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Risk Prediction Models for Intra-Abdominal Hypertension in Adult ICU Patients

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ABSTRACT

Objective: To investigate the independent risk factors of intra-abdominal hypertension in ICU patients, establish a risk prediction model of intra-abdominal hypertension in ICU patients, and conduct internal verification.

Methods: This study was a prospective cohort study. Convenience sampling method was used to select 261 patients in ICU departments of two Top three hospitals in Sichuan Province from August to December 2022 who met the standards for hypertension as the study subjects. A self-designed risk factor questionnaire was used to observe and collect relevant data of the study subjects, including general data, disease and related data. Independent risk factors of IAH in ICU patients were obtained by Cox univariate and multivariate regression analysis, and a risk nomogram prediction model for intra-abdominal hypertension in ICU patients was constructed. Internal validation of the nomogram model was carried out by Bootstrap 1000 repeated sampling method. AUC size was used to reflect the model's differentiation, calibration curve was used to reflect the model's calibration, and DCA was used to draw decision analysis curve to evaluate the clinical applicability of the model.

Results: Cox multifactor analysis showed that surgery, Ventosity, increase in abdominal contents, accumulation of abdominal contents, shock, and APACHE II score were independent risk factors for IAH within 1 to 6 days after ICU admission. The above six independent risk factors were used to construct a risk nomogram prediction model for intra-abdominal hypertension in ICU patients. The c-index of the nomogram model was 0.826 (0.736-0.890), and the c-index after Bootstrap1000 repeated sampling was 0.826 (0.792-0.861). The AUC of the model at 12h, 24h and 36h after admission to ICU was 0.836, 0.932 and 0.913, respectively. The calibration curves of 12h, 24h and 36h after admission to ICU showed a good agreement between the prediction results of the nomogram model and the actual observation. The DCA curve showed that at 12h after admission to ICU, the threshold was between 0.04 and 0.79. 24h after admission to ICU, when the threshold was > 0.28; At 36h after admission to ICU, when the threshold was > 0.38, the nomogram model had good clinical applicability.

Conclusions: The prediction model of the risk nomogram of intra-abdominal hypertension in ICU established in this study has good differentiation, calibration and clinical applicability, which can help ICU medical staff to identify high-risk groups of intra-abdominal hypertension more easily and quickly.

Relevance to Clinical Practice: To find patients prone to intra-abdominal hypertension earlier through the prediction model, so as to provide basis and guidance for clinical medical staff to prevent intra-abdominal hypertension early.

Keywords: ICU; Intra-Abdominal Hypertension; Intra-Abdominal Pressure; Influencing Factors; Prediction Model; Nomogram

Abbreviations: IAP: Intra-Abdominal Pressure; UBP: Urinary Bladder Pressure; SOFA: Sequential Organ Failure Score: IAH: Intra-Abdominal Hypertension; DCA: Decision Curve Analysis; AUC: Area Under the ROC Curve

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Introduction

Intra-abdominal Pressure (IAP) refers to the pressure in the abdominal cavity [1]. It is mainly generated [2] by the hydrostatic pressure of the internal organs in the abdominal cavity, which generally occurs in [3] critically ill patients. The development of IAH not only affects the blood perfusion of various organs, but also affects the hemodynamics [4] of the whole body, which can lead to rapid deterioration of organ function and even multiple organ failure and is an independent risk factor [4] for death in critically ill patients. Therefore, intra-abdominal pressure is an important physiological monitoring parameter [5], which requires nurses to monitor [6] patients on a regular basis. Urinary Bladder Pressure (UBP), the gold standard [7,8] IAP in clinical work, but it is an invasive procedure that can increase the risk of urinary system infection if performed without following the aseptic principle. Moreover, because UBP is performed through the bladder, it is not suitable [9] Meanwhile, it is also very costly to measure internal abdominal hypertension for every patient admitted to ICU. The Acute Physiology and Chronic Health score (APACHE II) and Sequential Organ failure score (SOFA) were associated with IAH. However, the purpose of these two scales is to evaluate the severity of disease and the degree of organ dysfunction/failure in critically ill patients, and they cannot directly predict the risk of IAH. To sum up, in order to help medical staff more quickly and easily identify the risk of IAH in ICU patients, this study conducted a prospective cohort study in ICU to build a risk prediction model of abdominal and internal hypertension in ICU patients, with a view to providing medical staff with a more convenient and rapid prediction tool to identify high-risk groups of IAH.

Data and Methods

General Information

Patients in ICU departments of two first-class hospitals in Sichuan Province from August 20, 2022 to December 15, 2022 were selected as the study objects by convenience sampling method.

