Clinical risk factors of extracorporeal membrane oxygenation support in older adults

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Abstract

Background

The ageing population and the expected increase in the number of elderly patients make an evidence-based assessment of Extracorporeal Membrane Oxygenation (ECMO) therapy in older patients progressively more important. Veno-arterial (VA) ECMO results for patient aged <65 years is well known. However, the risk profile and in-hospital prognosis of advanced age patients with ECMO still need more investigation. The aim of this study was to identify risk factors that predicted the outcomes for elderly patients who received VA-ECMO.

Methods

In this retrospective study, medical records for patients with ECMO aged 65 years and over were collected between 2009 and 2012 at a tertiary hospital.

Results

A total of 99 patients (mean age: 76.4±6.4 years) were included. The most common condition requiring VA-ECMO support was cardiogenic shock. Among survivors on VA-ECMO, 28 (28.3%) patients were successfully weaned from support. Thirteen (13.1%) patients were successfully discharged. We found that cardiogenic shock (OR = 3.158, P = 0.013), acute physiology and chronic health evaluation II (APACHE II) score (OR = 1.147, P < 0.001), and simplified acute physiology score II (SAPS II) score (OR = 1.054, P = 0.001) were risk factors associated with survival on VA-ECMO. By using the areas under the receiver operating characteristic (AUC) curve, the APACHE II score and SAPS II score displayed acceptable discriminative power (AUC 0.722; 0.715, respectively).
Conclusion
Our findings indicate that the risk of mortality increases with cardiogenic shock, higher APACHE II score, and higher SAPS II score. These risk factors can be utilized as potential predictors to identify the potential candidates for ECMO support.

Introduction
Extracorporeal membrane oxygenation (ECMO) is used for the management of life-threatening cardiac or pulmonary failure. ECMO uses the cardiopulmonary bypass circuit to provide prolonged respiratory or cardiorespiratory support for patients who fail to respond to conventional intensive care management practices like mechanical ventilation, increased oxygenation and medications [1,2]. Even though ECMO is not a disease treatment, it provides additional time to allow for recovery from existing lung and/or cardiac disease [3–5].

Due to the increased number of elderly people in the population, as well as an increased average life expectancy, an evidence-based assessment of ECMO therapy in this group is becoming more critical. According to Hsu et al.,[6] ECMO is used in Taiwanese patients with severe clinical condition to give added benefit, specifically among elder adults. However, there is no definite recommendation for the risk profile and in-hospital prognosis of older adult patients who receive ECMO. Therefore, the risk factors associated with hospital mortality in this population remain unclear. Making better decisions about how to allocate scarce medical resources requires a better understanding of the factors that influence who is likely to survive if given ECMO versus those who would die whether they receive ECMO or not. Therefore, this study was aimed to identify predictors of mortality in elderly patients successfully weaned from veno-arterial (VA)-ECMO.

Methods
This retrospective, single centre study was approved by the Institutional Review Board (No. 2013-02-011A) of the Taipei Veterans General Hospital, which is a national tertiary hospital in Taiwan. Data were retrieved from patient records with ECMO patients between 2009 and 2012.

Measures and definitions
Clinical data were obtained from a retrospective review of each patient’s medical records. Patients ≥65 years who received VA-ECMO support between January 2009 and December 2012 were included. Each patient’s pre-ECMO conditions (before ECMO deployment), duration of ECMO therapy, and survival to hospital discharge were collected and evaluated. The following variables were collected: age, gender, hospital stay, ICU stay, main diagnosis (cardiac failure: cardiogenic shock, acute myocardial infarction (AMI), acute resuscitation during CPR, acute myocarditis, septic shock, and pre-heart transplant recipient), underlying diseases (hypertension, diabetes mellitus (DM), end-stage renal disease (ESRD), cancer, congestive heart failure (CHF), cerebral vascular accident (CVA), and coronary artery disease (CAD)), renal failure, liver failure, duration of ECMO therapy (type and durations) and the outcomes (weaning off ECMO and survival to discharge).

