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ORIGINAL ARTICLE / ÖZGÜN MAKALE

# CASUS and APACHE II score in predicting mortality after coronary artery bypass grafting

*Koroner arter baypas greftleme sonrası mortaliteyi öngörmede CASUS ve APACHE II skoru*

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***ABSTRACT***

***Background:*** This study aims to compare Cardiac Surgery Score (CASUS) and the Acute Physiology and Chronic Health Evaluation (APACHE II) scoring systems for predicting mortality in patients undergoing isolated coronary artery bypass grafting.

***Methods:*** Between January 2019 and March 2019, a total of 204 patients (166 males, 38 females; mean age: 60.5±0.7 years; range, 59.2 to 61.9 years) who underwent isolated coronary artery bypass grafting and were monitored at least for 24 h in the intensive care unit postoperatively were included. Pre-, intra-, and postoperative data were recorded. The CASUS and APACHE II scores were calculated using the most abnormal values for each variable during the first 24 h, postoperatively. Clinical outcomes were seven-day mortality and 30-day mortality, need for reintubation, readmission to the intensive care unit, length of intensive care unit stay and length of hospital stay.

***Results:*** The 30-day overall mortality was 4.9% (n=10). The CASUS scores were significantly higher for patients developing mortality within 30 days postoperatively (p=0.030) and for patients needing reintubation (p=0.003). In the receiver operating characteristic curve analysis predicting seven-day mortality and prolonged intensive care unit stay, the area under curve was higher for CASUS scoring compared to APACHE II (0.90 *vs*. 0.72 and 0.82 *vs*. 0.76).

***Conclusion:*** The CASUS may prove to be a more reliable scoring system than APACHE II for predicting mortality and morbidity in patients undergoing isolated coronary artery bypass grafting.

***Keywords:*** APACHE II, cardiac surgery, CASUS, mortality.

***ÖZ***

***Amaç:*** Bu çalışmada izole koroner arter baypas greftleme yapılan hastalarda mortalitenin öngörülmesinde Kalp Cerrahisi Skoru (CASUS) ve Akut Fizyoloji ve Kronik Sağlık Değerlendirmesi (APACHE II) skorlama sistemleri karşılaştırıldı.

***Çalışma planı:*** Ocak 2019 - Mart 2019 tarihleri arasında izole koroner arter baypas greftleme yapılan ve ameliyat sonrası yoğun bakım ünitesinde en az 24 saat süreyle izlenen toplam 204 hasta (166 erkek, 38 kadın; ort. yaş: 60.5±0.7 yıl; dağılım, 59.2-61.9 yıl) çalışmaya alındı. Ameliyat öncesi, sırası ve sonrası veriler kaydedildi. CASUS ve APACHE II skorları, ameliyattan sonra ilk 24 saat içinde her değişken için en anormal değerler kullanılarak hesaplandı. Klinik sonuçlar yedi günlük ve 30 günlük mortalite, yeniden entübasyon ihtiyacı, yoğun bakım ünitesine yeniden yatış, yoğun bakım ünitesinde kalış süresi ve hastanede kalış süresi idi.

***Bulgular:*** Otuz günlük genel mortalite %4.9 idi (n=10). Ameliyat sonrası 30 gün içinde mortalite gelişen hastalarda (p=0.030) ve yeniden entübasyon ihtiyacı olan hastalarda (p=0.003) CASUS skorları anlamlı olarak daha yüksekti. Yedi günlük mortalite ve uzun süreli yoğun bakım ünitesinde kalış süresini öngören alıcı işletim karakteristik eğri analizinde, eğri altında kalan alan APACHE II'ye kıyasla CASUS için daha yüksekti (0.72'ye kıyasla 0.90 ve 0.76'ya kıyasla 0.82).

***Sonuç:*** CASUS, izole koroner arter baypas greftleme yapılan hastalarda mortalite ve morbiditeyi öngörmede APACHE II'den daha güvenilir bir skorlama sistemi olabilir.

***Anahtar sözcükler:*** APACHE II, kalp cerrahisi, CASUS, mortalite.

The reliability of most scoring systems, including the Sequential Organ Failure Assessment (SOFA), the Acute Physiology and Chronic Health Evaluation (APACHE) II, has been validated for patients in general intensive care units (ICUs). Therefore, using these scoring systems may not be reliable for patients undergoing cardiac surgery in the postoperative period. Evaluation of patients undergoing cardiac surgery without considering the factors such as transient biochemical and hemodynamic changes caused by

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cardiopulmonary bypass (CPB), intraaortic balloon pump (IABP), ventricular assist device (VAD), and hemofiltration may be misleading.[1] However, the scoring systems developed for cardiac surgery patients are not widely used.

Cardiac Surgery Score (CASUS) is a prognostic scoring system developed for cardiac surgery patients (Table 1). It is a simple model in which a failure of six organ systems is scored, which allows to gain total number of these points (Additive CASUS).

In the present study, we aimed to compare the reliability of Additive CASUS and APACHE II in predicting mortality and morbidity in patients undergoing isolated coronary artery bypass grafting (CABG).

