Replacing post–chest tube removal chest radiographs with clinical assessment in adult thoracic surgery patients: A single-center prospective study

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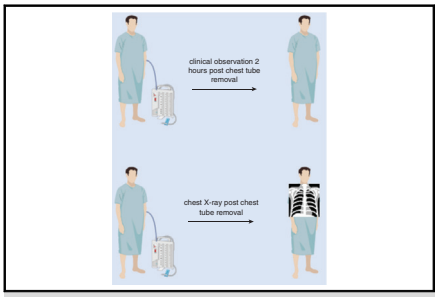
ABSTRACT

Objective: The necessity and utility of chest radiographs in the absence of clinical symptoms have been questioned after chest tube removal. This study aimed to evaluate the impact of replacing routine chest radiographs after chest tube removal with clinical observation on outcomes in patients undergoing elective thoracic surgery.

Methods: This was a single-center prospective study of adult patients undergoing elective lung resection. Standard chest radiographs after chest tube removal were replaced with a clinical observation protocol for 2 hours after removal. Chest radiographs after chest tube removal were meant to be obtained only for symptomatic patients. The primary outcome was the incidence of adverse events related to this change. Secondary outcomes included changes in clinical management, length of stay, and postoperative complications.

Results: A total of 248 patients were included in the study period, and the majority (n = 185, 75%) did not have chest radiographs after chest tube removal. There was no significant difference in the incidence of adverse events or postoperative complications between patients who received chest radiographs and those who did not. Additionally, length of stay was significantly shorter in patients who did not receive chest radiographs (median 2.3 vs 3 days; $P < .05$).

Conclusions: Clinical observation can safely replace routine chest radiographs after chest tube removal in asymptomatic patients undergoing elective thoracic surgery. 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. (JTCVS Open 2024;21:358-65)



Replacing post-CT removal CXRs with clinical observation.

CENTRAL MESSAGE

Replacing routine post-CT removal CXRs with clinical assessment in asymptomatic adults after thoracic surgery is safe and does not lead to adverse events.

PERSPECTIVE

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

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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 because this was a QI initiative.

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Abbreviations and Acronyms
CT = chest tube
CXR = chest radiograph
LOS = length of stay
QI = quality improvement

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Routine chest radiographs (CXRs) are performed frequently during the postoperative care of patients undergoing thoracic surgery to guide the management of the chest tube (CT). However, the utility of CXR after CT removal has been questioned in several patient populations, including cardiac surgery, pediatric, and trauma patients.[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 CXRs after CT removal had a low yield for changing clinical management of asymptomatic patients.[2,5,6] A similar observation was made in patients undergoing cardiac surgery. Khan and colleagues[7] assessed the role of post-CT removal CXR and concluded that patients' clinical status dictated the need for intervention as opposed to the CXR. Another study looking at trauma patients showed that only 3% of patients required CT reinsertion after initial CT removal, and the decision to reinsert the CT was based on clinical assessment rather than CXR findings.[8]

The clinical utility of post-CT removal CXR in patients undergoing thoracic surgery remains unclear. After thoracic surgery, patients might have abnormalities on their initial CXRs that are expected. Porter and colleagues[9] assessed the role of post-CT removal CXR in 241 adult patients undergoing thoracic surgery and reported 14% having CXR abnormalities. Only 1 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 and colleagues[10] reported their experience of obtaining CXRs post-CT removal in only one-third of their patients due to individual practice variations. Comparing the 2 groups, none of the patients in the group who did not have post-CT removal CXR experienced 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 patients after thoracic surgery are lacking. At our institution, all patients undergoing thoracic surgery, 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 patients undergoing elective thoracic surgery 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.

MATERIAL AND METHODS

Study Design

This was a single-institution prospective study of adult 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 patients undergoing elective thoracic surgery with clinical observation (Figure 1). 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, and wedge resection. Surgical approaches included video-assisted thoracic surgery, thoracotomy, and video-assisted thoracic surgery converted to open approach. Patients were all aged more than 18 years. 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 a CT were also excluded. All patients required intraoperative CT placement. Standard chest drainage was achieved with a 24F-32 F drain and secured in the standard fashion with a U-stitch to be tied at the time of CT removal. CTs were connected to a conventional Pleur-evac (Teleflex) 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 reexpansion, and outputs typically less than 400 mL in 24 hours. All CTs were removed by nurses trained in removal of CTs. 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 2). All patients were monitored clinically for 2 hours post-CT removal. Patients were examined at minimum when the CT was removed and at the end of the 2-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), and 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 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 postoperative order set or if new team members were unaware of the QI initiative. This interim analysis allowed us to modify the postoperative order sets to unselect routine CXRs, and providers were required to opt in if they wanted to order a CXR. All patients