The acute physiology and chronic health evaluation II (APACHE II) score [7], multiple organ dysfunction (MOD) score [8], and simplified acute physiology score II (SAPS II) score [9] were calculated using the worst variables recorded within the 24 hours before ECMO initiation to predict risk of hospital mortality.
The APACHE II, SAPS II score and MODS score are the widely used scoring systems in the intensive care unit (ICU). The APACHE II score is a severity of disease classification system developed from a large sample of ICU patients in the United States [7]. To calculate the APACHE II score (range 0 to 71), twelve common physiological, age and 2 disease-related variables are calculated.

The SAPS II score is a severity score and mortality estimation tool development from a large international sample of patients in Europe and North American [9]. The SAPS II score is made of 17 variables: age, 2 physiology variables, type of admission (scheduled surgical, unscheduled surgical, or medical), and three underlying disease variables (acquired immunodeficiency syndrome, metastatic cancer, and hematologic malignancy). The SAPS II score ranges from 0 to 163 points and provides a method to convert the score to probability of hospital mortality.

The MODS was calculated as described by Marshall et al in 1995 using six organ systems [8]. Multiple organ failure is the leading cause of mortality in patients admitted to the ICU.

Clinical management
The ECMO support is widely used in the majors of major hospitals in Taiwan. In our hospital, we applied around 200 cases of ECMO per year. Two main types of the devices are used which include (Sorin SCP revolution 5, LivaNova, London, UK and Maquet Rotaflow RF32, Rastatt, Germany). We routinely use peripheral cannulation for all VA-ECMO cases via femoral artery (percutaneously or cut-down) and femoral vein. Distal perfusion catheter to prevent lower limb ischemia is also routinely applied. If the patient has peripheral arterial disease (PAD), we shift the cannulation site to right side axillary artery. After initiation of the support, intravenous heparin is given to maintain activated partial thromboplastin time (aPTT) to 45–60 sec. the target level of hematocrit is above 30% and the platelet count is above 80,000/ml. Most of the time, we still use low to moderate dose of inotrope or vasopressor to maintain adequate whole body perfusion and blood pressure. The blood flow of ECMO is around 2.5–3.5 L/min. Intra-aortic balloon pump (IABP) is routinely used for all cardiogenic shock patient to provide better opportunity of survival. The setting target of the FiO\textsubscript{2} of the respirator is below 35% if possible. The peripheral artery line is inserted from right side radial artery to provide more accurate information of the blood saturation of coronary artery and right side hemisphere. The pulse oximetry is placed at right side finger under the same concern to prevent possible hypoxic injury of the myocardium and right side hemisphere (the blood directly from the left ventricle might be hypoxia).

The indications for VA-ECMO were the most common: cardiac arrest, refractory cardiogenic shock with maximum inotropic support, failure to wean from cardiopulmonary bypass after cardiac surgery, and bridge to decision for transplant or VAD. VA-ECMO support was contraindicated in patients with unrecoverable cardiac function, patients who are not candidates for transplantation or durable mechanical support, chronic organ dysfunction (emphysema, cirrhosis, renal failure), prolonged cardiopulmonary resuscitation (CPR) without adequate tissue perfusion, and those with compliance limitations (financial, cognitive, psychiatric, and social limitations).

Statistical analysis
Categorical data were presented as number and percentage. Pearson’s Chi-square test or Fisher’s exact test were used for categorical variables and to compare the differences between survivors and non-survivors. Continuous data were summarized as the mean±SD. Crude and adjusted odds ratios (ORs) and respective 95% confidence intervals were estimated with
univariate and multivariate logistic regression analysis in order to examine the risk of in-hospital mortality, age, indications, underlying diseases, comorbidities, and mortality risk scores in VA-ECMO patients.

The ability to predict mortality was evaluated by the receiver operating characteristic (ROC) curve and the areas under the receiver operating characteristics (AUC) curve. ROC and AUC were calculated to determine the diagnostic accuracy of the APACHE II score, MOD score, and SAPS II score. The best predictive cut-off values for risk scores were calculated based on ROC area under the curve analysis with the Youden index (sensitivity + specificity − 1) [10].

