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Early Extubation Reduces Respiratory Complications and Hospital Length of Stay Following Repair of Abdominal Aortic Aneurysms

Sara L. Zettervall, MD MPH[1,2], **Peter Soden, MD**[1], **Katie E. Shean, MD**[1], **Sarah E. Deery, MD**[1], **Klaas HJ Ultee, MD**[1], **Matthew Alef, MD**[3], **Jeffrey J. Siracuse, MD**[4], and **Marc L. Schermerhorn, MD**[1] **on behalf of On behalf of the Vascular Study Group of New England**

[1]Division of Vascular and Endovascular Surgery, Beth Israel Deaconess Medical Center, Boston MA

[2]Department of Surgery, George Washington University, Washington, DC

[3]Division of Vascular Surgery, University of Vermont Medical Center, Burlington VT

[4]Division of Vascular and Endovascular Surgery, Boston Medical Center, Boston MA

Abstract

Introduction—Early extubation following cardiac surgery is associated with decreased hospital stay and resource savings with similar mortality and has led to the widespread use of early extubation protocols. In the Vascular Quality Initiative, there is significant regional variation in the frequency of extubation in the operating room (Endovascular (EVAR): 77–97%, Open: 30–70%) following repair of intact abdominal aortic aneurysms (AAA). However, the effects extubation practices on patient outcomes after repair of AAAs are unclear.

Methods—All patients undergoing repair of an intact AAA in the Vascular Study Group of New England from 2003–2015 were evaluated. Patients undergoing concomitant procedures or conversions were excluded. Timing of extubation was stratified for EVAR (Operating Room, <12 hours, >12 hours) and open repair (Operating Room, <12 hours, 12–24 hours, >24 hours). Prolonged hospital stay was defined as >2 days following EVAR and >7 days following open repair. Univariate and multivariable analyses were completed, and independent predictors of extubation outside of the operating room were identified.

Results—5774 patients were evaluated (EVAR: 4453, Open: 1321). Following both EVAR and open repair, respiratory complications, prolonged hospital stay, and discharge to a skilled nursing facility (SNF) increased with intubation time. After adjustment, the odds of complications increased with each 12-hour delay in extubation: respiratory (EVAR-OR: 4.3, 95% CI: 3.0–6.1;

Corresponding Author / Reprints: Marc L. Schermerhorn, 110 Francis St. Suite 5B, Boston, MA 02215; Phone: 617-632-9971; mscherm@bidmc.harvard.edu.

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Open-OR: 1.8, 95% CI: 1.5–2.2), prolonged hospital stay (EVAR-OR: 2.7, 95% CI: 2.0–3.8; Open–OR: 1.3, 95% CI:1.1–1.4), and discharge to SNF (EVAR-OR: 2.0, 95% CI: 1.5–2.8; Open-1.4, 95% CI 1.1–1.6). Predictors of extubation outside of the operating room following EVAR included: increasing age (OR:1.5, 95% CI:1.2–1.8), congestive heart failure (CHF) (OR: 1.9, 95% CI:1.2–3.0), chronic obstructive pulmonary disease (OR: 2.0, 95% CI: 1.4–2.9), symptomatic aneurysm (OR: 3.8, 95% CI 2.3–5.7), and increasing diameter (OR: 1.01, 95% CI: 1.01–1.01). Following open repair increasing age (OR: 1.4, 95% CI: 1.1–1.6), CHF (OR: 1.8, 95% CI: 1.01–3.3), dialysis (OR: 2.8, 95% CI: 1.7–70), symptomatic aneurysm (OR 2.8, 95% CI: 1.9–4.3), and hospital practice patterns (OR: 1.01, 95% CI: 1.01–1.01) were predictive of extubation outside of the operating room.

Conclusions—The benefits of early extubation in cardiac patients are also seen following AAA repair. Suitable patients should be extubated in the operating room to decrease respiratory complications, length of stay, and discharge to SNF. Early extubation protocols should be considered to reduce regional variation in extubation practices and improve patient outcomes.

Introduction

Early extubation following cardiac surgery has been associated with decreased Intensive Care Unit (ICU) and hospital length of stay as well as cost savings with similar or improved mortality.[1–4] These findings have led to the widespread utilization of “fast track” and early extubation protocols among surgeons, anesthesiologists, and ICUs for patients undergoing coronary artery bypass grafting and valve replacement.[5, 6]

In patients undergoing abdominal aortic aneurysm repair (AAA), no guidelines for fast-track extubation exist, and early extubation protocols are not widely described. Furthermore, wide variation in anesthetic practice, including extubation time and epidural use exists within the United States.[7] Small studies have evaluated the impact of extubation timing at single institutions and found patients extubated on the day of surgery had lower costs and shorter hospital stays. However, this research was limited by limited sample size and a lack of adjusted analysis.[8] Moreover, no previous studies have evaluated the impact of extubation time on outcomes following endovascular repair (EVAR). Given these gaps in knowledge, this study aims to evaluate the effect of extubation time on patients’ outcomes following EVAR and open repair.