## PATIENTS AND METHODS

This single-center prospective, observational study was conducted at Cardiac Surgery ICU of a tertiary care center which has 45 beds between January 1st, 2019 and March 10th, 2019. The study included a total of 204 patients (166 males, 38 females; mean age: 60.5±0.7 years; range, 59.2 to 61.9 years) who underwent isolated CABG and were monitored at least for 24 h in the ICU postoperatively. Patients who underwent emergency surgery were excluded.

Both preoperative data including age, sex, body mass index, comorbidities, ejection fraction (EF), the European System for Cardiac Operative Risk (EuroSCORE) values and the durations of both CPB and cross-clamp were recorded. Additive CASUS and APACHE II score were calculated for each patient using the most abnormal values within the first 24 h postoperatively. To avoid possible inconsistencies and missing data, all data were collected by a single physician and were checked periodically by the physician attending ICU.

Clinical outcomes were determined as postoperative morbidity and mortality. Mortality was defined as early mortality within postoperative seven days and late mortality within postoperative 30 days, in-hospital or out-of-hospital. Morbidity indicators were described as the length of both ICU and hospital stay, reintubation, ICU readmission, and prolonged postoperative ICU stay >48 h.

Patients who died intraoperatively or in the first postoperative 24 h were excluded. We evaluated only the first postoperative ICU admission among patients who were re-admitted to the ICU. Postoperative IABP, VAD, renal replacement therapy (RRT), extracorporeal membrane oxygenation (ECMO) support, cardiac arrest, revision surgery and other complications were recorded.

### Statistical analysis

Statistical analysis was performed using the SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in mean ± standard deviation (SD), while categorical variables were expressed in median and interquartile range (IQR) or number and frequency. The Student t-test was used for normally distributed numerical variables comparing survivors and non-survivors. The Mann-Whitney U test for non-normally distributed numerical variables and chi-square

**Table 1. Additive Cardiac Surgery Score (CASUS)**

| | 0 Point | 1 Point | 2 Points | 3 Points | 4 Points |
|---|---|---|---|---|---|
| $PaO_2/FiO_2$ (mmHg/%) | Extubated | >250 | 151-250 | 75-150 | <75 |
| Serum creatinine (mg/dL) | <1.2 | 1.2-2.2 | 2.3-4 | 4.1-5.5 | >5.5 |
| Serum bilirubin (mg/dL) | <1.2 | 1.2-3.5 | 3.6-7.0 | 7.1-14 | >14 |
| PAR=HR* CVP / MAP | <10 | 10.1-15.0 | 15.1-20 | 20.1-30 | >30 |
| Lactic acid (mmol/L) | <2.1 | 2.1-4.0 | 4.1-8.0 | 8.1-12 | >12 |
| Platelets × $10^3/\mu L$ | >120 | 81-120 | 51-80 | 21-50 | <21 |
| Neurologic state | Normal | - | Confused | Sedated | Diffuse neuropathy |
| Intraaortic balloon pump (IABP) | No | - | - | - | Yes |
| Ventricular assist device (VAD) | No | - | - | - | Yes |
| CVVH/dialysis | No | - | - | - | Yes |

PAR: The pressure adjusted heart rate; HR: Heart rate; CVP: Central venous pressure; MAP: Mean arterial pressure; CVVH: Continuous veno-venous hemofiltration; $PaO_2/FiO_2$, the ratio of arterial $pO_2$ to fractional inspired oxygen concentration.

