Prediction model for death in patients with pulmonary tuberculosis accompanied by respiratory failure in ICU: retrospective study

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Background: The mortality rate of pulmonary tuberculosis (TB) patients with respiratory failure remains high. This study aimed to identify factors contributing to death in these patients, and develop a mortality prediction model for pulmonary TB patients with respiratory failure.

Methods: A retrospective study of patients admitted consecutively to the medical intensive care unit (ICU) of Beijing Chest Hospital, (Beijing, China), Chaoyang Fourth Hospital (Chaoyang, China) and Hebi Third People's Hospital (Hebi, China) from May 2018 to May 2019 was conducted. 153 patients with pulmonary TB accompanied by respiratory failure were enrolled. A multivariate analysis was performed to identify risk factors for death. A predictive fatality score was determined. The utility of the score for predicting death was evaluated using receiver operating characteristic (ROC) curve analysis.

Results: The patients' median age was 57.82±19.42 years (17.0–87.0 years) and there were 106 males (69.28%). The mortality rate was 39.22% (60 of 153). Independent predictive factors of mortality included the PaO_2 (hazard ratio 0.928, 95% CI: 0.882–0.976, P=0.004), Albumin (hazard ratio 0.881, 95% CI: 0.792–0.980, P=0.019), Apache II score (hazard ratio 1.120, 95% CI: 1.017–1.234, P=0.022) and C-reactive protein (hazard ratio 1.012, 95% CI: 1.004–1.019, P=0.003). Establishing a logistic model of the death risk grade of pulmonary TB with respiratory failure was Y=1.710 – 0.068*PaO_2–0.163* albumin + 0.215* Apache II +0.012* C-reactive protein. The value was Y=–0.494. If the Y value was greater than or equal to –0.494, the patients belonged to the deceased group, and if less than –0.494 the patients belonged to the survival group. AUC=0.818, The sensitivity was 83.3%; specificity was 73.1%.

Conclusions: Pulmonary TB patients with respiratory failure have a high mortality rate and poor prognosis, particularly those with high Apache II scores, high C-reactive protein levels, low PaO_2 admission to ICU and low albumin level. The prediction model will help assess the risk of death in patients with TB and respiratory failure.

Keywords: Intensive care unit; predictive factor; pulmonary tuberculosis; respiratory insufficiency

Introduction

Tuberculosis (TB) remains a major public health problem in most of the developing world, and the incidence and mortality of TB remain high worldwide. TB is also a major health problem in China, which has the second-highest burden of TB in the world (1,2). Approximately 1 million new TB cases occurred in China every year (3), with an incidence and mortality of 459 and 9.8 per 100,000 populations respectively (4). Sputum smear microscopy and chest radiography were used to confirm the diagnosis of TB nowadays. however, this is being replaced by Xpert MTB/RIF, which allows a bacteriologically confirmed diagnosis of TB within two hours. But a clinical diagnosis of TB is often the norm. Bedaquiline added to anti-TB treatment as a new drug, however, the treatment success of severe TB remains low globally, at 55% (5). Severe TB patients had poor outcomes with no standard evaluation criteria, especially TB patients combined with respiratory failure. Respiratory failure is a common disorder in the intensive care unit (ICU) and it is associated with high mortality and morbidity (6). Although TB cases requiring ICU represent only 1–3% of all hospital admissions for TB, in-hospital TB mortality rates associated are higher (range: 29–83%) than for other infections (7,8). However, in China today, pulmonary TB is rarely considered as a primary cause of respiratory distress. Despite this, pulmonary TB with respiratory failure is associated with high mortality (9).

The prognosis in pulmonary TB patients accompanied by respiratory failure is believed to be poor. It is commonly believed that these patients have a poor outcome, and if they need mechanical ventilation would consume a large amount of intensive care resources, and more than 50% of these patients required mechanical ventilation (10). There has been persistently high mortality (69–80%) in patients with severe pulmonary TB and respiratory failure (11,12). Several studies have evaluated risk factors for death during TB treatment, the factors related to age, sex, and nutritional status of the host (13-15). However, few studies have attempted to identify the predictive factors associated with severe pulmonary TB in the ICU.

