The modified Boey score (mBoey) for outcome prediction in patients with perforated peptic ulcer complicated by diffuse peritonitis: a retrospective study

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Research article

Keywords: perforated peptic ulcer, diffuse peritonitis, scoring systems, the mBoey score, morbidity, mortality

Posted Date: May 13th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-28623/v1>

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Abstract

Background

several scoring systems are developed to stratify the patients with perforated peptic ulcer (PPU), complicated by peritonitis. The aim of this study was to evaluate the accuracy of different scoring systems in outcome prediction in patients following surgical treatment for PPU complicated by diffuse peritonitis and to determine the possibility of enhancing the Boey score prognostic performance based on the addition of an age factor.

Methods

this is a retrospective multicenter study of 153 patients surgically treated for PPU with diffuse peritonitis in Pirogov Russian National Research Medical University's surgical clinics during 2014–2016 years. The outcome prediction accuracy of the modified Boey score (mBoey), Boey score, peptic ulcer perforation (PULP) score, the American Society of Anaesthesiologists (ASA) score, Mannheim peritonitis index (MPI) and WSES sepsis severity score (WSES SSS) was evaluated by receiver operating characteristics curve (ROC) analysis, and the corresponding areas under the curve (AUC) were compared.

Results

all scores demonstrated the high quality of the model according to the AUC values, both in relation to mortality and postoperative complications - from good (WSES SSS) to perfect (mBoey, Boey, PULP, ASA). The modified mBoey predicted morbidity (AUC – 0.932) and mortality (AUC – 0.943) better than other prognostic scoring systems.

Conclusions

the use of prognostic scores allows identifying the high-risk patients with perforated peptic ulcers complicated by diffuse peritonitis. The modified prognostic score developed by adding an age factor to Boey score was found to be superior in prediction of morbidity and mortality after repair of PPU.

Introduction

Every year thousands of procedures are performed for complicated peptic ulcer disease (PUD) worldwide. Perforated peptic ulcers (PPU) are second to bleeding in frequency (about 1:6 ratio), they represent the most frequent indication for emergency surgery for PUD [1]. Over the past decades, there has been a clear global trend to reduce the number of patients with complicated PUD [2–6]. However, despite technical progress, improvements in pharmacology, anesthesiology and intensive care, reduction the incidence of PPU, the problem of perforated peptic ulcers, complicated by diffuse peritonitis, is still relevant.

This relevance is explained by the still high rates of complications (17–63%) [1, 7, 8] and mortality (10–40%) after surgical treatment of PPU [2, 9–11].

The difficulty in defining a uniform set of prognostic factors is likely attributed to the overall complexity of the disease and the number of factors involved. The attempts have been made repeatedly to analyze factors that affect the outcome of the disease, as well as to develop prognostic scores specific to PPU. To stratify patients with PPU in the high-risk group, it is customary to use different prognostic scores. In addition to specificity concerning the etiology of the disease, all scores can be divided into preoperative and intraoperative. Worldwide variation in demography, socioeconomic status, *Helicobacter pylori* prevalence, and prescription drugs make investigation into risk factors for PPU difficult to create a universal ('ideal') prognostic score [12].

Different scoring systems (Table 1) used for prediction of outcomes for PPU patients were identified. These systems can be divided into specific and non-specific scores for PPU patients [13].

Table 1
Scoring systems used for outcome prediction in perforated peptic ulcer

Scoring systems (year of report, reference)	Specific for PPU	Parameters evaluated
ASA (1941) [19]	-	Degree of comorbidity and present systemic disease
Boey (1987) [14]	+	Presentation $\geq$ 24 hours; presence of preoperative shock; level of comorbidity.
Mannheim peritonitis index (1987) [20]	-	Age, gender, organ failure, duration of peritonitis, site of perforation, diffuse peritonitis, level of exudate
PULP (2012) [15]	+	Presentation $\geq$ 24 hours; presence of preoperative shock; ASA score, presence of aids, active malignancy, liver failure; serum creatinine > 130 mmol/l
WSES SSS (2015) [23]	-	Severe sepsis (acute organ dysfunction) at the admission, septic shock, healthcare associated infection, colonic non-diverticular perforation peritonitis, small bowel perforation peritonitis, diverticular diffuse peritonitis, post-operative diffuse peritonitis, delayed initial intervention (> 24 h), age > 70. immunosuppression

Peptic ulcer perforation score (PULP). American society of anesthesiologists (ASA) score. WSES Sepsis Severity Score (WSES SSS).