**Table 2. Comparison of data between survivors and non-survivors**

| | All patients | | | | | | Survivors | | | | | | Non-survivors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | Mean±SD | Median | Range | IQR | n | % | Mean±SD | Median | Range | IQR | n | % | Mean±SD | Median | Range | IQR | *p* |
| Age (year) | | | 60.5±0.7 | | | | | | 60.5±0.7 | | 59.1-61.9 | | | | 61.4±3.9 | | 52.7-70.1 | | 0.777 |
| Sex (frequency) | | | | | | | | | | | | | | | | | | | |
| Male | 166 | 81.4 | | | | | 157 | 76.9 | | | | | 9 | 90 | | | | | 0.692 |
| Body mass index | | | 28.0±0.3 | | | | | | 28.1±0.3 | | 27.5-28.8 | | | | 26.2±0.9 | | 24.2-28.1 | | 0.180 |
| Ejection fraction (%) | | | 51.1±0.7 | | | | | | 51.6±0.7 | | 50.3-52.9 | | | | 40.5±4.4 | | 30.6-50.4 | | 0.001* |
| Comorbidity | | | | | | | | | | | | | | | | | | | 0.472 |
| 0 | 58 | | | | | 28.4 | 57 | | | | | 29 | 1 | | | | | 10 | |
| 1 | 87 | | | | | 42.6 | 81 | | | | | 41.8 | 6 | | | | | 60 | |
| 2 | 51 | | | | | 25.0 | 48 | | | | | 24.7 | 3 | | | | | 30 | |
| >2 | 8 | | | | | 3.9 | 8 | | | | | 4.1 | 0 | | | | | 0 | |
| EuroSCORE | | | | 2 | 0-9 | | | | | 2 | 0-9 | 3 | | | | 3.5 | 0-5 | 2.25 | 0.156 |
| CPB time (min) | | | 107.2±2.5 | | 102.3-112.1 | | | | 106.0±2.4 | | 101.3-110.7 | | | | 130.8±21.9 | | 81.2-180.4 | | 0.289 |
| Cross-clamp time (min) | | | 66.4±2.0 | | 62.6-70.3 | | | | 185±95.4 | | 62.1-70.0 | | | | 74.3±9.7 | | 52.3-96.3 | | 0.363 |
| Extubation within 24 h, frequency | 191 | 93.6 | | | | 185 | 95.4 | | | | | | 6 | 60 | | | | | 0.002* |
| Reintubation, frequency | 17 | 8.3 | | | | 10 | 5.2 | | | | | | 7 | 70 | | | | | 0.001* |
| ICU readmission, frequency | 20 | 9.8 | | | | 14 | 7.2 | | | | | | 6 | 60 | | | | | 0.001* |
| ICU stay (h) | | | 45.5±4.9 | | 35.8-55.3 | | | | 40.4±4.5 | | 31.5-49.3 | | | | 144.6±39.6 | | 55.0-234.2 | | 0.028* |
| Hospital stay (h) | | | 213.9±11.1 | | 192.0-235.8 | | | | 209.8±11.2 | | 187.8-231.8 | | | | 294.1±64.5 | | 148.1-440.1 | | 0.101 |
| APACHE II | | | | 9 | 2-29 | | | | 9±4 | 9 | 2-26 | 4 | | | 10.5±6.5 | 10.5 | 7-29 | 6.5 | 0.051 |
| CASUS | | | | 3 | 0-17 | | | | | 2.5 | 0-17 | 2.25 | | | | 5 | 1-17 | 12 | 0.030* |
| Revision surgery, frequency | 23 | 11.3 | | | | | 18 | 9.3 | | | | | 5 | 50 | | | | | 0.002* |
| Cardiac arrest, frequency | 13 | 6 | | | | | 3 | 1.5 | | | | | 10 | 100 | | | | | 0.001* |
| ECMO, frequency | 2 | 1.0 | | | | | 1 | 0.5 | | | | | 1 | 10 | | | | | 0.096 |
| IABP, frequency | 11 | 5.4 | | | | | 7 | 3.6 | | | | | 4 | 40 | | | | | 0.001* |
| RRT, frequency | 5 | 2.5 | | | | | 1 | 0.5 | | | | | 4 | 40 | | | | | 0.001* |

SD: Standard deviation; IQR: Interquartile range; EuroSCORE: European System for Cardiac Operative Risk; CPB: Cardiopulmonary bypass; ICU: Intensive care unit; APACHE II: Acute Physiology and Chronic Health Evaluation; CASUS: Cardiac Surgery Score; ECMO: Extracorporeal membrane oxygenation; IABP: Intraaortic balloon pump; RRT: Renal replacement therapy; * p<0.05.

test for categorical variables were used. Univariate logistic regression analyses were performed including independent variables regarding 30-day and seven-day mortality as a dependent variable. Multivariate logistic regression analyses were carried out to identify statistically significant risk factors. Receiver operating characteristic (ROC) analyses were performed with the results of three scoring systems regarding the postoperative 30-day and seven-day mortality. The discrimination power of the area under the curve (AUC) of <0.70 was considered insignificant, 0.70-0.79 acceptable, 0.80-0.89 good, ≥0.90 superior. A *p* value of <0.05 was considered statistically significant.

## RESULTS

The 30-day mortality was 4.9% (n=10). Table 2 shows preoperative, intraoperative and postoperative data comparing survivors and non-survivors. There was a significant difference in preoperative EF between survivors and non-survivors within 30 days postoperatively (p=0.0001). It was significantly lower in non-survivors.

The mean duration was 107.2±2.5 min for CPB and 66.4±2.0 min for cross-clamp, and there was no significant difference in CPB and cross-clamp times between survivors and non-survivors (p=0.289 and p=0.363, respectively).

The mean duration was 45.5±4.9 h for ICU stay and 213.9±11.1 h for hospital stay. Of 204 patients, 191 (93.6%) patients were extubated within the first 24 h postoperatively: 17 (8.3%) patients were reintubated and 20 (9.8%) patients needed readmission to the ICU. Among the patients who died within 30 days postoperatively, the rate of extubation at 24 h postoperatively was significantly lower (p=0.002), duration of ICU stay was significantly longer (p=0.028), rates of reintubation and readmission to the ICU, as well as CASUS scores were significantly higher (p=0.0001, p=0.0001 and p=0.03, respectively). Rates of revision surgery, cardiac arrest, IABP implantation and RRT were significantly higher in patients who died within postoperative 30 days (p=0.002, p=0.0001, p=0.001 and p=0.0001, respectively).