Methods

Population

The Vascular Study Group of New England (VSGNE) was utilized to identify all patients undergoing EVAR or open repair of an intact infra-renal AAA from 2003–2015. All patients with ruptured AAA and conversions from EVAR to open repair were excluded. Additionally, patients undergoing concomitant abdominal operations or bypass, EVARs who were not intubated (local/regional anesthesia), and those patients with missing data on the timing of extubation were excluded.

Variables

Demographics, comorbid conditions, operative details, and outcomes were evaluated for all patients. Extubation time for EVAR was defined by the VSGNE database and included: extubation in the operating room, less than 12 hours, or greater than 12 hours. For open repair extubation was recorded as in the operating room, less than 12 hours, 12 to 24 hours, and greater than 24 hours. Each hospital was identified by their individual center identification number in the VSGNE, and was used to evaluate the effect of hospital practice patterns. Pneumonia was defined by the VSGNE as treatment with antibiotics for a diagnosis of pneumonia identified in chart review by trained reviewers. Mortality data were recorded from the Social Security Death Index and defined at 1 year. Prolonged length of stay was defined as more than 2 days following EVAR and more than 7 days following open repair or discharge to a non-home location in accordance with the Centers for Medicare and Medicaid Services clinical benchmarks.[9] Respiratory complications were defined as pneumonia or re-intubation. When patient discharge location was evaluated, those patients living in a nursing facility pre-operatively were excluded from analysis. Discharge to a nursing home, rehabilitation center, or other hospital after admission from home was considered discharge to a skilled nursing facility (SNF).

Statistical Analysis

Statistical analysis for this paper was completed using the SPSS statistical package (version 21.0) and all figures were produced using GraphPad (version 6.0). Binary variables were assessed using Chi-Square and Fisher's Exact test as appropriate. Continuous variables were evaluated with the Student's t-test, ANOVA, or Mann-Whitney U-test as appropriate. Logistic regression and Cox proportional hazard modeling were utilized to account for patient demographics, comorbid conditions, and operative details with extubation in the operating room used as a reference group. Multivariable regression was used to identify independent predictors of extubation outside of the operating room. Purposeful selection was utilized to identify covariates for inclusion in our multivariable model. This method includes variables identified on univariate analysis with $P < 0.1$ for each endpoint of interest and clinically relevant factors shown to be predictive of adverse events in previous studies.[10] The Hosmer-Lemshow test was used to confirm goodness of fit for each multivariable model. A p-value of less than 0.05 was considered significant. The institutional review board of Beth Israel Deaconess Medical Center approved this study and waived consent due to the de-identified nature of this database.

Results

A total of 5,774 patients were evaluated including 4453 patients undergoing EVAR and 1321 undergoing open repairs. Among patients who underwent EVAR, 4319 (97%) were extubated in the operating room, 75 (2%) were extubated in less than 12 hours, and 59 (1%) were extubated in more than 12 hours. Among open repairs, 1063 (81%) patients were extubated in the operating room, 170 (13%) were extubated in less than 12 hours, 47 (4%) were extubated in 12 to 24 hours, and 41 (3%) were extubated in more than 24 hours.

Demographics and Operative Details

Among EVARs, age increased with delayed extubation (Operating Room: 74, <12: 78, >12: 78, P < .01), as did the proportion with congestive heart failure (Operating room: 10%, < 12 hours: 17%, > 12 hours: 31%, P = 0.03) and chronic obstructive pulmonary disease (Operating Room: 33%, < 12 hours: 51%, > 12 hours: 52%, P < .01). The proportion of women extubated at each time interval demonstrated a trend toward delayed extubation in women but this did not achieve significance (Operating Room: 19%, <12 hours: 27%, > 12 hours: 29%; P = 0.05) (Table I). Among patients undergoing open repair, age increased with delayed extubation (Operating Room: 69 < 12 hours: 73, 12–24 hours: 71, > 24 hours: 72, P < .01) as did the proportion with congestive heart failure (Operating Room: 4%, <12 hours: 10%, 12–24 hours: 2%, >24 hours: 15%, P < .01), female gender (Operating Room: 24%, < 12 hours: 28%, 12–24 hours: 38%, > 24 hours: 37%, P = 0.047) and pre-operative dialysis (Operating Room: 2%, < 12 hours: 2%, 12–24 hours: 0%, > 24 hours: 0%, P = 0.02) (Table II).

