

Clinical prediction rule for delayed hemothorax after minor thoracic injury: a multicentre derivation and validation study

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Abstract

Background: About 75% of patients with minor thoracic injury are discharged after an emergency department visit. However, complications such as delayed hemothorax can occur. We sought to derive and validate a clinical decision rule to predict hemothorax in patients discharged from the emergency department.

Methods: We conducted a 6-year prospective cohort study in 4 university-affiliated emergency departments. Patients aged 16 years or older presenting with a minor thoracic injury were assessed at 5 time points (initial visit and 7, 14, 30 and 90 d after the injury). Radiologists' reports were reviewed for the presence of hemothorax. We used log-binomial regression models to identify predictors of hemothorax.

Results: A total of 1382 patients were included: 830 in the derivation phase and 552 in the validation phase. Of these, 151 (10.9%) had hemothorax at the 14-day follow-up. Patients 65 years of age or older represented 25.3% (210/830) and 23.7% (131/552) of the derivation and validation cohorts, respectively. The final clinical decision rule included a combination of age (> 70 yr, 2 points; 45–70 yr, 1 point), fracture of any high to mid thorax rib (ribs 3–9, 2 points) and presence of 3 or more rib fractures (1 point). Twenty (30.8%) of the 65 high-risk patients (score ≥ 4) experienced hemothorax during the follow-up period. The clinical decision rule had a high specificity (90.7%, 95% confidence interval 87.7%–93.1%) in this high-risk group, thus guiding appropriate post-emergency care.

Interpretation: One patient out of every 10 presented with delayed hemothorax after discharge from the emergency department. Implementation of this validated clinical decision rule for minor thoracic injury could guide emergency discharge plans.

Thoracic injuries represent about 5% to 15% of all injuries treated in the acute care setting.^{1,2} In 2005, the US National Hospital Ambulatory Medical Care Survey reported more than 800 000 visits to the emergency department each year for chest injuries.¹ Most blunt thoracic injuries are considered minor, and two-thirds of patients with rib fractures are treated as outpatients.^{1,3} Minor thoracic injuries cause substantial morbidity^{4–7} and pain,⁸ but rarely death.⁹

Physicians have focused on delayed pneumonia as a complication of minor thoracic injury or rib fracture.^{10,11} However, delayed pneumonia is rare, with reported incidence less than 2% among patients with minor thoracic injury.^{12,13} Delayed hemothorax, another complication, seems to be more frequent than delayed pneumonia.^{14–17} A 2004 prospective

study in Europe found that 7.4% of 709 outpatients who presented to the emergency department with at least 1 rib fracture received a diagnosis of hemothorax within 14 days.¹⁸ More recently, our group reported an incidence of 11.8% for delayed hemothorax in a prospective Canadian cohort study.¹⁹ We showed that hemothorax was associated with functional decline at 90 days after the injury and precluded regular activ-

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ities for a substantial number of days.²⁰ Our team also showed substantial discrepancies in follow-up practices for patients with minor thoracic injury after discharge from the emergency department.²¹ Misthos and colleagues¹⁸ suggested a general 2-week follow-up protocol for all patients with minor thoracic injury, which would place high demands on the limited follow-up resources in Canadian health care centres. No

large study has yet assessed predictors of delayed hemothorax to guide management after medical evaluation in the emergency department, taking into account limited care resources. Our primary objective for the study reported here was to derive and validate a clinical decision rule for delayed hemothorax in patients with minor thoracic injury discharged from the emergency department.

