Original Article

Development and validation of a pulmonary complications prediction model based on the Yang's index

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Background: Blunt chest trauma patients with pulmonary contusion are susceptible to pulmonary complications, and severe cases may develop respiratory failure. Some studies have suggested the extent of pulmonary contusion to be the main predictor of pulmonary complications. However, no simple and effective method to assess the severity of pulmonary contusion has been available yet. A reliable prognostic prediction model would facilitate the identification of high-risk patients, so that early intervention can be given to reduce pulmonary complications; however, no suitable model based on such an assumption has been available yet.

Methods: In this study, a new method for assessing lung contusion by the product of the three dimensions of the lung window on the computed tomography (CT) image was proposed. We conducted a retrospective study on patients with both thoracic trauma and pulmonary contusion admitted to 8 trauma centers in China from January 2014 to June 2020. Using patients from 2 centers with a large number of patients as the training set and patients from the other 6 centers as the validation set, a prediction model for pulmonary complications was established with Yang's index and rib fractures, etc., being the predictors. The pulmonary complications included pulmonary infection and respiratory failure.

Results: This study included 515 patients, among whom 188 developed pulmonary complications, including 92 with respiratory failure. Risk factors contributing to pulmonary complications were identified, and a scoring system and prediction model were constructed. Using the training set, models for adverse outcomes and severe adverse outcomes were developed, and area under the curve (AUC) of 0.852 and 0.788

were achieved in the validation set. In the model performance for predicting pulmonary complications, the positive predictive value of the model is 0.938, the sensitivity of the model is 0.563 and the specificity of the model is 0.958.

Conclusions: The generated indicator, called Yang's index, was proven to be an easy-to-use method for the evaluation of pulmonary contusion severity. The prediction model based on Yang's index could facilitate early identification of patients at risk of pulmonary complications, yet the effectiveness of the model remains to be validated and its performance remains to be improved in further studies with larger sample sizes.

Keywords: Pulmonary contusion; blunt chest trauma; prognosis; prediction model

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Introduction

Traumatic injuries occur at a high incidence and are among the leading causes of death in modern societies (1,2). Blunt pulmonary contusion is a commonly seen sequela following blunt chest trauma (3-5), with an incidence of over 50% among blunt chest trauma cases (6). Studies have shown that pulmonary contusion is a risk factor for the development of acute respiratory distress syndrome (ARDS), and is moreover reported to be a major cause of death (7,8). A contusion volume greater than 20% of the total lung volume is hereby reported to indicate an increased risk of pulmonary complications (9). The existing relevant prediction models rely excessively on dynamic indicators such as arterial blood gas (ABG) indicators, making it difficult to achieve real early prediction. The new method in this study is based on computed tomography (CT) images, which can be used to obtain the Yang's index for evaluating the degree of lung contusion through simple calculations. Other objective indicators that can be collected at admission such as the severity of rib fracture, and severe comorbid fracture(s) (of the spine, pelvis, and/or femur), can also be used in predicting the pulmonary complications. This model can identify high-risk patients at an early stage. We present the following article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-378/rc).

Highlight box

Key findings

- We constructed a prognostic model for pulmonary contusion severity.
- Yang's index is an easy-to-use method for the evaluation of pulmonary contusion.

What is known and what is new?

- So far, a prognostic model for early and accurate prediction of traumatic pulmonary has not been developed.
- Our model has a good performance in identifying patients with pulmonary complications and can guide clinicians to make effective intervention.

What is the implication, and what should change now?

- Pulmonary contusion is not the only determining factor of pulmonary complications.

Methods

Study design

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics committee of Shanghai Sixth People's Hospital (No. 2020-KY-034). Individual consent for this retrospective analysis was waived. The other 7 hospitals are informed and agreed with this study. This study is a retrospective analysis of anonymized patient data. The authors of this study are responsible for the accuracy and integrity of all data and analyses.

