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Research Article

The pulmonary contusion score: Development of a simple scoring system for blunt lung injury

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ABSTRACT

Background: Pulmonary contusions (PC) are common after blunt chest trauma and can be identified with computed tomography (CT). Complex scoring systems for grading PC exist, however recent scoring systems rely on computer-generated algorithms that are not readily available at all hospitals. We developed a scoring system for grading PC to predict the need for prolonged mechanical ventilation and initial hospital admission location.
Methods: A retrospective review was performed of adult blunt trauma patients with PC identified on initial chest CT during 2020. Data elements related to demographics, injury characteristics, disposition and healthcare utilization were extracted. The primary outcome was the need for mechanical ventilation for greater than 48 h. A novel scoring system, the Pulmonary Contusion Score (PCS) was developed. The maximum score was 10, with each lobe contributing up to 2 points. A score of 0 was given for no contusion present in the lobe, 1 for less than 50 % contusion, and 2 for greater than 50 % contusion. A PCS of 4 was hypothesized to correlate with need for mechanical ventilation for over 48 h. A confusion matrix of the scoring algorithm was created, and inter-rater concordance was calculated from a randomly selected 125 patients.
Results: A total of 217 patients were identified. 118 patients (54 %) were admitted to the ICU, but only 23 patients (19 %) were intubated, and only 17 patients (8 %) required mechanical ventilation > 48 h. Sensitivity of the scoring system was 20 %, while specificity was 93 %. Negative predictive value was 93 %. Inter-rater agreement was 77 %.
Conclusion: The PCS is a scoring system with high specificity and negative predictive value that can be used to evaluate the need for mechanical ventilation after sustaining blunt PC and can help properly allocate hospital resources.
Level of evidence: IV - diagnostic criteria

Background

Thoracic trauma occurs in approximately half of blunt trauma patients, with 30 to 75 % of these thoracic trauma patients sustaining pulmonary contusions [1–3]. Parenchymal lung injury seen in PC leads to pathophysiologic changes which manifest clinically as hypoxemia, hypercarbia, and increased work of breathing [4]. PC are an independent risk factor for developing pneumonia, acute respiratory distress syndrome (ARDS), and are associated with an increased mortality rate as high as 25 % [5].

Utilization of chest computed tomography (CT) has substantially increased in recent years. CT scans have greater sensitivity for detecting pulmonary injury than chest x-ray, thus PC are now more frequently diagnosed. A recent study found that patients with isolated PC seen only on CT scan had higher rates of admission but a similar mortality to patients without PC on imaging. [6] These potentially insignificant findings seen only on CT may not translate to injuries requiring intervention and close observation, and could indicate an overutilization of hospital resources.

Several scoring systems for PCs exist. Recently, the focus has been on measuring PC volume using three-dimensional reconstruction of chest CTs. While this may allow for a more precise measurement of contusion

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volume, this technology may not be widely available at all hospitals or immediately in the trauma bay to guide decision making. We developed a novel scoring system for grading PC that is reproducible and can be widely utilized at bedside in any trauma center. We hypothesized this scoring system could be used to predict the need for prolonged mechanical ventilation and whether intensive care unit (ICU) admission is needed in patients presenting with PC.

Methods

A retrospective analysis of prospectively collected data was conducted at a high-volume American College of Surgeons verified Level 1 trauma center. The study was approved by the hospital's Institutional Review Board. A waiver of informed consent was obtained due to the retrospective nature of this study and the minimal risk to the individual patients. Adult (≥ 18 years old) trauma patients presenting in the calendar year of 2020 were included.

Patients must have sustained trauma from a blunt mechanism including motor vehicle collision (MVC), motorcycle collision (MCC), other vehicle collision (auto versus pedestrian, bicycle, all-terrain vehicle, water vehicle) and other (fall, assault). Patients also must have had PC identified on initial chest CT obtained upon arrival at the trauma center. Patients were excluded if their head abbreviated injury score was greater than three or if they died within 24 h of arrival to the trauma center. (Fig. 1) Demographic characteristics, vital signs on presentation, injury severity score, abbreviated injury scores, admission location, intensive care unit (ICU) and hospital length of stay, and injury characteristics were obtained from the institution's professionally maintained trauma registry. Duration of mechanical ventilation, oxygen requirements, radiologic identified chest injuries including rib fractures, pneumothoraces, hemothoraces, clavicle fractures, sternal fractures, and scapula fractures as well as hospital procedures and outcomes were obtained by chart review.