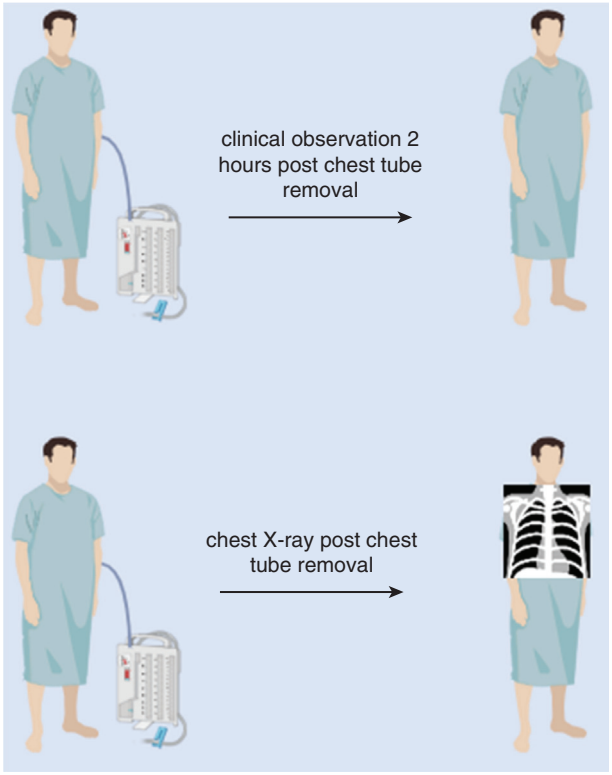

FIGURE 1. Replacing post-CT removal CXR with clinical observation.

had routine outpatient follow-up 2 to 3 weeks after 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 were 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 because 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. For secondary outcomes, we assessed the impact of eliminating post-CT removal CXR on change in clinical management, length of stay (LOS), and postoperative complications. Postoperative 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.[11] For patients with more than 1 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 with those who were only observed clinically. At interim analysis, it was noted that some asymptomatic patients had received a CXR erroneously; this provided an opportunity to compare the 2 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 exact test, as appropriate, for categorical variables. Statistical tests were performed using STATA14 (StataCorp LLC).

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 and perioperative characteristics for all patients in the study. Over the course of

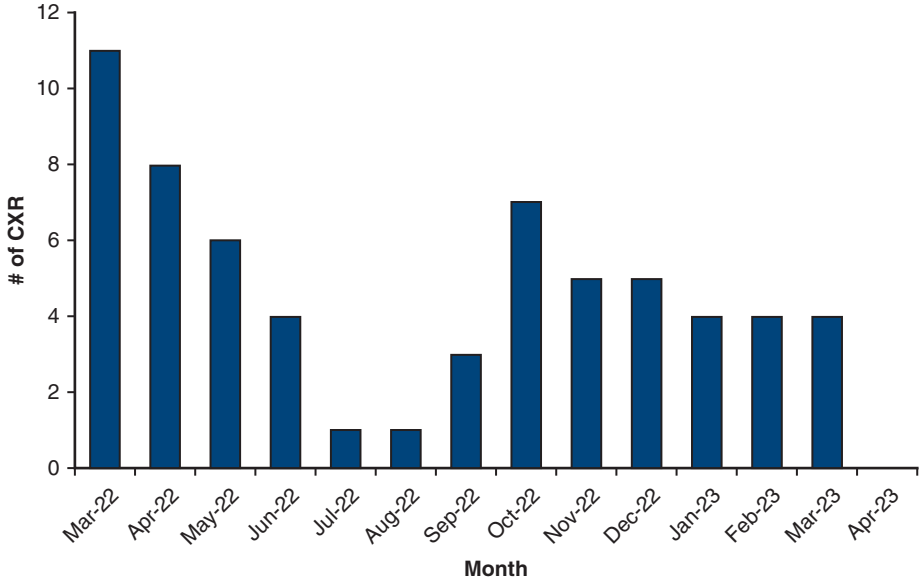

FIGURE 2. Number of monthly CXRs during the study period. *CXR*, Chest radiograph.

