Background Many variables measured in critically ill patients have been used to predict patient outcomes; however, it is unlikely that one measurement can replace all, but lactate levels may come close.

Aim This study aims to evaluate the role of blood lactate level as a predictor of patients’ outcome at Respiratory Intensive Care Unit at Zagazig University Hospitals (RICU-ZUH).

Patients and methods A prospective cohort study was conducted on 52 patients recruited from RICU-ZUH. All patients’ functional conditions were assessed on admission by the Simplified Acute Physiology Score II scoring system, Glasgow Coma Scale (GCS), and Sequential Organ Failure Assessment scores as well as assessment of sepsis. The blood lactic acid level was measured at H0 (initial blood lactate level), H6, H12, H24, and H48 (in mmol/l). Patients were classified into two groups: (i) normal blood lactate level group, and (ii) hyperlactatemia group. Lactate clearance and lactime were also measured.

Results Out of the 52 cases studied, hyperlactatemia was present in 22 (42.4%) patients, whereas a normal blood lactate level was found in 30 (57.6%) patients. H0 was significantly high (P<0.01) in the hyperlactatemia group (4.41 ±1.69 mmol/l), with lactime 42.4±10.5 h; also, lactate clearance at H6 was nonsignificantly high (P>0.05). The Simplified Acute Physiology Score II and Sequential Organ Failure Assessment scores were significantly positively correlated with H0 and lactime, but significantly negatively correlated with lactate clearance, whereas GCS was negatively correlated in a significant way with H0 and lactime and positively correlated with lactate clearance. The significant highest mortality risk of 2.86 was reported with lactime more than 48 h, followed by a 2.28 risk of mortality with H0 blood lactate level more than 3.9 mmol/l, and the least risk was reported with GCS less than 10.5.

Conclusion Hyperlactatemia at admission and a prolonged lactime are valuable independent predictors of mortality of RICU patients.

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Keywords: hyperlactatemia, lactate clearance, lactic acid, lactime

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Introduction

Many variables measured in critically ill patients have been used to predict patient outcomes; however, it is unlikely that one measurement can replace all, but lactate levels may come close [1]. It is frequently measured in critically ill patients to detect tissue hypoxia [2]. Furthermore, microcirculatory processes hampering oxygen utilization at the tissue level may also increase lactate level [2,3]. The correlation between lactate levels in arterial and venous blood was found to be acceptable [4]. Should we routinely monitor lactate in the critically ill? And if so, when should we measure it? What would be the best predictors of patient outcome? Accordingly, the research question was, would monitoring of blood lactate predict patients’ outcome in the respiratory intensive care unit (RICU)? We hypothesize that blood lactate level, clearance, and lactime predict patients’ outcome in the RICU.

The aim of this work was to assess the role of blood lactate level as a predictor of patients’ outcome at Respiratory Intensive Care Unit at Zagazig University Hospitals (RICU-ZUH).

Objectives

(1) To identify blood lactate level at patients’ admission.
(2) To monitor lactime and lactate clearance through RICU stay.
(3) To relate previous lactate measures to patients’ outcome to determine best predictors of mortality.

Patients and methods

This was a prospective cohort study and was conducted at the RICU of the Chest Department of Zagazig University Hospitals during the period from October 2014 to May 2015 after being approved by the Zagazig University Institutional Review Board.

Study population

Fifty-two patients (selected sample) were enrolled in the study from cases that were admitted to the RICU.
They included 33 male and 19 female patients, with an age range of 23–76 years and a mean±SD of 52.4±14.6 years.

**Inclusion criteria**
Patients aged 18 years or more, who had primary respiratory diseases with or without respiratory failure were included in the study.

**Exclusion criteria**
Patients with known chronic organ failure – for example, liver cell failure, renal failure, heart failure, pregnancy, recent trauma, diabetic ketoacidosis, and patients on chemotherapy and/or radiotherapy were excluded.