Specific scoring systems for prediction of outcome in PPU patients are: the Boey score [14], the peptic ulcer perforation (PULP) score [15], the Hacettepe score [16], the Jabalpur score [17] and the POMPP (practical scoring system of mortality in patients with perforated peptic ulcer) score [18]. Scores that have a non-specific design for PPU patients are: the American Society of Anesthesiologists (ASA) score [19], the Mannheim Peritonitis Index (MPI) [20], the Acute Physiology and Chronic Health Evaluation II (APACHE II) [21], the Simplified Acute Physiology Score II (SAPS II) [22], the WSES Sepsis Severity Score [23], etc. [24, 25].

Currently, the ASA score and the Boey score are the most frequently used prognostic scoring systems in patients with PPU [12, 24–27].

The Boey score was the first score directly aimed at outcome prediction for perforated peptic ulcer, which seeks to predict mortality based on the presence of major medical illness ($ASA \geq III$), pre-operative shock, and perforation longer than 24 hours [14]. The Boey score simplicity makes it very quick to calculate which is an advantage.

However, the positive predictive value of 94% reported earlier has not been replicated in subsequent studies. In addition, this score does not take into account the age of the PPU patients. In the same time, age has been shown to be an isolated predictor for mortality in PPU patients [12]. It has been shown that the mortality rate in patients older than 65 years is significantly higher when compared to younger patients (37.7% vs 1.4%) [28] and can reach 47% after PPU repair in elderly patients [29–31].

Our aim was to evaluate the accuracy of different scoring systems in outcome prediction in patients following surgical treatment for PPU complicated by diffuse peritonitis and to determine the possibility of enhancing the Boey score prognostic performance based on the addition of an age factor.

Material And Methods

In total, 153 patients, who underwent emergency surgery for PPU in Pirogov Russian National Research Medical University's surgical clinics (Moscow City Hospitals № 1, № 4, № 29), between 2014 and 2016, were included in this retrospective study. All data about treatment were analyzed.

The inclusion criteria of this study were: patients with diffuse peritonitis from PPU, who underwent simple closure of PPU (with/without omental patch) via laparoscopic or open approach.

The criteria of exclusion were: cases with local peritonitis, patients who underwent pyloroplasty or resection surgery for PPU.

A total of six different scoring systems used to predict outcome in PPU patients were identified: the Boey score, the peptic ulcer perforation (PULP) score, the ASA score, the Mannheim Peritonitis Index (MPI), the World society of Emergency Surgery sepsis severity score (WSES SSS) and modified Boey score (mBoey).

To determine the threshold value of the age parameter, a comparative assessment of the mBoey score prognostic value was carried out using ROC analysis when age criteria of more than 50, 60, or 70 years were included in it. As a result, the best prognostic efficiency of the score was established when the category 'age over 50 years' was added (AUC = 0.932). After that, this scoring system, taking into account the age factor > 50 years, acquired values from 0 to 4 points. The score was defined as mBoey (modified Boey), Table 2.

Table 2
Variables for the mBoey score in perforated peptic ulcer

Parameters	The Boey score	The mBoey score
Major medical illness (ASA $\geq$ III)	+	+
Shock on admission	+	+
Time from perforation to surgery > 24 h	+	+
Age > 50 years	-	+
The modified Boey score (mBoey).		

Additionally, receiver-operating characteristic (ROC) curve analysis [32] were used to calculate risk predictions for morbidity and mortality in Boey, PULP, ASA and WSES SSS scoring systems and their predictability on morbidity and mortality was compared with the new score (mBoey). Furthermore, AUC (Area under curve), sensitivity, specificity, the positive and negative predictive value (PPV, NPV) of the new clinical prediction rule and other scores were determined. The optimal cut-off value of the score was calculated by means of the sensitivity + specificity (Se + Sp).

The obtained data were processed using a commercial Statistica 13.3 (StatSoft Inc., Tulsa, OK) and XLSTAT 2019 (Microsoft Excel) software packages for Windows. In this article, the results are presented as mean values and standard deviations (SD) for continuous normally distributed variables, as a median with lower and upper quartiles (Q_1 - Q_3) for continuous non-normally distributed data, and as counts and percentages for categorical data. Normality of data distribution was tested using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Student's t test for independent samples was applied to compare continuous variables. Nonparametric quantitative data was assessed using the Mann-Whitney U test. Categorical data and proportions were compared using the Chi-squared test or Fisher's exact test. Differences were considered statistically significant at $p < 0.05$.

