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Pleural Effusion Following Rib Fractures in the Elderly: Are We Being Aggressive Enough?

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Abstract

Background: Delayed pleural effusion (DPF) is an understudied complication of rib fractures. Many DPF are not treated unless symptomatic, however, the consequences of DPF in the elderly has not been discussed in current literature. We sought to investigate the characteristics of rib fracture DPF, its associated outcomes, and implications for management in geriatric trauma patients.

Methods: A retrospective study was conducted from January 2012 to May 2014 on patients with rib fractures at a single Level-1 Trauma Center. Development of DPF was based on X-ray studies. Independent variables were: demographics, mechanism of injury, trauma factors, rib fracture severity, and laboratory values. Patient outcome variables were: ICU/hospital length of stay (LOS), and discharge disposition. Student's s t-test, *chi-square* test, logistic regression analysis was used for data analysis.

Results: 373 patients were identified with an average age of 73.6 years, 89.5% were white, 54.2% were male, and 54.4% of patients were involved in motor vehicle collisions. On average, 4.8 ribs were broken with an average ISS 13.9. 40.8% of patients developed DPF. We found statistically significant independent predictors for DPF as >6 rib fractures, flail chest, left sided fractures, bilaterality, motor vehicle collision (MVC, ISS >15, chest tube placement, hemothorax, pneumothorax, pulmonary contusion, WBC ≥11.3, glucose ≥142, albumin <3.5. Multivariate logistic regression derived a predictive Model: Loge(P/1-P) = -2.135 + 0.962 (MVC) + 0.831 (Chest tube placement) + 0.926 (pulmonary contusion) + 0.620 (rib frx ≥ 6) + 0.828 (Albumin <3.5) + 0.543 (left sided frx), where p is the probability of developing DPF.

Conclusion: The study suggests that early aggressive evaluation of the elderly trauma patient with rib fractures for delayed pleural effusion followed by an appropriate treatment (thoracentesis) would improve outcomes including decreased length of stay and favorable discharge home. A further avenue for inquiry would be to conduct comparative research between groups of elderly asymptomatic patients to determine whether their prognosis improves as opposed to those asymptomatic who do not receive treatment.

Keywords: Delayed pleural effusion; Rib fractures; Geriatrics; Trauma; G60 motor vehicle collisions

Introduction

The older population in the United States is rapidly increasing, with the most recent estimate of 72.7 million individuals over the age of 65 years by 2030 [1]. As a result, trauma centers in America are projected to see an increase in geriatric trauma patients in the years to come. Geriatric patients are not simply older adults, but are comprised of a population of individuals with decreased physiological reserve, concomitant co-morbidities and polypharmacy. Because of these factors, these patients demand aggressive management in trauma and the acute care settings [2,3]. Nevertheless, the current elderly population has a more active lifestyle than the generations before them. Consequently, the prevalence of geriatric trauma is increasing and the empirical evidence from our level I trauma center supports this notion.

Blunt thoracic trauma resulting in rib fractures is common in the geriatric population. We experienced an 18.6% increase in chest trauma and 17.0% increase in rib fractures among patients ≥60 years in 2014 compared to 2010. Care pathways for the management of patients with rib fractures has conventionally been conservative, consisting of adequate pain management and thoracentesis for symptomatic patients. At our trauma center, we have embarked on rib plating initiative as an innovation developed specifically to improve outcomes for patients with rib fractures in general and geriatric patients in particular. This approach is impactful because current medical literature indicates that geriatric patients with rib fractures have increased morbidity and mortality [4-6]. Among trauma patients with the same number of rib fractures, geriatric patients compared to younger patients are twice as likely to develop pneumonia or die more often [7]. Delayed pleural effusion (DPF) has been reported as an uncommon entity with significant morbidity among patients with blunt thoracic trauma [7-9].

The purpose of this study was to determine the prevalence of DPF among geriatric trauma patients with rib fractures and to investigate risk factors and patient outcomes among patients who developed and patients who did not develop pleural effusion after 24 hours of admission.

