

# Extended length of stay after elective ascending aortic surgery and associated risk factors

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## ABSTRACT

**OBJECTIVE:** Surgery on the ascending aorta incurs greater risk than other cardiac procedures. The primary aim of this study is to identify pre-operative and operative risk factors that play a role in extended length of stay (LOS) after elective surgery for ascending aortic aneurysms. The secondary aim is to determine post-operative outcomes associated with extended LOS.

**METHODS:** Patients who underwent elective surgery aged >18 between January 2018 and December 2019 for ascending aortic aneurysm with or without concomitant interventions in a single heart surgery center were retrospectively identified. Patients with days of hospital stay longer than the median length made up the extended stay group. The extended stay group was compared against the rest of the patients for demographics and operative parameters, as well as post-operative outcomes.

**RESULTS:** Patients with extended LOS were older (60.0±12.2 vs. 54.0±14.2, p=0.001) with more frequent coronary artery disease (CAD) (47.2% vs. 23.7%, p<0.001) and chronic obstructive pulmonary disease (COPD) (25.0% vs. 11.9% p=0.013). More patients in the extended LOS group required HCA for distal aortic anastomosis (43.5% vs. 17.5%, p<0.001) and cardiopulmonary bypass (CPB) durations were longer (283.1±83.9 vs. 225.3±84.2 min, p<0.001). Multivariate analysis revealed age, CAD, COPD, HCA, and CPB time as risk factors for extended LOS. Extended LOS patients had longer mechanical ventilation times (23.0±21.3 vs. 13.6±5.3 h, p<0.001), more frequently had acute renal failure (24.2% vs. 6.7%, p<0.001), reoperation for bleeding (20.7% vs. 6.7%, p=0.003), and stroke (14.3% vs. 4.3%, p=0.011)

**CONCLUSION:** In elective surgery for ascending aortic aneurysms older age, history of COPD and CAD, longer CPB times, and HCA during surgery are associated with extended LOS. Further studies are needed to investigate the association of prolonged hospital stay with long-term outcomes, as well as the impact of operation type on hospital stay.

*Keywords:* Cardiac surgery; length of stay; thoracic aortic aneurysm.

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Aneurysms of the ascending aorta can lead to a rupture or dissection with disastrous consequences if left untreated. Connective tissue disorders and genetic mutations have been associated with ascending aortic aneurysms and the disease follows a familial pattern even if a specific genetic disease is not identified in more than

half of affected patients [1]. The aim of surgical correction is to save patients from impending mortal complications with minimal risk. Elective surgery for ascending aortic diseases can be performed with acceptable mortality [2, 3]. Nevertheless, it is a major surgery with significant associated morbidity and cost.



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Surgery on the ascending aorta incurs greater risk than other cardiac procedures. The reasons for this include longer times on cardiopulmonary bypass (CPB) needed and the necessity for hypothermic circulatory arrest for the distal aortic anastomosis for cases with more distal involvement [4]. With the additional comorbidities of operated patients, patients face significant risks of heart failure, respiratory failure, increased bleeding, and stroke among others. All these post-operative events can contribute to prolonged length of stay (LOS) after ascending aortic operation. Identifying which patients are under increased risk for extended LOS can help the surgeons better advise patients preoperatively concerning expected risks and be attentive to possible associated post-operative adverse events. LOS is also an important indicator for resource utilization and patients with expected long LOS can be referred to high volume centers for better outcomes [5].

The primary aim of this study is to identify pre-operative and operative risk factors that play a role in extended LOS after surgery for ascending aortic aneurysms. The secondary aim is to determine, in which post-operative outcomes are associated with extended LOS.

## MATERIALS AND METHODS

Patients who underwent elective surgery aged >18 between January 2018 and December 2019 for ascending aortic aneurysm with or without concomitant interventions in a single heart surgery center were retrospectively identified. Patients with aneurysmatic involvement of the aortic arch were excluded from the study. Approval was obtained from the Health Sciences University Dr. Siyami Ersek Hospital Academic Research Committee for this study (12.03.2021/No.E-28001928-604.01.01).

Patients with ascending aortic aneurysms were assessed for aortic valve function with transthoracic echocardiography. Patients with aortic stenosis or insufficiency were treated with concomitant aortic valve replacement, resuspension, or repair. All patients aged >40 or with symptoms of coronary artery disease (CAD) underwent coronary angiography. Patients with severe (>70%) coronary stenosis were treated with coronary artery bypass grafting (CABG) at the time of surgery. Ascending aortic diameter and the extent of the aneurysm were evaluated with computed tomography in all patients. Post-operative atrial fibrillation was defined as new-onset atrial fibrillation not present preoperatively. Strokes included all hemorrhagic or thrombotic cerebrovascular events lasting >24 h.