A stratified analysis was used to evaluate in-hospital mortality rate among different patient subgroups. All statistical tests were two-tailed, with the level of significance set at a P value < 0.05. Data analysis was performed using SPSS for Windows.

Results

Among 120 ECMO patients aged ≥65 years during investigation period, 99 (82.5%) required VA-ECMO for hemodynamic instability with or without concomitant respiratory failure. Twenty-one patients (17.5%) who received VV-ECMO for respiratory failure were excluded. A total of 99 patients (22 female, 77 male) received ECMO therapy and were enrolled. Twenty-eight patients (28.3%) were successful weaned from ECMO therapy. Thirteen patients ultimately survived until discharge; the hospital survival rate was 13.1% (Fig 1).

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**Fig 1. Flow chart of patients received ECMO from 2009–2012.**

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Patient characteristics

The demographic and clinical characteristics of 99 ECMO patients are described in Table 1. The mean age of patients treated with ECMO was 77.9±6.4 and 75.9±6.4 years for the survival and non-survival groups, respectively. The survival versus the non-survival group had a lower proportion of females (14.3% vs 25.4%), but the differences were not statistically significant (P = 0.355).

The hospital stay and ICU stay were significantly longer for the survival group than those of the non-survival group (hospital stay: 69.5±76.2 vs 12.6±12.5 days, P = 0.001; ICU stay: 38.1±24.8 vs 9.4±11.0 days, P < 0.001). However, there was no significant difference in ECMO support duration between the survival and non-survival groups (6.4±4.0 vs 4.7±5.6 days, P = 0.158). The APACHE II score, MOD score, and SAPS II score were significantly higher for the non-survival group than the scores in the survival group (APACHE II score: 34.3±7.4 vs 40.2±6.1, P < 0.001; MOD score: 10.4±3.4 vs 11.9±3.1, P = 0.060; SAPS II score: 73.6±16.3 vs 86.1±14.4, P < 0.001).

Table 2 summarizes the results of univariate comparisons of clinical characteristics between patients with hospital survival and hospital non-survival. The most frequent reason (indication) for ECMO support was cardiogenic shock (65.7%), following by acute resuscitation during CPR (49.5%), and AMI (48.5%). The most frequent underlying disease was hypertension (69.7%) followed by renal failure (68.7%) and CAD (54.5%).

Predictors of ability to be weaned from VA-ECMO

To determine risk factors associated with in-hospital mortality in ECMO patients, ORs and P values were estimated using univariate logistic regression. These results showed that cardiogenic shock (OR = 3.158, P = 0.013) was significant risk factors on ECMO survival (Table 2).

We further determined the relationship between patients’ risk scores and in-hospital mortality. Table 3 shows that ECMO non-survivors had a significantly higher odds ratio for having a higher APACHE II score, and SPAS II score than those in survivors; the odds ratios of these risk scores were 1.147 and 1.054, respectively.

To assess the predictive value of each risk score in predicting in-hospital mortality, the AUC, cut-off value, sensitivity, and specificity are presented in Table 3. When predicting ECMO survival, the APACHE II score AUC was 0.722, and the sum of sensitivity and specificity was maximized at an APACHE II score of 37.5 (sensitivity = 0.696, specificity = 0.714). For SAPS II, the highest value of the Youden index was obtained at a cut-off point of 86.5 (sensitivity = 0.627, specificity = 0.786, AUC = 0.683).

