Replacing post chest tube removal chest x-rays with clinical assessment in adult thoracic surgery patients; a single center prospective study

**Method:** prospective study

**Results:**
- 248 chest tubes after elective thoracic surgery (Feb 2022-April 2023)
- 63 received a post-pull CXR
- 185 did not receive a post-pull CXR
- 15 had symptoms
- 48 had no symptoms
- 0 required intervention
- 0 required intervention

**Conclusions:**
- Length of stay (median days; p<0.05):
  - No CXR: 2.3
  - CXR: 3
- Any complications (p>0.05):
  - No CXR: 12%
  - CXR: 19%
- Replacing post CT removal CXR with clinical observation in elective thoracic surgery patients does not lead to adverse events
Replacing post chest tube removal chest x-rays with clinical assessment in adult thoracic surgery patients; a single center prospective study

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The study was approved by Michael Garron Hospital Research Ethics board on February 1, 2022 (NR-326). Informed consent was waived as this was a QI initiative.

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Glossary of abbreviations:

- CXR, chest x-ray
- CT, chest tube
- LOS, length of stay
- IQR, interquartile range
Central picture: Replacing post chest tube removal chest x-rays with clinical observation

Central Message:
Replacing routine post-chest tube removal chest x-rays with clinical assessment in asymptomatic adult post-operative thoracic surgery patients is safe and does not lead to adverse events.

Perspective Statement:
This study demonstrates that clinical observation can effectively replace chest radiographs in asymptomatic thoracic surgery patients. By showcasing the safety of reducing unnecessary imaging, this research contributes to more efficient, patient-centered care. The findings encourage re-evaluation of current practices, advocating for a shift towards evidence-based, cost-effective delivery of healthcare.

Structured abstract: (233 words)

Objective: The necessity and utility of chest x-rays (CXR) in the absence of clinical symptoms have been questioned post chest tube (CT) removal. This study aimed to evaluate the impact of replacing routine post-CT removal CXRs with clinical observation on patient outcomes in elective thoracic surgery patients.

Methods: This was a single-center prospective study of adult thoracic surgery patients undergoing elective lung resection. Standard post-CT removal CXR was replaced with a clinical observation protocol for two hours post-removal. Post-CT removal CXR was meant to be obtained only for symptomatic patients. The primary outcome was incidence of adverse events.
related to this change. Secondary outcomes included changes in clinical management, length of
stay (LOS), and postoperative complications.

**Results:** 248 patients were included in the study period, and the majority (n=185, 75%) did not
have a post-CT removal CXR. There was no significant difference in the incidence of adverse
events or postoperative complications between patients who underwent CXR and those who did
not. Additionally, LOS was significantly shorter in patients who did not receive a CXR (median
2.3 vs. 3 days; p<0.05).

**Conclusion:** Clinical observation can safely replace routine CXRs post-CT removal in
asymptomatic elective thoracic surgery patients. This approach may lead to shorter hospital stays
and reduced healthcare costs without compromising patient safety. The findings support a
clinically driven use of postoperative imaging in this patient population, highlighting the
importance of individualized patient care.

**Keywords:** chest tube, chest x-ray
Introduction

Routine chest x-rays (CXR) are performed frequently during the postoperative care of thoracic surgery patients to guide management of the chest tube (CT). However, the utility of CXRs after CT removal has been questioned in several patient populations including cardiac surgery, pediatric, and trauma patients.\textsuperscript{1–4} The role of post CT removal CXR in pediatric patients has been studied more extensively due to concerns regarding unnecessary radiation in this population. Studies in pediatrics have shown that CXR after CT removal had a very low yield for changing clinical management of asymptomatic patients.\textsuperscript{2,5,6} A similar observation was made in cardiac surgery patients where one study assessed the role of post CT removal CXR and concluded that patients’ clinical status dictated the need for intervention as opposed to the CXR.\textsuperscript{7} Another study looking at trauma patients showed that only 3% of patients required CT re-insertion after initial CT removal, and the decision to reinsert the CT was based on clinical assessment rather than CXR findings.\textsuperscript{8}