A novel scoring system, the Pulmonary Contusion Score (PCS) was developed. The maximum potential score is 10. The right lung was divided into three lobes (right upper lobe, right middle lobe, and right lower lobe), while the left lung was divided into two lobes (left upper lobe and left lower lobe). Each lobe could receive a maximum score of 2. A score of 0 is given for no contusion present in the lobe, 1 for less than 50 % contusion in the lobe, and 2 for greater than 50 % contusion in the lobe. A contusion score of ≥ 4 was hypothesized to correlate with the need for mechanical ventilation greater than 48 h.

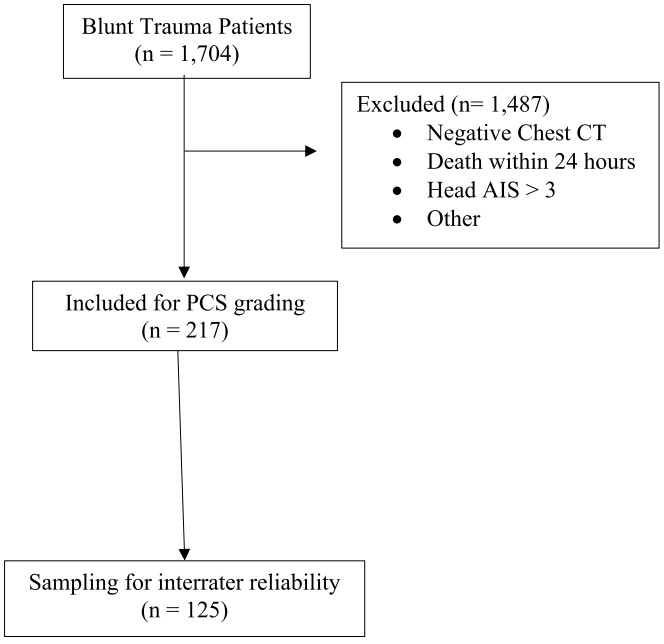

Fig. 1. Inclusion Flow Chart. Illustration of the inclusion and exclusion criteria. 1704 patients who suffered blunt trauma were initially identified. 1487 patients were excluded, leaving a remaining 217 patients to be included. Of the 217 patients 125 patients were sampled for inter-relater reliability of the computed tomography (CT) images.

Categorical variables were represented as frequencies and proportions, while continuous variables were presented as means and standard deviations. A confusion matrix of the scoring algorithm was created. For the confusion matrix, we calculated sensitivity, specificity, precision (aka positive predictive value), negative predictive value, accuracy, inaccuracy, diagnostic ratio [7–11]. We also conducted Receiver Operating Characteristic (ROC) analysis to assess the overall diagnostic performance of the tool. Chi-square and independent-samples-*t*-tests were utilized to analyze the data.

For interrater reliability, a subset of 125 chest CTs of the patients meeting inclusion criteria were reviewed and scored using the PCS by a fellowship-trained trauma provider. A second trauma provider independently reviewed the same 125 CT scans and provided a PCS. Interrater agreement was computed via Kappa statistics and findings were interpreted according to the criteria provided by McHugh in 2012 [12]. The significance level was set at 5 % and two-sided p values were considered. All analytic procedures were conducted using the Statistical Package for Social Sciences for Windows, version 28.0 (SPSS, Chicago, IL, USA).

Results

A total of 217 patients with PC met inclusion criteria. One hundred and sixty-one patients (74 %) were females, with a mean age of 42±17 years, most commonly injured by motor vehicle collisions (45 %) and having a mean Injury Severity Score (ISS) of 17± 8.5. Table 1

Patient's presenting blood pressure and heart rate were similar

Table 1
Demographic and injury characteristics of overall sample.