Table 1. The demographic and clinical characteristics in elderly patients receiving VA-ECMO.

| Pre-ECMO Variables | All patients (n = 99) | Successfully weaned from ECMO (n = 28) | non-survival (n = 71) | P value |
|------------------|----------------------|---------------------------------------|----------------------|---------|
| Age (years)      | 76.4±6.4             | 77.9±6.4                              | 75.9±6.4             | 0.244   |
| Sex (F/M)        | 22/77                | 4/24                                  | 18/53                | 0.355   |
| Hospital stay (Days) | 28.7±48.7         | 69.5±76.2                             | 12.6±12.5            | 0.001   |
| ICU stay (Days)  | 17.5±20.6            | 38.1±24.8                             | 9.4±11.0             | <0.001  |
| ECMO support Duration (Days) | 5.2±5.2             | 6.4±4.0                               | 4.7±5.6              | 0.158   |
| Risk score       |                      |                                       |                      |         |
| APACHE II score  | 38.5±7.0             | 34.3±7.4                              | 40.2±6.1             | <0.001  |
| MOD score        | 11.4±3.3             | 10.4±3.4                              | 11.9±3.1             | 0.060   |
| SAPS II score    | 82.5±15.9            | 73.6±16.3                             | 86.1±14.4            | <0.001  |

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Fig 2 depicts ECMO survival rate categorized by dichotomous APACHE II score >37/≤ 37, SAPS II score >86/≤ 86, and have/no indication of cardiogenic shock. Patients with cardiogenic shock and APACHE II score greater than 37 had a significantly poorer ECMO survival rate (7.5%) than patients with no cardiogenic shock and APACHE II score less than or equal to 37 (58.4%). Patients with cardiogenic shock and SAPS II score >86 had a significantly poorer ECMO survival rate (8.1%) than patients with no cardiogenic shock and SAPS II score ≤ 86 (54.5%).

Discussion
Taiwan is currently facing the challenge of an ageing population and widespread ECMO use in older adults [11]. In this study, our major findings in VA-ECMO patients aged ≥65 years are as follows: (1) cardiogenic shock (OR = 3.158, P = 0.013), APACHE II score (OR = 1.147, P<0.001), and SAPS II score (OR = 1.054, P = 0.001) were risk factors associated with survival.

Table 2. Clinical characteristics of hospital mortality in patients receiving VA-ECMO.

| Pre-ECMO Variables | n (%) | Successfully weaned from ECMO |
|--------------------|-------|-------------------------------|
| Age                |       |                               |
| Cardiac failure    |       |                               |
| Cardiogenic shock  | 65 (65.7) | 13 (20.0) |
| AMI                | 48 (48.5) | 12 (25.0) |
| Acute resuscitation during CPR | 49 (49.5) | 12 (24.5) |
| Pre-heart transplant recipient | 1 (1.0) | 0 (0) |
| Acute myocarditis  | 1 (1.0) | 0 (0) |
| Septic shock       | 12 (12.1) | 3 (25.0) |
| Underlying diseases|       |                               |
| Hypertension       | 69 (69.7) | 18 (26.1) |
| DM                 | 33 (33.3) | 10 (30.3) |
| ESRD               | 17 (17.2) | 6 (35.3) |
| Cancer             | 14 (14.1) | 4 (28.6) |
| Heart disease      |       |                               |
| CHF                | 18 (18.2) | 5 (27.8) |
| CVA                | 9 (9.1) | 2 (22.2) |
| CAD                | 54 (54.5) | 13 (24.1) |
| Aortic aneurysm    | 14 (14.1) | 4 (28.6) |
| Renal failure (before ECMO) | 68 (68.7) | 18(26.5) |
| Liver failure (before ECMO) | 7 (7.1) | 0 (0) |
| AMI, acute myocardial infarction; CPR, cardiopulmonary resuscitation; DM, diabetes mellitus; ESRD, end-stage renal disease; CHF, congestive heart failure; CVA, cerebral vascular accident; CAD, coronary artery disease, OR, Odds ratio.

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Table 3. Comparison of discrimination of the scoring method in predicting VA-ECMO survival.

| Pre-ECMO Variables | OR | P | ROC curve | Cut-off value | Sensitivity | Specificity |
|--------------------|----|---|-----------|--------------|-------------|-------------|
| APACHE II score    | 1.147 | <0.001 | AUC 0.722 P 0.001 | 37.5 | 0.696 | 0.714 |
| MOD score          | 1.159 | 0.064 | 0.629 | 0.070 | 12.5 | 0.460 | 0.760 |
| SAPS II score      | 1.054 | 0.001 | 0.715 | 0.001 | 86.5 | 0.627 | 0.786 |

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on VA-ECMO; (2) the APACHE II score (AUC = 0.722) and SAPS II score (AUC = 0.715) displayed acceptable discriminative power. We believe our study could be helpful in determining which patients should be selected as ECMO candidates before initiation.