A better understanding of mortality trends and factors associated with mortality may lead to more informed suggestions about the prognosis of pulmonary TB patients with respiratory failure. Accordingly, we sought to evaluate the clinical features of pulmonary TB patients with respiratory failure and to identify the factors contributing to in-hospital mortality in these patients, and finally, to develop a simple model to determine prognostic factors for death.

We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/apm-20-182).

Methods

Study population

Pulmonary TB patients were admitted to the medical ICU of Beijing Chest Hospital (Beijing, China), Chaoyang Fourth Hospital (Liaoning, China) and Hebi Third People's Hospital (Henan, China) from May 2018 to May 2019, and all the patients with diagnoses of acute respiratory failure secondary to active pulmonary TB. The inclusion criteria were: (I) diagnosis of active TB (16,17); (II) accompanied respiratory failure (18); (III) admitted to the ICU ≥1 day; (IV) age more than 18 years. The exclusion criteria were: (I) non-tuberculous mycobacterial disease; (II) incomplete clinical data; (III) HIV infection (our center refers to HIV positive patients to a specialist hospital).

Of 202 patients diagnosed with active pulmonary TB who were admitted to the ICU during the study period, 49 were excluded: 23 were admitted for surgery or other interventions, 16 had heart failure caused dyspnea, 10 were microbiologically confirmed as nontuberculous mycobacteria (*Figure 1*). Of these acute respiratory failure secondary to active pulmonary TB patients, a total of 153 patients were divided into the survivor group and non-survivor group, and the factors related to patient death were collected.

Data collection

Standard clinical and laboratory parameters were collected and outcomes of survivor or non-survivor were recorded. Age, gender, body mass index, comorbid diagnoses, Acute Physiology, Age, and Chronic Health Evaluation (Apache) II score, and duration of symptoms when admission to ICU was recorded and compared between groups. In addition, radiological findings were documented, chest radiographs were reviewed on admission to ICU. Pathogenic examinations for M. TB were obtained from all patients in ICU were recorded. Anti-TB drug susceptibility testing was done using the concentration method. Blood cell count and serum biochemical analysis on laboratory investigations
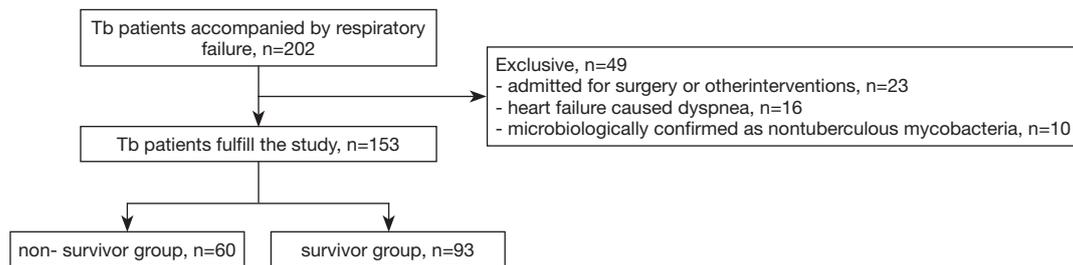
Figure 1 Schematic representation of pulmonary TB patients accompanied by respiratory failure. TB, Tuberculosis.

were recorded and compared. Arterial blood gas analysis at 0 and 24 hours after admission to ICU were collected. Furthermore, during hospitalization concomitant shock and organ failure were recorded.

Statistical analyses

Quantitative variables were expressed as median and range when not normally distributed, and as mean ± standard deviation (SD) when normally distributed. Categorical comparisons of death versus survival were performed using Pearson's chi-square tests. To evaluate the risk factors for death during TB treatment, we compared clinical variables between the deceased and surviving groups using univariate comparison and subsequent multiple logistic regression. Multiple logistic regression was used to develop a prediction model with significant predictor variables from the bivariate analyses, and the model was assessed using receiver operator characteristic (ROC) analysis, with a P value of <0.05 as the criterion for statistical significance. All statistical analyses were performed using SPSS software (Version 26.0; SPSS, Chicago, IL).

Ethics

The study was approved by the ethics committee of Beijing Chest Hospital, Chaoyang Fourth Hospital, and Hebi Third People's Hospital (No. 2018-ky-0102). The present study was conducted according to the principles of the Declaration of Helsinki.