TABLE 1. Baseline patient characteristics, operative details, and complications

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

IQR, Interquartile range; *FEV1*, forced expiratory volume in 1 second; *DLCO*, diffusing capacity for carbon monoxide; *VATS*, video-assisted thoracoscopic surgery; *LOS*, length of stay; *CT*, chest tube; *CXR*, chest radiograph.

the study, the number of cases remained the same, whereas the number of CXRs performed gradually decreased (Figure 3). 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 Chest Radiograph 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 Table 3. Nine patients (14%) underwent another follow-up CXR. Of the 15 symptomatic patients after CT removal, 10 (66%) had no significant radiographic changes on post-pull CXR and the other 5 (33%) had changes outlined in Table 3. No patient underwent any procedure after 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, and 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 2 groups with trends toward 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 2 weeks postdischarge after lung wedge resection. On review of the chart, he had complications from preexisting renal failure (on dialysis) that resulted in his death. Pleural-based complications including reoperations for postoperative bleeding and prolonged air leak were the most common complications seen in 10 patients (4%). All patients had the mentioned complications treated before the CT 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 and acute kidney injury. Six patients (2%) experienced cardiovascular complications including venous thromboembolism and atrial fibrillation. The LOS was significantly longer for patients who had a CXR post-CT removal (median 3 vs 2.3 days; $P < .05$) (Table 4). When comparing those who had a CXR entered in error, they still experienced a significantly longer LOS when compared with those who did not have a CXR (median 2.9 vs 2.3 days; $P < .05$).

Postdischarge Chest Radiograph and Associated Outcomes

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

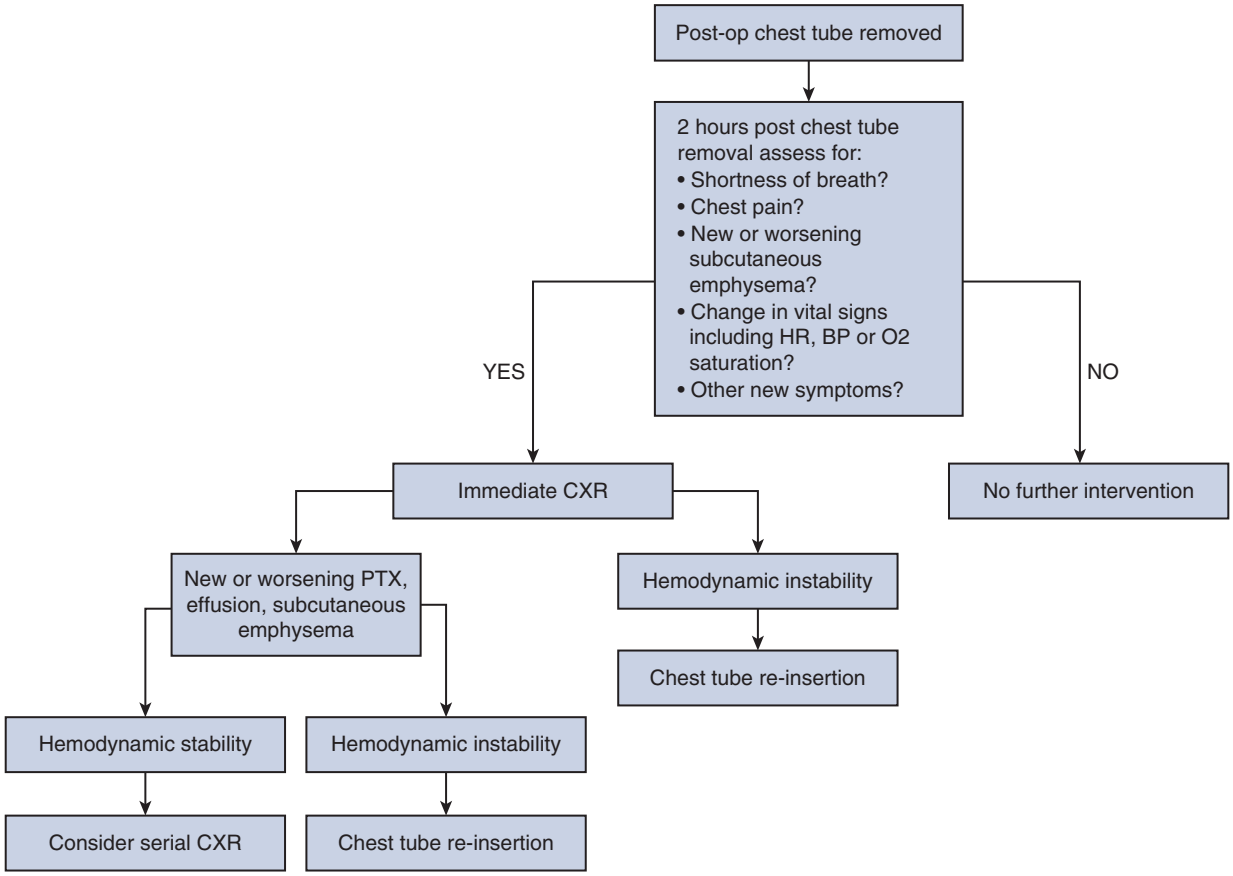

FIGURE 3. Decision-making flow chart post-CT removal in patients undergoing elective thoracic surgery. *HR*, Heart rate; *BP*, blood pressure; *O2*, oxygen; *CXR*, chest radiograph; *PTX*, pneumothorax.

