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Enhancing mortality Probability Model II predictive accuracy with the lethal triad in intensive care unit trauma patients: A retrospective study

Ching-Ya Huang[a], Pao-Jen Kuo[b], Johnson Chia-Shen Yang[b], Wei-Ti Su[c,*], Ching-Hua Hsieh[b,*]

Abstract

Background: The Mortality Probability Model II (MPM II) is a well-recognized predictive tool in the intensive care unit (ICU) scoring system. The presence of a lethal triad, including hypothermia, acidosis, and coagulopathy, is associated with a worse outcome for trauma patients. This study aimed to assess whether integrating the lethal triad could enhance the MPM II predictive accuracy for trauma patients in the ICU.

Materials and Methods: The study conducted a retrospective analysis of adult trauma patients admitted to an ICU from January 1, 2016, to December 31, 2022, in a level I trauma center in Southern Taiwan. It assessed the impact of the lethal triad variables incorporated into MPM II scores using the area under the receiver operating characteristic curve.

Results: Of the 3410 patients included, 257 had the lethal triad, and 3153 did not. The mortality rate was significantly higher in patients presenting the lethal triad than those without (46.7% vs 8%, $P < 0.001$). However, there was no significant improvement in predictive accuracy with both the MPM II with and without incorporating the variable of lethal triad having an area under the receiver operating characteristic curve of 0.893.

Conclusions: Although the lethal triad is important for understanding trauma-induced physiological changes, straight inclusion into MPM II has no substantial prognostic value. These findings indicate that the existing variables in the MPM II may already be indirectly capturing the impacts of the lethal triad, emphasizing the intricate interplay of physiological components in trauma patients. This underscores the importance of continued study in improving the prognostic modeling to ultimately predicting outcomes for trauma patients.

Keywords: Intensive care unit (ICU); Lethal triad; Mortality; Mortality Probability Models II (MPM II); Trauma

1. Introduction

Patients in the intensive care unit (ICU) for trauma are often in critical condition with severe physiological changes, and their survival rates vary significantly. An effective prognostic scoring system for ICU outcomes can objectively reflect the progression of the disease and serve as a reference for monitoring the effectiveness of treatment, assisting in medical decision-making, and providing a standard for objective comparison between diseases and medical systems. This becomes a valuable tool for managing medical quality.

In most scoring systems, ICU scoring systems are calculated based on data collected on the first day in the ICU—for example, the Acute Physiology and Chronic Health Evaluation (APACHE II),[1] the Simplified Acute Physiology Score (SAPS II),[2] and the Mortality Prediction Model (MPM II).[3] However, predictions made solely based on data collected on the first day of ICU admission may be biased and fail to reflect changes in the patient's condition. For instance, a prospective study by Meyer et al.[4] showed that more than 40% of patients predicted to die by clinical judgment and APACHE II score actually survived. Therefore, many utilize repeated scoring methods or data collected during the first 3 days of ICU hospitalization for predictions—SAPS II,[2] Mortality Probability Model (MPM II) (including at admission, 24 hours, 48 hours, and 72 hours),[3] Sepsis-related Organ Failure Assessment,[5] Organ Dysfunction and Infection System,[6] Multiple Organs Dysfunction Score, the Logistic Organ Dysfunction System,[7] and Three Days Recalibrated ICU Outcome Score.[8]

The MPM II, initially proposed by Lemeshow et al.,[3] is designed for use with critically ill patients admitted to the ICU. The variables of the MPM II model include health status (medical or unscheduled surgical admission), past diseases (metastatic tumors, cirrhosis), acute diagnoses (infection, coma, intracranial mass effect), physiological variables (creatinine, urine output, PaO_2 levels), laboratory data (prothrombin time), and other factors such as mechanical ventilation and the use of vasopressor drugs. Four versions of MPM II have been introduced, predicting mortality at admission and at 24, 48, and 72 hours, respectively.[3,9] MPM0 can immediately evaluate

[a] Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan, [b] Department of Plastic Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan, [c] Department of Trauma Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan

* Corresponding author. Address: Department of Trauma Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan 83301. E-mail address: s101132@adm.cgmh.org.tw (W.-T. Su); Department of Plastic Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan 83301. E-mail address: m93chinghua@gmail.com (C.-H. Hsieh).

