Increased Length of Hospital Stay after Endovascular Abdominal Aortic Aneurysm Repair: Role of Pulmonary Complications

Yang Yang 1, Erik Lehman 2, Faisal Aziz 3

1. Office of Medical Education, Drexel University College of Medicine, Philadelphia, USA 2. Surgery, Penn State College of Medicine, Penn State Milton S. Hershey Medical Center, Hershey, USA 3. Cardiac / Thoracic / Vascular Surgery, Penn State College of Medicine, Penn State Milton S. Hershey Medical Center, Hershey, USA

Corresponding author: Yang Yang, yyang0711@gmail.com
Disclosures can be found in Additional Information at the end of the article

Abstract

Objectives
The average hospital length of stay plays a significant role in healthcare costs, and is also used as a metric of hospital efficiency. An advantage of endovascular abdominal aortic aneurysm repair (EVAR) is the shorter postoperative time period after the surgery. The purpose of this study is to review the factors associated with increased length of stay after EVAR.

Methods
The records from American College of Surgeons National Quality Improvement Program (ACS-NSQIP) database in 2013 were obtained using Procedure Participant User File. Pre-, intra-, and post-operative factors were assessed of patients undergoing EVAR in 2013. Multivariable logistic regression analysis was used to identify independent variables for a hospital length of stay of at least seven days.

Results
A total of 1,991 patients (18.7% female, 81.3% males) underwent EVAR in 2013. Among these patients, 223 (11.2%) had a hospital stay greater than seven days. Variables significantly associated with length of stay in a multivariable model included: total operation time greater than 180 minutes (vs. less than 90 minutes, OR 1.88, CI 1.03-3.41, p = 0.039), postoperative, and intraoperative transfusions (OR 2.60, CI 1.66-4.08, p < 0.001), return to operating room (OR 2.88, CI 1.55-5.38, p < 0.001), rupture indication for surgery (OR 5.59, CI 3.18-9.83, p < 0.001), myocardial infarction (OR 5.85, CI 2.22-15.43, p < 0.001), preoperative transfusion (OR 13.05, CI 4.26-39.99, p < 0.001), and on ventilator greater than 48 hours (OR 49.65, CI 10.72-230.07, p < 0.001).

Conclusions
Multiple factors affect length of hospital stay in patients who have undergone EVAR. Patients with postoperative respiratory failure after EVAR have a significantly higher risk for longer hospital stays.

Categories: Cardiac/Thoracic/Vascular Surgery
Keywords: evar, respiratory failure, length of stay, aortic aneurysm
Introduction

In the United States health care system, there has been an emphasis on providing the best patient care while simultaneously maximizing hospital efficiency and expenditures. One factor that is commonly analyzed is length of stay (LOS), which is used as a proxy for resource utilization and healthcare delivery cost [1-3]. Previous studies have shown that decreased LOS results in significant cost savings [3-5]. By understanding factors that play a role in LOS, hospital administration and leaders may be able to improve unnecessarily long hospital stays without negatively impacting patient outcomes.

Abdominal aortic aneurysms (AAA) with large diameter aneurysms are known to have an increased risk of rupture, and in turn, mortality. This disease process can be treated with either open AAA repair or endovascular abdominal aortic aneurysm repair (EVAR). EVAR is quickly becoming the preferred treatment for patients with AAA, due to its shorter postoperative LOS compared to open repair.

The aim of our study was to examine predictors for a prolonged LOS in patients who have undergone EVAR in order to identify potential modifiable risk factors and areas to improve healthcare delivery. We hypothesize that a number of preoperative, intraoperative, and postoperative variables could be identified and used as targets to reduce LOS in patients undergoing EVAR.

Materials And Methods

Data set

The American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) is a national outcomes-based, surgical data set comprised of data from over 600 hospitals across the US [6]. It does not identify hospitals, healthcare providers, or patients, thus obviating the need for Institutional Review Board approval or patients’ consent. Patient demographics, pre-operative, intra-operative, and post-operative variables are recorded and maintained by trained clinical nurses at all the participating sites. A systemic sampling method is used to ensure adequate representation of all surgical operations. Outcomes are recorded for 30 days and have been shown to be highly reliable with less than 1.5% variable disagreements in annual audits [7]. The data set is maintained by the ACS and is compliant with the Health Insurance Portability and Accountability Act (HIPAA). Multiple publications based on analyses of this database have been published in literature.

Patients

ACS started using specific Procedure Targeted Participant User Files in year 2011 for certain vascular surgery and colorectal surgical operations. The procedure targeted file for patients who underwent EVAR in year 2013 was utilized. Using unique case identification numbers, this file was merged to the main ACS-NSQIP adult participant use data file for year 2013. Methods used to extract data from this data set have been described in previously published literature [7-11].

Outcomes

The primary outcome was increased length of stay, defined as total hospital stay greater than seven days. Basic demographic data was analyzed including age, gender, race, age range, and body mass index (BMI) range. The complete list of pre-operative, intra-operative, and post-operatives is included in Table 1 and Table 2.
Statistical analysis

All variables were initially summarized with frequencies and percentages or means, medians, and standard deviations. Level of statistical significance was set at $p = 0.05$. Logistic regression was used to determine any bivariate associations of independent variables with length of stay greater than seven days. Odds ratios were used to quantify the magnitude and direction of any significant associations. The independent variables that were significant in the initial bivariate analysis were then used in a process of stepwise selection to find the group of variables collectively that were most significantly associated with length of stay greater than seven days in a multivariable logistic regression model. Stringent entry and stay criteria of $p < 0.05$ were used for the stepwise process of variable selection to determine the best multivariable logistic regression model that included the factors most significantly associated with increased length of stay. Prior to any modeling selection, the pool of potential predictor variables were tested for multicollinearity using variance inflation factor (VIF) statistics, and those with VIF statistics greater than four were excluded from consideration. Forward, backward, and best subsets methods of variable selection were also employed to check for other potential models, and all four approaches resulted in a similar reduced model. The fit of the final model was assessed using the Pearson, Deviance, and Hosmer and Lemeshow goodness-of-fit tests. Predicted probabilities for patient characteristics were generated from an equation incorporating the parameter estimates from the model. All analyses were performed using SAS software version 9.4 (SAS Institute, Cary, NC).