Among patients undergoing EVAR, delayed extubation was associated with larger maximum diameter (Operating Room: 5.5, < 12 hours: 5.5, > 12 hours: 6, P < .01), symptomatic aneurysms (Operating Room: 7%, < 12 hours: 19%, > 12 hours: 27%, P < .01), and longer median operative time (Operating Room: 136 minutes, < 12 hours: 164 minutes, >12 hours: 230 minutes). There were no differences in the frequency of iliac aneurysms (Table I). Among open repairs, delayed extubation was associated with symptomatic aneurysms (Operating Room: 8%, < 12 hours: 18%, 12–24 hours: 28%, >24 hours: 22%), epidural use (Operating Room: 68%, <12 hours: 63%, 12–24 hours: 51%, > 24 hours: 37%, P < .01), and longer median operative time (Operating Room: 180 minutes, < 12 hours: 195 minutes, 12–24 hours: 240 minutes, > 24 hours: 267 minutes, P< .01). Maximum diameter and the frequency of iliac aneurysms were similar among all open repairs (Table II).

Outcomes

Thirty-day mortality differed for both EVAR (Operating Room: 1%, < 12 hours: 3%, > 12 hours: 10%, P< .01) and open repair (Operating Room: 1%, < 12 hours: 1%, 12–24 hours: 0%, > 24 hours: 20%, P< .01); however low event numbers prohibited multivariable analysis. On Kaplan Meier analysis, 1-year mortality worsened as time extubation increased for both EVAR (P < .01) and open repair (P < .01). After adjustment for demographics and operative characteristics, there was no difference 1-year mortality following EVAR; however following open repair, extubation time beyond 24 hours was associated with increased mortality (Odds Ratio (OR): 5.5, 95% Confidence Interval (CI) 2.6–11.5) (Figures 1 and 2).

Morbidity increased with intubation duration following both EVAR and open repair. Following EVAR, respiratory complications were more common with increased time to extubation (Operating Room: 1.5%, < 12 hours: 4%, > 12 hours: 40%, P< .01), as were pneumonia (Operating Room: 1%, < 12 hours: 0%, > 12 hours: 5%, P < .01), prolonged length of stay (Operating Room: 23%, < 12 hours: 48%, > 12 hours: 92%, P< .01), and discharge to a SNF (Operating Room: 7%, < 12 hours: 21%, >12 hours: 51%, P < .01). After open repair, respiratory complications also increased with delayed extubation (Operating Room: 5%, < 12 hours: 7%, 12–24 hours: 9%, > 24 hours: 46%, P< .01), as did prolonged length of stay (Operating Room: 34%, < 12 hours: 49%, 12–24 hours: 68%, > 24 hours: 86%, P< .01), and discharge to a SNF (Operating Room: 16%, < 12 hours: 29%, 12–24 hours: 46%, > 24 hours: 42%, P< .01) (Figure 3).

After multivariable analysis adjusting for demographics, comorbidities, operative differences (including diameter, procedure time, blood loss, epidural use, and symptom status) and hospital practice patterns, complications increased with each 12 hour delay in extubation for both EVAR and open repair. These including the following complications: respiratory (EVAR-OR: 4.3, 95% CI: 3.0–6.1; Open-OR: 1.8, 95% CI: 1.5–2.2), prolonged hospital stay (EVAR-OR: 2.7, 95% CI: 1.9–3.8; Open–OR: 1.4, 95% CI:1.2–1.7), and discharge to a SNF (EVAR-OR: 2.0, 95% CI: 1.5–2.8; Open-1.4, 95% CI 1.1–1.6) (Table III). All multivariable predictors of respiratory complications, prolonged length of stay, and discharge to a SNF are listed in supplemental Tables I–III.

Predictors of Extubation Outside of the Operating Room

Predictors of extubation outside of the operating room for EVAR were increasing age (OR: 1.5, 95% CI: 1.2–1.8), congestive heart failure (OR: 1.9, 95% CI: 1.2–3.0), chronic obstructive pulmonary disease (OR: 2.0, 95% CI: 1.4–2.9), symptomatic aneurysms (OR: 3.8, 95% CI: 2.3–5.7), and increasing diameter (OR: 1.01, 95% CI: 1.0–1.01). Following open repair increasing age (OR: 1.4, 95% CI: 1.1–1.6), congestive heart failure (OR: 1.8, 95% CI: 1.01–3.3), preoperative dialysis (OR: 11.0, 95% CI:1.7–69.6), and symptomatic aneurysms (OR: 2.8, 95% CI: 1.9–4.3) independently predicted extubation outside of the operating room. Importantly, however, the rate of extubation outside of operating room varied significantly by hospital for EVAR (Range: 0–12%, P < .01) and open repair (Range: 0–69%, P < .01). This difference in hospital practice patterns after open repair (OR: 1.01 95% CI: 1.01–1.01) remained associated with extubation outside of the operating room after adjustment for patient characteristics and significantly improved the fit of our multivariable model when the hospital identification number was included (Table IV).