With the emergence of value-based healthcare, clinicians need to carefully evaluate older adult patients’ clinical conditions to decide the most appropriate therapeutic approach for ECMO support. Making better decisions when allocating scarce medical resources requires a better understanding of who is likely to survive if given ECMO. Many risk factors may affect clinical outcomes for ECMO patients. Therefore, identifying these factors will provide clinicians with valuable prognostic information when making medical decisions.

In our study, increased risk of not successfully weaned from VA-ECMO was explained by three factors: cardiogenic shock, APACHE II score, and SAPS II score. Although advanced age is a general predictor of hospital mortality in critical ill patients, the effectiveness of ECMO in older adult patients has not been determined. Some previous reports have suggested that ECMO might be less suitable (a contraindication) in older adults [12,13]. Other studies have revealed that ECMO was effective in older adult patients, yielding hospital survival rates similar to the rates for younger patients [14]. Data from most ECMO studies suggest that advanced age is associated with the controversial results in ECMO patients. According to the guidelines published by the Extracorporeal Life Support Organization (ELSO), age is not a specific contraindication for respiratory failure and heart failure but should be considered one because the risk increases with ageing [13,15]. However, the poor prognosis may be due to the higher prevalence of coexisting medical conditions in older adult patients [16]. These results could make clinicians wary of using ECMO. Age itself should not preclude patients from being candidates for ECMO support. Thus, the decision to perform ECMO in older patients should not be based on age alone. For critically ill patients, current research has demonstrated that illness
severity, acute physiology, premorbid status, and multiple organ failure have a greater impact on prognosis than age alone [17–19]. These factors could be stronger predictors of hospital mortality than age.

Previous studies [11,12] indicated that cardiogenic shock in patients requiring ECMO support indicated a poor prognosis and were important predictors of hospital mortality. These results are consistent with our study and likely relate to disease processes and other comorbidities.

In the present study, the APACHE II score before ECMO initiation significantly predicted mortality in the critically ill patients (aged ≥65 years) who underwent VA-ECMO. The mortality rate increased with an increase in pre-ECMO APACHE II score. A recent prospective study demonstrated that a higher APACHE II score was associated with unsuccessful weaning from ECMO for ARDS patients [20]. Lin CY et al. showed that an APACHE II score >22 resulted in a higher mortality in critically ill patients (mean age: 47±22 years) undergoing VA-ECMO and VV-ECMO [21]. In a study conducted by Chiu LC et al, the prognostic scores for the APACHE II was 24 for ARDS patients (mean age: 48.0±17.3 years) in the ICU undergoing VV-ECMO [22]. These diverse prognostic values are likely to be influenced by different age groups, severity of diseases, indications for ECMO in each study.

We confirmed that a higher SAPS II score was a good predictor of in-hospital mortality in ECMO patients. A higher SAPS II score before the ECMO procedure, which probably represents a poor overall functional status, was an important risk factor predicting survival. It has been shown that a higher SAPS II score was a predictor of hospital mortality for ECMO patients and has a fair prediction ability [23–26]. The mortality rate increased significantly with an increase in pre-ECMO SAPS II score. In previous literature, a SAPS II score about 80 or above was considered an indicator of favourable outcomes before the use of ECMO in adult patients [23,24]. Therefore, we identified SAPS II as a predictor and suggest a SAPS II value of 86 as the cut off in the aged patient.

In this study, there are several limitations. First, this was a retrospective study performed at a single tertiary-care hospital, limiting the generalization of its findings. Second, different management approaches adopted by physicians may have influenced the study outcome. Third, there are no internal and external validation cohorts for score testing. The score testing for internal validation cohort cannot be performed due to the insufficient sample size. In addition, a multicentered and large scale study with independent cohort is suggested to validate our findings.