Results

A total of 153 patients were included. Median age was 45 (31–64) years, where 71.2% (109/153) of the patients were males, and 13,1% (20/153) had at least one, and 28,8% (44/153) had two or more co-morbid diseases.

114 patients with PPU and diffuse peritonitis underwent laparoscopic repair (74,5%), 19 patients – open approach (12.4%), 20 patients underwent PPU repair after conversion (13.1%). Overall morbidity rate after emergency surgery was 27.5% (42/153), where 15,7% (24/153) had two or more postoperative complications. Median age of the patients with postoperative complications was 68.5 (61–83) years and without complications – 35 (28–49) years. The values of all prognostic scores were significantly higher in patients with postoperative complications ($p < 0.001$), Table 3.

Table 3
The values of prognostic scores in patients with and without postoperative complications

Prognostic scores	No complications (n = 111)	Complications (n = 42)	p
mBoey	0.4 (0.7)	2.4 (0.9)	< 0.0001
M (SD), Me (Q1-Q3)	0 (0–0)	2 (2–3)	
Boey	0.1 (0.4)	1.5 (0.8)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	0 (0–0)	1 (1–2)	
PULP	1.1 (1.9)	6.7 (3.0)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	1 (0–1)	7 (5–9)	
ASA	1.7 (0.8)	3.2 (0.7)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	2 (1–2)	3 (3–4)	
WSES SSS	3.4 (1.0)	7 (3.1)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	3 (3–3)	6 (5–8)	
MPI	17.3 (4.9)	28 (6.0)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	16 (16–20)	28 (26–33)	

The modified Boey score (mBoey). Peptic ulcer perforation score (PULP). American society of anesthesiologists (ASA) score. WSES Sepsis Severity Score (WSES SSS). Mannheim peritonitis index (MPI).

In-hospital mortality rate was 13.7% (21/153), median age of non-survivors was 73 (66–86) years and survivors – 39.5 (29–58,5) years. When comparing the group of survivors and non-survivors, a significant difference in the indicators across all prognostic scores was revealed ($p < 0.001$), Table 4.

Table 4
The values of prognostic scores in survivors and non-survivors

Prognostic scores	Survivors (n = 132)	Non-survivors (n = 21)	p
mBoey	0.6 (0.9)	2.9 (0.7)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	0 (0-1)	3 (2-3)	
Boey	0.3 (0.6)	1.9 (0.7)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	0 (0-0)	2 (1-2)	
PULP	1.8 (2.7)	8 (2.3)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	1 (0-1)	9 (7-9)	
ASA	1.9 (0.9)	3.4 (0.5)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	2 (1-2)	3 (3-4)	
WSES SSS	3.8 (1.5)	8.3 (3.2)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	3 (3-3)	8 (6-11)	
MPI	18.5 (5.7)	31.1 (4.3)	< 0.0001
M (SD), Me (Q ₁ -Q ₃)	16 (16-21)	32 (28-33)	

The modified Boey score (mBoey). Peptic ulcer perforation score (PULP). American society of anesthesiologists (ASA) score. WSES Sepsis Severity Score (WSES SSS). Mannheim peritonitis index (MPI).

All scores demonstrated the high quality of the model according to the AUC values, both in relation to mortality and postoperative complications - from good (WSES SSS) to perfect (mBoey, Boey, PULP, ASA).

Our results demonstrate that the PULP score can be used to accurately predict postoperative complications in patients operated for PPU and diffuse peritonitis, but the mBoey score performs better than the PULP score and the other prognostic system (Fig. 1).

The AUC, sensitivity, specificity, the accuracy, the PPV and the NPV of the analyzed scores are presented in Table 5. The obtained AUC values can be represented by the following sequence: mBoey > PULP > ASA, i.e., the most effective in predicting postoperative complications is the mBoey score (AUC = 0.932 (95% CI: 0.884-0.980), sensitivity + specificity = 1.773 and the accuracy = 88.9% with the cut-off value ≥ 2 points).

