Risk factors of pulmonary complications after spine surgery and a risk assessment table was established: a retrospective cohort study

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Abstract

Purpose

To determine the risk factors for pulmonary complications after spine surgery and establish a risk assessment table.

Methods

A total of 627 patients, who underwent spine surgery at Hebei General Hospital from January 2018 to December 2019, were retrospectively collected and studied. Univariate analysis revealed significant variables. Risk factors and the effects of the model were determined by unconditional binary logistic regression analyses and the receiver operating characteristic (ROC) curve, respectively. A risk assessment scale for patients after spine surgery was also established based on the risk factors.

Results

49 patients were diagnosed with pulmonary complications (49/627, 7.81 %). Logistic regression analysis showed that age, body mass index (BMI), smoking, diabetes, type of spinal diseases, type of operation, surgical site, American society of anesthesiologists (ASA) scores, type of anesthesia and total length of stay (LOS) were risk factors of pulmonary complications after spine surgery ($P < 0.05$) and area under the curve was 0.883, 95 % confidence intervals (CI): 0.843–0.923. The risk assessment table included preoperative and postoperative evaluation indicators. There were 8 preoperative evaluation indicators including age, BMI, smoking, hypertension, diabetes, chronic pulmonary diseases, type of spinal diseases, surgical site. Preoperative hospitalization days, ASA scores, type of anesthesia, type of operation and duration of operation were five postoperative evaluation indicators. The highest assessment score of preoperative is 21, postoperative is 18, and the total is 39 points of all these indicators.

Conclusions

Significant risk factors of pulmonary complications were age, BMI, smoking, diabetes, type of spinal diseases, type of operation, surgical site, ASA scores, type of anesthesia and total LOS after spine surgery. There were 13 evaluation indicators in our established risk assessment table including preoperative and postoperative evaluation indicators. The higher the score, the higher the risk of pulmonary complications after spine surgery.

1 Introduction

Spinal diseases are some of the most frequently encountered problems that affecting people's quality of life in particular [1]. It was reported that the incidence and prevalence of myelopathy due to degeneration

of the spine were estimated at a minimum of 41% and 605 per million in North America respectively, and surgical rates caused by the disease was also on the rise [2]. Although most spinal diseases are not fatal, their incidence rate has caused huge losses from the individual and social perspective [3]. Injury complexity and propensity for related complications would happen because of the spinal column's intimate association with multiple vital structures [4]. Complications are the most concerned problems of patients and physicians, once they occur, they may have personal and economic consequences, and affect the quality of life and future independence of patients [5].

Prior studies have reported complications after spine surgery [6, 7]. Notably, pulmonary complications are especially responsible for morbidity and mortality, as well as prolonged hospitalization, generate substantial economic burden, and compromised quality of life [8, 9]. Risk factors for pulmonary complications after spine surgery had been identified in much research [10–13], and its rates vary from study to study, reported to range from 0.9–9% [7, 10, 14, 15]. At the same time, there is no report about establishing a risk assessment table. The identification and quantification of risk factors for postoperative complications of spinal surgery are very important for both patients and clinicians. In addition to the obvious importance to patient safety, risk factor information becomes critical as health care policy makers implement "quality" indicators. [16]

Age and surgical invasiveness had been reported as significant risk factors for patients who underwent spine procedures to infect complications during perioperative period [17]. It was also reported that based on these risk factors clinicians could stratify the risk of perioperative complications in patients undergoing spinal surgery [17, 18] and these results could be used to establish prediction models whereby the probability of a postoperative complication can be predicted for each patient who undergoes spine surgery.

Therefore, patients who underwent spine surgery at Hebei General Hospital from January 2018 to December 2019 were included in this study. Risk factors of pulmonary complications after spine surgery would been identified. Meanwhile, we attempted to establish a risk assessment scale for such patients based on the relevant literatures and our findings, which may be efficient for doctors and nurses to assess the risk of postoperative pulmonary complications.

2 Patients And Methods

2.1 Patients

Patients who underwent spine surgery at Hebei General Hospital from January 2018 to December 2019 were retrospectively collected and studied. Inclusion criteria of patients were as follows: 1) age ≥ 18 years; 2) fulfilled the follow-up no less than six months after surgery; 3) diagnosed by spinal surgery in hospital. The exclusion criteria of patients were as follows: 1) with severe pulmonary disease before

operation; 2) were diagnosed with combining surgeries in other parts; 3) had incomplete data; 4) age < 18 years.

