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The Impact of Completion and Follow-up Endoleaks on Survival, Reintervention, and Rupture

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Abstract

Objective: Endoleaks may be seen at case completion of endovascular abdominal aortic aneurysm repair (EVAR), and the presence of an endoleak may impact outcomes. However, the clinical implications of various endoleaks seen during follow-up is not well-described. Therefore, we studied the impact of endoleaks at completion and at follow-up on mid-term outcomes.

Methods: We reviewed patients who underwent EVAR from 2003 to 2016 within the VQI-Medicare database and identified patients with endoleak at procedure completion and during follow-up, excluding those presenting with rupture. We stratified cohorts by presence of completion and follow-up endoleak subtypes. The primary outcome was 5-year survival, and secondary outcomes included 5-year freedom-from-reintervention and freedom-from-rupture. We used Kaplan-Meier estimates and log-rank tests to analyze differences in time-to-event endpoints.

Results: Of 21,745 patients with completion endoleak data, 5,085 (23%) had an endoleak. Compared to those without endoleak, those with type I endoleaks had lower five-year survival (69% vs. 75%, P<.001), type II endoleaks had higher survival (79%, P<.001), and types III, IV and indeterminate were not statistically different (73%, 73%, 75%, respectively). Freedom-from-

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reintervention for types I and III endoleaks were significantly lower than no endoleak cohort (I: 76%, P<.001; III: 72%, P<.001, vs. 83%), but freedom-from-rupture was higher for those with type II and III endoleak (95% and 97% vs. 94%, P<.001).

Of 14,479 patients with detailed follow-up endoleak data, 2,290 (16%) had an endoleak. Compared to those without endoleak, types I and III had significantly lower 5-year survival (I: 80%, P=.002; III: 66%, P<.001 vs. 84%), but there were no differences for types II (82%) and indeterminate (77%). Those with any type of follow-up endoleak had lower 5-year freedom-from-reintervention (I: 70%, P<.001; II: 76%, P=.006; III: 36%, P<.001; indeterminate: 60%, P=.007 vs. 84%), and lower freedom-from-rupture (I: 92%, P<.001; II: 91%, P=.16; III: 88%, P=.01; indeterminate: 90%, P=.11 vs. 94%).

Conclusions: Compared to patients with no endoleak, those with type I completion endoleaks have lower 5-year survival and freedom-from-reintervention. Patients with types I and III follow-up endoleaks also have lower survival, and any endoleak at follow-up is associated with lower freedom-from-reintervention and freedom-from-rupture. These data highlight the importance of careful patient selection and close postoperative follow-up after EVAR, as the presence of endoleaks, specifically type I and III, over time portends worse outcomes.

TABLE OF CONTENT SUMMARY

In this retrospective analysis of VQI data linked to Medicare, those with type I completion endoleaks have lower 5-year survival and freedom-from-reintervention than those without endoleaks. Patients with types I and III endoleaks at follow-up also have lower survival, and any endoleak at follow-up is associated with lower freedom-from-reintervention and freedom-from-rupture.

Keywords

EVAR; AAA; aneurysm; completion endoleak; follow-up

INTRODUCTION

Since the introduction of endovascular aneurysm repair (EVAR) by Juan Parodi in 1991, EVAR has become the dominant approach for management of abdominal aortic aneurysms (AAAs).[1–3] While perioperative benefits of EVAR have been well-demonstrated, focus now lies in long-term outcomes, surveillance, and factors associated with sac expansion that can lead to graft failure or rupture. Endoleaks after EVAR have long been thought to contribute to aneurysm sac expansion and are not uncommon. However, depending on type of endoleak at the completion of the procedure, management varies. While completion type II endoleaks are generally observed, increasingly, some studies are showing that even select type I endoleaks can be observed and spontaneously resolve without additional intervention.[4,5]

It is clear that consistent radiographic follow-up is needed for completion endoleaks, and the fate of completion endoleaks over time needs to be further examined. Few studies examine the consequences of endoleaks found on follow-up, whether new or persistent. Therefore, using the Society of Vascular Surgery Vascular Quality Initiative (SVS VQI) database with

Medicare linkage, we evaluated the impact of completion and follow-up endoleaks on mid-term survival, reintervention, and rupture rates.

METHODS

Data and study population

We identified all patients who underwent infrarenal EVAR in the SVS VQI registry linked to Medicare claims, a validated process that directly links patients using unique identifiers with 95% matching success.[6] These data were made possible by the efforts of the Vascular Implant Surveillance and Interventional Outcomes Network (VISION) (https://www.vqi.org/data-analysis/blinded-datasets/) and are stored and managed at Cornell University. This method combines the granular clinical and procedural details of a vascular quality improvement registry and the long-term follow-up data including reinterventions, ruptures, follow-up imaging and mortality from an administrative database. Patients were included from January 1, 2003 to September 30, 2015, with follow-up available until December 2016.

A total of 23,253 patient underwent EVAR during the study period, of whom we excluded 1,263 (5.4%) patients who presented with a ruptured aneurysm or had missing indication for surgery. Within the remaining population of 21,990 patients, we separately analyzed 21,745 patients who had completion endoleak information and 14,479 patients with follow-up endoleak information. Completion endoleaks were identified by angiography at the conclusion of the procedure as part of the index hospitalization. Follow-up endoleak information was captured as part of the routine follow-up visits; however, the data lack granularity to determine when the endoleak was first identified. A small proportion of patients had multiple types of endoleaks documented. Thus, for the purpose of analysis, endoleak types were assigned as one single type based on the following priority: type I > III > II > IV > Indeterminate.

The Beth Israel Deaconess Medical Center Institutional Review Board approved this study and waived the informed consent. All patient's personal health information was deidentified, no testing or procedures were required, and there was minimal risk to study subjects.

Outcomes and definitions

For analysis of completion endoleaks and follow-up endoleaks, our primary outcome was 5-year survival. Secondary outcomes included 5-year freedom from reintervention, freedom from rupture, as well as perioperative outcomes by endoleak type. We also examined 5-year survival for patients who underwent additional reinterventions versus those who did not, stratified by types of completion or follow-up endoleak.