Informed consent was obtained either from the patients or their relatives. All patients were subjected to the following:

1. **Initial diagnosis** which was based on the following: medical history, clinical examination (general and local chest examination), radiological chest assessment [plain radiograph posteroanterior view and chest computed tomography when needed], and laboratory assessment (complete blood count (CBC), random blood sugar (RBS), kidney function test (KFT), liver function test (LFT), and arterial blood gases).
2. **Assessment of patients’ functional condition at admission** by calculating the following scores:
   - The Simplified Acute Physiology Score II (SAPS II) scoring system for assessing severity of the disease [5].
   - The Glasgow Coma Scale (GCS) for assessing the neurological condition of the patients [6].
   - The Sequential Organ Failure Assessment (SOFA) score for assessing organ failure [7].
3. **Assessment for the presence of sepsis:** sepsis is suspected infection in the presence of two or more systemic inflammatory response syndrome criteria [8,9]:
   - Body temperature less than 36°C or more than 38°C.
   - Heart rate more than 90 beats/min.
   - Tachypnea with more than 20 breaths/min or PaCO₂ less than 32 mmHg.
   - White blood cell count less than 4000 cells/mm³ or more than 12 000 cells/mm³, or the presence of more than 10% immature neutrophils (band forms). Band forms more than 3% is called bandemia or a ‘left-shift’.
4. **Plan of treatment:** conventional treatment according to the diagnosis of each patient with the guidelines in RICU-ZUH.
5. **Measurement of lactic acid blood level:**
   - **Type of sample:** arterial sample.
   - **Time of sampling:** lactic acid was measured on RICU admission (H₀, initial blood lactate level), 6 h later (H₆), 12 h later (H₁₂), 24 h later (H₂₄), and 48 h later (H₄₈) (in mmol/l) using the arterial blood gases analysis device (Epoc BGEM Blood Test; Epocal Inc. 2060 Walkley Road Ottawa, ON K1G 3P5 Canada).
   - According to H₀, the patients were classified as follows:
     - Normal blood lactate group (lactic acid blood level <2 mmol/l).
     - Hyperlactatemia group (lactic acid blood level >2 mmol) [10].
   - ‘Lactime’ was measured and defined as the time during which blood lactate was more than 2.0 mmol/l [10].
   - Lactate clearance at 6 h was measured using blood lactate level at RICU admission (H₀) and blood lactate level at H₆ according to the following equation: [(lactate initial (H₀)−lactate delayed (H₆))/lactate initial (H₀)]×100% [11].
6. **End point of the study:** patient death (nonsurvivors) or discharge home or to inpatient ward where continuation of conventional treatment was carried out.
7. **Outcome assessment:** survival or death (nonsurvivors).

**Statistical analysis**
The data were tabulated and statistically analyzed. Data were collected and analyzed using Microsoft Excel software (Microsoft Excel 2016 16.0.6741.2048 free download http://microsoft_excel.en.downloadastro.com/). Data were then imported into statistical package for the social sciences (SPSS, version 20.0; SPSS Inc., Chicago, Illinois, USA) software for analysis. According to the type of data, the following tests were used to test differences in significance; differences between frequencies (qualitative variables) and percentages in groups were compared by the χ²-test. Differences between means (quantitative variables) in parametric multiple groups were compared by the analysis of variance test, in parametric two groups by the t-test and in nonparametric variables by the Mann–Whitney test. Receiver operating characteristic curves were used for the assessment of sensitivity and specificity and cutoff, and logistic regression for independent predictors. P value was set at less than 0.05 for significant results, at less than 0.001 for highly significant results, and at less than 0.05 for nonsignificant results.
Results

The study included 52 patients, of whom 63.5% were male and 36.5% female, with a mean age of 52.4±14.6 years (Table 1). The median (range) of SAPS II score was 25 (8–120) and SOFA score was 7 (3–20), whereas GCS had a mean of 10.5±0.98. Sepsis was present only in 11 (21.2%) patients and no patients developed severe sepsis or septic shock (Table 2). The most common disease was chronic obstructive pulmonary disease (COPD) in 15 (28.8%) patients, whereas other diagnoses varied: overlap syndrome (COPD and obstructive sleep apnea (OSA)) in two (3.8%) patients, bronchial asthma in five (9.6%) patients, pneumonia in 12 (23.1%) patients, pulmonary embolism in six (11.5%) patients, pneumotheorax in two (3.8%) patients, interstitial lung diseases in seven (13.5%) patients, acute respiratory distress syndrome (ARDS) in three (5.8%) patients. The normal lactate blood level group included 22 (42.4%) patients and all survived (100%), whereas the hyperlactatemia group included 30 (57.6%) patients out of whom 18 (60%) survived and 12 (40%) did not survive, with a very high statistically significant difference (P<0.001). Initial blood lactate levels (H0) revealed 30 (57.6%) patients with hyperlactatemia and 22 (42.4%) patients with a normal blood lactate level (Table 3). There was significant difference between groups regarding initial blood lactate levels (H0), where it was 4.41±1.69 mmol/l in the hyperlactatemia group, whereas 1.81±0.09 mmol/l in the normal lactate group. Lactime, measured only in the hyperlactatemia group, was 42.4±10.5/h. Lactate clearance at H6 was 4.41±1.69 mmol/l in the hyperlactatemia group, whereas 18 patients [18/30 (60%)] survived. SAPS II [median (range)] was 25 (8–120). SOFA [median (range)] was 7 (3–20). GCS (mean±SD) was 10.5±0.98. Urine output (mean±SD) (ml/24 h) was 516.3±158.03. ABG, arterial blood gas; GCS, Glasgow Coma Scale; RR, heart rate; RR, respiratory rate; SAPS II, Simplified Acute Physiology Score II; SOFA, Sequential Organ Failure Assessment; WBCs, white blood cells count.

