# Risk Factors Affecting Morbidity and Mortality in Open Repair of Infrarenal Abdominal Aortic Aneurysms: A Retrospective Cohort Study in the University of the Philippines - Philippine General Hospital

Eduardo R. Bautista, MD, Tricia Angela G. Sarile, MD, Adrian E. Manapat, MD, Carlo Martin H. Garcia, MD, Racel Ireneo Luis C. Querol, MD and Leoncio L. Kaw, MD

*Division of Thoracic, Cardiac and Vascular Surgery, Department of Surgery, College of Medicine and Philippine General Hospital, University of the Philippines Manila*

## ABSTRACT

**Objectives.** To describe the treatment outcomes of patients who underwent open repair of infrarenal abdominal aortic aneurysm (AAA) and to determine the risk factors affecting morbidity and mortality.

**Methods.** Data were obtained from patients with infrarenal AAAs who underwent open surgical repair at the University of the Philippines-Philippine General Hospital (UP-PGH) from January 2013 to October 31, 2023. These patients' demographic and clinical profile, and treatment outcomes were evaluated using frequencies and percentages. Student's t-test and chi-square test were used for the inferential analysis. Multivariable logistic regression analysis was used to identify factors associated with in-hospital mortality and morbidity.

**Results.** In this study, 131 patients underwent open surgical repair of AAA. 82.4% of the patients were males, and 45.8% were between 61-70 years old. The majority of them had hypertension (81.4%) and were smokers (75%). The mortality rate was 17.6%, while the morbidity rate was 35.9%. For elective operations, the mortality was 8.9%, and for ruptured aneurysms, it was 56.5%. Eleven factors associated with mortality included ruptured aneurysm (OR=11.5, 95%CI=4.1 to 32.2), decreased hemoglobin (OR=1.1, 95%CI=1.05 to 1.2), decreased hematocrit (OR=1.1, 95%CI=1.06 to 1.4), emergency surgery (OR=10.3, 95%CI=2.9 to 36.3), higher volume of blood loss (OR=1.5, 95%CI=1.5 to 1.9), higher red cell transfusion (OR=1.3, 95%CI=1.1-1.5), intraoperative cardiopulmonary (CP) arrest (OR=15.9, 95%CI=1.6 to 159.2), need for multiple inotropes (OR=2.7, 95%CI=1.5-4.8), intraoperative hypotension (OR=3.6, 95%CI=1.4-9.7), juxta-renal location (OR=5.0, 95%CI=1.2 to 10.0), and presence of any complication (OR=5.7, 95%CI=2.1-15.1). Seven factors associated with morbidity included ruptured aneurysm (OR=3.9, 95%CI=1.5 to 9.8), decreased preoperative hemoglobin (OR=1.2, 95%CI=1.1 to 1.4), decreased preoperative hematocrit (OR=1.5, 95%CI=1.1 to 1.7), elevated pre-operative creatinine (OR=1.1, 95%CI=1.06 to 1.9), higher intra-operative blood loss (OR=1.4, 95%CI=1.1 to 1.6), higher red cell transfusion (OR=1.6, 95%CI=1.3-2.1),

Corresponding author: Eduardo R. Bautista, MD
Division of Thoracic, Cardiac and Vascular Surgery
Department of Surgery
Philippine General Hospital
University of the Philippines Manila
Taft Avenue, Ermita, Manila 1000, Philippines
Email: edbau1818@gmail.com

and preexisting chronic renal disease (OR=3.3, 95%CI=1.4 to 7.5). Other preoperative and intraoperative factors did not show a significant association with mortality or morbidity.

**Conclusion.** The open repair of an infrarenal AAA is linked to high overall mortality (17.6%) and morbidity (35.9%). The mortality rate for elective repair was 8.9%, but it significantly increased to 56.5% in cases of ruptured aneurysms. Factors with very high Odds Ratio such as emergency surgery, ruptured aneurysm, cardiac arrests during surgery, complex juxtarenal anatomy, and postoperative complications can lead to a high chance of mortality. Healthcare professionals should be vigilant and focus on early detection and repair of abdominal aneurysms to prevent emergency surgery, rupture, and mortality. It is crucial to prevent acute kidney injury, acute respiratory failure, and pneumonia, as these are common complications of open repair.

*Keywords: Infrarenal abdominal aortic aneurysm, open repair, morbidity and mortality*

## INTRODUCTION

Abdominal aortic aneurysm (AAA) is the permanent dilatation of the abdominal aortic wall past its maximum diameter of ≥30 mm.[1] Aneurysms usually stem from the gradual weakening of the arterial wall, often due to underlying hypertension or atherosclerosis.[2] The pathogenesis of AAA involves aortic vascular smooth muscle cell inflammation, apoptosis, angiogenesis, oxidative stress, and vascular remodeling.[3]

Progressive dilatation can lead to rupture, resulting in bleeding and death if not identified and treated promptly.

Elective surgical repair is recommended when aneurysms reach a critical size of 5.5 cm in diameter or exhibit a rapid expansion rate (5 mm in 6 months), as the risk of rupture outweighs the risk of surgery-related death.[4] Rupture of an abdominal aortic aneurysm is a serious complication associated with a high mortality rate. Despite ongoing advancements in surgical technique and technology, mortality rates following open surgical treatment of AAA have remained unchanged for decades.[5,6] With documented mortality rates ranging from 13-53%, open emergency repair of ruptured AAA has been linked to poor surgical outcomes.[7,8] Hence, early repair of an AAA can increase these patients' chances of survival.

In the Philippines, the lack of health surveillance and emergency center networking contributes to potentially higher pre-hospital mortality from AAAs. The lack of advanced resuscitation and monitoring equipment in end-referral centers and the financial inability of some families to afford intensive postoperative medical treatment may further contribute to unfavorable patient outcomes.[9]

Several parameters impact morbidity, mortality, and survival following open emergency repair for AAA. These factors include patient-related factors (age, gender, co-morbidities, and other preoperative clinical and biochemical profile), factors related to the surgery (blood loss, operating and cross-clamping time, urine output), and postoperative complications.[8,10,11] In the open repair of infrarenal AAA, Li noted age, emergent surgery, chronic obstructive pulmonary disease (COPD), history of cardiac dysfunction, and aortic occlusion time to have a significant impact on postoperative complications.[12] A similar study by Kim found that the duration of aortic cross-clamp, the volume of blood transfusion during surgery, and vasopressor infusion during clamp were risk factors.[13]

The present study aims to gather data on patients undergoing open surgical repair of infrarenal AAAs at the UP-PGH. Specifically, we aim to:1) describe the demographic and clinical profile of these patients, 2) determine the immediate outcomes of their treatment, and 3) identify predictors of morbidity and mortality.

This research will help us identify predictors of poor outcomes and modifiable risk factors, which can, in turn, improve medical and surgical interventions, reduce morbidity and mortality, and ultimately enhance patient outcomes.

## METHODS

This retrospective cohort study involved a review of patient medical records. The study included all adult patients (age >18 years) admitted at the UP-PGH with infrarenal AAA who underwent open repair between January 2013 and October 31, 2023. Patients were identified using the Integrated Surgical Information System (ISIS) database of the Department of Surgery, PGH Medical Records Section, and the Philippine General Hospital's Computerized Registry of Admissions and Discharges (RADISH). Patients with juxta-renal AAA were included. Patients with suprarenal and thoracoabdominal aortic aneurysms and those who underwent Endovascular Aneurysm Repair (EVAR) were excluded. One hundred fifty-four patients were initially screened. Twenty-three patients were excluded due to incomplete records. Data from the remaining one hundred thirty-one patients were collected.

Demographic and preoperative clinical data were collected, such as age, sex, chief complaint, type of surgery - emergency or elective, aneurysm diameter, aneurysm type - fusiform or saccular, ruptured, co-morbidities (hypertension, diabetes mellitus, stroke, coronary artery disease, smoking, COPD, COVID history, renal disease), preoperative blood tests that check renal function, hemoglobin, hematocrit, and vital signs (preoperative systolic blood pressure, heart rate, consciousness level).