Patients were censored at the date of death. Follow-up duration was determined by the survival days as recorded within the VQI or until December 30, 2016, date of the last available Medicare data. Reintervention was identified using a previously validated *International Classification of Diseases, 9th edition* (ICD-9) claims algorithm with reported 92% sensitivity and 96% specificity.[7] Late rupture was identified as any patient encounter with a primary ICD-9 diagnosis code of abdominal aortic aneurysm rupture (441.3) that was associated with a reintervention or death within 14 days of index admission.[8] Perioperative death was defined as death within 30 days of the procedure.

Sac changes over time were also examined; although less than two-thirds of the 21,990 patients had information on follow-up aneurysm diameter. We defined sac regression as a decrease in sac diameter of greater than or equal to 5 mm when comparing the maximum follow-up aneurysm diameter (only available postoperative measurement) to the preoperative diameter. Sac expansion was defined as an increase in sac diameter of greater than or equal to 5 mm. The remaining are considered stable in size.[9,10]

Statistical analysis

Categorical variables are represented as counts and percentages. Continuous variables are represented as mean ± standard deviation (SD) or median, interquartile range (IQR), where appropriate. We compared baseline characteristics and postoperative outcomes using Chi-squared tests for categorical variables or analysis of variance for continuous variables. Kaplan-Meier estimates were used to describe 5-year outcomes for survival, reintervention rate, and rupture rate. The log-rank test was used to determine unadjusted between-group differences using no endoleak cohort as the standard for comparison. Multivariable logistic regression was used to determine the association of endoleak type and aneurysm sac changes. A P-value less than .05 was considered statistically significant. All statistical analyses were conducted using Stata version 16 (StataCorp LP, College Station, TX).

RESULTS

Baseline characteristics

Of 21,745 patients with completion endoleak information, nearly 77% of patients had no endoleaks, while 3.4% had a type I endoleak, 17% had type II, 0.5% type III, 0.4% type IV, 1.9% had an indeterminate endoleak, and 31 (0.1%) patients had multiple types of endoleaks. Of the latter, 16 patients had type I/II endoleaks, eight had type II/IV, two had type II/indeterminate, two had types I/II/IV, and one patient each had type I/III, I/indeterminate, and IV/indeterminate. In order to facilitate analysis, endoleaks were prioritized as defined in the methods, resulting in 16,660 patients without endoleaks, 734 with type I, 3,764 with type II, 102 with type III, 78 with type IV, and 407 with indeterminate type of endoleak. Patients who had no endoleak were younger, less often female or on dialysis, but more often obese, a current smoker, or have COPD (Table 1).

Of 14,479 patients with detailed follow-up endoleak data, 84% of patients had no endoleak, 6.1% had a type I endoleak, 7.4% type II, 0.6% type III, 1.9% had an indeterminate type endoleak, and 26 (0.2%) patients had multiple types of endoleaks. Of the latter, 15 patients had type I/II endoleaks, eight had type II/indeterminate endoleaks, two had type III/indeterminate endoleaks, and one patient with type I/indeterminate endoleak. After prioritization of endoleaks, there were 12,189 patients without endoleaks, 882 with type I, 1,060 with type II, 89 with type III, and 259 with indeterminate type endoleak. Patients without follow-up endoleaks were also younger and less often female, but were more often a current smoker, have insulin dependent diabetes or have COPD (Table 2).

Perioperative outcomes

Patients with type I, III, and indeterminate completion endoleak had the highest perioperative mortality compared to those without completion endoleak (2.9% [I], 2.0 [III], 2.5% [indeterminate], vs. .9% [none]). Those with types II and IV completion endoleaks had the lowest perioperative mortality, .5% and 0%, respectively. Compared to those without completion endoleak, patients with type I completion endoleak also had the longest length of stay (3.9 vs. 2.9 days) and higher rates of postoperative myocardial infarction [MI] (1.6% vs. 1.1%), dysrhythmia (4.6% vs. 2.7%), and return to the operating room [RTOR] (5.2% vs. 2.2%). Patient with type IV completion endoleaks had the highest rates of postoperative pneumonia (1.3% vs. .6% [no endoleak]) and ventilator dependence (3.9% vs. 1.3% [no endoleak]). Those with type II completion endoleaks overall had the shortest length of stay (2.4 days), and the lowest rates of MI (.7%), dysrhythmia (1.7%), pneumonia (.5%), ventilator dependence (.9%), and RTOR (1.7%) (Table 3).

For patients with follow-up endoleaks, looking back on their postoperative outcomes, those with type I and III endoleaks had longer lengths of stay, 2.9 and 2.7 days, respectively compared to 2.3 days for those without endoleak. There were otherwise no significant differences in other perioperative outcomes (Table 4).

Overall survival

Patients with no completion endoleak have a 5-year overall survival of 75%. When compared to the no completion endoleak group, patients with type II completion endoleak had higher survival (79%, $P<.001$); whereas, those with type I completion endoleak had significantly lower survival (69%, $P<.001$) (Figure 1). Types III and IV completion endoleaks had lower survival as well, 73% and 73% respectively, but these were not statistically significant.

In comparison, patients without follow-up endoleak had a 5-year survival of 84% (Figure 2). Patients with type I follow-up endoleaks had significantly lower survival of 80% ($P=.002$), and type III follow-up endoleaks had the worst 5-year survival at 66% ($P<.001$). Patients with type II and indeterminate types of endoleaks had 5-year survival of 82% ($P=.80$) and 77% ($P=.42$), respectively.

Freedom from reintervention

For those without completion endoleaks, 83% remained free from reintervention at 5-years, compared to 76% of type I endoleaks ($P<.001$) and 72% ($P<.001$) of patients with type III completion endoleak (Figure 3). Type II endoleaks and indeterminate type endoleaks had no significant differences in 5-year reintervention rate compared to the no endoleak cohort (83% and 81%, respectively).

In patients with no follow-up endoleak, the freedom from reintervention at five years was 84% (Figure 4). Patients with all types of endoleaks had significantly lower freedom from reintervention: type II 76% ($P=.006$), type I 70% ($P<.001$), indeterminate type 60% ($P=.007$), and type III 36% ($P<.001$).