### Highlight key points

- In elective surgery for ascending aortic aneurysms older age, history of COPD and CAD, higher Euroscore II, longer CPB times, concomitant CABG, and HCA during surgery are associated with extended LOS.
- Extended LOS is associated with postoperative adverse outcomes including atrial fibrillation, longer mechanical ventilation times, acute renal failure, reoperation for bleeding, and stroke.
- Further studies are needed to investigate the association of prolonged hospital stay with long-term outcomes as well as the impact of operation type on hospital stay.

All operations were performed with a median sternotomy. The ascending aorta was used for arterial cannulation when the extent of anatomy permitted a clear aortic zone devoid of aneurysms or atherosclerotic walls. If the aneurysmatic segment involved the ascending aorta or ascending aorta did not permit cannulation due to friable vessel wall or extensive atherosclerosis, the axillary or the innominate arteries were used for arterial cannulation depending on surgeon preference. When patient factors such as obesity or atherosclerotic vessel walls did not permit axillary or innominate artery cannulations, the femoral artery was cannulated. The right atrium or the femoral vein was used for venous cannulation. The aorta was cross-clamped distal to the aneurysmatic segment. If the distal anastomosis required removal of the cross-clamp, the anastomosis was performed under moderate HCA at 20–28°C with antegrade cerebral perfusion through the innominate or the axillary cannula or under deep HCA at 18°C without antegrade cerebral perfusion. Patients were cooled 28–32°C if the operation was concluded without HCA.

Patients with mortality in the operating room were removed from analysis and median LOS was calculated. Patients with days of hospital stay longer than the median length made up the extended stay group. The extended stay group was compared against the rest of the patients for demographics and operative parameters, as well as post-operative outcomes.

### Statistics

IBM SPSS Statistics 22 was used to conduct statistical analysis. Categorical variables are presented as count and percentage, variables with normal distribution as mean ± standard deviation, and variables without normal distribution as median and interquartile range. Student's

**TABLE 1.** Operations performed on ascending aortic aneurysm patients

Operation type	Number of cases (%)
Supracoronary aortic replacement	29 (13.7)
Supracoronary aortic replacement with concomitant procedures	100 (47.2)
Bentall procedure	49 (23.1)
Bentall procedure with concomitant procedures	24 (11.3)
Cabrol procedure	3 (1.4)
Cabrol procedure with concomitant procedures	1 (0.5)
Valve sparing aortic root replacement	1 (0.5)
Valve sparing aortic root replacement with concomitant procedures	5 (2.4)

t-test and Chi-square tests were used to compare groups for quantitative data. Factors significant in univariate analysis were carried on to multivariate analysis. Odds ratios are presented with 95% confidence intervals. Significance was set at  $p < 0.05$ .

## RESULTS

A total of 212 patients who underwent elective surgery for ascending aortic aneurysm met inclusion criteria. The performed operations included supracoronary aortic replacement, Bentall procedure, Cabrol procedure, or valve sparing aortic root replacement (David procedure) with or without concomitant valve or coronary interventions (Table 1).

The mean age of included patients was  $56.6 \pm 13.7$  and 52 patients (24.5%) were female. The median LOS for our patients was 7 days. Of all patients, 92 stayed in the hospital after the operation for  $\geq 8$  days. These patients were placed in the extended LOS group. Patients in this group were compared against the rest of the patients with  $\leq 7$  days of hospital stay (Table 2).

Patients with extended LOS were older ( $60.0 \pm 12.2$  vs.  $54.0 \pm 14.2$ ,  $p = 0.001$ ). CAD (47.2% vs. 23.7%,  $p < 0.001$ ) and chronic obstructive pulmonary disease (COPD) (25.0% vs. 11.9%  $p = 0.013$ ) were more frequent in patients with extended LOS. The rate of female gender, the incidence of DM, HT, HL, and CRD were not different between the groups. The incidence of pre-operative atrial fibrillation or history of cerebrovascular events was not different between groups. Extended LOS group patients had higher

**TABLE 2.** Demographic and pre-operative parameters

	No extended length of stay (n=120)	Extended length of stay (n=92)	p
Age	$54.0 \pm 14.2$	$60.0 \pm 12.2$	<b>0.001</b>
Female gender (%)	20.0	30.4	0.080
Diabetes mellitus (%)	22.5	30.8	0.175
Hypertension (%)	59.7	65.2	0.410
Hyperlipidemia (%)	47.4	42.0	0.451
Coronary artery disease (%)	23.7	47.2	<b>&lt;0.001</b>
LVEF <40% (%)	3.4	6.5	0.284
Previous cardiac surgery (%)	6.7	6.5	0.966
COPD (%)	11.9	25.0	<b>0.013</b>
Chronic renal disease (%)	7.3	15.3	0.077
Atrial fibrillation (%)	3.4	6.6	0.335
History of stroke (%)	1.7	3.3	0.655
Euroscore II	$4.2 \pm 4.2$	$5.7 \pm 5.3$	0.023
Diameter of ascending aorta (mm)	$52.0 \pm 7.6$	$51.8 \pm 7.9$	0.833