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the in-hospital mortality rate upon admission, with some researchers suggesting that taking the patient's parameters at the time of admission without treatment intervention would provide a more accurate judgment of the condition and prognosis. MPM II applies different weights to variables using logistic regression to calculate the probability of death.[3,9] It also has the lowest abstraction burden and is less susceptible to interobserver variability because it employs fewer physiological and laboratory data points.[10]

The MPM II has been extensively studied and proven effective in predicting outcomes in intensive care settings, including for trauma patients. Lemeshow et al.[3] validated MPM II internationally, highlighting its robust calibration and discrimination capabilities, making it suitable for quality assessment and benchmarking in ICUs. Castella et al.[11] found MPM II comparable to APACHE II in predicting hospital outcomes, supporting its practical value. Álvarez et al.[12] showed MPM II's superior predictive accuracy for head trauma patients over APACHE II and SAPS II. Saadat-Niaki and Abtahi[13] further confirmed MPM II's utility in diverse healthcare settings in Iran. Arabi et al.[14] suggested that customizing MPM II could improve its performance for specific conditions such as severe sepsis. Our previous comparison of the registration data of trauma patients in the ICU over 3 years studied these common prognostic indicators, revealing that the predictive performance of the MPM II was significantly better than the others.[15] Collectively, these studies underscore MPM II's relevance and effectiveness, justifying its broader adoption in trauma care and supporting the inclusion of additional prognostic factors to enhance its predictive accuracy.

The lethal triad includes the following conditions observed upon a patient's arrival at the emergency room: (1) metabolic acidosis (pH <7.2), (2) low body temperature (measured with an ear thermometer <35°C), and (3) coagulopathy (international normalized ratio [INR] >1.5).[16] The lethal triad observed in trauma patients has been proven to be a powerful indicator for predicting mortality.[17–19] As all three components of the lethal triad increase, the mortality rate within 24 hours for trauma patients also increases. In patients with multiple traumas, the lethal triad predicted a 96% mortality rate within 24 hours.[19] If a trauma patient exhibits all three parts of the lethal triad, the overall fatality rate may increase to 47.8%.[17] Patients with abdominal gunshot wounds and significant vascular injuries had a mortality rate of up to 40%, and those with the lethal triad accounting for 85% of deaths.[20] The lethal triad provides crucial information for risk stratification in the emergency treatment of trauma patients.

Although the lethal triad is a well-documented set of clinical signs that is significantly associated with the risk of mortality in trauma patients, this factor, indicative of severe trauma and physiological derangement, was not the ready variable imputed into the MPM II model. Thus, the study aims to investigate whether the incorporation of the lethal triad variable into the MPM II model can enhance the model's predictive accuracy.

2. Methods

2.1. Patient enrollment and study design

The procedure was performed according to the ethical standards of the Declaration of Helsinki and was granted authorization by the institutional review board of Chang Gung Memorial Hospital prior to the commencement of the research with the approval number 202301370B0. Patient consent was waived by the institutional review board as a result of the retrospective nature of this research. This study examined registered medical information from the registered trauma database from January 1, 2016, to December 31, 2022, in a level I trauma hospital in Southern Taiwan.[21–23] The study includes all patients 20 years or older admitted to the ICU due to trauma. Exclusion criteria include patients with burns, hangings, or drownings and those with incomplete registry data. The research method involves detailed recording of all retrieved cases' basic information (age, sex, medical history, injury in the body region and mechanism, clinical presentation and symptoms, blood tests at ICU admission, in-hospital mortality, Glasgow Coma Scale [GCS], and the Injury Severity Score [ISS]). We also collected if patient had the presence of all components of the lethal triad at the emergency department arrival, including (1) metabolic acidosis (pH <7.2), (2) low body temperature (body temperature measured with an ear thermometer <35°C), and (3) coagulopathy (INR >1.5) Then, the MPM II scores, including MPM II at admission and 24, 48, and 72 hours, are calculated. Their predictive performance is referenced by the area under the receiver operating characteristic curve (AUC of ROC). The primary goal of this study is to compare patients divided into two groups: one with all three of the lethal triad and one without, and to see if incorporating the lethal triad variables into the model of MPM II at admission improves the model's mortality predictive accuracy using AUC of ROC.