Results

Demographics and pre-operative co-morbidities

A total of 1,991 patients (18.7% female, 81.3% males) underwent EVAR in 2013. Among these patients, 223 (11.2%) had a hospital stay greater than seven days.

Comparing variables between length of stay greater than seven days and less than seven days

Patients were divided into two groups: length of stay greater than seven days ($N = 223$) and length of stay less than seven days ($N = 1,768$). The following factors were found to be significantly associated with longer length of stay in bivariate analysis using logistic regression: Black race, dyspnea at rest, dependent functional health status, ventilator dependent, severe chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), open wound or infection, more than 10% loss of body weight, pre-operative blood transfusion, emergency case, American Society of Anesthesiologists (ASA) classification 4-5: life threatening or moribund, rupture indication for surgery, transferred, access vessels, total operation time greater than 180, lower extremity revascularization, ischemic colitis, lower extremity ischemia, discharge destination, pneumonia, unplanned intubation, ventilator dependency greater than 48 hours, renal insufficiency, acute renal failure, urinary tract infection, stroke with neurological deficits, cardiac arrest requiring cardiopulmonary resuscitation (CPR), myocardial infarction, perioperative transfusions, deep vein thrombosis (DVT), sepsis, septic shock, return to operating room, days from admission to operation greater than one (Table 1).

| Variable                     | Total | Length of stay ≥ 7 days ($N = 223$) | Length of stay < 7 days ($N = 1,768$) | OR (95% CI) | P-value |
|------------------------------|-------|------------------------------------|--------------------------------------|-------------|---------|
| Preoperative Variables       |       |                                    |                                      |             |         |
| Age (years)                  |       |                                    |                                      |             |         |
| Age Group | N | % | Reference | 95% CI |
|-----------|---|---|-----------|--------|
| <60       | 113 (5.7) | 18 (15.9) | 95 (84.1) | Reference |
| 60-69     | 487 (24.5) | 43 (8.8) | 444 (91.2) | 0.51 (0.28-0.93) |
| 70-79     | 796 (40.0) | 76 (9.6) | 720 (90.4) | 0.56 (0.32-0.97) |
| ≥80       | 595 (29.9) | 86 (14.5) | 509 (85.5) | 0.89 (0.51-1.55) |

| Sex (gender) | | | Reference |
|--------------|---|---|-----------|
| Female       | 373 (18.7) | 55 (14.8) | 318 (85.2) | 1.49 (1.08-2.07) |
| Male         | 1618 (81.3) | 168 (10.4) | 1450 (89.6) | Reference |

| Race         | | | Reference |
|--------------|---|---|-----------|
| Non-Hispanic White | 18.24 (91.6) | 191 (10.5) | 1633 (89.5) | Reference |
| Non-Hispanic Black | 121 (6.1) | 24 (19.8) | 97 (80.2) | 2.12 (1.32-3.39) |
| Hispanic     | 46 (2.3) | 8 (17.4) | 38 (82.6) | 1.80 (0.83-3.92) |

| BMI          | | | Reference |
|--------------|---|---|-----------|
| <25 (normal) | 515 (26.3) | 80 (15.5) | 435 (84.5) | Reference |
| 25-30 (overweight) | 769 (39.3) | 68 (8.8) | 701 (91.2) | 0.53 (0.37-0.75) |
| ≥30 (obese)  | 673 (34.4) | 65 (9.7) | 608 (90.3) | 0.58 (0.41-0.83) |

| Inpatient/outpatient | | | Reference |
|----------------------|---|---|-----------|
| Inpatient            | 1976 (99.2) | 223 (11.3) | 1753 (88.7) | Reference |
| Outpatient           | 15 (0.8) | 0 (0.0) | 15 (100.0) | <0.001 (<0.001-999.99) |