Results

Demographic and clinical characteristics of the study participants

The baseline characteristics of both survivors and deceased

patients are shown in *Table 1*. In total, 93 of 153 patients survived ICU admission (ICU mortality 39.22%) and 72 survived to hospital discharge (in-hospital mortality 52.94%). The median age of the 163 patients was 57.82± 19.42 years (17.0–87.0 years), and there were 106 males (69.28%). *Table 1* shows the risk factors for death due to pulmonary TB with respiratory failure following admission to the ICU. There were no differences between the survivors and fatalities in terms of age, sex, smoke history, dust exposure, and comorbid diseases. MODS in complications was significantly higher for non-survivors (17/60, 28.33%) than for survivors (11/93, 11.83%) (P=0.018; *Table 1*). But the cardiac, hepatic and renal insufficiency were not significantly different between the non-survivors and survivors groups (P>0.05). TB characteristics and radiological findings of Miliary TB (12/93, 12,90%), Multi-lobar involvement (≥3 lobes) (53/93, 56.99%) and Cavitation (34/93, 36.56%) were not significantly different in survivors group. The clinical features of temperature (36.32±2.71 *vs.* 36.90±0.18 ℃, P=0.048), mean arterial blood pressure (MAP) (76.94±17.39 *vs.* 87.76±16.17 mmHg, P<0.001), Body mass index (19.08±2.55 *vs.* 20.44±4.08 kg/m², P=0.023) of the non-survivors group was significantly lower than that of the survivors group. PaO_2/FiO_2, and PaO_2 in patients admitted to the ICU were significantly lower for non-survivors (46.85±10.00 mmHg) than for survivors (52.43± 12.57 mmHg) in univariate analyses (P=0.004). The Apache II score was significantly higher for non-survivors (25.12±4.16) than for survivors (22.06±5.34) in univariate analyses (P<0.001).

Mortality risk factors of TB patients with respiratory failure during ICU treatment

The mean length of the ICU stay for all patients were 10.21 days (range: 1–78 days). *Table 2* shows that the PaO_2/FiO_2,

Table 1 Patient characteristics and comparison between the surviving and non-surviving group of TB patients with respiratory failure on admission to the ICU

Parameter	Survivors	Non-survivors	t/χ^2 value	P value
Subjects n	93	60		
Demographic parameters				
Age, years	57.17±19.88	58.82±18.85	0.510	0.611
Sex ratio, male	65 (69.89)	41 (68.33)	0.042	0.838
Ever smoked	31 (33.33)	23 (38.33)	0.399	0.527
Dust exposure	4 (4.30)	2 (3.33)	0.091	0.763
Comorbid diseases				
Chronic obstructive pulmonary disease	79 (84.95)	46 (76.67)	1.642	0.206
Diabetes mellitus	28 (30.12)	24 (40.00)	1.180	0.277
Hypertension	42 (45.16)	20 (33.33)	1.655	0.200
Complications				
Cardiac insufficiency	17 (18.28)	10 (16.67)	0.002	0.970
Hepatic insufficiency	28 (30.11)	26 (43.33)	2.244	0.134
Renal insufficiency	28 (30.11)	21 (35.00)	0.208	0.649
MODS	11 (11.83)	17 (28.33)	5.587	0.018
ARDS	19 (20.43)	18 (30.00)	1.822	0.177
Septic shock	9 (9.68)	12 (20.00)	2.468	0.116
Tuberculosis characteristics				
Pulmonary tuberculosis	93 (100.00)	60 (100.00)	0.000	0.999
Extrapulmonary tuberculosis	3 (3.23)	2 (3.33)	0.001	0.970
Radiological findings				
Miliary TB	12 (12.90)	5 (8.33)	0.378	0.539
Multi-lobar involvement (≥3 lobes)	53 (56.99)	37 (61.67)	0.165	0.685
Cavitation	34 (36.56)	23 (38.33)	0.003	0.960
Clinical features				
Temperature, ℃	36.90±0.18	36.32±2.71	1.989	0.048
Mean arterial blood pressure, mmHg	87.76±16.17	76.94±17.39	4.975	<0.001
Heart rate, beats/min	118.60+12.33	122.37+17.29	1.573	0.118
Respiratory rate, breaths/min	29.00+3.09	30.19+5.08	1.802	0.073
Body mass index, kg/m^2	20.44±4.08	19.08±2.55	2.304	0.023
Biological parameters				
Initial PaO_2/FiO_2, mmHg	86.30±22.80	77.32±19.06	2.53	0.012
Initial pH	7.3126±0.1512	7.3353±0.1690	0.864	0.401
Initial PaO_2, mmHg	52.43±12.57	46.85±10.00	2.896	0.004