Intraoperative patient data were collected, such as the duration of the operation, blood loss, hypotension, trans-fusion, inotrope use, intraoperative CP arrest, aortic cross-clamp time, aortic aneurysm anatomy (infrarenal/juxta-renal), and the type of graft used - straight or bifurcated.

Postoperative patient data collected were complications (pulmonary complications, acute kidney injury, chronic kidney injury, myocardial infarction, bleeding, multiple organ failure, sepsis, surgical reintervention, stroke, and others), length of hospital stay, and in-hospital mortality.

The data were evaluated using frequencies and percentages. Descriptive statistics summarized the demographic, clinical profile, and outcomes. The clinical outcomes observed were subjected to univariate data analysis and were reported as frequency, mean, median, and standard deviation. Continuous variables (e.g., preoperative blood tests, vital signs, length of hospital stay) were expressed as mean ± SD, while categorical variables (e.g., age, sex, complications, mortality) were summarized as counts and percentages. For the inferential analysis, Student's t-test and Chi-square test were used. Logistic regression was used to identify factors associated with in-hospital mortality and morbidity. All analyses were done using Statistical Package for the Social Sciences (SPSS) version 19 and were evaluated at alpha 0.05.

Patients' data were made anonymous by assigning a code. The University of the Philippines Manila Research Ethics Board approved the study protocol.

**Table 1.** Demographic Profile and Clinical Presentation of Patients Who Underwent Open Surgical Repair

| | Number (n=131) | Percentage (%) |
|---|---|---|
| ***Gender*** | | |
| Male | 108 | 82.4 |
| Female | 23 | 17.6 |
| ***Age (years)*** | | |
| <50 | 4 | 3.0 |
| 51-60 | 16 | 12.2 |
| 61-70 | 60 | 45.8 |
| 71-80 | 47 | 35.9 |
| >80 | 4 | 3.0 |
| ***Co-morbidities*** | | |
| Smoker | 96 | 75.0 |
| >15 Pack years | 81 | 61.8 |
| Hypertension | 105 | 81.4 |
| COPD | 17 | 13.2 |
| Previous stroke | 10 | 7.8 |
| Diabetes mellitus | 18 | 13.9 |
| Ischemic heart disease | 22 | 17.2 |
| Renal disease | 33 | 25.6 |
| Takayasu disease | 2 | 1.5 |
| COVID Positive | 0 | 0.0 |
| ***Chief complaint*** | | |
| Abdominal mass | 21 | 16.0 |
| Abdominal pain | 91 | 69.5 |
| Others | 27 | 20.6 |

## RESULTS

Between January 2013 and October 31, 2023, 131 patients admitted to the UP-PGH with infrarenal AAA and who underwent open repair were included in the study. The demographic profile of the patients is presented in Table 1. Most patients were males (82.4%), and almost half were aged 61-70 years (45.8%). Additionally, the majority of the patients were hypertensive (81.4%), and 75% were smokers. More than half of the smokers (61.8%) have been smoking for more than 15 pack years. In addition, 25.6% of patients also presented with co-existing renal disease. The most common chief complaint was abdominal pain (69.5%), while others presented with referred pain in the back, hypogastric area, or flank (20.6%).

Table 2 describes the patients' preoperative characteristics and their association with mortality. The overall mortality rate after AAA's open surgical repair was 17.6% (23/131). The mortality rate is significantly higher among those with ruptured aneurysm (56.5%, 13/23) (p<0.001). For elective surgery, the mortality was 8.9% (4/45). Mean hemoglobin count was significantly lower among those who did not survive (98.9 g/L) compared to those who survived (120.2) (p<0.001). Likewise, the mean hematocrit count was also significantly lower among those who did not survive (30.2%) than those who survived (36.2%) (p=0.001). The mean base excess was also significantly lower among non-survivors (-6.1 vs -2.1) (p=0.017). Likewise, a higher mean pre-operative cardiac rate was found among those who could not survive (86.9 vs 78.8 bpm) (p=0.026). The patients were further classified based on the timing of the surgery performed: Elective if they have aneurysms >5.5 cm in widest diameter, have signs of rapid aneurysm expansion (>1 cm per year), and with occasional abdominal pain; Urgent for those who have characteristics of impending rupture such as pain in the back or flank, or persistent abdominal pain; and Emergency for those who had signs of aneurysm rupture on imaging and those presenting with hemodynamic instability. Almost half of the cases were performed as Urgent (44.3%), while 21.4% were done as Emergency. Of these, there were significantly more patients who did not survive after an emergency surgery (60.9%, 14/23) compared to those who had an elective (17%, 4/23) or urgent surgery (21.7%, 5/23) (p<0.001). Other factors such as age, sex, chief complaint, aneurysm diameter, comorbidities, pre-operative vital signs, and level of consciousness did not show a significant association with mortality.

The survival rate during surgery was affected by several factors, as detailed in Table 3. The average blood loss during surgery was significantly higher for those who did not survive (3.8 liters) compared to those who did (1.9 liters) (p<0.001). Similarly, the average number of units of red blood cells transfused was significantly higher for non-survivors (5.3 units) than for survivors (3.0 units) (p=0.002). Moreover, experiencing intra-operative hypotension (45.5%) (p<0.012), requiring at least two inotropes (50%) (p<0.001), and suffering from cardiopulmonary arrest (13%) (p=0.017) were all associated with increased mortality. A more significant percentage of patients with juxta-renal aortic aneurysms did not survive (21.7%, 5/23) (p=0.023). On the other hand, patients who had an aortic replacement using a bifurcated Dacron graft had a significantly higher survival rate at 84.6% (p=0.026). However, the duration of surgery and aortic cross-clamping did not significantly impact survival.

In general, the presence of any complication was found to be linked to a mortality rate of 69.6% (16/23) (p<0.001). Specifically, Table 4 shows that the following post-operative complications have a negative impact on the survival of patients after open surgical repair of AAA (p<0.001): re-

**Table 2.** Relationship between Preoperative Characteristics and Mortality of Patients who Underwent Open Surgical Repair