| Table 1 Characteristics of the studied patients |
|-----------------------------------------------|
| Patients’ criteria (n=52)                      |
| Sex [N (%)]                                    |
| Male                                          | 33 (63.5) |
| Female                                        | 19 (36.5) |
| Age (mean±SD) (years)                         | 52.4±14.6 |
| ABGs                                          |
| pH (mean±SD)                                  | 7.4±1.4  |
| PaO2 (mean±SD)                                | 56.9±5.4 |
| PaCO2 [median (range)]                        | 27.5 (12–102) |
| HCO3 [median (range)]                         | 20.0 (11.0–46.0) |
| SAPS II [median (range)]                      | 25 (8–120) |
| SOFA [median (range)]                         | 7 (3–20)  |
| GCS (mean±SD)                                 | 10.5±0.98 |
| WBCs (mean±SD)                                | 16.1±3.8 |
| Temperature (°C) (mean±SD)                    | 38±2.1   |
| RR (breaths/min) (mean±SD)                    | 30.9±2.9 |
| Systolic blood pressure (mean±SD) (mmHg)      | 99.8±19.8 |
| Diastolic blood pressure (mean±SD) (mmHg)     | 60.4±12.03 |
| HR (mean±SD) (beats/min)                      | 124.6±11.1 |
| Urine output (mean±SD) (ml/24 h)              | 516.3±158.03 |

Table 2 Characteristics of the studied patients with regard to critical illness, presence of sepsis, and diagnosis

| Patients’ criteria (n=52)                      |
|-----------------------------------------------|
| Sepsis                                        |
| Sepsis                                        | 11 (21.2) |
| No                                           | 41 (78.8) |
| Diagnosis                                     |
| COPD                                          | 15 (28.8) |
| Bronchial asthma                              | 5 (9.6)   |
| Pneumonia                                     | 12 (23.1) |
| Pulmonary embolism                            | 6 (11.55) |
| Pneumothorax                                  | 2 (3.8)   |
| Interstitial lung diseases                    | 7 (13.5)  |
| Overlap syndrome (COPD+OSA)                   | 2 (3.8)   |
| ARDS                                         | 3 (5.8)   |

| Table 3 Survival, initial lactate levels (H0), lactime, and lactate clearance at H6 in the hyperlactatemia group in comparison with the normal lactate group |
|---------------------------------------------------------------------------------|
| Normal lactate (n=22) | Hyper lactatemia (n=30) | χ² (t/MW) | P      |
| Survived (n=40) [N (%)] | 22 (100.0) | 18 (60) | 11.4 | <0.001** |
| Nonsurvived (n=12) [N (%)] | 0 (0.0) | 12 (40) | – | – |
| Initial lactate (H0) (mean±SD) (mmol/l) | 1.81±0.09 | 4.41±1.69 | 6.53 | <0.01** |
| Lactime (h) | 0.0 | 42.4±10.5 | – | – |
| Lactate clearance H6 [median (range)] (%) | 14.08 | 16.6 | Z=0.41 | >0.05 |

Z, Mann–Whitney (MW) test. **Highly significant.
and lactate clearance (cutoff value <13.6) were significantly valid for the detection of mortality (Table 5).

