



# Complication to consider: delayed traumatic hemothorax in older adults

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► Additional material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/tsaco-2020-000626>).

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Received 20 October 2020

Revised 10 February 2021

Accepted 21 February 2021

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**To cite:** Choi J, Anand A, Sborov KD, et al. *Trauma Surg Acute Care Open* 2021;**6**:e000626.

## ABSTRACT

**Background** Emerging evidence suggests older adults may experience subtle hemothoraces that progress over several days. Delayed progression and delayed development of traumatic hemothorax (dHTX) have not been well characterized. We hypothesized dHTX would be infrequent but associated with factors that may aid prediction.

**Methods** We retrospectively reviewed adults aged  $\geq 50$  years diagnosed with dHTX after rib fractures at two level 1 trauma centers (March 2018 to September 2019). dHTX was defined as HTX discovered  $\geq 48$  hours after admission chest CT showed either no or 'minimal/trace' HTX. Two blinded, board-certified radiologists reviewed inpatient chest imaging and classified injury patterns according to Chest Wall Injury Society (CWIS) taxonomy. Descriptive analysis was performed for demographic and hospitalization characteristics.

**Results** We identified 14 patients with pooled dHTX rate of 1.3%. After initial chest CT negative for concerning hemothoraces, the patients did not undergo follow-up imaging until new symptoms (shortness of breath, chest pain) developed: eight (57%) were not diagnosed until after discharge from initial hospitalization (mean (range): 9 (2–20) days after discharge). Aspirin and/or anticoagulants were involved in fewer than half of cases (43%). According to CWIS taxonomy, all patients had a series of posterolateral fractures with at least one offset or displaced fracture, and an average of six consecutive rib fractures. All patients underwent tube thoracostomy and six patients (42%)—all aged  $< 65$ —underwent operative interventions.

**Discussion** Preliminary data suggest older adults with rib fractures may be at risk of experiencing delayed progression of trace hemothoraces or a delayed presentation of hemothoraces. Asymptomatic progression or readmission to other services/hospitals likely occurs and true dHTX rates are likely higher. Our preliminary findings suggest a possible anatomic explanation for severe chest wall injury patterns' association with dHTX. Further characterization and capturing the true incidence of dHTX first requires wider recognition of this complication.

## INTRODUCTION

The burden of traumatic rib fractures in elderly patients is well recognized. Hemothorax (HTX) is a common concomitant injury with rib fractures and is usually diagnosed at time of presentation:

very small hemothoraces rarely require intervention whereas larger hemothoraces often undergo immediate drainage. However, emerging evidence suggests HTX in older adults with rib fractures may experience subtle hemothoraces that progress in a delayed fashion over several days.<sup>1,2</sup> If true, older adults may be at risk of developing empyema or other complications without close monitoring.

Delayed progression and delayed development of traumatic hemothorax (dHTX) have not been well characterized in literature. The ageing US population and increasing incidence of rib fractures among older adults underscore a pressing need for better understanding.<sup>3</sup> This preliminary study examined older adults with dHTX after suffering rib fractures in-depth to inform future research direction. We hypothesized that dHTX would be infrequent but associated with factors that may aid identification.

## METHODS

### Study population

We retrospectively reviewed adults aged  $\geq 50$  years diagnosed with dHTX after rib fractures at two level 1 trauma centers between March 2018 and September 2019. We defined dHTX as HTX discovered  $\geq 48$  hours after admission chest CT showed either no or 'minimal/trace' HTX. We identified patients by querying both centers' trauma registries and electronic medical records for patients aged  $\geq 50$  years with rib fractures and dHTX diagnosed during index admission or on readmission.

### Variables

We report patient characteristics (age, sex, body mass index, smoking status, Charlson Comorbidity Index, aspirin/antiplatelet/anticoagulant use within 7 days of injury), injury characteristics (mechanism of injury, number of rib fractures, evidence of lung parenchymal injury), and hospitalization characteristics (hospital length of stay (LOS), interventions, and readmissions).

### Detailed characterization of rib fractures

Two blinded, board-certified radiologists reviewed all inpatient chest X-rays and CT scans; every patient's imaging was reviewed by one of two radiologists. Rib fracture patterns were characterized according to Chest Wall Injury Society (CWIS) taxonomy.<sup>4</sup> The CWIS taxonomy was established by an international Delphi consensus panel and classifies rib fractures based on displacement

degree (undisplaced, offset (<90% cortical contact), displaced (no cortical contact)), fracture type (simple, wedge, complex), neighboring rib fractures (series, not series), and chest wall location (anterior, lateral, posterior, costal). In addition to rib fractures, we also noted radiographic lung injury (chest wall soft tissue emphysema, pulmonary laceration or contusion, pneumothorax).