The odds ratios of CASUS and APACHE II were significant regarding seven-day and 30-day mortality (1.36 *vs*. 1.26 and 1.23 *vs*. 1.17) in the univariate logistic regression analysis (Table 3). The odds ratio of CASUS was observed higher regarding both seven-day and

**Table 3. The univariate logistic regression analysis in terms of 7-day mortality and 30-day mortality**

| | Omnibus tests | | | | Hosmer and Lemeshow test | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | OCC % | Model coefficients | Sig *(p)* | Nagelkerke R square | Chi-square | df | *p* | OR | 95% CI |
| 7-day mortality | | | | | | | | | |
| CASUS | 98 | 9.626 | 0.002* | 0.263 | 9.513 | 5 | 0.090 | 1.361 | 1.125-1.646 |
| APACHE II | 98,5 | 7.258 | 0.007* | 0.199 | 7.363 | 7 | 0.392 | 1.260 | 1.076-1.476 |
| EuroSCORE | 98 | 0.4464 | 0.496 | | 6.292 | 5 | 0.279 | 1.173 | 0.749-1.837 |
| 30-day mortality | | | | | | | | | |
| CASUS | 95.1 | 0.005 | 0.005 | 0.118 | 5.030 | 5 | 0.412 | 1.227 | 1.076-1.399 |
| APACHE II | 95.1 | 0.018 | 0.018 | 0.084 | 2.654 | 7 | 0.915 | 1.166 | 1.035-1.313 |
| EuroSCORE | 95.1 | 0.308 | 0.308 | 0.016 | 4.864 | 5 | 0.433 | 1.168 | 0.872-1.562 |
| Age | 95.1 | 0.775 | 0.775 | 0.001 | 10.352 | 8 | 0.241 | 1.01 | 0.946-1.077 |
| Sex | 95.1 | 0.441 | 0.441 | 0.009 | | | | 0.471 | 0.058-3.838 |
| Comorbidity | 95.1 | 0.546 | 0.546 | 0.006 | 1.671 | 1 | 0.196 | 1.262 | 0.596-2.67 |
| Ejection fraction | 95.1 | 0.001 | 0.001* | 0.151 | 4.687 | 5 | 0.455 | 0.911 | 0.861-0.965 |
| CPB time | 95.1 | 0.057 | 0.057 | 0.054 | 10.278 | 8 | 0.246 | 1.014 | 1.001-1.028 |
| Cross-clamp time | 95.1 | 0.385 | 0.385 | 0.011 | 5.997 | 8 | 0.648 | 1.009 | 0.989-1.029 |

OCC: Overall correct classification; OR: Odds ratio; CI: Confidence interval; CASUS: Cardiac Surgery Score; APACHE II: Acute Physiology and Chronic Health Evaluation; EuroSCORE: European System for Cardiac Operative Risk; * p<0.05.

**Table 4. The ROC curve analysis of EuroSCORE, CASUS and APACHE II score in terms of 7-day mortality and 30-day mortality**

| | AUC | 95% CI | The best cut-off value | Sensitivity % | Specificity % |
|---|---|---|---|---|---|
| 7-day mortality | | | | | |
| EuroSCORE | 0.624 | 0.315-0.934 | 3.5 | 75 | 70 |
| APACHE II | 0.721 | 0.449-0.993 | 18.5 | 50 | 98 |
| CASUS | 0.909 | 0.823-0.995 | 4.5 | 100 | 81 |
| 30-day mortality | | | | | |
| EuroSCORE | 0.631 | 0.480-0.782 | 1.5 | 90 | 37.1 |
| APACHE II | 0.682 | 0.529-0.835 | 8.5 | 80 | 45.4 |
| CASUS | 0.700 | 0.515-0.884 | 4.5 | 60 | 81.4 |

ROC: Receiver operating characteristic; EuroSCORE: European System for Cardiac Operative Risk; CASUS: Cardiac Surgery Score; APACHE II: Acute Physiology and Chronic Health Evaluation; AUC: Area Under the Curve; CI: Confidence interval.

30-day mortality than that of APACHE II. In the ROC analysis, the highest AUC (0.700) was found in the CASUS for 30-day mortality (Table 4 and Figure 1), the highest AUC (0.909) in the CASUS for seven-day mortality (Table 4 and Figure 2).

To predict mortality more precisely, we also performed multivariate analyses using CASUS and the parameters that were found significant in the univariate logistic regression analyses, including EF, APACHE II, and CPB time (Table 5). When CASUS, APACHE II, EF and CPB time were evaluated combined, the correct classification rate was up to 96.1%. The Hosmer-Lemeshow test results yielded a p value of 0.018, which showed that there was a significant difference between predicted and observed results.