2.2 Diagnostic of pulmonary complication

Postoperative pulmonary complications (PPCs) could be broadly defined as conditions affecting the respiratory tract that can adversely influence the clinical course of a patient after surgery [19, 20]. Nevertheless, PPCs definitions usually include pneumonia, exacerbation of chronic obstructive pulmonary disease, respiratory failure, bronchospasm, pneumothorax, pleural effusion, atelectasis, and various forms of upper airway obstruction.

In this study, fever, pulmonary inflammation, respiratory failure, atelectasis, respiratory tract infection, pleural effusion, venous thrombosis of lower extremity, urinary infection, arrhythmia,gastrointestinal discomfort and so on were all the complications after operation. Pulmonary complication was diagnosed by patients' symptoms of pulmonary inflammation, upper respiratory tract infection, pulmonary embolism and pleural effusion.

2.3 Risk factors

Gender, age, BMI, smoking, alcohol abuse, hypertension, diabetes, prior spine surgery, type of spinal diseases, type of operation, surgical site, operation time limit, operation start time, type of anesthesia, ASA scores, length of stay in operating room, duration of operation, preoperative hospitalization days and hospitalization days were used to analyze the risk factors of pulmonary complications after spine surgery.

2.4 Statistical Analysis

Statistical analysis was performed using SPSS 21.0 (IBM). Continuous variables were expressed as means ± standard deviation and analyzed by independent samples T test. χ^2 test was used for categorical and discrete variables. Meaningful factors and risk factors considered by clinical experts were added to unconditional binary logistic regression. Risk factors were searched by unconditional binary logistic regression, which were independent variables with univariate analysis of $P < 0.05$, and the dependent variables were with or without pulmonary complication. The ROC curve was used to evaluate the effect of the logistic regression model. P value of less than 0.05 was considered significant.

2.5 Establishment of the risk assessment scale

A risk assessment scale for patients after spine surgery was established based on the results of logistic regression analysis. The independent risk factors were grouped according to clinical significance or usage habits. For each risk factor, an appropriate group was selected as the basic risk reference value, and the score of this group was recorded as 0 in the subsequent construction of the rating scale. In this study, the β value of age was used as the reference value, and each component value was calculated according to the β value and stratification of each risk factor. According to the opinion of clinical experts, other risk factors (hypertension, chronic pulmonary diseases, preoperative LOS, duration of operation)

were added to the risk assessment table too. Adjust each evaluation factor reasonably and construct a risk assessment scale.

3 Results

A total of 656 patients were enrolled in this study. However, among them, 8 patients with severe pulmonary disease before operation, 4 patients were younger than 18 years old and 17 patients without following up were excluded. Finally, a total of 627 patients were included in this retrospective study, among which 49 patients (7.81 %) had pulmonary complications after surgery (Table 1).

Table 1
Pulmonary adverse occurrence

PC	Prevalence
Pulmonary inflammation	19(3.03%)
Respiratory tract infection	9(1.44%)
Pleural effusion	7(1.12%)
Respiratory failure	3(0.48%)
Atelectasis	3(0.48%)
Combine two or more of the above PC	8(1.28%)
Total pulmonary adverse occurrence events	49(7.81%)
PC: Pulmonary complications.	

These 49 patients was 71.47 ± 14.223 years old and included 27 females and 22 males. The remaining 578 patients (92.19 %) without pulmonary complications was 63.02 ± 14.958 years and included 346 females and 232 males. There were statistically significant differences between patients with and without pulmonary complications in terms of age, BMI, smoking, hypertension, diabetes, type of spinal diseases, type of operation, surgical site, operation time limit, ASA scores, total LOS, preoperative LOS ($P < 0.05$, Table 2). Meaningful factors and risk factors (prior spine surgery, type of anesthesia, duration of operation) considered by clinical experts were added to unconditional binary logistic regression analysis. The variable assignment of each risk factor was shown in Table 3.

Table 2
Univariate analysis of related factors between patients with and without pulmonary complications.