Conclusion
In conclusion, this study observed the in-hospital mortality under VA-ECMO in older adult patients. According to these results, it is still difficult to conclude that ECMO is a recommended therapy for the elderly patients. However, the poor prognosis may be due to the higher prevalence of coexisting medical conditions in older adult patients. ECMO should be performed only in carefully selected patients over 65 years.

Our findings indicate that the risk of mortality increases with cardiogenic shock, high APACHE II score, and SAPS II score and should be taken into account when considering initiation of ECMO support among adults aged 65 and over. This study provides clinicians with valuable prognostic information for medical decision-making.

Author Contributions

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References
1. Hajbagheriy MA, Mousavi G, Akbari H. Factors influencing survival after in-hospital cardiopulmonary resuscitation. Resuscitation. 2005; 66: 317–321. https://doi.org/10.1016/j.resuscitation.2005.04.004 PMID: 16081201
2. Shih CL, Lu TC, Jerg NS, Lin CC, Liu YP, Chen WJ, et al. A web-based Utstein style registry system of in-hospital cardiopulmonary resuscitation in Taiwan. Resuscitation. 2007; 72: 394–403. https://doi.org/10.1016/j.resuscitation.2006.07.020 PMID: 17161519
3. Lewandowski K. Extracorporeal membrane oxygenation for severe acute respiratory failure. Crit Care. 2000; 4: 156–168. https://doi.org/10.1186/cc889 PMID: 11094500
4. Hemmila MR, Rowe SA, Boules TN, Miskulin J, McGillicuddy JW, Schuerer DJ, et al. Extracorporeal life support for severe acute respiratory distress syndrome in adults. Ann Surg. 240: 595–605; discussion 605–597. https://doi.org/10.1097/01.sla.0000141159.90676.2d PMID: 15383787
5. Extracorporeal Life Support Organization. ELSO GUIDELINES FOR ECMO CENTERS. 2010. Available from: http://www.elsonet.org.
6. Hsu CP, Lee WC, Wei HM, Sung SH, Huang CY, Shih CC, et al. Extracorporeal membrane oxygenation use, expenditure, and outcomes in Taiwan from 2000 to 2010. J Epidemiol. 2015; 25: 321–331. https://doi.org/10.2188/jea.JE20140027 PMID: 25797598
7. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. Crit Care Med. 1985; 13:818–829. PMID: 3928249
8. Marshall JC, Cook DJ, Christou NV, Bernard GR, Sprung CL, Sibbald WJ. Multiple organ dysfunction score: a reliable descriptor of a complex clinical outcome. Crit Care Med. 1995; 23: 1638–1652. PMID: 7587228
9. 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. PMID: 8254858
10. Youden WJ. Index for rating diagnostic tests. Cancer. 1950; 3: 32–35. PMID: 15405679
11. Chang CH, Chen HC, Caffrey JL, Hsu J, Lin JW, Lai MS, et al. Survival Analysis After Extracorporeal Membrane Oxygenation in Critically III Adults: A Nationwide Cohort Study. Circulation. 2016; 133: 2423–2433. https://doi.org/10.1161/CIRCULATIONAHA.115.019143 PMID: 27199466
12. Saxena P, Neal J, Joyce LD, Greason KL, Schaff HV, Guru P, et al. Extracorporeal Membrane Oxygenation Support in Postcardiomyotomy Elderly Patients: The Mayo Clinic Experience. Ann Thorac Surg. 2015; 99: 2053–2060. https://doi.org/10.1016/j.athoracsur.2014.11.075 PMID: 25865760
13. Extracorporeal Life Support Organization: Extracorporeal Life Support Organization (ELSO) Guidelines for Adult Cardiac Failure. 2013. Available from: https://www.else.org/Portals/0/IGD/Archive/FileManager/e76ef78eabacusersshydserifdocumentselsoguidelineforadultcardiacfailure1.3.pdf.
14. Saito S, Nakatani T, Kobayashi J, Tagusari O, Bando K, Niwaya K, et al. Is extracorporeal life support contraindicated in elderly patients? Ann Thorac Surg. 2007; 83: 140–145. https://doi.org/10.1016/j.athoracsur.2006.08.006 PMID: 17184647
15. Extracorporeal Life Support Organization. Extracorporeal Life Support Organization (ELSO) Guidelines for Adult Respiratory Failure. 2013. Available from: https://www.else.org/Portals/0/IGD/Archive/FileManager/989df4d1d14cusersshydserifdocumentselsoguidelineforadultrespiratoryfailure1.3.pdf.
16. de Rooij SE, Abu-Hanna A, Levi M, de Jonge E. Factors that predict outcome of intensive care treatment in very elderly patients: a review. Crit Care. 2005; 9: R307–314. https://doi.org/10.1186/cc3536 PMID: 16137342
17. Hood E, Bhang A, Pandit D, Michael A. Is age a predictor of mortality in a UK medical high dependency unit? Br J Anaesth. 2011; 107: 186–192. https://doi.org/10.1093/bja/aer105 PMID: 21616942