The clinical utility of post CT removal CXR in thoracic surgery patients remains unclear. Post thoracic surgery patients might have abnormalities on their initial CXRs that are expected. Porter et al.\textsuperscript{9} assessed the role of post CT removal CXR in 241 adult thoracic surgery patients and reported 14% having CXR abnormalities. Only one patient (0.4%) experienced a change in care which was another repeat CXR. Variation in practice of obtaining a post CT removal CXR has been reported among practitioners. In 2009, Whitehouse et al. reported their experience of obtaining CXRs post CT removal in only one third of their patients due to individual practice variations.\textsuperscript{10} Comparing the two groups, none of the patients in the group who did not have post CT removal CXR suffered any adverse event.
Ultimately, routine CXRs frequently lead to further unnecessary imaging, prolonged hospital stays, and increased cost. The utility of these CXRs in the absence of clinical symptoms is unclear. Evidence-based guidelines for appropriate use of CXRs in postoperative thoracic surgery patients are lacking. At our institution all thoracic surgery patients, regardless of clinical status, received a routine CXR after CT removal. The objective of our study was to assess the impact of replacing post CT removal CXRs with clinical observation on patient outcomes in elective thoracic surgery patients in a prospective manner. We hypothesized that replacing post CT removal CXR with clinical observation in clinically asymptomatic patients does not lead to adverse events. Post CT removal CXRs should be reserved for symptomatic patients only.

Methods

Study Design

This was a single institution prospective study of adult thoracic surgery patients who underwent elective lung resection. As part of a quality improvement (QI) initiative starting in March 2022, a protocol was implemented to replace routine post CT removal CXRs in elective thoracic surgery patients with clinical observation. The aim of our QI initiative was to reduce post CT removal CXRs in asymptomatic patients by 100% in 1 year at our institution. This was instituted across the entire thoracic surgery division and all surgeons agreed to participate. We studied the impact of this implementation prospectively with multiple interim analyses to ensure there were no adverse events resulting from eliminating the post CT removal CXRs. Ordering practices were altered through reminder emails, printed educational resources available on each ward, and educational efforts from attending thoracic surgeons during rounds. Elective thoracic surgery procedures included lobectomy, segmentectomy, or wedge resection. Surgical approaches
included video assisted thoracic surgery (VATS), thoracotomy, or VATS converted to open approach. Patients were all over 18 years of age. We excluded all patients undergoing urgent or emergency surgery and those undergoing pleurodesis as part of their surgical procedure. Patients with prolonged air leak requiring discharge with CT were also excluded. All patients required intraoperative CT placement. Standard chest drainage was achieved with a 24-32 Fr drain and secured in the standard fashion with a U-stitch to be tied at the time of chest tube removal. CTs were connected to a conventional Pleur-evac chest drainage system. Postoperative management of the CT was at the discretion of the primary surgeon, although the general criteria for removal were absence of air leak, appropriate lung re-expansion, and outputs typically less than 400ml in 24 hours. All chest tubes were removed by nurses trained in removal of chest tubes. The study period was between March 2022 and April 2023 at Michael Garron Hospital, Toronto, Canada. All healthcare providers and students within the division were given multiple educational seminars on implementation of this QI initiative and advised of the protocol to monitor the patients (figure 1). All patients were monitored clinically for two hours post CT removal. Patients were examined at minimum when the CT was removed and at the end of the two-hour observation period, however, they may have been examined more often if symptoms arose. Symptoms monitored included: shortness of breath, chest pain, subcutaneous emphysema, change in vital signs (heart rate, blood pressure, oxygen saturation), along with any new patient-reported symptom. Patients who remained asymptomatic with no change in vital status or other clinical findings 2 hours after CT removal had no further interventions and were discharged. All patients who had any symptoms underwent a CXR.