Risk Factors	PC (n = 49)	NPC (n = 578)	OR	95% CI	P-value
Gender					
Male	22	232	0.823	0.458–1.480	0.515
Female	27	346			
Age	71.47 ± 14.223	63.02 ± 14.958		4.096–12.805	**0.000**
BMI	27.704 ± 4.916	25.028 ± 3.551		1.237–4.116	**0.000**
Smoking					
Yes	23	166	0.455	0.253–0.821	**0.008**
No	26	412			
Alcohol abuse					
Yes	18	160	0.659	0.359–1.212	0.177
No	31	418			
Hypertension					
Yes	27	235	0.558	0.310–1.004	**0.049**
No	22	343			
Diabetes					
Yes	17	95	0.37	0.198–0.694	**0.001**
No	32	483			
Prior spine surgery					
Yes	11	88	0.62	0.306–1.260	0.183

PC: pulmonary complications; NPC: no pulmonary complications; OR: odds ratio; CI: confidence intervals; BMI: body mass index; Fracture related: Compression fracture, traumatic fracture, removal of internal fixation, etc.; Spinal cord, intervertebral disc and other related: Intervertebral disc herniation, spinal stenosis, spinal cord injury, etc.; ASA: American Society of Anesthesiologists CIIA: combined intravenous and inhalation anesthesia; LOS: length of stay.

Risk Factors	PC (n = 49)	NPC (n = 578)	OR	95% CI	P-value
No	38	490			
Type of spinal diseases					
Fracture related	9	122			**0.000**
Spinal cord, intervertebral disc and other related	10	306			
Spinal tumors, masses, infectious diseases	4	20			
Combine the above two or more	26	130			
Type of operation					
Open surgery	19	140	0.505	0.276–0.925	**0.025**
Minimally invasive surgery	30	438			
Surgical site	5	54			**0.000**
Cervical	24	119			
Thoracic	20	405			
Lumbar					
0peration time limit					
Emergency surgery	16	117	0.523	0.279–0.983	**0.041**
Limited time surgery	33	461			
Operation start time					
8:00–12:00	23	262			0.859
12:00–14:00	9	111			
14:00–18:00	13	173			
18:00–24:00	4	32			
ASA scores					

PC: pulmonary complications; NPC: no pulmonary complications; OR: odds ratio; CI: confidence intervals; BMI: body mass index; Fracture related: Compression fracture, traumatic fracture, removal of internal fixation, etc.; Spinal cord, intervertebral disc and other related: Intervertebral disc herniation, spinal stenosis, spinal cord injury, etc.; ASA: American Society of Anesthesiologists CIIA: combined intravenous and inhalation anesthesia; LOS: length of stay.

Risk Factors	PC (n = 49)	NPC (n = 578)	OR	95% CI	P-value
≤2	22	443	4.027	2.221–7.302	**0.000**
≥3	27	135			
Type of anesthesia					
CIIA	11	146	1.168	0.582–2.344	0.663
Non-CIIA	38	432			
LOS in operating room (minutes)	151.43 ± 127.033	165.74 ± 102.962		-44.997-16.366	0.36
Duration of operation (minutes)	87.04 ± 102.409	99.30 ± 80.086		-42.356-17.831	0.417
Total LOS	15.08 ± 9.970	9.82 ± 7.882		2.330–8.193	**0.001**
Preoperative LOS	5.90 ± 5.217	3.31 ± 3.153		1.0701–4.109	**0.001**

PC: pulmonary complications; NPC: no pulmonary complications; OR: odds ratio; CI: confidence intervals; BMI: body mass index; Fracture related: Compression fracture, traumatic fracture, removal of internal fixation, etc.; Spinal cord, intervertebral disc and other related: Intervertebral disc herniation, spinal stenosis, spinal cord injury, etc.; ASA: American Society of Anesthesiologists CIIA: combined intravenous and inhalation anesthesia; LOS: length of stay.

Table 3
Logistic regression analysis variable assignment

Risk Factors	Variable assignment		
Age (years)	18–35, =1	36–55, =2	56–65, =3
	66–75, =4	76–85, =5	≥ 8, 6 = 6
BMI	18.5–23.9, =1	24-27.9, =2	≥ 28.0 or 18.5, =3
Smoking	No = 0	Yes = 1	
Hypertension	No = 0	Yes = 1	
Diabetes	No = 0	Yes = 1	
Prior spine surgery	No = 0	Yes = 1	
Type of spinal diseases	Fracture related = 1		
	Spinal cord, intervertebral disc and other related = 2		
	Spinal tumors, masses, infectious = 3		Combine the above two or more = 4
Type of operation	Minimally invasive surgery = 0		Open surgery = 1
Surgical site	Cervical/ Lumbar = 0		Thoracic = 1
0peration time limit	Emergency surgery = 1		Limited time surgery = 2
ASA scores	≤ 2, =1	≥ 3, =2	
Type of anesthesia	Non-CIIA = 1	CIIA = 2	
Duration of operation (minutes)	≤ 240, =1	240, =2	
Total LOS	≤ 6, =1	7–13, =2	≥ 14, =3
Preoperative LOS	≤ 2, =1	3–6, =2	≥ 7, =3

BMI: body mass index; ASA: American Society of Anesthesiologists; CIIA: combined intravenous and inhalation anesthesia; LOS: length of stay.