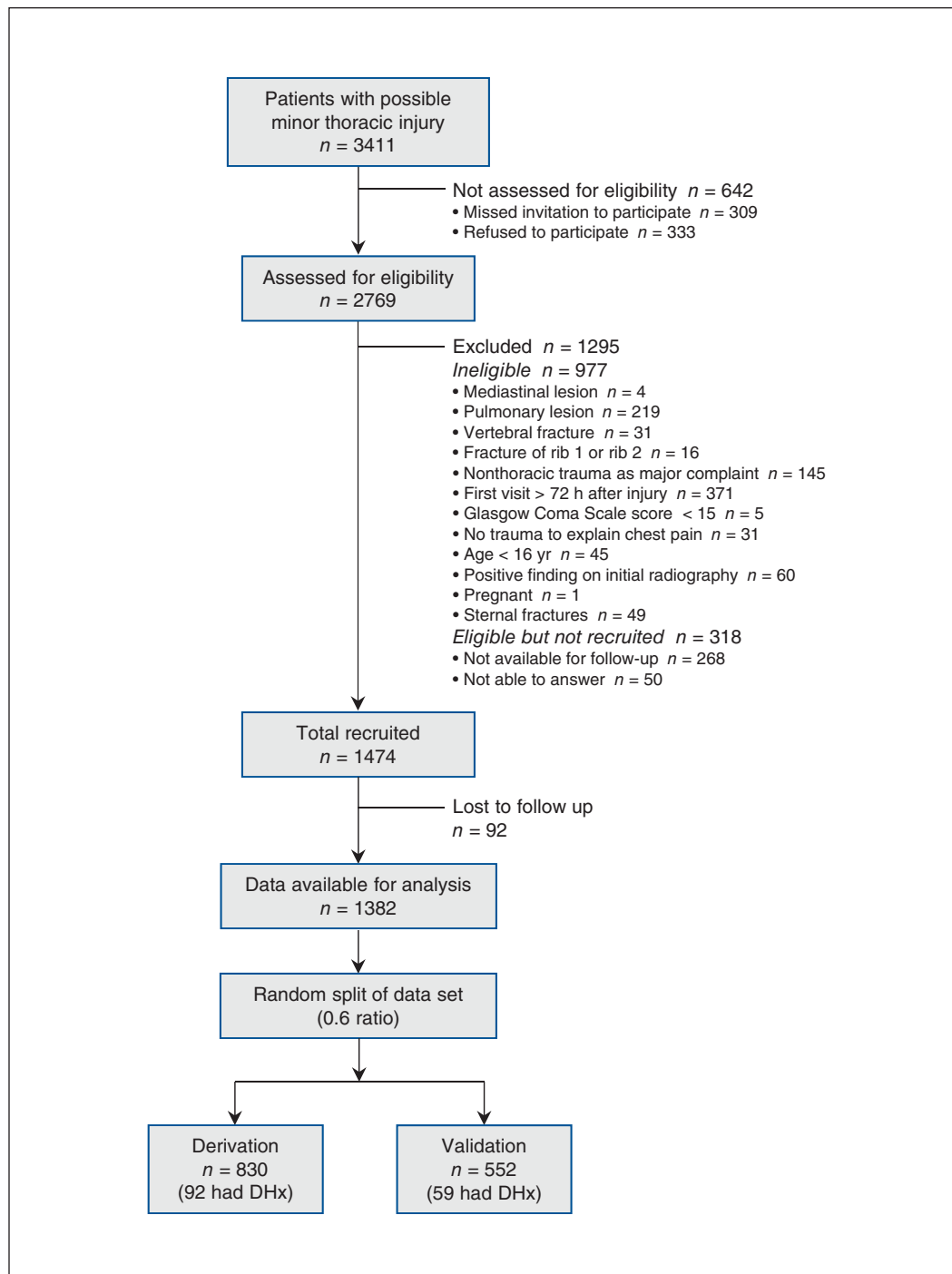


Figure 1: Flow diagram for patients in a study to derive and validate a clinical decision rule for delayed hemothorax (DHx) after minor thoracic injury. Patients included in the study were recruited in Quebec emergency departments between November 2006 and May 2012.

Methods

Setting

We conducted this prospective observational cohort study from November 2006 to May 2012 in 4 Canadian university-affiliated emergency departments: 2 level-1 trauma centres (Hôpital de l'Enfant-Jésus, Quebec City; Hôpital du Sacré-Coeur de Montréal, Montréal), a level-2 trauma centre (Centre hospitalier de Charles-Lemoyne, Greenfield Park, Que.) and a nontrauma centre (Centre hospitalier de l'Université Laval, Quebec City).

Study design

We included patients 16 years of age or older with a main medical complaint of minor thoracic injury. Minor thoracic injury was defined by the presence of any of the following: chest abrasion, chest contusion or "traumatic" chest pain, or suspected or confirmed rib fracture on radiography. This broad, pragmatic definition represents all potential types of minor chest trauma seen in the emergency department and was used to allow general reproducibility of results.

All participants were discharged from the emergency department after receiving care from the attending physician. The exclusion criteria were confirmed diagnosis of hemothorax, pneumothorax, lung contusion, flail chest or any other important thoracic or abdominal internal injury at the initial visit; inability to attend follow-up appointments; and presentation to the emergency department more than 3 days after the injury. This cut-off was based on a previous publication which showed that 90% of patients seek medical attention within 72 hours.²¹