The association of scoring systems with morbidity was evaluated considering reintubation, length of stay in the ICU and readmission to the ICU (Table 6). The CASUS score was significantly higher in patients requiring reintubation (p=0.003). The CASUS and APACHE II scores at postoperative 24 h were significantly higher in patients staying in

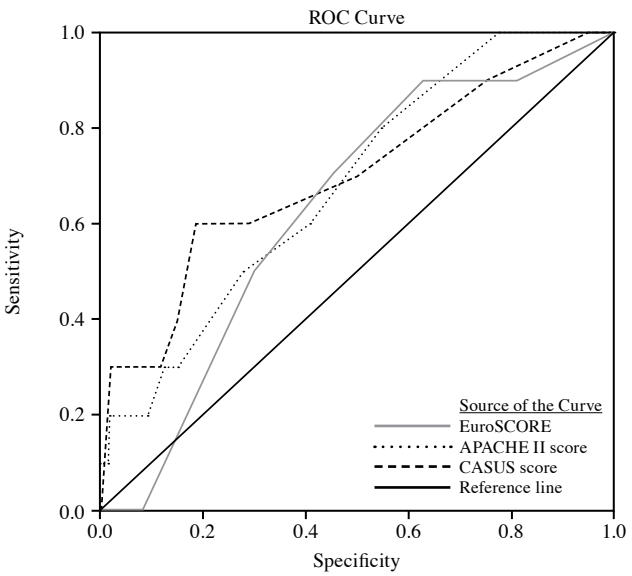


**Figure 1.** ROC of EuroSCORE, CASUS and APACHE II score concerning 30-day mortality.

ROC: Receiver operating characteristic; EuroSCORE: European System for Cardiac Operative Risk; APACHE II: Acute Physiology and Chronic Health Evaluation; CASUS: Cardiac Surgery Score.

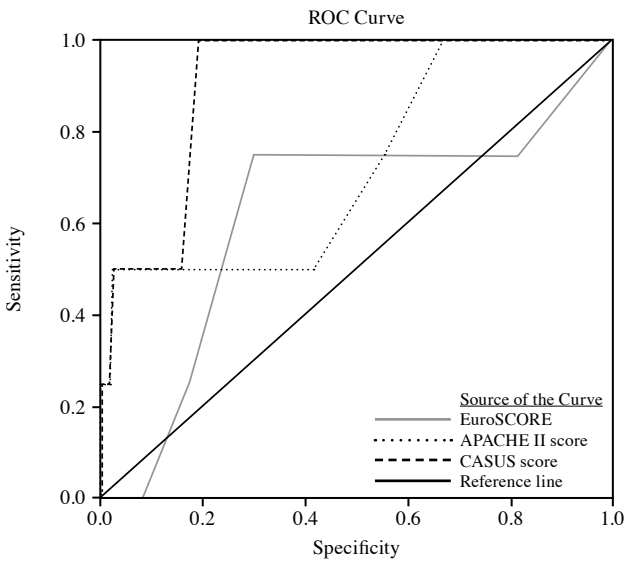


**Figure 2.** ROC of EuroSCORE, CASUS and APACHE II score concerning 7-day mortality.

ROC: Receiver operating characteristic; EuroSCORE: European System for Cardiac Operative Risk; APACHE II: Acute Physiology and Chronic Health Evaluation; CASUS: Cardiac Surgery Score.

**Table 5. The multivariate logistic regression analysis in terms of 30-day mortality**

| | Omnibus tests | | | | Hosmer and Lemeshow test | | |
|---|---|---|---|---|---|---|---|
| | OCC % | Model coefficients | Sig *(p)* | Nagelkerke R square | Chi-square | df | *p* |
| CASUS<br>APACHE II | 95.1 | 8.398 | 0.015 | 0.125 | 4.423 | 8 | 0.817 |
| CASUS<br>APACHE II<br>Ejection fraction | 95.1 | 15.367 | 0.002 | 0.224 | 7.259 | 8 | 0.509 |
| CASUS<br>APACHE II<br>CPB time | 95.6 | 9.861 | 0.020 | 0.146 | 20.73 | 8 | 0.008 |
| CASUS<br>APACHE II<br>CPB time<br>Ejection fraction | 96.1 | 16.13 | 0.003 | 0.235 | 18.459 | 8 | 0.018 |

OCC: Overall correct classification; CASUS: Cardiac Surgery Score; APACHE II: Acute Physiology and Chronic Health Evaluation; CPB: Cardiopulmonary bypass; * p<0.05.

the ICU >48 h (p=0.001 and p=0.001, respectively). In the ROC analysis of ICU stay, AUC was 0.828 for CASUS and 0.767 for APACHE II (Figure 3).