| Transferred | | | Reference |
|-------------|---|---|-----------|
| No          | 1790 (89.9) | 136 (7.6) | 1654 (92.4) | Reference |
| Yes         | 201 (10.1) | 87 (43.3) | 114 (56.7) | 9.28 (6.68-12.90) |
|                                | No               | Yes              | Reference |        |
|--------------------------------|------------------|------------------|-----------|--------|
| Days from admission to operation ≥1 | 1717 (86.2)     | 274 (13.8)       |           | <0.001 |
|                                | 117 (6.8)        | 106 (38.7)       | 168 (61.3)| 8.63 (6.35-11.73) |
| Infrarenal proximal aneurysm extent | 1684 (90.0)     | 188 (10.0)       |           | 0.031  |
|                                | 30 (16.0)        | 180 (10.7)       | 1504 (89.3)| 0.63 (0.41-0.96) |
| Distal extent                  |                 |                  |           |        |
| Aortic                         | 778 (47.2)       | 81 (10.4)        | 697 (89.6)|         |
| Common iliac                   | 636 (38.6)       | 68 (10.7)        | 568 (89.3)| 1.03 (0.73-1.45) |
| External iliac                 | 97 (5.9)         | 13 (13.4)        | 84 (86.6) | 1.33 (0.71-2.50) |
| Internal iliac                 | 138 (8.4)        | 14 (10.1)        | 124 (89.9)| 0.97 (0.53-1.77) |
| Clean wound                    |                 |                  |           |        |
|                                | 25 (1.3)         | 2 (92.0)         | 23 (8.0)  | 0.613  |
|                                |                  |                  |           |        |
| Open wound/wound infection     |                 |                  |           |        |
|                                | 1966 (98.7)      | 221 (11.2)       | 1745 (88.8)| 1.46 (0.34-6.21) |
|                                | 210 (10.7)       | 1756 (89.3)      |           | <0.001 |
|                                | 13 (52.0)        | 12 (48.0)        | 9.06 (4.08-20.11) |
| Steroid use for chronic condition |             |                  |           |        |
|                                | 1897 (95.3)      | 94 (4.7)         |           | 0.070  |
|                                | 207 (10.9)       | 16 (17.0)        | 78 (83.0) | 1.68 (0.96-2.92) |
| >10% loss body weight in last 6 months |               |                  |           | <0.001 |
|                                | 1970 (99.0)      |                  | 1756 (89.1)|         |
|                          | Yes       | No        | Reference |
|--------------------------|-----------|-----------|-----------|
| **Bleeding disorders**   |           |           |           |
| No                       | 21 (1.0)  | 1720 (86.4) | Reference |
| Yes                      | 271 (13.6) | 37 (13.6)  | 234 (86.4) | 1.30 (0.89-1.91) |
| **Pre-op transfusion**   |           |           |           |
| No                       | 1951 (98.0) | 194 (9.9)  | 1757 (90.1) | Reference |
| Yes                      | 40 (2.0)   | 29 (72.5)  | 11 (27.5)   | 23.87 (11.74-48.54) |
| **Prior abdominal aortic surgery** |           |           |           |
| No                       | 1286 (71.0) | 142 (11.0) | 1144 (89.0) | Reference |
| Yes                      | 525 (29.0)  | 57 (10.9)  | 468 (89.1)  | 0.98 (0.71-1.36) |
| **HTN requiring medication** |           |           |           |
| No                       | 384 (19.3) | 46 (12.0)  | 338 (88.0)  | Reference |
| Yes                      | 1607 (80.7) | 177 (11.0) | 1430 (89.0) | 0.91 (0.64-1.29) |
| **Diabetes with oral agents or insulin** |           |           |           |
| No                       | 1681 (84.4) | 186 (11.1) | 1495 (88.9) | Reference |
| Insulin                  |           |           | 69 (3.5)   | 9 (13.0)   | 60 (87.0) | 1.21 (0.59-2.47) |
| Non-insulin              |           |           | 241 (12.1) | 28 (11.6)  | 213 (88.4) | 1.06 (0.69-1.61) |
| **Current smoker within one year** |           |           |           |
| No                       | 1370 (68.8) | 145 (10.6) | 1225 (89.4) | Reference |
| Yes                      | 621 (31.2)  | 78 (12.6)  | 543 (87.4)  | 1.21 (0.91-1.63) |
| **Dyspnea**              |           |           |           |
| No                       | 1577 (79.2) | 166 (10.5) | 1411 (89.5) | Reference |