Discussion

This study found that extubation outside of the operating was associated with increased respiratory complications, prolonged hospital stay, and discharge to a skilled nursing facility following AAA repair. Additionally, predictors of extubation outside of the operating room included age, increased comorbidities, and hospital practice patterns.

Few studies have evaluated the effect of extubation time on outcomes following vascular surgery. In 2001, Cohen et al. completed the only prospective randomized trial comparing immediate extubation (< 2 hours) and delayed extubation (> 4 hours) following elective open AAA repair and concluded that immediate extubation could be performed safely with no differences in mortality or hospital stay.[11] However, due to small sample size and randomization, Cohen et al were unable to identify predictors of delayed extubation or identify pre-operative factors that could impact decision making surrounding extubation time. Similar conclusions were drawn by Stone et al. when they evaluated the outcomes of patients who underwent immediate extubation (<2 hours) and found that reintubation rates of 4.8% with 1.6% mortality.[12] Despite these studies concluding that early extubation is safe, it should be noted rapid extubation was widely achieved, even in Cohen's delayed cohort (median time 340 minutes). To further evaluate this topic, a study of 191 Japanese patients evaluated patients extubated on the day of surgery compared to those extubated later, with median post-operative extubation times of 2.6 versus 17.4 hours respectively. Researchers found decreased costs and length of stay among those patients extubated on the day of surgery. However, similar to previous studies, adjustment was prohibited by low event rates.[8]

Following cardiac surgery, the effect of extubation time on adverse outcomes and hospital costs is well studied in patients younger than 70 as well as the elderly populations.[1, 3, 13] Randomized controlled trials demonstrated significant cost savings and shorter ICU and hospital stays.[2] Similarly, a Cochrane review of 25 randomized trials also found fast track anesthesia to be safe resulting in shorter ICU stays.[13] When morbidity and mortality were evaluated, similar or improved outcomes were seen among patients undergoing early extubation.[4, 13] As a result of these data, the American College of Cardiology and American Heart Association guidelines now recommend anesthetic management directed toward early post-operative extubation for patients undergoing coronary artery bypass grafting.[6]

Similar to research in cardiac patients and those undergoing open AAA, our study found increased hospital stay, as well as respiratory complications, and discharge to SNF following EVAR and open AAA repair. These results have important clinical implications for resource utilization and quality improvement. Given the high cost of hospital care, skilled nursing facilities, and rehab, the benefits of early extubation shown in this work offer the potential for cost savings which have been previously demonstrated in trials evaluating the savings associated with early extubation in cardiac surgery.[2]

In addition to cost saving, early extubation may also offer the opportunity to decrease ventilator-associated pneumonia (VAP). In a large study of ventilated patients in a surgical ICU, an extubation protocol that reduced intubation time demonstrated a reduction of ventilator-associated pneumonia, reintubation, and shorter ICU length of stay following implementation.[14] This study has several notable limitations. First, this study is impacted by all potential limitations of the VSGNE including missing data, errors in coding, and limited long-term follow-up. However, all variables addressed in this study had less than 5% missing data, and only well populated mortality data were evaluated in the long-term. This study is also limited to the variables available in the VSGNE database, and additional confounders that we are unable to adjust for may effect extubation time. Example may include: severity of comorbidities, nutritional status, and cognitive function. This study is also unable to define extubation time more precisely than the 12-hour intervals documented in the VSGNE. More specific data here could help define optimal extubation time. Finally, following both EVAR and open AAA repair, those patients intubated the longest are likely to have complications and comorbidities that are partly responsible for their delayed extubation time, and as such, extubation duration may not be easily changed. Additionally, multivariable models are able to provide correlation, but we are unable to determine if delayed extubation is the cause of worse outcomes in the current study. However, hospital practice patterns did have significant effect on extubation timing, even after adjusting for all relevant differences, which suggests that practice patterns also play a large role in the timing of extubation. Despite, these limitations, the current work provides a large multicenter study capable of adjusted analysis, which has not been possible previously due to the small sample sizes of prior studies.