18. Leong IY, Tai DY. Is increasing age associated with mortality in the critically ill elderly. Singapore Med J. 2002; 43: 33–36. PMID: 12008774

19. Chelluri L, Pinsky MR, Donahoe MP, Grenvik A. Long-term outcome of critically ill elderly patients requiring intensive care. JAMA. 1993; 269:3119–3123. PMID: 8505814

20. Liu X, Xu Y, Zhang R, Huang Y, He W, et al. Survival Predictors for Severe ARDS Patients Treated with Extracorporeal Membrane Oxygenation: A Retrospective Study in China. PLoS One. 2016; 11: e0158061. https://doi.org/10.1371/journal.pone.0158061 PMID: 27336170

21. Lin CY, Tsai FC, Tian YC, Jenq CC, Chen YC, et al. Evaluation of outcome scoring systems for patients on extracorporeal membrane oxygenation. Ann Thorac Surg. 2007; 84:1256–1262. https://doi.org/10.1016/j.athoracsur.2007.05.045 PMID: 17888979

22. Chiu LC, Tsai FC, Hu HC, Chang CH, Hung CY, et al. Survival predictors in acute respiratory distress syndrome with extracorporeal membrane oxygenation. Ann Thorac Surg. 2015; 99:243–250. https://doi.org/10.1016/j.athoracsur.2014.07.064 PMID: 25442984

23. Kim KI, Lee HS, Kim HS, Ha SO, Lee WY, Park SJ, et al. The pre-ECMO simplified acute physiology score II as a predictor for mortality in patients with initiation ECMO support at the emergency department for acute circulatory and/or respiratory failure: a retrospective study. Scand J Trauma Resusc Emerg Med. 2015; 23:59. https://doi.org/10.1186/s13049-015-0135-x PMID: 26283075

24. Choi MJ, Ha SO, Kim HS, Park S, Han SJ, Lee SH. The Simplified Acute Physiology Score II as a Predictor of Mortality in Patients Who Underwent Extracorporeal Membrane Oxygenation for Septic Shock. The Ann Thorac Surg. 2017; 103: 1246–1253. https://doi.org/10.1016/j.athoracsur.2016.07.069 PMID: 27743640

25. Lee S, Yeo HJ. Validity of Outcome Prediction Scoring Systems in Korean Patients with Severe Adult Respiratory Distress Syndrome Receiving Extracorporeal Membrane Oxygenation Therapy. J Korean Med Sci. 2016; 31: 932–938. https://doi.org/10.3346/jkms.2016.31.6.932 PMID: 27247503

26. Lee SH, Shin DS, Kim JR, Kim H. Factors associated with mortality risk in critical care patients treated with veno-arterial extracorporeal membrane oxygenation. Heart Lung. 2017; 46: 137–142. https://doi.org/10.1016/j.hrtlng.2017.02.003 PMID: 28318620