2019 Yang et al. Cureus 11(6): e4986. DOI 10.7759/cureus.4986
| Condition                                      | Moderate Exertion | At Rest   | Ventilator Dependent | History of Severe COPD | Congestive Heart Failure in 30 Days Prior to Surgery | Currently on Dialysis (Pre-operative) | Ischemic Colitis | Dependent Functional Health Status Prior to Surgery | Disseminated Cancer |
|------------------------------------------------|-------------------|-----------|----------------------|------------------------|---------------------------------------------------|-------------------------------------|------------------|--------------------------------------------------|----------------------|
| Moderate exertion                              | 378 (19.0)        | 36 (1.8)  | 1973 (99.1)          | 1638 (82.3)            | 1952 (98.0)                                       | 1967 (98.8)                        | 1969 (98.9)     | 1915 (96.9)                                      | 1982 (99.5)          |
| At rest                                        | 45 (11.9)         | 12 (33.3) | 212 (10.7)           | 157 (9.6)              | 205 (10.5)                                        | 218 (11.1)                         | 209 (10.6)      | 199 (10.4)                                       | 220 (11.1)           |
| Ventilator dependent                           |                   |           | 45 (11.9)            | 212 (10.7)             | 12 (33.3)                                         | 157 (9.6)                          | 209 (10.6)      | 199 (10.4)                                       | 220 (11.1)           |
| No                                             |                   |           | 45 (11.9)            | 212 (10.7)             | 12 (33.3)                                         | 157 (9.6)                          | 209 (10.6)      | 199 (10.4)                                       | 220 (11.1)           |
| Yes                                            | 333 (88.1)        | 333 (88.1)| 1761 (89.3)          | 1481 (90.4)            | 1747 (89.5)                                       | 1749 (88.9)                        | 1760 (89.4)     | 1716 (89.6)                                      | 1762 (88.9)          |
| No                                             |                   |           |                      |                        | 13.05 (5.01-34.03)                                |                                    |                  |                                                  |                      |
| Yes                                            | 18 (0.9)          | 18 (0.9)  | 7 (38.9)             | 2.17 (1.59-2.97)       | 21 (53.8)                                        | 21 (53.8)                          | 14 (63.6)       | 8 (36.4)                                         | 42 (68.9)            |
| History of severe COPD                         |                   |           |                      |                        | 2.17 (1.59-2.97)                                  |                                    |                  |                                                  |                      |
| No                                             | 1638 (82.3)       | 1638 (82.3)| 1481 (90.4)          | 7.31 (3.83-13.94)      | 2.11 (0.78-5.71)                                  | 2.11 (0.78-5.71)                   |                  |                                                  |                      |
| Yes                                            | 353 (17.7)        | 353 (17.7)| 287 (81.3)           | 2.17 (1.59-2.97)       | 2.11 (0.78-5.71)                                  | 2.11 (0.78-5.71)                   |                  |                                                  |                      |
| Congestive heart failure in 30 days prior to surgery | 1952 (98.0) | 1952 (98.0)| 1747 (89.5)          | 7.31 (3.83-13.94)      | 2.11 (0.78-5.71)                                  | 2.11 (0.78-5.71)                   |                  |                                                  |                      |
| Currently on dialysis (pre-operative)          | 1967 (98.8)       | 1967 (98.8)| 1749 (88.9)          | 7.31 (3.83-13.94)      | 2.11 (0.78-5.71)                                  | 2.11 (0.78-5.71)                   |                  |                                                  |                      |
| No                                             |                   |           |                      |                        | 2.17 (1.59-2.97)                                  |                                    |                  |                                                  |                      |
| Yes                                            | 24 (1.2)          | 24 (1.2)  | 21 (53.8)            | 2.11 (0.78-5.71)       | 2.11 (0.78-5.71)                                  | 2.11 (0.78-5.71)                   |                  |                                                  |                      |
| Ischemic colitis                               |                   |           |                      |                        | 2.17 (1.59-2.97)                                  |                                    |                  |                                                  |                      |
| No                                             | 1969 (98.9)       | 1969 (98.9)| 1760 (89.4)          | 14.74 (6.11-35.54)     | 14.74 (6.11-35.54)                                | 14.74 (6.11-35.54)                 |                  |                                                  |                      |
| Yes                                            | 22 (1.1)          | 22 (1.1)  | 8 (36.4)             | 14.74 (6.11-35.54)     | 14.74 (6.11-35.54)                                | 14.74 (6.11-35.54)                 |                  |                                                  |                      |
| Dependent functional health status prior to surgery | 1915 (96.9) | 1915 (96.9)| 1716 (89.6)          | 14.74 (6.11-35.54)     | 14.74 (6.11-35.54)                                | 14.74 (6.11-35.54)                 |                  |                                                  |                      |
| No                                             |                   |           |                      |                        | 14.74 (6.11-35.54)                                 |                                    |                  |                                                  |                      |
| Yes                                            | 61 (3.1)          | 61 (3.1)  | 42 (68.9)            | 14.74 (6.11-35.54)     | 14.74 (6.11-35.54)                                | 14.74 (6.11-35.54)                 |                  |                                                  |                      |
| Disseminated cancer                            |                   |           |                      |                        | 14.74 (6.11-35.54)                                 |                                    |                  |                                                  |                      |
| No                                             | 1982 (99.5)       | 1982 (99.5)| 1762 (88.9)          | 14.74 (6.11-35.54)     | 14.74 (6.11-35.54)                                | 14.74 (6.11-35.54)                 |                  |                                                  |                      |
| Yes                                            | 220 (11.1)        | 220 (11.1)| 1762 (88.9)          | 14.74 (6.11-35.54)     | 14.74 (6.11-35.54)                                | 14.74 (6.11-35.54)                 |                  |                                                  |                      |
|                        | Yes | No    | Reference | Statistic |
|------------------------|-----|-------|-----------|-----------|
| Rupture indication for surgery |     |       |           |           |
| Yes                    | 9 (0.5) | 1819 (93.0) | Reference | 0.051     |
| Rupture of aneurysm    |     |       |           |           |
| Yes                    | 137 (7.0) | 1984 (99.6) | Reference | <0.001    |
| Emergency case         |     |       |           |           |
| No complication        | 7 (0.4) | 1801 (90.5) | Reference | <0.001    |
| Emergency case         |     |       |           |           |
| Yes                    | 190 (9.5) | 190 (9.5) | Reference | 0.019     |
| Intraoperative Variables|     |       |           |           |
| Main body device       |     |       |           |           |
| Gore Excluder          | 626 (32.0) | 220 (11.1) | Reference |           |
| Cook                   | 461 (23.6) | 143 (7.9) | Reference | 0.86 (0.60-1.23) |
| Medtronic              | 581 (29.7) | 55 (9.5) | Reference | 1.30 (0.90-1.88) |
| Other                  | 287 (14.7) | 80 (42.1) | Reference | 1.31 (0.82-2.08) |
| Iliac branched device  |     |       |           |           |
