Serum lactate and the mortality of critically ill patients in the emergency department: A retrospective study

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Abstract. Serum lactate levels have been widely studied as a prognostic marker in critically ill patients, particularly those in the intensive care unit. However, it remains unknown whether the serum lactate levels affect the mortality rate of critically ill patients admitted to hospital. To investigate this hypothesis, the vital signs and blood gas analysis data of 1,393 critically ill patients who visited the Emergency Department of Affiliated Kunshan Hospital of Jiangsu University (Kunshan, China) between January and December 2021 were collected. Patients were divided into two groups, 30-day survival group and a 30-day death group, and logistic regression analysis was used to investigate the association between vital signs, laboratory results and mortality rates of critically ill patients. A total of 1,393 critically ill patients was enrolled in the present study, with a male-to-female ratio of 1.17:1.00, a mean age of 67.72±19.29 years and a mortality rate of 11.6%. The multivariate logistic regression analysis revealed that increased serum lactate levels were an independent risk factor for mortality rate of critically ill patients [Odds ratio (OR)=1.50, 95% confidence interval (95% CI): 1.40-1.62]. The critical cut-off value for the serum lactate levels was identified as 2.35 mmol/l. In addition, OR values of age, heart rate, systolic blood pressure, transcutaneous oxygen saturation (SpO_2) and hemoglobin were 1.02, 1.01, 0.99, 0.96 and 0.99, respectively (95% CI: 1.01-1.04, 1.00-1.02, 0.98-0.99, 0.94-0.98 and 0.98-1.00, respectively). The logistic regression model was found to be of value in terms of identifying the mortality rate of patients and the area under the receiver operating characteristic curve was 0.894 (95% CI: 0.863-0.925; P<0.001). In conclusion, the present study showed that high serum lactate levels in critically ill patients upon admission to hospital are associated with higher 30-day mortality rate.

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Introduction

Critically ill patients are those who have unstable vital signs, rapid disease progression, instability or failure of more than two organ systems and a high risk of mortality due to their condition (1). The emergency department serves a crucial role during the process of diagnosing and treating certain critically ill patients. The physiological parameters and laboratory blood gas analysis results measured at the time of first admission to the emergency department may serve as auxiliary parameters for physicians to determine whether hospitalization is necessary and their likely risk of mortality (2). Among these parameters, serum lactate is a product of the metabolic reaction in cases of acute disease, and it is easily measured in the laboratory (3-6). Serum lactate measurements have been shown to be strongly associated with prognosis of sepsis, gastrointestinal bleeding, pulmonary embolism and other disease (7-9).

Previous studies have used lactate levels to stratify risk in patients with sepsis (7,10,11). Lactate levels <2 mmol/l are considered low and lactate >4 mmol/l is considered high; high levels of serum lactate are considered to be an independent predictor of mortality (12). However, to the best of our knowledge, whether serum lactate levels can be used as a predictor of mortality rate in critically ill patients admitted to emergency departments remains unknown (12,13). In addition, the role of other physiological and laboratory parameters in predicting patient mortality remains unclear.

The aim of the present study was to identify parameters and their cutoff values that were independently associated with mortality in critically ill patients who presented to the Emergency Department in the Affiliated Kunshan Hospital of Jiangsu University (Kunshan, China). Furthermore, a prediction model was constructed to assess the mortality of patients to aid diagnosis and treatment.

Patients and methods

Study design and setting. This was a single center, retrospective cohort study. Cases attending the Emergency Department of Affiliated Kunshan Hospital of Jiangsu University between

January and December 2021 were collected. Cases under the age of 16 years and those transferred to the hospital after admission or discharged against medical advice were excluded. Finally, a total of 1,393 cases was included in the present study. These critically ill patients were divided into 30-day survival (n=1,231) and a 30-day death group (n=162).