Across the different types of completion and follow-up endoleaks, 5-year survival for those with any reintervention was overall lower compared to those without reintervention. However, this observation was statistically significant only for patients with no completion endoleak (71% vs. 76%, reintervention vs. no reintervention, P<.001), no follow-up endoleak (79% vs. 84%, P<.001), type I follow-up endoleak (74% vs. 82%, P=.03), and indeterminate type follow-up endoleak (64% vs. 79%, P=.03) (Table 5).

Freedom from rupture

Patients with no completion endoleak had 94% freedom from rupture at 5-years, which is overall similar across all types of endoleaks (Figure 5). Patients with type II (95%, P=.001) and III (97%, P<.001) endoleaks had higher freedom from rupture compared to the no completion endoleak cohort.

Compared to no endoleaks at follow-up (94%), freedom from rupture was lower for types I (91%, P<.001), II (91%, P=.16), indeterminate (90%, P=.11) and type III follow-up endoleaks (88%, P=.01) (Figure 6).

Aneurysm sac expansion—Rates of sac regression and expansion were significantly different across different types of completion and follow-up endoleak (Table 6). After adjusting for baseline comorbidities, only completion type I endoleak was associated with sac expansion (OR 1.5, 95% CI 1.1–2.0, P=.014). However, for endoleak at follow-up, all endoleak types were associated with sac expansion compared to no endoleak cohort (type I: OR 2.7, 95% CI 2.2–3.3, P<.001; type II: OR 2.6, 95% CI 2.1–3.1, P<.001; type III: OR 4.8, 95% CI 2.8–8.1, P<.001; indeterminate: OR 3.8, 95% CI 2.7–5.2, P<.001).

DISCUSSION

In this retrospective study using VQI-Medicare linked data, we compared rates of survival, freedom from reintervention, and freedom from rupture at 5-years for patients with different types of completion and follow-up endoleaks. We found that compared to no completion endoleak patients, those with type I completion endoleaks have lower 5-year survival and freedom-from-reintervention. Compared to no follow-up endoleak patients, those with types I or III endoleaks at follow-up had lower 5-year survival, and any endoleak at follow-up is associated with lower freedom-from-reintervention. While there were no differences in rate of rupture based on completion endoleaks, the presence of any endoleak at follow-up resulted in higher rates of rupture at 5-years compared to patients with no endoleaks found at follow-up.

Studies examining endoleaks frequently use completion endoleaks as the basis for examining subsequent outcomes.[4,11] Few demonstrate the effects of endoleaks found in follow-up on mid-or late-term outcomes.[12,13] In a study by Jones et al, the data demonstrated that persistent type II endoleaks, rather than transient (<6 month), were associated with higher adverse outcomes including reintervention and rupture.[12] This suggests that knowing the completion endoleak status alone is not sufficient to determine late outcomes after EVAR, but rather additional knowledge of how endoleaks evolve is important in determining the long-term successes of EVAR. This study similarly found the evolution of endoleaks over time, as the proportion of each endoleak type changed from completion to follow-up. We hypothesize that this shift in distribution is in part due to type II endoleaks resolving without intervention over time, and perhaps a shift of type II endoleaks into type I or III endoleaks as the aneurysm sac enlarges . While we could not elucidate the persistence or timing of follow-up endoleaks with the present study, the data suggest that there are indeed differing outcomes base on completion versus follow-up endoleak, and that the presence of follow-up endoleaks portend overall worse outcomes.

Patients with type I and III endoleaks appear to have higher rates of perioperative complications, including perioperative death, longer length of stay, and more frequently return to the operating room. Tan et al similarly report that type I endoleaks are associated with higher risk of in-hospital mortality, as well as cardiac complications.[11] One explanation for this observation is the patient anatomy and baseline characteristics. Type I and III endoleaks tend to occur in patients with less favorable anatomy, such as those with larger aneurysm diameters or neck calcification. Factors such as age and smoking status have also been associated with higher rates of type I endoleak.[11,14] These factors are likely surrogate markers for more advanced cardiovascular diseases at baseline which put patients at risk for more perioperative complications. This was also observed in our study with type I completion endoleak patients having the highest rate of perioperative MI and dysrhythmias. In addition, type I and III endoleak patients had higher rates of return to the OR compared to all other cohorts, which can further put patients at risk for cardiovascular complications.

Reinterventions over time for type I and III endoleaks are also not uncommon. In our data, those with type I and III completion endoleaks had reintervention rates of 24% and 28% at 5 years, and if found on subsequent follow-up, the rate of reintervention increases to 30% and 67%, respectively. O'Donnell et al reported 11% reintervention rate over a median follow-up time of four years for type Ia endoleaks.[5] While historical pedagogy recommends treatment for all type I and III endoleaks,[16] current literature suggests that non-operative management of select type I and III endoleaks at completion may be appropriate as they can resolve spontaneously within the first year.[4,5,11] Some factors that are associated with presence of completion type I endoleak include female sex, age over 70 years, larger main body diameter or unplanned use of graft extensions, and factors associated with the persistence of type I endoleaks include extensive neck calcification.[5,11] Literature on type III endoleak is limited as they are generally rare, but they appear to occur with higher incidence in first and second generation devices.[17] While some occur during the index procedure and are readily recognized at the completion angiogram, others occur after many years and may have a delay in diagnosis.[17] This late onset and delayed recognition may in part explain the significantly lower survival (66% vs. 84% no endoleak) we observed for type III endoleaks during follow-up.

Despite typically being considered indolent, self-limited, and not associated with rupture or worse survival, type II endoleaks at completion are associated with higher rates of reintervention.[18] Similar to existing studies, we found that patients with type II follow-up endoleaks had reintervention rates as high as 24% in our study. It appears that the persistence of type II endoleaks, rather than early or transient, seems to result in worse outcomes.[12] Furthermore, this apparent persistence of type II endoleak despite reintervention raises concern for occult type I or III endoleaks which increase in odds of occurrence with each subsequent reintervention.[19,20] These occult endoleaks can have late onset, with mean time to intervention reported around 5 years.[13,19] The delayed recognition of occult type I/III endoleaks concurrent with type II endoleaks may lead to multiple reinterventions incorrectly targeting a culprit.