| No                     | 1708 (85.8) | 192 (11.2) | Reference | 0.888     |
| Yes                    | 283 (14.2) | 31 (10.9) | Reference | 0.97 (0.65-1.45) |
| Aortic bare metal stent|     |       |           |           |
| No                     | 1946 (97.7) | 219 (11.2) | Reference | 0.620     |
| Yes                    | 45 (2.3) | 4 (8.9) | Reference | 0.77 (0.27-2.17) |
|                          | No                | Yes               | Reference | Value   |
|--------------------------|-------------------|-------------------|-----------|---------|
| Iliac bare metal stent   |                   |                   |           | 0.915   |
| No                       | 1922 (96.5)       | 69 (3.5)          |           | 1.04 (0.49-2.21) |
| Yes                      | 1707 (88.8)       | 61 (88.4)         |           |         |
| General anesthesia       |                   |                   |           | 0.860   |
| No                       | 190 (9.5)         | 1801 (90.5)       |           | 0.96 (0.60-1.53) |
| Yes                      | 168 (88.4)        | 1600 (88.8)       |           |         |
| ASA classification       |                   |                   |           | <0.001  |
| 1-2 No/mild disturbance  | 98 (4.9)          | 1282 (64.4)       |           | 3.19 (0.77-13.18) |
| 3 Severe disturbance     | 2 (2.0)           | 80 (6.2)          |           |         |
| 4-5 Life threatening/moribund | 609 (30.6)      | 141 (23.2)        |           | 14.45 (3.52-59.35) |
| 1-2 No/mild disturbance  | 190 (9.5)         | 1801 (90.5)       |           | 0.96 (0.60-1.53) |
| 3 Severe disturbance     | 168 (88.4)        | 1600 (88.8)       |           |         |
| Vascular surgical specialty |                   |                   |           | 0.193   |
| No                       | 54 (2.7)          | 1937 (97.3)       |           | 2.18 (0.67-7.04) |
| Yes                      | 51 (94.4)         | 1717 (88.6)       |           |         |
| EVAR access              |                   |                   |           |         |
| Bilateral groin cutdown  | 1212 (61.1)       | 142 (11.7)        |           | Reference |
| Attempted percutaneous access converted to open cutdown | 20 (1.0) | 5 (25.0) | 15 (75.0) | 2.51 (0.90-7.02) |
| One groin cutdown        | 198 (10.0)        | 27 (13.6)         | 171 (86.4) | 1.19 (0.77-1.85) |
| Percutaneous bilateral   | 553 (27.9)        | 48 (8.7)          | 505 (91.3) | 0.72 (0.51-1.01) |
| Total operation time     |                   |                   |           |         |
| ≤90                      | 336 (16.9)        | 27 (8.0)          | 309 (92.0) | Reference |
| 91-120                   | 497 (25.0)        | 26 (5.2)          | 471 (94.8) | 0.63 (0.36-1.10) |
|                           |                   |                   |           | <0.001  |
| Variable                          | No                  | Yes                  | Reference | Significance | Value (CI) |
|----------------------------------|---------------------|----------------------|-----------|--------------|------------|
| **Acute conversion to open procedure** |                     |                      |           |              |            |
| No                               | 1968 (99.3)         | 1749 (88.9)          | Reference | 0.036        |            |
| Yes                              | 13 (0.7)            | 9 (69.2)             | 3.55 (1.08-11.63) |              |            |
| **Access vessels (conduit, repair)** |                     |                      |           | <0.001       |            |
| No                               | 1853 (93.1)         | 1658 (89.5)          | Reference |              | <0.001     |
| Yes                              | 138 (6.9)           | 110 (79.7)           | 2.16 (1.39-3.36) |              |            |
| **Renal stent**                  |                     |                      |           | 0.004        |            |
| No                               | 1831 (92.0)         | 1637 (89.4)          | Reference |              | 0.004      |
| Yes                              | 160 (8.0)           | 131 (81.9)           | 1.87 (1.22-2.87) |              |            |
| **Hypogastric embolization**     |                     |                      |           | 0.069        |            |
| No                               | 1853 (93.1)         | 1652 (89.2)          | Reference |              | 0.069      |
| Yes                              | 138 (6.9)           | 116 (84.1)           | 1.56 (0.97-2.52) |              |            |
| **Hypogastric revascularization**|                     |                      |           | 0.298        |            |
| No                               | 1902 (95.5)         | 1692 (89.0)          | Reference |              | 0.298      |
| Yes                              | 89 (4.5)            | 76 (85.4)            | 1.38 (0.75-2.53) |              |            |
| **Lower extremity revascularization** |                     |                      |           | <0.001       |            |
| No                               | 1907 (95.8)         | 1706 (89.5)          | Reference |              | <0.001     |
| Yes                              | 84 (4.2)            | 62 (73.8)            | 3.01 (1.81-5.01) |              |            |
| **Postoperative variables**      |                     |                      |           |              |            |
| **Discharge destination**        |                     |                      |           |              |            |
| Home                             | 1779                | 1671 (93.9)          | Reference |              |            |
| Event                                | No complication | Deep incisional SSI | Pneumonia                      | Unplanned intubation | Ventilator >48 hours | Urinary tract infection | Renal insufficiency |
|--------------------------------------|-----------------|---------------------|--------------------------------|----------------------|----------------------|------------------------|---------------------|
| Expired                              | 1965 (98.7)     | 26 (1.3)            | 1966 (98.7)                    | 1950 (97.9)          | 1949 (97.9)          | 1965 (98.7)            | 1978                |
|                                      | 217 (11.0)      | 6 (23.1)            | 202 (10.3)                     | 201 (10.3)           | 187 (9.6)            | 215 (10.9)            |                     |
|                                      | 1748 (89.0)     | 20 (76.9)           | 1764 (89.7)                    | 1749 (89.7)          | 1762 (90.4)          | 1750 (89.1)           |                     |
|                                      | Reference        | 2.42 (0.96-6.08)    | Reference                      | Reference            | Reference            | Reference              |                     |
|                                      |                 |                     |                                |                      |                      |                        |                     |
| Superficial surgical site occurrence | No complication | Superficial incisional SSI | Deep incisional SSI | Pneumonia | Unplanned intubation | Ventilator >48 hours | Urinary tract infection | Renal insufficiency |
|                                      | Expired         | Other               |                               |                      |                      |                        |                     |
|                                      | 42 (2.1)        | 169 (8.5)           | 1982 (99.5)                    | 1966 (98.7)          | 1950 (97.9)          | 1965 (98.7)            | 1978                |
|                                      | 17 (40.5)       | 97 (57.4)           | 222 (11.2)                     | 202 (10.3)           | 201 (10.3)           | 215 (10.9)            |                     |
|                                      | 25 (59.5)       | 72 (42.6)           | 1760 (88.8)                    | 1764 (89.7)          | 1749 (89.7)          | 1750 (89.1)           |                     |
|                                      | 10.52 (5.51-20.08) | 20.84 (14.51-29.92) | Reference                      | Reference            | Reference            | Reference              |                     |
|                                      |                 |                     |                                |                      |                      |                        |                     |
| Pneumonia                            | No complication | Deep incisional SSI | Pneumonia                      | Unplanned intubation | Ventilator >48 hours | Urinary tract infection | Renal insufficiency |
|                                      | Expired         |                     |                               |                      |                      |                        |                     |
