RESEARCH ARTICLE

Association between lactate/albumin ratio and all-cause mortality in patients with acute respiratory failure: A retrospective analysis

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Abstract

Previous studies have shown that lactate/albumin ratio (LAR) can be used as a prognostic biomarker to independently predict the mortality of sepsis and severe heart failure. However, the role of LAR as an independent prognostic factor in all-cause mortality in patients with acute respiratory failure (ARF) remains to be clarified. Therefore, we retrospectively analyzed 2170 patients with ARF in Medical Information Mart for Intensive Care Database III from 2001 to 2012. By drawing the receiver operating characteristic curve, LAR shows a better predictive value in predicting the 30-day mortality of ARF patients (AUC: 0.646), which is higher than that of albumin (AUC: 0.631) or lactate (AUC: 0.616) alone, and even higher than SOFA score (AUC: 0.642). COX regression analysis and Kaplan-Meier curve objectively and intuitively show that high LAR is a risk factor for patients with ARF, which is positively correlated with all-cause mortality. As an easy-to-obtain and objective biomarker, LAR deserves further verification by multi-center prospective studies.

1. Introduction

More than 50% of critically ill patients in the intensive care unit (ICU) will suffer from acute respiratory failure (ARF) due to respiratory diseases or pulmonary vascular diseases, accompanied by pulmonary ventilation and/or ventilation dysfunction [1–3]. ARF can cause metabolic disorders and accelerate the deterioration of the underlying condition, which is related to a mortality rate of 35%-46% [4]. Therefore, effective assessment of the prognosis of patients with ARF is of great significance for clinically formulating treatment strategies and improving the survival rate of patients [5].

Due to severe tissue hypoxia in patients with ARF, pyruvic acid cannot be oxidized and is reduced to lactate [6–8]. Therefore, lactate increases in the early stages of ARF. Lactate reflects the imbalance between the supply and demand of oxygen in the organs [9, 10], so the continuous increase in the level of lactate is not only related to hypoxia. ARF causes acute organ hypoxia and vascular endothelial cell damage, which easily induces inflammation [11]. Serum albumin is a negatively regulated acute inflammatory response protein [12]. Previous studies have shown that lactate/albumin ratio (LAR) can be used as a better prognostic biomarker and
can independently predict the mortality of critically ill patients, such as sepsis [13, 14] and severe heart failure [15].

The role of LAR as an independent prognostic factor in predicting all-cause mortality in patients with ARF remains to be clarified. Therefore, this study is aimed to explore the prognostic value of LAR in predicting the outcome of patients with ARF.

2. Materials and methods

2.1 Data resource and study population

Medical Information Mart for Intensive Care Database III (MIMIC-III) [16] provides all clinical data of about 50000 unidentified patients at the Beth Israel Deaconess Medical Center (Boston, USA) from 2001 to 2012 for the study, including admission and discharge information, vital signs, laboratory parameters, etc. Author Lu gained access to the database and was responsible for data extraction and analysis (certification number: 35953547).

All patients with ARF over 16 years old, who had ICU admission information, were included in the study. Patients with ARF were identified by ICD-9 code and extracted from the MIMIC-III database. The detailed ICD-9 codes were "51851" and "51881". The exclusion criteria included: ① patients without lactate and serum albumin data within 24 hours after admission to ICU; ② Patients who received albumin infusion before entering ICU. In addition, patients with ARF who had repeated admission to ICU only kept the record of the first admission to ICU.

2.2 Data extraction

The extraction of MIMIC-III database data was performed in PostgreSQL 10 software. The data extracted for the study include: gender, age, height, weight, first care unit, mechanical ventilation, comorbidities (diabetes, hypertension, chronic obstructive pulmonary disease, heart failure, pneumonia, chronic kidney disease, chronic liver disease, sepsis, and malignancy), vital signs (pH, temperature, oxygen saturation), severity scores (Sequential Organ Failure Assessment (SOFA) [17], Oxford Acute Severity of Illness Score (OASIS) [18], Simplified Acute Physiology Score II (SAPS II) [19]), laboratory parameters (white blood cells, platelet, bicarbonate, creatinine, lactate, albumin). Vital signs and laboratory parameters were extracted within 24 hours after ICU admission. If there were multiple test values, only the first test value could be included.