2.2. Statistical analysis

The statistical method involves using SPSS version 23 (IBM Corp, Armonk, New York), where the homogeneity of variances is first tested with the Levene test, followed by the use of analysis of variance to calculate the differences among continuous variables within categorical items. Based on the homogeneity or lack thereof in the data sample, the Scheffé or Games-Howell post hoc test is applied for adjustments. Univariate logistic regression analysis was used in the comparison between demographics among patients with or without lethal triad. The lethal triad would be used as one variable and incorporated into the MPM II model using logistic regression to predict the mortality of a person in the study population, and the AUCs of ROC were used to compare the MPM II models with and without the lethal triad at the emergency room to see if incorporating the lethal triad would improve predictive performance.

3. Results

3.1. Patient enrollment

Between 2016 and 2022, there were total of 26,605 patients enrolled in the Trauma Registry System; there were 24,193 adult trauma patients 20 years or older. Of these, 3540 were admitted to the ICU. The study excluded patients with burn injuries (112 patients), hanging injuries (11 patients), and drowning (one patient), as well as those lacking MPM II data (six patients), resulting in a final study population of 3410 patients. Within this cohort, 257 patients presented with the lethal triad, whereas 3153 did not. (Fig. 1)

3.2. Patient demographics

Table 1 presents analysis of factors associated with the lethal triad in patients. Males with the lethal triad were 1.65 times more likely to present with the lethal triad than females. Age did not significantly differ between groups (57.3 ± 19.1 vs 57.1 ± 19.7, P = 0.868). Notably, diabetes mellitus was significantly less prevalent in patients with the lethal triad, whereas other comorbidities such as coronary artery disease showed no significant difference. A significant contrast was observed in the GCS scores, with median scores being significantly lower in patients with the lethal triad, correlating with higher ISS. The mortality rate was significantly higher in patients presenting the lethal triad than those without (46.7% vs 8%, P < 0.001), underscoring the severity of their condition. However, the length of hospital stay did not significantly differ between groups (18.4 vs 16.8 days, P = 0.135).

3.3. Comparison of the predictive performance of MPM II with or without the presence of lethal triad

As shown in Fig. 2, the AUC for the ROC of MPM II and MPM II with a lethal triad presented no difference in the predicting a mortality outcome (both 0.893), indicating a high predictive accuracy for mortality with or without the inclusion of the lethal triad variables.

4. Discussion

The results indicate that the incorporation of the lethal triad does not significantly increase the predictive accuracy of the MPM II. This finding implies that the variables currently included in MPM II may already encapsulate the physiological disturbances highlighted by the lethal triad—namely, hypothermia, acidosis, and coagulopathy—either directly or indirectly through their associated clinical and laboratory parameters.

Trauma-induced coagulopathy, affecting 25%–35% of severely injured patients upon hospital admission, significantly impacts mortality rates. This condition's pathophysiology involves endothelial damage, impaired thrombin generation, hypofibrinogenemia, activation of fibrinolysis, and platelet dysfunction.[24,25] Patients typically require more blood transfusions and longer hospital stays. Common in severe injuries as reflected by high ISS, especially in head and abdominal traumas, and more prevalent in males, its early detection is crucial. Signs such as tachycardia or changes in the shock index necessitate immediate intervention, emphasizing the importance of vigilant monitoring and rapid response in the emergency room.[26] In MPM II factors, conditions such as metastatic cancer, which can cause thrombosis, and cirrhosis, which disrupts coagulation factor synthesis, significantly predispose patients to coagulopathy. Severe brain dysfunction, indicated by low GCS scores, also indirectly affects the body's hemostatic balance. Severe infections can trigger a dysregulated inflammatory response that leads to coagulation abnormalities, including disseminated intravascular coagulation. Additionally, prothrombin time directly reflects the status of coagulopathy.