Demographic parameters (age and sex), patient classification (disease type), vital signs [systolic blood pressure (SBP), diastolic blood pressure (DBP), heart and respiratory rate, temperature and transcutaneous oxygen saturation (SpO_2)] and laboratory results [serum lactate levels, white blood cell (WBC) count, hemoglobin levels, platelet count, prothrombin time, creatinine and total bilirubin levels and base excess (BE)] of cases were analyzed. Blood samples (0.5-1.0 ml) were collected for blood gas analysis within 30 min of arrival at the emergency department. The laboratory results were measured using an ABL90FLEX blood gas analyzer (Radiometer Medical).

The present study was approved by the Ethics Review Committee of The Affiliated Kunshan Hospital of Jiangsu University (grant no. 2021-03-015-H01). The requirement for consent to participate was waived due to the retrospective nature of the study.

Statistical analysis. IBM SPSS version 26 software was used for statistical analysis (IBM Corp.). Descriptive statistical parameters (mean, standard deviation, median, minimum, maximum and frequency) were used to evaluate data. First, whether the quantitative data conformed to the normal distribution was tested using quantile-quantile and probability-probability plots and the Shapiro-Wilk test. An unpaired Student's t-test was used to compare the quantitative variables with normal distribution between survival group and death group. The Mann-Whitney U test was used to compare the quantitative variables without normal distribution. Pearson's χ^2 test was used to compare qualitative data between the two groups. Binary logistic regression analysis was used to construct the prognosis model. Sensitivity, specificity and the area under receiver operating characteristic (AUROC) curve analysis were used to determine the diagnostic critical value for the parameters. P<0.05 was considered to indicate a statistically significant difference.

Results

Demographics and outcomes. A total of 1,393 cases was included in the present study, of which 63.1% (n=879) were male and 36.9% (n=514) were female. The ages of the cases were between 16 and 104 years and the mean age was 67.72±19.29 years. Patients were primarily diagnosed with the following seven categories of disease: Respiratory (38.3%), cardiovascular (17.1%), nervous system (13.2%), digestive system (10.8%) and endocrine system (7.8%), poisoning (4.5%) and urinary system diseases (4.0%); a residual population (4.1%) were classified as 'other diseases'. Serum lactate measurements ranged between 0.20 and 26.00 mmol/l, with a mean value of 2.64±3.15 mmol/l. Blood glucose measurements ranged between 0.90 and 73.30 mmol/l, with a mean value of 11.13±7.80 mmol/l. Vital signs and laboratory results of the cases are shown in Table I. Of total cases, 1,042 hospitalizations (74.8%) and 162 deaths (11.6%) were observed. The number of days of hospitalization was 0-90, with a mean value of 9.55±9.15 days (Table I).

Association between serum lactate levels and clinical outcomes in critically ill patients. Among the demographic parameters, ages of the cases in the mortality group were significantly higher compared with the survival group (P=0.003), whereas the mortality rates did not differ significantly between males and females (P=0.936; Table II). Among the vital signs, heart rate (P=0.001), SBP (P<0.001), DBP (P<0.001) and SpO_2 (P<0.001) in the mortality group were significantly higher compared with those in the survival group, although no significant differences were observed with respiratory rate (P=0.492) or temperature (P=0.443; Table II). Among the laboratory results, the serum lactate (P<0.001), BE (P<0.001) and hemoglobin levels (P<0.001), platelet (P=0.049) and WBC count (P<0.001), creatinine levels (P<0.001) and prothrombin time (P<0.001) in the mortality group were significantly higher compared with those in the survival group, whereas glucose and total bilirubin measurements were not found to be associated with mortality (P=0.085; Table II).