Logistic regression analysis showed that age, BMI, smoking, diabetes, type of spinal diseases, type of operation, surgical site, ASA scores, type of anesthesia, total LOS were risk factors of pulmonary complications after spine surgery ($P < 0.05$, Table 4).

Table 4
Unconditional binary logistic regression analysis of risk factors for pulmonary complications.

Risk Factors	β	Standardized error	Wald	P-value	OR	95% CI	
						Lower	Upper
Age (years)	0.433	0.179	5.868	0.015	1.542	1.086	2.190
BMI	0.512	0.242	4.481	0.034	1.668	1.039	2.678
Smoking	1.221	0.370	10.898	0.001	3.391	1.642	7.000
Diabetes	0.937	0.378	6.135	0.013	2.552	1.216	5.357
Type of spinal diseases	0.537	0.163	10.869	0.001	1.710	1.243	2.353
Type of operation	2.370	0.663	12.772	0.000	10.695	2.916	39.230
Surgical site	1.322	0.363	13.276	0.000	3.750	1.842	7.635
ASA scores	0.682	0.378	3.254	0.071	1.977	0.943	4.148
Type of anesthesia	2.832	0.698	16.483	0.000	16.981	4.327	66.638
Total LOS	0.785	0.257	9.347	0.002	2.192	1.325	3.626
Constant	-15.927	2.032	61.451	0.000	0.000		

OR: odds ratio; CI: confidence intervals; BMI: body mass index; ASA: American Society of Anesthesiologists; LOS: length of stay.

Area under the receiver operating characteristic curve (AUC) can be used to measure the reliability of the model, with values close to 1.0 indicating high diagnostic accuracy [21]. AUC was 0.883 (95% CI: 0.843–0.923, Fig. 1 and Table 5), which meant the above indicators were reliability.

Table 5
Area Under the Curve

Test Result Variable(s): Predicted probability				
Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
0.883	0.021	0.000	0.843	0.923

A risk assessment table was established for patients in this study. Risk factors of pulmonary complications included age, BMI, smoking, diabetes, type of spinal diseases, type of operation, surgical site, ASA scores, type of anesthesia, total LOS were assigned values (Table 6). The other risk factors (hypertension, chronic pulmonary diseases, preoperative LOS, duration of operation) considered by clinical experts were added to the risk assessment table too.

Table 6
Assignment Values of risk factors

Risk Factors	Categories	Reference values	β	Assignment Values
Age	18–35	1	0.433	0
	36–55	2		1
	56–65	3		2
	66–75	4		3
	76–85	5		4
	≥ 86	6		5
BMI	18.5–23.9	0	0.512	0
	24-27.9	1		1
	≥ 28.0;□18.5	2		2
Smoking	No	0	1.221	0
	Yes	1		3
Diabetes	No	0	0.937	0
	Yes	1		2
Type of spinal diseases	Fracture related	0	0.537	0
	Spinal cord, intervertebral disc and other related	1		1
	Spinal tumors, masses, infectious	2		2
	Combine the above two or more	3		4
Type of operation	Minimally invasive surgery	0	2.370	0
	Open surgery	1		6
Surgical site	Cervical/ Lumbar	0	1.322	0
	Thoracic	1		3
ASA scores	≤ 2	1	0.682	0
	≥ 3	2		2
Type of anesthesia	Non-CIIA	1	2.832	0
	CIIA	2		7

BMI: body mass index; ASA: American Society of Anesthesiologists; LOS: length of stay.

Risk Factors	Categories	Reference values	β	Assignment Values
Total LOS	≤ 6	1	0.785	0
	7–13	2		2
	≥ 14	3		4

BMI: body mass index; ASA: American Society of Anesthesiologists; LOS: length of stay.

There were 13 evaluation indicators including preoperative and postoperative evaluation indicators. Age, BMI, smoking, hypertension, diabetes, chronic pulmonary diseases, type of spinal diseases, surgical site, were preoperative evaluation indicators. The postoperative evaluation indicators include preoperative hospitalization days, ASA scores, type of anesthesia, type of operation and duration of operation were postoperative evaluation indicators. The highest assessment score of preoperative is 21, postoperative is 18, and the total is 39 points of all these indicators (Table 7). The higher the score, the higher the risk of pulmonary complications after spine surgery.