Study population

A retrospective analysis was performed on the clinical data of blunt chest trauma patients with pulmonary contusion admitted to the thoracic surgery departments of eight hospitals (Shanghai Jiao Tong University School of Medicine Affiliated Sixth People's Hospital, Tianjin

Hospital of Tianjin University, General Hospital of Southern Theater Command of PLA, Fuzhou Second Hospital, Shijiazhuang Third Hospital, the Third Xiangya Hospital of Central South University, Hong Hui Hospital of Xi'an Jiao Tong University, and Shanghai Ninth People's Hospital of Shanghai Jiao Tong University School of Medicine) in China from January 2014 to June 2020. The inclusion criteria for this study were as follows: adult male or female patients aged 18–80 years with blunt thoracic trauma combined with pulmonary contusion who had chest CT within 72 hours of injury. The exclusion criteria were as follows: Glasgow Coma Scale <9; traumatic brain injury requiring neurosurgical intervention; abdominal trauma requiring emergency surgery; vertebral fractures combined with spinal cord injury; lung infection before injury; previous history of chronic lung diseases, such as pulmonary tuberculosis, bronchiectasis, emphysema, chronic bronchitis or chronic obstructive pulmonary disease (COPD); unilateral atelectasis; pleural effusion/haemothorax >30%.

In this study, a total of 9 dead patients were collected during the same period, among which 7 died within 48 hours after admission and 2 died after 48 hours. Through analysis, the causes of death were not related to pulmonary contusion, but mainly to cerebral hemorrhage or other organ hemorrhage and renal failure. To avoid statistical errors, these deaths were not included in this study.

In Stage One, cases from two tertiary referral centers for trauma treating over 1,000 patients with chest trauma annually—Shanghai Jiao Tong University School of Medicine Affiliated Sixth People's Hospital and Tianjin Hospital of Tianjin University—were chosen as the training set for the model. In Stage Two, the test set consisted of patients with chest trauma from General Hospital of Southern Theater Command of PLA, Fuzhou Second Hospital, Shijiazhuang Third Hospital, the Third Xiangya Hospital of Central South University, Hong Hui Hospital of Xi'an Jiao Tong University, and Shanghai Ninth People's Hospital of Shanghai Jiao Tong University School of Medicine.

Measurement and variables

The following variables were analyzed extracted from the electronic patient records and analyzed: age, sex, body mass index (BMI), smoking history, diabetes, mechanism of injury (MOI; e.g., fall from a great height, car accident, etc.), severe comorbid fracture(s) (of the spine, pelvis, and/or femur), Injury Severity Score (ISS), severity of pulmonary contusion (the Yang's index), pulmonary atelectasis, rib fractures (number and whether they are unilateral/bilateral), surgical history of rib fractures and the primary outcome: pulmonary complications.

The pulmonary complications included pulmonary infection and respiratory failure. Images alone hardly differentiate between consolidation due to inflammation (i.e., pneumonia) and/or blunt trauma. In real life, there is a mix of the two phenomena. The pulmonary infection could be diagnosed if the patient was discovered to have: (I) fever ≥38 ℃; (II) cough, expectoration or aggravation in the original respiratory symptoms; (III) moist rales in the lung and (IV) the count of white blood cell $\geq 10\times10^9$/L or $<4\times10^9$/L by routine blood test or pathogenic bacteria found in sputum culture. In addition to blood gas analysis as a diagnostic criterion for respiratory failure [partial pressure of oxygen (PaO_2)/fraction of inspired oxygen (FiO_2) ≤300 mmHg or PaO_2 <60 mmHg], patients lacking blood gas analysis parameters were diagnosed with respiratory failure if tracheal intubation or tracheostomy was performed and mechanical ventilation was required for more than 24 hours after surgical operation.

Pulmonary contusion index

The pulmonary contusion volume was measured by three-dimensional reconstruction, according to methods developed by Dr. Yang. Theoretically, contusion volume can be calculated by measuring the long diameter of the contusion tissue in 3 dimensions (axial, coronal and sagittal), and the total lung volume can be determined in the same manner. Unilateral pulmonary contusion index = pulmonary contusion volume (a×b×c)/total lung volume (A×B×C) ×100%, with the Yang's index defined as the sum of the unilateral pulmonary contusion indexes of both lungs, where A is the distance measured on the coronal plane between the top of the thorax at the carina and the top of the dome of the diaphragm on the same side. B is the vertical distance between the bottom of the posterior chest wall and the anterior chest wall at the level of the carina on the cross-section; and C is the horizontal distance between the lateral wall of the trachea and the opposite chest wall at the level of the carina on the cross-section. These measurements are as shown in *Figure 1A,1B*.