Interestingly, patients with type II completion endoleak had lower rates of perioperative complications and higher 5-year survival compared to those without completion endoleak. One hypothesis is that patients with completion type II endoleaks have more frequent follow-up and more encounters with physicians who may be able to mitigate baseline factors that cause death. Another reason could be that those with no endoleaks are more likely to be lost-to-follow-up, and thus return with late complications. Furthermore, type II endoleaks are associated with patent inferior mesenteric artery and lumbar arteries, which may be occluded in patients with more severe atherosclerotic disease.[21] Therefore, the presence of a type II endoleak may indicate patients with less comorbidities and at less risk for complications. This survival benefit is no longer seen when we examine the follow-up endoleaks which suggest that the initial survival benefit due to potential positive patient selection may be lost over time. While late rupture contributing to mortality may be seen with type II endoleaks, its incidence is relatively rare, and the evidence remains unclear.[22–25] However, our data, along with others, suggest that the presence of type II endoleak at follow-up, whether persistent or late-onset, may lead to higher rates of late rupture rather than early completion endoleak alone.[26,27]

Even patients without documented endoleaks at completion or follow-up undergo some type of reintervention over time. In the Medicare database, reinterventions are identified by associated current procedural terminology codes.[7] As such, it is possible that some of these reinterventions may not be directly related to the aneurysm repair, but rather complications associated with the repair or co-existing conditions such as cardiac catheterizations for MI. We found in a previous study that most interventions after the index procedure are non-aneurysm-related and cardiac in nature.[28] A topic of future study will evaluate what proportion of completion endoleaks resolve over time, with or without reintervention, and of those without endoleaks, what proportion ultimately develop endoleaks over time. Nonetheless, these findings only highlight the importance of continued surveillance after EVAR.

Another topic of interest is how the aneurysm sac changes with time and its impact on survival. Deery et al found that aneurysm sac expansion was associated with late mortality after EVAR; while O'Donnell et al in a follow-up paper showed that even failure of the sac to regress (stable or expansion) negatively impacted survival.[9,10] We found that only type I completion endoleak, associated with lower overall survival, was associated with sac expansion. In addition, follow-up endoleaks of all types were associated with sac expansion and all had lower survival than those without follow-up endoleaks. Furthermore, patients with type I follow-up endoleak had the highest rate of failure-to-regress (75%). While we could not determine which came first, the follow-up endoleak or the sac expansion, the temporal relationship of endoleaks to aneurysm sac changes and how reintervention plays a role warrants further investigation.

These results must be interpreted in the context of the limitations in data capture and the retrospective nature of the study design. Administrative data relies on the diagnosis and procedure codes to identify postoperative events, which may incompletely capture or inaccurately capture postoperative complications. Furthermore, while data entry in the VQI is performed by trained clinical data managers, there is no additional review of imaging performed to confirm the presence/absence of endoleaks. Also limited is the ability to determine the cause of death, as it is currently not yet extrapolated from the Medicare database by diagnosis codes. Another limitation is the incomplete information on the chronicity of endoleaks during follow-up and the timing of reinterventions relative to endoleak development, as this detail was lost during the data merging process. As a result, we were unable to determine whether follow-up endoleaks occurred shortly after the index procedure or many years thereafter and whether the timing of its development impacts outcomes. Lost-to-follow-up is a problem within registry data which limit the ability to interpret long-term data. Previous studies using the VQI have documented 1-year imaging rates as low as 49%; thus it was not surprising that only a little over 60% of procedures had long-term endoleak information.[9] Factors affecting lost-to-follow-up have previously been studied.[29,30] Furthermore, we also do not have data on the anatomical changes in aneurysm morphology over time to know the exact reasoning for reintervention or whether the presence of follow-up endoleak contributed to the decision.

CONCLUSION

This study provides a comprehensive overview of 5-year survival, reintervention and rupture rates for patients with/without completion and follow-up endoleaks of all types. While the majority of endoleaks, including select type I completion endoleaks, can be closely monitored, the presence of endoleaks at follow-up generally lead to higher rates of reintervention over time. Patients with type III endoleaks either at completion or follow-up are at especially high risk of reintervention, as well as overall lower survival over time. Even patients with otherwise unimpressive type II endoleaks at completion or no completion endoleaks undergo reintervention at unexpectedly high rates. These data highlight the importance of close postoperative follow-up after EVAR and the need for further studies to better select patients who would benefit the greatest from reinterventions for endoleaks.

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ARTICLE HIGHLIGHTS:

Type of research:

Retrospective analysis of prospectively collected Vascular Quality Initiative data linked to Medicare claims.

Key findings:

Compared to patients with no endoleak, those with type I completion endoleaks have lower 5-year survival and freedom-from-reintervention. Patients with types I and III follow-up endoleaks also have lower survival, and any endoleak at follow-up is associated with lower freedom-from-reintervention and freedom-from-rupture.

Take home message:

Careful patient selection and close postoperative follow-up after EVAR is important, as the presence of endoleaks, specifically type I and III, portends worse outcomes.

