

# Prospective Evaluation of Early Follow-up Chest Radiography after Penetrating Thoracic Injury

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## Abstract

**Background** In asymptomatic patients with penetrating thoracic trauma and a normal initial chest x-ray, successive prospective trials have decreased the minimum observation period required for exclusion of significant injury from 6 to 3 h. Despite the quality of these studies, this interval remains arbitrary and the true requisite observation time for safe discharge remains unknown. The current study evaluates the ability of “early” repeat chest x-ray, at intervals approaching 1 h, to exclude clinically significant injury.

**Methods** Eighty-eight, asymptomatic patients with penetrating chest trauma and normal initial chest radiographs were prospectively enrolled in this study. All patients received an “early” follow-up chest x-ray, at a median interval of 1 h and 34 min (interquartile range: 1 h 35 min to 2 h 22 min), and a second repeat x-ray at a “delayed” interval no earlier than 3 h postadmission. Radiographic abnormalities in clinically stable patients were followed with serial examination and repeat imaging for a minimum of 6 h. All patients received both “early” and “delayed” repeat CXRs with no patient discharged before full assessment.

**Results** One of the 88 patients with initially normal chest x-ray underwent tube thoracostomy at the discretion of the attending surgeon before any repeat imaging. Of the remaining patients, 4 of 87 (4.6 %) demonstrated radiographic abnormalities on “early” repeat imaging. Two patients had pneumothoraces, successfully managed without intervention; the remaining two demonstrated evidence of hemothorax, subsequently undergoing tube thoracostomy. Two more patients (2.3 %) developed pneumothoraces on “delayed” imaging, both successfully observed without intervention.

**Conclusions** In asymptomatic patients with penetrating thoracic trauma and normal initial chest radiographs, “early” repeat chest x-ray, at intervals approaching 1 h, appears sufficient to exclude clinically significant pathology and to allow safe patient discharge.

## Introduction

During the past three decades, the management of asymptomatic patients with penetrating torso injury has undergone considerable change, shifting from policies of mandatory hospital admission and observation [1, 2], to evidence-based strategies of selective emergency department discharge after repeat interval radiography [3–5]. In 1982, Weigelt et al. [5] reported no significant clinical progression between chest films performed at 6 and 24 h postinjury, in 110 asymptomatic patients with thoracic stab wounds. Subsequent replication of these findings prompted wide adoption of a “6-h rule” for observation, repeat imaging, and discharge of stable patients [3].

Need for 6 h observation was initially challenged by retrospective review, suggesting equivalency of a 3 h interval for injury exclusion in both blunt and penetrating

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trauma [4]. Shatz et al. [6, 7] provided the first prospective validation for a 3 h time interval and these findings were subsequently replicated. Despite this concurrence, the choice of a 3 h interval remains arbitrary, derived by halving the previously accepted observation period. The current objective was to evaluate the ability of “early” repeat CXR (at intervals approaching 1 h) to detect clinically significant injuries not visualized on admission imaging, and to determine the optimal period of observation required for safe discharge.

## Methods

After Institutional Review Board approval, a convenience sample of asymptomatic, adult patients presenting to LAC+USC Medical Center between February 2006 and August 2010 with penetrating chest injury and a normal initial CXR were prospectively enrolled. Patients were excluded if they were: hemodynamically unstable; demonstrated signs of vascular or aerodigestive tract injury; evinced respiratory distress or clinical signs of significant hemo- or pneumothorax; were clinically unevaluable; or required immediate operative intervention.

All patients were assessed and treated by the trauma team in accordance with standard protocols. Focused assessment with sonography for trauma (FAST) was performed to rule out cardiac injury and assess for intra-abdominal hemorrhage. An initial portable AP chest x-ray (CXR) was performed in the trauma bay. Patients were enrolled in the study after initial CXR revealed no abnormality.

Enrolled patients then underwent two repeat CXRs during their observation period. An “early” repeat upright CXR was ordered for 1 h postinjury. A second repeat CXR was then performed at a “delayed” interval, not less than 3 h postadmission. All patients underwent serial clinical examination for a minimum of 6 h after the delayed CXR. Further investigation with computed tomography (CT) was ordered at the discretion of the attending surgeon.