|                                      | 25 (1.3)        | 9 (0.5)             | 25 (1.3)                       | 41 (2.1)             | 1949 (97.9)          | 1965 (98.7)            | 1978                |
|                                      | 17 (68.0)       | 1 (11.1)            | 21 (84.0)                      | 22 (53.7)            | 187 (9.6)            | 215 (10.9)            |                     |
|                                      | 10 (38.0)       | 8 (88.9)            | 4 (16.0)                       | 19 (46.3)            | 1762 (90.4)          | 1750 (89.1)           |                     |
|                                      | 2.42 (0.96-6.08) | 0.99 (0.12-7.96)    | 45.83 (15.58-134.81)           | 10.01 (5.36-18.94)   |                      |                        |                     |
|                                      |                 |                     |                                |                      |                      |                        |                     |
| Unplanned intubation                 | No complication | Deep incisional SSI | Pneumonia                      | Unplanned intubation | Ventilator >48 hours | Urinary tract infection | Renal insufficiency |
|                                      | Expired         |                     |                               |                      |                      |                        |                     |
|                                      | 41 (2.1)        | 9 (0.5)             | 41 (2.1)                       | 42 (2.1)             | 1949 (97.9)          | 1965 (98.7)            | 1978                |
|                                      | 22 (53.7)       | 1 (11.1)            | 22 (53.7)                      | 36 (85.7)            | 187 (9.6)            | 215 (10.9)            |                     |
|                                      | 19 (46.3)       | 8 (88.9)            | 19 (46.3)                      | 6 (14.3)             | 1762 (90.4)          | 1750 (89.1)           |                     |
|                                      | 10.01 (5.36-18.94) | 0.99 (0.12-7.96)    | 45.83 (15.58-134.81)           | 56.54 (23.51-135.93) |                      |                        |                     |
|                                      |                 |                     |                                |                      |                      |                        |                     |
| Ventilator >48 hours                 | No complication | Deep incisional SSI | Pneumonia                      | Unplanned intubation | Ventilator >48 hours | Urinary tract infection | Renal insufficiency |
|                                      | Expired         |                     |                               |                      |                      |                        |                     |
|                                      | 42 (2.1)        | 9 (0.5)             | 42 (2.1)                       | 42 (2.1)             | 1949 (97.9)          | 1965 (98.7)            | 1978                |
|                                      | 36 (85.7)       | 1 (11.1)            | 36 (85.7)                      | 36 (85.7)            | 187 (9.6)            | 215 (10.9)            |                     |
|                                      | 6 (14.3)        | 8 (88.9)            | 6 (14.3)                       | 6 (14.3)             | 1762 (90.4)          | 1750 (89.1)           |                     |
|                                      | 56.54 (23.51-135.93) | 0.99 (0.12-7.96)    | 45.83 (15.58-134.81)           | 56.54 (23.51-135.93) |                      |                        |                     |
|                                      |                 |                     |                                |                      |                      |                        |                     |
| Urinary tract infection              | No complication | Deep incisional SSI | Pneumonia                      | Unplanned intubation | Ventilator >48 hours | Urinary tract infection | Renal insufficiency |
|                                      | Expired         |                     |                               |                      |                      |                        |                     |
|                                      | 26 (1.3)        | 9 (0.5)             | 26 (1.3)                       | 26 (1.3)             | 1949 (97.9)          | 1965 (98.7)            | 1978                |
|                                      | 8 (30.8)        | 1 (11.1)            | 8 (30.8)                       | 8 (30.8)             | 187 (9.6)            | 215 (10.9)            |                     |
|                                      | 18 (69.2)       | 7 (88.9)            | 18 (69.2)                      | 18 (69.2)            | 1762 (90.4)          | 1750 (89.1)           |                     |
|                                      | 3.62 (1.56-8.42) | 0.99 (0.12-7.96)    | 45.83 (15.58-134.81)           | 56.54 (23.51-135.93) |                      |                        |                     |
|                                      |                 |                     |                                |                      |                      |                        |                     |
| Renal insufficiency                  | No complication | Deep incisional SSI | Pneumonia                      | Unplanned intubation | Ventilator >48 hours | Urinary tract infection | Renal insufficiency |
|                                      | Expired         |                     |                               |                      |                      |                        |                     |
|                                      | 1978            | 215 (10.9)          | 1978                           | 1978                 | 1949 (97.9)          | 1965 (98.7)            | 1978                |
|                                      | 1763 (89.1)     | 1763 (89.1)         | 1763 (89.1)                    | 1763 (89.1)          | 1762 (90.4)          | 1750 (89.1)           |                     |
|                                      | Reference        |                        |                                |                      |                      |                        |                     |
| Condition                          | No complication | Acute renal failure | Reference | p-value |
|-----------------------------------|------------------|---------------------|-----------|---------|
| Progressive renal insufficiency  | 13 (0.6)         | 8 (61.5)            | 5 (38.5)  | 13.12 (4.25-40.46) | <0.001 |
| Acute renal failure               | 1973 (99.1)      | 209 (10.6)          | 1764 (89.4) | Reference | <0.001 |
| No complication                   | 18 (0.9)         | 14 (77.8)           | 4 (22.2)  | 29.50 (9.63-90.42) | <0.001 |
| CVA/stroke with neurological deficit | 1982 (99.5)    | 217 (11.0)          | 1765 (89.0) | Reference | <0.001 |
| Stroke/CVA                        | 9 (0.5)          | 6 (66.7)            | 3 (33.3)  | 16.26 (4.04-65.46) | <0.001 |
| Cardiac arrest requiring CPR      | 1975 (99.2)      | 217 (11.0)          | 1758 (89.0) | Reference | 0.002 |
| No complication                   | 16 (0.8)         | 6 (37.5)            | 10 (62.5) | 4.86 (1.75-13.51) | <0.001 |
| Myocardial infarction             | 1960 (98.4)      | 208 (10.6)          | 1752 (89.4) | Reference | <0.001 |
| No complication                   | 31 (1.6)         | 15 (48.4)           | 16 (51.6) | 7.89 (3.85-16.20) | <0.001 |
| Myocardial infarction             | 1973 (99.1)      | 210 (10.6)          | 1763 (89.4) | Reference | <0.001 |
| No complication                   | 18 (0.9)         | 13 (72.2)           | 5 (27.8)  | 21.82 (7.70-61.82) | <0.001 |
| DVT/thrombophlebitis              | 1968 (98.8)      | 208 (10.6)          | 1760 (89.4) | Reference | <0.001 |
| No complication                   | 23 (1.2)         | 15 (65.2)           | 8 (34.8)  | 15.87 (6.65-37.87) | <0.001 |
| Sepsis                            | 1974 (99.2)      | 210 (10.6)          | 1764 (89.4) | Reference | <0.001 |
| No complication                   | 12 (0.6)         | 8 (61.5)            | 5 (38.5)  | 13.12 (4.25-40.46) | <0.001 |
The following factors were found to have significant associations with longer hospital stay: total operation time greater than 180 minutes (vs. less than 90 minutes, OR 2.02, CI 1.03-3.41, p = 0.039), postoperative and intraoperative transfusions (OR 2.60, CI 1.66-4.08, p < 0.001), return to operating room (OR 2.88, CI 1.55-5.38, p < 0.001), rupture indication for surgery (OR 5.59, CI 3.18-9.83, p < 0.001), myocardial infarction (OR 5.85, CI 2.22-15.43, p < 0.001), preoperative transfusion (OR 13.05, CI 4.26-39.99, p < 0.001), and time on ventilator greater than 48 hours (OR 49.65, CI 10.72-230.07, p < 0.001) (Table 2).
### TABLE 2: Multivariable analysis for variables associated with increased length of stay.

