# PREDICTING MORTALITY AFTER SURGERY IN A MIDDLE EASTERN INTENSIVE CARE UNIT

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## Abstract

**Background:** Predicting postoperative mortality could optimize the use of resources including intensive care unit (ICU) admission.

**Aim:** We analyzed postoperative mortality predictors in the largest Middle Eastern ICU and tailored a prediction model accordingly.

**Patients and Methods:** All pertinent data of adult postoperative patients who were admitted to our ICU from 01-01-2016 to 31-12-2017 were retrospectively analyzed by means of logistic regression to identify mortality predictors. Using the probabilities recorded for the latter and a cut-off value of 0.5 for death, a prediction model was tailored and its accuracy tested by receiver operator characteristics (ROC) analysis with reporting of area under the curve (AUC).

**Results:** The study included 751 patients [aged 53.12 ± 18.1years old, 464 males, with Acute Physiology and Chronic Health Evaluation (APACHE) 4 score of 100.8 ± 26.5 and American Society of Anesthesiology Physical Status score (ASA-PS) of 2.8 ± 1] baring a postoperative mortality rate of 5.1%. Significant mortality predictors depicted were (all $p < 0.05$): age [odds ratio (OR) 1.09, 95% confidence intervals (CI): 1.02 - 1.2], longer ICU length of stay (OR 1.1, 95% CI: 1.04 - 1.17), ASA-PS (OR 33.2, 95% CI: 4.97 - 222.02), lactate levels upon ICU admission (OR 1.73, 95% CI: 1.08 - 2.76), and intraoperative use of inotropes/vasopressors (OR 1.9, 95% CI: 52.6 - 367.5). The featured prediction model integrating the aforementioned variables showed that 98.8% of cases were appropriately classified with AUC of 0.997 (95% CI: 0.989 - 0.999).

**Conclusion:** Despite limitations, our postoperative mortality prediction model proved to be an effective tool in depicting patients' outcome.

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## Introduction

Postoperative complications remain a leading cause of mortality worldwide with estimated annual deaths of up to 12 million, surpassing the health care burden of traffic road accidents and/or diabetes[1,2]. Admission to an intensive care unit (ICU) can reduce postoperative mortality among high risk patients[3]. Also, a high proportion of postoperative cases is admitted to the ICU for a short-period of time, particularly in the developed world[4]. However, the demand for ICU beds is steadily increasing with medical advancement and aging populations baring multiple co-morbidities[5]. Although there is a documented expansion in the number of ICU beds, this remains largely dependent upon regional variabilities within health care systems 6. In that sense, previous studies reported less than 15% ICU admission rate of high-risk surgical patients[7]. An optimized perioperative identification of high-risk surgical patients who will be thereafter admitted to the ICU could facilitate proper utilization of available resources in a cost-efficient manner[8-10]. However, the former is a challenging process which could be at least partially attributed to the fact that several ethical and medical dilemmas exist when designing clinical studies to elucidate whether post-operative ICU admission could benefit the outcome of high-risk cases[11]. Moreover, the aforementioned outcome is subjected to a complex interaction of variable perioperative risk factors integrating the nature of the surgical procedure per se[4]. Hence, several risk stratification perioperative tools were developed which are further subdivided into risk scores and prediction models[12]. The American Society of Anesthesiology Physical Status Score (ASA-PS) remains a user friendly and well-established risk stratification tool; however, it does not allow individualized risk prediction of an adverse outcome[13]. The latter can be accurately evaluated by risk prediction models integrating various tools (i.e., measurement of functional capacity by exercise testing) that remain complex to use[12,14].

In this study, we aimed on identifying predictors of ICU mortality among postoperative patients by retrospectively analyzing data derived from the largest critical care unit in the Middle East. Moreover, we tailored a statistical model for predicting mortality after surgery.