At interval analyses it was noted that some asymptomatic patients were still undergoing post CT removal CXRs. Further investigation into this revealed that some asymptomatic patients
received a CXR if it was part of an automatically selected routine post-operative order set or if new team members were unaware of the QI initiative. This interim analysis allowed us to modify the post-operative order sets to unselect routine CXRs, and providers were required to opt-in if they wished to order a CXR. All patients had routine outpatient follow up 2-3 weeks following discharge, and all had a CXR at the time of their clinic visit.

Data collection

This was a prospective study and patients were followed for 30 days post CT removal. Data was obtained by reviewing the medical records of each patient. Patient demographics and surgical characteristics collected included age, gender, surgical procedure, and surgical approach.

The study was approved by Michael Garron Hospital Research Ethics board on February 1, 2022 (NR-326). Informed consent was waived as this was a QI initiative.

Outcomes

The primary outcome of this study was the incidence of adverse events as a result of replacing the post CT removal CXR with clinical observation. As secondary outcomes, we assessed the impact of eliminating post CT removal CXR on change in clinical management, length of stay (LOS), and postoperative complications. Post-operative complications were defined as any deviation from the normal postoperative course, and were classified and graded in severity according to a modified Clavien–Dindo scale as previously described. For patients with more than one complication, the more severe complication was included in the analysis.

This study was not designed to compare cohorts of patients undergoing CXR post CT removal to those who were only observed clinically. At interim analysis it was noted that some asymptomatic patients had undergone a CXR erroneously; this provided an opportunity to
compare the two groups to gain further insight into the role of a post CT removal CXR in
asymptomatic patients.

Statistical Analysis

Baseline patient and surgical characteristics are presented as median values (interquartile
range) or percentages. Analysis was conducted using a Student t test for continuous variables and
chi square test or Fisher’s exact test, as appropriate, for categorical variables. Statistical tests
were performed using STATA14® (Stata Corporation, College Station, TX). A p-value < 0.05
was considered statistically significant.

Results

Patient demographics and study characteristics

During the 13-month study period, 248 patients met the inclusion criteria and were
included in the study. Of those, 185 (75%) did not have a post CT removal CXR. Table 1
summarizes patient demographics as well as perioperative characteristics for all patients in the
study. Over the course of the study, the number of cases remained the same while the number of
CXRs performed gradually decreased (figure 2). Among the 15 symptomatic patients who
underwent CXR, 10 (66%) underwent lobectomy and 5 (33%) had a wedge resection.

Furthermore, of the 48 patients who were asymptomatic and had a CXR erroneously post CT
removal, 34 (71%) had a lobectomy and 10 (21%) had a wedge resection.

Post pull CXR and associated outcomes

Of all 63 CXRs done post CT removal, the majority (n=43, 68%) were entered by error
and 15 (24%) were done for symptoms or change in vital signs. The indications for obtaining
post CT removal CXR are listed in table 2. Of all CXRs performed, 44 (70%) showed no
significant radiological change and 19 showed some minor radiographic changes as listed in
Nine patients (14%) underwent another follow up CXR. Of the 15 symptomatic patients after CT removal 10 patients (66%) had no significant radiographic changes on post pull CXR while the other 5 (33%) had changes outlined in table 3. No patient underwent any procedure following the post CT removal CXR. In this study, no patient experienced any adverse outcome as a direct result of eliminating the post CT removal CXR. Overall, 34 patients (14%) experienced a postoperative complication within 30 days of surgery. The majority of complications (n=24, 70%) were Grade I or II complications while 10 patients experienced Grade III and above complications Table 4 compares postoperative complications between those who had a CXR post CT removal and those who were clinically observed. There was no significant difference in complications experienced between the two groups with trends towards more serious complications (Grade III and above) in patients who had a post CT removal CXR. There was one 30-day mortality in a patient who presented with cardiac arrest two weeks post discharge after lung wedge resection. Based on review of the chart, he suffered complications from pre-existing renal failure (on dialysis) that resulted in his death. Pleural based complications including reoperations for post-operative bleeding and prolonged air leak were the most common complication seen in 10 patients (4%). All patients had the above-mentioned complications treated prior to the chest tube removal and 5 of those patients did not have a post CT removal CXR without any adverse events. The second most common complication occurring in 8 patients (3%) was renal, including urinary retention requiring foley catheter insertion as well as acute kidney injury. Six patients (2%) experienced cardiovascular complications including venous thromboembolism or atrial fibrillation. The length of stay was significantly longer for patients who had a CXR post CT removal (median 3 vs. 2.3 days; p<0.05) (table 4). When comparing those who had a CXR entered in error, they still
experienced a significantly longer length of stay when compared to those who did not have a CXR (median 2.9 vs 2.3 days; p<0.05).

