

Establishment and Application of Early Risk Stratification Method for Acute Abdominal Pain in Adults

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Abstract

Background: Acute abdominal pain is a common symptom of emergency patients. The severity was always evaluated based on physicians' clinical experience. The aim of this study was to establish an early risk stratification method (ERSM) for addressing adults with acute abdominal pain, which would guide physicians to take appropriate and timely measures following the established health-care policies.

Methods: In Cohort 1, the records of 490 patients with acute abdominal pain that developed within the past 72 h were enrolled in this study. Measurement data and numeration data were compared with analysis of variance and Chi-square test, respectively. Multiple regression analysis calculated odd ratio (*OR*) value. *P* and *OR* values showed the impacts of factors. ERSM was established by clinical experts and statistical experts according to Youden index. In Cohort 2, data from 305 patients with acute abdominal pain were enrolled to validate the accuracy of the ERSM. Then, ERSM was prospectively used in clinical practice.

Results: The ERSM was established based on the scores of the patient's clinical characteristics: right lower abdominal pain + 3 × diffuse abdominal pain + 3 × cutting abdominal pain + 3 × pain frequency + 3 × pain duration + fever + 2 × vomiting + 5 × stop defecation + 3 × history of abdominal surgery + hypertension history + diabetes history + hyperlipidemia history + pulse + 2 × skin yellowing + 2 × sclera yellowing + 2 × double lung rale + 10 × unconsciousness + 2 × right lower abdominal tenderness + 5 × diffuse abdominal tenderness + 4 × peritoneal irritation + 4 × bowel sounds abnormal + 10 × suspicious diagnosis + white blood cell count + hematocrit + glucose + 2 × blood urea nitrogen + 3 × creatine + 4 × serum albumin + alanine aminotransferase + total bilirubin + 3 × conjugated bilirubin + amylase. When the score was <18, the patient did not need hospitalization. A score of ≥18 and <38 indicated that the patient should be under observation or hospitalized. A score of ≥38 and <50 indicated the need for an emergent operation. A score of ≥50 indicated the need for admission to the Intensive Care Unit. The area under the receiver operating characteristic curve of the ERSM in Cohorts 1 and 2 were 0.979 and 0.988, respectively.

Conclusions: This ERSM was an accurate and reliable method for making an early determination of the severity of acute abdominal pain. There was the strong correlation between scores of ERSM and health-care decision-making.

Key words: Acute Abdominal Pain; Emergency; Risk Factor; Stratification

INTRODUCTION

Abdominal pain is a common clinical symptom, accounting for 6.8% of complaints addressed in an emergency situation.^[1] The severity of the pain varies, ranging from mild to severe enough to require an immediate intervention or to result in death. Etiologies of abdominal pain are numerous and complex, and they often involve multiple systems, which accounts for the high number of misdiagnoses.^[2,3] Many physicians evaluate the severity of abdominal pain and design a health-care policy based on

their clinical experience, which may not be accurate and is often difficult for junior doctors. Therefore, it is necessary

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to establish an accurate, efficient risk stratification system for early, quantitative assessment of the severity of the acute abdominal pain.

Some strategies have been proposed and continued to evolve in an attempt to identify risk factors for acute abdominal pain. Although some clinical scoring systems have been established,^[4-9] they still need further improve. First, some risk factors cannot be evaluated completely or immediately in patients with acute abdominal pain because some examinations are performed only after hospitalization. Second, most methods only predict the severity of some kinds or categories of diseases and cannot be used for all patients with acute abdominal pain. Third, treatment methods for patients with acute abdominal pain are complex, which include no need for hospitalization, hospitalization, emergency surgery, and Intensive Care Unit (ICU) admission. However, most previous established criteria only predict whether emergency surgery is needed.

In this study, we sought to develop a simple and practical early risk stratification method (ERSM) to guide physicians to assess the overall status of patients with acute abdominal pain. With the information derived from the ERSM, the physician is able to take an appropriate and timely treatment that will improve the patient's prognosis.