Table 7
Risk assessment of pulmonary complications after spine surgery

Stage	Items	Grading rules	Scores	Score
Preoperative assessment	Age (Year)	18–35	0	
		36–55	1	
		56–65	2	
		66–75	3	
		76–85	4	
		≥ 86	5	
	BMI	18.5–23.9	0	
		24-27.9	1	
		≥ 28.0;18.5	2	
	Smoking	Yes	3	
	Hypertension	Yes	1	
	Diabetes	Yes	2	
	Chronic pulmonary diseases	Yes	1	
	Type of spinal diseases	Fracture related diseases. Spinal cord, intervertebral disc and other related diseases.	1	
		Spinal tumors, masses, infectious diseases.	2	
		Combine the above two or more spine related diseases	4	
	Surgical site	Cervical/ Lumbar	0	
		Thoracic	3	
	Preoperative assessment scores			
Postoperative assessment	Preoperative LOS	≤ 3	0	
		4–6	1	
		≥ 7	2	
	ASA scores	≤ 2	0	

BMI: body mass index; LOS: length of stay; ASA: American Society of Anesthesiologists; CIIA: combined intravenous and inhalation anesthesia.

Stage	Items	Grading rules	Scores	Score
		≥ 3	2	
	Type of anesthesia	Non- CIIA	0	
		CIIA	7	
	Type of operation	Minimally invasive surgery	0	
		Open surgery	6	
	Duration of operation (minutes)	240	0	
		≥ 240	1	
Total scores				
BMI: body mass index; LOS: length of stay; ASA: American Society of Anesthesiologists; CIIA: combined intravenous and inhalation anesthesia.				

4 Discussion

It is estimated that more than 230 million major operations occur annually in the world [22]. Surgeons and patients are very concerned about the possibility and likelihood of a postoperative medical complication after surgery, which will affect their decision-making. Prior to extensive spinal surgery, high-risk patients are often evaluated by medical providers for risk stratification and health optimization [23]. Spinal surgery is no exception. PPCs are common, and can be considered as a composite outcome measure [24, 25]. PPCs had been shown to be more common than cardiac complications in some studies [26, 27]. Although many scoring systems can be used to quantify PPCs risk, there is no consensus on the best one to use, especial for spine surgery, and they remain too complex to use clinically [24].

In the present study, we retrospectively evaluated patients who underwent spine surgery at our hospital from January 2018 to December 2019. The incidence of pulmonary complications after surgery was 7.81 % in 627 enrolled patients. Age, BMI, smoking, hypertension, diabetes, type of spinal diseases, type of operation, surgical site, operation time limit, ASA scores, total LOS, preoperative LOS were significantly different between patients with and without pulmonary complications. Logistic regression analysis showed that age, BMI, smoking, diabetes, type of spinal diseases, type of operation, surgical site, ASA scores, type of anesthesia, total LOS were risk factors of pulmonary complications after spine surgery. Moreover, a risk assessment table was established for patients who underwent spine surgery in this study. There were 13 evaluation indicators including preoperative and postoperative evaluation indicators. The highest assessment score of preoperative is 21, postoperative is 18, and the total is 39 points of all these indicators. The higher the score, the higher the risk of pulmonary complications after spine surgery.

Obesity has been illustrated to reduce lung volume and change ventilation pattern [28], which is more likely to occur in the elderly patients. In addition, obesity was revealed to be a risk factor in certain studies, which examined the prevalence and risk factors of pulmonary embolism (PE) after spinal surgery [29]. Patients with diabetes, two or more spinal diseases are also at a significantly increased risk for complication. Compared with other parts of the spine, thoracic surgery is more likely to affect the lung function. Many studies also show that minimally invasive surgery has the advantages of small incision, small trauma, fast recovery, short hospital stay, and can effectively reduce the surgical complications, including pulmonary complications. The higher the anesthesia score, the more serious the patient's condition is. In addition, because of the combined intravenous and respiratory anesthesia, it is bound to affect the function of the lung. These risk factors are consistent with previous reports [10].

This study has several limitations. Firstly, the data were retrospectively collected in a single center which might lead to an unavoidable selection bias. Secondly, the established risk assessment table in our study has not been used in clinic. In the next study, we will conduct prospective studies to verify the validity of this risk assessment table. Furthermore, the sample sizes in this study are relatively small, and further study with a larger number of samples is warranted. These limitations notwithstanding, the risk factors of pulmonary complications after spine surgery were determined in our study. Furthermore, the risk assessment table was established, which could assess the risk of postoperative pulmonary complications.