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\text{LAR} = \frac{\text{lactate (mmol/L)}}{\text{serum albumin (g/dL)}}; \quad \text{and body mass index (BMI)} \]
\[
= \frac{\text{weight (kg)}}{\text{height squared (m}^2\text{)}}.
\]

The outcome of this study was 30-day mortality. The survival date starts when the patient enters the ICU.

2.3 Statistical analysis

Statistical analysis was performed in Stata software (version 14). Categorical variables are expressed as frequency and percentage. Continuous variables with normal distribution are expressed as mean ± standard deviation, and the differences between groups are analyzed by two-sample t-test [20]. On the contrary, continuous variables with non-normal distribution are expressed as median and interquartile range. The difference was analyzed by Wilcoxon test. When the p value between the two groups was <0.05, it was considered to have a significant difference [21]. Use IBM SPSS Statistics (version 23.0) to draw the receiver operating characteristic (ROC) curve, and the area under the curve (AUC) was used to evaluate the predictive
value of LAR for all-cause mortality in patients with ARF [22]. The Youden Index was used to
determine the optimal cut-off value. According to the cut-off value, LAR was divided into low
LAR group and high LAR group.

The survival difference between the high LAR group and the low LAR group was shown by
Kaplan-Meier curve [23]. Three cox regression models were used to prove the independent
correlation between LAR and all-cause mortality. Model I was unadjusted; Model II was
adjusted by gender, age, BMI, and first care unit; based on model II, Model III added mechani-
cal ventilation, comorbidities (diabetes, hypertension, chronic obstructive pulmonary disease,
heart failure, pneumonia, chronic kidney disease, chronic liver disease, sepsis, and malign-
nancy), vital signs (temperature, pH, oxygen saturation), severity scores (SOFA, OASIS, SAPS
II), laboratory parameters (white blood cells, bicarbonate, creatinine, and platelets) as
covariates.

3. Results

Initially, 7490 patients with ARF were screened from the MIMIC-III database. According to
the inclusion and exclusion criteria, 2170 patients were finally enrolled in the study cohort,
including 1351 survivors and 819 non-survivors. As shown in Table 1, there was a significant
difference in LAR levels between the survivor group and the non-survivor group [0.577
(0.387–1) vs. 0.857 (0.519–1.636), p < 0.001].

The ROC curve was analyzed for the predictive value of LAR in the 30-day mortality of
ARF patients (Fig 1). The predictive value of LAR [AUC: 0.646, 95% confidence interval (CI)
0.622–0.670] was better than that of lactate (AUC: 0.616, 95% CI 0.592–0.641) or albumin
(AUC: 0.631, 95% CI 0.607–0.655) alone, and even higher than that of SOFA (AUC: 0.642,
95% CI 0.618–0.666). According to the Youden Index, the optimal cut-off point of LAR was
0.597 with a sensitivity of 0.690, and a specificity of 0.522. Compared with SOFA and SAPS II,
LAR has better sensitivity in predicting the 30-day mortality of ARF (sensitivity: 0.690 vs.
0.490, 0.637) (Table 2).

According to the optimal cut-off point of LAR, the study population was divided into the
high LAR group (LAR ≥ 0.597) and low LAR group (LAR < 0.597). There were 1211 people
in the high LAR group and 959 people in the low LAR group. There were significant differ-
ences in age, comorbidities, severity scores, and laboratory parameters between the two groups
(Table 3).

As shown in Fig 2, the Kaplan-Meier curve shows that the 30-day all-cause mortality in the
high LAR group was significantly higher than that in the low LAR group. In the COX Regres-
sion Model I, compared with the low LAR group, the unadjusted hazard ratio (95% CI) of the
high LAR group was 2.12 (1.82–2.45). After Model II adjusted gender, age, BMI, and first care
unit, the higher risk in the high LAR group remained unchanged, and the hazard ratio (95%
CI) was 2.06 (1.77–2.39). Model III was adjusted by adding 23 covariates, and the rising trend
of the risk of the high LAR group was still significant, and the hazard ratio (95% CI) was 1.56
(1.33–1.83) (Table 4).