The attending physician performed initial care, medical evaluation and standardized data collection and ordered mandatory chest and rib radiography. Patients received usual management, including treatment for pain and discharge instructions. They returned for standardized medical outpatient evaluations at 7 and 14 days after discharge. These visits included pain assessment, clinical examination and mandatory upright chest radiography, to assess for possible delayed complications. A standardized data collection sheet was used for each medical evaluation. Candidate variables for the clinical decision rule were established, following a literature review, by consensus among the authors. Research nurses performed the 30- and 90-day evaluations through telephone interviews, aiming to uncover previously missed complications. Patients lost to follow-up were those with no outpatient visit at 7 or 14 days. Interobserver agreement between emergency physicians and research nurses was assessed on clinical variables for about 10% of the derivation cohort. The study complied with the STROBE statement on observational epidemiologic studies.²²

Outcomes

Delayed hemothorax, the primary complication in this study, was considered to be present if any pleural fluid was noted on follow-up upright chest radiographs (as stated in the radiologist's report) at 7 or 14 days after discharge. No

Table 1: Characteristics of study participants and patients lost to follow-up

Characteristic	Group; no. (%) of patients*	
	Participants n = 1382	Lost to follow-up n = 92
Demographic		
Age, yr, mean \pm SD	52.5 \pm 16.7	44.8 \pm 17.9
No. aged \geq 65 yr	341 (24.7)	13 (14.1)
Sex, male	868 (62.8)	60 (65.2)
Mechanism of injury†		
Simple fall	482 (35.0)	36 (39.1)
Fall above ground level	314 (22.8)	14 (15.2)
Motor vehicle crash	339 (24.6)	16 (17.4)
Pedestrian v. car	14 (1.0)	1 (1.1)
Cyclist v. car	10 (0.7)	1 (1.1)
Direct hit	142 (10.3)	20 (21.7)
Other	78 (5.7)	4 (4.3)
\geq 1 pre-existing comorbidity	333 (24.1)	16 (17.4)
Smoking status‡		
Former smoker	297 (25.3)	4 (9.8)
Current smoker	353 (30.1)	25 (61.0)
Never smoker	522 (44.5)	12 (29.3)
Alcohol intoxication	92 (6.7)	4 (4.3)
Pre-injury antiplatelet/ anticoagulant medication		
ASA	229 (16.6)	7 (7.6)
Clopidogrel	21 (1.5)	1 (1.1)
Warfarin	51 (3.7)	5 (5.4)
Any	278 (20.1)	12 (13.0)
Triage vital signs, mean \pm SD or median (IQR)		
Heart rate, beats/min	80.8 \pm 14.1	81.3 \pm 14.0
Oxygen saturation, %	97.7 \pm 1.9	97.6 \pm 2.1
Systolic blood pressure, mm Hg	140.5 \pm 20.7	136.6 \pm 19.1
Respiratory rate, breaths/min	16 (16–20)	16 (16–20)
No. of rib fractures§¶		
None	914 (67.0)	75 (81.5)
1	203 (14.9)	10 (10.9)
2	130 (9.5)	4 (4.3)
\geq 3	117 (8.6)	3 (3.3)
Atelectasis¶¶	129 (9.3)	2 (2.2)

Note: ASA = acetylsalicylic acid, IQR = interquartile range, SD = standard deviation.

*Except where indicated otherwise.

†For mechanism of injury, data were available for 1379 of the participants.

‡For smoking status, data were available for 1172 of the participants and 41 of those lost to follow-up.

§For number of rib fractures, data were available for 1364 of the participants.

¶Confirmed by initial radiography.

robust guidelines are available on the amount of pleural fluid that is considered clinically relevant; therefore, any pleural fluid was considered a positive finding, because this should be investigated, especially in older patients.²³ Radiologists were blinded to data collection for this study. Interobserver agreement between emergency physicians and radiologists was assessed in the derivation cohort. Potentially important delayed hemothorax was considered to have been missed if reported by patients for the first time at the 30- or 90-day telephone follow-up.

Statistical analysis

The analysis involved distinct derivation and validation data sets. We derived models with one set of patients, and the best of these models (according to the C statistic) was subsequently validated with a different set of patients. We described clinical and demographic characteristics using univariable analyses.

Given the possibly high morbidity^{2,14,20} associated with minor thoracic injury and limited post-emergency resources, our objective was to derive and validate a stratification model with at least 90% sensitivity for delayed hemothorax, the highest possible specificity (near 50%) and the most parsimonious model achievable. We used log-binomial regression to identify the predictors of outcome measures. This type of analysis was preferred over logistic regression because it provides accurate relative risks (RRs), rather than odds ratios, when the incidence of an outcome is higher than 10%.²⁴ The cut point for continuous variables was assessed by iteration. We used the forward stepwise method to derive the model. The variables found to be both reliable (κ coefficient > 0.5) and strongly associated with the outcome measures according to univariable analysis ($p < 0.15$) were considered for multivariable analysis. We reported predictive capacities of the model for both the derivation