On the cross-sectional CT image, the pulmonary contusion volume can be calculated by multiplying the maximum diameters a, b, and c on the corresponding contusion tissue, where a is the maximum diameter of the

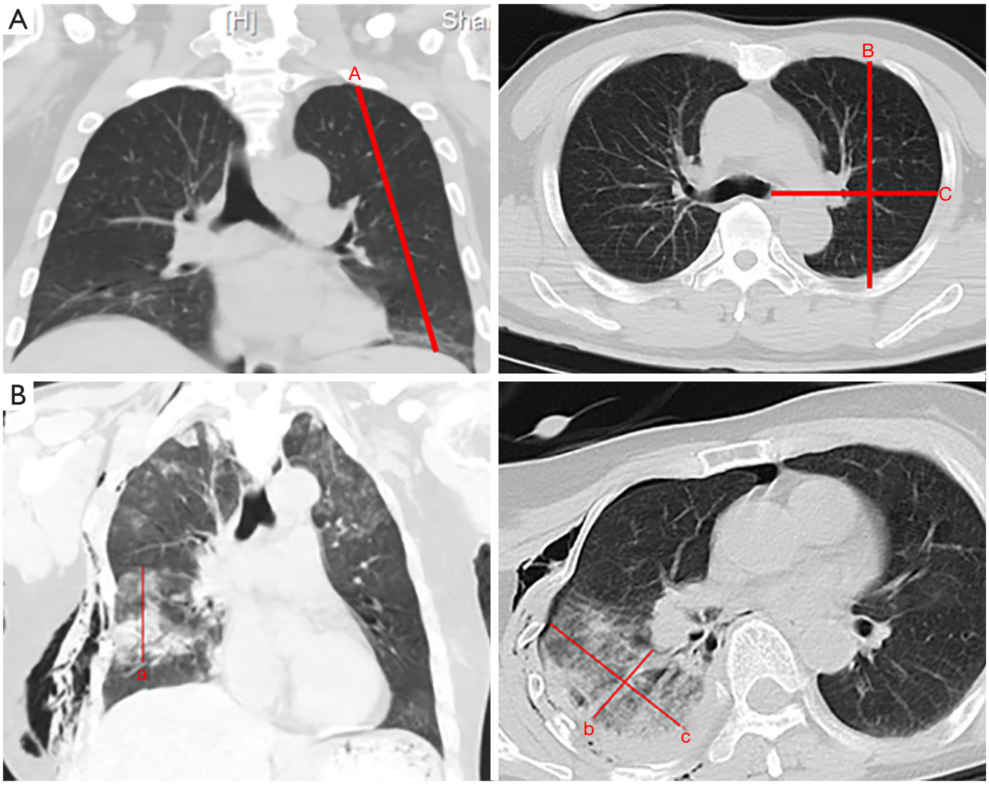

Figure 1 Measurement of lung volume and pulmonary contusion volume using the Yang's index. (A) Measurement of unilateral total lung volume. (B) Measurement of pulmonary contusion volume. A is the distance measured on the coronal plane between the top of the thorax at the carina and the top of the dome of the diaphragm on the same side. B is the vertical distance between the bottom of the posterior chest wall and the anterior chest wall at the level of the carina on the cross-section; and C is the horizontal distance between the lateral wall of the trachea and the opposite chest wall at the level of the carina on the cross-section. The a is the maximum diameter of the contusion tissue perpendicular to the ground on the coronal plane, b denotes the maximum vertical dimension of the contusion area on the plane and c expresses the maximum horizontal dimension of the contusion area on the plane.

contusion tissue perpendicular to the ground on the coronal plane, and the product of b and c represents the maximum cross-sectional area of the contusion tissue on the CT image, with b denoting the maximum vertical dimension of the contusion area on the plane and c expressing the maximum horizontal dimension of the contusion area on the plane.

In case of a pulmonary contusion in multiple discontinuous areas, the sum of the pulmonary contusion index of each area should be calculated after the calculation of separate pulmonary contusion indexes respectively. The image of each patient was calculated and averaged by two radiologists with >5 years' working experience in Imaging Department. For data with a great difference, the third senior doctor in Imaging Department should be consulted for joint discussion and further determination. The Yang's index was proven to have a linear correlation with volume reconstruction.