Inclusion criteria:

1. Age ≥18 years old
2. Patients with indwelling urinary tube.

Exclusion criteria:

1. Patients with IAH upon admission to ICU
2. Patients who could not have their internal bladder pressure measured (e.g., women with pelvic fracture, severe hematuria or nervous bladder spasm, pregnant women)
3. Patients who cannot remain supine
4. Patients with ICU admission time < 24h
5. Patients who meet inclusion criteria but cannot be continuously monitored for other reasons
6. The patient asked to withdraw during observation. The inclusion and exclusion criteria for patients are shown in Figure 1.

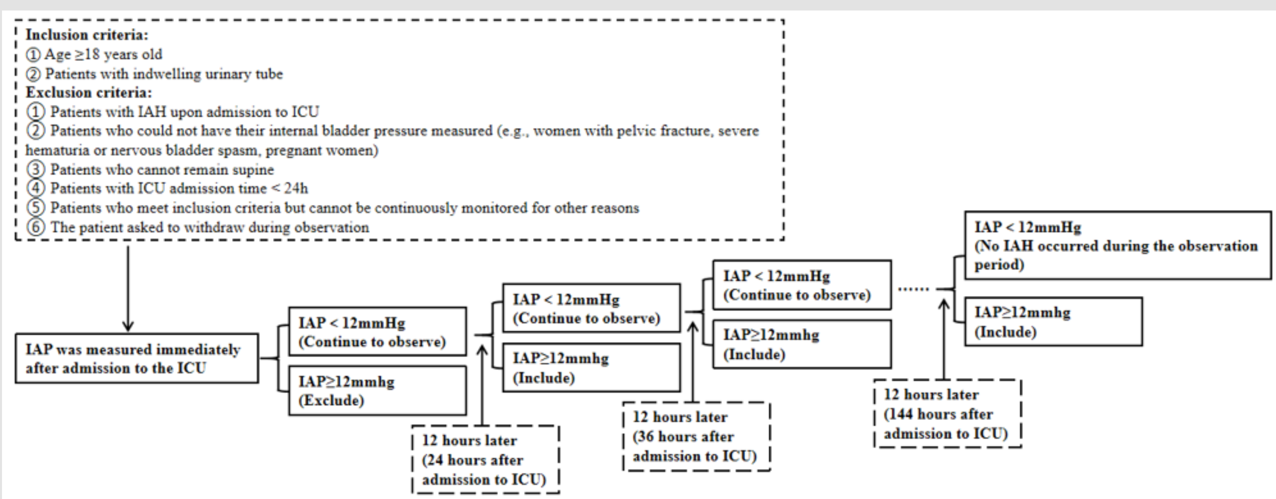

Figure 1: Patient inclusion flow chart.

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This study was a prospective cohort study. The sample size is calculated using the principle of 10 EPV (Event Per Variable) in the construction of risk prediction model [10-12], that is, the number of positive outcome events should be more than 10 times the number of variables eventually included in the model. It is estimated that the risk prediction model of this study eventually included 5 to 7 predictive variables. Combined with the expert consensus of the Chinese Abdominal Critical Care Cooperation Group [2], the incidence of IAH in ICU was 30% to 40%, and the loss of follow-up rate of 5% was considered, so the sample size required for modeling in this study was 245 cases. The specific calculation formula is as follows: (7×10) ÷30%×(1+5%) =245. A total of 261 samples were included in this study, meeting the above sample requirements.

Methods

Measuring Tools: The case data questionnaire was developed by reviewing the previous domestic and foreign literatures and discussing at expert group meetings. It includes

1) General data; Age, gender, BMI, and whether surgery was performed prior to ICU admission.

2) Disease and related information: Including oliguria, hypokalemia, abdominal dilation, lung infection, various types of shock, use of vasoactive drugs, positive end-expiratory pressure ventilation (PEEP≥7cmH2O), MAP, CVP, lactic acid, urea, creatinine, uric acid, increased abdominal contents, accumulation of abdominal contents, decreased abdominal wall compliance, capillary leakage and fluid resuscitation, APACHE II score, SOFA score. All our data came from the electronic medical record system of the department. After patients were admitted to ICU, doctors would evaluate the APACHE II score and SOFA score of patients. All data to be collected were generated within 12h after admission to the ICU, reflecting the health status of the patient within 12h after admission to the ICU.

Outcome Indicators: The outcome measure was whether IAH occurred within 1 to 6 days after admission to ICU. The criteria for determining intra-abdominal hypertension (IAH) were as follows: When IAP≥12mmHg, IAH occurred.

Data Collection Methods: After obtaining the consent of the ethics committee of the hospital and the managers of relevant departments, the three survey implementeers were given unified training by clinical specialist teachers and carried out the measurement of IAP under their guidance. They were familiar with the measurement process and operational methods and jointly completed the collection and recording of data. Another researcher checked and verified the data.