Risk factors for mortality of critically ill patients. The univariate logistic regression showed that age, heart and respiratory rate, SBP, DBP, SpO_2, serum lactate and BE levels, WBC count, creatinine, hemoglobin and total bilirubin levels and prothrombin time were risk factors for mortality of critically ill patients (all P<0.05; Table III). The multivariate logistic regression analysis showed that age (OR=1.02; P=0.003), heart rate (OR=1.01; P=0.012), SBP (OR=0.99; P<0.001), SpO_2 (OR=0.96; P<0.001) and serum lactate (OR=1.50, P<0.001) and hemoglobin levels (OR=0.99; P=0.004) were significantly associated with the mortality of critically ill patients, whereas DBP, BE, creatinine, prothrombin time and WBC and platelet count were not associated with mortality (Table III). The prediction model was constructed as follows:

$$logit(p)=0.021*age + 0.010*\text{heart rate} + (-0.013)*systolic\ blood\ pressure + (-0.041)*SpO_2 + 0.407*serum\ lactate + (-0.012)*hemoglobin + 0.869$$

The prediction model was found to be of good value with respect to identifying the mortality rate of patients [sensitivity=44.4% (72/162) and specificity=98.5% (1,213/1,231)]. AUROC curve was 0.894 [95% confidence interval (95% CI): 0.863-0.925; P<0.001; Fig. 1]. The estimated probability was 0.095; values >0.095 were classified as a case of poor prognosis.

AUROC value of the model of serum lactic acid levels and predicted mortality was 0.891 (95% CI: 0.864-0.919; P<0.001; Fig. 2). The sensitivity and specificity values were 87.7 and 75.8%, respectively. The cut-off value obtained for the serum lactate levels was identified as ≥2.35 mmol/l. The OR values of the other parameters were close to 1 and their AUROC values were too small to accurately predict the mortality of patients.

Discussion

The present study identified the vital signs and laboratory parameters associated with mortality in patients admitted to the emergency department and constructed a predictive

Table I. Descriptive characteristics and distribution of demographic parameters, vital signs and laboratory results.

Characteristic	Median (range)	Mean ± SD or number (%)	Mortality rate, n (%)
Age, years	73 (16-104)	67.72±19.29	
Sex			
Male		879 (63.1)	102 (11.6)
Female		514 (36.9)	60 (11.7)
Disease			
Respiratory		533 (38.3)	50 (9.4)
Urinary system		56 (4.0)	6 (10.7)
Endocrine system		109 (7.8)	2 (1.8)
Nervous system		184 (13.2)	37 (20.1)
Digestive system		152 (10.8)	15 (9.9)
Cardiovascular		240 (17.1)	30 (12.5)
Poisoning		62 (4.5)	5 (8.1)
Other		57 (4.1)	17 (29.8)
Total mortality rate			162 (11.6)
SBP, mmHg	140.0 (43.0-265.0)	141.28±32.44	
DBP, mmHg	83.0 (23.0-167.0)	83.02±20.63	
Temperature, ˚C	37.0 (33.6-40.5)	37.21±0.88	
Heart rate, bpm	99.0 (10.0-212.0)	100.15±25.27	
Respiratory rate, breaths/min	22.0 (0-49.0)	23.40±5.59	
pH	7.4 (6.8-7. 7)	7.36±0.13	
SpO_2, %	95.0 (39.0-100.0)	90.97±10.23	
Serum lactate, mmol/l	1.6 (0.2-26.0)	2.64±3.15	
Prothrombin time, sec	11.9 (1.2-104.2)	12.76±4.64	
Hemoglobin, g/l	133.0 (34.0-225.0)	131.42±27.78	
Platelet count, $x10^9$/l	196.0 (6.0-725.0)	203.16±86.30	
WBC count, $x10^9$/l	9.8 (0.58-151.9)	11.16±7.33	
Creatinine, mg/dl	80 (21-1465)	117.80±144.14	
Total bilirubin, mg/dl	14.7 (2.4-172.2)	19.62±16.88	
BE, mmol/l	-0.4 (-29.5-27.0)	-1.21±8.17	
Glucose, mmol/l	8.6 (0.9-73.3)	11.13±7.80	
Hospitalization length, days	9 (0-90)	9.55±9.15	

SBP, systolic blood pressure; DBP, diastolic blood pressure; SpO_2, transcutaneous oxygen saturation; WBC, white blood cell; BE, base excess.

model for patient mortality. There were significant differences between the mortality and survival group with respect to the age, heart rate, SBP, DBP, SpO_2, serum lactate, BE, hemoglobulin, platelet and WBC count, creatinine and prothrombin time. However, in the multivariate model, only age, heart rate, SBP, SpO_2, serum lactate and hemoglobin were significantly associated with the mortality of patients. Among these, serum lactate was the most useful independent predictor, with a critical cut-off value of 2.35 mmol/l.