Variable	Categories	Overall Sample (*n* = 217)	Patients Requiring Mechanical Ventilation > 48 H		P-value
			Yes (*n* = 23)	No (*n* = 194)	
Gender	Female	161 (74 %)	6 (26 %)	50 (26 %)	0.97
Age, years (Mean ± SD)	–	42 ± 17	41 ± 17	43 ± 17	0.60
Race	White	120 (55 %)	15 (65 %)	105 (54 %)	0.49
	Black	45 (21 %0	2 (9 %)	43 (22 %)	
	Asian	11 (5 %)	1 (4 %)	10 (5 %)	
	Other	41 (19 %)	5 (22 %)	36 (18 %)	
Ethnicity	Hispanic	43 (20 %)	4 (17 %)	39 (20 %)	0.75
	Non-Hispanic	173 (80 %)	19 (83 %)	154 (80 %)	
Mechanism of Injury	MVC	98 (45 %)	11 (48 %)	87 (45 %)	0.84
	Motorcycle	38 (17 %)	5 (22 %)	33 (17 %)	
	Vehicular Other	42 (19 %)	3 (13 %)	39 (20 %)	
	Other	39 (18 %)	4 (17 %)	35 (18 %)	
Injury Severity Score (Mean ± SD)	–	16.7 ± 8.5	23.9 ± 8.6	15.9 ± 8.1	**<0.001**

P values less than 0.05 are considered statistically significant (bold).

between those who required mechanical ventilation > 48 h and those who did not. Sixty percent of patients required supplemental oxygen in the form of nasal cannula or face mask on presentation. The most commonly associated chest injury in patients that were found to have pulmonary contusions were rib fractures followed by pneumothoraces. Upon comparing the clinical characteristics, patients requiring mechanical ventilation for > 48 h had significantly higher proportions of oxygen supplementation (91% vs. 56 %, p= 0.001), right-sided rib fractures (61% vs 33 %, p=0.007), right pneumothorax (52% vs 28 %, p=0.019), right hemothorax (35% vs 14 %, p=0.01) and sternal fractures (17% vs 3 %, p=0.002). Table 2.

One hundred eighteen patients (54 %) were admitted to the ICU, 18 patients (8.3 %) were admitted to intermediate level of care, 70 patients (32 %) were admitted to the lowest level of care, and 11 patients (5 %) were discharged from the Emergency Department. Thirty-four (16 %) patients of the total 217 patients required intubation and mechanical ventilation, with 23 on the ventilator for greater than 48 h. Table 3.

Confusion matrix of the scoring system revealed a sensitivity of 20 % and a specificity of 93 %. The negative predictive value was 93 %. Additional statistics from the confusion matrix can be seen in Table 4.

Inter-rater agreement of the scoring system was 77 % (SE = 0.073, P< 0.001) among the randomly selected 125 patients. The receiving operator curve had an area under the curve of 55.6 %, indicating the scoring algorithm has less discriminatory power to classify cases. (Fig. 2)

Discussion

PC commonly occur after blunt trauma. In the era of whole-body CT imaging, PC and other thoracic injuries such as rib fractures are more frequently diagnosed. While PCs increase the risk of pneumonia, ARDS and death, the majority of patients are not likely to have severe contusions. [5] Quantification of these contusions can help determine the degree of pulmonary injury and risk for development of pneumonia, ARDS and need for mechanical ventilation.

Table 2
Clinical and injury characteristics of overall sample.

Clinical Characteristic	Overall Sample (n = 217)	Patients Requiring Mechanical Ventilation > 48 H		P value
		Yes (n = 23)	No (n = 194)	
Systolic Blood Pressure, mm Hg (Mean ± SD)	133 ± 26	132 ± 26	133 ± 26	0.80
Heart Rate, bpm (Mean ± SD)	96 ± 22	107 ± 34	94 ± 19	0.10
Oxygen Supplementation	130 (60 %)	21 (91 %)	109 (56 %)	**0.001**
Right Rib Fractures	77 (36 %)	14 (61 %)	63 (33 %)	**0.007**
Left Rib Fractures	86 (40 %)	10 (44 %)	76 (39 %)	0.69
> 3 Bilateral Rib Fractures	11 (5 %)	3 (13 %)	8 (4 %)	0.65
Right Pneumothorax	67 (31 %)	12 (52 %)	55 (28 %)	**0.02**
Left Pneumothorax	73 (34 %)	8 (35 %)	65 (34 %)	0.91
Right Hemothorax	35 (16 %)	8 (35 %)	27 (14 %)	**0.01**
Left Hemothorax	40 (18 %)	7 (30 %)	33 (17 %)	0.12
Sternal Fracture	10 (5 %)	4 (17 %)	6 (3 %)	**0.002**
Scapula Fracture	21 (10 %)	3 (13 %)	18 (9 %)	0.56
Clavicle Fracture	24 (11 %)	2 (9 %)	22 (11 %)	0.70

P values less than 0.05 are considered statistically significant (bold).