Patients and Methods

A retrospective study was conducted using trauma registry at our Level-1 trauma center. All patients ≥60 years of age with at least 1 rib fracture from January 2012 to May 2014 were identified using abbreviated injury scale (AIS 807.0013 to 807.0953). Pleural effusion is defined as a collection of fluid in the pleural space based on imaging studies. The physiological volume of pleural fluid in the absence of pathology is about 5 ml. For the purpose of this study, we operationally defined DPF as either a newly developed or increased pleural effusion per X-ray reading following admission image studies until discharge. Delayed pleural effusion during the index patient hospitalization was therefore the study target. No special efforts were made to quantify the volume of pleural effusion from imaging studies. We excluded patients who had hospital length of stay (LOS) <1 day to improve specificity. Patients with LOS <1 day were unlikely to have had sufficient time interval from admission to the time of patient assessment for the study endpoint.

Injury severity score (ISS) and trauma revised ISS (TRISS) were used as baseline measures of injury severity. Study data pertaining to rib fractures and sequalae, including number of fractures, identity of ribs broken, laterality, flail chest, a diagnosis of pneumothorax, hemothorax, and pulmonary contusion were extracted from radiology reports as well as the AIS designation. When there was an uncertainty in the radiology report as to whether or not the patient had DPF, primary data source materials such as X-rays and/or CT studies were retrieved and re-evaluated by trauma surgeons or radiologist for resolution. Mechanism of injury (MOI) examined included motor vehicle collisions (MVC), ground level falls (GLF), fall from ladder, and others. Co-morbidities were extracted. Pre-determined laboratory variables included albumin, total serum protein, white blood cells (WBC), blood glucose and hemoglobin A1C were also abstracted. The primary study outcome was a diagnosis of DPF after 24 hours. Secondary patient outcomes variables were: hospital length of stay (HLOS), ICU length of stay (ICULOS), and discharge disposition (home, rehab/LTC/SNF, or mortality/hospice).

Statistical analysis performed

The outcome or response variable in this study (+DPF or -DPF) was dichotomous and well-defined based X-ray and/or CT imaging studies. We then collected specific patient data (Table 1) that described the characteristics of the majority of trauma patients with rib fractures who were admitted to our trauma center. This was followed by comparison of variables between +DPF and -DPF patients. Patient variables with normal distribution were compared using independent Student's t-test. Univariate logistic regression analysis was completed using Pearson's *Chi-Square* test to determine the goodness of fit between each categorical risk factor (e.g. pulmonary contusions vs. no pulmonary contusion) and response variable categories (+DPF or -DPF). Risk factors pre-identified from the *Chi-Square* test ($p<0.05$) were entered into a multivariate regression model. An equation was generated showing the probability of a patient developing DPF as an outcome given the independent variables identified from the univariate model.

Age	73.6 ± 0.48 years
Gender	
Male	54.2%
Female	45.8%
Ethnicity	
White	89.5%
Asian	1.3%
Black	1.1%
Other	8.0%
Mechanism of injury	
Motor vehicle collisions (MVC)	54.4%
Ground level falls (GLF)	23.9%
Fall from ladder	6.7%
Other	15.0%
Average no of co-morbidities	1.35
ISS	13.9 ± 0.49
TRISS	0.91 ± 0.01
HLOS	7.08 ± 0.31
ICULOS	5.46 ± 0.37
Discharge disposition	
Home	46.8%
Rehab/long term care/skilled nursing facility	48.7%
Dead/hospice	4.5%
Ribs Fractured	
Mean	4.8 ± 0.2
Mode	3
Range	1-19
Left rib fractures	
Left side total	62.2%
Left side only	46.6%
Mean ribs fractured	4.2 ± 0.16
Right rib fractures	
Right side total	50.7%
Right side only	37.8%
Mean ribs fractured	4.5 ± 0.18
Bilateral rib fractures	
Bilateral total	15.5%
Mean ribs fractured	9.4 + 0.51

HLOS=Hospital length of stay, ICULOS=ICU length of stay, ISS=Injury severity score, TRISS=Trauma revised injury severity score

Table 1: Characteristics of geriatric rib fracture patients.