## RESULTS

### Patient characteristics

We identified 14 older adults who experienced dHTX after rib fractures, with overall dHTX rate of 1.3%. Five patients (36%) had delayed progression of a trace HTX and nine (64%) had delayed development of HTX after a negative CT. Mean age was 72 years and 86% (n=12) were male (table 1). A total of 57% of patients were not on blood thinning medications within a week prior to injury; among those who were, aspirin was the most common medication (n=4, 29%). Patients were placed on low molecular weight heparin for inpatient venous thromboembolism chemoprophylaxis. All patients aged  $\geq 65$  years suffered ground-level falls, the most common mechanism of injury (n=6, 43%), whereas those younger than 65 years experienced higher force injuries. Online supplemental data detail individual patient characteristics.

### Radiographic characteristics

All patients underwent chest CT on presentation. Six patients (43%) had underlying lung injury. The average number of rib fractures was 5.8 and four patients (29%) had flail chest. According to CWIS taxonomy, all patients had a series of fractures, with an average of 5.6 consecutive rib fractures. Only three patients had less than four consecutive rib fractures: these patients had two consecutive offset or completely displaced fractures. All patients had at least one displaced or offset fracture, with an average of 3.5 displaced or offset fractures. All patients had posterolateral fractures and the following fracture pattern between the 6th and 10th ribs: a series of posterolateral fractures with at least one offset or displaced fracture.

### Hospitalization characteristics

Six patients (43%) were diagnosed with dHTX during initial hospitalization but eight (57%) were not diagnosed until readmission. Patients were diagnosed with dHTX after new shortness of breath or chest pain prompted repeat imaging. Delayed hemothoraces discovered during initial hospitalization were diagnosed an average of 5.3 days (range 3–8 days) after admission; dHTX discovered at readmission was diagnosed an average of 9.3 days (range 2–20 days) after discharge from initial hospitalization. Of nine patients with coagulation profiles sent on the day of dHTX diagnosis, six had normal values; three patients had mildly elevated international normalized ratios (1.3–1.5). A total of seven patients received blood transfusion.

Patients who were ultimately readmitted had shorter initial hospital LOS compared with those who were not readmitted (mean 6.3 vs. 18.5 days). Readmitted patients had similar LOS at initial hospitalization (6.3 $\pm$ 1.6 days) and readmission (6.9 $\pm$ 1.0 days). All patients underwent tube thoracostomy for dHTX and six patients (42%)—all younger than 65 years—underwent operative interventions when HTX persisted despite tube thoracostomy. No patients had empyema.

**Table 1** Characteristics of patients aged  $\geq 50$  years diagnosed with delayed progression of a hemothorax after rib fractures at two institutions

	n=14
<b>Patient characteristics</b>	
Age, mean (SD), years	72.4 (4.0)
Male, n (%)	12 (86)
Body mass index, mean (SD), kg/m <sup>2</sup>	26.8 (1.3)
Charlson Comorbidity Index, mean (SD)	3.3 (1.6)
Medication use within 7 days prior to injury, n (%)	
ASA	4 (29)
Other antiplatelet	1 (7)
Anticoagulant	1 (7)
<b>Injury characteristics</b>	
Mechanism of injury, n (%)	
Ground-level fall	6 (43)
Fall from height	3 (21)
Motor vehicle crash	2 (14)
Bicycle crash	2 (14)
Motorcycle crash	1 (7)
Injury Severity Score, mean (SD)	13.3 (7.2)
Number of rib fractures, mean (SD)	6.1 (2.6)
Underlying lung injury*, n (%)	
Initial chest imaging, n (%)	
No hemothorax	9 (64)
Scant pleural effusion	5 (36)
<b>CWIS taxonomy characterization of rib fractures</b>	
Flail chest, n (%)	
$\geq 2$ consecutive fractures, n (%)	14 (100)
Number of consecutive fractures, mean (SD)	
Anterior fractures, n (%)	5.6 (2.5)
Posterolateral fractures, n (%)	4 (29)
Displaced/offset fracture, n (%)	14 (100)
Number of displaced/offset fractures, mean (SD)	
Wedge or complex fractures, n (%)	3.5 (1.9)
7 (50)	
<b>Interventions for delayed hemothorax</b>	
Tube thoracostomy, n (%)	14 (100)
Video-assisted thoracoscopic surgery, n (%)	5 (76)
Thoracotomy, n (%)	1 (17)
<b>Hospitalization characteristics</b>	
Single admission (n=6)	
Hospital LOS, mean (SD), days	18.5 (3.0)
Time to delayed hemothorax diagnosis, mean (range), days	5.3 (3–8)
Readmitted (n=8)	
Initial hospitalization LOS, mean (SD), days	6.3 (1.6)
Readmission LOS, mean (SD), days	6.9 (1.0)
Time to delayed hemothorax diagnosis, mean (range), days	9.3 (2–20)

\*Lung injury comprised pulmonary laceration, contusion, or pneumothorax seen on CT. ASA, acetylsalicylic acid; CWIS, ChestWall Injury Society; LOS, length of stay.