## DISCUSSION

Our study showed that CASUS had a very good performance with respect to seven-day mortality with an acceptable performance regarding 30-day mortality in patients undergoing isolated CABG and it was superior to APACHE II in terms of predicting both seven-day and 30-day mortality. In addition, CASUS was also practical for morbidity prediction, including reintubation and prolonged ICU stay. The APACHE II was helpful only for predicting prolonged ICU stay, but not reintubation. The CASUS better discriminated patients who stayed in the ICU longer than 48 h than

**Table 6. Comparison of scoring systems in terms of predicting morbidity**

| | No | | Yes | | |
|---|---|---|---|---|---|
| | Mean±SD | Median | Mean±SD | Median | *p* |
| Reintubation | | | | | |
| CASUS | 3.20±2.90 | 2.00 | 6.41±4.79 | 5.00 | 0.003* |
| APACHE II | 9.26±3.47 | 9.00 | 1211±6.67 | 10.00 | 0.467 |
| EuroSCORE | 2.51±2.02 | 2.00 | 2.38±2.14 | 3.00 | 0.397 |
| Length of ICU stay | | | | | |
| CASUS | 2.59±1.75 | 2.00 | 8.15±4.88 | 8.00 | 0.001* |
| APACHE II | 8.71±2.97 | 8.00 | 13.05±5.39 | 12.00 | 0.001* |
| EuroSCORE | 2.51±2.05 | 2.00 | 2.67±1.91 | 3.00 | 0.372 |
| Readmission to the ICU | | | | | |
| CASUS | 3.31±2.98 | 3.00 | 4.90±4.72 | 3.50 | 0.080* |
| APACHE II | 9.35±3.80 | 9.00 | 10.80±4.57 | 10.00 | 0.301 |
| EuroSCORE | 2.54±2.05 | 2.00 | 2.50±1.79 | 3.00 | 0.544 |

SD: Standard deviation; CASUS: Cardiac Surgery Score; APACHE II: Acute Physiology and Chronic Health Evaluation; EuroSCORE: European System for Cardiac Operative Risk; * p<0.05.

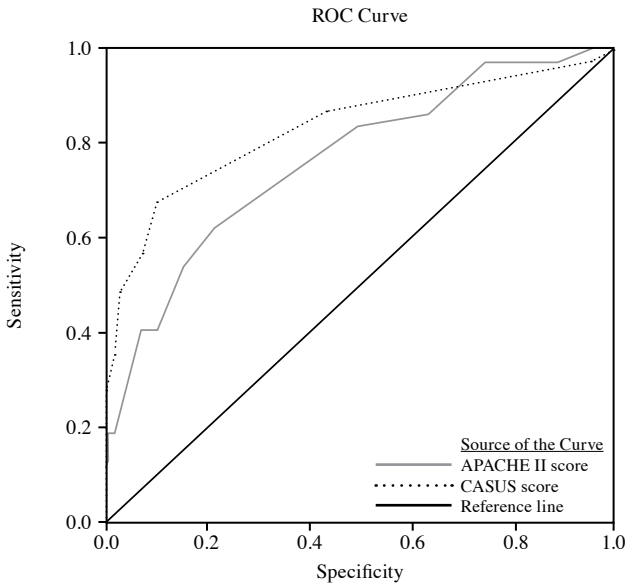


**Figure 3.** ROC of CASUS and APACHE II concerning ICU stay.

ROC: Receiver operating characteristic; EuroSCORE: European System for Cardiac Operative Risk; APACHE II: Acute Physiology and Chronic Health Evaluation; CASUS: Cardiac Surgery Score.

APACHE II. These results suggest that additive CASUS may prove to be a more reliable scoring system than APACHE II for predicting mortality and morbidity in patients undergoing isolated CABG. Considering the results related to need for reintubation after surgery as well as length of ICU stay, we propose CASUS may also guide to predict morbidity.

Scoring systems common in ICUs were designed regardless of cardiac surgery patients; however, the reliability of APACHE II and SOFA for cardiac surgery patients has been proven.[2,3] The use of APACHE II and EuroSCORE were moderately beneficial to predict mortality after cardiac surgery.[2] A retrospective study involving 40 patients by Kartufan and Karaoğlu[3] reported that SOFA scores on the first postoperative day were significant and discriminated well to predict mortality (from 60 days to 1 year) after cardiac surgery. However, there are studies reporting that scores, including APACHE II, SOFA, the Simplified Acute Physiology Score (SAPS) II, Multiple Organ Dysfunction Score (MODS) were less accurate than CASUS.[4-7] Doerr et al.[4] reported that, of four scoring systems (CASUS, APACHE II, SAPS II and SOFA), CASUS and SOFA were reliable in predicting the mortality risk; and CASUS had the best discrimination among patients undergoing cardiac surgery. Exarchopoulos et al.[5] compared EuroSCORE II, CASUS, APACHE II, SAPS II and SOFA at the postoperative 24 h in predicting 30-day mortality and morbidity among cardiac surgery patients and found that CASUS had the best calibration and discrimination. Hekmat et al.[6] compared CASUS, APACHE II and MODS at postoperative 0 to five days after cardiac surgery in predicting mortality and reported that CASUS had a good calibration and the best discrimination for each day. Badreldin et al.[7] reported that CASUS and SOFA were reliable in predicting mortality among cardiac surgery patients and that CASUS predicted mortality more accurately. Badreldin et al.[8] in another study, identified that CASUS was eligible for daily scoring and could be used up to the sixth postoperative day. This study showed, consistent with previous studies, CASUS had very good discrimination regarding seven-day mortality, while the APACHE II did not. Our study may contribute to the utilization of additive CASUS more commonly in daily practice.