The multivariate logistic model (logit) we developed was as follows:

$$\text{Log } (p/(1-p)) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots \beta_p X_{ip} \quad (1)$$

Log is the natural logarithmic function (base e) and p is the probability of developing DPF, α is a constant, and β_1, β_2+ ... + βp are unstandardized beta coefficients and X_1, X_2, $X_3 \ldots X_{ip}$ are independent variables. These independent variables included, MCV, chest tube placement, pulmonary contusion, number of ribs fractured equal or greater than 6, albumin<3.5 g/dL and rib fracture on the left. From equation (1) we obtained the following algebraic solution to p.

$$p = 1/ (1+ e^{\wedge} (\alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots \beta_p X_{ip})))$$

IBM R SPSSR statistics V22.0 and Graphpad Prism v.5 were used for statistical analysis. This study was approved by an Institutional Review Board.

Results

From January 2012 to May 2014, a total of 414 patients ≥ 60 years of age with at least 1 rib fracture were identified from our level I trauma database (AIS codes 807.00 1 3 to AIS code 807.09 5 3). After excluding patients with <1 day of admission, 373 patients remained. The characteristics of the majority of trauma patients admitted to our trauma center with rib fractures are described in Table 1. The mean age was 73.6 ± 0.48 years, 54.2% were male, and 89.5% were white. The primary mechanism of injury was MVC (54.4%), followed by ground level falls (23.9%). The median value of ribs broken was 4. Two out of five (40.8%) patients with rib fractures developed DPF. The average time for the development of DPF was 2.9 ± 0.2 days.

Although all patients in this study had at least 1 broken rib, not every patient with broken ribs developed DFP. Patients who developed DPF (+DPF) and patients who did not develop DPF (-DPF) differ in several ways (Table 2).

Factors	+DPF	-DPF	P-value
(mean ± SEM)		(mean ± SEM)	
Age	74.2 ± 0.75	73.2 ± 0.63	0.272
HLOS	9.1 ± 0.44	5.6 ± 0.39	<0.001*
ICULOS	6.4 ± 0.51	4.3 ± 0.53	0.005*
ISS	16.6 ± 0.80	12.0 ± 0.59	<0.001*
TRISS	0.89 ± 0.013	0.92 ± 0.011	0.099
# rib fracture	6.0 ± 0.3	4.0 ± 0.2	<0.001*
WBC	12.0 ± 0.37	10.5 ± 0.35	<0.007*
Glucose	148.9 ± 4.6	134 ± 3.2	0.008*
Hemoglobin A1C	6.1 ± 0.12	6.0 ± 0.09	0.227
Albumin	3.38 ± 0.04	3.53 ± 0.03	0.001*
Total Protein	6.7 ± 0.7	8.0 ± 0.6	0.102

+DPF=Patients who developed delayed pleural effusion, -DPF=Patients who failed to develop delayed pleural effusion, HLOS=Hospital length of stay, ICULOS =ICU length of stay, ISS=Injury severity score, TRISS=Trauma Revised Injury Severity Score, WBC=white blood cells.

Table 2: Characteristic differences between +DPF and -DPF.

ISS was significantly higher for +DPF (p<0.001), and they also had a higher number of rib fractures (P<0.001). Admission glucose levels were higher in +DPF group (p=0.008), while HgA1C level were not significantly different. Albumin levels were lower in +DPF group (0.001), although total protein levels were not significantly different. The odds ratio and 95 percent confidence intervals for risk factors associated with the development of DFP are shown in Table 3. Significant risk factors for developing DFP were injuries on admission, including MVC, hemothorax, pneumothorax, flail chest, and pulmonary contusion (p<0.001, 0.041, 0.001, 0.005, <0.00, respectively). Interestingly, patients with left sided rib fractures were more likely to develop DPF than patients with right sided rib fractures. (p=0.007).