## DISCUSSION

Our preliminary study suggests older adults with rib fractures may be at risk of experiencing delayed progression of trace hemothoraces or a delayed development of hemothoraces. Concerning hemothoraces were not apparent on initial imaging, routine follow-up imaging was not obtained, and repeat imaging was only performed when symptoms developed (after discharge in many patients, requiring lengthy readmissions). Delayed recognition of

hemothoraces sometimes necessitated surgical drainage and decortication. Patients aged 50–64 years with dHTX experienced higher force trauma and required operative intervention, a potentially different phenotype than those older than 65 years, who experienced ground-level falls and were managed with tube thoracostomy.

Older adults with dHTX had features of serious chest wall injury with either  $\geq 4$  consecutive fractures or two fractures with displacement. A common injury pattern was a series of offset or displaced posterolateral fractures between the 6th and 10th ribs. Chest wall anatomy explains why this injury pattern may be associated with dHTX. Compared with undisplaced fractures, offset or displaced fractures may be more likely to disrupt intercostal vessels with continued respiration, causing either delayed injury or clot disruption. The 6th–10th ribs are also the largest ribs, associated with longer intercostal arteries and have greater bone mass to disrupt underlying vessels.<sup>5</sup> Unlike floating (11th and 12th) or more cranial ribs, these lower ribs are intimately involved in respiratory mechanics<sup>5</sup>; greater movement during respiration may pose greater risk to damage underlying intercostal arteries over time. The physiologic significance is doubtful, but the posterolateral intercostal arteries derive blood from the aorta and are larger than anterior intercostal arteries branching from internal mammary arteries.<sup>6</sup> Furthermore, blood velocity is highest within lower intercostal arteries (sixth and caudal).<sup>7</sup>

Delayed traumatic HTX after rib fractures in older adults may be an elusive complication that needs wider recognition. The complication has been recognized in the outpatient setting, but to our knowledge, has yet to be characterized in the inpatient setting.<sup>1,2</sup> Both delayed progression (scant HTX at presentation that accumulates over time) and delayed development (no HTX at presentation) may be at play. Patients may have reassuring chest CT at presentation without even scant hemothoraces, but accumulate significant hemothoraces that require lengthy readmissions or operative interventions. All patients who were ultimately readmitted had been discharged home after a shorter initial hospitalization and presented with symptoms up to 20 days after discharge—older adults may silently accumulate hemothoraces over time. Delayed detection impedes managing hemothoraces with tube thoracostomy because older blood can clot or serve as a nidus for empyema. If dHTX progresses without symptoms, delineating risk factors such as a common rib fracture pattern may be critical to preemptively identify high-risk patients. To mitigate avoidable readmissions and operations, targeted follow-up imaging, even in the absence of clinical symptoms, may be necessary for high-risk patients.

Our study offers preliminary findings to direct future research and has several limitations. We evaluated few patients and cannot establish the incidence of dHTX. This preliminary study originated from anecdotal observations from two level 1 trauma centers, to draw attention to an understudied and poorly understood complication among older adults admitted with rib fractures. Second, our study only identified patients who were readmitted to our own trauma centers. Patients may have presented with dHTX to other hospitals after discharge. Moreover, both trauma centers see high volumes of patients with rib fractures and our management patterns may not reflect those of non-trauma, or lower volume trauma centers. Third, we lack definitive physiologic explanation for why older adults may experience delayed progression or development of hemothoraces. To our knowledge, there is no physiologic model supporting our anatomic hypothesis that dHTX accumulates from displaced ribs disrupting underlying intercostal arteries throughout respiratory chest wall motion. Physiologic modeling is likely impractical, but

wider recognition of this complication may facilitate validating risk factors with multi-institutional evaluations in the future.

Mitigating dHTX requires larger study to better understand prevalence and validate proposed risk factors. A case–control study to further evaluate potential risk factors for dHTX may be helpful, but would likely suffer from verification bias. A prospective cohort study is needed to assess injury patterns and mechanisms that portend increased dHTX risk. Associations between dHTX and home blood thinner use or venous thromboembolism prophylaxis dosing, quantifying CT chest HTX volumes to guide management, and the role of surgical stabilization of displaced rib fractures to mitigate dHTX risk should also be explored. Cost-effectiveness analysis may guide timing and method for targeted follow-up imaging among asymptomatic patients.