For patients in the intensive care unit (ICU), elevated lactate levels provide an indicator of critical clinical condition, and are a marker of poor prognosis (14). Respiratory or circulatory failure in critically ill patients due to shock and other reasons leads to a lack of oxygen in tissues and organs (15-17). Therefore, when oxygenation is poor, cells utilize glucose through anerobic glycolysis, resulting in an increase in the serum lactate levels, leading to hyperlactemia (16). Several studies have investigated the association between serum lactate and a variety of diseases, such as sepsis, cardiac arrest, hypoxia or heart failure, in hospitalized patients and identified serum lactate as an independent predictor of mortality (15,18-25). Liu *et al* (26) included 3,713 patients with sepsis from the MIMIC III database and found that lactate was an independent predictor of sepsis prognosis and its AUROC (0.664; 95% CI: 0.639-0.689) was significantly higher compared with the AUROC of the quick Sequential Organization Failure Assessment (0.547; 95% CI: 0.521-0.574) recommended by the Third International Consumption Definitions for Sepsis and Sepsis Shock (Sepsis-3) (27). Nichol *et al* (28) evaluated the lactic acid levels at the admission of 7,155 patients in the ICU of four Australian university hospitals and found that a higher time-weighted lactic acid concentration was independently associated with an increase in in-hospital mortality (OR=3.7, 95% CI: 1.9-7.00; P<0.0001). Another study of a German population showed that lactate, pH and BE were all predictors of mortality for patients in the ICU, although

Table II. Vital signs and laboratory tests at admission to hospital.

	Survival group (n=1,231)	Mortality group (n=162)	
Characteristic	Mean ± SD or n (%)	Mean ± SD or n (%)	P-value
Age, years	67.21±19.42	71.52±17.90	0.003
Sex			0.936
Male	777 (88.40)	102 (11.60)	
Female	454 (88.33)	60 (11.67)	
Temperature, ˚C	37.22±0.92	37.19±1.03	0.443
Heart rate, bpm	99.47±23.87	105.34±33.75	0.001
Respiratory rate, breaths/min	23.60±4.99	21.86±8.76	0.492
SBP, mmHg	144.16±30.24	119.38±39.57	<0.001
DBP, mmHg	84.57±19.46	71.26±25.12	<0.001
pH	7.38±0.11	7.26±0.19	<0.001
SpO_2, %	91.94±9.25	83.59±13.76	<0.001
Serum lactate, mmol/l	1.99±1.88	7.56±5.59	<0.001
<2.35	933 (97.9)	20 (2.1)	0.001
≥2.35	298 (67.7)	142 (32.3)	
BE, mmol/l	-0.31±7.64	-8.05±8.83	<0.001
Glucose, mmol/l	11.09±7.88	11.50±7.15	0.067
Hemoglobin, g/l	132.69±27.03	121.77±31.37	<0.001
Platelet count, $x10^9$/l	204.68±84.28	191.57±99.90	0.049
WBC count, $x10^9$/l	10.80±6.14	13.83±13.01	<0.001
Creatinine, mg/dl	112.46±138.51	158.38±176.61	<0.001
Prothrombin time, sec	12.42±4.35	15.36±5.83	<0.001
Total bilirubin, mg/dl	19.26±16.61	22.33±18.60	0.085

SBP, systolic blood pressure; DBP, diastolic blood pressure; SpO_2, transcutaneous oxygen saturation; WBC, white blood cell; BE, base excess.