All patients received both early and delayed repeat CXRs. No patients left against medical advice before full assessment. Demographic and clinical injury data, final radiologist CXR interpretation, and all surgical interventions were collected.

## Results

During the study period, 88 asymptomatic patients with penetrating chest injury and a normal initial CXR were prospectively enrolled. Study population demographics and injury characteristics are described in Table 1. The

majority of patients (61/88, 69.3 %) sustained a stab wound (SW), whereas 26.1 % (23/88) suffered a gunshot wound (GSW). A small number of patients (5/88, 5.7 %) demonstrated signs of penetrating injury to both chest and abdomen. All patients underwent an “early” repeat upright CXR at a median of 1 h 34 min (interquartile range (IQR): 1 h 35 min to 2 h 22 min), followed by a “delayed” repeat CXR at a median 7 h 16 min (IQR: 7 h 12 min to 8 h 47 min). Twenty-seven patients (27/88, 30.7 %) also underwent chest CT during the course of their assessment, at the discretion of the attending clinician.

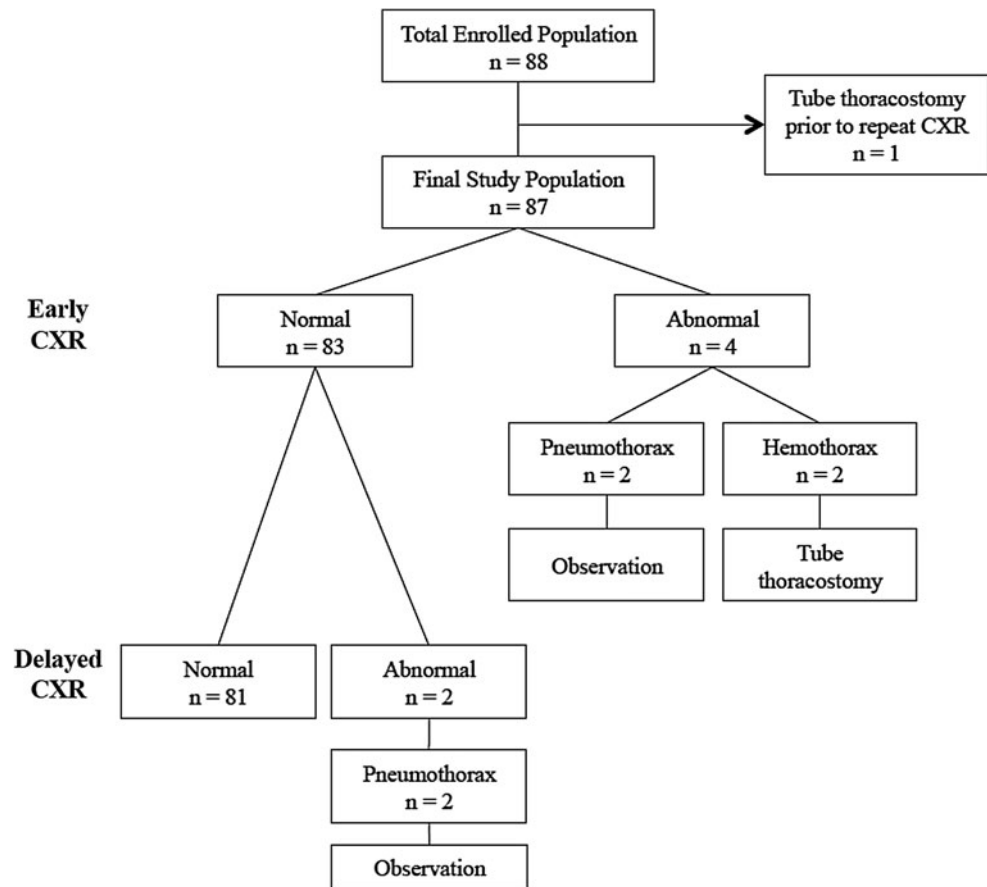
Figure 1 summarizes the study outline, radiologic findings, and interventions performed. One patient with an initially normal CXR (1/88, 11.4 %) underwent tube thoracostomy at the discretion of the supervising clinician, before their 1 h repeat CXR, for unilaterally diminished breath sounds without derangement of cardiopulmonary mechanics. It is unclear whether this procedure was clinically necessary, because a pneumothorax was not seen on the initial CXR, nor did the patient develop significant hypotension or hypoxemia before intervention. This patient was excluded from the subsequent analysis.