## CONCLUSION

Delayed progression and delayed development of HTX among older adults with rib fractures require wider recognition. Delayed diagnosis of HTX may be associated with readmissions and increased interventions. The full scope and consequences of dHTX require prospective study for further characterization.

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**Acknowledgements** We thank Denise Greci, RN, MS, for assistance in gathering the registry data.

**Contributors** JC, AA, KDS, WW, and LC contributed to data collection and analysis. JC and AA contributed to article writing. OG, BMD, DS, and KS contributed to study conception and critical review of the article.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not required.

**Ethics approval** Institutional Review Boards of Stanford University and Vanderbilt University approved this study and waived need for consent. We provide descriptive statistics.

**Provenance and peer review** Not commissioned; externally peer reviewed.

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## Supplemental data. Characteristics of patients diagnosed with delayed hemothoraces

Patient characteristics														
Age range (years)	80s	70s	50s	80s	60s	90s	90s	50s	90s	60s	50s	60s	60s	60s
Body mass index (kg/m <sup>2</sup> )	18.1	28.8	29.9	28.7	24.6	22.2	23.9	25.2	19.5	27.3	35.5	29.9	30.6	30.6
Charlson Comorbidity Index	6	3	1	4	2	5	6	1	4	2	3	3	3	3
Use within seven days of injury														
ASA	no	yes	no	yes	no	yes	yes	no	no	no	no	no	no	no
anti-platelet	no	no	no	yes	no	no	no	no	no	no	no	no	no	no
anticoagulant	no	no	no	no	no	no	no	no	yes	no	no	no	no	no
Injury characteristics														
Mechanism of Injury	GLF	GLF	BA	GLF	MCC	GLF	GLF	MA	MVC	GLF	MVC	FFH	FFH	FFH
Injury severity score	9	5	22	9	22	9	9	29	17	10	14	17	10	4
Number of rib fractures	6	2	7	6	7	8	8	9	8	2	9	7	4	2
Underlying lung injury	no	yes	no	yes	yes	no	no	yes	no	no	no	yes	no	yes
Scant pleural effusion on CT	yes	yes	no	no	no	yes	no	no	no	no	no	yes	no	yes
CWIS taxonomy characterization for rib fractures														
Flail chest	no	no	no	yes	no	no	no	yes	yes	no	yes	no	no	no
Number of consecutive fractures	5	2	6	6	7	8	8	9	8	1	6	7	4	2
Fracture characteristic (rib#)														
anterior			6						4		2-9	2,3		
posterolateral	4-8, 10	8,9	7-12	3-8	6-11	4-11	4-12	2-10	2-9	9,10	1-7, 9	2-9	8-11	9,10
displaced or offset	10	8,9	10-12	3-8	8-10	4-11	6-8	2-4,6,7,10	7,8	9,10	2-5,9	2,3,6	9-11	9,10
wedge or complex			12	5,6				3,4	7,8		5	3,6	8	
Initial hospitalization characteristics														
Hospital length of stay (days)	27	3	19	18	12	5	26	7	9	2	16	9	2	6
Intervention														
Tube thoracotomy	yes		yes	yes	yes	no	yes	no	yes	no	no	no	no	no
VATS	no		yes	no	yes	no	no	no	no	no	no	no	no	no
Thoracotomy	no		yes	no	no	no	no	no	no	no	no	no	no	no
Blood transfusion	no		yes	no	yes	no	yes	yes	yes	no	no	no	no	no
Time from admission to dHTX diagnosis (days)	8		4	4	3		7		6					
Re-admission hospitalization characteristics														
Re-admission reason?		CP				SOB		SOB		CP	CP, SOB	CP, SOB	CP, SOB	CP
Hospital length of stay (days)		10				4		9		3	8	9	8	4
Intervention														
Tube thoracotomy		yes				yes		yes		yes	yes	yes	yes	yes
VATS		no				no		yes		no	no	yes	yes	no
Thoracotomy		no				no		no		no	no	no	no	no
Blood transfusion		yes				yes		no		no	no	no	no	no
Time from discharge to dHTX diagnosis (days)		5				14		8		2	2	20	11	12

Abbreviations: GLF= ground level fall, BA= bicycle accident, MCC= motorcycle crash, MVC= motor vehicle crash, FFH= fall from height, CT= computed tomography, dHTX= delayed hemothorax, CP= chest pain, SOB= shortness of breath, VATS= video assisted thoracoscopic surgery.

Exact age and sex is not specified to ensure anonymity.