Conclusions

The benefits of early extubation that have previously been demonstrated following cardiac surgery are also seen among patients undergoing repair of an intact AAA. Suitable patients should be extubated in the operating room to decrease length of stay, respiratory complications, and discharge to a SNF. Consideration of early extubation protocols among these patients should be given to reduce the regional variation in extubation practices and improve patient outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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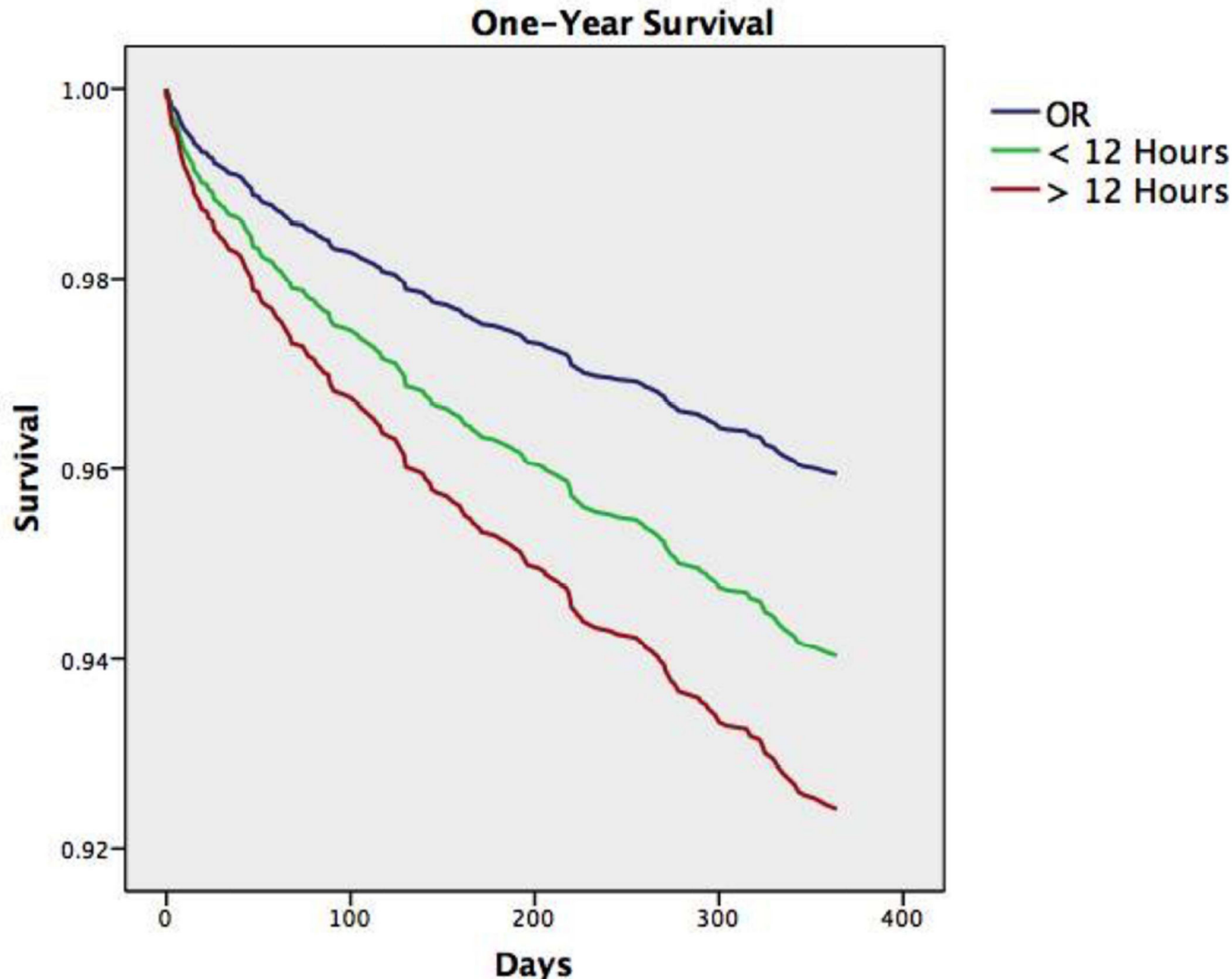
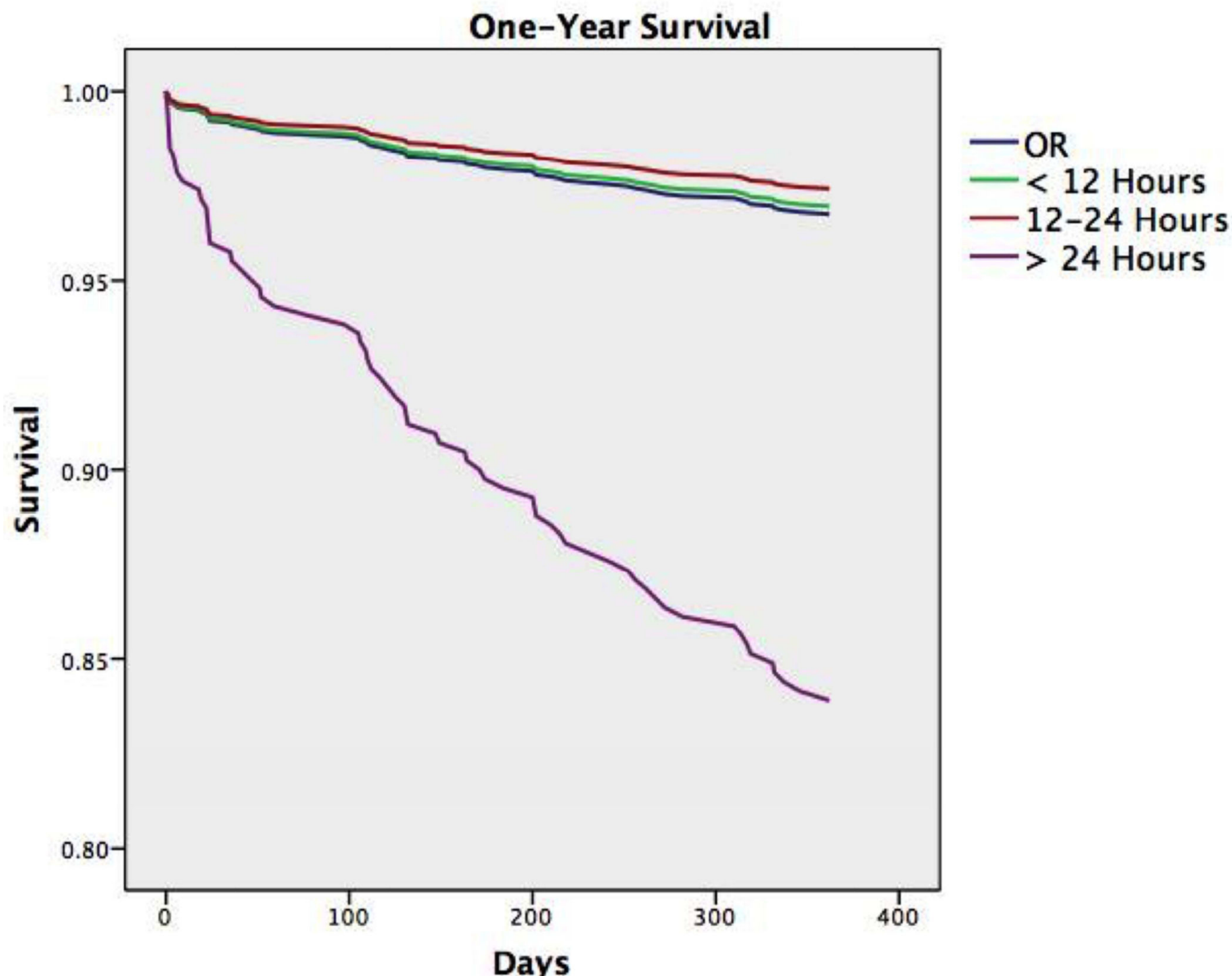