Of the remaining patients, 6 of 87 (6.9 %) developed a new finding on subsequent imaging. Of these, 4 of 87 (4.6 %) were detected on the “early” repeat CXR. On this “early” repeat CXR, 2 of 87 patients (2.3 %) demonstrated small pneumothoraces. Both patients were successfully observed without intervention. Another 2 of 87 (2.3 %) demonstrated radiologic evidence of a unilateral effusion.

**Table 1** Population demographics, injury patterns and outcomes

	Total (N = 88)
Demographics and vitals on admission	
Age (year), mean $\pm$ SD	31.7 $\pm$ 13.1
Age $\geq$ 55 year	5 (5.7 %)
Male (%)	82 (93.2 %)
Mechanism of injury	
GSW	23 (26.1 %)
SW	61 (69.3 %)
Other	4 (4.5 %)
Injury severity	
Thoracoabdominal injury	5 (5.7 %)
Head AIS $\geq$ 3	0 (0.0 %)
Abdominal AIS $\geq$ 3	8 (9.1 %)
Extremity AIS $\geq$ 3	3 (3.4 %)
ISS $\leq$ 15	86 (97.7 %)
ISS: 16–24	2 (2.3 %)
ISS, mean $\pm$ SD	4.5 $\pm$ 4.6
Outcomes	
HLOS, median (range)	2 (1–20)
Survival to discharge	88 (100 %)

Fig. 1 Study outline



Both patients remained asymptomatic. Both patients underwent subsequent chest CT, confirming moderate size hemothoraces, and both underwent tube thoracostomy before repeat “delayed” CXR.

Of the 83 of 87 patients (95 %) with an initially normal “early” repeat CXR, 2 developed small pneumothoraces on “delayed” imaging. Both patients also were successfully managed without intervention and demonstrated no significant progression on repeat imaging.

In this study, the rate of CXR abnormality after an initially normal trauma bay radiograph was 6.9 % (6/87). Pneumothoraces accounted for the majority of observed abnormalities (4/6, 66.7 %), occurring in 4.6 % (4/87) of the overall population. Half of the observed pneumothoraces were diagnosed on the “early” repeat CXR. None required clinical intervention.

## Discussion

In the current study, “early” repeat CXR, at a median interval of 1 h 34 min (IQR: 1 h 35 min to 2 h 22 min), detected all clinically significant pathology in asymptomatic patients with penetrating thoracic trauma and normal initial CXR. A pneumothorax, half of which were diagnosed on the “early”

repeat CXR, developed in 4 of 88 (4.5 %) of the population, but none required clinical intervention or demonstrated significant subsequent progression. “Early” repeat CXR also successfully detected all cases of delayed hemothorax (2/88, 2.3 %). A normal “early” repeat CXR strongly supports the absence of significant underlying pathology.

Previous series of thoracic stab wounds reported rates of delayed pneumo- or hemothorax of 8–12 %, prompting recommendations for hospital admission for up to 72 h [1, 2, 8, 9]. Subsequent studies evaluated progressively shorter, radiographic follow-up intervals for exclusion of injury and safe hospital discharge. Weigelt et al., in the first prospective study of asymptomatic patients with thoracic stab wounds, found 9 % developed delayed hemo- or pneumothorax. All abnormalities were detected on a repeat 6 h film with no subsequent findings at 24 h. However, 39 % of the patients discharged at 6 h did not return for their 24 h CXR [5]. A subsequent study of 105 thoracic stab wound patients undergoing mandatory admission found only a 4 % incidence of delayed pathology, all detected on the 6 h CXR with no subsequent injuries found at 24 h [3]. These two studies prompted wide adoption of a 6 h observation period for stable patients.

Retrospective review of blunt and penetrating trauma patients initially supported shortening the required

observation period to 3 h. Only 4 % (12/285) of these patients developed delayed pneumothoraces, all detected on a 3 h repeat film with no further injuries found at 6 h [4]. Shatz et al. [7] provided prospective validation of a 3 h interval in patients with penetrating injury, finding no additional injuries at 6 h. More recently, a 3 year prospective study of 100 patients reported a 2 % incidence of delayed pneumothorax, all present on repeat 3 h CXR, confirming Shatz's original findings [6].