The most sensitive variables were the SOFA score, GCS, lactime, and lactate clearance at H6 (91.7%) and the most specific variables were the initial lactate level (H0) (95%) and SAPS II (92.5%); also, Table 6 showed the superiority of lactate over studied scores in mortality prediction such as area under the curve (AUC), which was 0.93 for initial lactate (H0) against 0.85 for SOFA, 0.91 for SAPS II, and 0.44 for GCS. The significant (P<0.05) highest mortality risk (odds ratio=2.869) was reported with lactime cutoff value more than 48, followed by the risk of mortality with initial blood lactate level (H0) cutoff value more than 3.9 mm/l (odds ratio=2.28), and the least risk reported was with GCS cutoff value less than 10.5 (odds ratio=0.109). Accordingly, the best independent predictors of mortality in RICU-ZUH were initial lactate level (H0) more than 3.9, lactime more than 48 h, and GCS less than 10.5.

**Discussion**

To understand the importance of an increased lactate level, it is important not only to consider anaerobic production, but also aerobic mechanisms and changes in lactate clearance. Despite this complex evaluation, increased lactate levels usually reflect increased morbidity and high mortality [1]. Physicians need accurate and very early indications concerning the prognosis, and both initial blood lactate levels and early lactate clearance were appropriate tools [12]. In trauma patients, alcohol or drug use, which are frequently encountered conditions, do not modify the predictive accuracy of initial blood lactate levels [13]. Blood lactate level can be measured using various devices (central laboratory, point-of-care blood gas analyzers, hand-held devices), and generally most devices used at the bed side have acceptable limits of agreement.
compared with laboratory devices [14,15]. In addition, the sampling site of the blood (arterial, venous, capillary, etc.) also does not seem to affect the results much [16,17]. The current study revealed that the initial blood lactate level (H0) was highly significantly (P<0.01) elevated in the hyperlactatemia group, which concurs with the study of Régnier et al. [12] and van Beest et al. [18], who worked on a heterogeneous ICU population including cases with respiratory failure as well as Zhang et al. [19] who used initial lactate (H0) with normalization time (lactate clearance) to assess the predictive value of lactate in unselected critically ill patients. In contrast, the lactime in the hyperlactatemia group (P>0.05) as well as lactate clearance at H6 were nonsignificant. The current study selected H6 based on the study of Nguyen et al. [20] and van Beest et al. [18] who found that normalization of lactate less than 6 h (lactate clearance at H6) after ICU admission revealed better survival compared with normalization of lactate at greater than 6 h; moreover, Zhang et al. [19] stated that most studies defined lactate clearance as the relative reduction in serum lactate levels within 6 h. Also, the study of Marty et al. [11] showed that there is a significant difference between the H0 lactate value and H6, H12, or H24 lactate values in the survivor group. No significant difference was found in the nonsurvivor group between H6, H12, and H24 lactate values compared with H0. Hyperlactatemia in the current study was reported to be associated significantly with increased severity of disease as assessed by SAPS II, and was highly significantly positively correlated with H0 and significantly positively correlated with lactate time, but highly significantly negatively correlated with lactate clearance as well as SOFA scores, where it was highly significantly positively correlated with H0 and significantly positively correlated with lactate time, but highly significantly negatively correlated with lactate clearance, whereas GCS was negatively correlated with H0 and lactate time and positively correlated with lactate clearance; these findings concurred those of Zhang et al. [19] about the predictive value of lactate in critically ill patients, where nonsurvivors had higher SAPS II SOFA scores