Statistical Methods

SPSS 23.0 was used for general data analysis, and R4.2.2 software and R studio software were used to construct the risk prediction model. In the general data, measurement data conforming to normal distribution were expressed as mean ± standard deviation (± s), non-normal measurement data were expressed as median and quartile distance M (P25, P75), and counting data were expressed as frequency and percentage. In the construction of risk prediction model, unifactor and multi-factor Cox regression analysis were carried out successively, and then the nomogram model for risk prediction of abdominal and internal hypertension in ICU patients was constructed. Bootstrap1000 repeated sampling method was used to validate the nomogram model internally. Area under ROC curve (AUC) was used to reflect the model's differentiation, calibration curve was used to reflect the model's calibration, and decision curve analysis method (DCA) was used to draw decision analysis curve to evaluate the clinical applicability of the model. The above test level was α=0.05, and $P < 0.05$ was considered to be statistically significant.

Results

Status of IAH Occurrence in ICU Patients

A total of 261 patients in ICU were included in this study. Among them, 198 patients developed IAH during the observation period, with an incidence rate of 76%. Iah occurred within 12 to 72 hours. Among them, 104 patients (52.5%) developed IAH within 12 hours. 30.3% of the patients with IAH occurred within 12 to 24 hours; 11.6% of the patients developed IAH within 24~36 hours; Only 3%, 1%, and 1.5% of patients developed IAH within 36 to 48 hours, 48 to 60 hours, and 60 to 72 hours, respectively. During the observation period, the median time for IAH to occur was 12h after ICU admission.

Cox Univariate Regression Analysis

The results of single factor analysis showed that Age, BMI, surgical treatment prior to ICU admission, abdominal dilation, increased abdominal contents, accumulation of abdominal contents, decreased abdominal wall compliance, shock, use of vasoactive drugs, PEEP≥7cmH2O, MAP, lactic acid, urea, uric acid, APACHE II score and SOFA score were associated with IAH in ICU patients during the observation period ($P < 0.05$), as shown in Table 1.

 DOI: 10.26717/BJSTR.2025.61.009648

Table 1: Univariate analysis of risk factors for IAH in ICU patients.

Factors	Regression coefficient (β)	Standard error (SE)	P	HR	95%CI
age	0.010	0.004	0.010*	1.010	1.002-1.018
Gender (female)	0.251	0.144	0.083	0.778	0.587-1.033
Whether surgery was performed prior to ICU admission (Yes)	0.395	0.145	0.007*	1.484	1.117-1.972
BMI	0.001	0.000	0.001*	1.001	1.000-1.002
Oliguria (yes)	0.244	0.191	0.201	1.277	0.878-1.856
Hypokalemia (yes)	0.049	0.143	0.734	0.953	0.720-1.261
Ventosity (yes)	1.125	0.148	< 0.001*	3.080	2.303-4.119
Increased abdominal cavity contents (yes)	0.623	0.147	< 0.001*	1.865	1.398-2.486
Accumulation of abdominal contents (Yes)	0.706	0.148	< 0.001*	2.026	1.516-2.708
Decreased abdominal wall compliance (yes)	0.388	0.150	0.010*	1.473	1.097-1.978
Capillary leakage and fluid resuscitation (yes)	0.333	0.198	0.093	1.396	0.946-2.059
Lung infection (yes)	0.277	0.149	0.063	1.320	0.984-1.768
Shock (yes)	0.820	0.145	< 0.001*	2.269	1.709-3.013
Whether to use vasoactive drugs (yes)	0.615	0.145	< 0.001*	1.850	1.392-2.458
PEEP≥7cmH2O (Yes)	0.323	0.144	0.025*	1.382	1.041-1.833
MAP	0.011	0.003	< 0.001*	0.989	0.983-0.995
Lactic acid	0.056	0.014	< 0.001*	1.058	1.030-1.087
Urea	0.007	0.002	< 0.001*	1.007	1.003-1.011
Creatinine	0.000	0.000	0.492	1.000	0.999-1.000
Uric acid	0.001	0.000	0.001*	1.001	1.000-1.002
APACHE II	0.077	0.009	< 0.001*	1.080	1.062-1.098
SOFA	0.121	0.015	< 0.001*	1.128	1.097-1.161

Note: * is P < 0.05

Cox Multivariate Regression Analysis

The relevant factors of IAH in the univariate analysis were included in the multivariate Cox regression. The results showed that surgical treatment before admission to ICU, Ventosity, increase in abdominal contents, accumulation of abdominal contents, shock, and APACHE II score were independent risk factors for IAH in ICU patients during the observation period (P< 0.05), as shown in Table 2.

Table 2: Multi-factor analysis of IAH risk factors in ICU patients.