Table 2 (part 1 of 2): Characteristics of the derivation and validation cohorts

Characteristic	Cohort; no. (%) of patients*		<i>p</i> value†
	Derivation <i>n</i> = 830	Validation <i>n</i> = 552	
Demographic			
Age, yr, mean ± SD	53.3 ± 16.2	51.3 ± 17.4	0.03
No. aged ≥ 65 yr	210 (25.3)	131 (23.7)	0.5
Sex, male	522 (62.9)	346 (62.7)	0.9
Clinical			
Pleuritic chest pain	437 (52.6)	295 (53.4)	0.2
Dyspnea at rest	55 (6.6)	36 (6.5)	0.9
Dyspnea	177 (21.3)	121 (21.9)	0.8
Hemoptysis	6 (0.7)	5 (0.9)	0.8**
Mechanism of injury‡			
Simple fall	294 (35.9)	188 (34.5)	0.6
Fall above ground level	184 (22.5)	129 (23.7)	0.6
Motor vehicle crash	200 (24.4)	139 (25.5)	0.6
Cyclist v. car	5 (0.6)	5 (0.9)	0.5
Direct hit	85 (10.4)	57 (10.4)	> 0.9
Other	51 (6.2)	27 (5.0)	0.3
Pre-existing comorbidity			
COPD	34 (4.1)	11 (2.0)	0.03
Asthma	77 (9.3)	35 (6.3)	0.05
Osteoporosis	60 (7.2)	40 (7.2)	> 0.9
Diabetes mellitus	85 (10.2)	48 (8.7)	0.3
≥ 1 pre-existing comorbidity	213 (25.7)	119 (21.6)	0.09
Smoking status§			
Former smoker	179 (25.0)	117 (25.7)	0.9
Current smoker	219 (30.6)	134 (29.5)	0.6
Never smoker	318 (44.4)	204 (44.8)	0.9
Alcohol intoxication	56 (6.7)	36 (6.5)	0.9

Table 2 (part 2 of 2): Characteristics of the derivation and validation cohorts

Characteristic	Cohort; no. (%) of patients*		p value†
	Derivation n = 830	Validation n = 552	
Pre-injury antiplatelet/anticoagulant medication			
ASA	138 (16.6)	90 (16.3)	0.9
Clopidogrel	14 (1.7)	7 (1.3)	0.5
Warfarin	32 (3.9)	19 (3.4)	0.7
Any	171 (20.6)	106 (19.2)	0.5
Results of physical examination in emergency department			
Chest abrasion	36 (4.3)	29 (5.3)	0.4
Chest contusion	154 (18.6)	95 (17.2)	0.5
Bone crepitus	24 (2.9)	13 (2.4)	0.5
Other	213 (25.7)	139 (25.2)	0.8
Vital signs, mean ± SD			
Heart rate, beats/min	81.0 ± 14.1	80.6 ± 14.1	0.7
Oxygen saturation, %	97.6 ± 1.9	97.9 ± 1.9	0.01
Systolic blood pressure, mm Hg	141.0 ± 21.4	139.6 ± 19.6	0.2
Diastolic blood pressure, mm Hg	82.1 ± 12.4	81.1 ± 12.5	0.1
Respiratory rate, breaths/min	17.7 ± 3.1	17.8 ± 3.5	0.9††
No. of rib fractures¶			
None	560 (68.5)	354 (64.8)	0.2
1	112 (13.7)	91 (16.7)	0.1
2	78 (9.5)	52 (9.5)	> 0.9
≥ 3	68 (8.3)	49 (9.0)	0.6
Location of fracture¶			
Any high rib (3–5)	59 (7.2)	47 (8.6)	0.3
Any mid rib (6–9)	194 (23.7)	132 (24.2)	0.8
Any high or mid rib (3–9)	221 (27.0)	159 (29.1)	0.4
Any low rib (10–12)	81 (9.9)	54 (9.9)	> 0.9
Atelectasis‡	84 (10.1)	45 (8.2)	0.2
Note: ASA = acetylsalicylic acid, COPD = chronic obstructive pulmonary disease, SD = standard deviation. *Except where indicated otherwise. †All statistical analyses were performed with the Student <i>t</i> test or χ^2 test, except where indicated otherwise. ‡For mechanism of injury, data were available for 819 patients in the derivation group and 545 in the validation group. There were no patients with pedestrian v. car as the mechanism of injury. ¶For smoking status, data were available for 716 patients in the derivation group and 455 patients in the validation group. ¶Number and location of fractures were confirmed by initial radiography. For these variables, data were available for 818 patients in the derivation group and 546 in the validation group. **Fisher exact test. ††Wilcoxon test.			