## Study Design

This was a retrospective study based on data derived from the electronic ICU database of King Saud Medical City (KSMC), Riyadh, Saudi Arabia. The latter is a tertiary referral hospital integrating the largest ICU (127 operational beds) in the Middle East. In the aforementioned ICU, beds are constantly available for postoperative admissions. Our hospital policy dictates that admission to ICU beds postoperatively should be scheduled 24 hours prior to surgery based on the evaluation of anesthesiologists and surgeons and in agreement with the on-call ICU team. In case emergency surgery, the aforementioned multidisciplinary team decided for patient ICU admission accordingly. This retrospective study was conducted with waiver of consent due to its inherent nature but conformed to the principles outlined in the Declaration of Helsinki and was approved by the institutional ethics committee.

## Patients

The electronic stored data of all adult postsurgical patients (aged $\geq$ 18 years old) who were admitted to ICU fast-track beds from 01-01-2016 to 31-12-2017 were retrieved and analyzed for this study.

## Data Collection and Methods

We focused on collecting various information pertinent to our study such as patients' general and demographic features as well as peri - and intra - operative data integrating type and duration of the procedure, intraoperative administration of inotropes and/or vasopressors as well as blood products, details regarding the anesthesia technique used, whether surgery was scheduled or urgent and whether the patient was operated for the first time or it was a re-do procedure. Also, we analyzed other pertinent data such as Acute Physiology and Chronic Health Evaluation (APACHE) 4 score, ASA-PS, and ICU length of stay (LOS). Finally, the outcome of each patient was recorded as a binary parameter of either death or discharge alive from the ICU.

## Statistical Analysis

Continuous variables were summarized as mean ± standard deviation, while categorical data were summarized as number (percentage) both baring 95% confidence intervals (CI).

In order to identify predictors of ICU mortality post-operatively, all recorded data were fitted in a logistic regression model (with ICU outcome as the dependent variable), while other pertinent variables were fitted in the model using enter method with a p value < 0.1. Results were reported as odds ratio (OR) with 95% CI, while the model's goodness of fit was assessed with Hosmer-Lemeshow test for logistic regression (considered to be well fitted if p value > 0.05)[15]. Using the probabilities recorded by the logistic regression model for all significant predictors and a cutoff value of 0.5 for death, a mortality prediction model in the form of a nomogram was created. Thereafter, a receiver operator characteristics (ROC) curve was drawn for the aforementioned model with reporting of area under the curve (AUC)[16]. A two-tailed significance level of 0.05 was regarded statistically significant. All analyses were performed using a commercially available statistical package (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp).

## Results

### *Cohort Analysis*

Out of the 814 fast-track post-operative admissions to the ICU, 751 patients were ≥ 18 years and were included in the final analysis. Table 1 summarizes the general and perioperative features

*Table 1*
*General and perioperative features of the study population (n = 751)*

| Parameters | Mean ± SD | 95% CI |
|---|---|---|
| Age (years) | 53.12 ± 18.1 | 51.8 to 54.4 |
| APACHE 4 score | 100.8 ± 26.5 | 98.9 to 102.7 |
| ASA-PS | 2.8 ± 1 | 2.7 to 2.9 |
| Surgery Duration (min) | 187.2 ± 64.5 | 182.6 to 191.8 |
| Transfused Blood Units | 1.3 ± 1.5 | 1.2 to 1.4 |
| Number of Inotropes and/or Vasopressors | 0.2 ± 0.7 | 0.2 to 0.3 |
| Lactate levels upon ICU admission (mg/dl) | 5.2 ± 2.8 | 5 to 5.4 |
| LOS (days) | 4.4 ± 10.4 | 3.6 to 5.1 |
| | N (%) | 95% CI |
| Gender (Males) | 464 (61.8%) | 58.2% to 65.3% |
| Source of admission (Ward) | 678 (90.3%) | 88% to 92.3% |
| First Surgery | 728 (96.9%) | 95.4% to 98% |
| Anesthesia (General) | 737 (98.1%) | 96.8% to 99% |
| Received Blood Transfusion | 380 (50.6%) | 47% to 54.2% |
| Inotropes and/or Vasopressors (used) | 664 (88.4%) | 86% to 91% |
| ICU outcome (death) | 38 (5.1%) | 3.6% - 6.9% |
| Admitting Specialty | | |
| GS | 324 (43.1%) | 39.5% to 46.7% |
| Orthopedic Surgery | 110 (14.6%) | 12.2% to 17.3% |
| Neurosurgery | 94 (12.5%) | 10.2% to 15.1% |
| Other | 223 (29.8%) | 26.5% to 33.2% |