Logistic CASUS (logCASUS) was established integrating the number of ICU days into additive CASUS, which improved the prediction of mortality.[9] However, the calibration of the logCASUS was poor and the predicted and observed mortality were more consistent after recalibration.[10-12] In a comprehensive retrospective study by Wilson et al.,[10] logCASUS was shown to overpredict mortality after cardiac surgery and the expected and observed mortality were comparable after recalibration. However, Singh et al.[11] reported in their retrospective study with 7,098 patients that logCASUS underpredicted mortality compared with additive CASUS after cardiac surgery. The Rapid Clinical Evaluation (RACE), logCASUS and SOFA had good discrimination but poor calibration in predicting mortality after cardiac surgery. The logCASUS and RACE performed better after recalibration.[12] Changing treatment approaches and improvement in patient care may have highlighted need for recalibration. We used additive CASUS due to short ICU stay. Both additive CASUS and logCASUS predicted 30-day mortality well, and they had good discrimination.[11]

In the present cross-sectional study, the rate of mortality was higher than the expected rate, as was the need for IABP. While including patients in the study, we did not take account of preoperative EF values of patients. The non-survivors included in the study had significantly low preoperative EF, which may result in high mortality rates. In our study, age was found not to be a predictor for mortality, despite being a risk factor for open heart surgery. This was a finding consistent with the study conducted during the development of CASUS and that was likely to

be related to the criteria for patient selection for surgery.[1] In the current study, preoperative EF was a predictor of mortality, while the duration of CPB was not. Madhavan et al.[13] examined patients undergoing isolated CABG, and reported that the total duration of CPB longer than 180 min was associated with increased postoperative complications. The duration of CPB was not a predictor for mortality in our study. It may be explained by the average duration of CPB <180 min.

Based on our study results, the EuroSCORE was not reliable in predicting 30-day mortality, which can be explained by the fact that parameters evaluating intraoperative and postoperative events are not included in EuroSCORE and the EuroSCORE consists of only the preoperative parameters. With experience gained over the years when logistic models were used, the EuroSCORE was updated as EuroSCORE II due to its overestimation of mortality.

Long-term ICU stay is associated with both operative and postoperative complications and it is also a predictor of morbidity and mortality. However, the definition of prolonged ICU stay after cardiac surgery is controversial, varying from 24 h to 14 days after ICU admission.[9] This study described prolonged postoperative ICU stay as longer than 48 h. The CASUS and APACHE II in the first 24 h postoperatively were significantly higher in patients with ICU stay longer than 48 h. In the ROC analysis regarding prolonged ICU stay, the CASUS showed a good discrimination, while APACHE II showed an acceptable discrimination. According to the current study, the CASUS can be used to predict prolonged ICU stay as it was previously reported.[5]

The CASUS, Intensive Care National Audit and Research Centre Score (ICNARC), APACHE II, and logistic EuroSCORE were compared and the CASUS was the best predictor of 30-day mortality. The ICNARC was superior to CASUS in predicting renal and pulmonary complications.[14] As compared with CASUS, ICNARC uses further data including age, a history of cardiopulmonary resuscitation before admission, cause of admission, urgent admission, as well as physiological parameters. The CASUS can more accurately predict mortality than other scoring systems. Using more data does not mean the prediction of mortality is more accurate. Moreover, optimal variables should be straightforward, repeatable and readily available. CASUS, comprising 10 variables, is more easily performed than the APACHE II and ICNARC.

Comparing CASUS and EuroSCORE, CASUS at 24 h postoperatively was not significant in predicting 30 day-mortality, despite its scores being higher in non-survivors.[15] This result may be related to the small sample size and the heterogeneity of the patient group.

The original study and most validation studies on CASUS were conducted in Germany. External validation studies were conducted long after the original study, being limited in numbers. Therefore, validation studies are required in diverse populations. Nonetheless, clinicians may benefit from CASUS in many ways in which they are able to explain the severity of the disease to patients and to their caregivers by predicting the mortality and morbidity more accurately as well as constructing a treatment plan. The CASUS can also be benefited to standardize research, to compare treatment modalities, to evaluate quality of care in the ICUs and to compare ICUs with each other, to provide proper use of ICU resources. Moreover, it is a practical evaluation method taking a few minutes in daily routine.

As the study was performed in a single center with small sample size, its results cannot be generalized. The CASUS and APACHE II were scored only for the first postoperative 24 h. Short ICU stay made it impossible to collect and evaluate data on the second and following days postoperatively.

In conclusion, the CASUS is more reliable than APACHE II in predicting mortality and morbidity among patients undergoing isolated coronary artery bypass grafting. Developed specifically for cardiac surgery patients, CASUS performs better, substantiating our main hypothesis. To predict mortality more accurately, further comprehensive studies evaluating patients undergoing a variety of open hearth surgeries are required with increasing number of patients and centers. Additional studies can be performed using logistic scoring systems to predict mortality for prolonged intensive care unit stay. We believe that CASUS should be widely used to obtain robust data for prediction of mortality and postoperative complications in centers where cardiac surgery is performed.