| Characteristics | Survivors n=108 (82.4%) | Non-survivors n=23 (17.6%) | *P* value | Odds Ratio | 95% Confidence Interval | *P* value |
|---|---|---|---|---|---|---|
| ***Age (years), n (%)*** | | | 0.339 | 1.5 | 0.8-2.6 | 0.204 |
| ≤50 | 3 (2.8) | 1 (4.3) | | | | |
| 51-60 | 14 (13.0) | 2 (8.7) | | | | |
| 61-70 | 52 (48.2) | 8 (34.8) | | | | |
| 71-80 | 37 (34.3) | 10 (43.5) | | | | |
| >80 | 2 (1.8) | 2 (8.7) | | | | |
| ***Sex, n (%)*** | | | 0.784 | | | 0.600 |
| Male | 89 (82.4) | 19 (82.6) | | 0.5 | 0.03-10.1 | |
| Female | 19 (17.6) | 4 (17.4) | | 2.1 | 0.1-29.6 | |
| ***Chief complaint, n (%)*** | | | 0.097 | | | 0.353 |
| Abdominal mass | 19 (17.6) | 2 (8.7) | | 1.2 | 0.6-3.2 | |
| Abdominal pain | 70 (64.8) | 21 (91.3) | | 0.3 | 0.1-2.6 | |
| Others | 26 (24.1) | 1 (4.3) | | 0.6 | 0.1-3.3 | |
| ***Urgency of surgery*** | | | | | | |
| Elective | 41 (38.0) | 4 (17.4) | <0.001 | 0.1 | 0.03-0.34 | <0.001 |
| Urgent | 53 (49.1) | 5 (21.7) | | 1.0 | 0.24-3.8 | 0.962 |
| Emergency | 14 (13.0) | 14 (60.9) | | 10.3 | 2.9-36.3 | <0.001 |
| ***Aneurysm diameter (cm), n (%)*** | | | 0.772 | 1.0 | 0.6-1.3 | 0.963 |
| <5.5 | 31 (31.0) | 7 (30.4) | | | | |
| 5.5-6 | 14 (14.0) | 2 (8.7) | | | | |
| 6.1-6.5 | 13 (13.0) | 1 (4.3) | | | | |
| 6.6-7 | 12 (12.0) | 3 (13.0) | | | | |
| 7.1-7.5 | 7 (7.0) | 2 (8.7) | | | | |
| >7.5 | 23 (23.0) | 8 (34.8) | | | | |
| ***Aortic aneurysm type, n (%)*** | | | 0.211 | | | |
| Fusiform | 66 (79.5) | 11 (64.7) | | | | |
| Saccular | 17 (20.5) | 6 (35.3) | | | | |
| ***Ruptured aneurysm, n (%)*** | 11 (10.2) | 13 (56.5) | <0.001 | 11.5 | 4.1-32.2 | <0.001 |
| ***Co-morbidities, n (%)*** | | | | | | |
| Hypertension | 86 (80.4) | 19 (86.4) | 0.511 | 1.2 | 0.1-10.6 | 0.895 |
| Diabetes mellitus | 14 (13.1) | 4 (18.2) | 0.530 | 0.6 | 0.05-10.2 | 0.823 |
| Coronary artery disease | 17 (16.0) | 5 (22.7) | 0.449 | 1.6 | 0.2-12.0 | 0.632 |
| Previous stroke | 10 (9.4) | 0 (0.0) | 0.133 | 1.3 | 0.1-11.6 | 0.921 |
| COPD | 14 (13.1) | 3 (13.6) | 1.000 | 6.3 | 0.2-189.9 | 0.286 |
| Smoking (>15 pack years) | 67(62.0) | 10 (43.5) | 1.000 | 0.8 | 0.1-10.2 | 0.862 |
| Renal disease | 28 (26.2) | 5 (22.7) | 0.736 | 0.2 | 0.02-2.0 | 0.180 |
| Takayasu disease | 2 (1.9) | 0 (0.0) | 1.000 | | | |
| COVID Positive | 0 (0.0) | 0 (0.0) | n/a | | | |
| ***Pre-operative blood tests (mean ± SD)*** | | | | | | |
| Hemoglobin (g/L) | 120.2 ± 19.6 | 98.9 ± 26.1 | <0.0001 | 1.1 | 1.05-1.2 | <0.001 |
| Hematocrit (%) | 36.2 ± 7.5 | 30.2 ± 8.1 | 0.001 | 1.1 | 1.06-1.4 | <0.001 |
| Creatinine (mmol/L) | 138.3 ± 154 | 182.4 ± 72.3 | 0.188 | 1.6 | 0.2-13.0 | 0.531 |
| Base excess | -2.0 ± 4.2 | -6.1 ± 4.5 | 0.017 | 0.3 | 0.03-10.3 | 0.833 |
| ***Vital signs (mean ± SD)*** | | | | | | |
| Highest preoperative SBP (mm Hg) | 126.8 ± 19.5 | 121.6 ± 26.0 | 0.268 | 0.5 | 0.03-10.2 | 0.632 |
| Pre-operative cardiac rate (bpm) | 78.8 ± 15.2 | 86.9 ± 18.2 | 0.026 | 0.6 | 0.05-9.6 | 0.658 |
| ***Level of consciousness (GCS), n (%)*** | | | 0.662 | 0.9 | 0.5-1.6 | 0.653 |
| 11 | 3 (2.8) | 1 (4.5) | | | | |
| 15 | 105 (97.2) | 21 (95.5) | | | | |

**Table 3.** Table 3. Relationship between Intraoperative Characteristics and Mortality of Patients who Underwent Open Surgical Repair of Abdominal Aortic Aneurysm

| Characteristics | Survivors n=108 (82.4) | Non-survivors n=23 (17.6) | *P* value | Odds Ratio | 95% Confidence Interval | *P* value |
|---|---|---|---|---|---|---|
| ***Duration of operation (hours), n (%)*** | | | 0.165 | 2.3 | 0.1-6.5 | 0.386 |
| <4 | 29 (26.8) | 7 (31.8) | | | | |
| 4-5 | 42 (38.9) | 4 (18.2) | | | | |
| >5 | 37 (34.3) | 11 (50.0) | | | | |
| ***Intraoperative blood loss (L) (mean ± SD)*** | 1.9 ± 1.4 | 3.8 ± 4.8 | <0.001 | 1.5 | 1.2-1.9 | 0.001 |
| ***Intraoperative hypotension, n (%)*** | 19 (18.6) | 10 (45.5) | 0.012 | 3.6 | 1.4-9.7 | 0.009 |
| ***Red cell transfusion (units) (mean ± SD)*** | 3.0 ± 2.1 | 5.3 ± 3.8 | 0.002 | 1.3 | 1.1-1.5 | 0.002 |
| ***Inotrope use, n (%)*** | | | <0.001 | 2.7 | 1.5-4.8 | 0.001 |
| 0 | 48 (46.6) | 4 (18.2) | | | | |
| 1 | 41 (39.8) | 6 (27.3) | | | | |
| 2 | 11 (10.7) | 11 (50.0) | | | | |
| 3 | 3 (2.9) | 1 (4.5) | | | | |
| ***Intraoperative cardiopulmonary (CP) arrest, n (%)*** | 1 (0.9) | 3 (13.0) | 0.017 | 15.9 | 1.6-159.2 | 0.019 |
| ***Aortic cross-clamp time (min) (mean ± SD)*** | 1.2 ± 0.7 | 1.3 ± 0.7 | 0.721 | 0.3 | 0.2-3.9 | 0.362 |
| ***Aortic aneurysm anatomy, n (%)*** | | | 0.023 | | | 0.016 |
| Infrarenal | 99 (93.4) | 18 (78.3) | | 0.2 | 0.1-0.83 | |
| Juxtarenal | 7 (6.6) | 5 (21.7) | | 5.0 | 1.2-10.0 | |
| ***Graft type, n (%)*** | | | 0.026 | | | 0.220 |
| Straight | 16 (15.4) | 8 (40.0) | | 5.0 | 0.5-33.3 | |
| Bifurcated | 88 (84.6) | 12 (60.0) | | 0.2 | 0.03-1.8 | |

**Table 4.** Relationship between Postoperative Characteristics and Mortality of Patients who Underwent Open Surgical Repair

| Characteristics | Survivors n=108 (82.4) | Non-survivors n=23 (17.6) | *P* value |
|---|---|---|---|
| ***Complications, n (%)*** | | | |
| Any complication | 31 (28.7) | 16 (69.6) | <0.001 |
| Reoperation | 4 (3.7) | 7 (30.4) | <0.001 |
| Chronic kidney disease requiring hemodialysis | 5 (4.7) | 7 (30.4) | <0.001 |
| Chronic kidney disease not requiring hemodialysis | 3 (2.3) | 0 (0.0) | 1.000 |
| Acute kidney injury | 14 (13.2) | 13 (57.0) | <0.001 |
| Acute respiratory failure | 3 (2.8) | 9 (39.1) | <0.001 |
| Pneumonia | 13 (12.3) | 10 (43.5) | <0.001 |
| Upper GI bleeding | 3 (2.8) | 0 (0.0) | 1.000 |
| ***Length of hospital stay (days), (mean ± SD)*** | | | |
| Preoperative | 5.9 ± 7.9 | 4.5 ± 9.1 | 0.452 |
| Postoperative | 8.3 ± 5.6 | 9.0 ± 8.7 | 0.629 |

operation (30.4%), chronic kidney disease requiring hemodialysis (30.4%), acute kidney injury (57.0%), acute respiratory failure (39.1%), and pneumonia (43.5%). Meanwhile, the length of hospital stay did not significantly impact survival.

Factors contributing to morbidity after surgical repair of AAA were also considered in Table 5. Among the preoperative characteristics, ruptured aneurysm is significantly linked to the occurrence of perioperative complications (31.9%, 15/47) (p<0.004). Those with pre-existing renal disease (40.4%, 19/47) (p=0.003) and elevated creatinine (193.7 mmol/L vs 118.2 mmol/L) (p=0.005) also significantly experienced perioperative complications. In addition, those with a low mean hemoglobin count (108 g/L vs 121 g/L) (p=0.002) were more predisposed to have complications. Meanwhile, preoperative aneurysm size, aneurysm type, and urgency of surgery did not have a significant association with the incidence of complications.