Factors	Regression coefficient (β)	Standard error (SE)	P	HR	95%CI
Whether surgery was performed prior to ICU admission (yes)	0.421	0.178	0.018*	1.524	1.075-2.161
Ventosity (yes)	0.734	0.166	< 0.001*	2.082	1.505-2.881
Increased abdominal contents (yes)	0.619	0.165	< 0.001*	1.857	1.343-2.567
Accumulation of abdominal contents (Yes)	0.405	0.170	0.017*	1.500	1.074-2.095
Shock (yes)	0.591	0.200	0.003*	1.806	1.218-2.677
APACHE II	0.046	0.015	0.002*	1.047	1.016-1.078

Note: * is P < 0.05

Construction of a Prediction Model for the Risk of Intra-Abdominal Hypertension in ICU

The independent risk factors of IAH were included in the construction of risk nomogram prediction model. R software was used to make the 12h, 24h and 36h nomogram prediction model for ICU patients, as shown in Figure 2. The scores of all variables were added together to obtain the total score, and the prediction probability corresponding to the total score was the probability of the non-occurrence of intra-abdominal hypertension in ICU patients during 12h, 24h and 36h after admission to ICU. Subtracting the predicted probability of non-occurrence of IAH corresponding to the total score by 1 is the probability of occurrence of IAH in the patient, that is, probability of occurrence of IAH =1- probability of non-occurrence of IAH.

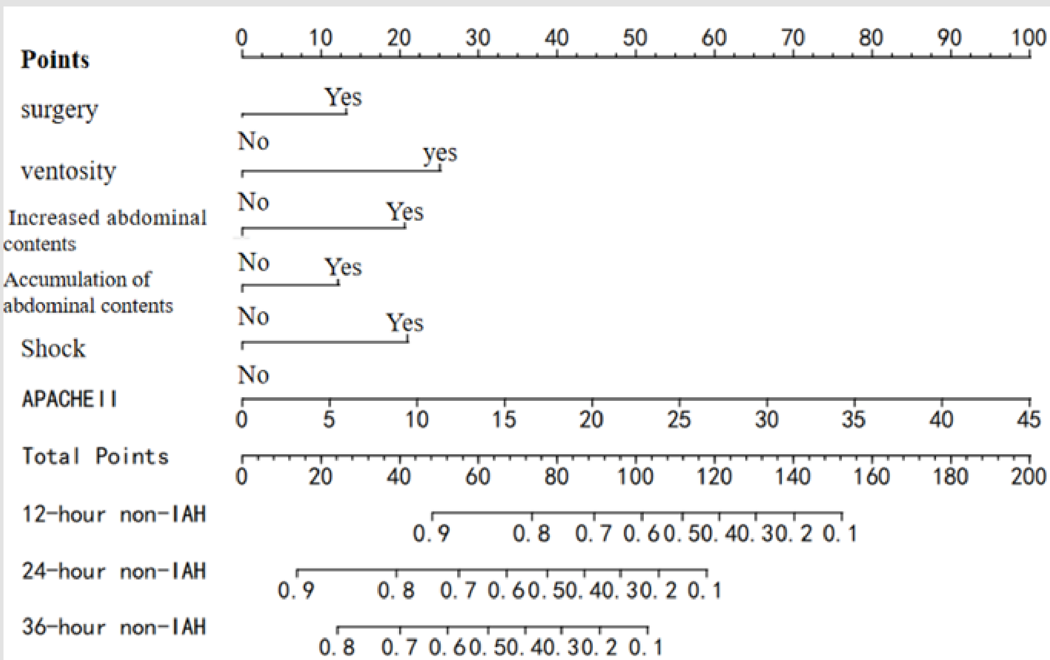

Figure 2: The risk prediction model for intra-abdominal hypertension in ICU patients is a nomogram.

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Internal Verification and Evaluation of the Risk Prediction Model of Intra-Abdominal Hypertension in ICU

Bootstrap1000 repeated sampling method was used for internal verification of the nomogram model. The c-index of the nomogram model was 0.826 (0.736-0.890), and that of the nomogram model after repeated sampling was 0.826 (0.792, 0.861). The coefficient before and after repeated sampling was stable, and the difference was small, indicating that the model had good repeatability.

Differentiation Evaluation: The size of the area under the ROC curve (AUC) reflected the differentiation of the model. Differentiation was measured using the C-index or Area under the ROC Curve (AUC). The ROC curve of the constructed model was drawn, as shown in Figure 3. The results showed that the AUC of 12h was 0.836, 95%CI (0.77-0.884); For 24h, the AUC was 0.932, 95%CI (0.900-0.964); The AUC of 36h was 0.913, 95%CI (0.877 -- 0.950), indicating that the model had good differentiation. At 12h, the sensitivity and specificity of the model were 65.4%, 89%, the Jorden index was 0.544, and the cutoff value was 112.672. For 24h, the sensitivity and specificity were 80.8%, 93.7%, 0.746, and 93.146. 36h sensitivity is 82.3%, specificity is 94.3%, Jorden index is 0.766, truncation value is 78.611. See Table 3 for details.