Statistical analysis

R version 4.0.5 (The R Foundation for Statistical Computing, Vienna, Austria) was used for statistical analysis Continuous variables were expressed as medians and interquartile ranges. Categorical variables we represented as frequencies and percentages. Categorical variables were examined by the chi-squared test or Fisher's exact test; comparisons between 2 continuous variables were performed with the Mann-Whitney U test, A two-tailed P value of <0.05 was considered statistically significant.

A linear correlation analysis and Bland-Altman approach were used to investigate the correlation and agreement

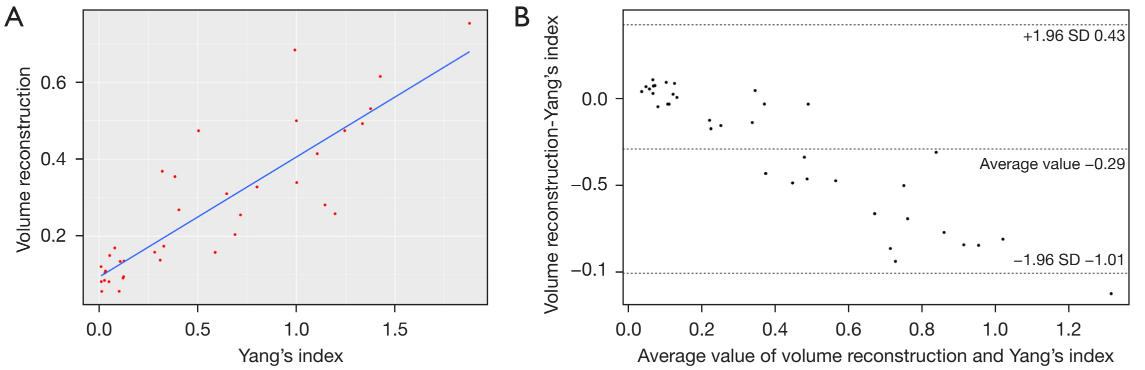

Figure 2 Study of consistency between Yang's index and volume reconstruction. (A) The correlation between Yang's index and volume reconstruction. (B) Bland-Altman plot of Yang's index and volume reconstruction. SD, standard deviation.

between the Yang's index and volume reconstruction. A prognostic model was constructed using logistic regression algorithms to predict adverse and severe adverse outcomes. Logistic regression algorithms were used to screen for risk factors related to adverse and severe adverse outcomes in patients with pulmonary contusion, and the risk factors included in this study were evidence-based on previous publications. A nomogram in predicting the probability of outcomes in patients with pulmonary contusion was obtained by the training set according to Occam's Law of Razor, namely, the best model should be one that can achieve the aim of study with fewer variables.

Logistic regression-based predictions of outcomes were demonstrated by an alignment diagram, and the performance of the prediction model was evaluated in terms of sensitivity, specificity, accuracy, and area under the curve (AUC), receiver operating characteristic (ROC) analyses were performed to determine the best cut-off values to detect the outcome.

Results

Thirty-eight cases were used to evaluate the agreement of the Yang's index and volume reconstruction. As shown by *Figure 2A*, the correlation was 0.857 (95% CI: 0.740–0.924). The Bland-Altman plot is shown in *Figure 2B*.

According to the inclusion and exclusion criteria, 515 patients were included in the subsequent predictive study, including 188 (36.5%) cases of pulmonary complications and 92 (17.86%) cases of respiratory failure. The training set comprised 363 patients, and the test set comprised 152 patients.

Table 1 summarizes the results of the univariate analysis of pulmonary complications and respiratory failure. ROC curves and alignment diagrams were plotted using the independent risk factors and indicators of potential clinical significance associated with pulmonary complications and respiratory failure. The prediction performance of the models is shown in *Table 2*, *Figure 3A,3B*, and *Figure 4A,4B*. Using the training set, models for pulmonary complications and respiratory failure were developed, and AUCs of 0.852 and 0.788 were achieved in the validation set. In the model performance for predicting pulmonary complications, the positive predictive value of the model is 0.938.