In Table 6, the intraoperative factors associated with morbidity are presented. A higher average intraoperative blood loss of 2.9 liters (p=0.041) and a higher red cell transfusion (average 4.9 units PRBC transfused) (p<0.001) were found to be linked to morbidity. However, the duration of surgery, presence of intraoperative hypotension, inotrope use, intraoperative CP arrest, cross-clamp time, aneurysm location, and type of graft used were not associated with the occurrence of complications.

Based on further analysis, the eleven factors significantly predisposing patients who underwent open surgical repair of

AAA to mortality are as follows (Table 7): ruptured aneurysm (OR=11.5, 95%CI=4.1 to 32.2), decreased hemoglobin (OR=1.1, 95%CI=1.05 to 1.2), decreased hematocrit (OR=1.1, 95%CI=1.06 to 1.4), emergency surgery (OR=10.3, 95%CI=2.9 to 36.3), higher volume of blood loss (OR=1.5, 95%CI=1.5 to 1.9), greater units of red cell transfusion (OR=1.3, 95%CI=1.1-1.5), intra-operative cardiopulmonary (CP) arrest (OR=15.9, 95%CI=1.6 to 159.2), need for 2-3 inotropes (OR=2.7, 95%CI=1.5-4.8), intraoperative hypotension (OR=3.6, 95%CI=1.4-9.7), juxta-renal location of the aneurysm (OR=5.0, 95%CI=1.2 to 10.0), and presence of any complication (OR=5.7, 95%CI=2.1-15.1).

**Table 5.** Relationship between Preoperative Characteristics and Morbidity of Patients who Underwent Open Surgical Repair

| | Without complication n=84 (64.1) | With complication n=47 (35.9) | *P* value | Odds Ratio | 95% Confidence Interval | *P* value |
|---|---|---|---|---|---|---|
| ***Age (years), n (%)*** | | | 0.426 | 0.8 | 0.5-1.2 | 0.257 |
| <50 | 1 (1.2) | 3 (6.4) | | | | |
| 51-60 | 10 (11.9) | 6 (12.8) | | | | |
| 61-70 | 38 (45.2) | 22 (46.8) | | | | |
| 71-80 | 33 (39.3) | 14 (29.8) | | | | |
| >80 | 2 (2.4) | 2 (4.3) | | | | |
| ***Sex, n (%)*** | | | 0.812 | | | 0.545 |
| Male | 70 (83.3) | 38 (80.8) | | 0.2 | 0.02-10.3 | |
| Female | 14 (16.7) | 9 (19.2) | | 4.1 | 0.1-47.7 | |
| ***Chief complaint, n (%)*** | | | 0.150 | | | 0.424 |
| Abdominal mass | 15 (14.2) | 7 (14.6) | | 1.4 | 0.7-4.3 | |
| Abdominal pain | 55 (51.9) | 32 (66.7) | | 0.4 | 0.1-4.7 | |
| Others | 36 (34.0) | 9 (18.8) | | 0.7 | 0.1-4.5 | |
| ***Urgency of surgery*** | | | 0.102 | | | |
| Elective | 28 (33.3) | 17 (36.2) | | 0.5 | 0.2-1.2 | 0.109 |
| Urgent | 44 (52.4) | 14 (29.8) | | 0.5 | 0.2-1.2 | 0.137 |
| Emergency | 12 (14.3) | 16 (34.0) | | 2.2 | 0.8-5.7 | 0.109 |
| ***Aneurysm diameter (cm), n (%)*** | | | 0.831 | 1.1 | 0.9-1.3 | 0.293 |
| <5.5 | 27 (33.8) | 11 (25.6) | | | | |
| 5.5-6 | 10 (12.5) | 6 (13.9) | | | | |
| 6.1-6.5 | 9 (11.2) | 5 (11.6) | | | | |
| 6.6-7 | 11 (13.8) | 4 (9.3) | | | | |
| 7.1-7.5 | 5 (6.3) | 4 (9.3) | | | | |
| >7.5 | 18 (22.5) | 13 (30.2) | | | | |
| ***Aortic aneurysm type, n (%)*** | | | 0.614 | | | |
| Fusiform | 53 (79.1) | 24 (72.7) | | | | |
| Saccular | 14 (20.9) | 9 (27.3) | | | | |
| ***Ruptured aneurysm, n (%)*** | 9 (10.7) | 15 (31.9) | 0.004 | 3.9 | 1.5-9.8 | 0.004 |
| ***Co-morbidities, n (%)*** | | | | | | |
| Hypertension | 64 (78.1) | 41 (87.2) | 0.244 | 1.4 | 0.1-10.7 | 0.775 |
| Diabetes mellitus | 13 (15.8) | 5 (10.6) | 0.411 | 0.7 | 0.05-11.4 | 0.731 |
| Coronary artery disease | 12 (14.8) | 10 (21.3) | 0.466 | 1.5 | 0.4-13.0 | 0.725 |
| Previous stroke | 6 (7.5) | 4 (8.6) | 1.000 | 1.4 | 0.1-11.7 | 0.741 |
| COPD | 12 (14.6) | 5 (10.6) | 0.598 | 7.4 | 0.4-125.7 | 0.477 |
| Smoking (>15 pack years) | 55 (65.5) | 22 (55.3) | 0.266 | 0.8 | 0.1-10.4 | 0.744 |
| Renal disease | 14 (17.1) | 19 (40.4) | 0.003 | 3.3 | 1.4-7.5 | 0.004 |
| COVID Positive | 0 (0.0) | 0 (0.0) | n/a | | | |
| ***Pre-operative blood tests (mean ± SD)*** | | | | | | |
| Hemoglobin (g/L) | 121 ± 20.7 | 108 ± 22.8 | 0.002 | 1.2 | 1.1-1.4 | 0.003 |
| Hematocrit (%) | 36.2 ± 8.3 | 33.3 ± 6.9 | 0.059 | 1.5 | 1.1-1.7 | 0.002 |
| Creatinine (mmol/L) | 118.2 ± 83.9 | 193.7 ± 208.2 | 0.005 | 1.1 | 1.06-1.9 | 0.025 |
| Base excess | -2 ± 4.2 | -4 ± 4.7 | 0.159 | 0.4 | 0.04-10.4 | 0.744 |
| ***Vital signs (mean ± SD)*** | | | | | | |
| Highest preoperative SBP (mm Hg) | 126.3 ± 17.9 | 125.9 ± 24.5 | 0.703 | 0.5 | 0.04-10.4 | 0.744 |
| Preoperative cardiac rate (bpm) | 79.1 ± 14.1 | 82.1 ± 19.0 | 0.314 | 0.7 | 0.05-7.7 | 0.757 |
| ***Level of consciousness (GCS), n (%)*** | | | 0.107 | 1.0 | 0.9-1.03 | 0.312 |
| 11 | 0 (0.0) | 4 (8.5) | | | | |
| 15 | 83 (100.0) | 43 (91.5) | | | | |