4. Discussion

This study has some interesting findings. First, after adjusting for confounding factors using
multivariate COX regression analysis, LAR is still an independent risk factor for 30-day mor-
tality in patients with ARF. Second, LAR has shown similar predictive value to the commonly
used scoring systems for critically ill patients such as SOFA and OASIS. Finally, patients with
high LAR have a significantly higher risk of 30-day mortality than patients with low LAR.
As far as we know, this is the first study focusing on the relationship between LAR and the prognosis of patients with ARF. Currently, severity scores are widely used clinically to evaluate the prognosis of patients [24–26]. However, compared with the severity score composed of multiple clinical factors, LAR has the same superior performance in assessing the prognosis of patients with ARF, similar to SOFA and OASIS. In addition, both lactate and albumin are easily obtained laboratory results and are objective values. Therefore, LAR has fewer restrictions in clinical application and is easier to be accepted clinically.

Patients with ARF have hypoxemia and (or) hypercapnia due to respiratory dysfunction, resulting in blockage of aerobic metabolic pathways. Lactate is a product of anaerobic metabolism, and albumin is an index of nutritional status and liver function. LAR integrates the impact of these factors on the body, providing a more comprehensive assessment of the condition of patients with ARF.
respiration, which is produced in large amounts under hypoxia, and is positively correlated with mortality [27, 28]. Most patients with ARF die from the progressively worsening pulmonary gas exchange obstruction and diffuse pulmonary inflammation [29]. Albumin promotes the formation of anti-inflammatory substances such as lipoxins, resolvins and protectins, which can promote wound healing and inhibit disease progression [30]. This may explain the poor prognosis caused by albumin reduction. Many studies have shown that albumin has potential as a prognostic marker of ARF [31–33]. Lactate and albumin are regulated by different mechanisms, so LAR can reduce the influence of a single factor on the regulation mechanism [34]. Our study also proved that the predictive value of LAR can be better than lactate or albumin alone.

Table 2. Diagnostic performance of LAR, albumin, lactate, SOFA, OASIS, and SAPS II in the 30-day mortality of ARF patients.

|       | AUC   | 95% CI    | Sensitivity | Specificity |
|-------|-------|-----------|-------------|-------------|
| LAR   | 0.646 | 0.622–0.670 | 0.690       | 0.522       |
| Albumin | 0.631 | 0.607–0.655 | 0.696       | 0.503       |
| Lactate | 0.616 | 0.592–0.641 | 0.420       | 0.751       |
| SOFA  | 0.642 | 0.618–0.666 | 0.490       | 0.726       |
| OASIS | 0.649 | 0.625–0.673 | 0.697       | 0.522       |
| SAPS II | 0.727 | 0.706–0.749 | 0.637       | 0.701       |
LAR is not a novel prognostic marker proposed for the first time. In 2015, Biao Wang et al. proposed that high LAR would accelerate multiple organ failure and increase mortality in patients with severe sepsis [35]. Since then, LAR has been widely analyzed as a risk stratification tool for critically ill patients [34]. However, the condition of critically ill patients in the ICU is complex and the main causes are quite heterogeneous. Therefore, we think that it is not a trustworthy practice to include all critically ill patients in the ICU with a unified standard.

Acute respiratory failure is one of the main causes of short-term mortality in critically ill patients, but most of them have multiple comorbidities. Therefore, whether LAR is an

Table 3. Patient characteristics of the study patients according to LAR levels.