Table 5
Results from the internal validation of the six clinical prediction rules for postoperative complications

Models	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC (95% CI)	Accuracy (%)
mBoey	≥ 2	88.1	89.2	75.5	95.2	0.932 (0.884–0.980)	88.9
PULP	≥ 2	88.1	85.6	69.8	95	0.930 (0.885–0.974)	86.3
ASA	$\geq$ III	85.7	87.4	72	94.2	0.906 (0.861–0.952)	86.9
Boey	≥ 1	88.1	87.4	72.5	95.1	0.904 (0.846–0.962)	87.6
MPI	≥ 25	85.7	87.4	72	94.2	0.885 (0.809–0.961)	86.9
WSES SSS	≥ 5	78.6	84.7	66	91.3	0.851 (0.776–0.926)	83

The modified Boey score (mBoey). Peptic ulcer perforation score (PULP). American society of anesthesiologists (ASA) score. WSES Sepsis Severity Score (WSES SSS). Mannheim peritonitis index (MPI). AUC (area under the receiver operating characteristic curve). 95% CI (95% confidence interval). The positive and negative predictive value (PPV, NPV).

ROC - curves of prognostic scores for mortality after surgical treatment of PPU complicated by diffuse peritonitis are shown in Fig. 2. We found that the mBoey score predicted in-hospital mortality better than the other prognostic systems (AUC = 0.943 (95% CI: 0.909–0.978) and sensitivity + specificity = 1.788 and the accuracy = 81.7% with the cut-off value ≥ 2 points).

The PULP score showed the highest values of specificity (82.6%) and accuracy (84.3%) in relation to the mortality prediction, however, its sensitivity (95.2%) was lower than that of mBoey (100%), Boey (100%), and ASA (100%) (Table 6).

Table 6
Results from the internal validation of the six clinical prediction rules for mortality

Models	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC (95% CI)	Accuracy (%)
mBoey	≥ 2	100	78.8	42.9	100	0.943 (0.909–0.978)	81.7
Boey	≥ 1	100	77.3	41.2	100	0.941 (0.905–0.976)	80.4
MPI	≥ 25	100	78	24	100	0.940 (0.896–0.983)	81
PULP	≥ 5	95.2	82.6	46.5	99.1	0.937 (0.892–0.982)	84.3
ASA	$\geq$ III	100	78	42	100	0.902 (0.858–0.945)	81
WSES SSS	≥ 5	90.5	76.5	38	98.1	0.895 (0.811–0.979)	78.4

The modified Boey score (mBoey). Peptic ulcer perforation score (PULP). American society of anesthesiologists (ASA) score. WSES Sepsis Severity Score (WSES SSS). Mannheim peritonitis index (MPI). AUC (area under the receiver operating characteristic curve). 95% CI (95% confidence interval). The positive and negative predictive value (PPV, NPV).

Discussion

Early diagnosis and promptly surgical intervention in any urgent pathology of the abdominal cavity, including PPU, are the key to a favorable outcome of the disease, especially in diffuse peritonitis cases. With increasing age of patients, the duration of the perforation, as well as the presence of severe concomitant diseases, the morbidity and mortality rates increase [33]. The use of prognostic systems makes it possible to identify high-risk surgical patients with perforated peptic ulcer, but currently there is no 'ideal' score and, according to the literature, clinical prediction rules are not routinely used in PPU patients in everyday clinical practice [18].

The association of poor outcomes with increasing age, major medical illness, perioperative hypotension, and delay in diagnosis and management greater than 24 hours was previously shown [23]. All above listed factors are included in the Boey score except the age of the patients. That is why we tried to increase the prognostic performance of the Boey score by adding an absent age parameter.

In this retrospective study, which included 153 patients with PPU complicated by diffuse peritonitis, a comparative analysis of several prognostic scores was performed: Boey, PULP, ASA, WSES SSS, MIP and modified Boey score (mBoey). All prediction rules demonstrated high quality of the model, especially in predicting mortality. The mBoey score showed better predictive effectiveness, both for the morbidity and mortality.

The Boey score is the most commonly and easily implemented among different scoring systems, and accurately predicts perioperative morbidity and mortality preoperatively in PPU patients [33]. However, the positive predictive value of 94% reported earlier has not been replicated in subsequent studies [1]. This can be explained by the fact that the Boey score does not take into account the patient's age, also the Boey score may vary due to the definitions used, including the definition of shock with a systolic blood pressure < 90 mm Hg in the original study by Boey [12].

ASA is not specific scoring system for PPU patients and it is mainly based on the co-morbid diseases and their severity. Although co-morbidities are important risk factors for mortality, under diagnosed or unknown chronic diseases on emergency admission can result to underscoring of ASA. Hence, the main problem of the ASA score has been the inter-observer variability [18].