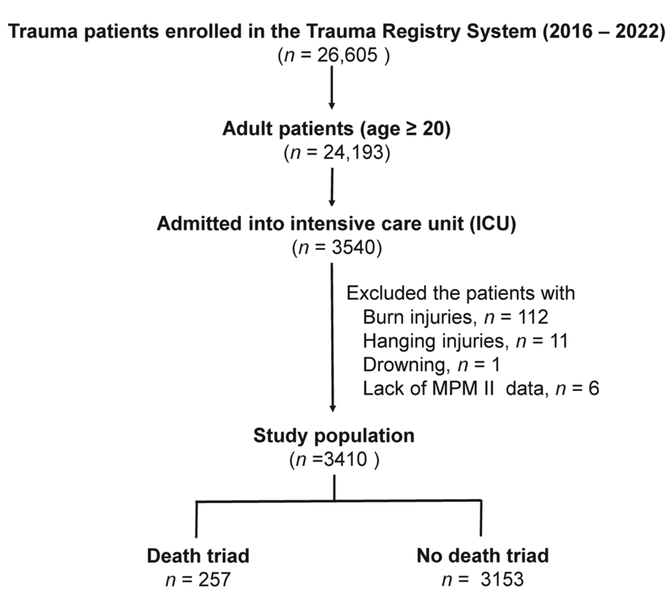

Figure 1. Enrollment of the adult trauma patients administered into the intensive care unit in this study.

Table 1

Patient Demographics in the Presence or Absence of Lethal Triad

Variables	Lethal triad Yes n = 257	Lethal triad No n = 3153	OR (95% CI)	P
Sex				0.001
Male, n (%)	191 (74.3)	2,010 (63.7)	1.65 (1.23–2.20)	
Female, n (%)	66 (25.7)	1,143 (36.3)	0.61 (0.46–0.81)	
Age, y (SD)	57.3 ± 19.1	57.1 ± 19.7	-	0.868
Comorbidities				
CAD, n (%)	21 (8.2)	273 (8.7)	0.94 (0.59–1.49)	0.789
CHF, n (%)	3 (1.2)	19 (0.6)	1.95 (0.57–6.63)	0.277
CVA, n (%)	7 (2.7)	168 (5.3)	0.50 (0.23–1.07)	0.069
DM, n (%)	39 (15.2)	681 (21.6)	0.65 (0.46–0.92)	0.015
ESRD, n (%)	12 (4.7)	100 (3.2)	1.50 (0.81–2.76)	0.195
HTN, n (%)	86 (33.5)	1,134 (36.0)	0.90 (0.68–1.17)	0.421
GCS, median (IQR)	6 (3–13)	15 (11–15)	-	<0.001
3–8, n (%)	163 (63.4)	578 (18.3)	7.73 (5.90–10.11)	<0.001
9–12, n (%)	29 (11.3)	336 (10.7)	1.07 (0.71–1.60)	0.754
13–15, n (%)	65 (25.3)	2,239 (71.0)	0.14 (0.10–0.19)	<0.001
ISS, median (IQR)	25 (20–33)	17 (16–25)	-	<0.001
1–15, n (%)	25 (9.7)	738 (23.4)	0.35 (0.23–0.54)	<0.001
16–24, n (%)	58 (22.6)	1,558 (49.4)	0.30 (0.22–0.40)	<0.001
≥25, n (%)	174 (67.7)	857 (27.2)	5.62 (4.28–7.38)	<0.001
Mortality, n (%)	120 (46.7)	253 (8.0)	10.0 (7.61–13.24)	<0.001
Hospital stay, d	18.4 ± 19.9	16.8 ± 15.9	-	0.135

CAD, coronary artery disease; CHF, congestive heart failure; CI, confidence interval; DM, diabetes mellitus; ESRD, end-stage renal disease; GCS, Glasgow Coma Scale; HTN, hypertension; IQR, interquartile range; ISS, Injury Severity Score; OR, odds ratio.

Hypothermia is often exacerbated by traumatic hemorrhage, leading to hypovolemic shock and worsening the lethal triad of hypothermia, coagulopathy, and acidosis, thereby deteriorating outcomes in trauma patients.[27–30]

Forristal et al.[27] highlight the importance of identifying predictors of hypothermia in the prehospital phase and the critical need for active warming practices by emergency medical services to mitigate mortality associated with hypothermia. This underscores the profound impact of hypothermia on physiological functions, particularly coagulation and acidosis. In the context of MPM II factors, hypothermia is indirectly addressed through its impact on bodily regulation, particularly influenced by severe brain dysfunction and trauma as indicated by low GCS scores and high ISS.[26] Also, hypoxia indicating by PaO_2 <60 mm Hg can lead to decreased metabolic activity and a subsequent drop in core body temperature, resulting in hypothermia.