Post discharge CXR and associated outcomes

All patients had a post discharge CXR at their first postoperative clinic visit except for the one mortality (n=247). Only 4 patients (1.6%) had new or adverse findings. Two patients (0.8%) had moderate to large pleural effusion, 1 (0.4%) had moderate to large pneumothorax, and 1 (0.4%) had new subcutaneous emphysema. All of these patients had undergone a lobectomy. Of these patients, two of them had a post pull CXR during the index hospitalization while the other two did not. Only 2 (0.8%) patients had further investigations based on post discharge CXR, one patient had a serial CXR, and one patient required CT insertion for a large pneumothorax (PTX). The patient who had a large PTX necessitating pigtail insertion post discharge had a post pull CXR during the index hospitalization that was normal. This was entered in error and the patient was asymptomatic after CT removal.
Discussion

The utility of CXR after CT removal in the postoperative setting for elective thoracic surgery patients remains controversial. Currently, there are no standardized guidelines on post CT removal management and the need for CXR. At our center prior to March 2022, the standard of care was to obtain routine CXR after all CT removals, regardless of patient symptoms or prior CXR findings. Furthermore, all patients had a routine CXR at the first postoperative visit. We implemented a QI initiative in March 2022 at our institution where post CT removal CXR was replaced with clinical observation for two hours. This was implemented across the entire division and applied to all patients undergoing elective lung resection. Patient symptoms were used to determine the necessity of chest radiography, establishing a new CT management guideline at our institution (figure 1). Multiple educational sessions were held within the department before implementation of the protocol to ensure valid and reliable assessment of symptoms were performed. The first interim analyses showed CXRs were still being done on asymptomatic patients as some healthcare providers were unaware of the QI initiative. Further educational efforts as well as changes to our electronic order sets were carried out to ensure adherence to the protocol. The number of monthly CXRs done in asymptomatic patients gradually decreased over time (figure 2). This illustrates the importance of ongoing education when implementing a practice changing initiative. We held a number of in-service sessions with the interprofessional team and incoming trainees to educate them about this new initiative aimed at decreasing the number of CXRs being done on asymptomatic patients post CT removal. This also highlights the importance of performing frequent interim analyses when implementing a new QI initiative to assess for any adverse outcomes and to improve protocol adherence.
In our prospective cohort of 248 patients, we found that 63 patients (25%) underwent a post CT removal CXR, however only 15 (6%) patients were actually symptomatic after CT removal. We demonstrated that routine post CT removal CXR resulted in a change to patient management in only 9 (14%) patients. All these patients went on to have a repeat CXR, and none required CT reinsertion. No patient had an adverse event associated with omitting a post CT removal CXR. Furthermore, we did not observe any increase in the rate of any complications. The prospective nature of the study allowed us to assess the safety of this practice at multiple points throughout the study. This study demonstrates the safety of judicious CXR use post CT removal in elective thoracic surgery patients. Our data aligns with the body of growing evidence that has shown routine post CT removal CXR led to a change in patient management in only 3-14% of patients.\textsuperscript{9,10,12,13} Zukowski et al.\textsuperscript{12} investigated the necessity of routine post CT removal CXR in 433 thoracic surgery patients and showed that although 87% of asymptomatic patients underwent routine post CT removal CXR, none required any change in management including chest tube re-insertion or any invasive procedures. More recently, Heidel et al.\textsuperscript{13} demonstrated that patients undergoing post CT removal CXR for symptoms had significantly increased changes in management compared with those who received a routine CXR (24.2% vs 3.2%, respectively). A recent systematic review looking at the efficacy of CXR after CT removal showed that none of the asymptomatic patients required reintervention but only required repeat CXRs.\textsuperscript{14} The majority of published literature to date has retrospectively analyzed practice variations among different surgeons - those who obtain post CT removal CXRs vs. those who do not. Our study possesses the unique quality of analyzing a global change across the entire thoracic surgery division at our institution with all surgeons agreeing to participate.
CXRs post lung resection often lead to findings that are clinically insignificant and delay patient discharge. Previous studies have shown that the incidence of post pull CXR abnormalities was similar regardless of clinical status. In our study, the majority of post pull CXRs (n=43, 68%) were done due to being entered in error. This was mostly due to the interdisciplinary team not being familiar with the new initiative during the earlier phase of the study. Although this study was not designed to compare cohorts, we utilized this comparison to gain further insight in the utility of post CT removal CXR in asymptomatic patients. When reviewing post CT removal CXRs in asymptomatic patients, abnormalities such as increased pleural effusion or residual pneumothorax were commonly reported. In these asymptomatic patients, a few patients (n=5) underwent another repeat CXR, prolonging their hospital stay without any change in management. Therefore, despite the knowledge of common abnormal CXR findings in post lung resection patients and the lack of any new symptoms, healthcare professionals tend to often treat the CXR with another repeat CXR. Ultimately, eliminating the unwarranted initial CXR in the first place can reduce the need for any further unnecessary investigations.