**Table 6.** Relationship between Intraoperative Characteristics and Morbidity of Patients who Underwent Open Surgical Repair

| Characteristics | Without complication n=84 (64.1) | With complication n=47 (35.9) | *P* value | Odds Ratio | 95% Confidence Interval | *P* value |
|---|---|---|---|---|---|---|
| ***Duration of operation (hours), n (%)*** | | | 0.314 | 4.4 | 0.1-7.5 | 0.477 |
| <4 | 26 (30.9) | 10 (21.7) | | | | |
| 4-5 | 26 (30.9) | 20 (43.5) | | | | |
| >5 | 32 (38.1) | 16 (34.8) | | | | |
| ***Intraoperative blood loss (L) (mean ± SD)*** | 2.0 ± 1.4 | 2.9 ± 3.3 | 0.041 | 1.4 | 1.1-1.7 | 0.041 |
| ***Intraoperative hypotension, n (%)*** | 18 (23.1) | 11 (23.9) | 0.915 | 0.7 | 0.4-4.4 | 0.545 |
| ***Red cell transfusion (units) (mean ± SD)*** | 2.5 ± 1.8 | 4.9 ± 3.2 | <0.001 | 1.6 | 1.3-2.1 | <0.001 |
| ***Inotrope use, n (%)*** | | | 0.078 | 1.4 | 0.4-4.7 | 0.744 |
| 0 | 35 (44.3) | 17 (37.0) | | | | |
| 1 | 33 (41.8) | 14 (30.4) | | | | |
| 2 | 10 (12.7) | 12 (26.1) | | | | |
| 3 | 1 (1.3) | 3 (6.5) | | | | |
| ***Intraoperative cardiopulmonary (CP) arrest, n (%)*** | 3 (3.7) | 1 (2.1) | 1.000 | 11.7 | 0.7-32.5 | 0.145 |
| ***Aortic cross-clamp time (min) (mean ± SD)*** | 1.1 ± 0.67 | 1.3 ± 0.6 | 0.781 | 0.5 | 0.3-5.1 | 0.489 |
| ***Aortic aneurysm location, n (%)*** | | | 1.000 | | | 0.481 |
| Infrarenal | 74 (90.2) | 43 (91.5) | | 0.4 | 0.01-4.7 | |
| Juxtarenal | 8 (9.8) | 4 (8.5) | | 2.5 | 0.2-100.4 | |
| ***Graft type, n (%)*** | | | 0.481 | | | 0.432 |
| Straight | 14 (17.5) | 10 (22.7) | | 2.5 | 0.7-25.0 | |
| Bifurcated | 66 (82.5) | 34 (77.3) | | 0.4 | 0.04-1.7 | |

**Table 7.** Summary of Factors that Predispose Patients who Underwent Open Surgical Repair to Mortality (Final Regression Model)

| | Mortality rate | Odds Ratio | 95% Confidence Interval | *P* value |
|---|---|---|---|---|
| ***Ruptured Aneurysm*** | 13 (56.5) | 11.5 | 4.1-32.2 | <0.001 |
| ***Preoperative blood tests **** | | | | |
| Decrease in hemoglobin | 98.9 ± 26.1 | 1.1 | 1.05-1.2 | <0.001 |
| Decrease in hematocrit | 30.2 ± 8.1 | 1.1 | 1.06-1.4 | <0.001 |
| ***Urgency of surgery*** | | | | |
| Elective | 4 (17.4) | 0.1 | 0.03-0.34 | <0.001 |
| Emergency | 14 (60.9) | 10.3 | 2.9-36.3 | <0.001 |
| ***Higher intraoperative blood loss**** | 3.8 ± 4.8 | 1.5 | 1.2-1.9 | 0.001 |
| ***Intraoperative hypotension*** | 10 (34.5) | 3.6 | 1.4-9.7 | 0.009 |
| ***Need for higher red cell transfusion**** | 5.3 ± 3.8 | 1.3 | 1.1-1.5 | 0.002 |
| ***Need for 2-3 inotropes*** | 12 (46.0) | 2.7 | 1.5-4.8 | 0.001 |
| ***Intraoperative CP arrest*** | 3 (75.0) | 15.9 | 1.6-159.2 | 0.019 |
| ***Aortic aneurysm anatomy*** | | | | |
| Infrarenal | 18 (13.6) | 0.2 | 0.1-0.83 | 0.016 |
| Juxtarenal | 5 (41.7) | 5.0 | 1.2-10.0 | |
| ***Any Complication*** | 16 (33.3) | 5.7 | 2.1-15.1 | 0.001 |

**Not categorical variable, so frequencies cannot be computed.*

Table 8 indicates that a ruptured aneurysm, coexisting renal disease, pre-operative decrease in hemoglobin and hematocrit, high creatinine, high intraoperative blood loss, and high red blood cell transfusion are predictors of morbidity in patients undergoing open surgical repair of AAA.

## DISCUSSION

Asymptomatic aneurysm ≥5.5 cm, quickly expanding (>10 mm/year) or symptomatic, should receive definitive treatment.[14] These patients should undergo elective repair if the risk of rupture outweighs the risks from surgery. Patients with small AAA, at low risk of rupture, are generally monitored through surveillance imaging.[15] Quitting smoking, managing comorbidities affecting the cardio-vascular system, and engaging in moderate physical exercise are all non-surgical treatments that may slow the disease's progression.[14]

The short-term mortality associated with the elective repair of infrarenal aortic aneurysms has decreased steadily

**Table 8.** Summary of Factors that Predispose Patients who Underwent Open Surgical Repair to Morbidity (Final Regression Model)

| | Morbidity rate | Odds Ratio | 95% Confidence Interval | *P* value |
|---|---|---|---|---|
| ***Ruptured Aneurysm*** | 15 (20.8) | 3.9 | 1.5-9.8 | 0.004 |
| ***Co-morbidities*** | | | | |
| Renal disease | 10 (57.6) | 3.3 | 1.4-7.5 | 0.004 |
| ***Pre-operative blood tests**** | | | | |
| Decrease in hemoglobin | 108 ± 22.6 | 1.2 | 1.1-1.4 | 0.003 |
| Decrease in hematocrit | 33.5 ± 6.9 | 1.5 | 1.1-1.7 | 0.002 |
| Increase in creatinine | 193.7 ± 208.2 | 1.1 | 1.06-1.9 | 0.025 |
| ***Higher intraoperative blood loss **** | 2.9 ± 3.3 | 1.4 | 1.1-1.6 | 0.041 |
| ***Need for higher red cell transfusion **** | 4.9 ± 3.2 | 1.6 | 1.3-2.1 | <0.001 |

**Not categorical variable, so frequencies cannot be computed.*

over the past several years. These improvements result from surgical technique, anesthesia, and critical care advancements.[16]

However, despite advancements in diagnosis and surgical techniques, mortality with open surgical repair of ruptured abdominal AAA remains high. Previous studies have shown variable mortality rates ranging from 13.0% to 53.0%.[7,8] Hammo reported that ruptured aneurysm predicted mortality in open surgical repair.[17] Our study showed that over the past ten years, the overall mortality rate after open repair of AAA is at 17.6%. This mortality rate was slightly higher compared to the earlier study done in the same institution (UP-PGH) by Nicolas in 2000, which reported an overall mortality rate of 10.4% and included 222 patients.[18]

Gabitoya reported an overall mortality rate of 16.59% for abdominal aortic aneurysms at the Philippine Heart Center.[19] Other studies have reported mortality rates of 22.9-38%.[17,20,21]

## Predictors of Outcomes in our Study

### *Demographic Data*

#### *Age and Gender*

The incidence of abdominal aortic aneurysm rises with increasing age. In our study, most of the patients belonged to the 61-70-year-old age group and were predominantly males. This finding is similar to another local study wherein the mean age of the population is 65 years old, and the majority are males (78.91%).[18] Siracuse also reported that males comprise 76.2% of their study population, and the mean age is 72. They also reported that advanced age predicts 30-day mortality.[22] Markovic had a similar population comprising primarily males. His study was divided into group A (patients in 1991-2001), having a mean age of 72 years, which also did not influence mortality, but in group B (2002-2011), the mean age was 69.2 years. Those younger than 73 years old showed significantly better outcomes.[23] Hammo found out in their study that females are at a higher risk of mortality within 48 hours after the repair of ruptured AAA.[17]

In the study by Barakat, an increase in age also increases mortality.[7] Similarly, in Kim's study, an increase in age was associated with increased complications.[13]

On the contrary, age and gender did not significantly correlate with morbidity and mortality after open surgical repair in our study.