Table 1 (*Continued*)

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Parameter	Survivors	Non-survivors	t/χ^2 value	P value
Initial $PaCO_2$, mmHg	51.64±21.19	49.12±25.27	0.664	0.508
Physiological score				
Apache II score	18.77±3.24	21.40±4.32	4.28	<0.001

Data are shown as number (percentage), mean ± SD, or median (IQR). TB, Tuberculosis; SD, standard deviation; ARDS, acute respiratory distress syndrome; MODS, multiple organ dysfunction syndrome; Apache II, Acute Physiology and Chronic Health Evaluation Score II; ICU, intensive care unit; PaO_2/FiO_2, Partial arterial O_2 pressure/inspired O_2 fraction ratio; $PaCO_2$, partial arterial CO_2 pressure; PaO_2, partial arterial O_2 pressure.

the increased partial arterial O_2 from 0 to 24 hours after admission to ICU at 24 hours were significant prognostic factors in univariate analyses. For all the patients, 77.12% were AFB-positive, 82.35% had positive sputum cultures and 84.97% had positive Xpert MTB/RIF test. The diagnosis of TB in the absence of direct microbiological proof was based on clinical and radiological evidence. All the patients had pathogenic examinations, about patients were sputum smear positive, there was no difference between deceased (71.67%) and surviving (80.65%) groups. There was no significant difference between two groups in positive sputum cultures, Xpert MTB/RIF and TB Drug-Resistant also. The albumin was significantly lower for non-survivors (24.56±3.04 g/L) than for survivors (27.29± 5.50 g/L) in univariate analyses (P=0.001). Serum C-reactive protein (116.87±65.07 *vs.* 77.96±59.15 mg/L, P<0.001) and creatinine (137.16±101.13 *vs.* 107.40± 79.73 μmol/L, P=0.045) in patients were significantly higher for non-survivors than for survivors. There were only about two-thirds of patients had anti-TB therapy in the ICU (surviving groups 60.22% *vs.* non-surviving groups 61.67%). there was a significant difference in new or retreatment between the two groups (80.65% first time-anti-TB treatment in survivor groups *vs.* 65.00% first time-anti-TB treatment in non-survivor groups). Non-survivors had significantly high ratios in mechanical ventilation (56/60, 93.33%, P=0.020). However, non-survivors had high ratios in CRRT than survivors, but there were no significant differences.

Multivariate logistic regression analyses for risk factors for death of patients with pulmonary TB with respiratory failure

In multivariate analyses, PaO_2 (hazard ratio 0.928, 95% CI: 0.882–0.976, P=0.004), Albumin (hazard ratio 0.881, 95% CI: 0.792–0.980, P=0.019), Apache II score (hazard ratio 1.120, 95% CI: 1.017–1.234, P=0.022) and C-reactive protein (hazard ratio 1.012, 95% CI: 1.004–1.019, P=0.003) were independent risk factors for death of patients with pulmonary TB with respiratory failure during ICU treatment (*Table 3*).

Establishing a logistic model

Of the aforementioned 14 most significant univariate variables MAP, albumin, Apache II score and C-reactive protein were selected as the input variables for the model. The model of the death risk grade of pulmonary TB with respiratory failure was Y=1.710−0.068*PaO_2−0.163* albumin +0.215*APACH II+0.012* C-reactive protein. The value was Y=−0.494. If the Y value was greater than or equal to −0.494, the patients belonged to the deceased group, and if less than −0.494 the patients belonged to the survival group. Verified the prediction model by using the present clinical data. Receiver operator characteristics (ROC) regression modeling was done to retrospectively measure the overall predictive performance of the screening tool. The area under the ROC curve (AUR) is a measure of the accuracy, or the discriminative capacity of the screening test, and ROC curve analyses show the tradeoff between the differences in sensitivity and specificity of a test. A diagonal reference line (AUR =0.50) defines points where a test is no better than chance at identifying priority individuals (*Figure 2*). The sensitivity was 83.3%; specificity was 73.1%.