METHODS

The study was conducted with the approval from the Ethics Committee of Beijing Friendship Hospital and Beijing Tongren Hospital, Capital Medical University. Written informed consent was obtained from each participant.

Study population

Two different cohorts were used in this study. Cohort 1 was used to derive the ERSM, and Cohort 2 was used to validate it.

Cohort 1 included 490 adult patients who developed acute abdominal pain within the past 72 h from September 2013 to November 2014 in Beijing Friendship Hospital. Their records were retrospectively reviewed. Data on clinical symptoms and signs (location, nature, frequency, and duration of abdominal pain, fever, vomiting, stopped defecation, skin yellowing, sclera yellowing, and unconsciousness), laboratory examination results (e.g., white blood cell count, hematocrit, glucose, albumin), diagnoses, and prognosis were collected and entered into an excel database as described in detail previously.^[10] The prognosis was classified into four types: No need for hospitalization, hospitalization, emergency surgery, and ICU admission. Patients with a history of trauma or pregnancy were excluded from the study because the cause and treatment were obvious. If data for specific findings were missing, those patients also were not included in the final analysis. Then, the accuracy of ERSM was validated in the Cohort 2, which included 305 patients with acute abdominal pain patients from May 2015 to November 2015 in Beijing Tongren Hospital using the same inclusion and exclusion criteria of the Cohort 1.

Statistical analysis

All statistical analyses were performed with SPSS for Windows, version 18.0 software (SPSS Inc., Chicago, IL, USA). The data are shown as mean \pm standard deviation (SD) for measurement data and median (range) or percentage for numeration data. Chi-square test was used for comparing numeration data and one-way analysis of variance (ANOVA) for measurement data. Multiple regression analysis was applied to identify risk factors for being in a severe state. Six suspicious diagnoses were encoded: acute appendicitis, acute cholecystitis, acute pancreatitis, acute cholangitis, intestinal obstruction, and gastrointestinal perforation and prognosis. ERSM was then formulated. Receiver operating characteristic (ROC) analysis of the weighted cumulative scores was performed to evaluate the diagnostic accuracy of the ERSM. A $P < 0.05$ was considered to indicate statistical significance. After the initial establishment of the ERSM, the data of 490 cases were calculated, and the distribution of the cases was observed. With the discussion of the clinical experts' opinions and the maximum principle of Youden index on the statistics, the three cutoff values of the four groups (without hospitalization, hospitalization, emergency operation, and ICU) were determined.

RESULTS

There were 490 patients with acute abdominal pain in Cohort 1 (including 223 women and 267 men; median age: 55 years, range 22–95 years). In Cohort 2, 305 patients with acute abdominal pain (including 134 women, 171 men; median age: 51 years, range 19–90 years) were enrolled. There were no significant differences according to age and gender between Cohorts 1 and 2.

Among 490 patients with acute abdominal pain, there were 91 patients in non-hospitalization group, 296 patients in hospitalization group, 97 patients in emergency surgery group, and 6 patients in ICU group. Tables 1 and 2 showed the identified factors of four groups for acute abdominal pain, which were analyzed by Chi-square test or one-way ANOVA. From non-hospitalization group to ICU group, 2.2%, 7.1%, 30.9% and 0.0% of patients had right lower abdominal pain respectively; 2.2%, 23.3%, 22.7%, and 33.3% of patients had the history of abdominal surgery respectively; 8.8%, and 42.2%, 62.9%, and 100.0% of patients had bowel sounds abnormal respectively. There were 53 cases with intermittent abdominal pain and 38 cases with persistent abdominal pain in non-hospitalization group, 70 cases with intermittent abdominal pain and 226 cases with persistent abdominal pain in hospitalization group, 20 cases with intermittent abdominal pain and 77 cases with persistent abdominal pain in emergency surgery group respectively. All patients in ICU group had persistent abdominal pain. From non-hospitalization group to ICU group, pain duration were 10.3 ± 13.1 h, 44.3 ± 24.4 h, 31.4 ± 23.2 h, and 45.0 ± 22.7 h respectively; serum albumin were 40.4 ± 5.9 g/L, 36.4 ± 5.4 g/L, 36.6 ± 6.2 g/L, and 28.5 ± 3.2 g/L respectively; and