| Variable                                           | OR    | 95% CI       | P-value |
|----------------------------------------------------|-------|--------------|---------|
| Total operation time: >180 vs ≤90                  | 1.88  | 1.03–3.41    | 0.039   |
| Post-operative/Intra-operative transfusions        | 2.60  | 1.66–4.08    | <0.001  |
| Return to OR                                       | 2.88  | 1.55–5.38    | <0.001  |
| Ruptured AAA                                       | 5.59  | 3.18–9.83    | <0.001  |
| Myocardial infarction                              | 5.85  | 2.22–15.43   | <0.001  |
| Pre-operative transfusion                          | 13.05 | 4.26–39.99   | <0.001  |
| Time on ventilator greater than 48 hours           | 49.65 | 10.72–230.07 | <0.001  |

**Predicted probability of increased length of stay**

The probability of an increased length of stay was calculated for all of the factors to be significant in the multivariable analysis. The probability of an increased length of stay was 8.0% for patients who had operations in the fourth quartile, 10.7% for patients who required transfusions, 11.8% for patients who had to return to the operating room, 20.5% for patients who had rupture as an indication for surgery, 21.3% for patients who had a myocardial infarction in the post-operative period, 37.6% for patients who required a pre-operative transfusion, 69.7% for patients who were on a ventilator for more than 48 hours, and 99.9% for patients who had all of these seven factors present (Table 3).
TABLE 3: Predicted probability of increased length of hospital stay.

OR: Operating room.

Discussion

This analysis shows that multiple factors play a role in LOS greater than seven days. Preoperative and intraoperative variables include preoperative transfusion, rupture as an indication for surgery, perioperative transfusions, and greater operation time. Postoperative variables include return to the operating room, myocardial infarction, and ventilator dependency duration greater than 48 hours.

Preoperative variables relating to longer LOS in patients have been extensively studied. In a study done by Siracuse et al., the authors identified dependent functional status as the most significant risk factor for protracted LOS in patients undergoing lower extremity bypass for critical limb ischemia [12]. This was also seen in a study by King et al. evaluating risk factors for increased LOS after elective EVAR. The authors noted the importance of identifying preoperative risk factors such as chronic renal insufficiency, recent weight loss, dependent functional status, ASA classification of IV, and dyspnea at rest [13]. These studies emphasize the importance of modifying risk factors in order to optimize surgery but do not evaluate postoperative outcomes as our study has.

Postoperative complication rates have been linked to higher cost of surgical care and have been shown to be more important than preoperative and intraoperative risk factors after major surgery [14]. Additionally, postoperative complications that are more severe can often lead to longer LOS [15]. In our study, postoperative factors that were independently linked to a longer length of stay included return to the operating room, myocardial infarction, and ventilator dependency greater than 48 hours. Patients with postoperative respiratory failure, defined in this study as a failure to wean from a ventilator after 48 hours, had a 50 times greater risk of longer LOS (Table 2), with a predicted probability of almost 70% (Table 3). Patients who returned to operating room and had postoperative myocardial infarction had a three-fold and six-fold increase in risk for longer hospital stay, respectively. This identifies postoperative
respiratory failure as an important risk factor for longer LOS and may present as a target for decreasing healthcare costs and shortening hospital stay. Prior studies have emphasized the significance of respiratory failure in surgery outcomes and have demonstrated its association with mortality and overall cost [14, 16-18].