Predictive Factors	*Chi-square* (P-Value) Value)	Odds Ratio
MVC	<0.001	2.310 (1.506-3.545)
Hemothorax	0.041	2.62 (1.007-6.818)
Pneumothorax	0.001	2.387 (1.443-3.948)
Bilaterality	0.067	1.786 (0.955-3.340)
Flail chest	0.005	4.40 (1.409-11.583)
Pulmonary contusion	0.000	3.233 (1.792-5.835)
Left rib fracture	0.007	1.826 (1.178-2.830)
HLOS (<8* *vs.* ≥8)	<0.001	5.674 (3.574-9.007)
ICULOS (<5* *vs.* ≥5)	0.002	2.511 (1.410-4.472)
ISS (<14* *vs.* ≥14)	<0.001	2.751 (1.790-4.228)
WBC (<11.3* *vs.* ≥11.3)	0.003	1.896 (1.234-2.915)
Glucose (<142* *vs.* ≥142)	0.032	1.621 (1.040-2.527)
Albumin (<3.5* *vs.* ≥3.5)	<0.001	0.436 (0.280-0.677)
Total rib fracture (<6* *vs.* ≥ 6)	<0.001	3.093 (1.988-4.811)
Chest tube	<0.001	2.896 (1.672-5.015)
Home	<0.001	0.388 (0.252-0.599)
Rehab/LTC/SNF	<0.001	2.938 (1.915-4.506)
Mortality/Hospice	0.197	1.924 (0.701-5.284)

*denotes reference category. MVC: motor vehicle collision, HLOS: hospital length of stay, ICULOS: ICU length of stay, ISS: injury severity score, WBC: White blood cell, UTI: urinary tract infection, Rehab/LTC/SNF: rehabilitation/long term care/skilled nursing facility.

Table 3: Univariate logistic regression for significant factors associated with +DPF.

On the basis of these empirical observations, we sought to characterize the rib fractures on the left, right or both more extensively. Ribs did not fracture equally on both sides; 62.2% of all fractures were on the left, 50.7% were on the right side and 15.5% were bilateral. The percentage of ribs broken sorted by individual rib is shown in Table 4.

The pattern of broken ribs on the right-side or on the left-side and their relation to the risk of developing DPF were examined. Broken rib numbers 2-9 on the left were significant risk factors for developing of DPF. This compares and contrasts with broken rib numbers 4-7 on the right as significant risk factors for DFP predictors. Top and bottom rib fractures were not significant for DPF development.

Rib	Frx %	Univariate OR	p-value
L1	8.3%	1.403 (0.671-2.931)	0.366
L2*	16.6%	2.736 (1.562-4.793)	<0.001
L3*	23.1%	2.860 (1.742-4.696)	<0.001
L4*	32.2%	1.936 (1.246-3.009)	0.003
L5*	34.3%	2.172 (1.405-3.359)	<0.001
L6*	35.1%	2.030 (1.317-3.130)	0.001
L7*	34.0%	1.824 (1.181-2.817)	0.006
L8*	26.3%	1.658 (1.173-2.979)	0.008
L9*	21.2%	1.899 (1.150-3.134)	0.011
L10	13.4%	1.281 (0.704-2.332)	0.417
L11	8.8%	1.079 (0.523-2.224)	0.838
L12	4.6%	1.309 (0.493-3.472)	0.588
R1	8.3%	0.784 (0.364-1.688)	0.533
R2	12.9%	1.269 (0.690-2.335)	0.443
R3	22.5%	1.437 (0.881-2.343)	0.146
R4	29.0%	2.826 (1.143-2.826)	0.011*
R5	30.0%	1.719 (1.098-2.690)	0.017*
R6	31.4%	1.610 (1.034-2.506)	0.034*
R7	28.7%	2.166 (1.373-3.417)	0.001*
R8	22.0%	1.622 (0.990-2.656)	0.054
R9	18.2%	1.370 (0.808-2.325)	0.242
R10	11.8%	1.302 (0.686-2.472)	0.727
R11	6.4%	1.041 (0.450-2.410)	0.925
R12	4.8%	0.922 (0.349-2.434)	0.869

* denotes significance. L1-L12: Left rib 1-left rib 12 (cephalic to caudal), R1-R12 (cephalic to caudal)

Table 4: Rib fracture percentage in all fractures and odds ratio for +DPF sorted by rib.