direct bilirubin were $5.5 \pm 4.3 \mu\text{mol/L}$, $19.1 \pm 12.4 \mu\text{mol/L}$, $6.6 \pm 4.1 \mu\text{mol/L}$, and $81.4 \pm 50.0 \mu\text{mol/L}$ respectively. Logistic regression identified the six statistically significant factors (right lower abdominal pain, history of abdominal surgery, bowel sounds abnormal, pain duration, albumin, and direct bilirubin) that were closely associated with the prognosis [Table 3].

Chi-square automatic interaction detection was used to analyze each risk factor and determine the score for each independent risk factor. Then, ERSM was established based on the scores of the patient's clinical characteristics: right lower abdominal pain + 3 × diffuse abdominal pain + 3 × cutting abdominal pain + 3 × pain frequency + 3 × pain duration + fever + 2 × vomiting + 5 × stop defecation + 3 ×

Table 1: Univariate analysis for qualitative data of four groups for acute abdominal pain, *n* (%)

Variables	Non-hospitalization group (<i>n</i> =91)	Hospitalization group (<i>n</i> =296)	Emergency surgery group (<i>n</i> =97)	ICU group (<i>n</i> =6)	Chi-square values	<i>P</i>
Right lower abdominal pain	2 (2.2)	21 (7.1)	30 (30.9)	0 (0.0)	52.657	2.16E-11
Diffuse abdominal pain	1 (1.1)	7 (2.4)	14 (14.4)	2 (33.3)	36.245	6.64E-8
Cutting abdominal pain	0 (0.0)	8 (2.7)	14 (14.4)	2 (33.3)	37.097	4.39E-8
Fever	8 (8.8)	96 (32.4)	30 (30.9)	2 (33.3)	20.131	1.59E-4
Vomiting	38 (41.8)	147 (49.7)	54 (55.7)	6 (100.0)	9.733	0.21 E-1
Stop defecation	3 (3.3)	66 (22.3)	26 (26.8)	3 (50.0)	23.026	3.98E-5
History of abdominal surgery	2 (2.2)	69 (23.3)	22 (22.7)	2 (33.3)	21.540	8.13E-5
Hypertension history	13 (14.3)	102 (34.5)	18 (18.6)	1 (16.7)	19.467	2.18E-4
Diabetes history	5 (5.5)	47 (15.9)	6 (6.2)	2 (33.3)	13.293	0.04E-1
Hyperlipidemia history	0 (0.0)	21 (7.1)	3 (3.1)	1 (16.7)	9.786	0.020
Skin yellowing	0 (0.0)	23 (7.8)	1 (1.0)	1 (16.7)	14.223	0.03E-1
Sclera yellowing	0 (0.0)	39 (13.2)	1 (1.0)	1 (16.7)	24.584	1.88E-5
Double lung rale	0 (0.0)	10 (3.4)	1 (1.0)	2 (33.3)	25.939	9.82E-6
Unconsciousness	0 (0.0)	0 (0.0)	0 (0.0)	1 (16.7)	80.832	2.03E-17
Right lower abdominal tenderness	4 (4.4)	19 (6.4)	20 (20.6)	0 (0.0)	21.806	7.15E-5
Diffuse abdominal tenderness	1 (1.1)	20 (6.8)	26 (26.8)	4 (66.7)	61.019	3.50E-13
Peritoneal irritation	1 (1.1)	20 (6.8)	42 (43.3)	1 (16.7)	100.001	1.55E-21
Bowel sounds abnormal	8 (8.8)	125 (42.2)	61 (62.9)	6 (100.0)	67.140	1.74E-14

E-*n* = 10^{-*n*} (*n*>0).