Table III. Association between serum lactate levels and mortality of critically ill patients using logistic regression analysis.

	Univariate			Multivariate		
Characteristic	β-value	P-value	OR (95% CI)	β-value	P-value	OR (95% CI)
Sex	0.007	0.969	1.01 (0.72-1.41)			
Age	0.013	0.008	1.01 (1.00-1.02)	0.021	0.003	1.02 (1.01-1.04)
Temperature	-0.036	0.688	0.96 (0.81-1.15)			
Heart rate	0.009	0.005	1.01 (1.00-1.02)	0.010	0.012	1.01 (1.00-1.02)
Respiratory rate	-0.060	<0.001	0.94 (0.91-0.97)			
SBP	-0.026	<0.001	0.97 (0.97-0.98)	-0.013	<0.001	0.99 (0.98-0.99)
DBP	-0.035	<0.001	0.97 (0.96-0.97)			
SpO_2	-0.60	<0.001	0.94 (0.93-0.95)	-0.041	<0.001	0.96 (0.94-0.98)
Serum lactate	0.456	<0.001	1.58 (1.48-1.69)	0.407	<0.001	1.50 (1.40-1.62)
BE	-0.103	<0.001	0.90 (0.89-0.92)			
WBC count	0.044	<0.001	1.05 (1.02-1.07)			
Platelet count	-0.002	0.069	1.00 (1.00-1.00)			
Glucose	0.006	0.529	1.01 (0.99-1.03)			
Creatinine	0.001	<0.001	1.00 (1.00-1.00)			
Hemoglobin	-0.014	<0.001	0.99 (0.98-0.99)	-0.012	0.004	0.99 (0.98-1.00)
Total bilirubin	0.009	0.033	1.01 (1.00-1.02)			
Prothrombin time	0.113	<0.001	1.12 (1.08-1.16)			

SBP, systolic blood pressure; DBP, diastolic blood pressure; SpO_2, transcutaneous oxygen saturation; WBC, white blood cell; BE, base excess.

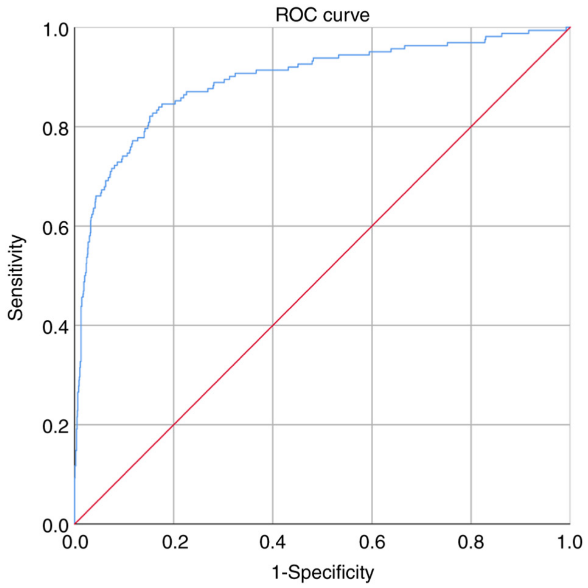

Figure 1. Performance of the logistics model of predicting the mortality of critically ill patients. ROC, receiver operating characteristic.

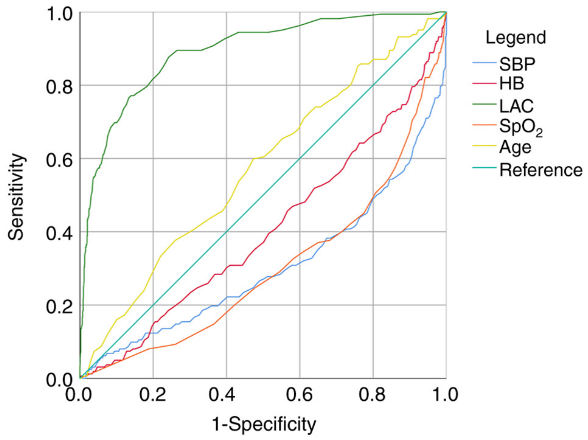

Figure 2. Receiver operating characteristic curve for predicting the mortality of critically ill patients. HB, hemoglobin; LAC, serum lactate; SBP, systolic blood pressure; SpO_2, transcutaneous oxygen saturation.