*APACHE = Acute Physiology and Chronic Health Evaluation, ASA-PS = American Society of Anesthesiology Physical Status Score, LOS = length of stay, ICU = intensive care unit, GS = general surgery, SD = standard deviation, n = number, CI = confidence intervals.*

of the study population. The majority of patients (90.3%) were admitted as prescheduled fast-track cases mainly under general surgery, neurosurgery and orthopedic surgery (Table 1). The average duration of surgical procedures was 187.2 ± 64.5 min and most of the patients (737; 98.1%) underwent general anesthesia. Almost half of the patients (380; 50.6%) received blood transfusion intraoperatively [average number of received packed red blood cells (PRBCs) was 1.3 ± 1.5]. Most patients (664; 88.4%) did not require administration of vasoactive medications intraoperatively (the average number of used inotropes and/or vasopressors per patient was 0.2 ± 0.7). Serum lactate levels obtained upon ICU admission were 5.2 ± 2.8 mg/dl (Table 1). The ICU LOS was 4.4 ± 10.4 days and most of the patients (713; 94.9%) were discharged alive from the ICU.

## *ICU Mortality Predictors*

All the study variables were fitted in a logistic regression model as previously described. The model was well fitted with Hosmer-Lemeshow test p value = 1 (Table 2). Statistically significant predictors of ICU mortality for the postoperative cases were: increased age (OR 1.09, 95% CI: 1.02 - 1.2; p = 0.021), longer ICU LOS (OR 1.1, 95% CI: 1.04 - 1.17; p = 0.002), higher ASA score (OR 33.2, 95% CI: 4.97 - 222.02; p < 0.001), higher post-operative serum lactate (OR 1.73, 95% CI: 1.08 - 2.76; p = 0.023), and use of vasoactive substances intraoperatively (OR 1.9, 95% CI: 52.6 - 367.5; p = 0.001).

Using a probability cut-off value of 0.5 for ICU mortality we tailored a mortality prediction model which integrated the score given to each of the significant predictors. A straight line was drawn from the corresponding value of each predictor to the score line; hence, the scores were then summed up to get a total score which was evaluated against the probability line to get an overall mortality probability (Figure 1).

Notably, the drawn ROC curve of the aforementioned mortality prediction model had an area under the curve (AUC) of 0.997 (95% CI: 0.989 - 0.999) with 98.8% of cases appropriately classified (Figure 2).

*Table 2*
*Logistic regression model for ICU mortality predictors*

| | Odds Ratio | p value | 95% CI |
|---|---|---|---|
| Age | 1.09 | 0.021 | 1.02 - 1.2 |
| Gender (Male) | 0.28 | 0.357 | 0.031 - 2.5 |
| Admission (from the emergency room) | 2.24 | 0.484 | 0.3 - 18.4 |
| APACHE 4 | 1.002 | 0.615 | 0.97 - 1.04 |
| LOS | 1.1 | 0.002 | 1.04 - 1.17 |
| ASA-PS | 33.2 | 0.000 | 4.97 - 222.02 |
| Duration of Surgery | 1.005 | 0.370 | 0.99 - 1.02 |
| Lactate levels upon ICU admission | 1.73 | 0.023 | 1.08 - 2.76 |
| Intraoperative blood transfusion | 0.045 | 0.137 | 0.0013 - 1.6 |
| Blood Units count | 0.43 | 0.076 | 0.17 - 1.1 |
| Intraoperative use of Inotropes and/or Vasopressors | 1.9 | 0.001 | 52.6 - 367.5 |
| Inotropes and/or Vasopressors count | 1.9 | 0.388 | 0.4 - 8.6 |
| General Anesthesia | 75.3 | 0.099 | 0.3 - 20812.5 |
| Re-Do Surgery | 1.45 | 0.789 | 0.12 - 17.1 |