LVEF: Left ventricular ejection fraction; COPD: Chronic obstructive pulmonary disease.

mean Euroscore II values ( $5.7 \pm 5.3$  vs.  $4.2 \pm 4.2$ ,  $p = 0.023$ ). Rates of the previous cardiac operations, low (<40%) EF, and ascending aortic diameter were similar between the groups.

More patients in the extended LOS group required HCA for distal aortic anastomosis (43.5% vs. 17.5%,  $p < 0.001$ ). Among the cases, in which HCA was employed, the mean duration of HCA was not different. The need for aortic valve intervention did not differ between groups; however, more patients required CABG in the extended LOS group. Patients in the extended LOS group had longer CPB times ( $283.1 \pm 83.9$  vs.  $225.3 \pm 84.2$  min,  $p < 0.001$ ) (Table 3).

To determine independent risk factors for extended LOS, a multivariate analysis was carried out with factors significant in univariate analysis (Table 4). CAD and not CABG were included in the model due to their interrelation and Euroscore II was not included as it is a composite score of other parameters in the model. In our cohort, the presence of CAD (OR: 2.21), HCA during surgery (OR: 2.24), and CPB time (OR: 1.04 for every 10 min) were factors independently associated with extended LOS.

**TABLE 3.** Operative parameters

	No extended length of stay (n=120)	Extended length of stay (n=92)	p
HCA (%)	17.5	43.5	< <b>0.001</b>
HCA duration* (hours)	20.8±6.0	23.4±6.9	0.185
CPB Duration (minutes)	225.3±84.2	283.1±83.9	< <b>0.001</b>
Site of arterial cannulation (%)			0.131
Ascending aorta	55.0	66.3	
Innominate artery	13.3	9.8	
Axillary artery	20.8	20.6	
Femoral artery	10.8	3.3	
Need for aortic valve intervention	75.0	77.2	0.714
Need for coronary bypass	21.7	37.0	<b>0.014</b>

HCA: Hypothermic circulatory arrest; CPB: Cardiopulmonary bypass; \*: Includes only the 61 patients that required HCA.

**TABLE 4.** Multivariate analysis of risk factors for extended length of stay

	p	OR (95% CI)
Age	0.132	1.02 (0.99–1.05)
Coronary artery disease	0.022	2.21 (1.12–4.37)
Chronic obstructive pulmonary disease	0.084	2.06 (0.91–4.66)
Hypothermic cardiac arrest	0.029	2.24 (1.09–4.60)
Cardiopulmonary bypass time (10 min)	0.027	1.04 (1.01–1.07)

OR: Odd ratios; CI: Confidence interval.

Groups were also compared for post-operative outcomes (Table 5). Post-operative mortality was not different between patients with and without extended LOS. Extended LOS patients had longer mechanical ventilation times (23.0±21.3 vs. 13.6±5.3 h,  $p<0.001$ ). Acute renal failure was more frequent (24.2% vs. 6.7%,  $p<0.001$ ) in the extended LOS group. More patients in the extended LOS group experienced reoperation for bleeding (20.7% vs. 6.7%,  $p=0.003$ ) and stroke (14.3% vs. 4.3%,  $p=0.011$ ). Post-operative atrial fibrillation was also more frequent (9.9% vs. 7.5%,  $p<0.001$ ) in patients with extended LOS.

## DISCUSSION

Extended LOS after aortic surgery results in increased resource expenditure and is associated with various adverse outcomes. Understanding the pre-operative and

**TABLE 5.** Post-operative outcomes

	No extended length of stay (n=120)	Extended length of stay (n=92)	p
Intensive care unit stay (days)	1 (1–1)	2 (1–4)	< <b>0.001</b>
Mechanical ventilation time (hours)	13.6±5.3	23.0±21.3	< <b>0.001</b>
Acute renal failure (%)	8 (6.7)	22 (24.2)	< <b>0.001</b>
Reoperation for bleeding (%)	8 (6.7)	19 (20.7)	<b>0.003</b>
Post-operative stroke (%)	5 (4.3)	13 (14.3)	<b>0.011</b>
Post-operative atrial fibrillation (%)	25 (21.2)	43 (46.7)	< <b>0.001</b>
Mortality (%)	9 (7.5)	9 (9.9)	0.538

operative factors that contribute to extended LOS can allow for better management of patients under greater risk for longer expected hospital stay. In our retrospective cohort, older age, CAD, COPD, HCA during surgery, concomitant CABG, and longer CPB times were associated with extended LOS. Patients with longer LOS more frequently experienced adverse events of longer ventilation times, acute renal failure, reoperation for bleeding, stroke, and post-operative AF.