Table 3
Hospital disposition and healthcare utilization.

		Overall Sample (n = 217)	Patients Requiring Mechanical Ventilation > 48 H		P-value
			Yes (n = 23)	No (n = 194)	
Admission Location	Floor	70 (32 %)	1 (4 %)	69 (36 %)	**<0.001**
	Intermediate	18 (8 %)	0 (0 %)	18 (9.3 %)	
	ICU	118 (54 %)	22 (96 %)	96 (49 %)	
	ED Discharge	11 (5 %)	0 (0 %)	0 (0 %)	
Ventilator Use	–	34 (16 %)	23 (100 %)	11 (6 %)	**<0.001**
Intubation in ED	–	23 (11 %)	17 (74 %)	6 (3 %)	**<0.001**
Length of Stay, days (Mean ± SD)	–		19 ± 17	5 ± 4	**<0.001**

P values less than 0.05 are considered statistically significant (bold).

Table 4
Confusion matrix statistics.

Result	Value
Sensitivity (True Positive Rate)	20 %
Specificity (True Negative Rate)	93 %
Positive Predictive Value	22 %
Negative Predictive Value	923 %
Accuracy	87 %
False Negative Rate (Miss Rate)	80 %
False Positive Rate (Fall-out Rate)	6.6 %
False Omission Rate	7.5 %
Positive Likelihood Ratio	3.0
Negative Likelihood Ratio	0.9
Diagnostic Odds Ratio	3.1

Scoring systems for PCs exist, and the most recent studies have focused on computer software to accurately measure volumes of contusions [5,6,13-17]. In patients with 20 % overall contusion volume, 75 % have a chance of developing pneumonia or ARDS and 40 % of patients may require mechanical ventilation [5,6]. While computer software models may accurately predict total volume of lung contusion, this software is not readily available at all trauma centers. A scoring system performed by the trauma provider reviewing the images may be more generalizable and expedient.

This study attempted to simplify a scoring system previously described by de Moya et al. [11]. Instead of a maximum score of 18, our PCS had a maximum score of 10. We found that if a patient had a PCS < 4, the patient was unlikely to need prolonged mechanical ventilation with a high specificity and negative predictive value. Depending on the overall clinical picture, a patient with a PCS score of 3 or less may not require ICU admission and could be admitted to a lower level of care instead. This could potentially conserve valuable hospital resources such as ICU beds. Our scoring system also had high inter-rater agreement allowing for reproducibility. Our data did not show any significant trends in rate of need for mechanical ventilation and correlation with other thoracic injuries such as rib, sternal or scapular fractures.

Our study had several limitations inherently due to its retrospective design limiting the quality and quantity of the data that were collected. Many patients who were mechanically ventilated for more than 48 h were excluded from our study because they had concomitant severe traumatic brain injuries with head AIS > 3. Thus, only a few patients had