Discussion

Since pulmonary contusion has no highly specific, unique clinical symptoms, chest CT is considered to be the most reliable approach for diagnosing and monitoring this dynamic condition (10,11). Pulmonary contusion-induced edema and exudative effusion reach their peaks within 48–96 hours after injury (12). It is a highly complex, multifactorial phenomenon. In our study, pulmonary contusion indexes identifiable and quantifiable on CT performed within the first 3 days have been adopted as indicators to evaluate the severity of pulmonary contusion. There are two methods to evaluate pulmonary contusions based on CT images: clinicians may simply observe and interpret the CT images to evaluate the condition of the pulmonary lobes (13,14), which inevitably introduces subjectivity and substantial relative errors, or they may adopt a complex method with limited clinical application, i.e., volume reconstruction, to obtain precise measurements (4). Through stringent analysis of the chest CT findings in hundreds of patients with pulmonary contusion, a self-developed method,

Table 1 Baseline characteristics of patients with and without pulmonary complications (respiratory failure)

Factor	Training set			Testing set		
	No	Yes	P value	No	Yes	P value
Pulmonary complications	N=255	N=108		N=72	N=80	
Age, median (IQR)	57.00 (50.00, 65.00)	55.00 (49.00, 64.00)	0.483	52.00 (48.00, 58.00)	52.00 (44.75, 61.00)	0.865
Sex, male, n (%)	184 (72.16)	80 (74.07)	0.806	49 (68.06)	68 (85.00)	0.022
Smoking history, n (%)	77 (30.20)	31 (28.70)	0.874	15 (20.83)	10 (12.50)	0.244
Diabetes, n (%)	25 (9.80)	25 (23.15)	0.001	8 (11.11)	6 (7.50)	0.626
MOI, n (%)			0.065		6.000	<0.001
Fall from a great height	20 (7.84)	18 (16.67)		15 (20.83)	19 (23.75)	
Car accident	136 (53.33)	52 (48.15)		26 (36.11)	45 (56.25)	
Injury caused by falling object	14 (5.49)	8 (7.41)		5 (6.94)	12 (15.00)	
Other	85 (33.33)	30 (27.78)		26 (36.11)	4 (5.00)	
Comorbid fracture of the spine/pelvis/femur, n (%)	49 (19.22)	38 (35.19)	0.002	11 (15.28)	36 (45.00)	<0.001
Pulmonary atelectasis, n (%)	162 (63.53)	88 (81.48)	0.001	23 (31.94)	33 (41.25)	
ISS, median (IQR)	13.00 (9.00, 18.00)	13.00 (9.00, 20.25)	0.112	9.00 (4.00, 14.00)	23.50 (18.00, 30.00)	<0.001
Rib fracture site, n (%)			0.002			<0.001
Unilateral	194 (76.08)	64 (59.26)		55 (76.39)	38 (47.50)	
Bilateral	61 (23.92)	44 (40.74)		17 (23.61)	42 (52.50)	
Number of fractured rib(s), %, median (IQR)	7.00 (5.00, 9.00)	8.00 (6.00, 13.00)	<0.001	6.00 (4.00, 8.00)	9.00 (6.00, 11.00)	0.001
Number of broken end(s) of rib fracture(s), %, median (IQR)	8.00 (5.00, 12.00)	12.00 (8.00, 16.00)	<0.001	7.00 (5.00, 10.00)	13.00 (8.00, 18.00)	<0.001
Ratio of broken end(s) of rib fracture(s) to fractured rib(s), median (IQR)	1.00 (1.00, 1.40)	1.36 (1.09, 1.57)	<0.001	1.00 (1.00, 1.33)	2.00 (1.12, 2.00)	<0.001
Internal fracture fixation, n (%)	211 (82.75)	97 (89.81)	0.119	50 (69.44)	68 (85.00)	0.035
Yang's index, median (IQR)	14.60 (9.10, 28.00)	22.40 (16.85, 40.62)	<0.001	12.85 (0.00, 21.72)	53.05 (36.07, 75.10)	<0.001
Respiratory failure	N=339	N=24		N=84	N=68	
Age, median (IQR)	57.00 (50.00, 65.00)	56.50 (50.75, 63.00)	0.683	52.00 (48.00, 59.25)	52.00 (44.75, 59.50)	0.591
Sex, male, n (%)	248 (73.16)	16 (66.67)	0.651	58 (69.05)	59 (86.76)	0.017
Smoking history, n (%)	102 (30.09)	6 (25.00)	0.767	16 (19.05)	9 (13.24)	0.459