and the validation phases. The multivariable stratification model allows clinicians to choose their own cut point, favouring either sensitivity or specificity.²⁵ This approach could be helpful in clinical practice settings, because it has been shown that the use of clinical decision rules differs between US and Canadian physicians.²⁶

We aimed to enter about 10 to 15 outcomes per variable in the log-binomial model.²⁷ According to previous reports of the incidence of delayed hemothorax (7% to

12%^{18,28}), we determined that a cohort of 800 patients for the derivation phase would allow 6 candidate variables for creation of the clinical decision rule, and a cohort of 500 patients for the validation phase would allow refinement and validation of a rule with at least 4 variables.²⁷ Thus, a total cohort of 1300 patients was needed. Participants were randomly assigned to the derivation or validation set during analyses based on previous optimal suggested scenarios.^{29,30}

Ethics approval

This study was approved by the research ethics board of each institution, and all participants provided written consent.

Results

During the study period, 2769 patients were screened for eligibility, and 1474 were recruited, with 92 of these being lost to follow-up (Figure 1). Relative to patients included in the study, those lost to follow-up were younger (mean age \pm standard deviation 44.8 ± 17.9 yr v. 52.5 ± 16.7 yr, $p = 0.001$),

more of them were smokers (61.0% [25/41] v. 30.1% [353/1172], $p < 0.001$), fewer had rib fractures (81.5% [75/92] v. 67.0% [914/1364] with no fractures, $p = 0.04$) and fewer had regular use of acetylsalicylic acid (7.6% [7/92] v. 16.6% [229/1382], $p = 0.02$). No other significant clinical differences were observed (Table 1). Data for 1382 patients were available for the analyses. The 7-, 14-, 30- and 90-day follow-up evaluations were completed for 1261 (91.2%), 1133 (82.0%), 1036 (75.0%) and 826 (59.8%) patients, respectively. Overall, 1341 patients (97.0%) had at least 1 medical or research evaluation within the first 14 days after discharge.

Table 3 (part 1 of 2): Characteristics of the 151 patients with hemothorax

Characteristic	Group; no. (%) of patients*			<i>p</i> value†
	Derivation <i>n</i> = 92	Validation <i>n</i> = 59	Total <i>n</i> = 151	
Demographic				
Age, yr, mean ± SD	59.6 ± 13.2	58.1 ± 15.6	59.0 ± 14.2	0.5
No. aged ≥ 65 yr	27 (29.3)	19 (32.2)	46 (30.5)	0.7
Sex, male	64 (69.6)	41 (69.5)	105 (69.5)	> 0.9
Clinical				
Pleuritic chest pain	48 (52.2)	28 (47.5)	76 (50.3)	0.6
Severe chest pain‡	46 (63.9)	30 (65.2)	76 (64.4)	0.9
Dyspnea at rest	10 (10.9)	4 (6.8)	14 (9.3)	0.4
Dyspnea	21 (22.8)	12 (20.3)	33 (21.9)	0.8
Hemoptysis	0 (0.0)	1 (1.7)	1 (0.7)	0.4††
Mechanism of injury§				
Simple fall	27 (29.7)	28 (48.3)	55 (36.9)	0.02
Fall above ground level	33 (36.3)	16 (27.6)	49 (32.9)	> 0.9
Motor vehicle crash	21 (23.1)	12 (20.7)	33 (22.1)	0.7
Other	10 (11.0)	2 (3.4)	12 (8.1)	0.4
Pre-existing comorbidity				
COPD	3 (3.3)	2 (3.4)	5 (3.1)	> 0.9††
Asthma	4 (4.3)	3 (5.1)	7 (4.6)	> 0.9††
Osteoporosis	4 (4.3)	6 (10.2)	10 (6.6)	0.2††
Diabetes mellitus	10 (10.9)	7 (11.9)	17 (11.3)	0.9
≥1 pre-existing comorbity	19 (20.7)	16 (27.1)	35 (23.2)	0.4
Smoking status¶				
Former smoker	15 (19.5)	17 (34.0)	32 (25.2)	0.04
Current smoker	30 (39.0)	15 (30.0)	45 (35.4)	0.3
Never smoker	32 (41.6)	18 (36.0)	50 (39.4)	0.5
Alcohol intoxication	9 (9.8)	5 (8.5)	14 (9.3)	0.8
Pre-injury antiplatelet/ anticoagulant medication				
ASA	18 (19.6)	11 (18.6)	29 (19.2)	0.9
Clopidogrel	0 (0.0)	0 (0.0)	0 (0.0)	NA
Warfarin	3 (3.3)	3 (5.1)	6 (4.0)	0.7††
Any	20 (21.7)	13 (22.0)	33 (21.9)	> 0.9