lactate was the best predictor [AUROC, 0.74; cut-off value, 2.7 mmol/l; hazard ratio (HR), 3.20] (29). Here, serum lactate levels of patients admitted to the emergency department with non-traumatic conditions were significantly associated with mortality. Therefore, collectively, these results suggested that higher serum lactate levels may be associated with increased risk of mortality in the population, regardless of whether patients are infected or not.

In the present study, AUROC curve exhibited a cut-off value of 2.35 mmol/l for the serum lactate prediction of mortality in non-traumatic disease. Aduen *et al* (30) found that lactate concentration >4 mmol/l has 96% specificity in terms of predicting mortality in non-hypotensive patients. Nichol *et al* (28) found that when the weighted lactate concentration is >0.75 mmol/l, the lactate concentration was significantly associated with an increase in the in-hospital mortality rate of patients. The cut-off value of serum lactate may be 2.7 or 3.6 mmol/l (2,29). Different studies may report different cut-off values for mortality in critically ill patients for several reasons, including heterogeneity of patient populations, variability in study designs and diversity of statistical analysis methods. In addition to serum lactate, other parameters may also predict the mortality of critically ill patients in the emergency department. Univariate analysis has shown that age is a key factor in the prognosis of patients: Seker *et al* (2) investigated 1,382 patients in the emergency department of a hospital in Turkey, and found that the mortality of patients >65 years of age is significantly higher compared with that of patients <65 years old. Chebl *et al* (12) also demonstrated that age is an independent risk factor for mortality.

The present study showed that heart rate was an independent risk factor for mortality. Ley *et al* (31) investigated the admission heart rate of 103,799 patients with trauma in Los Angeles (USA); mortality rate (2.0%) of patients with moderate and severe injury with a heart rate of 80-89 was lower compared with that of all other heart rate ranges, whereas the mortality rate of patients with a heart rate <60 or ≥100 was significantly higher. To the best of our knowledge, however, at present, studies on the cut-off value of heart rate, together with randomized controlled trials based on heart rate, are lacking. The present study revealed that higher SBP was a predictive factor for mortality. Kristensen *et al* (32) suggested that the SBP threshold for predicting mortality is 100-110 mmHg. However, the mean SBP of patients in the present mortality group was 119.38±39.57 mmHg. Meanwhile, it was difficult to determine the cut-off value of SBP at time of admission due to its poor performance in predicting mortality.

The present study had certain limitations. This was a single-center, retrospective study and there was a large difference between patient numbers in the mortality and survival groups, which could have interfered with the predictive performance of logistic regression model.

In conclusion, the present study demonstrated that serum lactate serves as an independent predictor of mortality in critically ill patients. The logistic regression model composed of age, heart rate, SBP, SpO2 and serum lactate and hemoglobin levels may be effective in predicting the mortality of patients.

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Availability of data and materials