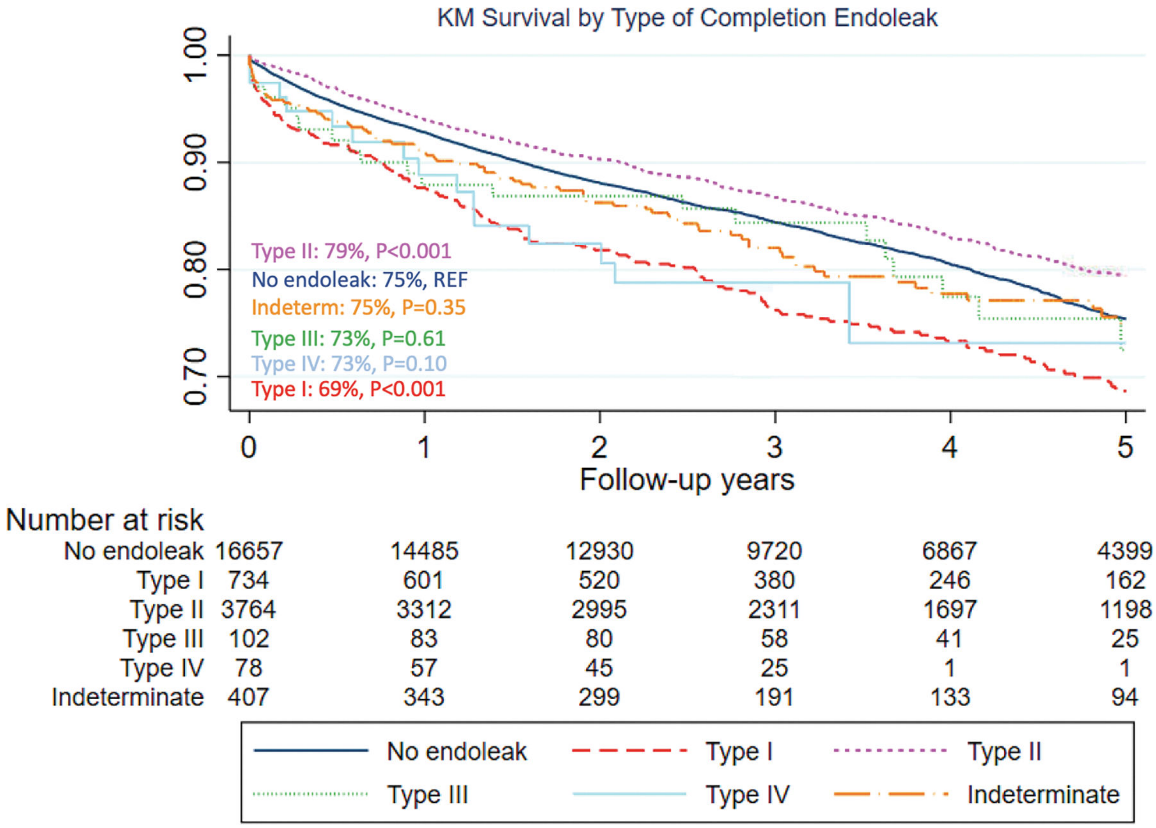

Figure 1.