Table 3 (part 2 of 2): Characteristics of the 151 patients with hemothorax

Characteristic	Group; no. (%) of patients*			p value†
	Derivation n = 92	Validation n = 59	Total n = 151	
Results of physical examination in emergency department				
Chest abrasion	3 (3.3)	2 (3.4)	5 (3.3)	> 0.9††
Chest contusion	12 (13.0)	5 (8.5)	17 (11.3)	0.4
Clinical rib fracture	36 (39.1)	31 (52.5)	67 (44.4)	0.1
Bone crepitus	3 (3.3)	1 (1.7)	4 (2.6)	> 0.9††
Other	17 (18.5)	17 (28.8)	34 (22.5)	0.1
Vital signs, mean ± SD				
Heart rate, beats/min	80.3 ± 12.8	79.3 ± 15.7	79.9 ± 14.0	0.7
Oxygen saturation, %	97.2 ± 2.1	97.2 ± 1.9	97.2 ± 2.0	0.9
Respiratory rate, breaths/min	18.3 ± 3.3	17.6 ± 3.3	18.0 ± 3.3	0.3‡‡
No. of rib fractures**				
None	30 (32.6)	19 (32.2)	49 (32.5)	> 0.9
1	21 (22.8)	10 (16.9)	31 (20.5)	0.4
2	13 (14.1)	13 (22.0)	26 (17.2)	0.2
≥ 3	28 (30.4)	17 (28.8)	45 (29.8)	0.8
Location of fracture**				
Any high rib (3–5)	22 (23.9)	14 (23.7)	36 (23.8)	> 0.9
Any mid rib (6–9)	52 (56.5)	32 (54.2)	84 (55.6)	0.8
Any high or mid rib (3–9)	60 (65.2)	38 (64.4)	98 (64.9)	0.9
Any low rib (10–12)	14 (15.2)	9 (15.3)	23 (15.2)	> 0.9
Atelectasis†	18 (19.6)	10 (16.9)	28 (18.5)	0.7
Note: ASA = acetylsalicylic acid, COPD = chronic obstructive pulmonary disease, SD = standard deviation. *Except where indicated otherwise. †All statistical analyses were performed with the Student t test or χ^2 test, except where indicated otherwise. ‡For severe chest pain, data were available for 72 patients in the derivation group and 46 patients in the validation group (118 patients total). §For mechanism of injury, data were available for 91 patients in the derivation group and 58 patients in the validation group (149 total). Here, the category "other" incorporates data for pedestrian v. car, cyclist v. car and direct hit (these categories are reported separately in Table 1). ¶For smoking status, data were available for 77 patients in the derivation group and 50 patients in the validation group (127 patients total). **Number and location of fractures were confirmed by initial radiography. ††Fisher exact test. ‡‡Wilcoxon test.				

In the study cohort, 868 participants (62.8%) were men, and the mean age was 52.5 years (Table 1). Hemothorax was identified at the 7-day follow-up for 1180 (85.4%) of the patients. Delayed hemothorax occurred within the 14-day follow-up period for 151 patients (10.9%): 92 (11.1%) in the derivation phase and 59 (10.7%) in the validation phase. No cases of hemothorax were reported after the 14-day evaluations. Only 5 patients underwent drainage of the hemothorax, and no deaths were reported during the study period. Table 2 shows the clinical and demographic characteristics of study participants in the derivation and validation groups. Patients in the derivation group were slightly older (53.3 v. 51.3 yr), and had higher rates of chronic obstructive pulmonary disease (4.1% [34/830] v. 2.0% [11/552]) and asthma (9.3% [77/830]

v. 6.3% [35/552]). No other significant clinical differences were observed. Characteristics of participants with delayed hemothorax in both phases are described in Table 3.

Clinical decision rule for minor thoracic injury

All candidate variables had moderate to high interobserver agreement (κ coefficient > 0.5; Table 4). Table 5 shows the derived and validated log-binomial model and RRs with 95% confidence intervals (CIs). The final model included 4 variables: age ≥ 70 years old (RR 3.84, 95% CI 1.71–8.60), fracture in the high to mid rib region (ribs 3–9; RR 3.37, 95% CI 2.14–5.31), age 45 to 70 years (RR 2.72, 95% CI 1.26–5.89) and presence of 3 or more rib fractures (RR 1.97, 95% CI 1.31–2.95). The use of anticoagulants was initially included on

a theoretical basis, but this variable was highly correlated with patient age and was therefore omitted from the final model.