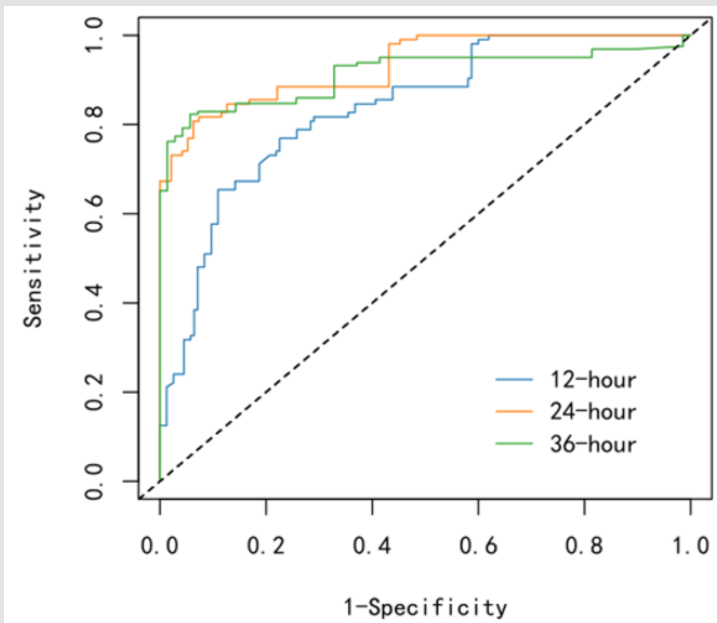

Figure 3: ROC curve of IAH risk within 12h, 24h and 36h after ICU admission.

Table 3: Area under Model ROC Curve (AUC).

Time	AUC value	95%CI of the AUC value	Sensitivity	Specificity	Jorden index	Truncation
12h	0.836	0.787-0.884	0.645	0.89	0.544	112.672
24h	0.932	0.900-0.964	0.808	0.937	0.746	93.146
36h	0.913	0.877-0.950	0.823	0.943	0.766	78.611

Calibration Degree Evaluation: Calibration curves are used to reflect the calibration degree of the model. The calibration degree of the model was verified by Bootstrap resampling method, and the prediction accuracy of the model in 12h, 24h and 36h after ICU admission was analyzed. The prediction curve basically coincided with the diagonal line, indicating that the model had a good calibration degree at 12h, 24h and 36h. See Figure 4 for the results.

 DOI: 10.26717/BJSTR.2025.61.009648

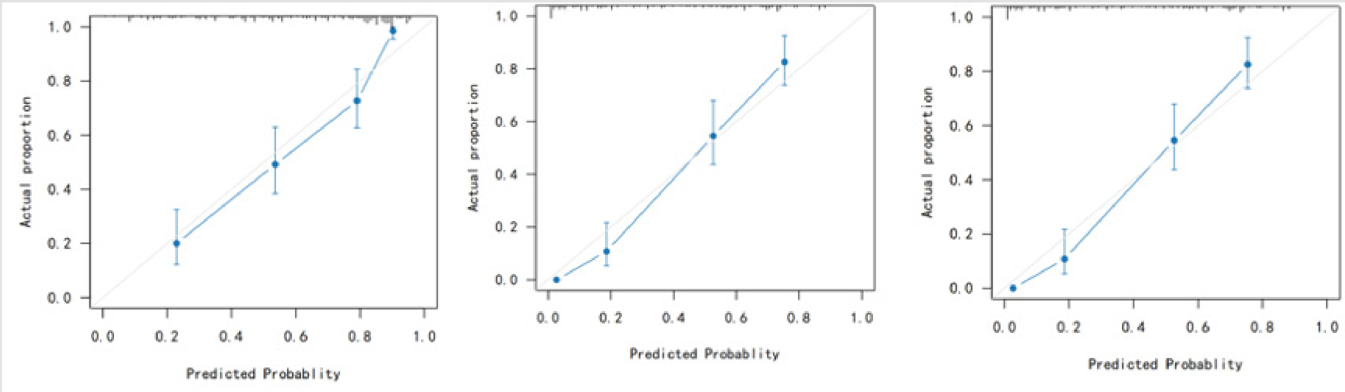

Figure 4: Calibration curves at 12h, 24h and 36h after admission to ICU.