| Variables                          | Low LAR group       | High LAR group       | P-value |
|------------------------------------|---------------------|----------------------|---------|
| LAR                                | 0.406 (0.313–0.5)   | 1.087 (0.792–1.8)    | <0.001  |
| Age, years                         | 64.61 (52.60–77.24) | 65.71 (51.75–78.31)  | 0.409   |
| Male, n (%)                        | 504 (52.55)         | 687 (56.73)          | 0.052   |
| BMI, kg·m⁻²                        | 27.02 (23.05–31.99) | 26.98 (23.11–31.64)  | 0.522   |
| First care unit, n (%)             |                     |                      | 0.087   |
| Coronary Care Unit                 | 120 (12.51)         | 134 (11.07)          |         |
| Cardiac Surgery Intensive Care Unit | 33 (3.44)          | 37 (4.71)            |         |
| Medicine Intensive Care Unit       | 622 (64.86)         | 773 (63.83)          |         |
| Surgical Intensive Care Unit       | 126 (13.14)         | 144 (11.89)          |         |
| Trauma Surgery Intensive Care Unit | 58 (6.05)           | 103 (8.51)           |         |
| Mechanical Ventilation, n (%)      | 853 (88.95)         | 1110 (91.66)         | 0.033   |
| Comorbidities, n (%)               |                     |                      |         |
| Diabetes                           | 319 (33.26)         | 315 (26.01)          | <0.001  |
| Hypertension                       | 358 (37.33)         | 403 (33.28)          | 0.049   |
| chronic obstructive pulmonary disease | 68 (7.09)    | 31 (2.56)            | <0.001  |
| Heart failure                      | 112 (11.68)         | 99 (8.18)            | 0.006   |
| Pneumonia                          | 440 (45.88)         | 446 (36.83)          | <0.001  |
| Chronic kidney disease             | 204 (21.27)         | 198 (16.35)          | 0.003   |
| Chronic liver disease              | 41 (4.28)           | 83 (6.85)            | 0.010   |
| Malignancy                         | 115 (11.99)         | 195 (16.10)          | 0.007   |
| Sepsis                             | 661 (68.93)         | 936 (77.29)          | <0.001  |
| Vital signs                         |                     |                      |         |
| pH                                 | 7.35 (7.28–7.42)    | 7.32 (7.23–7.39)     | <0.001  |
| SPO₂, %                            | 88 (85–98)          | 90 (85–98)           | 0.019   |
| Temperature, °C                    | 36.89 (36.28–37.44) | 36.72 (36–37.5)      | 0.018   |
| Severity scores                    |                     |                      |         |
| SOFA                               | 5 (4–8)             | 8 (5–11)             | <0.001  |
| OASIS                              | 38.04±7.94          | 41.80±8.75          | <0.001  |
| SAPSII                             | 41 (33–51)          | 51 (41–62)          | <0.001  |
| white blood cell, 10¹²/L            | 11.4 (8–16.6)       | 13.2 (8.1–19.5)      | <0.001  |
| Platelet, 10¹³/L                   | 217 (157–291)       | 183 (113–274)        | <0.001  |
| Bicarbonate, mmol/L                | 24 (20–28)          | 20 (16–24)           | <0.001  |
| Creatinine, mg/dL                  | 1.1 (0.7–2)         | 1.3 (0.9–2.2)        | <0.001  |
| Albumin, g/dL                      | 3.1 (2.7–3.5)       | 2.6 (2.2–3.1)        | <0.001  |
| Lactate, mmol/L                    | 1.2 (1–1.5)         | 2.9 (2.1–4.7)        | <0.001  |
| 30-day mortality                   | 254 (26.49)         | 565 (46.66)          | <0.001  |

LAR is not a novel prognostic marker proposed for the first time. In 2015, Biao Wang et al. proposed that high LAR would accelerate multiple organ failure and increase mortality in patients with severe sepsis [35]. Since then, LAR has been widely analyzed as a risk stratification tool for critically ill patients [34]. However, the condition of critically ill patients in the ICU is complex and the main causes are quite heterogeneous. Therefore, we think that it is not a trustworthy practice to include all critically ill patients in the ICU with a unified standard. Acute respiratory failure is one of the main causes of short-term mortality in critically ill patients, but most of them have multiple comorbidities. Therefore, whether LAR is an
independent prognostic factor for the prognosis of ARF is still controversial. This study demonstrated the potential of high LAR as an independent risk factor for ARF through multiple models.