A multivariate logistic regression model to predict DPF was developed, Risk factors pre-identified from the Chi-Square test ($p<0.05$) were entered into a multivariate regression model. The results are summarized in Table 5. The unstandardized beta coefficients associated with variables in the equation were used to derive the following equation: Log (p/1-p) = -2.135 + 0.962 (MVC) + 0.831 (Chest tube placement) + 0.926 (pulmonary contusion) + 0.620 (rib fracture ≥ 6) + 0.828 (Albumin < 3.5) + 0.543 (left sided fracture). The beta coefficients are all positive. Thus indicates that MVC, chest tube placement, pulmonary contusion, six or more ribs broken and hypoalbuminemia were independent factors that increased the risk of developing DPE. The sensitivity of this prediction model is 56.9%, and specificity of 80.0%, giving an accuracy of 70.2%.

Predictive Factors	Odds Ratio (95% CI)	P-values
Left side fracture	1.720 (1.035-2.859)	0.036
Rib fracture (<6* *vs.* ≥ 6)	1.860 (1.124-3.076)	0.016
Albumin (<3.5* *vs.* ≥3.5)	0.437 (0.270-0.708)	0.001
Pulmonary contusion	2.523 (1.284-4.960)	0.007
Motor vehicle crashes (MVC)	2.616 (1.586-4.960)	<0.001
Chest tube placement	2.296 (1.228-4.293)	0.009

* denotes reference category. MVC=Motor vehicle collision

Table 5: Multivariate logistic regression for +DPF.

The prevalence of co-morbidities, including hypertension, diabetes, and coronary artery disease, were not significantly different between patients who developed DFP and those who did not. However, there was statistically significant association between complications such as pneumonia ($p<0.001$) and UTI ($p=0.015$) and the development of DPF. Patients who developed DPF had longer HLOS and ICULOS days (Table 2).

Discharge disposition was different between the two groups. Patients with DPF were less likely to be discharged home ($p<0.001$), and more likely to go to Rehab/LTC/SNF ($P<0.001$). Rate of Mortality/Hospice showed no significant differences ($p=0.197$).

Discussion

As our population ages, more attention is being paid to the care of geriatric trauma patients. Many studies have reported increased morbidity and mortality in the elderly compared to younger patients regardless of injury patterns [10,11]. In chest trauma, age has been shown to be a significant predictor of increased morbidity and mortality [5,12]. Although rib fractures are common in the geriatric population they have often been considered as minor injuries. More importantly, the relationship between rib fractures and DPF remains poorly understood. In the present study we report a new finding that the prevalence of DPF, (40.8%) is high suggesting this could be clinically important. Second we compared and contrasted the characteristics of patients who developed DPE and those that did not with the aim of identifying risk factors for the development of DPF which we did accomplish. As shown in Table 2, patients who developed DPF had higher ISS, TRISS, a greater number of ribs fractured, abnormal laboratory values but no differences in age or total serum protein levels. Similarly, using univariate logistic regression analysis of risk factors for DPF (Table 3) we calculated the odds ratio as a relative assessment.

Although not all DPFs were severe enough to warrant treatment such as thoracentesis, the association between +DPF and significant patient outcomes is impactful (Table 2). For example, patients who developed DPF had increased HLOS, ICULOS, complications rate, and adverse discharge disposition. These observations are clearly important and support our assertion that DPE is a serious entity based both on its high prevalence (40.8%) and its statistically significant association with adverse patient outcomes. Thus the answer to the question "Pleural effusion following rib fractures in the elderly: are we being aggressive enough?" has been addressed to a highly satisfactory degree based on study design. The physiology in older patients combined with trauma to the chest can overwhelm compensatory mechanisms. Thus, complications such as DPF can become severe in geriatric patients, prolonging their HLOS, ICULOS, and ultimately their adverse discharge disposition.