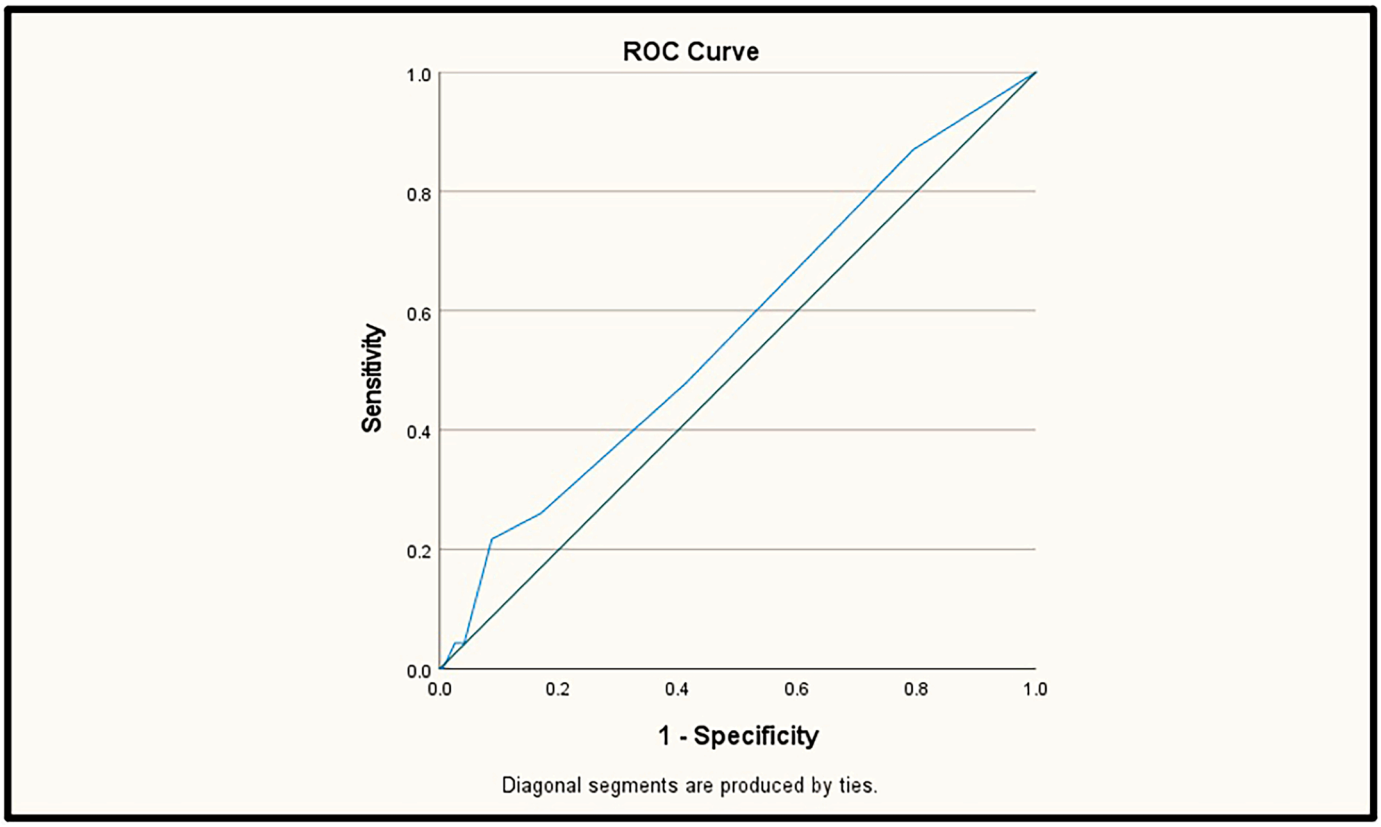

Fig. 2. Receiver Operator Curve Analysis. ROC Curves plot (ROC) representing the true positive rate (sensitivity) against the false positive rate (1-specificity) for the different possible cut points of a diagnostic test. Each point on the ROC curve represents a sensitivity/specificity pair.

PCS $\geq$ 4. A greater sample of patients with PCS $\geq$ 4 could strengthen the results of our study. Lastly only 125 patients were reviewed independently by two providers. A large sample size of CT scans reviewed could strengthen the confusion matrix analysis and allow for more robust receiver operating characteristic curve analysis. A prospective study should also be performed to validate the PCS.

Additionally for this study, we intentionally included only the PC size to determine the feasibility of our scoring system. Including only PC, allows the scoring to be efficient and translatable for all trauma providers. This scoring system could be enhanced by adding additional variables such as the number of rib fractures and pneumo- or hemothoraces to increase its discriminatory power. These findings could be identified on the initial chest CT used to score the PC. However, adding these additional variables would make the scoring more cumbersome and time-consuming.

A future direction for the PCS would be to determine its predictability in regards for need for hospital admission after sustaining blunt chest trauma. Our trauma surgery service is frequently consulted for patients with an isolated pulmonary contusion. Depending on the size of the contusion, these patients are either discharged or admitted for observation. Using the PCS to determine need for hospital admissions could further conserve limited hospital resources, such as ICU beds.

In conclusion, the PCS is a scoring system with high specificity and negative predictive value that can be used to evaluate the need for mechanical ventilation after sustaining blunt PC and can help to properly allocate hospital resources.

Meeting presented

American College of Surgeons Committee on Trauma Region IX Resident Paper Competition, November 30, 2022, Phoenix, Arizona.

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CRediT authorship contribution statement

Lisa J. Toelle: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Allison G. McNickle:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Declan Feery:** Writing – review & editing, Formal analysis, Data curation. **Salman Mohammed:** Writing – review & editing, Formal analysis, Data curation. **Paul J. Chestovich:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Kavita Batra:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation. **Douglas R. Fraser:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sipas.2024.100247.