In conclusion, targeted prevention interventions should be used to prevent pulmonary complications after spine surgery, in order to comprehensively manage risk factors in the perioperative period. In our research, age, BMI, smoking, diabetes, type of spinal diseases, type of operation, surgical site, ASA scores, type of anesthesia, total LOS were defined significant risk factors of pulmonary complications. The established risk assessment scale could help prospectively evaluated risk of pulmonary complications after spine surgery.

Abbreviations

BMI: body mass index; ASA: American Society of Anesthesiologists; LOS: length of stay; PPCs: postoperative pulmonary complications; PC: pulmonary complications; NPC: no pulmonary complications; PE: pulmonary embolism; DM: diabetes mellitus; OR: odds ratio; CI: confidence intervals; CIIA: combined intravenous and inhalation anesthesia; ROC: receiver operating characteristic; AUC: area under the receiver operating characteristic curve.

Declarations

Ethics approval and consent to participate: The ethics committee of Hebei general Hospital approved the research.

Consent for publication: All of the listed authors have offered the consent to the submission.

Availability of data and material: All data generated or analyzed during this study are included in this published article.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions:

HX carried out the risk factors studies, performed the statistical analysis and drafted the manuscript. CJ, MY and YB participated in the collation of data. JD and SX participated in its design and coordination. WY conceived of the study and helped to draft the manuscript. All authors read and approved the final manuscript.

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Figures

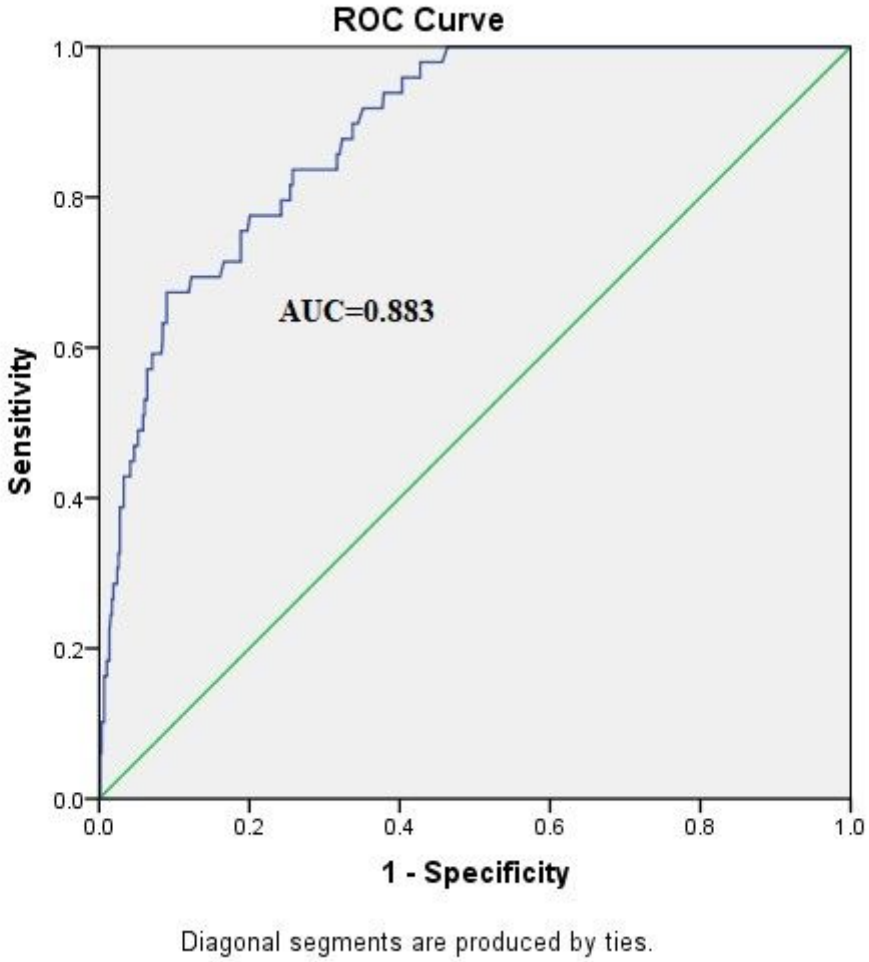

Figure 1

Area under the curve of the predicted meaningful and risk factors.