Number at Risk				
OR:	4319	4163	3999	3814
< 12:	75	69	64	54
>12:	59	50	46	43

Figure 1.

EVAR Adjusted 1-Year Survival

Cox Proportional Hazard Models Adjusted for age, gender, smoking, congestive heart failure, COPD, Symptom status, dialysis, procedure time, blood loss, diameter, and Hospital ID



Number at Risk				
OR:	1063	1032	1005	977
< 12:	170	165	163	160
12-24:	47	46	42	39
>24:	41	31	29	26

Figure 2.

Open Adjusted 1-Year Survival

Cox Proportional Hazard Models Adjusted for age, gender, smoking, congestive heart failure, COPD, Symptom status, dialysis, epidural use, procedure time, blood loss, diameter, and Hospital ID

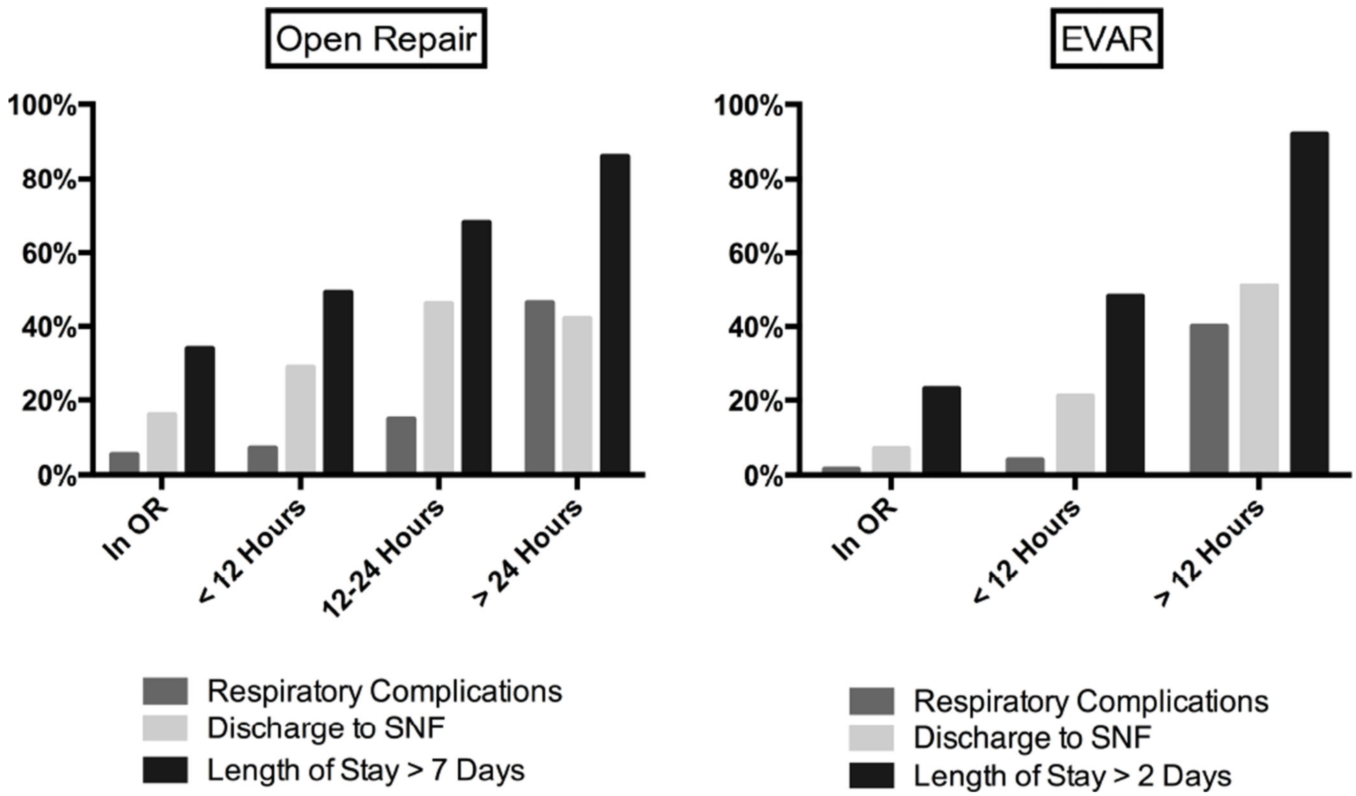


Figure 3.
Rates of Post-Operative Complications (univariate)

Table I

EVAR: Demographics, Comorbidities, and Operative Details

	Extubated In OR (N=4319)	**<12 hours (N=75)**	**>12 hours (N=59)**	**P-Value**
Demographics				
Age – mean (SD)	74 (9)	78 (9)	78 (9)	**<.01**
Male Gender (%)	3489 (81)	55 (73)	42 (71)	0.05
White Race (%)	4150 (96)	69 (92)	56 (95)	0.18
Smoking (%)	3719 (86)	68 (91)	49 (83)	0.42
Diabetes (%)	871 (20)	18 (24)	13 (22)	0.68
Coronary Artery Disease (%)	1432 (33)	27 (36)	21 (36)	0.81
Congestive Heart Failure (%)	440 (10)	13 (17)	18 (31)	**0.03**
Chronic Obstructive Pulmonary Disease (%)	1412 (33)	38 (51)	31 (53)	**<.01**
Dialysis (%)	31 (1)	1 (1)	0 (0)	0.66
Pre-op Nursing Home (%)	51 (7)	1 (1)	4 (7)	**<.01**
Operative Details				
Diameter (centimeters) – median (IQR)	5.5 (5.2-6)	5.5 (5.1-6.9)	6 (5.5-7.3)	**<.01**
Symptomatic (%)	278 (7)	13 (19)	18 (28)	**<.01**
Iliac Aneurysm (%)	919 (21)	16 (21)	17 (28)	0.39
Operative Time (minutes)– median (IQR)	136 (105-180)	164 (120-225)	230 (179-380)	**<.01**
Estimate Blood Loss (mL) – median (IQR)	150 (100-250)	150 (100-300)	500 (250-1500)	**<.01**