#### *Comorbidities*

The most common co-existing medical conditions seen in our study were hypertension (81.5%), smoking (75%), and renal disease (25.6%). Similarly, another local study by Gabitoya also found hypertension and smoking as the most common comorbidities.[19]

According to the previous local study of Nicolas, COPD, the need for emergency surgery, diabetes mellitus, hypertension, and smoking history were all risk factors connected to morbidity. Several variables increased overall mortality, including the need for emergent surgery, rupture, COPD, ischemic heart disease, smoking, a size of more than 5.0 centimeters, and a history of myocardial infarction.[18]

Among the comorbidities identified in our study, only pre-existing renal disease increases the odds of morbidity (OR 3.3, p<0.004). This finding is similar to the findings of Law and Markovic, which correlated preexisting renal disease with mortality.[23,24] While other studies may have reported that advanced age, hypertension, and smoking are linked to mortality, this association was not found in our study. Although Nicolas observed COPD and myocardial infarction to be predictors of mortality[18]; these comorbidities were no longer observed to be so in our recent study.

Risk factors predicting postoperative complications after an open infrarenal AAA repair were also determined in a vascular center in China. Age was identified as one of the risk factors for postoperative complications in the study. Age was associated with a higher prevalence of diabetes, heart disease, and renal impairment among patients aged 65 and older. In addition, COPD, history of cardiac dysfunction, and the aortic occlusion time substantially affect postoperative complications following open repair.[12]

### Pre-operative Characteristics

#### Aneurysm Size, Type, and Rupture

While most of the complications and deaths in our study occurred when the aneurysm was >7.5 cm and was of a fusiform type, Gabitoya likewise reported an average aneurysm size of 7.08 ± 1.57 cm and is primarily fusiform (81.09%).[19] Both factors, however, did not predict morbidity and mortality in our study. The mean aneurysm size was 6.5 cm in the study of Law[24], while it was 7.25 cm and 7.96 cm (for groups A and B, respectively) in Markovic's study.[23] In both studies, aneurysm size was also not predictive of mortality.[23,24] This is in contrast to the study of Nicolas from 1980-1998, which reported an aneurysm size of more than 5 cm to be predictive of mortality.[18] The greatest diameter of AAA at the time of surgery is similarly associated with reduced 5-year survival.[16,25] Both factors, size, and type, did not predict morbidity and mortality in our study.

More importantly, in our study, mortality was highest when the aneurysm was ruptured (56.5%, OR 11.5, p<0.001). The incidence of complication also significantly rises with a ruptured aneurysm (31.9%, OR 3.9, p<0.004). In a previous study by Bautista in the same institution in 2013, the mortality for ruptured aneurysm was 50%.[9] We further analyzed our study population based on the urgency of surgery.

#### Urgency of Surgery

Surgeries were further classified as Emergency, Urgent, or Elective based on the earlier definition. In elective open repair, reported mortality rates are as low as 0% to 3.1%, whereas emergency surgeries have a mortality rate of 7.2%.[24-27] In our center, mortality after elective surgery is slightly higher at 8.9%, which rises to 50% after emergency repairs. In the same way, our morbidity rate was also highest in those who underwent emergency surgeries. These findings are consistent with Nicolas' earlier study.[18] Lieberg reported a 0.9% 30-day mortality and 2.6% 90-day mortality in elective repairs. Meanwhile, after five years, the reported mortality increased to 32%, which was independently associated with older age and higher preoperative creatinine levels.[20] While the number of emergency surgeries performed is the same as in other centers, more urgent surgeries were performed in our center, accounting for lower elective surgeries.[24] The lack of a standardized local screening approach that should have allowed earlier detection and treatment of aortic aneurysms could have reduced this incidence. While our center caters to many aortic diseases, an aortic center that shall promptly and effectively manage these cases is yet to be established. Access to high-volume institutions still needs to be improved. Hence, aortic aneurysms were likely to be diagnosed only when there are persistent symptoms, or worse, when already ruptured, explaining the higher number of urgent and emergency surgeries performed compared to elective. Nonetheless, the relatively low mortality rates, especially in elective aortic surgery in the study of Law, were attributed to short travel time to the hospital and outstanding anesthetic and intensive care in their institution.[24]

In a study on the Koreans, Kim also noted that emergency operation is an independent risk factor for postoperative complications.[13]

#### Laboratory Parameters

In our study, preoperative blood tests showing low hemoglobin and hematocrit were attributed to morbidity and mortality after open surgical repair of AAA. In the study of Lieberg, they reported that 22.9% 30-day mortality in ruptured AAA was associated with low hemoglobin and high lactate levels.[20] Conversely, Law and Markovic found no significant association between mortality and hemoglobin and hematocrit levels.[23,24]

Base excess was also found to be significantly higher among those who died (BE -6.1, p<0.017), but this did not increase the odds of morbidity and mortality in our study, even in other studies.[24]

Elevated creatinine (193.7 mmol/L) was also a predisposing factor to morbidity in our study (p=0.025) but was not correlated with mortality. Markovic also found a significant link between renal malfunction and mortality, with preoperative creatinine levels that are slightly lower in comparison to our study (185.7 umol/L in Group A and 163.22 umol/L in Group B) among those who died post-operatively (p<0.01, p<0.001).[23]

### Intra-operative Characteristics

#### Intra-operative Blood Loss and Blood Transfusion

In our study, a significant association with mortality was seen at 3.8 liters of blood loss, while complications were seen at 2.9 liters of blood loss. Similarly, Markovic found that significant bleeding favored a lethal outcome, with a blood loss of 5.29 liters (Group A) and 4.78 liters (Group B) among those who did not survive (p<0.005, p<0.01).[23] Uchida also noted that intraoperative blood loss was an independent risk factor for surgical death.[28] At 4.9 units of PRBC transfused, the risk for complication increased significantly, while at 5.3 units of PRBC transfused, the mortality risk increased in our study. This observation is similar to Kim's, where the blood transfusion volume is an independent risk for post-operative complications.[13] While other studies have already included autologous blood transfusion as part of their protocol for ruptured abdominal aortic aneurysms, this was not yet consistently observed in our center, especially during the earlier half of the study.

#### Hypotension, Inotrope Use, and Cardiopulmonary Arrest

The occurrence of intra-operative hypotension, cardiopulmonary arrest, and the need for multiple inotropes were attributed to mortality and morbidity after open surgical AAA repair in our study. This situation may reflect an extreme hypovolemic shock condition, mainly from ruptured AAA with massive blood loss.

Robinson utilized a risk scoring system to predict mortality after the open repair of ruptured AAA. In-hospital mortality is at 38%, and it was found that preoperative cardiac arrest is significantly attributable to death.[21]

The time lag between the onset of the symptoms and the presence of a fully developed shock was a significant predictor of mortality. Scarcello showed that the prognosis of patients with rapid onset of shock was worse than that of patients with delayed onset. Their findings suggest that a time lag of fewer than 10 hours has a short compensatory stage and immediately reaches the stage of organ hypoperfusion.[29]

Kim also noted that vasopressor infusion needed during aortic clamping was an independent risk factor for postoperative complications.[13] This situation may reflect a patient who is in a worse state of hypovolemic shock.

### *Aneurysm Location*

In our study, the complex nature of juxta-renal aneurysms has been linked to higher mortality (OR 5.0, p=0.016) but not to increased morbidity. A juxta-renal aneurysm has its neck very close to the renal arteries. Fixing this type of AAA is more technically challenging regarding the application of the aortic cross-clamp and suturing of the graft to the proximal neck of the native aorta. Our result regarding juxta-renal AAA is contrary to the findings of van Beek in their study of open repair of ruptured AAA that there was no difference in complication rate, length of hospital and ICU stay, and amount of perioperative blood loss based on whether the aneurysm had a friendly anatomy or a hostile neck.[30]

### *Operative Time, Aortic Cross-clamp Time, and Graft Type*

Our study found no correlation between the duration of surgery and cross-clamping and morbidity and mortality rates. Law also discovered in their study that although a ruptured AAA increased the mean cross-clamp time, it did not significantly prolong the operative time and, therefore, is not predictive of mortality.[24] Additionally, the type of aortic reconstruction, whether straight or bifurcated grafts are used, had no impact on survival in our study. Similar findings were reported by Marković, who found that the kind of reconstruction (straight or bifurcated) and cross-clamp time did not influence survival but that infrarenal clamping favored better survival. Furthermore, they noted that a longer total operative time predicted a lethal outcome and observed a 0.5% risk for every additional minute of operative time.[23] Kim, however, noted that the duration of the clamp time was an independent risk factor for postoperative complications.[13]

### *Post-operative Characteristics*

Bakarat noted that multiple organ failures were predictors of in-hospital mortality and long-term prognosis.[7]

In our study, any single complication was associated with an adverse outcome (OR 5.7, p=0.001). The two most frequent complications were renal and respiratory failure.