5-year survival by type of completion endoleak

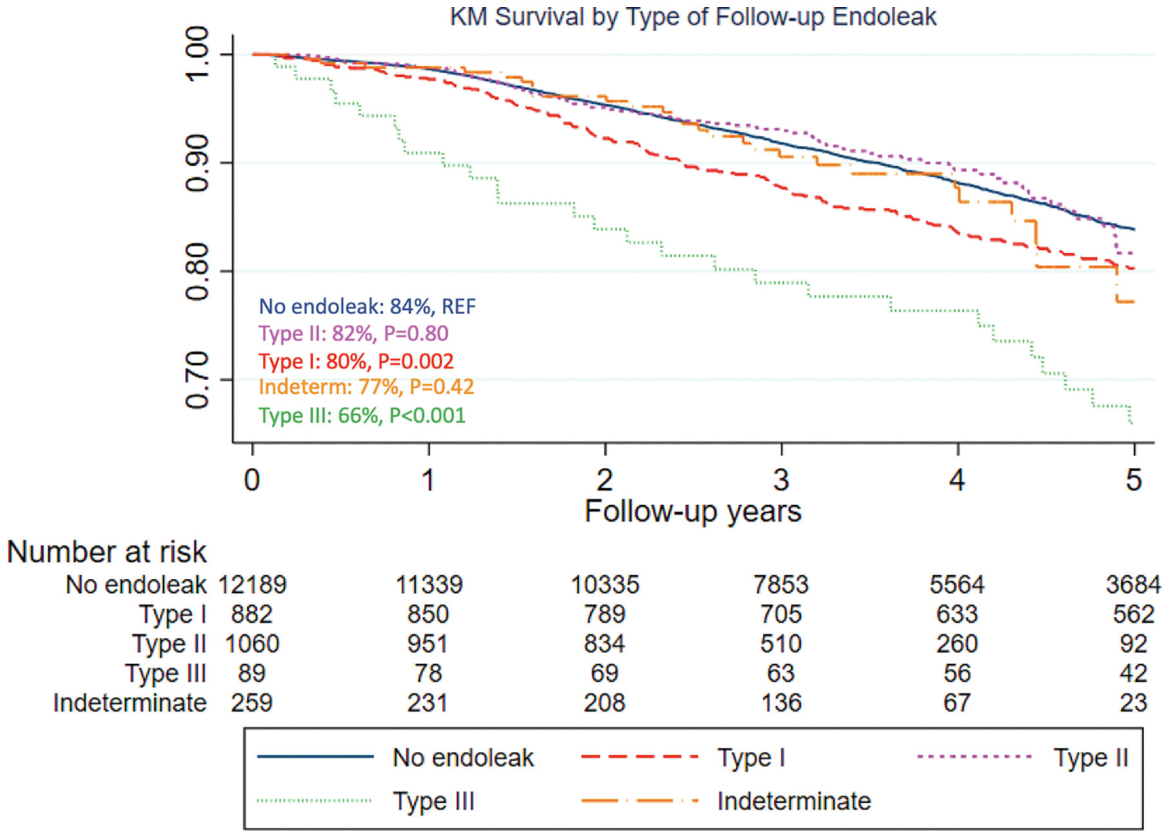

Figure 2.
5-year survival by type of follow-up endoleak

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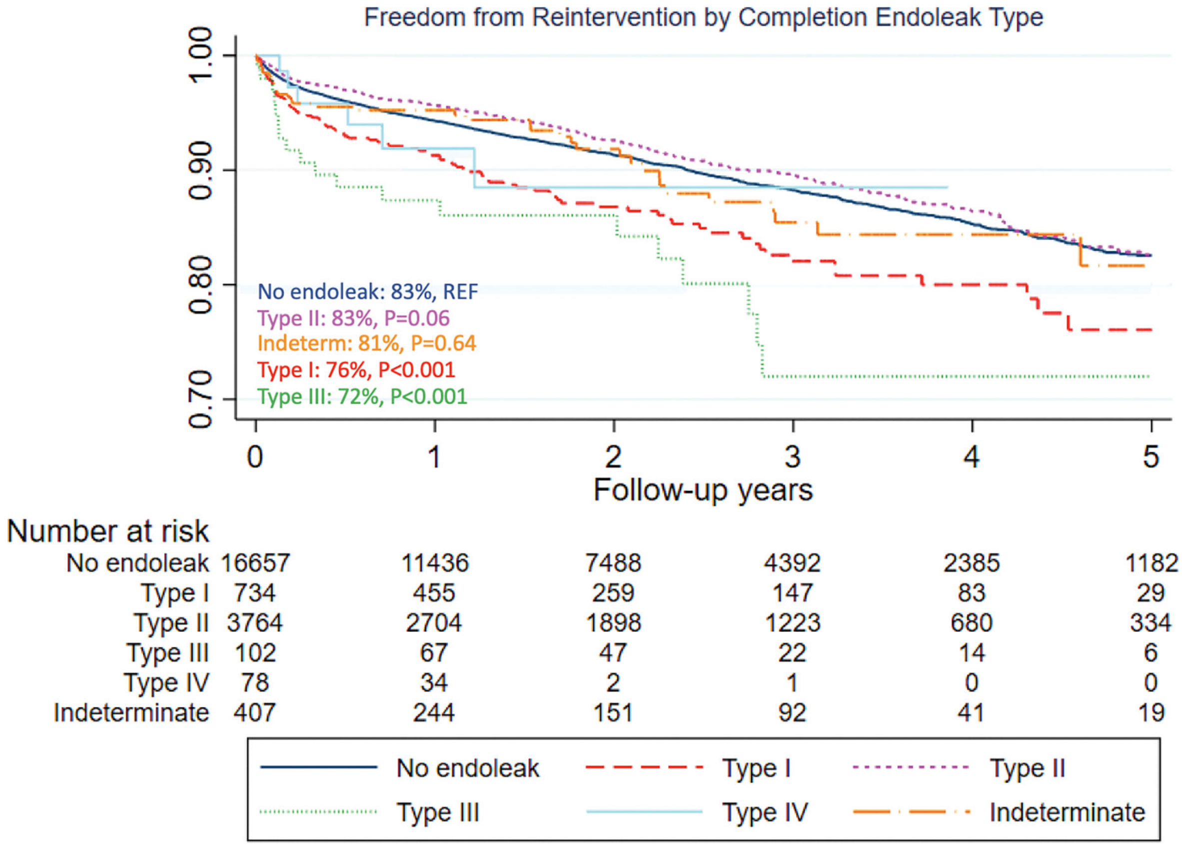

Figure 3.