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

Authors' contributions

XM, JL and QZ collected and analyzed the data. XM and JW confirm the authenticity of all the raw data. XM and JW designed the study. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Ethics Review Committee of The Affiliated Kunshan Hospital of Jiangsu University (No. 2021-03-015-H01). The requirement for patient consent was waived as the present study was a retrospective study.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. Kayambankadzanja RK, Schell CO, Wärnberg MG, Tamras T, Mollazadegan H, Holmberg M, Alvesson HM and Baker T: Towards definitions of critical illness and critical care using concept analysis. BMJ Open 12: e060972, 2022.
2. Seker YC, Bozan O, Sam E, Topacoglu H and Kalkan A: The role of the serum lactate level at the first admission to the emergency department in predicting mortality. Am J Emerg Med 45: 495-500, 2021.
3. del Portal DA, Shofer F, Mikkelsen ME, Dorsey PJ Jr, Gaieski DF, Goyal M, Synnestvedt M, Weiner MG and Pines JM: Emergency department lactate is associated with mortality in older adults admitted with and without infections. Acad Emerg Med 17: 260-268, 2010.
4. Kruse O, Grunnet N and Barfod C: Blood lactate as a predictor for in-hospital mortality in patients admitted acutely to hospital: A systematic review. Scand J Trauma Resusc Emerg Med 19: 74, 2011.
5. Baxter J, Cranfield KR, Clark G, Harris T, Bloom B and Gray AJ: Do lactate levels in the emergency department predict outcome in adult trauma patients? A systematic review. J Trauma Acute Care Surg 81: 555-566, 2016.
6. Kraut JA and Madias NE: Disorders of fluids and electrolytes lactic acidosis. New Engl J Med 371: 2309-2319, 2014.
7. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, Sevransky JE, Sprung CL, Douglas IS, Jaeschke R, *et al*: Surviving sepsis campaign: International guidelines for management of severe sepsis and septic shock: 2012. Crit Care Med 41: 580-637, 2013.
8. Vanni S, Viviani G, Baioni M, Pepe G, Nazerian P, Socci F, Bartolucci M, Bartolini M, and Grifoni S: Prognostic value of plasma lactate levels among patients with acute pulmonary embolism: The thrombo-embolism lactate outcome study. Ann Emerg Med 61: 330-338, 2013.
9. Contenti J, Occelli C, Lemoel F, Ferrari P and Levraut J: Blood lactate measurement within the emergency department: A two-year retrospective analysis. Am J Emerg Med 37: 401-406, 2019.
10. Spahn DR, Bouillon B, Cerny V, Duranteau J, Filipescu D, Hunt BJ, Komadina R, Maegele M, Nardi G, Riddez L, *et al*: The European guideline on management of major bleeding and coagulopathy following trauma: Fifth edition. Crit Care 23: 98, 2019.
11. Rossaint R, Bouillon B, Cerny V, Coats TJ, Duranteau J, Fernández-Mondéjar E, Filipescu D, Hunt BJ, Komadina R, Nardi G, *et al*: The European guideline on management of major bleeding and coagulopathy following trauma: Fourth edition. Crit Care 20: 100, 2016.
12. Chebl RB, El Khuri C, Shami A, Rajha E, Faris N, Bachir R and Dagher GA: Serum lactate is an independent predictor of hospital mortality in critically ill patients in the emergency department: A retrospective study. Scand J Trauma Resusc Emerg Med 25: 69, 2017.
13. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, Peterson E and Tomlanovich M: Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med 345: 1368-1377, 2001.
14. Trzeciak S, Dellinger RP, Chansky ME, Arnold RC, Schorr C, Milcarek B, Hollenberg SM and Parrillo JE: Serum lactate as a predictor of mortality in patients with infection. Intensive Care Med 33: 970-977, 2007.
15. Espinosa K and Brown SR: Serum lactate testing to predict mortality in patients with sepsis. Am Fam Physician 103: 309-310, 2021.