Table 2: Univariate analysis for quantitative data of four groups for acute abdominal pain

Variables	Non-hospitalization group (<i>n</i> =91)	Hospitalization group (<i>n</i> =296)	Emergency surgery group (<i>n</i> =97)	ICU group (<i>n</i> =6)	<i>F</i>	<i>P</i>
Pain duration (h)	10.3 ± 13.1	44.3 ± 24.4	31.4 ± 23.2	45.0 ± 22.7	54.549	2.09E-30
Pulse (beat/min)	76.6 ± 11.2	78.8 ± 13.0	85.5 ± 14.7	103.3 ± 22.6	14.840	2.93E-9
Hematocrit (%)	40.8 ± 5.4	38.8 ± 8.4	37.7 ± 8.4	35.4 ± 11.3	2.937	0.33E-1
White blood cell count (×10 ⁹ /L)	10.6 ± 6.8	10.7 ± 4.9	12.2 ± 4.8	16.7 ± 5.9	4.455	0.04E-1
Glucose (mmol/L)	6.8 ± 1.5	7.6 ± 3.6	7.5 ± 2.7	10.1 ± 4.0	2.694	0.46E-1
Blood urea nitrogen (mmol/L)	4.5 ± 1.5	5.7 ± 3.3	6.0 ± 5.8	7.9 ± 5.5	3.810	0.10 E-1
Creatine (μmol/L)	67.7 ± 17.5	82.5 ± 34.7	85.6 ± 34.6	119.6 ± 65.9	8.639	1.35E-5
Serum albumin (g/L)	40.4 ± 5.9	36.4 ± 5.4	36.6 ± 6.2	28.5 ± 3.2	16.995	1.64E-10
Alanine aminotransferase (U/L)	30.4 ± 28.7	155.0 ± 94.1	40.6 ± 26.9	406.9 ± 300.2	16.366	1.52E-10
Total bilirubin (μmol/L)	12.9 ± 7.6	25.0 ± 12.8	18.2 ± 10.4	81.7 ± 59.6	14.189	7.04E-9
Direct bilirubin (μmol/L)	5.5 ± 4.3	19.1 ± 12.4	6.6 ± 4.1	81.4 ± 50.0	16.981	1.62E-10
Amylase (U/L)	57.4 ± 27.7	395.3 ± 238.0	144.3 ± 78.7	1252.7 ± 864.3	17.846	5.28E-11

All data are shown as mean ± standard deviation. E-*n* = 10^{-*n*} (*n*>0).

Table 3: Multiple regression analysis for OR detection

Variable	<i>B</i>	<i>SE</i>	<i>Wald</i>	<i>df</i>	<i>P</i>	<i>OR</i> (95% <i>CI</i>)
Right lower abdominal pain	1.863	0.748	6.203	1	0.013	6.442 (1.487–27.904)
History of abdominal surgery	2.090	0.742	7.924	1	0.005	8.083 (1.886–34.634)
Bowel sounds abnormal	1.457	0.396	13.516	1	<0.001	4.292 (1.974–9.330)
Pain duration	2.153	0.434	24.605	1	<0.001	8.611 (3.678–20.162)
Serum albumin	1.251	0.500	6.260	1	0.012	3.495 (1.311–9.316)
Direct bilirubin	1.781	0.482	13.687	1	<0.001	5.939 (2.311–15.260)

B: Partial regression coefficient; *SE*: Standard error; *df*: Degrees of freedom; *OR*: Odds ratio; *CI*: Confidence interval.