In our study, MPI showed higher specificity and accuracy for mortality than the Boey score, but adding an age parameter (mBoey) to the Boey prognostic system increased the specificity and accuracy of the score. This seems to us extremely important, because the many prognostic scores include laboratory tests, intraoperative risk factors assessment, which makes it difficult to calculate. The mBoey score is easy to calculate and it can perform preoperatively.

There are a small number of studies in the literature, where comparing AUC values from ROC analyses, several limitations have to be considered. First of all, different inclusion criteria and patient characteristics will potentially bias direct comparison of AUC values among studies. Hence, comparing ROC curve analysis and AUC values is best done on the same mix of patients. Secondly, the different sample size and the number of poor outcomes to the study population will influence the AUC accuracy and its precision [12].

Adding an age parameter to the original Boey score not only preserves the simplicity of calculating its value, additionally improves preoperative prognostic effectiveness compared to other predicting rules.

It should be noted, that the results of this study are based on the analysis of patients with PPU and diffuse peritonitis, which undoubtedly negatively affects the postoperative complications and mortality.

Of course, our study has several limitations. First of all, we had analyzed only patients with diffuse peritonitis, that may affect more older patients in trial. The second one is selective attitude to the choice of the analyzed type of surgical intervention (simple repair of PPU with/without omental patch).

In our study the median age of patients with PPU and diffuse peritonitis was 45 (31–64) years. The median age of the patients without complications was 35 (28–49) years. It means that 75% of patients

with no complications were younger than 49 years. Similar PPU patient groups are found in other developing countries, but the patient demography is quite different in non-developing countries, with older age and minor differences between genders [12]. A shift in demography of PPU is noted, with past studies having few patients (< 10%) older than 60 years, while current studies have a majority of patients > 60 years. Notably, the number of persons aged > 60 years is increasing rapidly in both developing and developed countries [34].

In our database, major medical illness, preoperative shock, and perforation longer than 24 h (the three parameters of the Boey score) are defined slightly different than what was originally proposed by J Boey et al. Major medical illness is defined as ASA $\geq$ III. By comparison, Boey et al. defined major medical illness as cardiorespiratory disease, renal failure, diabetes, or hepatic pre-coma. We define pre-operative shock as blood pressure below 100 mmHg and simultaneous heart rate above 100 beats per min, whereas J Boey et al. defined shock as blood pressure below 90 mmHg [12]. Perforation longer than 24 h is defined by us as > 24 h time from debut of symptoms (or aggravation of symptoms) to the time of emergency surgery (just like in J Boey's work).

Because the ASA score is based on the surgeon's subjective evaluation of the patient's disease severity and functional status, inter-observer variation may be an inherent problem [15].

Conclusions

The use of prognostic scores allows identifying the category of high-risk patients with perforated peptic ulcers complicated by diffuse peritonitis. The modified prognostic score developed by adding an age factor to Boey score was found to be superior in prediction of morbidity and mortality after repair of PPU.

Abbreviations

AUC: area under the receiver operating characteristic curve; ASA score–American society of anesthesiologists score; MPI–Mannheim peritonitis index; mBoey score–modified Boey score; PPU: perforated peptic ulcer; PULP score–peptic ulcer perforation score; WSES SSS–WSES Sepsis Severity Score; ROC–receiver-operating characteristic; 95% CI–95% confidence interval; PPV, NPV–the positive and negative predictive value; SD–standard deviations.

Declarations

Consent for publication:

Not applicable.

Competing interests:

The authors declare that they have no competing interests.

Declaration of funding

There is no sponsorship/funding, manuscript preparation.

Declaration of financial/other relationships

There are no relationships to be declared.

Availability of data and materials:

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate:

Given the retrospective nature of the study, a specific ethical review board approval was not required.

Author's Contributions:

S.A.V.: the design or conceptualization of the study. I.G.B.: study design, analysis and interpretation of the data. S.E.A.: data acquisition, analysis and interpretation, drafting or revising the manuscript for intellectual content. P.V.A.: manuscript preparation, drafting or revising the manuscript for intellectual content. T.S.M.: data analysis and interpretation, manuscript preparation. All authors participated in the study, read and approved the final manuscript and agree to be accountable for all aspects of the work.

Acknowledgements:

Not applicable.

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