than survivors, and there was a significant correlation between H0 and lactime with the SOFA score and the SAPS II score, whereas Yolbaş et al. [21] showed that there is a considerably significance difference between lactate level and GCS in a study about the relationship between different lactate levels and mortality rate. The current study reported 100% survival rate in the normal lactate group, whereas it was 60% in the hyperlactatemia group, and this is nearly matched with the results of van Beest et al. [18] where hospital mortality of their population was 18% and was higher in patients with hyperlactatemia during ICU stay compared with those without hyperlactatemia. Also, in the Pasha et al.’s [22] study there were 25% nonsurvivors out of 125 patients, and was higher in patients with hyperlactatemia during ICU stay when compared with those without hyperlactatemia. The current study determined that the most sensitive variables as predictors of mortality were the SOFA score, GCS, lactime, and lactate clearance at H6 (91.7%) and the most specific variables were the initial lactate level (H0) (95%) and SAPS II (92.5%); also, the superiority of lactate over studied scores in mortality prediction such as AUC was 0.93 for initial lactate (H0) against 0.85 for SOFA, 0.91 for SAPS II, and 0.44 for GCS. This is matched with the results of Bakker et al. [10] where among patients with septic shock, the lactime was the best predictor of outcome in a multiple regression analysis. Similarly, in trauma patients, lactate normalization within 24 h was associated with 100% survival [2]. Further data showed that a decrease in lactate of at least 10% during the first 6 h of septic shock was associated with an improved outcome, and an 11% decrease in mortality was observed with each 10% increase in lactate clearance [20]. Badreddin et al. [23] compared the predictive value of lactate with complex physiological scores in a cohort of cardiothoracic surgery patients, where they found that the diagnostic performance of lactate was significantly superior to these scores, as reflected by an AUC of 0.88 for lactate against 0.83, 0.79, and 0.76 for SOFA, SAPS II, and APACHE II, respectively, which are in accordance with the current study. The current study reported that by multivariate logistic regression analysis, significant independent predictors of mortality were initial lactate (H0) more than 3.9 mmol/l with odds ratio 2.28, lactime (>48 h) with odds ratio 2.86, and GCS (<10.5) with odds ratio 0.109. In agreement with the current study, Maarslet et al. [24] found that an increased initial lactate (H0) more than 4.5 mmol/l resulted in an odds ratio of 8.4 (95% confidence interval: 1.5–46.1) for mortality and this is also confirmed in the study of Hajjar et al. [25] in which the lactate level measured at 6 h after ICU admission was also found to be an independent predictor of complications after major cardiothoracic surgery, whereas the study of Régnier et al. [12] showed that the best cutoffs for initial blood lactate (H0) level was 4.7 mm/l (95% confidence interval: 3.4–5.6). Although the normalization time used for predicting mortality commonly ranged from 6 to 72 h, Marty et al. [11], Puskarich et al. [26], and Zhang et al. [19] showed that a normalization time (lactate clearance) within 100 h was positively associated with the hazard. This difference between cutoffs values in different studies can be
explained by the differences in sample size, excluded patients, and the specialty of the study. Our study showed that lactate clearance did not have the same value as H0 and lactime in predicting outcome. In contrast, Nguyen et al. [20] reported that lactate clearance was an independent predictor of mortality. According to a recent study on patients with hyperlactatemia in ICU admission, lactate-guided therapy significantly reduced hospital fatal outcomes, which suggests that initial lactate monitoring has much clinical benefit [27]. In conclusion, initial blood lactate levels and lactime are valuable prognostic tools for the prediction of RICU outcomes.