### *Renal Complications*

The present study observed that acute kidney injury was one of the most common complications. This injury may be a direct result of hypovolemic shock from acute blood loss, causing acute tubular necrosis. Other causes of kidney injury may result from damage to the renal arteries and embolization of atherosclerotic material, which could be due to technical factors, potentially leading to renal failure.[31,32] Additionally, the incidence of perioperative morbidity is influenced by pre-existing chronic renal disease upon admission. Factors such as perioperative hypotension, embolization, ureteral damage, or suprarenal aortic clamping increase the likelihood of renal failure postoperatively.[2] It is worth noting that despite the clamp position mostly below the renal artery, renal problems were also common in other studies. Therefore, it is essential to maintain a sufficient intravascular volume to avoid kidney injury from hypovolemic shock.[13] Furthermore, several studies found that the need for hemodialysis after surgery in patients with chronic kidney disease also negatively impacts survival.[7,13,23]

### *Respiratory Complications*

After surgery, a common problem in our study was acute respiratory failure (9.2%, 12/131) and pneumonia (17.6%, 23/131). Law found that the overall incidence of respiratory complications is 13.6%. The presence of a ruptured aneurysm alone contributes to respiratory complications, among other complications.[24] Siracuse observed pulmonary complications as high as 42.3% after repair of ruptured AAA, and having COPD and hypotension at presentation predicts this outcome.[22] A similar study revealed that distant organs, including the lungs, were often the site of postoperative complications likely from pulmonary embolization.[13]

### *Length of Hospital Stay*

Our study found that the average length of time patients stayed in the hospital before (4.5 to 5.9 days) and after surgery (8.3 to 9 days) was not significantly different for those who survived and those who did not. Markovic's study showed a more extended hospital stay, with an average of 17 days from 1991-2001, which decreased to 9 days after that.[23] Siracuse reported a more extended postoperative stay with an average of 13.1 days.[22] However, the length of stay in these studies did not correlate with illness and death, similar to our findings.

In a separate study by Bautista from the same institution in 2013, they determined that ruptured aneurysms with multiple organ failure and uncontrolled bleeding best-predicted mortality. These characteristics were related to parameters indicative of severe shock, depressed sensorium, hypotension, and acidosis.[9]

The findings of our study outline the typical sequence of events when the patient is severely symptomatic, an aneurysm ruptures, and surgery becomes urgently necessary. Preoperative hemoglobin and hematocrit levels are low due to increased intraabdominal bleeding. As a result, the patient may become hypotensive due to significant blood loss when the bleeding source is not controlled or resuscitation is inadequate. Controlling bleeding by applying the aortic cross-clamp and proximal graft suturing during surgery becomes even more complex when the anatomy of the AAA is juxta-renal. Clamping the aorta is also challenging, especially when the retroperitoneum is filled with hematoma. Failure to correct hypovolemic shock with blood transfusion could lead to cardiopulmonary arrest. Multiple inotropes may be necessary to maintain adequate hemodynamics. If the patient survives the surgery, factors such as rupture, pre-existing renal disease, low preoperative hemoglobin and hematocrit, elevated creatinine, massive blood loss, and transfusion could contribute to postoperative morbidities. The most common complications are kidney failure and pneumonia.

### Limitations of the Study

The study has several limitations. First, this is a retrospective study highly subject to information bias. Prognostic factors such as preoperative medications could not be included in this analysis as these were poorly documented in the medical records. Second, this study involves a small sample size of 131 patients, limiting these findings' generalizability. Third, only patients who underwent open repair were included in the study.

## CONCLUSION

In this study, open repair of an infrarenal AAA is linked to high overall mortality (17.6%) and morbidity (35.9%). The mortality rate for elective repair was 8.9%, but it significantly increased to 56.5% in cases of ruptured aneurysms. Eleven factors associated with a higher likelihood of mortality include emergency surgery, ruptured aneurysm, significant blood loss, low hemoglobin and hematocrit levels preoperatively, intra-operative hypotension, intraoperative cardiopulmonary arrest, high volume transfusion, use of multiple inotropes, juxta-renal anatomy and development of complications. Predictors of morbidity include pre-existing chronic renal disease, decreased preoperative hemoglobin and hematocrit, elevated preoperative creatinine, ruptured aneurysm, higher intra-operative blood loss, and higher red cell transfusion. Healthcare professionals should be vigilant and focus on early detection and repair of abdominal aneurysms to avoid emergency surgery or prevent rupture leading to a cascade of complications and mortality. It is crucial to prevent acute kidney injury, acute respiratory failure, and pneumonia, as these are common complications of open repair of an infrarenal AAA.

### Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

### Author Disclosure

All authors declared no conflicts of interest.


### Funding Source

None.


## REFERENCES


1. Kumar Y, Hooda K, Li S, Goyal P, Gupta N, Adeb M. Abdominal aortic aneurysm: pictorial review of common appearances and complications. Ann Transl Med. 2017 Jun;5(12):256. doi: 10.21037/atm.2017.04.32. PMID: 28706924; PMCID: PMC5497081.
2. Aggarwal S, Qamar A, Sharma V, Sharma A. Abdominal aortic aneurysm: a comprehensive review. Exp Clin Cardiol. 2011 Spring;16(1):11-5. PMID: 21523201; PMCID: PMC3076160.
3. Li J, Krishna SM, Golledge J. The potential role of Kallistatin in the development of abdominal aortic aneurysm. Int J Mol Sci. 2016 Aug 11;17(8):1312. doi: 10.3390/ijms17081312. PMID: 27529213; PMCID: PMC5000709.
4. Chaikof EL, Dalman RL, Eskandari MK, Jackson BM, Lee WA, Mansour MA, et al. The Society for Vascular Surgery practice guidelines on the care of patients with an abdominal aortic aneurysm. J Vasc Surg. 2018 Jan;67(1):2-77.e2. doi: 10.1016/j.jvs.2017.10.044. PMID: 29268916.
5. Gwon JG, Kwon TW, Cho YP, Han YJ, Noh MS. Analysis of in hospital mortality and long-term survival excluding in hospital mortality after open surgical repair of ruptured abdominal aortic aneurysm. Ann Surg Treat Res. 2016 Dec;91(6):303-8. doi: 10.4174/astr.2016.91.6.303. PMID: 27904852; PMCID: PMC5128376.
6. Brown LC, Powell JT, Thompson SG, Epstein DM, Sculpher MJ, Greenhalgh RM. The UK EndoVascular Aneurysm Repair (EVAR) trials: randomised trials of EVAR versus standard therapy. Health Technol Assess. 2012;16(9):1-218. doi: 10.3310/hta16090. PMID: 22381040.
7. Barakat HM, Shahin Y, Din W, Akomolafe B, Johnson BF, Renwick P, et al. Perioperative, postoperative, and long-term outcomes following open surgical repair of ruptured abdominal aortic aneurysm. Angiology. 2020 Aug;71(7):626-32. doi: 10.1177/0003319720911578. PMID: 32166957; PMCID: PMC7436436.
8. Bown MJ, Sutton AJ, Bell PR, Sayers RD. A meta-analysis of 50 years of ruptured abdominal aortic aneurysm repair. Br J Surg. 2002 Jun;89(6):714-30. doi: 10.1046/j.1365-2168.2002.02122.x. PMID: 12027981.
9. Bautista ER, Garcia CM, Kaw L. Predictors of outcomes of open surgery for ruptured infrarenal abdominal aortic aneurysms. Phil J Thorac Cardiovasc Surg. 2013;14(1):36-41.
10. Cho JS, Kim JY, Rhee RY, Gupta N, Marone LK, Dillavou ED, et al. Contemporary results of open repair of ruptured abdominal aortoiliac aneurysms: effect of surgeon volume on mortality. J Vasc Surg. 2008 Jul;48(1):10-7; discussion 17-8. doi: 10.1016/j.jvs.2008.02.067. PMID: 18515039.
11. Dueck AD, Kucey DS, Johnston KW, Alter D, Laupacis A. Survival after ruptured abdominal aortic aneurysm: effect of patient, surgeon, and hospital factors. J Vasc Surg. 2004 Jun;39(6):1253-60. doi: 10.1016/j.jvs.2004.02.006. PMID: 15192566.
12. Li C, Yang WH, Zhou J, Wu Y, Li YS, Wen SH, et al. Risk factors for predicting postoperative complications after open infrarenal abdominal aortic aneurysm repair: results from a single vascular center in China. J Clin Anesth. 2013 Aug;25(5):371-378. doi: 10.1016/j.jclinane.2013.01.013. Erratum in: J Clin Anesth. 2013 Dec;25(8):691. Dosage error in article text. PMID: 23965198.