Acidosis, stemming from organ failure and shock, was commonly seen in trauma patients. Corwin et al.[31] reported that 64.7% of trauma patients were acidotic upon presentation, correlating with a high mortality rate of 23.7%, particularly in those with a pH ≤7.2. Severe acidosis (pH ≤7.0) greatly increased mortality odds, with associated factors such as base deficit ≥–8, GCS ≤8, systolic blood pressure ≤90 mm Hg, INR >1.6, and ISS >15.[32] Lv et al.[33] found that acidosis significantly impaired thromboelastography variables, suggesting that maintaining a pH above 7.2 is crucial in trauma care to mitigate coagulation issues and reduce mortality. This indicates the critical impact of acidosis on the lethal triad, exacerbating patient outcomes in trauma settings.[34] In MPM II factors, reduced urine output and elevated creatinine levels indicate renal impairment and may be a result of inadequate intravascular volume from trauma bleeding, leading to the electrolyte balance further contributing to acidosis. Also, infection in trauma patients contributes to acidosis through mechanisms such as lactic acidosis, ketoacidosis,

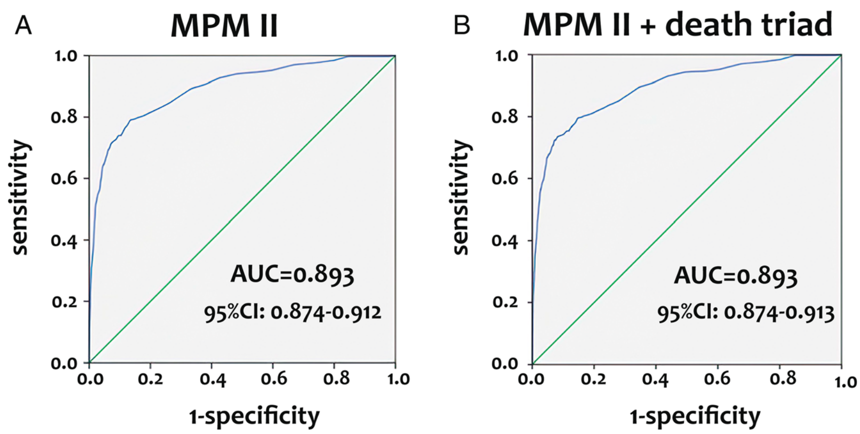

Figure 2. Comparison of the predictive performance of MPM II with or without the presence of lethal triad. MPM II, Mortality Probability Model II.

and renal dysfunction, whereas acidosis can also predispose patients to infectious complications by impairing immune function and pathogen growth.

Collectively, these MPM II factors provide a multifaceted view of the patient's risk profile and evaluate a comprehensive set of variables that, directly and indirectly, reflect the concepts of lethal triad. This finding also opens avenues for further research into the development and refinement of prognostic models in trauma care. It suggests that although the inclusion of specific variables such as the lethal triad is intuitive, the real challenge lies in understanding and modeling the dynamic and multifaceted nature of physiological deterioration following severe injury. Future studies might focus on exploring new variables or combinations of variables that can add predictive value to existing models or on developing advanced modeling techniques that can capture the complex relationships between different predictors of mortality. Moreover, the result prompts a reevaluation of how we understand and utilize prognostic models in clinical practice. It highlights the need for models that are not only accurate in their predictions but also actionable, providing insights that can guide interventions and improve patient outcomes.

In conclusion, although adding the lethal triad to MPM II did not improve its predictive performance, this study adds to our understanding of predicting outcomes in trauma. It highlights the complexities of forecasting outcomes in critically damaged individuals, as well as the importance of continued research to refine and enhance prognostic models. The goal remains to create tools that are both predictive and practical, allowing physicians to make educated decisions that improve patient care.

5. Conclusion

The analysis of the incorporation of the lethal triad variables—hypothermia, acidosis, and coagulopathy—into the MPM II has demonstrated that although these variables are integral to understanding the physiological derangements in severely injured patients, their addition to the MPM II does not significantly enhance the model's predictive accuracy. This finding suggests that the variables currently within MPM II may already encapsulate, to some extent, the effects and underlying mechanisms represented by the lethal triad.

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Data availability statement

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

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Conflicts of interest statement

Ching-Hua Hsieh, a section editor at *Formosan Journal of Surgery*, had no role in the peer review process of or decision to publish this article. The other authors declare that they have no competing interests.

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