoms and reintervention rates were investigated in a setting in which postremoval chest radiographs were still routinely acquired. Even though only one reintervention was performed in an asymptomatic patient, it remains unknown whether this case would have led to any complications if no chest radiograph had been acquired. Finally, although this is the largest study so far, the sample size is still limited.

In conclusion, this study showed that abnormalities on routinely acquired postremoval chest radiography are common in nonventilated trauma patients but only rarely lead to acute reinterventions, especially in the absence of symptoms. Therefore, it seems safe to omit routine postremoval chest radiography in nonventilated trauma patients. We recommend to obtain chest radiographs selectively in patients only, who present with clinical signs or symptoms pointing toward recurrent chest trauma pathology (e.g., pneumothorax, hemothorax, pleural effusion, or empyema). Most reinterventions are performed several days after chest tube removal when chest radiographs have been

obtained based on clinical grounds. Future research should further investigate the safety of omitting the routine use of postremoval chest radiography in trauma patients.

AUTHORSHIP

A.A.R.S. contributed in the study design, data collection, data analysis, interpretation of data, and writing. T.K. contributed in the study design, interpretation of data, and critical revision. R.M.H. contributed in the study design, interpretation of data, and critical revision. L.P.H.L. contributed in the study design, interpretation of data, and critical revision. P.A.d.J. contributed in the study design, interpretation of data, and critical revision. W. B.V. contributed in the study design, interpretation of data, and critical revision. F.F.A.I. contributed in the study design, interpretation of data, and critical revision. M.C.P.M.v.B. contributed in the study design, data analysis, interpretation of data, and critical revision.

DISCLOSURE

The authors declare no conflicts of interest.

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