13. Kim GS, Ahn HJ, Kim WH, Kim MJ, Lee SH. Risk factors for postoperative complications after open infrarenal abdominal aortic aneurysm repair in Koreans. Yonsei Med J. 2011 Mar;52(2):339-46. doi: 10.3349/ymj.2011.52.2.333. PMID: 21319356; PMCID: PMC3051228.
14. Moll FL, Powell JT, Fraedrich G, Verzini F, Haulon S, Waltham M, et al. European Society for Vascular Surgery. Management of abdominal aortic aneurysms clinical practice guidelines of the European society for vascular surgery. Eur J Vasc Endovasc Surg. 2011 Jan;41 Suppl 1:S1-S58. doi: 10.1016/j.ejvs.2010.09.011. PMID: 21215940.
15. Lederle FA, Wilson SE, Johnson GR, Reinke DB, Littooy FN, Acher CW, et al. Aneurysm Detection and Management Veterans Affairs Cooperative Study Group. Immediate repair compared with surveillance of small abdominal aortic aneurysms. N Engl J Med. 2002 May 9;346(19):1437-44. doi: 10.1056/NEJMoa012573. PMID: 12000813.
16. Bahia SS, Holt PJ, Jackson D, Patterson BO, Hinchliffe RJ, Thompson MM, et al. Systematic review and meta-analysis of long-term survival after elective infrarenal abdominal aortic aneurysm repair 1969-2011: 5-year survival remains poor despite advances in medical care and treatment strategies. Eur J Vasc Endovasc Surg. 2015 Sep;50(3):320-30. doi: 10.1016/j.ejvs.2015.05.004. PMID: 26116489; PMCID: PMC4831642.
17. Hammo S, Grannas D, Wahlgren CM. Time distribution of mortality after ruptured abdominal aortic aneurysm repair. Ann Vasc Surg. 2022 Oct;86:313-9. doi: 10.1016/j.avsg.2022.01.035. PMID: 35248744.
18. Nicolas R, Gonzales J, Hernandez D, Bautista ER, Manapat AE, Danguilan J. Risk factors that determine perioperative mortality and morbidity in surgery for infrarenal abdominal aortic aneurysms. Phil J Thorac Cardiovasc Surg. 2000;7(1):37-43.
19. Gabitoya E, Arellano R. In-hospital outcomes of patients with thoracic and abdominal aortic aneurysm who underwent surgical, endovascular and conservative medical management. Philippine Heart Center Journal. 2017;22(1):1-9.
20. Lieberg J, Pruks LL, Kals M, Paapstel K, Aavik A, Kals J. Mortality after elective and ruptured abdominal aortic aneurysm surgical repair: 12-year single-center experience of Estonia. Scand J Surg. 2018 Jun;107(2):152-7. doi: 10.1177/1457496917738923. PMID: 29117792.
21. Robinson WP, Schanzer A, Li Y, Goodney PP, Nolan BW, Eslami MH, et al. Derivation and validation of a practical risk score for prediction of mortality after open repair of ruptured abdominal aortic aneurysms in a US regional cohort and comparison to existing scoring systems. J Vasc Surg. 2013 Feb;57(2):354-61. doi: 10.1016/j.jvs.2012.08.120. PMID: 23182157; PMCID: PMC3773208.
22. Siracuse JJ, Krafcik BM, Farber A, Kalish JA, McChesney A, Rybin D, et al. Contemporary open repair of ruptured abdominal aortic aneurysms. J Vasc Surg. 2017 Apr;65(4):1023-8. doi: 10.1016/j.jvs.2016.08.115. PMID: 27986483.
23. Marković M, Tomić I, Ilić N, Dragaš M, Končar I, Bukumirić Z, et al. The rationale for continuing open repair of ruptured abdominal aortic aneurysm. Ann Vasc Surg. 2016 Oct;36:64-73. doi: 10.1016/j.avsg.2016.02.037. PMID: 27395813.
24. Law Y, Chan YC, Cheung GC, Ting AC, Cheng SW. Outcome and risk factor analysis of patients who underwent open infrarenal aortic aneurysm repair. Asian J Surg. 2016 Jul;39(3):164-71. doi: 10.1016/j.asjsur.2015.03.009. PMID: 25982448.
25. McArdle GT, Price G, Lewis A, Hood JM, McKinley A, Blair PH, et. al. Positive fluid balance is associated with complications after elective open infrarenal abdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg. 2007 Nov;34(5):522-7. doi: 10.1016/j.ejvs.2007.03.010. PMID: 17825590.
26. Carvalho FC, Brito VP, Tribulatto EC, van Bellen B. Estudo prospectivo da morbi-mortalidade precoce e tardia da cirurgia do aneurisma da aorta abdominal [Prospective study of early and late morbidity and mortality in the abdominal aortic aneurysm surgical repair]. Arquivos brasileiros de cardiologia, 2005;84(4):292–6. doi: 10.1590/s0066-782x2005000400004.
27. Bayly PJ, Matthews JN, Dobson PM, Price ML, Thomas DG. In-hospital mortality from abdominal aortic surgery in Great Britain and Ireland: Vascular Anaesthesia Society audit. Br J Surg. 2001 May;88(5):687-92. doi: 10.1046/j.0007-1323.2001.01778.x. PMID: 11350442.
28. Uchida K, Io A, Akita S, Munakata H, Hibino M, Fujii K, et al. Recent risk factors for open surgical mortality in patients with ruptured abdominal aortic aneurysm. Acute Med Surg. 2014 May 19;1(4): 207-13. doi: 10.1002/ams2.42. PMID: 29930850; PMCID: PMC5997233.
29. Scarcello E, Ferrari M, Rossi G, Berchiolli R, Adami D, Romagnani F, et al. A new preoperative predictor of outcome in ruptured abdominal aortic aneurysms: the time before shock (TBS). Ann Vasc Surg. 2010 Apr;24(3):315-20. doi: 10.1016/j.avsg.2009.07.011. PMID: 19900784.
30. van Beek SC, Reimerink JJ, Vahl AC, Wisselink W, Reekers JA, Legemate DA, et al. Amsterdam Acute Aneurysm Trial Collaborators. Outcomes after open repair for ruptured abdominal aortic aneurysms in patients with friendly versus hostile aortoiliac anatomy. Eur J Vasc Endovasc Surg. 2014 Apr;47(4):380-7. doi: 10.1016/j.ejvs.2014.01.003. PMID: 24485844.
31. Colson P, Ribstein J, Séguin JR, Marty-Ane C, Roquefeuil B. Mechanisms of renal hemodynamic impairment during infrarenal aortic cross-clamping. Anesth Analg. 1992 Jul;75(1):18-23. doi: 10.1213/00000539-199207000-00004. PMID: 1616156.
32. Gamulin Z, Forster A, Morel D, Simonet F, Aymon E, Favre H. Effects of infrarenal aortic cross-clamping on renal hemodynamics in humans. Anesthesiology. 1984 Oct;61(4):394-9. doi: 10.1097/00000542-198410000-00006. PMID: 6486501.