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 patients undergoing elective thoracic surgery remains controversial. Currently, there are no standardized guidelines on post-CT removal management and the need for CXR. At our center before 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 2 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 CXR, establishing a new CT management guideline at our institution (Figure 2). 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 because some healthcare providers were unaware of the QI initiative. Further educational efforts and 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 3). 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 after 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 (25%) underwent a post-CT removal CXR; however, only 15 patients (6%) were actually symptomatic after

TABLE 2. Reasons for obtaining chest radiograph after chest tube removal

Post-CT removal CXR	n (%)
Entered in error	43 (68)
Patient reported symptoms	15 (24)
Desaturation	8 (13)
Shortness of breath	2 (3)
Subcutaneous emphysema	2 (3)
Pain	2 (3)
Other	1 (2)
Miscellaneous	5 (8)

CT, Chest tube; *CXR*, chest radiograph.

CT removal. We demonstrated that routine post-CT removal CXR resulted in a change to patient management in only 9 patients (14%). 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 patients undergoing elective thoracic surgery. Our data align with the body of growing evidence that has shown routine post-CT removal CXR led to a change in patient management in only 3% to 14% of patients.[9,10,12,13] Zukowski and colleagues[12] investigated the necessity of routine post-CT removal CXR in 433 patients undergoing thoracic surgery and showed that although 87% of asymptomatic patients underwent routine post-CT removal CXR, none required any change in management including CT reinsertion or any invasive procedures. More recently, Heidel and colleagues[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.[14] The majority of published literature to date has retrospectively analyzed practice variations among different surgeons: those who obtain post-CT removal CXRs versus 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.

TABLE 3. Radiological findings of chest radiograph after chest tube removal

Post-pull CXR findings	n (%), total n = 63
No change	44 (70)
Minor increased air/fluid	13 (21)
Symptomatic patient	3 (5)
Asymptomatic patient (entered in error)	10 (16)
Moderate increased air/fluid	4 (6)
Symptomatic patient	1 (1.6)
Asymptomatic patient (entered in error)	3 (4.8)
New or worsening subcutaneous emphysema	2 (3)
Symptomatic patient	1 (1.6)
Asymptomatic patient (entered in error)	1 (1.6)

CXR, Chest radiograph.

CXRs after 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.[12] 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 used 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 patients after lung resection 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 with those who did not (median 2.3 vs 3 days, $P < .05$). One may argue that patients who had a longer LOS 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; $P < .05$). Other studies also have shown significantly longer LOS for patients receiving routine CXRs versus those who did not, despite similar CT duration.[13]

Some previous studies have also questioned the utility of clinic follow-up CXR.[13] 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 a change in patient management in only 2 patients (1%), further adding to the growing body of literature questioning

TABLE 4. Postoperative outcomes stratified by whether a post–chest tube removal chest radiograph was performed

Postoperative outcomes	No CXR	CXR	*P* value
Patients, n (%)	185 (75)	63 (25)	
Any grade complication, n (%)	22 (12)	12 (19)	.15
Grade III and above complication, n (%)	5 (3)	5 (8)	.07
LOS, median days (IQR)	2.3 (1.3-2.4)	3 (2.2-4.3)	.0001
Abnormal finding on postoperative clinic CXR (eg, effusion, subcutaneous emphysema), n (%)	2 (1)	2 (3)	.3

CXR, Chest radiograph; *LOS*, length of stay; *IQR*, interquartile range.

its value in asymptomatic patients. Other studies have found that routine postoperative clinic visit CXR did not result in a change to patient management. Heidel and colleagues[13] showed that of the 146 patients who received routine CXRs 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.[15,16] On average, our center performs approximately 300 lung resections per year. Eliminating the post-pull CXR would result in approximately 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 healthcare system in Canada where cost savings are paramount.