Table 4: The thresholds for encoding risk factors

Risk factors	Threshold of encoding = 1	Threshold of encoding = 0
Right lower abdominal pain	Yes	No
Diffuse abdominal pain	Yes	No
Cutting abdominal pain	Yes	No
Pain frequency (times/h)	>3/24	≤3/24
Pain duration (h)	>24	≤24
Fever (°C)	>37	≤37
Vomiting	Yes	No
Stop defecation	Yes	No
History of abdominal surgery	Yes	No
Hypertension history	Yes	No
Diabetes history	Yes	No
Hyperlipidemia history	Yes	No
Pulse (beat/min)	>100	≤100
Skin yellowing	Yes	No
Sclera yellowing	Yes	No
Double lung rale	Yes	No
Unconsciousness	Yes	No
Right lower abdominal tenderness	Yes	No
Diffuse abdominal tenderness	Yes	No
Peritoneal irritation	Yes	No
Bowel sounds abnormal	Yes	No
Suspicious diagnosis	Acute appendicitis, acute cholecystitis, acute pancreatitis, acute cholangitis, intestinal obstruction, or gastrointestinal perforation	Others
White blood cell count (×10 ⁹ /L)	>10	≤10
Hematocrit (%)	<37	≥37
Glucose (mmol/L)	>6.16	≤6.16
Blood urea nitrogen (mmol/L)	>7.14	≤7.14
Creatine (μmol/L)	>115	≤115
Serum albumin (g/L)	<35	≥35
Alanine aminotransferase (U/L)	>40	≤40
Total bilirubin (μmol/L)	>17.1	≤17.1
Direct bilirubin (μmol/L)	>6.84	≤6.84
Amylase (U/L)	>115	≤115

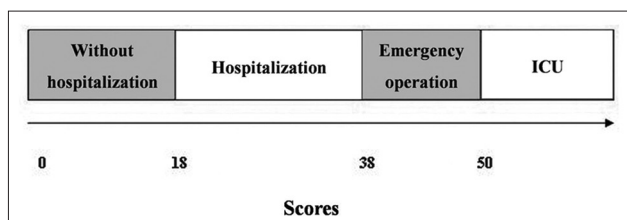


Figure 1: The relationship between early risk stratification method scores and prognosis.

history of abdominal surgery + hypertension history + diabetes history + hyperlipidemia history + pulse + 2 × skin yellowing + 2 × sclera yellowing + 2 × double lung rale + 10 × unconsciousness + 2 × right lower abdominal tenderness + 5 × diffuse abdominal tenderness + 4 × peritoneal irritation + 4 × bowel sounds abnormal + 10 × suspicious diagnosis + white blood cell count + hematocrit + Glucose + 2 × blood urea nitrogen + 3 × creatine + 4 × serum albumin + alanine aminotransferase + total bilirubin + 3 × conjugated bilirubin + amylase. The thresholds for the above encoding risk factors are shown in Table 4.

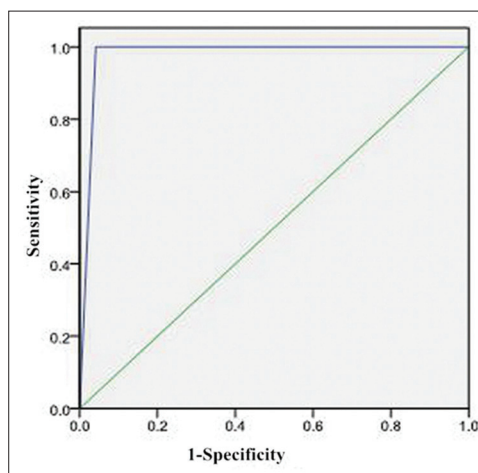


Figure 2: Receiver operating characteristic curve of the early risk stratification method calculated from Cohort 1.

Cutoff values for independent risk factors were used to judge the risk of acute abdominal pain by ROC curve analysis. Figure 1 showed the relationship between ERSM and four

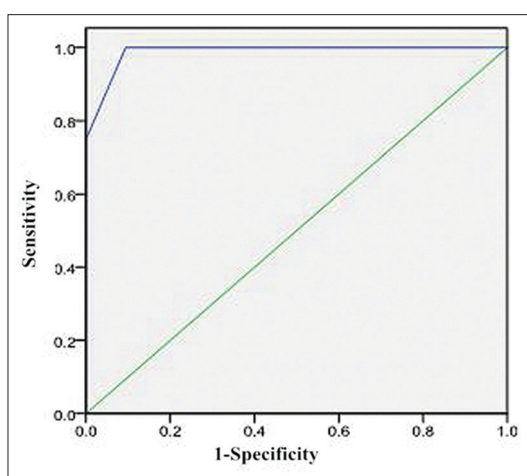


Figure 3: Receiver operating characteristic curve of the early risk stratification method calculated from Cohort 2.