We cannot deny that our results have limitations. First, this is a single-center retrospective study. It is difficult to obtain data using blind methods and to follow the principle of randomness. As a result, there may be potential biases caused by other interfering factors. Second, the

![Kaplan-Meier curves of 30-day all-cause mortality for patients with ARF.](https://doi.org/10.1371/journal.pone.0255744.g002)

| Table 4. Hazard ratio (95% confidence interval) of 30-day all-cause mortality according to groups of LAR levels. |
|------------------------------------------------------|
| 30-day mortality | Hazard ratio | 95% Confidence Interval | P-value |
| Model I          | 2.12         | 1.82–2.45              | <0.001  |
| Model II         | 2.06         | 1.77–2.39              | <0.001  |
| Model III        | 1.56         | 1.33–1.83              | <0.001  |

Model I: Non-adjusted.
Model II: Adjusted by gender, age, BMI, and first care unit.
Model III: Adjusted by gender, age, BMI, first care unit, diabetes, chronic obstructive pulmonary disease, heart failure, pneumonia, hypertension, chronic kidney disease, chronic liver disease, malignancy, sepsis, mechanical ventilation, temperature, pH, SPO2, SOFA, OASIS, SAPS II, white blood cells, bicarbonate, creatinine and platelet.

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data was collected from 2001 to 2012. We cannot ignore the improvement of medical technology such as the continuous improvement of ICU management level and the continuous optimization of patient treatment plans. It is unknown whether this will affect the results. Therefore, we need a multi-center prospective study to verify our results.

5. Conclusion

High lactate/albumin ratio is an independent risk factor for all-cause mortality in patients with ARF. As an easy-to-obtain and objective biomarker, LAR deserves further verification by multi-center prospective studies.

Author Contributions

Data curation: Yan Lu.

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Methodology: Haoyang Guo, Xuya Chen.

Software: Qiaohong Zhang.

Writing – original draft: Yan Lu, Haoyang Guo, Qiaohong Zhang.

References

1. Vincent JL, Akça S, De Mendonça A, Haji-Michael P, Sprung C, Moreno R, et al. The epidemiology of acute respiratory failure in critically ill patients. Chest. 2002; 121(5): 1602–9. https://doi.org/10.1378/chest.121.5.1602 PMID: 12006450
2. Barman B, Parihar A, Kohli N, Agarwal A, Dwivedi DK, Kumari G. Impact of Bedside Combined Cardio-pulmonary Ultrasound on Etiological Diagnosis and Treatment of Acute Respiratory Failure in Critically Ill Patients: Indian Journal of Critical Care Medicine: peer-reviewed, official publication of Indian Society of Critical Care Medicine. 2020; 24(11): 1062–70. https://doi.org/10.5005/jp-journals-10071-23661 PMID: 33384512
3. Franca SA, Toufen C, Jr., Hovnanian AL, Albuquerque AL, Borges ER, Pizzo VR, et al. The epidemiology of acute respiratory failure in hospitalized patients: a Brazilian prospective cohort study. Journal of critical care. 2011; 26(3): 330.e1–8. https://doi.org/10.1016/j.jcrc.2010.10.010 PMID: 21106336
4. Parcha V, Kalra R, Bhatt SP, Berra L, Arora G, Arora P. Trends and Geographic Variation in Acute Respiratory Failure and ARDS Mortality in the United States. Chest. 2020. https://doi.org/10.1016/j.chest.2020.10.042 PMID: 33393472
5. Fröhlich S, Murphy N, Doolan A, Ryan O, Boylan J. Acute respiratory distress syndrome: underrecognition by clinicians. Journal of critical care. 2013; 28(5): 663–8. https://doi.org/10.1016/j.jcrc.2013.05.012 PMID: 23806247
6. Akram M. Citric acid cycle and role of its intermediates in metabolism. Cell biochemistry and biophysics. 2014; 68(3): 475–8. https://doi.org/10.1007/s12013-013-9750-1 PMID: 24068518
7. Feron O. Pyruvate into lactate and back: from the Warburg effect to symbiotic energy fuel exchange in cancer cells. Radiotherapy and oncology: Journal of the European Society for Therapeutic Radiology and Oncology. 2009; 92(3): 329–33. https://doi.org/10.1016/j.radonc.2009.06.025 PMID: 19604589
8. Rabinowitz JD, Enerbäck S. Lactate: the ugly duckling of energy metabolism. 2020; 2(7): 566–71. https://doi.org/10.1038/s42255-020-0243-4 PMID: 32694798
9. Minton J, Sidebotham DA. Hyperlactataemia and Cardiac Surgery. The journal of extra-corporeal technology. 2017; 49(1): 7–15. PMID: 28298660
10. Jansen TC, van Bommel J, Schoonderbeek FJ, Sleeswijk 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. American journal of respiratory and critical care medicine. 2010; 182(6): 752–61. https://doi.org/10.1164/rccm.200912-1918OC PMID: 20483176
11. Colgan SP, Campbell EL, Kominsky DJ. Hypoxia and Mucosal Inflammation. Annual review of pathology. 2016; 11: 77–100. https://doi.org/10.1146/annurev-pathol-012615-044231 PMID: 27193451
12. Basile-Filho A, Lago AF, Meneguetti MG, Nicolini EA, Rodrigues LAB, Nunes RS, et al. The use of APACHE II, SOFA, SAPS 3, C-reactive protein/albumin ratio, and lactate to predict mortality of surgical
13. Bou Chebl R, Jamali S, Sabra M, Safa R, Berbari I, Shami A, et al. Lactate/Albumin Ratio as a Predictor of In-Hospital Mortality in Septic Patients Presenting to the Emergency Department. Frontiers in medicine. 2020; 7: 550182. https://doi.org/10.3389/fmed.2020.550182 PMID: 33072780