The final derived and validated clinical decision rule had a maximum score of 5. Sensitivity and specificity values for the model for both cohorts are presented in Table 6. The moderate-risk (score 2 or 3) and high-risk (score 4 or 5) levels had equivalent sensitivities and specificities across cohorts. The area under the receiver operating characteristic curve was 0.78 (95% CI 0.74–0.82) for the derivation cohort and 0.74 (95% CI 0.67–0.81) for the validation cohort. In the high-risk category, about 1 in every 3 patients experienced delayed hemothorax.

Table 4: Interobserver agreement for potential predictors

Predictor	Kappa (95% CI)
Clinical history (n = 62)*	
Mechanism of injury	0.97 (0.91–1.00)
Presence of comorbidity	
COPD	0.79 (0.51–1.00)
Asthma	0.73 (0.48–0.98)
Osteoporosis	0.58 (0.21–0.95)
Diabetes mellitus	1.00 (1.00–1.00)
Pre-injury antiplatelet/ anticoagulant medication	
ASA	0.91 (0.82–1.00)
Warfarin	1.00 (1.00–1.00)
Clopidogrel	1.00 (1.00–1.00)
Any	0.92 (0.84–1.00)
Clinical	
Severe chest pain	0.54 (0.37–0.71)
Pleuretic chest pain	0.41 (0.26–0.56)
Smoking status	0.87 (0.78–0.96)
Alcohol intoxication	0.87 (0.72–1.00)
Radiologic findings (n = 299)†	
No. of confirmed rib fractures	
≥ 1	0.60 (0.56–0.65)
≥ 3	0.47 (0.38–0.56)
Location of fractures	
Any high rib (3–5)	0.59 (0.46–0.73)
At least 2 high ribs (3–5)	0.59 (0.39–0.79)
Any mid rib (6–9)	0.50 (0.42–0.59)
At least 2 mid ribs (6–9)	0.37 (0.23–0.50)
Any low rib (10–12)	0.56 (0.44–0.67)
At least 2 low ribs (10–12)	0.39 (0.14–0.63)
Atelectasis	0.58 (0.50–0.66)

Note: ASA = acetylsalicylic acid, CI = confidence interval, COPD = chronic obstructive pulmonary disease.
 *For a total of 62 patients, an emergency physician and nurse performed an assessment of the clinical history.
 †For a total of 299 patients, a radiologist and an emergency physician performed radiologic evaluation of the number and location of rib fractures.

Interpretation

In this study, we developed a clinical decision rule for minor thoracic injury, which takes into account 4 clinically sensitive and robust variables to predict hemothorax in the 14 days after discharge from the emergency department. Use of this clinical decision rule in moderate- and high-risk groups will permit efficient use of follow-up services. Almost one-third of patients at high risk will have a hemothorax on follow-up, and the clinical decision rule has specificity of more than 90% for that category of patients. Use of this rule, in conjunction with risk stratification, may therefore promote efficient use of limited resources and meets our targeted sensitivity and specificity.

Until recently, only a few studies have reported potential predictive factors for delayed complications after minor thoracic injury, but none were derived and validated according to the methodologic standards for development of clinical decision rules.^{27,31,32} Most studies have reported that patients with at least 1 rib fracture represented about 90% of cases of delayed hemothorax;^{14,18,33,34} however, delayed hemothorax also has been reported in the absence of rib fractures.^{16,18} One retrospective study reported a prodrome of pain and acute dyspnea in 82% of emergency patients with delayed hemothorax after discharge,¹⁷ whereas other prospective prediction studies reported that the presence of thoracic contusions alone could represent a predictive factor for delayed complications.^{3,18} Age over 45 years³⁵ or age over 65 years³⁶ was also considered as a possible stand-alone predictive factor. The incidence of delayed hemothorax in the current study was slightly higher than in previous studies, which could be attributed to our prospective design, the important follow-up rate and the slightly older age of our cohort relative to previous studies.^{18,34} In their prospective study, Misthos and colleagues¹⁸ reported a 7.4% incidence of delayed hemothorax in an outpatient setting among patients under 65 years of age who underwent cardiothoracic evaluation in the emergency department. However, some patients with minor thoracic injury who were discharged without any cardiothoracic consultation may have had undetected hemothorax, which would have introduced selection bias. Patients 65 years of age or older accounted for 24.7% of our study cohort versus 21.5% in the study by Sharma and colleagues.³⁴ Moreover, the identification of older patients with delayed hemothorax is of importance, because it has been suggested that surgical drainage could be an early treatment option in these patients.²³