Discussion

This is a multicenter study to evaluate the death risk factors of TB patients with respiratory failure in China. The reported mortality rate in patients with pulmonary TB and respiratory failure is high. This study found a mortality rate of 39.21% in patients with TB accompanied by respiratory failure. This is within the 29% to 83% mortality

Table 2 Comparison of mortality risk factors between the surviving and non-surviving group of TB patients with respiratory failure during ICU treatment

Parameter	Survivors	Non-survivors	t/χ^2 value	P value
Subjects n	93	60		
Pathogenic examinations				
Sputum smear positive	75 (80.65)	43 (71.67)	1.667	0.197
Positive sputum cultures	81 (87.10)	45 (75.00)	2.887	0.089
Xpert MTB/RIF	83 (89.25)	47 (78.33)	2.600	0.107
Drug-resistant tuberculosis	32 (34.41)	23 (38.33)	0.1033	0.748
Blood gas analysis				
24 h PaO_2/FiO_2, mmHg	193.58±85.32	162.22±76.58	2.207	0.029
24 h pH	7.3720±0.1247	7.3591±0.1141	0.619	0.142
24 h PaO_2, mmHg	134.4659±60.6017	117.9094±63.8482	1.55	0.123
24 h $PaCO_2$, mmHg	46.6052±18.7453	46.989±16.6042	0.123	0.902
△ PO_2, mmHg	82.2054±59.5621	55.5200±45.8789	2.954	0.004
△ PCO_2, mmHg	15.1132±16.3268	20.7867±20.0956	1.915	0.057
Biological parameters				
White cell count, ×10^9/L	14.25±13.86	12.44±7.37	0.934	0.352
Hemoglobin, g/L	102.37±28.21	96.60±24.12	1.302	0.195
Albumin, g/L	27.29±5.50	24.56±3.04	3.503	0.001
B-type natriuretic peptide, U/L	2,168 (672–6,547)	3,714 (1,137–9,101)	1.160	0.246
D-dimer, mol/L	0.4 (0.3–1.6)	0.7 (0.3–1.3)	0.336	0.737
Creatinine, μmol/L	107.40±79.73	137.16±101.13	2.026	0.045
C-reactive protein, mg/L	77.96±59.15	116.87±65.07	3.819	<0.001
Erythrocyte sedimentation rate, mm/h	51 (26–65)	45 (32–55)	1.205	0.228
Treatment				
Anti-TB treatment in ICU, n (%)	56 (60.22)	37 (61.67)	0.032	0.857
First anti-TB treatment	75 (80.65)	39 (71.67)	4.700	0.030
mechanical ventilation	74 (79.57)	56 (93.33)	5.409	0.020
CRRT	24 (25.81)	19 (31.61)	0.364	0.546
Outcome				
Length of ICU stay, days	9.3152±8.6392	11.6379±9.567	1.330	0.186

Data are shown as number (percentage), mean ± SD, or median (IQR). PaO_2/FiO_2 (24 h): partial arterial O_2 pressure/inspired O_2 fraction ratio at 24 hours after admission to ICU. $PaCO_2$ (24 h): partial arterial CO_2 pressure at 24 hours after admission to ICU. PaO_2 (24 h): partial arterial O_2 pressure at 24 hours after admission to ICU. △ PO_2: the difference partial arterial O_2 pressure between 0 and 24 hours after admission to ICU. △ PCO_2: the difference partial arterial O_2 pressure between 0 and 24 hours after admission to ICU. CRRT, continuous renal replacement therapy; TB, Tuberculosis; ICU, Intensive care unit.