We can recommend the measurement of blood lactate level on RICU admission, and monitoring lactime and lactate clearance during ICU stay for (a) prediction of outcome and (b) application of lactate-guided therapy.

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Conflicts of interest There is no conflict of interest.

References

1. Bakker J, Nijsten MW, Jansen TC. Clinical use of lactate monitoring in critically ill patients. Ann Intensive Care 2013; 3:12.
2. Ronco JJ, Fenwick JC, Tweeddale MG, Wiggs BR, Phang PT, Cooper DJ, et al. Identification of the critical oxygen delivery for anaerobic metabolism in critically ill septic and nonseptic humans. JAMA 1993; 270:1724–1730.
3. Levy B, Gibot S, Franck P, Cravoisy A, Bollaert PE. Relation between muscle Na+K+ ATPase activity and raised lactate concentrations in septic shock: a prospective study. Lancet 2005; 365:671–675.
4. Kruse O, Grunnet N, Barford 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 2011; 19:74.
5. Le Gall JR, Lemeshow S, Saulnier F. A new Simplified Acute Physiology Score (SAPS II) based on a European/North American multicenter study. JAMA 1993; 270:2957–2963.
6. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet 1974; 2:81–84.
7. Vincent JL, de Mendonça A, Cantraine F, Moreno R, Takala J, Suter PM, et al. Use of the SOFA score to assess the incidence of organ dysfunction/failure in intensive care units: results of a multicenter, prospective study. Working group on ‘sepsis-related problems’ of the European Society of Intensive Care Medicine. Crit Care Med 1998; 26:1793–1800.
8. Levy MM, Fink MP, Marshall JC, Abraham E, Angus D, Cook D, et al. 2001 SCCM/ESICM/ACP/ATS/ScS International Sepsis Definitions Conference. Intensive Care Med 2003; 29:530–538.
9. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, et al. Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock. Crit Care Med 2013; 41:580–637.
10. Bakker J, Gris P, Coffeemis M, Kahn RJ, Vincent JL. Serial blood lactate levels can predict the development of multiple organ failure following septic shock. Am J Surg 1996; 171:221–226.
11. Marty PH, Roquilly A, Vallerie F, Luzi A, Ferré F, Fourcade O, et al. Lactate clearance for death prediction in severe sepsis or septic shock patients during the first 24 h in intensive care unit: an observational study. Ann Intensive Care 2013; 3:3.
12. Régnier MA, Raux M, Le Manach Y, Asencio Y, Gaillard J, Devilliers C, et al. Prognostic significance of blood lactate and lactate clearance in trauma patients. Anesthesiology 2012; 117:1276–1288.
13. Dunne JR, Tracy JK, Scales TM, Napolitano LM. Lactate and base deficit in trauma: does alcohol or drug use impair their predictive accuracy? J Trauma 2005; 58:959–966.
14. Aduen J, Bernstein WK, Khastgir T, Miller J, Kerzner R, Bhatiani A, et al. The use and clinical importance of a substrate-specific electrode for rapid determination of blood lactate concentrations. JAMA 1994; 272:1678–1685.
15. Brinkert W, Rommes JH, Bakker J. Lactate measurements in critically ill patients with a hand-held analyser. Intensive Care Med 1999; 25:966–969.
16. Weil MH, Michaels S, Rackow EC. Comparison of blood lactate concentrations in central venous, pulmonary artery, and arterial blood. Crit Care Med 1987; 15:489–490.
17. Fauchere JC, Bauschatz AS, Arlettaz R, Zimmermann-Bar U, Bucher HU. Agreement between capillary and arterial lactate in the newborn. Acta Paediatr 2002; 91:78–81.
18. Van Beest PA, Lukas B, Sebastianan PA, Johannes HR, Michaeli AK, Peter ES. Cumulative lactate and hospital mortality in ICU patients. Ann Intensive Care 2013; 3:6.
19. Zhang Z, Chen K, Ni H, Fan H. Predictive value of lactate in unselected critically ill patients: an analysis using fractional polynomials. J Thorac Dis 2014; 6:995–1003.
20. Nguyen HB, Rivers EP, Knoblich BP, Jacobsen G, Muzzin A, Ressler JA. Early lactate clearance is associated with improved outcome in severe sepsis and septic shock. Crit Care Med 2004; 32:1637–1642.
21. Yolbaş I, şen V, Bojnack M, Kellekı S, Yel S, Gümüş A. The relationship between blood lactate levels and mortality in pediatric intensive care patients. J Clin Exp Invest 2013; 4:289–292.
22. Pasha A, Rao N, Prabodh S, Sripad DV, Chowdary NVS. Relationship between serum lactate levels and fatal outcome in critically ill patients: a prospective study in intensive care unit. Int J Sci Stud 2015; 2:51–63.
23. Badreddin AM, Doerr F, Elsobky S, Brehm BR, Abul-Dahab M, Lehmann T, et al. Mortality prediction after cardiac surgery: blood lactate is dispensible. Thorac Cardiovasc Surg 2013; 61:708–717.
24. Maarslet L, Moller MB, Dal R, Hjortholm K, Ravn H. Lactate levels predict mortality and need for peritoneal dialysis in children undergoing congenital heart surgery. Acta Anaesthesiol Scand 2012; 56:459–464.
25. Hajjar LA, Almeida JP, Fukushima JT, Rhodes A, Vincent JL, Osawa EA, et al. High lactate levels are predictors of major complications after cardiac surgery. J Thorac Cardiovasc Surg 2013; 146:455–460.
26. Puskarich MA, Trzeciak S, Shapiro NI, Albers AB, Hefner AC, Kline JA, et al. Whole blood lactate kinetics in patients undergoing quantitative resuscitation for severe sepsis and septic shock. Chest 2013; 143:1548–1553.
27. Jansen TC, van Bommel J, Schoonheberbeek FJ, Sleeuwssijk Visser SJ, van der Klooster JM, Lima AP, et al. Early lactate-guided therapy in intensive care unit patients: a multicenter, open-label, randomized controlled trial. Am J Respir Crit Care Med 2010; 182:752–761.