The results of this study showed that patients who received a post CT removal CXR had a significantly longer LOS when compared to those who did not (median 2.3 vs. 3 days, p<0.05). One may argue that patients who had a longer length of stay due to complications or other reasons were also more likely to have additional CXRs - therefore proving a causal relationship is challenging. However, when we compared the LOS between those who had a CXR done in error (no symptoms) and those who did not have a CXR, their LOS was still significantly longer (median 2.9 vs 2.3 days; p<0.05). Other studies have also shown significantly longer LOS for patients receiving routine CXR versus those who did not, despite similar CT duration.
Some previous studies have also questioned the utility of clinic follow up CXR. In our study group, only 4 patients (2%) were found to have radiographic abnormalities on follow up clinic CXR. Ultimately, the clinic CXR led to change in patient management in only 2 (1%) patients, further adding to the growing body of literature questioning its value in asymptomatic patients. Other studies have also found that routine postoperative clinic visit CXR did not result in a change to patient management. Heidel et al. showed that of the 146 patients who received routine CXR on their first postoperative visit, not a single one had a significant change in management, and 3 (2.1%) had an additional CXR not leading to any other intervention.

Eliminating an unnecessary CXR can result in some cost savings for the patient and the hospital. Based on the institutional cost analysis from other Canadian studies, the cost of a CXR was estimated at CDN $60. On average, our center performs around 300 lung resections per year. Eliminating the post pull CXR would result in about CAD $18,000 of savings yearly on CXR alone, not considering other costs associated with hospitalization and prolonged inpatient stay. Eliminating routine CXRs post CT removal can lead to significant cost-savings and resource stewardship for the healthcare system, this is especially important given the publicly administered health care system in Canada where cost savings are paramount.

Limitations

While the study presents compelling evidence, it is important to acknowledge its limitations. This was a single-center study in a university affiliated community hospital and the results might not necessarily be generalizable to all thoracic surgery settings. While we captured incidence of post CT removal CXRs, we were not able to capture subjective factors involved in the decision making for ordering a CXR. Charts reviews have the inherent limitation of missing data. The study was designed to institute practice changes at our institution while carrying out
interim analyses along the way to ensure patient safety, however, our study is limited given we did not have a large control group for comparison. The patient population included a selective group of patients and excluded all those who had emergency surgery or pleurodesis as part of their surgical procedure. In some of these patients the decision to remove the CT is often more nuanced and often requires multiple CXRs, particularly in those with prolonged air leak. Furthermore, cost savings could not be directly assessed and were estimated based on previous Canadian studies that likely represent a conservative estimate.