types of prognoses. A score of ≥ 18 and < 38 indicated that the patient should be under observation or hospitalized. A score of ≥ 38 and < 50 indicated the need for an emergent operation. A score of ≥ 50 indicated the need for admission to the ICU.

ROC analysis of the weighted cumulative scores was performed to evaluate the effectiveness of the ERSM. The area under the ROC curve (AUC) of the ERSM in Cohorts 1 and 2 was 0.979 and 0.988, respectively [Figures 2 and 3].

DISCUSSION

In this study, an ERSM was established, which showed that with increasing scores, the admission rate and risk of acute abdominal pain increased. A score of 18 was the “trigger” level. A score of < 18 indicated that the patient did not require hospitalization; a score of ≥ 18 and < 38 indicated the need for observation or hospitalization; a score of ≥ 38 and < 50 indicated the need for emergency surgery; and a score of ≥ 50 indicated the need for ICU admission. This clinical scoring system could be used to guide emergency physicians to make a timely assessment of the overall status of a patient with acute abdominal pain, allowing the physician to set up an appropriate treatment program.

Some evaluated strategies have proposed in previous studies. However, these strategies cannot be well used and early assessed the overall status of all patients with acute abdominal pain in the emergency department. Early warning scores^[4-6] are commonly used in the ICU and emergency department in developed countries. It could accurately predict the death rate of patients after 3 days of hospitalization (AUC: 0.920), and the prognosis of those with acute pancreatitis within 24 h after admission (AUC: 0.768). However, they did not give an early evaluation of the overall status of patients who presented to the emergency department with acute abdominal pain. Deibener-Kaminsky *et al.*^[7] found that neutrophilia, eosinopenia, and lymphopenia were independent predictors of the severity of abdominal pain in patients of emergency department. Although the specificity of this method was

94.9%, the sensitivity was only 27.5%. Chen *et al.*^[8] designed a method to predict whether surgery was required for patients with abdominal pain coexisting with diarrhea. The sensitivity was 100%, but the specificity was only 23%. Furthermore, the method was also not suitable for all patients with abdominal pain. Akyildiz *et al.*^[9] suggested that D-dimer was an important risk factor when deciding whether an emergency operation or laparotomy was needed immediately. The method, however, could not distinguish patients who needed an operation from others who required hospitalization or ICU admission.

There are some advantages of our ERSM. First, ERSM is suitable for all patients with acute abdominal pain. Second, ERSM is a simple and timely method to assess the overall status of a patient at an early stage because all predictors could be acquired easily and timely in tertiary hospitals, and the score could be calculated by the ERSM within 1 h after the patient presenting to the emergency department. Furthermore, 305 cases were putted into the ERSM and used ROC curve to evaluate the accuracy of the ERSM. The AUC of 0.988 showed ERSM accurately and reliably.

We also acknowledged some limitations of this study. First, although 490 patients with acute abdominal pain were enrolled to establish the ERSM and 305 patients with acute abdominal pain were enrolled to verify its validity, the sample size was still not very large. Second, the development and validation of the ERSM was based on the data provided by only two hospitals. Third, to improve the specificity and sensitivity, the ERSM is too complex which can only be used easily in a big hospital. In the future, we will continue to enroll more cases to evaluate the accuracy of the ERSM in clinical practice at more centers and establish a simpler ERSM which could be used in the rural hospitals.

In conclusion, this study established an ERSM to evaluate the severity of acute abdominal pain in patients of emergency department. This ERSM is accurate and reliable and will help physicians to make an appropriate and timely treatment to improve patients’ prognosis.

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Conflicts of interest

There are no conflicts of interest.

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