14. Cakir E, Turan IO. Lactate/albumin ratio is more effective than lactate or albumin alone in predicting clinical outcomes in intensive care patients with sepsis. Scandinavian journal of clinical and laboratory investigation. 2021: 1–5. https://doi.org/10.1080/00365513.2021.1901306 PMID: 33745405

15. Guo W, Zhao L, Zhao H, Zeng F, Peng C, Guo W, et al. The value of lactate/albumin ratio for predicting the clinical outcomes of critically ill patients with heart failure. Annals of translational medicine. 2021; 9 (2): 118. https://doi.org/10.21037/atm-20-4519 PMID: 33569420

16. Johnson AE, Pollard TJ, Shen L, Lehman LW, Feng M, Ghassemi M, et al. MIMIC-III, a freely accessible critical care database. 2016; 3: 160035. https://doi.org/10.1038/sdata.2016.35 PMID: 27219127

17. Kao HC, Lai TY, Hung HL, Chen YM, Chou PA, Wang CC, et al. Sequential oxygenation index and organ dysfunction assessment within the first 3 days of mechanical ventilation predict the outcome of adult patients with severe acute respiratory failure. TheScientificWorldJournal. 2013; 2013: 413216. https://doi.org/10.1155/2013/413216 PMID: 23476133

18. Chen QG, Xie RJ, Chen YZ, Zeng M. [Clinical value of Oxford acute severity of illness score in identifying quick sequential organ failure assessment-negative patients with sepsis]. Zhonghua jie he he huxi zazhi = Chinese journal of tuberculosis and respiratory diseases. 2018; 41(9): 701–8. https://doi.org/10.3760/cma.j.issn.1001-0939.2018.09.010 PMID: 3096603

19. Gilani MT, Razavi M, Azad AM. A comparison of Simplified Acute Physiology Score II, Acute Physiology and Chronic Health Evaluation II and Acute Physiology and Chronic Health Evaluation III scoring system in predicting mortality and length of stay at surgical intensive care unit. Nigerian medical journal: journal of the Nigeria Medical Association. 2014; 55(2): 144–7. https://doi.org/10.4103/0300-1652.129651 PMID: 24791049

20. Xu M, Frielick D, Zheng JZ, Wang B, Tu XM, Feng C. The Differences and Similarities Between Two-Sample T-Test and Paired T-Test. Shanghai archives of psychiatry. 2017; 29(3): 184–8. https://doi.org/10.11191/bj.issn.1002-0829.217070 PMID: 28904516