Table 3 Multivariate logistic regression analyses for risk factors for death of patients with pulmonary TB with respiratory failure during ICU treatment

Variable	B	S.E.	Wald	P	OR	95% CI	
						Lower	Upper
PaO_2	−0.075	0.026	8.422	0.004	0.928	0.882	0.976
Albumin	−0.161	0.056	8.436	0.004	0.851	0.763	0.949
Apache II score	0.232	0.068	11.510	0.001	1.262	1.103	1.443
C-reactive protein	0.012	0.004	8.702	0.003	1.013	1.004	1.021

TB, Tuberculosis; ICU, Intensive care unit; SE, standard error; OR, odds ratio; CI, confidence interval.
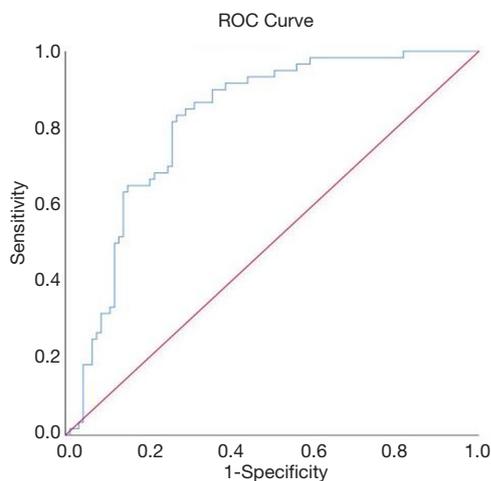
Figure 2 Receiver operator characteristics (ROC) evaluated effect of the model. The area under the ROC curve is 0.818.

rate reported for patients admitted to the ICU (19-21). Pathogenic examinations for M. TB were obtained from all patients, most patients had some degree of resistance to anti-TB drugs, there were about 2/3 fully susceptible. These results suggest that ICU patients' resistance to anti-TB drugs were more serious and complex than in the common ward (21). In this retrospective study, factors contributing to mortality included the PaO_2, albumin, Apache II score and C-reactive protein. We determined a simple scoring system that was predictive of fatality based on these independent factors.

As shown in this study, the PO_2 of pulmonary TB patients with respiratory failure on admission to the ICU was lower for non-survivors than for survivors. As previous study reported, it is generally believed that the PaO_2 level is associated with the severity of respiratory failure and prediction of outcomes (22). Belton *et al.* used hypoxia-

specific tracer (^{18}F) FMISO to investigate hypoxia, found that the presence of severe hypoxia within TB lesions in man, and IKK-β inhibition significantly decreased MMP-1 secretion in a dose-dependent manner in hypoxia (23), and hypoxia reduces inflammatory responses concerning macrophage motility and invasiveness, phagocytic capacity and most importantly bacterial killing (24). The lower the level of PaO_2, the higher the death rate. Our data confirm evidence that low PaO_2 is reliable in differentiating patients with poorer outcomes (12). The value of PaO_2 level to screen for patients with active pulmonary TB with respiratory failure is that it enables early institutions of proven therapies.

Many previous studies reported that nutritional status is an important factor in TB treatment (25,26). Malnutrition leads to a decrease in immunity and M. TB is susceptible to infection; on the other hand, increased consumption of TB leads to malnutrition in the body. A previous cross-sectional study reported, 300 adult TB patients have surveyed China, they found that most male (90.8%) and female (58.4%) TB patients had insufficient daily protein intake. Li *et al.* found that more TB patients had albumin levels <35 g/L (27). Our results showed that pulmonary TB with respiratory failure patients albumin levels were even lower, ≤30 g/L. These results indicate that the results of this study are in line with the research conducted by Bhurayanontachai *et al.* (10), found that more TB patients command with respiratory failure had albumin levels <30 g/L. The body mass index and albumin was significantly lower in non-survivors than survivors, in multivariate analyses, albumin was an independent risk factor for death of patients with pulmonary TB with respiratory failure during ICU treatment, implying that the nutritional status was correlated with poor prognosis, thus demonstrating that albumin is good indicators of poor prognosis (10,28).