We identified several independent predictive factors (Table 3), in multivariate model. We found that based on the unstandardized beta coefficients patients who developed pleural effusion were those injured in a MVC, suffered >6 rib fractures, sustained left sided fractures, pulmonary contusion, had a chest tube placement, and had albumin <3.5 g/dL on admission. Our model for predicting DPF has a specificity of 80.0% but the sensitivity was only 56.9%.

Pleural fluid accumulation is understood and explained in terms of hydrostatic pressure pushing fluid into the pleural space which is then counter-balanced by osmotic pressure which causes fluid absorption back into the circulatory system. Pleural effusion occurs when the rate of filtration exceeds the rate of absorption. Thus many processes, including both mechanical and biological, mechanisms can cause fluid accumulation. A disruption in the pressure seal by trauma (i.e. rib fracture, atelectasis, and pulmonary contusion) can disrupt the pleural pressure as well as increase local pro-inflammatory response [13] that favors pleural accumulation. Hypoalbuminemia also contributes to pleural effusion by decreasing oncotic pressure.

Albumin found in the blood stream is an important transport protein in the delivery of drugs, hormones, vitamins and toxins. The molecule itself is key for maintaining the osmotic pressure of the fluid in the blood vessel. Hypoalbuminemia has been attributed to increased hospital length of stay and early mortality in trauma patients [14,15]. We also observed high blood glucose levels at patient admission for both +DPF and DPF groups. This observation was not unexpected because trauma has been shown to cause hyperglycemia [16]. However, patients with DPF had a significantly higher glucose levels than those patients who did not (p=0.008). We are unable to completely explain this observation. However, the higher level of glucose found in patients who developed DPF may be reflective of the higher injury severity (Table 2). Both groups had similar Hemoglobin A1C levels (P=0.227), indicating that the risk or prevalence of diabetes or prediabetes among + DPF and –DPF were indistinguishable. Hyperglycemia is correlated with many negative outcomes including morbidity, mortality, and other complications such as infections [15-17].

Given that most of the elderly suffered some form of trauma mostly MCV and they had this propensity for left sided fractures, it is intriguing what the underlying physiological mechanism was. We were uncertain if there is an underlying physiological mechanism that will account for the propensity of rib fractures to occur more often on the left compared to the right. However, Crandal [18] reported that in simulated frontal collisions, torso belt loading produced rib fractures generally located along the path of the car seat belt. Torso belt marks were associated with rib fractures located primarily in the upper left and lower right aspects of the body. In our study we observed statistically significant association between fractures involving L2-L8 and R4-R7 (Table 4) and DPF. Thus the propensity for left sided fractures is driven not by an underlying physiology mechanism but rather by the geometric and physico-mechanical configuration of the seat belt loading. This inference is clearly supported by the report that superimposition of airbag loading results in more evenly distributed and posterolateral pattern.

The mechanisms contributing to DPF are unclear, and future studies are warranted.

It is likely that +DPF patients were at higher risks of pneumonia (p<0.001) and UTI (p=0.015) because the stayed longer in the ICU or in the hospital. Similarly, patients with more severe injuries would require longer ICULOS and HLOS days. We found that patients who developed DPF had higher ISS values. The cause and effect of this relationship could not be established in this study due to methodological limits. Future studies could examine this relationship further.

Discharge outcomes of +DPF patients were less favorable compared to –DPF patients, with significant decreased likelihood of being discharged home (P<0.001). This correlation could be due to patients with +DPF having a more severe injury as evidenced by increased ISS (P<0.001) and increased number of rib fractures (P<0.001). In our analysis for DPF, ISS was an independent predictor of DPF, but not in a multivariate analysis.

Conclusion

The study suggests that early aggressive evaluation of the elderly trauma patient with rib fractures for delayed pleural effusion followed by an appropriate treatment (thoracentesis) would improve outcomes including decreased length of stay and favorable discharge home. A further avenue for inquiry would be to conduct comparative research between groups of elderly asymptomatic patients to determine whether their prognosis improves as opposed to those asymptomatic who do not receive treatment.

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