References

[1] Daurat A, Millet I, Roustan JP, Maury C, Taourel P, Jaber S, et al. Thoracic Trauma Severity score on admission allows to determine the risk of delayed ARDS in trauma patients with pulmonary contusion. Injury 2016;47(1). https://doi.org/10.1016/j.injury.2015.08.031.

[2] Probst C, Pape HC, Hildebrand F, Regel G, Mahlke L, Giannoudis P, et al. 30 years of polytrauma care: an analysis of the change in strategies and results of 4849 cases treated at a single institution. Injury 2009;40(1):77–83. https://doi.org/10.1016/j.injury.2008.10.004.

[3] Allen GS, Cox CS. Pulmonary contusion in children: diagnosis and management. South. Med. J. 1998;91. https://doi.org/10.1097/00007611-199812000-00002.

[4] Cohn SM, DuBose JJ. Pulmonary Contusion: an Update on Recent Advances in Clinical Management. World J Surg 2010;34. https://doi.org/10.1007/s00268-010-0599-9.

[5] Miller PR, Croce MA, Bee TK, Qaisi WG, Smith CP, Collins GL, et al. Ards after pulmonary contusion: accurate measurement of contusion volume identifies high-risk patients. J Trauma 2001;51(2). https://doi.org/10.1097/00005373-200108000-00003.

[6] Rodriguez RM, Friedman B, Langdorf MI, Baumann BM, Nishijima DK, Hendey GW, et al. Pulmonary contusion in the pan-scan era. Injury 2016;47(5). https://doi.org/10.1016/j.injury.2015.11.043.

[7] Balayla J. Prevalence threshold (Phi;e) and the geometry of screening curves. PLoS ONE 2020;15(10 October). https://doi.org/10.1371/journal.pone.0240215.

[8] Fawcett T. An introduction to ROC analysis. Pattern Recognit Lett 2006;27(8). https://doi.org/10.1016/j.patrec.2005.10.010.

[9] Powers D. Evaluation: from precision, recall, and F-measure to ROC, informedness, markedness & correlation. J Mach Learn Technol 2011;2(1):37–63. https://doi.org/10.48550/arXiv.2010.16061.

[10] Chicco D, Jurman G. The advantages of the Matthews correlation coefficient (MCC) over F1 score and accuracy in binary classification evaluation. BMC Genomics 2020 Dec 2;21(1):6. https://doi.org/10.1186/s12864-019-6413-7.

[11] Chicco D, Tötsch N, Jurman G. The matthews correlation coefficient (Mcc) is more reliable than balanced accuracy, bookmaker informedness, and markedness in two-class confusion matrix evaluation. BioData Min 2021;14. https://doi.org/10.1186/s13040-021-00244-z.

[12] McHugh ML. Interrater reliability: the kappa statistic. Biochem Medica 2012;22(3). PMID: 23092060.

[13] Becher RD, Colonna AL, Enniss TM, Weaver AA, Crane DK, Martin RS, et al. An innovative approach to predict the development of adult respiratory distress syndrome in patients with blunt trauma. J Trauma Acute Care Surg 2012;73(5). https://doi.org/10.1097/TA.0b013e31825b2124.

[14] Wang S, Ruan Z, Zhang J, Jin W. The value of pulmonary contusion volume measurement with three-dimensional computed tomography in predicting acute respiratory distress syndrome development. Ann Thorac Surg 2011;92(6). https://doi.org/10.1016/j.athoracsur.2011.05.020.

[15] Mahmood I, El-Menyar A, Younis B, Ahmed K, Nabir S, Ahmed MN, et al. Clinical significance and prognostic implications of quantifying pulmonary contusion volume in patients with blunt chest trauma. Med Sci Monit 2017;23:3641–8. https://doi.org/10.12659/msm.902197.

[16] Choi J, Tennakoon L, You JG, Kaghazchi A, Forrester JD, Spain DA. Pulmonary contusions in patients with rib fractures: the need to better classify a common injury. Am J Surg [Internet] 2021;221(1):211–5. https://doi.org/10.1177/1747493018778713.

[17] De Moya MA, Manolakaki D, Chang Y, Amygdalos I, Gao F, Alam HB, et al. Blunt pulmonary contusion: admission computed tomography scan predicts mechanical ventilation. J Trauma - Inj Infect Crit Care 2011;71(6). https://doi.org/10.1097/TA.0b013e31822c4a8b.