The Apache II score was given by the sum of the acute

physiology score comprising 12 variables, age points and chronic health points. The patient's condition was more serious, the prognosis was poorer, and the mortality rate was higher with higher scores. This score is widely used in the validation and prediction of clinical results of severe patients in the ICU, and there are some studies to indicate that the score can be used in TB patients (29). Other studies found a mean Apache II score of 21.2±6.5, indicating a mortality rate of 30–40% on ICU admission (10). In this study, the mean Apache II score was 21.40±4.32 in the fatalities group, indicating a mortality rate of 39.22% on ICU admission as previously reported (30). However, the high mortality rates in our study suggest that the Apache II score of pulmonary TB with respiratory failure on ICU admission and their mortality rate may be higher than for other diseases admitted to the ICU. The Apache II score was an independent risk factor for the death of pulmonary TB with respiratory failure during ICU treatment in multivariate analyses. However, another study found no correlation between mortality and Apache II score, and Apache II score made it less useful and potentially misleading for patients with PTB requiring intensive care in that study (30). As another previous study reported that acute respiratory failure caused by pulmonary TB necessitating mechanical ventilation has a high mortality rate and poor prognosis, particularly in patients with high Apache II score (31), our study suggests that the Apache II score may be used to predict their outcomes.

C-reactive protein is a highly sensitive biomarker of inflammation but is not specific to infection. Its serum levels increase in both infectious and non-infectious causes of inflammation (32). C-reactive protein has also been considered to be an important factor affecting patients' outcomes. Our results showed that levels of C-reactive protein were significantly higher in non-survivors than survivors. The results of this study were comparable to the results of previous studies. Bajwa *et al.* found that high plasma C-reactive protein levels predict a favorable outcome in adults with ARDS, and they hypothesized that high C-reactive protein levels might reduce neutrophilic inflammation (33). Paradoxically, other reports showed that C-reactive protein levels are generally used as a biomarker for systemic inflammation, and higher values are associated with adverse outcomes (34). Albuquerque *et al.* found that C-reactive protein was strong discriminators of active TB and thus could be considered as biomarkers useful in

discrimination different TB clinical forms (35). Another study found high C-reactive protein level was associated with sputum smear turn to negative (36). The association between C-reactive protein levels and outcome has not previously been investigated in TB patients with respiratory failure, so our study is the first to show that high C-reactive protein levels are associated with fatal outcome.

In our study, we determined a simple scoring system for pulmonary TB patients with respiratory failure isolated that was predictive of fatality based on these independent variables. This scoring system only applies to HIV negative patients. The sensitivity was 83.3%, and specificity was 73.1%. The prediction model will be beneficial for risk assessment in patients with TB and respiratory failure, enabling early institutions of proven therapies, allowing the prediction of outcomes, and facilitating clinical research. However, a larger sample is needed to verify this scoring system further.

Further study

One limitation of our study was its retrospective design. Firstly, limited ICU resources may have introduced a selection bias to the patients, and the number of patients may have been too small for analysis. Secondly, using past patient records was a limiting factor. As many risk factors are affecting the prognosis of pulmonary TB patients with respiratory failure, we still need prospective studies to explore the risk factors for mortality in this group of patients. This pilot study gave values of Apache II scores, C-reactive protein levels, PaO_2, and albumin levels associated with surviving and non-surviving TB patients combined with respiratory failure that can then be used to design randomized clinical trials mainly focused on patients with a high risk of death.

Conclusions

Overall, TB patients with respiratory failure had a high mortality rate and poor prognosis, particularly those with high Acute Physiology and Chronic Health Evaluation II scores, high C-reactive protein levels and low PaO_2 and low albumin. Our study suggests that paying attention to mortality-related risk factors would help reduce the mortality of patients. The use of these results to guide shared decisions between TB patients with respiratory

failure and their clinicians may lead to improvements in the ICU and hospital outcome.

Footnote

Reporting Checklist: The authors have completed the STROBE Reporting Checklist. Available at http://dx.doi. org/10.21037/apm-20-182

Data Sharing Statement: Available at http://dx.doi. org/10.21037/apm-20-182

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi. org/10.21037/apm-20-182). The 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 approved by the ethics committee of Beijing Chest Hospital, Chaoyang Fourth Hospital, and Hebi Third People's Hospital (No. 2018-ky-0102). The present study was conducted according to the principles of the Declaration of Helsinki.

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