Evaluation of Clinical Applicability: Decision curve analysis (DCA) was used to draw decision analysis curve to evaluate the clinical applicability [13] of the model. As shown in Figure 5, the column-line model was used to predict IAH risk in ICU patients, when the threshold value was between 0.04 and 0.79 within 12 hours of admission to ICU. Within 24h after admission to ICU, when the threshold was > 0.28; Within 36h of ICU admission, when the threshold was > 0.38, the net benefit level of applying the nomogram model was significantly higher than that of "none treatment" and "all treatment protocols". This indicates that the model has good clinical applicability in 12h, 24h and 36h after admission to ICU.

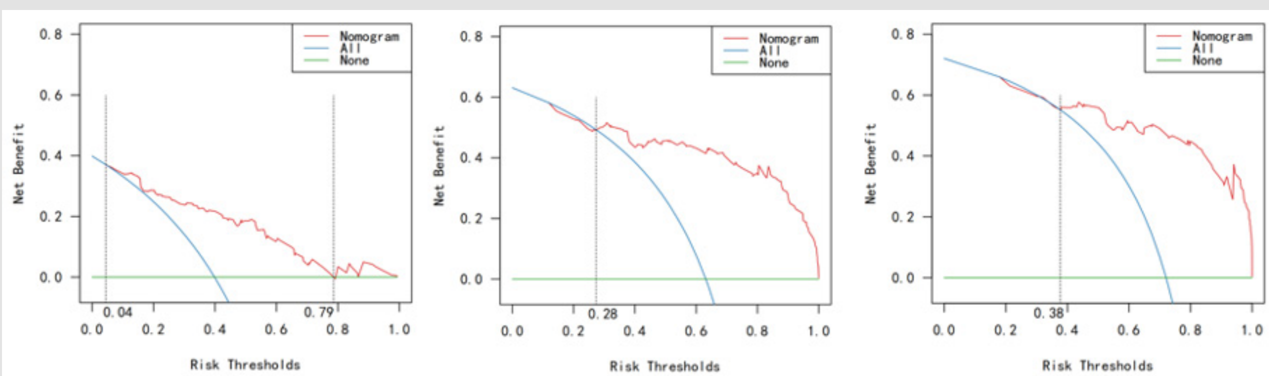

Figure 5: DCA curves at 12h, 24h and 36h after ICU admission.

Discussion

Status of Occurrence of Intra-Abdominal Hypertension in ICU Patients

A total of 261 ICU patients were included in this study. During the study period, 198 patients, accounting for 75.9%, experienced IAH, which was found to be very common in ICU patients. In this study, IAH occurred within 36h after admission to the ICU, and at the latest within 72h after admission to the ICU, with a median time of 12h after admission to the ICU. The pathophysiological changes of IAH and ACS often involve intraperitoneal organs as well as respiratory, cardiovascular, and central nervous systems. In addition, diagnosis and treatment are often delayed in clinical work, which greatly increases the risk [3] of organ failure and death. Therefore, medical staff should conduct risk assessment of IAH in ICU patients as soon as possible. High-risk patients should be observed for IAP within 36h after admission to the ICU, and preventive measures should be taken within 12h after admission to the ICU. The results of this study showed that the incidence of intra-abdominal hypertension in severe patients was as high as 75.9%, which was actually related to potential selection bias. After we excluded patients who stayed in ICU for less than 24h, the remaining patients had more critical conditions and higher APACHE II scores, which may be the reason for the high incidence of intra-abdominal hypertension in this study.

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Analysis of Influencing Factors of Intra-Abdominal Hypertension in ICU Patients

Age: The results of this study showed that the age of patients was correlated with the occurrence of IAH, and the older the age, the greater the likelihood of IAH occurrence. Possible reasons for this are: Abdominal wall compliance is a measure of the extent to which the abdominal wall expands in response to increased abdominal pressure and is determined by the elasticity of the abdominal wall and diaphragm. With age, especially in the elderly, the elasticity of the skin and muscles decreases, which in turn shows a decrease in abdominal wall compliance. In the face of changes in abdominal pressure caused by abdominal contents or other reasons, the compensatory function of the abdominal wall of the elderly is insufficient, and then internal abdominal high pressure occurs. Secondly, with the increase of age, the coexistence of basic chronic diseases and the influence of bad living habits, it is very common for the elderly to have liver insufficiency and the weakening of gastrointestinal digestive ability, which is also one of the potential reasons for the occurrence of intra-abdominal hypertension. Therefore, for older patients, medical staff should take the initiative to pay attention to the changes in internal abdominal pressure.

Surgery: The results of this study showed that surgical treatment before admission to ICU was an independent risk factor for IAH, and patients who underwent surgical treatment were 1.524 times more likely to develop IAH than those who underwent non-surgical treatment, especially those who underwent gastrointestinal surgery, orthopedics (trauma), and cesarean section. It was mainly associated with increased abdominal contents, accumulation of abdominal contents, and mass fluid resuscitation in these patients.