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**Ethics Committee Approval:** Haydarpaşa Numune Training and Research Hospital Clinical Research Ethics Committee, İstanbul (Chairperson Prof Ç. Nuhoğlu) approved this study (Ethical Committee Number 2018/91) on 17 December, 2018. The study was conducted in accordance with the principles of the Declaration of Helsinki.

**Patient Consent for Publication:** As the current study required only collecting the data, the Hospital Clinical Research Ethics Committee confirmed that informed consent from the patients were not warranted.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## REFERENCES

1. Hekmat K, Kroener A, Stuetzer H, Schwinger RH, Kampe S, Bennink GB, et al. Daily assessment of organ dysfunction and survival in intensive care unit cardiac surgical patients. Ann Thorac Surg 2005;79:1555-62. doi: 10.1016/j.athoracsur.2004.10.017.
2. Yalçın M, Gödekmerdan E, Tayfur K, Yazman S, Ürkmez M, Ata Y. The APACHE II score as a predictor of mortality after open heart surgery. Turk J Anaesthesiol Reanim 2019;47:41-7. doi: 10.5152/TJAR.2018.44365.
3. Kartufan FF, Karaoğlu K. Mortality after cardiac surgery; a comparison of BNP, EuroSCORE and SOFA Score. GKD Anest Yoğ Bak Dern Derg 2018;24:111-7. doi: 10.5222/GKDAD.2018.06978.
4. Doerr F, Badreldin AM, Heldwein MB, Bossert T, Richter M, Lehmann T, et al. A comparative study of four intensive care outcome prediction models in cardiac surgery patients. J Cardiothorac Surg 2011;6:21. doi: 10.1186/1749-8090-6-21.
5. Exarchopoulos T, Charitidou E, Dedeilias P, Charitos C, Routsi C. Scoring systems for outcome prediction in a cardiac surgical intensive care unit: A comparative study. Am J Crit Care 2015;24:327-34. doi: 10.4037/ajcc2015500.
6. Hekmat K, Doerr F, Kroener A, Heldwein M, Bossert T, Badreldin AM, et al. Prediction of mortality in intensive care unit cardiac surgical patients. Eur J Cardiothorac Surg 2010;38:104-9. doi: 10.1016/j.ejcts.2010.01.053.
7. Badreldin AM, Doerr F, Ismail MM, Heldwein MB, Lehmann T, Bayer O, et al. Comparison between Sequential Organ Failure Assessment score (SOFA) and Cardiac Surgery Score (CASUS) for mortality prediction after cardiac surgery. Thorac Cardiovasc Surg 2012;60:35-42. doi: 10.1055/s-0030-1270943.
8. Badreldin AM, Kroener A, Heldwein MB, Doerr F, Vogt H, Ismail MM, et al. Prognostic value of daily cardiac surgery score (CASUS) and its derivatives in cardiac surgery patients. Thorac Cardiovasc Surg 2010;58:392-7. doi: 10.1055/s-0030-1250080.
9. Doerr F, Heldwein MB, Bayer O, Sabashnikov A, Weymann A, Dohmen PM, et al. Inclusion of 'ICU-Day' in a logistic scoring system improves mortality prediction in cardiac surgery. Med Sci Monit Basic Res 2015;21:145-52. doi: 10.12659/MSMBR.895003.
10. Wilson B, Tran DTT, Dupuis JY, McDonald B. External validation and updating of the cardiac surgery score for prediction of mortality in a cardiac surgery intensive care unit. J Cardiothorac Vasc Anesth 2019;33:3028-34. doi: 10.1053/j.jvca.2019.03.066.
11. Singh A, Liang C, Mick SL, Udeh C. External validation of the cardiac surgery score in a quaternary hospital in the United States of America. J Intensive Care Med 2022;37:1318-27. doi: 10.1177/08850666211066820.
12. Howitt SH, Caiado C, McCollum C, Goldstein M, Malagon I, Venkateswaran R, et al. Validation of three postoperative risk prediction models for intensive care unit mortality after cardiac surgery. Thorac Cardiovasc Surg 2018;66:651-60. doi: 10.1055/s-0037-1608897.
13. Madhavan S, Chan SP, Tan WC, Eng J, Li B, Luo HD, et al. Cardiopulmonary bypass time: Every minute counts. J Cardiovasc Surg (Torino) 2018;59:274-81. doi: 10.23736/S0021-9509.17.09864-0.
14. Raut S, Hussain A, Ariyaratnam P, Ananthasayanam A, Vijayan A, Chaudhry M, et al. Validation of Cardiac Surgery Score (CASUS) in postoperative cardiac patients. Semin Cardiothorac Vasc Anesth 2020;24:304-12. doi: 10.1177/1089253220936786.
15. Polat S, Yurtseven N. Kardiyak cerrahide mortalite tayini: Kalp cerrahi skorlaması (CASUS) sistemi etkin mi? GKDA Derg 2021;27:44-50. doi: 10.5222/GKDAD.2021.46547.