The outcomes for ascending aortic aneurysm surgery can vary greatly with the demographics of the cohort and the type of operation performed. Notwithstanding, stroke, reoperation for bleeding, and prolonged ventilation are among the most severe complications experi-

enced in the post-operative period. Our outcomes are comparable with other reports in the literature [6, 7]. Mortality was not increased in our patients with extended LOS. While 30-day mortality is not increased in patients with extended LOS, Longer LOS has also been shown to negatively affect 1-year hospital readmissions and long-term mortality [8–10]. Therefore, understanding associated risk factors and preventing modifiable parameters can have long-lasting benefits for aortic surgery patients.

Few studies on ascending aortic aneurysm surgery have specifically studied LOS. In one single-center study on aortic root surgery patients, age, redo sternotomy, pre-operative cardiac disease, and intraoperative blood transfusion were independent predictors of LOS >9 days [11]. As this study included elective and urgent operations for aneurysm and dissection, the results may not be directly comparable to ours. In their subgroup analysis on elective patients, redo sternotomy, history of smoking, and intraoperative blood transfusion were found as independent risk factors. We lacked data on blood transfusion; however, more patients in the extended LOS group required reoperation for bleeding, suggesting increased bleeding is an important factor for extended LOS. The increased CPB times and the need for HCA in these patients lead to coagulopathy which results in increased blood loss. Increased bleeding increases the need for prolonged hospitalization and patients who require reoperation require even longer hospitalization times after cardiac and aortic surgery [12].

Extended LOS in proximal aortic surgery has been associated with prolonged ventilation, atrial fibrillation, and acute renal insufficiency [11]. Atrial fibrillation can bring about cardiac and neurological complications. Post-operative AF is often resolved with proper medical treatment, which, however, can prolong ICU and hospital stay following cardiac surgery [13, 14]. Acute renal failure and prolonged ventilation are also associated with further complications that prolong ICU and hospital stay depending on severity. Aortic procedures are associated with longer ventilation times than other cardiac procedures and extended LOS is seen more frequently in patients with prolonged ventilation [15]. Known risk factors for prolonged ventilation following general cardiac surgery include older age, history of COPD, longer CPB time, and reoperation [16, 17]. These factors were observed in our patients with longer LOS. Age and COPD are not modifiable risk fac-

tors, whereas surgeons can explore methods to reduce CPB times and reoperations in high-risk patients so that prolonged ventilation and its associated extended LOS are prevented. Euroscore II is a major risk-scoring system widely used and validated for mortality prediction in cardiac surgery. While Euroscore II is intended for mortality prediction, higher scores have been also correlated with adverse events and prolonged hospital stay following cardiac surgery including thoracic aortic surgery [18]. Similarly, our extended LOS patients had higher Euroscore II values, confirming the ability of Euroscore II of correctly predicting patients under risk for extended LOS.

Aortic surgery comprises a greater risk of stroke than other types of cardiac surgery [19]. Besides inherent factors such as atherosclerosis of the carotid or cerebral vessels, the use of CPB brings important risks for stroke due to systemic inflammation, atheromatous debris, or air embolism. HCA provides a bloodless field for the distal aortic anastomosis while providing cerebral protection with reduced cerebral metabolism. Antegrade cerebral perfusion through the subclavian or innominate arteries allows a safer HCA period [20]. Despite these techniques of cerebral protection, stroke is the most debilitating morbidity following thoracic aortic surgery and a very important risk factor for mortality, prolonged mechanical ventilation, and longer LOS [21].

There are several limitations to our study. Our study was conducted in a single center which may constitute a selection bias. Data were collected retrospectively and analysis could be performed only on parameters available in the hospital database. The number of included patients did not permit comparison of LOS across different operation types and patients undergoing different operations had to be grouped together. We did not have long-term follow-up data to comment on the effects of extended LOS on long-term survival and adverse event.

## Conclusion

In elective surgery for ascending aortic aneurysms older age, history of COPD and CAD, higher Euroscore II, longer CPB times, concomitant CABG, and HCA during surgery are associated with extended LOS. Extended LOS is associated with post-operative adverse events. Further studies are needed to investigate the association of prolonged hospital stay with long-term outcomes as well as the impact of operation type on hospital stay.

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