Table 1 *(continued)*

Table 1 *(continued)*

Factor	Training set			Testing set		
	No	Yes	P value	No	Yes	P value
Diabetes, n (%)	46 (13.57)	4 (16.67)	0.757	8 (9.52)	6 (8.82)	1.000
MOI, n (%)			0.012			<0.001
Fall from a height	33 (9.73)	5 (20.83)		18 (21.43)	16 (23.53)	
Car accident	174 (51.33)	14 (58.33)		33 (39.29)	38 (55.88)	
Blunt trauma	19 (5.60)	3 (12.50)		5 (5.95)	12 (17.65)	
Other	113 (33.33)	2 (8.33)		28 (33.33)	2 (2.94)	
Comorbid fracture of the spine/pelvis/femur, n (%)	76 (22.42)	11 (45.83)	0.019	14 (16.67)	33 (48.53)	0.002
Pulmonary atelectasis, n (%)	229 (67.55)	21 (87.50)	0.070	29 (34.52)	27 (39.71)	0.624
ISS, median (IQR)	13.00 (9.00, 18.00)	19.50 (13.00, 30.00)	<0.001	10.00 (4.75, 14.25)	25.00 (20.75, 30.50)	<0.001
Rib fracture site, n (%)			0.002			0.001
Unilateral	248 (73.16)	10 (41.67)		62 (73.81)	31 (45.59)	
Bilateral	91 (26.84)	14 (58.33)		22 (26.19)	37 (54.41)	
Number of fractured rib(s), %, median (IQR)	7.00 (5.00, 9.00)	11.50 (7.75, 14.00)	<0.001	6.50 (5.00, 8.00)	9.00 (5.00, 11.00)	0.007
Number of broken end(s) of rib fracture(s), %, median (IQR)	9.00 (6.00, 13.00)	14.00 (9.75, 19.00)	<0.001	8.00 (5.00, 10.25)	14.00 (8.00, 20.00)	<0.001
Ratio of broken end(s) of rib fracture(s) to fractured rib(s), median (IQR)	1.13 (1.00, 1.45)	1.26 (1.17, 1.46)	0.132	1.00 (1.00, 1.33)	2.00 (1.54, 2.00)	<0.001
Internal fracture fixation n (%)	290 (85.55)	18 (75.00)	0.232	60 (71.43)	58 (85.29)	0.065
Yang's index, median (IQR)	17.00 (10.05, 30.40)	55.00 (19.65, 87.53)	<0.001	15.75 (2.45, 24.65)	56.15 (39.09, 76.96)	<0.001

IQR, interquartile range; MOI, mechanism of injury; ISS, Injury Severity Score.

Table 2 Prediction performance of the models in the validation set

Model	Cut-off	Sensitivity	Specificity	PPV	NPV	AUC
Model (A)	0.397	0.563	0.958	0.938	0.663	0.852
Model (B)	0.2689	0.647	0.798	0.721	0.736	0.788

Model (A): model for predicting pulmonary complications; Model (B): model for predicting respiratory failure. PPV, positive predictive value; NPV, negative predictive value; AUC, area under the curve.

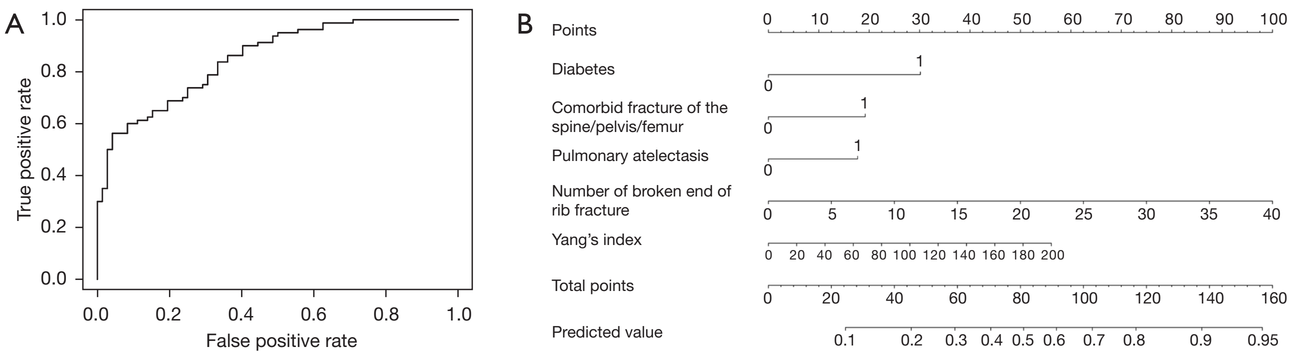

Figure 3 ROC curve and visualization scoring system for predicting pulmonary complications using the model. (A) Area under the receiver operating characteristic curve for predicting pulmonary complications in the validation cohort. (B) Nomogram including predictors from the multivariate regression analysis for predicting pulmonary complications. ROC, receiver operating characteristic.