*APACHE = Acute Physiology and Chronic Health Evaluation, ASA = American Society of Anesthesiology Physical Status Score, LOS = length of stay, CI = confidence interval.*

*Fig. 1*
*Mortality prediction model after surgery in the intensive care unit*

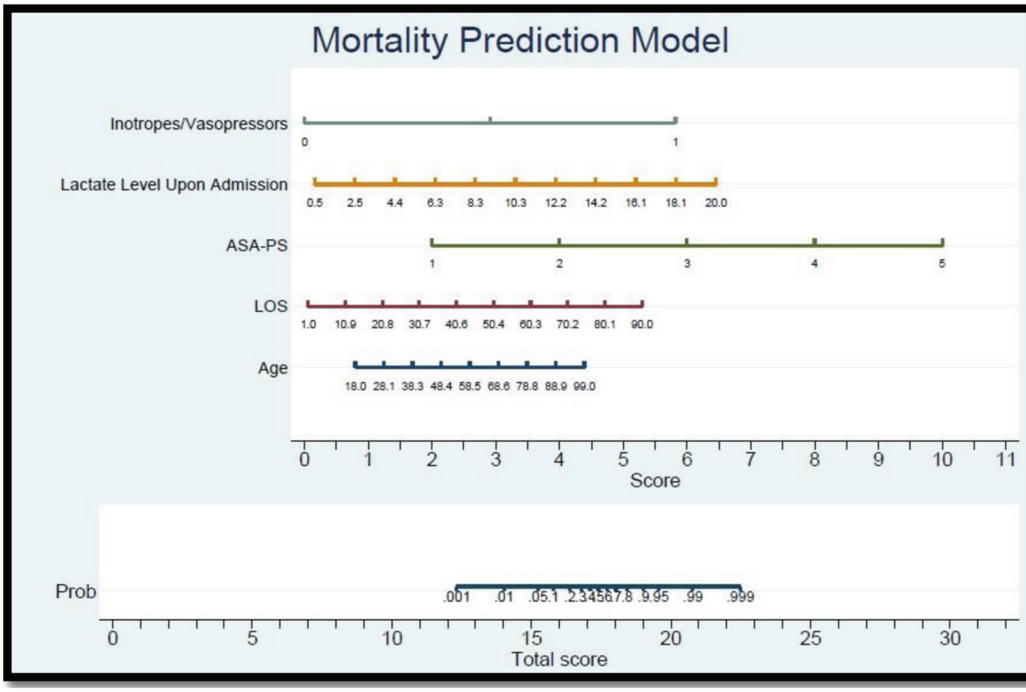
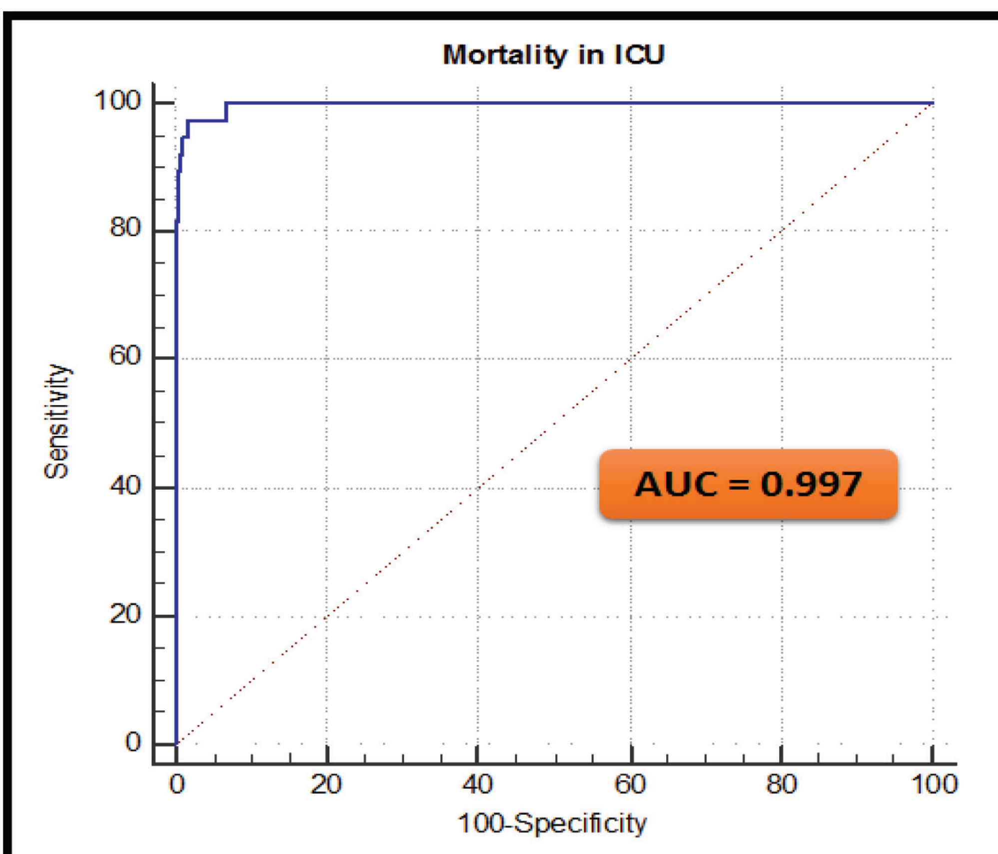