The rarity of clinically significant delayed pneumothorax after only an hour of observation is consistent with studies examining postprocedural complications in non-trauma patients. A large review of 673 transthoracic, needle aspiration procedures found an overall 23.8 % incidence of pneumothorax with 11.5 % requiring tube thoracostomy. Most pneumothoraces (89 %) were immediately clinically apparent. No clinically significant pneumothoraces were detected after 1 h [9].

Our study demonstrated an overall 4.5 % (4/88) incidence of delayed pneumothorax, an incidence within the range of 1.1–4 % reported by recent studies [3, 4, 6, 7]. None of these proved clinically significant. Delayed hemothorax occurred in 2 of 88 (2.3 %) of our population, both detected by the “early” repeat CXR. Absence of abnormality on “early” repeat CXR is strongly indicative of the absence of clinically significant injury.

Interest in determining the minimum “safe” period of observation derives from concern about emergency department resource utilization [10, 11] as well as proven difficulty in convincing asymptomatic trauma patients to remain in hospital for longer observation [6, 7]. As the observation and repeat radiographic exam interval decreases, the question arises as to whether this “delayed” pathology represents true progression of an initially occult injury or is instead a function of the technical limitations of the initial film compared with subsequent CXRs. Sensitivity of chest radiography is technique-dependent; the standard trauma CXR, often performed supine with portable equipment, may miss injuries later seen on more formal series. In a review of 1,121 patients with penetrating trauma, standard erect trauma films missed up to 17 % of pneumothoraces seen on subsequent CT scans. Supine trauma films missed up to 80 %. Upright CXRs performed better, missing only 8 % of pneumothoraces detected by CT [12]. In another recent series of penetrating torso trauma, initial trauma chest film sensitivity for detecting pneumo- and hemothoraces was 71 and 63 %, respectively [13]. Previously reported “delayed” pathology may therefore reflect the technical capabilities of different radiographic approaches. In a recent attempt to evaluate this, Zehtabchi et al. [14] examined whether a delayed CXR at 3–6 h after initial assessment demonstrated any significant pathology beyond that seen on technically adequate,

upright trauma bay CXRs. They found a 1.1 % incidence of delayed pneumothorax on CXR, suggesting that these rates are in part due to the technical adequacy of the initial exam. These authors were unable to establish the incidence of delayed clinically significant injury; however, as both patients underwent tube thoracostomy for relatively small pneumothoraces for which observation may have been an acceptable strategy. Our study utilized both supine and upright AP views for the initial CXR, perhaps accounting for the higher rate of “delayed” pathology.

Initial noncontrast CT screening of asymptomatic patients with penetrating thoracic injury has been advocated for rapid diagnosis and early discharge. Magnotti et al. [15] examined 104 asymptomatic patients with penetrating thoracic injury with initial and 6 h CXRs as well as CT. The 6 h CXR did not show any additional pathology compared with initial CT scan. The authors concluded that discharge after CT would result in both time and hospital cost savings. This cost savings was not compared to a 3 h follow-up strategy however. Compared with repeat CXR assessment at shorter (1–3 h) intervals, the additional cost of CT imaging, the requisite time to obtain definitive radiologic interpretation, and the greater patient radiation exposure are unlikely to support this approach as a routine strategy.

Our study was limited by variable timing of repeat CXRs. As a busy County Level I facility, our capacity to obtain precisely timed CXRs is restricted by radiologic technician availability and high patient volume. The median time to repeat CXR was 1 h 34 min in our study (IQR: 1 h 35 min to 2 h 22 min), greater than our initial target of 1 h. To date, none of the previous prospective studies have explicitly reported the timing of repeat CXRs, an omission that prohibits direct comparison of our efforts with theirs.

Nevertheless, the current prospective series suggests that “early” repeat CXR, at intervals approaching 1 h, may be sufficient for detection of clinically significant pathology, allowing safe, early patient discharge in the absence of other injury. Patients without radiographic abnormality at this interval are unlikely to develop further pathology. Small pneumothoraces are unlikely to become clinically significant. Suspicion of hemothorax should prompt tube thoracostomy or, if the findings are equivocal, reimaging with CT or interval CXR.

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