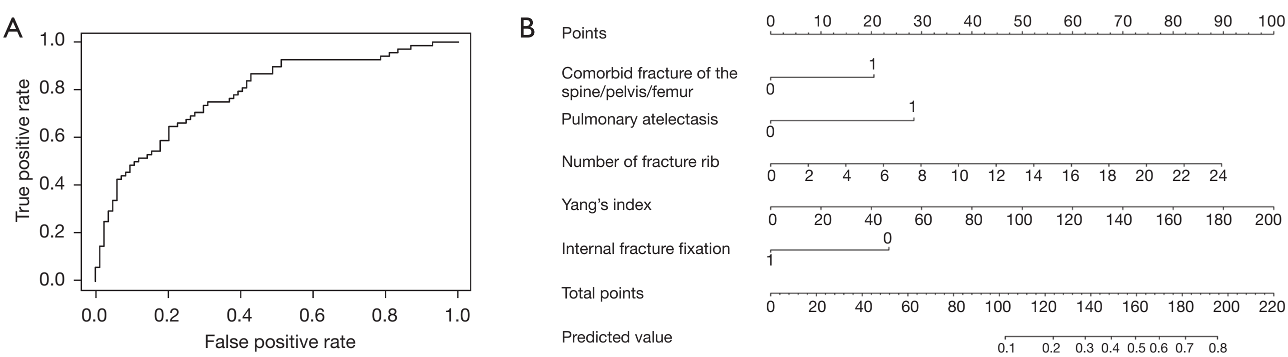

Figure 4 ROC curve and visualization scoring system for predicting respiratory failure using the model. (A) Area under the receiver operating characteristic curve for predicting respiratory failure in the validation cohort. (B) Nomogram including predictors from the multivariate regression analysis for predicting respiratory failure. ROC, receiver operating characteristic.

Yang's index, was developed and introduced in this study. Yang's index, which is linearly correlated with volume reconstruction, was demonstrated to have statistical significance and to help clinically evaluate pulmonary contusions; therefore, it is worthy of wide application and promotion in clinical practice.

In this study, diabetes, pulmonary atelectasis, severe comorbid fracture(s) (of the spine, pelvis and/or femur), severity of rib fracture(s), and the Yang's index were found to be risk factors predicting pulmonary complications. The independent risk factors associated with pulmonary complications included diabetes, pulmonary atelectasis, severity of rib fracture(s) and the Yang's index. These results suggested that patients with diabetes, severe comorbid fracture(s) (of the spine, pelvis and/or femur), or pulmonary atelectasis were at higher risk of pulmonary contusion an ideal environment for subsequent pulmonary infection. Although the ratio of pulmonary contusion volume to total lung volume is a significant cutoff value when predicting pulmonary complications (8,9,14), previous studies have reported that the prognosis of patients with chest trauma is affected by many other factors. Some researchers believe it is unnecessary to repeat chest imaging in patients with pulmonary contusion on initial imaging if they present without any clinical symptoms of respiratory compromise and that pulmonary contusion (PC) was infrequently clinically significant (15). Therefore, it is unwise to make prognosis of respiratory complications based solely on the presence or absence of pulmonary contusion on CT images alone. The Abbreviated Injury Scale (AIS) and ISS are based on overall considerations and lacks specificity on the severity of PC. Likewise, the Lung Organ Failure Score (LOFS) enables multifactorial prediction of respiratory failure in patients with chest trauma without taking pulmonary contusion into consideration (16). Moreover, we believe this method is not suitable for early prediction because of the unavailability of solid predictors upon admission. The Thoracic Trauma Severity (TTS) score can be used to evaluate the severity of chest trauma (17,18) and has been demonstrated to be a favorable method for predicting the occurrence of ARDS in patients with chest trauma (19). The TTS score focuses on the occurrence of ARDS, one of the pulmonary complications discussed in this study. According to the scoring system, PaO_2/FiO_2 and age are two important predictive factors; in fact, hypoxemia is not pronounced in some patients during the early onset of ARDS. In this retrospective study, continuous data on ABG and FiO_2 were not available. A prediction model showing ideal performance was constructed using basic standard clinical data.