**Conclusion**

In conclusion, this study contributes valuable insight to the ongoing debate regarding the necessity of routine post-CT removal CXRs in thoracic surgery patients. It advocates for a shift towards clinically driven postoperative care, potentially leading to more efficient and patient-centered healthcare delivery. For elective thoracic surgery patients, the automatic practice to arrange routine post pull CXRs does not lead to a meaningful change in patient management and prolongs hospital length of stay. In this setting, it is safe to reserve post CT removal CXRs for symptomatic patients alone.

**Acknowledgements**

No conflicts of interest to disclose.
References


Table 1: Baseline patient characteristics, operative details, and complications

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>TOTAL (n=248)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median years (IQR)</td>
<td>67 (59-74)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>107 (43)</td>
</tr>
<tr>
<td>Female</td>
<td>141 (57)</td>
</tr>
<tr>
<td>Pulmonary function</td>
<td></td>
</tr>
<tr>
<td>FEV1, mean % (IQR)</td>
<td>88 (75-99)</td>
</tr>
<tr>
<td>DLCO, mean % (IQR)</td>
<td>86 (73-101)</td>
</tr>
<tr>
<td>Surgical procedure, n (%)</td>
<td></td>
</tr>
<tr>
<td>Lobectomy</td>
<td>154 (62)</td>
</tr>
<tr>
<td>Segmentectomy</td>
<td>14 (6)</td>
</tr>
<tr>
<td>Wedge resection</td>
<td>80 (32)</td>
</tr>
<tr>
<td>Surgical approach, n (%)</td>
<td></td>
</tr>
<tr>
<td>VATS</td>
<td>242 (98)</td>
</tr>
<tr>
<td>Thoracotomy</td>
<td>3 (1)</td>
</tr>
<tr>
<td>Converted to open</td>
<td>3 (1)</td>
</tr>
<tr>
<td>LOS, median (IQR)</td>
<td>2 (1-3)</td>
</tr>
<tr>
<td>Any complication, n (%)</td>
<td>34 (14)</td>
</tr>
<tr>
<td>Grade I</td>
<td>2 (0.8)</td>
</tr>
<tr>
<td>Grade II</td>
<td>22 (9)</td>
</tr>
<tr>
<td>Grade III</td>
<td>8 (3)</td>
</tr>
<tr>
<td>Grade IV</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Grade V</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Post CT removal symptoms, n (%)</td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>15 (6)</td>
</tr>
<tr>
<td>NO</td>
<td>233 (94)</td>
</tr>
<tr>
<td>Post CT CXR, n (%)</td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>63 (25)</td>
</tr>
<tr>
<td>NO</td>
<td>185 (75)</td>
</tr>
</tbody>
</table>

Abbreviations: interquartile range (IQR), video-assisted thoracoscopic surgery (VATS), length of stay (LOS), chest tube (CT), chest x-ray (CXR)
Table 2: Reasons for obtaining post chest tube removal chest x-ray

<table>
<thead>
<tr>
<th>Post chest tube removal CXR</th>
<th>n (%)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entered in error</td>
<td></td>
<td>43 (68)</td>
</tr>
<tr>
<td>Patient reported symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desaturation</td>
<td>8 (13)</td>
<td></td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>2 (3)</td>
<td></td>
</tr>
<tr>
<td>subcutaneous emphysema</td>
<td>2 (3)</td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>2 (3)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td>5 (8)</td>
</tr>
</tbody>
</table>