BMI and Obesity: The results of this study showed that the greater the patient's BMI, the higher the probability of IAH. Moreover, patients with BMI≥30Kg/m2 and obesity were significantly associated with IAH. The IAP of obese patients was higher than that of healthy people mainly due to increased volume of abdominal or retroperitoneal contents and decreased abdominal wall compliance caused by abdominal fat deposition in obese patients. Therefore, for patients with BMI≥30Kg/m22 or BMI < 30Kg/m combined with abdominal obesity, healthcare professionals should strengthen their observation of IAP.

Ventosity: The results of this study show that ventosity is significantly correlated with the occurrence of IAH and is one of the independent risk factors for IAH. Abdominal dist [7], especially in patients with acute pancreatitis [10]. Ventosity is a nonspecific symptom characterized by sagittal abdominal diameter (SAD) greater than the chest or hip height. The cause of distension is not necessarily from the gastrointestinal tract, but is mostly associated [11] with increased abdominal volume and accumulation of abdominal contents due to ascites, intestinal edema, hematoma, intestinal dilation, or intestinal obstruction. It is recommended that health care professionals observe the patient from the side while the patient is lying on his or her back. IAP monitoring is recommended if the shape of the patient's abdomen is curved, extending in a convex manner above the virtual line between the xiphoid process and the union.

Increased Abdominal Contents: Increased abdominal content is one of the independent risk factors for IAH in ICU patients. The main causes of increased abdominal content include gastroparesis, gastric dilatation, intestinal obstruction, pseudocolonic obstruction, abdominal tumor, retroperitoneal tumor, and damage control laparotomy [12] For these patients, the medical staff should formulate corresponding management measures according to the patient's condition, such as gastrointestinal decompression, fasting and alcohol prohibition, to reduce the pressure in the gastrointestinal tract; Observation of IAP should be strengthened to reduce the possibility of higher grade IAH or ACS in patients.

Accumulation of Abdominal Contents: The accumulation of peritoneal contents is an independent risk factor for IAH in ICU patients and can cause or contribute to IAH and ACS [14]. The accumulation of peritoneal contents includes: peritoneal fluid (cirrhosis, ovarian hyperstimulation, etc.), peritoneal hemoperitoneum, pneumoperitoneum, abdominal closure injury, peritoneal dialysis, pancreatitis, inflammatory peritonitis, and peritoneal absc [12] ess. The main reasons for its occurrence are: portal hypertension caused by cirrhosis, decrease of plasma colloid osmotic pressure, excessive production of hepatic lymph fluid, insufficient effective circulating blood volume, resulting in ascites; Intestinal contents escape, leading to peritonitis, abdominal fluid accumulation of gas; Edema of the abdominal contents increases its volume. For patients with concomitant accumulation of abdominal contents, the health care provider may perform abdominal drainage. This method is most effective [14] due to pancreatitis, cirrhosis and other causes.

Decreased Abdominal Wall Compliance: The results of this study show that decreased abdominal wall compliance is a risk factor for IAH, and any conditions that can cause decreased abdominal wall compliance can increase IAP. Causes of decreased abdominal wall compliance include obesity, abdominal surgery, prone ventilation, abdominal wall bleeding and/or rectus abdominis hematoma, abdominal skin burns, high positive end-expiratory pressure ventilation, and mechanical ventilation (human-machine asynchronous). Studies have shown that a variety of pathologic factors, such as visceral edema and fluid accumulation in the abdominal cavity, can lead to increased IAH and Ventosity, resulting in decreased [15] abdominal compliance. For such patients, if the cause can be intervened, the cause should be relieved as soon as possible according to the patient's condition.

Shock: The results of this study show that shock is an independent risk factor for IAH in ICU patients. In clinical practice, the consensus [16-18] is that fluid resuscitation is recommended for early treatment of shock patients, but a large amount of fluid resuscitation may promote IAH. The relationship between capillary osmotic syndrome/ mass fluid resuscitation and IAH and ACS has been well documented [6,19,20] in related studies. Systemic and local injuries in patients can lead to an inflammatory response that produces and releases cellular mediators that cause cell damage and capillary leakage with accompanying fluid transfer from the intravascular to the tissue space. Factors such as shock are potential triggers for these chain reactions, and the infusion of large amounts of fluid during resuscitation, which can lead to reperfusion injury and further capillary leakage, further complicates the situation and exacerbates IAH. Therefore, it is recommended that medical staff should calculate the fluid requirement of a patient according to the type of shock and the actual condition of the patient when shock occurs and observe the patient's reaction in real time to avoid IAH.

Use of Vasoactive Drugs: The risk of IAH is indirectly increased by the fact that patients on such drugs are often accompanied by organ failure, shock, and need to be resuscitated with large amounts of fluids.