*Fig. 2*
*Receiver operator curve analysis of the mortality prediction model after surgery*



## Discussion

Our documented mortality rate was 5.1% which is consistent with the findings of the European 7 day cohort study for postoperative mortality in which the latter ranged from 1.2% to 21.5%[17]. We found that age was a significant mortality which is in accordance with published series, although with varying end-points, patients' characteristics and following different type of surgical procedures[18-20]. Longer ICU LOS was another significant mortality predictor in our study as others also reported[21]. We identified a higher ASA-PS to be a strong predictor of postoperative mortality which is consistent with previously published literature[21-23]. Notably, in a recent study the risk of mortality was increased by 6.4 for every 1-point increase in the ASA-PS[24]. Increased serum lactate, upon ICU admission, was a significant mortality predictor in our study. The former was reported to be significantly increased postoperatively in non-survivors of cardiac surgery as well as following colorectal perforation and head/neck cancer surgeries[24-26]. We found that the administration of vasoactive substances intraoperatively was an important mortality predictor, similarly, inotropic exposure intra-operatively was associated with hospital mortality in a study following cardiac surgery[27], and with 30-day mortality in non-cardiac surgery patients[28]. Other studies have reported male gender and urgency of the surgical procedure as postoperative mortality predictors in various cohorts following mainly colorectal cancer surgery and cardiac surgery[17,20,29,30]. The aforementioned predictors were not linked to mortality in this study may be due to our smaller in size cohort and its distinct features (i.e., we did not study any cardiac surgery cases).

Notably, low preoperative serum albumin (less than 30 gm/L) was found to be an important mortality predictor with reported odds ratios ranging from 2.1 to 2.23 in other series [19,30]; however, we failed to confirm the aforementioned reports hereby. Moreover, type of surgery was not linked to mortality in our report; whereas other authors showed that it might be pertinent[31].

This study has many limitations mainly due to its inherent nature and the retrospective manner of data collection and analysis. Also, the size of our cohort was smaller compared to other series. Despite the aforementioned limitations, the current study provided evidence that age, ASA-PS, ICU LOS, postoperative serum lactate, and intraoperative exposure to vasoactive substances were strong predictors of postoperative mortality in the ICU. Thus, our featured model for predicting mortality after surgery correctly identified 98.8% of the patients' outcome baring an AUC of 0.997. Larger prospective studies are clearly required in search of a robust model for predicting mortality after surgery.

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