Table 3: Radiological findings of post chest tube removal chest x-ray

<table>
<thead>
<tr>
<th>Post pull CXR findings</th>
<th>n (%), total n=63</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
<td>44 (70)</td>
</tr>
<tr>
<td>Minor increased air/fluid</td>
<td>13 (21)</td>
</tr>
<tr>
<td>Symptomatic patient</td>
<td>3 (5)</td>
</tr>
<tr>
<td>Asymptomatic patient (entered in error)</td>
<td>10 (16)</td>
</tr>
<tr>
<td>Moderate increased air/fluid</td>
<td>4 (6)</td>
</tr>
<tr>
<td>Symptomatic patient</td>
<td>1 (1.6)</td>
</tr>
<tr>
<td>Asymptomatic patient (entered in error)</td>
<td>3 (4.8)</td>
</tr>
<tr>
<td>New or worsening subcutaneous emphysema</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Symptomatic patient</td>
<td>1 (1.6)</td>
</tr>
<tr>
<td>Asymptomatic patient (entered in error)</td>
<td>1 (1.6)</td>
</tr>
</tbody>
</table>
Table 4: Postoperative outcomes stratified by whether a post chest tube removal chest x-ray was performed

<table>
<thead>
<tr>
<th></th>
<th>No CXR</th>
<th>CXR</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patients, n (%)</strong></td>
<td>185 (75)</td>
<td>63 (25)</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Any grade complication, n (%)</strong></td>
<td>22 (12)</td>
<td>12 (19)</td>
<td></td>
</tr>
<tr>
<td><strong>Grade III and above complication, n (%)</strong></td>
<td>5 (3)</td>
<td>5 (8)</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Length of stay, median days (IQR)</strong></td>
<td>2.3 (1.3-2.4)</td>
<td>3 (2.2-4.3)</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Abnormal finding on post-op clinic CXR (e.g. effusion, subcutaneous emphysema), n (%)</strong></td>
<td>2 (1)</td>
<td>2 (3)</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Abbreviations: interquartile range (IQR), chest x-ray (CXR)
Figure 1: Decision making flow chart post chest tube removal in elective thoracic surgery patients. Abbreviations: heart rate (HR), blood pressure (BP), oxygen (O2), chest x-ray (CXR), pneumothorax (PTX)

Figure 2: Number of monthly chest x-rays during the study period

Table 1: Baseline patient characteristics, operative details, and complications. Abbreviations: interquartile range (IQR), video-assisted thoracoscopic surgery (VATS), length of stay (LOS), chest tube (CT), chest x-ray (CXR)

Table 2: Reasons for obtaining post chest tube removal chest x-ray

Table 3: Radiological findings of post chest tube removal chest x-ray

Table 4: Postoperative outcomes stratified by whether a post chest tube removal chest x-ray was performed. Abbreviations: interquartile range (IQR), chest x-ray (CXR)

Figure 3: Graphical abstract

Figure 4: Central picture. Replacing post chest tube removal chest x-rays with clinical observation
Post-op chest tube removed

2 hours post chest tube removal assess for:
- Shortness of breath?
- Chest pain?
- New or worsening subcutaneous emphysema?
- Change in vital signs including HR, BP or O2 saturation?
- Other new symptoms?

YES

Immediate CXR
- New or worsening PTX, effusion, subcutaneous emphysema
  - Hemodynamic stability
    - Consider serial CXR
  - Hemodynamic instability
    - Chest tube re-insertion
- Hemodynamic instability
  - Chest tube re-insertion

NO

No further intervention
Replacing post chest tube removal chest x-rays with clinical assessment in adult thoracic surgery patients; a single center prospective study

**Method:** prospective study

- Clinical observation 2 hours post chest tube removal
- Chest x-ray post chest tube removal

**Results:**

- 248 chest tubes after elective thoracic surgery (Feb 2022-April 2023)
  - 63 received a post-pull CXR
  - 185 did not receive a post-pull CXR
    - 15 had symptoms
    - 48 had no symptoms
    - 0 required intervention
    - 0 required intervention

**Conclusions:**

- Length of stay (median days; p<0.05):
  - No CXR: 2.3
  - CXR: 3
- Any complications (p>0.05):
  - No CXR: 12%
  - CXR: 19%

Replacing post CT removal CXR with clinical observation in elective thoracic surgery patients does not lead to adverse events.
Replacing post chest tube removal chest x-rays with clinical assessment in adult thoracic surgery patients; a single center prospective study

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