Physicians' practice is highly heterogeneous in the management of minor thoracic injury, with or without rib fractures, especially in terms of discharge follow-up plans and admission.²¹ Because hemothorax is associated with important consequences, such as acute respiratory distress syndrome, emphysema, functional limitations, infections and longer lengths of stay in hospital,^{20,37–41} post-emergency planning creates challenges for both health care professionals and patients. It is impossible to follow all patients with minor thoracic injury in overcrowded emergency departments. In Canada, the current wait time for a follow-up appointment with a family physician is about 30 days.⁴² Current post-emergency resources would be insufficient to meet the demand if all

Table 5: Derivation of points for clinical decision rule

Characteristic	RR (95% CI)	β coefficient	β coefficient after inflation*	Points
Age \geq 70 yr	3.84 (1.71–8.60)	1.3447	2.0	2
High or mid rib fracture†	3.37 (2.14–5.31)	1.2156	1.8	2
Age 45–70 yr	2.72 (1.26–5.89)	1.0004	1.4	1
At least 3 rib fractures	1.97 (1.31–2.95)	0.6771	1.0	1
Maximum total				5

Note: CI = confidence interval, RR = relative risk.
 *Inflation of β coefficients was accomplished by dividing each β coefficient by the smallest β coefficient in the preceding column (i.e., 0.6771). Points were then derived by rounding the inflated β coefficient to the nearest integer. C statistic = 0.779.
 †Ribs 3–9.

Table 6: Sensitivity and specificity of the model for derivation and validation cohorts*

Risk level	Score	<i>n</i>	Risk per stratum	Sensitivity (95% CI)	Specificity (95% CI)
Derivation cohort					
Low	0	199	0	100.0	0.0
	1	290	7.6	100.0 (96.1–100.0)	27.49 (24.3–30.9)
Moderate	2 or 3	242	15.7	76.1 (66.1–84.4)	64.50 (60.9–67.9)
High	4 or 5	85	37.7	34.8 (25.2–45.4)	92.68 (90.5–94.5)
Validation cohort					
Low	0	157	3.82	100.0	0.0
	1	171	4.7	89.8 (79.2–96.2)	31.3 (27.2–35.6)
Moderate	2 or 3	149	16.7	76.3 (63.4–86.4)	65.0 (60.6–69.3)
High	4 or 5	65	30.8	33.9 (22.1–47.4)	90.7 (87.7–93.1)

Note: CI = confidence interval.
 *The derivation and validation categories provide the risk per stratum of a delayed hemothorax. The sensitivity and specificity are represented by score categories.

patients with minor thoracic injury were to be followed. Our clinical decision rule provides a risk stratification process that would allow cost-effective use of existing resources by identifying patients with specific minor thoracic injuries who would benefit most from follow-up. The Quebec clinical decision rule for minor thoracic injury is likely to have widespread applicability and could be used by a wide range of front-line physicians, including emergency and primary care physicians, in urban, rural and remote areas worldwide.

Limitations

This study had some limitations. Our definition of minor thoracic injury was deliberately broad, and the decision to admit patients to hospital was left to the attending physician, to reflect a pragmatic approach. However, the inclusion of patients who had only simple chest abrasion and contusion may have increased the number of patients at very low risk of delayed hemothorax. Nevertheless, because it has been reported that patients who have “simple” chest contusion without rib fracture may experience delayed hemothorax,¹⁸ these patients were retained in our analysis. Furthermore, some variables may have

been overlooked in the creation of the derivation models; however, a consultant statistician found no systematic bias because of missing variables. There may have been selection bias because we excluded patients who were less sick and thus less likely to seek medical care. The number of rib fractures and their location (high or mid level) was assessed by upright chest and hemithorax radiography, to increase generalizability of the rule. These variables may have been subject to classification bias because there may be underdetection of rib fractures with simple radiography relative to ultrasonography and computed tomography. The number of rib fractures was recorded from radiologists’ reports, and the fractures themselves could have been misclassified, given that radiographic diagnosis of rib fracture may be imperfect.⁴³ Lastly, because the random assignment of participants to the derivation or validation set may have improved the performance of our model,^{29,30} future external validation could show different classification performance.^{27,44}

Conclusion

This large prospective study of patients with minor thoracic injury showed a 10.9% incidence of delayed hemothorax. The

validated Quebec minor thoracic injury clinical decision rule, using 4 variables (age ≥ 70 yr, rib fracture location, age 45–70 yr and number of rib fractures) identified patients at high risk of delayed hemothorax with 90% specificity. The Quebec minor thoracic injury rule should be further implemented to improve detection of delayed consequences in patients discharged from the emergency department.

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