16. Haas SA, Lange T, Saugel B, Petzoldt M, Fuhrmann V, Metschke M and Kluge S: Severe hyperlactatemia, lactate clearance and mortality in unselected critically ill patients. Intensive Care Med 42: 202-210, 2016.
17. James JH, Luchette FA, McCarter FD and Fischer JE: Lactate is an unreliable indicator of tissue hypoxia in injury or sepsis. Lancet 354: 505-508, 1999.
18. Hu W, Yuan L, Wang X, Zang B, Zhang Y, Yan X, Zhao W and Chao Y: Predictive value of arterial blood lactic acid concentration on the risk of in-hospital all-cause death in patients with acute heart failure. Int J Clin Pract 2022: 7644535, 2022.
19. Kang MK, Oh SY, Lee H and Ryu HG: Pre and postoperative lactate levels and lactate clearance in predicting in-hospital mortality after surgery for gastrointestinal perforation. BMC Surg 22: 93, 2022.
20. Chaudhry S, Haroon F, Waheed KA, Victor G, Shahzad M and Fatima B: Blood lactate levels and lactate clearance as predictors of mortality in neonatal sepsis. J Ayub Med Coll Abbottabad 34: 438-441, 2022.
21. Doganay F, Ak R and Yilmaz E: Predictive performance of lactate as a mortality predictor in patients with acute pancreatitis. J Coll Physicians Surg Pak 32: 440-444, 2022.
22. Morris KP, Kapetanstrataki M, Wilkins B, Slater AJ, Ward V and Parslow RC: Lactate, base excess, and the pediatric index of mortality: Exploratory study of an international, multicenter dataset. Pediatr Crit Care Med 23: e268-e276, 2022.
23. Erdogan M and Findikli HA: Prognostic value of the lactate/albumin ratio for predicting mortality in patients with pneumosepsis in intensive care units. Medicine (Baltimore) 101: e28748, 2022.
24. Wright SW, Hantrakun V, Rudd KE, Lau CY, Lie KC, Van Vinh NC, Teparrukkul P, West TE and Limmathurotsakul D: Enhanced bedside mortality prediction combining point-of-care lactate and the quick sequential organ failure assessment (qSOFA) score in patients hospitalised with suspected infection in Southeast Asia: A cohort study. Lancet Glob Health 10: e1281-e1288, 2022.
25. Suo S, Luo L, Song Y, Huang H, Chen X and Liu C: Early diagnosis and prediction of death risk in patients with sepsis by combined detection of serum PCT, BNP, Lactic Acid, and Apache II Score. Contrast Media Mol Imaging 2022: 8522842, 2022.
26. Liu Z, Meng Z, Li Y, Zhao J, Wu S, Gou S and Wu H: Prognostic accuracy of the serum lactate level, the SOFA score and the qSOFA score for mortality among adults with Sepsis. Scand J Trauma Resusc Emerg Med 27: 51, 2019.
27. Seymour CW, Liu VX, Iwashyna TJ, Brunkhorst FM, Rea TD, Scherag A, Rubenfeld G, Kahn JM, Shankar-Hari M, Singer M, *et al*: Assessment of clinical criteria for sepsis: For the third international consensus definitions for sepsis and septic shock (Sepsis-3). JAMA 315: 762-774, 2016.
28. Nichol AD, Egi M, Pettila V, Bellomo R, French C, Hart G, Davies A, Stachowski E, Reade MC, Bailey M and Cooper DG: Relative hyperlactatemia and hospital mortality in critically ill patients: A retrospective multi-centre study. Crit Care 14: R25, 2010.
29. Schork A, Moll K, Haap M, Riessen R and Wagner R: Course of lactate, pH and base excess for prediction of mortality in medical intensive care patients. PLoS One 16: e0261564, 2021.
30. Aduen J, Bernstein WK, Khastgir T, Miller J, Kerzner R, Bhatiani A, Lustgarten J, Bassin AS, Davison L and Chernow B: The use and clinical importance of a substrate-specific electrode for rapid-determination of blood lactate concentrations. JAMA 272: 1678-1685, 1994.
31. Ley EJ, Singer MB, Clond MA, Ley HC, Mirocha J, Bukur M, Margulies DR and Salim A: Admission heart rate is a predictor of mortality. J Trauma Acute Care 72: 943-947, 2012.
32. Kristensen AKB, Holler JG, Mikkelsen S, Hallas J and Lassen A: Systolic blood pressure and short-term mortality in the emergency department and prehospital setting: A hospital-based cohort study. Crit Care 19: 158, 2015.