During early onset, PaO_2/FiO_2 is more of an indicator of the progression of lung damage than an independent prognostic factor. In the traditional prediction model of pulmonary complications, great importance has been attached to indicators of ABG. Undoubtedly, the result of ABG is one of the key indicators reflecting the progress or improvement of pulmonary diseases. Significantly, by using the prediction model established in this study, the prediction could be completed on the basis of the clinical objective data (excluding indicators of ABG) collected from patients at the time of admission, thus identifying high-risk patients who might develop pulmonary complications. In the model performance for predicting pulmonary complications, the positive predictive value of the model is 0.938, which means that the model has a good performance in identifying patients with pulmonary complications and can guide clinicians to make effective intervention.

Extensive evidence and common sense have shown that advanced age was an independent risk factor for poor prognosis in patients with severe chest trauma (20,21). However, the results of this study suggested that age was not a risk factor, which might be explained by the fact that the research participants included a number of younger adults who suffered from occupational or high-energy injuries, and that this study excluded elderly patients because of the presence of multiple underlying chronic conditions.

Our study results showed that the number of fractured rib(s) and the Yang's index were two independent risk factors for respiratory failure. Numerous studies have indicated a correlation between the number of fractured rib(s) and poor prognosis in trauma patients (22,23). The presence of fractured ribs implies a severe high-energy MOI predisposing the patient to an underlying pulmonary contusion that is highly likely to be complicated with injuries in other locations. Patients with respiratory failure largely suffer from severe pulmonary contusions that progress rapidly and experience serious pathological effusion in their lung tissue. On this basis, multiple rib fractures cause intense pain, chest wall instability, limited expectoration, and worsening respiration, eventually resulting in respiratory failure in a short time. In this study, 59 patients required mechanical ventilation due to respiratory failure within 72 hours after chest trauma, representing 64% of all respiratory failure cases. Internal fixation of rib fractures remains controversial in the treatment of severe chest trauma complicated with pulmonary contusion (24-26). Although surgical treatment was not assessed as a risk factor for pulmonary complications, this treatment approach might help reduce the risk of respiratory failure or mitigate the long-term effects. Improved prognostic tools may help providers determine both the need for surgical intervention and identify the true clinical impact of PC in patients with concomitant severe chest wall injuries.

Limitations

This study had several limitations. As a retrospective study, important biochemical parameters were not available in every case for statistical analysis. To ensure data accuracy and integrity, these parameters were excluded from the study, which might impose limitations on the modeling results. In addition, this study had a relatively long study period but failed to include all patients meeting the inclusion criteria from the eight trauma centers; instead, patients with adverse outcomes were largely included in the study. The inclusion and exclusion criteria might also have introduced bias to the study results. Polytrauma patients are missing from the analysis, therefore the validity of the Yang's index needs a much extensive, prospective observational study. For patients whose condition is complicated with severe hemopneumothorax, there is still no accurate strategy to evaluate the degree of pulmonary contusion owing to the significant changes in pulmonary volume, which remains to be further explored in the future.

Conclusions

In summary, a prognostic model for blunt chest trauma was successfully constructed based on the self-developed the Yang's index in combination with the severity of chest trauma and other related clinical factors, and the prognostic model was demonstrated to have favorable prediction performance. The predictors were closely associated with clinical outcomes and could be collected upon admission to achieve early predictions and identification of high-risk patients and allow for pertinent treatment including aggressive physiotherapy, pain control and supportive therapy. The Yang's index is an easy-to-use method for the accurate evaluation of pulmonary contusion severity and seems to be promising in a wider range of clinical application and decision making.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-378/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-378/coif). PG reports that he serves as a paid instructor and product development advisor for Zimmer Biomet and chest wall trauma division, the chairman for Chest Wall Injury Society and the History and Archives Committee (American College of Surgeons), also on the advisory board for Zimmer Biomet. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics committee of Shanghai Sixth People's Hospital (No. 2020-KY-034), the other 7 hospitals are informed and agreed with this study. Individual consent for this retrospective analysis was waived.

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