21. Sil A, Betkerur J, Das NK. P-Value Demystified. Indian dermatology online journal. 2019; 10(6): 745–50. https://doi.org/10.4103/idoj.IDOJ_368_19 PMID: 32195200

22. Ma H, Bandos AI, Gur D. On the use of partial area under the ROC curve for comparison of two diagnostic tests. Biometrical journal Biometrische Zeitschrift. 2015; 57(2): 304–20. https://doi.org/10.1002/bimj.201400023 PMID: 25537143

23. Ranstam J, Cook JA. Kaplan-Meier curve. The British journal of surgery. 2017; 104(4): 442. https://doi.org/10.1002/bjs.10238 PMID: 28199017

24. Ferreira FL, Bota DP, Bross A, Melot C, Vincent JL. Serial evaluation of the SOFA score to predict outcome in critically ill patients. Jama. 2001; 286(14): 1754–8. https://doi.org/10.1001/jama.286.14.1754 PMID: 11594901

25. Chen Q, Zhang L, Ge S, He W, Zeng M. Prognosis predictive value of the Oxford Acute Severity of Illness Score for sepsis: a retrospective cohort study. PeerJ. 2019; 7: e7083. https://doi.org/10.7717/peerj.7083 PMID: 31218129

26. Czajka S, Ziębińska K, Marczenko K, Posmyk B, Szczepańska AJ, Krzych L J. Validation of APACHE II, APACHE III and SAPS II scores in in-hospital and one year mortality prediction in a mixed intensive care unit in Poland: a cohort study. BMC anesthesiology. 2020; 20(1): 296. https://doi.org/10.1186/s12871-020-01203-7 PMID: 33267777

27. Leverve XM. Energy metabolism in critically ill patients: lactate is a major oxidizable substrate. Current opinion in clinical nutrition and metabolic care. 1999; 2(2): 165–9. https://doi.org/10.1097/0000075197-19990300-00013 PMID: 10453349

28. Fuller BM, Dellinger RP. Lactate as a hemodynamic marker in the critically ill. Current opinion in critical care. 2012; 18(3): 267–72. https://doi.org/10.1097/MCC.0b013e3283532b6a PMID: 22517402

29. Zapol WM, Snider MT, Hill JD, Fallat RJ, Bartlett RH, Edmunds LH, et al. Extracorporeal membrane oxygenation in severe acute respiratory failure. A randomized prospective study. Jama. 1979; 242(20): 2193–6. https://doi.org/10.1001/jama.242.20.2193 PMID: 490805

30. Das UN. Albumin and lipid enriched albumin for the critically ill. The Journal of the Association of Physicans of India. 2009; 57: 53–9. PMID: 19753760

31. Thongprayoon C, Cheungpasitporn W, Chewcharat A, Mao MA, Thirunavukkarasu S, Kashani KB. Risk of acute respiratory failure among hospitalized patients with various admission serum albumin...
32. Chen CW, Chen YY, Lu CL, Chen SC, Chen YJ, Lin MS, et al. Severe hypoalbuminemia is a strong independent risk factor for acute respiratory failure in COPD: a nationwide cohort study. International journal of chronic obstructive pulmonary disease. 2015; 10: 1147–54. https://doi.org/10.2147/COPD.S85831 PMID: 26124654

33. Khilnani GC, Banga A, Sharma SK. Predictors of mortality of patients with acute respiratory failure secondary to chronic obstructive pulmonary disease admitted to an intensive care unit: a one year study. BMC pulmonary medicine. 2004; 4: 12. https://doi.org/10.1186/1471-2466-4-12 PMID: 15566574

34. Gharipour A, Razavi R, Gharipour M, Mukasa D. Lactate/albumin ratio: An early prognostic marker in critically ill patients. The American journal of emergency medicine. 2020; 38(10): 2088–95. https://doi.org/10.1016/j.ajem.2020.06.067 PMID: 33152585

35. Wang B, Chen G, Cao Y, Xue J, Li J, Wu Y. Correlation of lactate/albumin ratio level to organ failure and mortality in severe sepsis and septic shock. Journal of critical care. 2015; 30(2): 271–5. https://doi.org/10.1016/j.jcrc.2014.10.030 PMID: 25537574