Study Limitations

Although the study presents compelling evidence, it is important to acknowledge its limitations. This was a

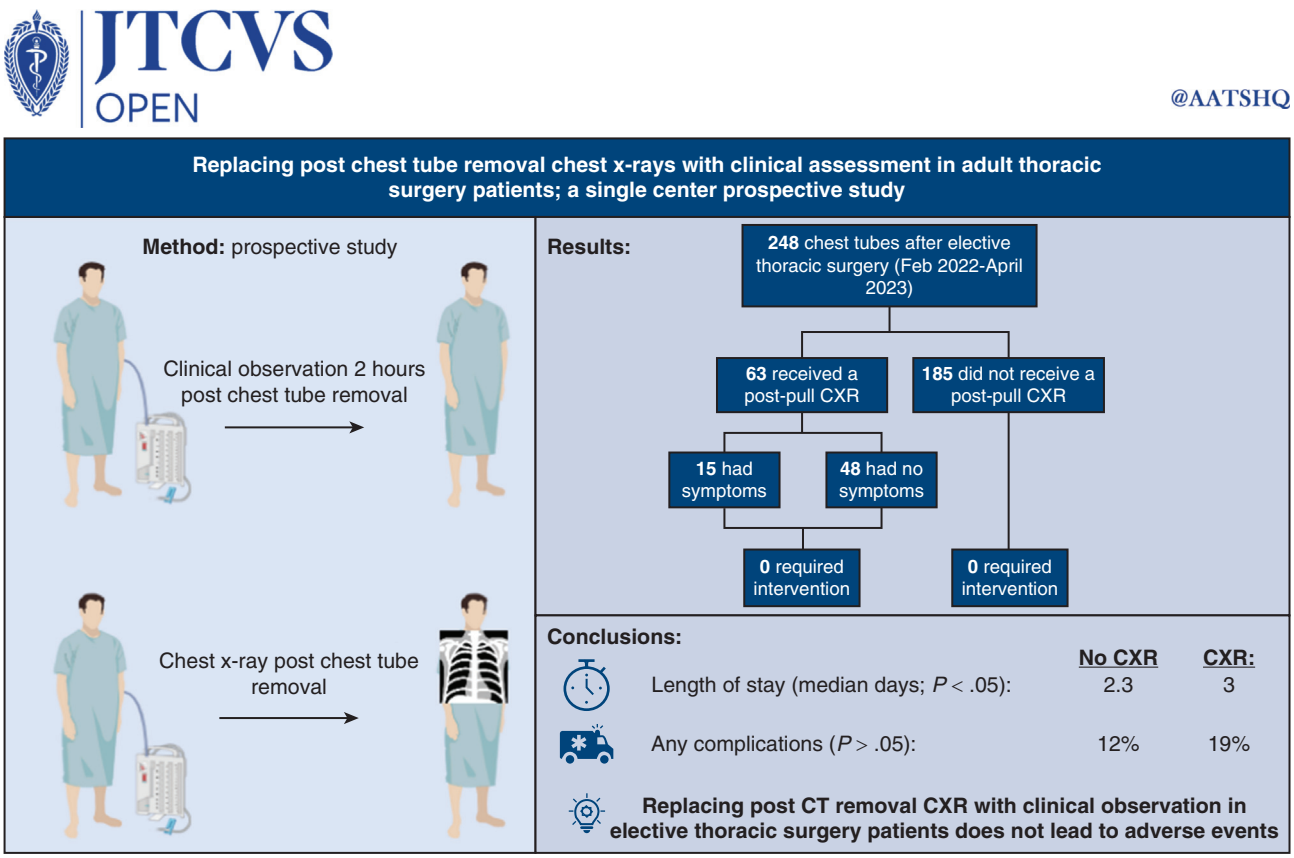

FIGURE 4. Graphical Abstract.

single-center study in a university-affiliated community hospital, and the results might not necessarily be generalizable to all thoracic surgery settings. Although we captured the incidence of post-CT removal CXRs, we were not able to capture subjective factors involved in the decision making for ordering a CXR. Chart 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 received 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.

CONCLUSIONS

This study contributes valuable insight to the ongoing debate regarding the necessity of routine post-CT removal CXRs in patients undergoing thoracic surgery. It advocates for a shift toward clinically driven postoperative care, potentially leading to more efficient and patient-centered healthcare delivery (Figure 4). For patients undergoing elective thoracic surgery, the automatic practice to arrange routine post-pull CXRs does not lead to a meaningful change in patient management and prolongs hospital LOS. In this setting, it is safe to reserve post-CT removal CXRs for symptomatic patients alone.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/replacing-post-chest-tube-remo-7355.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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