OR: Operating Room, SD: standard deviation, IQR: Interquartile Range, mL: milliliter

Table II

Open Repair: Demographics, Comorbidities, and Operative Details

	Extubated In OR (N=1063)	<12 hours (N=170)	12–24 hours (N-47)	>24 hours (N=41)	P-Value
Demographics					
Age – mean (SD)	69 (8)	73 (9)	71 (9)	72 (9)	**<.01**
Male Gender (%)	805 (76)	123 (72)	29 (62)	26 (63)	**0.047**
White Race (%)	1034 (97)	162 (95)	45 (96)	40 (98)	0.52
Smoking (%)	975 (92)	158 (93)	42 (89)	38 (93)	0.87
Diabetes (%)	148 (14)	32 (19)	11 (23)	6 (15)	0.14
Coronary Artery Disease (%)	318 (30)	63 (37)	14 (30)	14 (34)	0.29
Congestive Heart Failure (%)	46 (4)	17 (10)	1 (2)	6 (15)	**0.01**
Chronic Obstructive Pulmonary Disease (%)	330 (31)	66 (39)	19 (40)	18 (44)	0.05
Dialysis (%)	2 (0.2)	3 (2)	0 (0)	0(0)	**0.02**
Pre-op Nursing Home (%)	3 (0.3)	1 (1)	1 (2)	1 (2)	0.06
Operative Details					
Diameter (centimeters) – median (IQR)	5.7 (5.2–6.5)	5.8 (5.4–6.5)	5.5 (5.1–8.1)	5.7 (5.3–6)	0.25
Symptomatic (%)	81 (8)	30 (18)	13 (28)	9 (22)	**<.01**
Iliac Aneurysm (%)	311 (29)	50 (30)	11 (23)	11 (27)	0.83
Epidural (%)	725 (68)	107 (63)	24 (51)	15 (37)	**<.01**
Retroperitoneal exposure (%)	132 (12)	24 (14)	6 (13)	7 (17)	0.78
Operative Time (minutes)– median (IQR)	180 (140–228)	195 (160–270)	240 (200–310)	267 (188–386)	**<.01**
Estimate Blood Loss (L) – median (IQR)	1 (0.7–1.5)	1.2 (0.7–2.0)	1.5 (0.9–2.5)	1.4 (0.9–2.2)	**<.01**

OR: Operating Room, SD: standard deviation, IQR: Interquartile Range, L: Liter

Table III

Multivariable Outcomes

	Odds of Complications per 12 hour delay (Odds Ratio, 95% Confidence Interval)
EVAR[a]	
Respiratory Complication	4.3 (3.0–6.1)
Length of Stay > 2 Days	2.7 (1.9–3.8)
Discharge to SNF[c]	2.0 (1.5–2.8)
Open[b]	
Respiratory Complication	1.8 (1.5–2.2)
Length of Stay > 7 Days	1.4 (1.2–1.7)
Discharge to SNF[c]	1.4 (1.1–1.6)

SNF: Skilled Nursing Facility

a) Adjusted for Age, Gender, COPD, Smoking, CHF, COPD, Dialysis, Symptom Status, Blood Loss, Procedure Time, Diameter, Hospital ID

b) Adjusted for Age, Gender, COPD, Smoking, CHF, COPD, Dialysis, Epidural Use, Symptom Status, Procedure Time, Blood Loss, Diameter, Hospital ID

c) Patients living in nursing home pre-operatively excluded

Table IV

Predictors of Extubation Outside of OR

	EVAR OR (95% CI)	P-Value	Open OR (95% CI)	P-Value
Age (Decade)	1.5 (1.2–1.8)	**<.01**	1.4 (1.1–1.6)	**<.01**
Female Gender	1.4 (0.9–2.0)	0.16	1.2 (0.8–1.6)	0.38
Smoking	1.2 (0.7–2.1)	0.53	1.2 (0.7–2.1)	0.57
Congestive Heart Failure	1.9 (1.2–3.0)	**<.01**	1.8 (1.01–3.3)	**0.047**
COPD	2.0 (1.4–2.9)	**<.01**	1.3 (0.9–1.8)	0.11
Dialysis	0.96 (0.3–7.3)	0.97	11.0 (1.7–69.6)	**0.01**
Symptomatic Aneurysm	3.8 (2.3–5.7)	**<.01**	2.8 (1.9–4.3)	**<.01**
Diameter	1.01 (1.0–1.01)	**0.046**	1.01 (0.99–1.02)	0.36
Hospital Identification	1.01 (0.99–1.01)	0.12	1.01 (1.01–1.01)	**<.01**

COPD: Chronic Obstructive Pulmonary Disease