5-year freedom from reintervention by type of completion endoleak

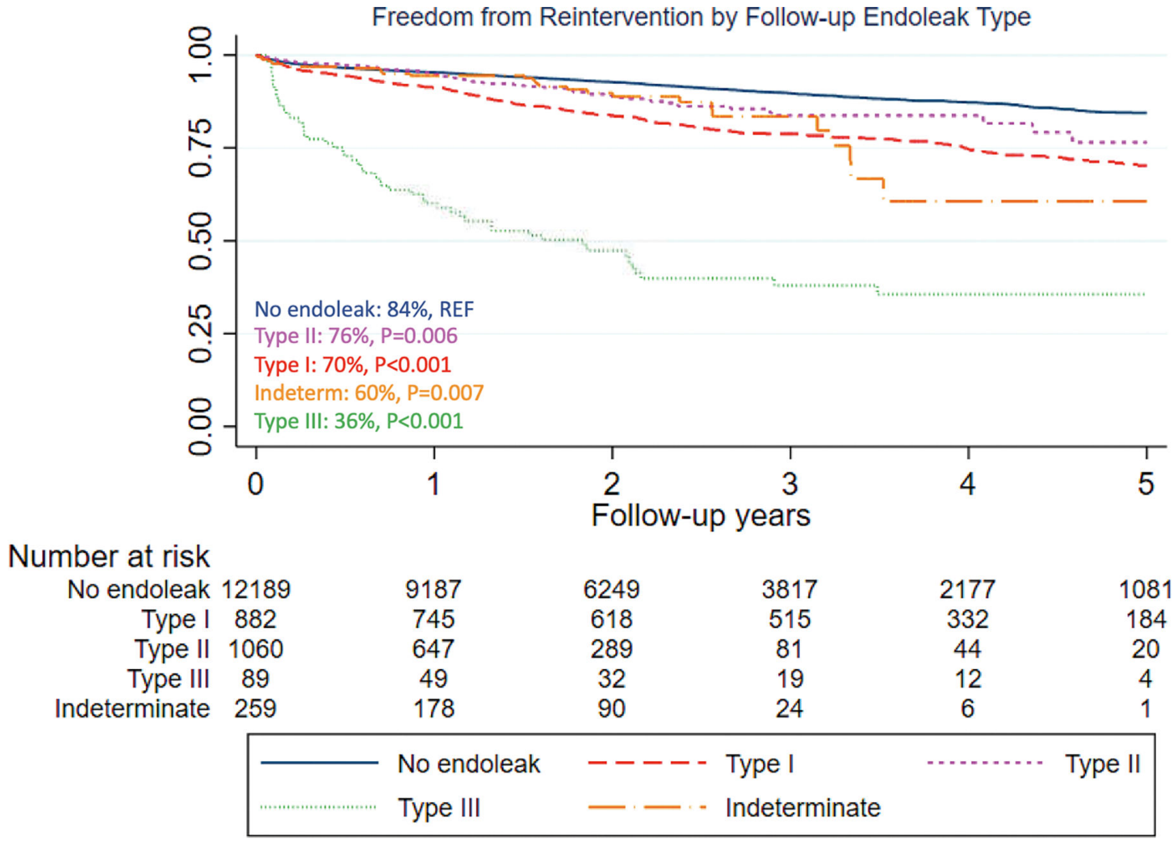

Figure 4.
5-year freedom from reintervention by type of follow-up endoleak

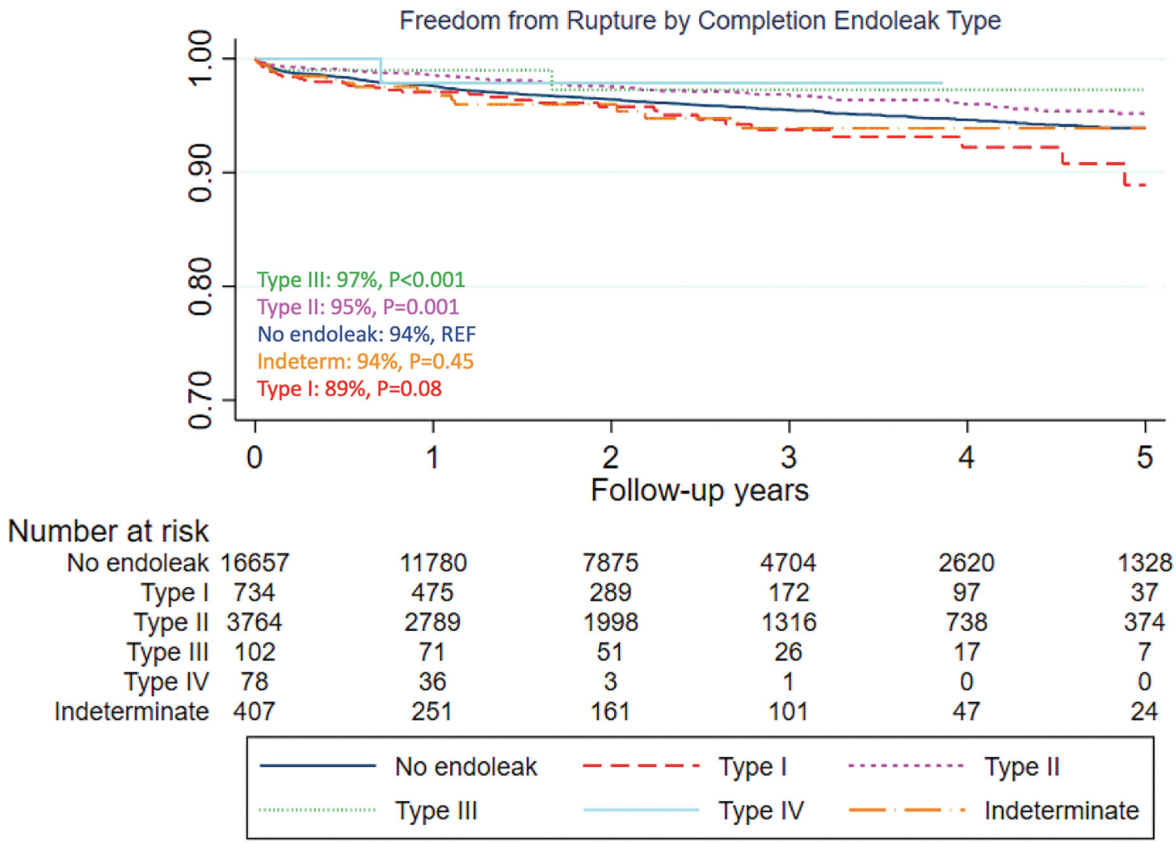

Figure 5.

5-year freedom from rupture by type of completion endoleak

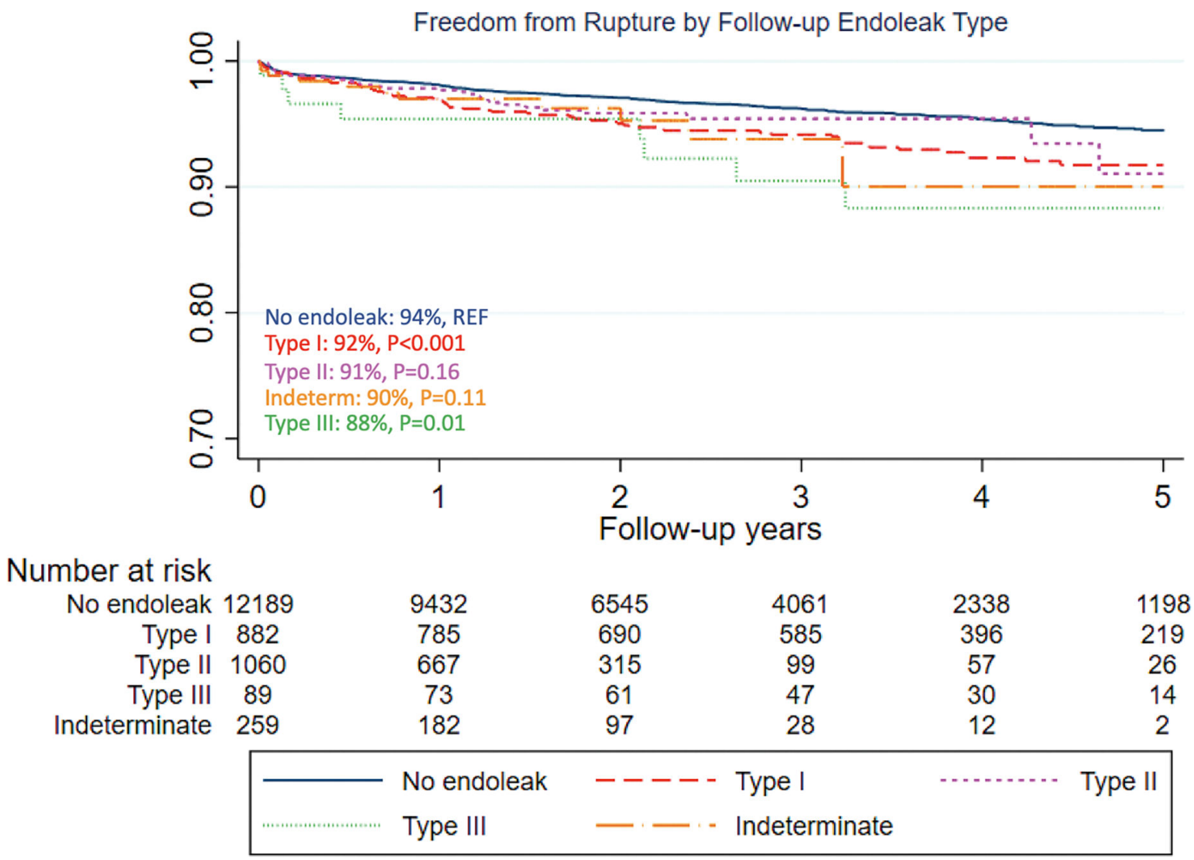

Figure 6.
5-year freedom from rupture by type of follow-up endoleak

Table 1:

Baseline characteristics of patients with completion endoleak, by type

	None N=16,660 (%)	Type I N=734 (%)	Type II N=3,764 (%)	Type III N=102 (%)	Type IV N=78 (%)	Indeterminate N=407 (%)	P
Age, mean (SD), years	75.2 (7.3)	77.9 (7.5)	75.8 (7.4)	77.1 (7.6)	77.3 (7.6)	77.0 (7.8)	<.001
Female	20	32	19	23	33	23	<.001
White	94	94	95	94	91	95	.008
Obese	30	24	28	24	21	26	.003
Current Smoker	29	23	24	20	18	23	<.001
IDDM	3.9	4.0	30	4.9	1.3	3.0	.062
COPD	35	31	30	25	31	35	<.001
CHF	5.3	5.1	4.0	3.0	7.7	7.4	.002
Family history	8.2	9.1	9.9	8.9	7.7	8.5	0.040
HTN	84	87	84	82	87	84	.170
Prior dialysis	1.1	1.8	1.2	2.9	2.6	27	.010

*SD, standard deviation; IDDM, insulin dependent diabetes mellitus; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; HTN, hypertension

Table 2:

Baseline characteristics of patients with follow-up endoleak, by type

	None N = 12,189 (%)	Type I N=882 (%)	Type II N=l,060 (%)	Type III N=89 (%)	Indeterminate N=259 (%)	P
Age, mean (SD), years	74.8 (7.1)	77.0 (7.4)	76.7 (7.4)	78.9 (7.8)	77.0 (7.2)	<.001
Female	19	23	20	30	22	.002
White	95	95	93	98	95	.001
Obese	30	32	33	26	32	.294
Current Smoker	28	17	17	17	21	<.001
IDDM	3.5	2.7	2.4	2.3	2.7	.202
COPD	32	26	27	28	34	<.001
CHF	4.4	4.7	6.0	5.7	6.2	.092
Family history	9.2	11	12	2.3	5.9	.001
HTN	83	84	85	88	85	.515
Prior dialysis	0.8	0.9	1.1	3.4	0	.032

* SD, standard deviation; IDDM, insulin dependent diabetes mellitus; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; HTN, hypertension

Table 3:

Postoperative outcomes of patients with completion endoleak, by type

	None N=16,660 (%)	Type I N=734 (%)	Type II N=3,764 (%)	Type III N=102 (%)	Type IV N=78 (%)	Indeterminate N=407 (%)	P
Perioperative death	.9	2.9	.5	2.0	0	2.5	<.001
LOS, mean (SD), days	2.9 (4.3)	3.9 (5.8)	2.4 (2.8)	3.7(7.9)	3.3(4.7)	2.8 (3.2)	<.001
MI	1.1	1.6	.7	1.0	1.3	1.5	.208
Dysrhythmia	2.7	4.6	1.7	2.0	3.9	2.5	<.001
Pneumonia	.6	1.0	.5	1.0	1.3	.5	.694
Ventilator dependence	1.3	3.1	.9	2.0	3.9	1.2	<.001
Stroke	.2	.1	.2	0	0	.5	.754
Return to OR	2.2	5.2	17	3.9	2.6	2.7	<.001

*LOS, length of stay; SD, standard deviation; MI, myocardial infarction; OR, operating room

Table 4:

Postoperative outcomes of patients with follow-up endoleak, by type

	None N = 12,189 (%)	Type I N=882 (%)	Type II N=l,060 (%)	Type III N=89 (%)	Indeterminate N=259 (%)	P
LOS, mean (SD), days	2.3 (2.9)	2.7 (3.5)	2.1 (3.0)	2.9 (3.4)	2.5 (3.0)	<.001
MI	.7	1.3	0.3	0	1.2	.079
Dysrhythmia	2.3	2.3	1.6	1.1	1.5	.491
Pneumonia	.4	.5	.5	1.2	.8	.774
Ventilator dependence	.6	.7	.4	0	.8	.812
Stroke	.1	.1	.1	0	0	.964
Return to OR	1.6	.9	1.1	3.4	1.5	.203

* LOS, length of stay; SD, standard deviation; MI, myocardial infarction; OR, operating room

Table 5:

5-year Kaplan-Meier survival estimate for patients with and without reintervention, stratified by type of completion or follow-up endoleak

Type of Completion Endoleak	No reintervention	Any reintervention	P
None	76%	71%	<.001
Type I	69%	66%	.62
Type II	80%	78%	.52
Type III	74%	67%	.23
Type IV	75% (3-yr 82%)	-- (3-yr 50%)	.07
Indeterminate	74%	75%	.87
Type of Follow-up Endoleak	**No reintervention**	**Any reintervention**	**P**
None	84%	79%	<.001
Type I	82%	74%	.03
Type II	82%	77%	.13
Type III	64%	67%	.89
Indeterminate	79%	64%	.03

Table 6:

Rates of aneurysm sac regression, stability, and expansion by type of completion and follow-up endoleak.

Type of Completion Endoleak	Sac Regression N (%)	Sac Stability N (%)	Sac Expansion N (%)	Total	P
No endoleak	4743 (46)	4792 (47)	715 (7.0)	10250	.042
Type I	169 (38)	226 (51)	46 (10)	441	
Type II	H78 (46)	1196 (47)	170 (67)	2544	
Type III	32 (50)	27 (42)	5 (7.8)	64	
Type IV	23 (48)	22 (46)	3 (6.2)	48	
Indeterminate	100 (41)	127 (52)	16 (6.6)	243	

Type of Follow-up Endoleak	Sac Regression N (%)	Sac Stability N (%)	Sac Expansion N (%)	Total	P
No endoleak	5729 (51)	4945 (44)	625 (5.5)	11299	<.001
Type I	214 (25)	513 (61)	119 (14)	846	
Type II	695 (67)	204 (20)	140 (13)	1039	
Type III	43 (54)	18 (23)	18 (23)	79	
Indeterminate	141 (57)	61 (25)	46 (19)	248	