Length of stay is one of many benchmarks that are used to assess healthcare efficiency as well as cost [1-3]. Given what is known about postoperative respiratory failure and our study results demonstrating its role in patients who have undergone EVAR, optimizing patients' pulmonary status presents as a potential target to improve unnecessarily long LOS and in turn, healthcare costs.

The current study contains some inherent limitations. The NSQIP database is retrospective in nature and therefore has all of the associated limitations of a retrospective study. Outcomes are limited to 30 postoperative days and contain no further follow-up data. Additionally, the database provides no information regarding socioeconomic status or education level. The strength of this study is that NSQIP database has been proven to be reliable and reproducible, and is the most comprehensive surgical database available in the US. Furthermore, the data is collected from multiple institutions throughout the country, thus removing potential geographic biases.

Conclusions
Multiple factors affect length of hospital stay in patients who have undergone EVAR. Preoperative and intraoperative variables include preoperative transfusion, rupture indication for surgery, perioperative transfusions, and greater operation time. Postoperative variables include return to the operating room, myocardial infarction, and ventilator dependency greater than 48 hours. This study suggests that patients with postoperative respiratory failure after EVAR have a significantly higher risk for longer hospital stays.

Additional Information

Disclosures

**Human subjects:** All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Morgan M, Beech R: Variations in lengths of stay and rates of day case surgery: implications for the efficiency of surgical management. J Epidemiol Community Health. 1990, 44:90-105. 10.1136/ech.44.2.90
2. Brasel KJ, Lim HJ, Nirula R, Weigelt JA: Length of stay: an appropriate quality measure? Arch Surg. 2007, 142:461-466. 10.1001/archsurg.142.5.461
3. Reed T Jr, Veith FJ, Gargiulo NJ 3rd, et al.: System to decrease length of stay for vascular surgery. J Vasc Surg. 2004, 39:395-399. 10.1016/j.jvs.2003.09.015
4. Calligaro KD, Dougherty MJ, Raviola CA, Musser DJ, De Laurentis DA: Impact of clinical pathways on hospital costs and early outcome after major vascular surgery. J Vasc Surg. 1995, 22:649-660.
5. Mehaffey JH, LaPar DJ, Tracci MC, Cherry KJ, Kerna JA, Upchurch GR Jr: Targets to prevent prolonged length of stay after endovascular aortic repair. J Vasc Surg. 2015, 62:1413-1420. 10.1016/j.jvs.2015.06.219

6. The American College of Surgeons National Surgical Quality Improvement Program. (2019). Accessed: November 11, 2017: https://www.facs.org/quality-programs/acnqsip.

7. Shiloach M, Frencher SK Jr, Steeger JE, et al.: Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. J Am Coll Surg. 2010, 210:6-16. 10.1016/j.jamcollsurg.2009.09.031

8. Daley J, Khuri SF, Henderson W, et al.: Risk adjustment of the postoperative morbidity rate for the comparative assessment of the quality of surgical care: results of the National Veterans Affairs Surgical Risk Study. J Am Coll Surg. 1997, 185:328-340.

9. Bilimoria KY, Cohen ME, Ingraham AM, Bentrem D, Richards K, Hall B, Ko C: Effect of postdischarge morbidity and mortality on comparisons of hospital surgical quality. Ann Surg. 2010, 252:183-190. 10.1097/SLA.0b013e3181e4846e

10. Khuri SF, Daley J, Henderson W, et al.: The National Veterans Administration Surgical Risk Study: risk adjustment for the comparative assessment of the quality of surgical care. J Am Coll Surg. 1995, 180:519-531.

11. Khuri SF, Daley J, Henderson W, et al.: Risk adjustment of the postoperative mortality rate for the comparative assessment of the quality of surgical care: results of the National Veterans Affairs Surgical Risk Study. J Am Coll Surg. 1997, 185:315-327.

12. Siracuse JJ, Gill HL, Jones DW, et al.: Risk factors for protracted postoperative length of stay after lower extremity bypass for critical limb ischemia. Ann Vasc Surg. 2014, 28:1452-1458. 10.1016/j.avsg.2013.12.027

13. King EG, Farber A, Rybin D, Doros G, Kalish JA, Eslami MH, Siracuse JJ: Preoperative risk factors predict protracted hospital length of stay after elective endovascular abdominal aortic aneurysm repair. Ann Vasc Surg. 2017, 45:73-78. 10.1016/j.avsg.2016.12.017

14. Khuri SF, Henderson WG, DePalma RG, Mosca C, Healey NA, Kumbhani DJ: Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. Ann Surg. 2005, 242:326-341. 10.1097/01.sla.0000179621.33268.83

15. McAleese P, Odling-Smee W: The effect of complications on length of stay. Ann Surg. 1994, 220:740-744. 10.1097/00000658-199412000-00006

16. Johnson RG, Arozullah AM, Neumayer L, Henderson WG, Hosokawa P, Khuri SF: Multivariable predictors of postoperative respiratory failure after general and vascular surgery: results from the patient safety in surgery study. J Am Coll Surg. 2007, 204:1188-1198. 10.1016/j.jamcollsurg.2007.02.070

17. Johnson AP, Altmark RE, Weinstein MS, Pitt HA, Yeo CJ, Cowan SW: Predicting the risk of postoperative respiratory failure in elective abdominal and vascular operations using the National Surgical Quality Improvement Program (NSQIP) participant use data file. Ann Surg. 2017, 266:968-974. 10.1097/SLA.0000000000001989

18. Dimick JB, Chen SL, Taheri PA, Henderson WG, Khuri SF, Campbell DA Jr: Hospital costs associated with surgical complications: a report from the private-sector National Surgical Quality Improvement Program. J Am Coll Surg. 2004, 199:531-537. 10.1016/j.jamcollsurg.2004.05.276