MAP: The results of this study showed that MAP was negatively associated with the occurrence of IAH. Increased IAP leads to decreased diaphragm movement and upward elevation, which increases intrathoracic pressure, which significantly reduces venous return, resulting in decreased [19] cardiac output and decreased [21] mean arterial pressure. According to the actual situation of this study, the possible reasons for the negative correlation are as follows: when MAP is low, the patient may be in shock and need to undergo fluid rehydration therapy, and abundant fluid resuscitation is a risk factor for IAH, which will promote the development of IAH.

Lactic Acid: In this study, elevated lactic acid was positively associated with the development of IAH. As a resuscitation endpoint and biochemical marker of cellular metabolic disorders, lactic acid is related to the severity of the patient's disease. The results of this study suggest that the risk of IAH is increased in patients with critical illness combined with organ failure. This suggests that medical staff should be alert to IAH when the lactate level of patients is high.

Urea and Uric Acid: The results of this study showed that IAH was related to urea and uric acid levels. It is speculated that the kidney is more sensitive to blood supply and blood pressure. When IAP continues to increase, it will lead to decreased renal blood flow, significantly increased renal venous pressure and renal vascular resistance, and compression of renal veins will lead to renal insufficiency and acute kidney injury [22], which will be manifested as abnormal kidney related indicators. Patients with renal disease may experience hypoproteinemia and ascites, which may lead to increased IAP.

Apache II Score and Sofa Score: The APACHE II score is often used in ICU to assess the severity of a patient's condition. The results of this study showed that APACHE II score was positively correlated with the occurrence of IAH and was an independent risk factor for IAH in ICU patients. APACHE II score can be calculated in conjunction with disease status of patients, so it is widely [23] used because of its compatibility with clinical practice. However, it is greatly affected by treatment, so it is not recommended for medical staff to evaluate the possibility of IAH occurrence in ICU patients only by APACHE II score. This study also showed that SOFA score was correlated with IAH occurrence in ICU patients, and the higher the score of SOFA score, the greater the risk of IAH occurrence. This finding is consistent with the conclusion drawn by Pritesh [24] in their research.In clinical practice, we should pay attention to the changes of IAP in patients with high SOFA score.

Risk Nomogram Prediction Model of Intra-Abdominal Hypertension in ICU Patients

Chen established a risk nomogram prediction model for critically ill patients with internal abdominal hypertension based on ultrasound and clinical data. Our study is different from his study in that the predictors in this study model can be obtained by medical staff only through electronic medical record system or bedside observation. In this study, Cox regression analysis was used to establish the risk prediction model of intraabdominal hypertension for 12h, 24h and 36h after admission to ICU for severe patients and preliminarily verified. The application of the nomogram prediction model has the advantage of simple operation. Clinical staff can directly calculate the corresponding value of each indicator through the model, screen high-risk patients, increase the number of IAP measurements for patients with IAH high risk, formulate measurement intervals and implement targeted prevention strategies according to the actual situation. The nomogram model in this study showed good differentiation, calibration and clinical applicability, which provided a reference for medical staff to identify high risk patients of IAH in the early stage and formulate targeted measures. Early identification of high-risk patients with intra-abdominal hypertension is conducive to reminding medical staff to pay more attention to the functional status of relevant organs in such patients. Studies have shown that IAH is correlated with acute kidney injury [21,25].

Therefore, we should pay attention to the renal function indicators of high-risk patients with IAH and take preventive measures in advance to avoid the occurrence of acute kidney injury in high-risk patients with IAH. IAH is related to nutrition and the occurrence of nosocomial infection [26,27]. With the increase of stomach contents, intra-abdominal hypertension can easily lead to gastroesophageal reflux in patients, resulting in aspiration and increase the occurrence of VAP. Therefore, for high-risk IAH patients, we should increase the frequency of empty needle extraction or antral ultrasound to monitor the gastric residual volume of these patients. For patients with gastric retention, we should slow down or suspend enteral nutrition according to the medical advice of the patients, so as to reduce the possibility of aspiration. In the circulatory system, for high-risk IAH patients combined with shock, we should plan the amount of resuscitation fluid replenishment in advance [28] to avoid the interaction between large amounts of fluid replenishment and IAH, resulting in a vicious cycle. In summary, surgical treatment prior to ICU admission, Ventosity, increased abdominal contents, accumulation of abdominal contents, shock, and high APACHE II score were independent risk factors for IAH within 1 to 6 days after ICU admission. Health care professionals should assess the risk of IAH within 1-6 days after admission to the ICU, especially within 36h, so as to make preparations for early identification of high-risk groups of patients with intra-abdominal hypertension and prevent further development of IAH.

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