Incidence, natural course, and outcome of type II endoleaks in infrarenal endovascular aneurysm repair based on the ENGAGE registry data

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ABSTRACT

Objective: The purpose of this study was to report the incidence, natural history, and outcome of type II endoleaks in the largest prospective real-world cohort to date.

Methods: Patients were extracted from the prospective Endurant Stent Graft Natural Selection Global Postmarket Registry (ENGAGE). Two groups were analyzed: first, patients with an isolated type II endoleak; and second, patients with a type II endoleak who later presented with a type I endoleak. A health status analysis between patients with an early type II endoleak and patients with no endoleak was performed. Second, an attempt was made to identify risk factors in patients with a type II endoleak who later presented with a type I endoleak.

Results: Through 5 years of follow-up, a total of 197 (15.6%) patients with isolated type II endoleaks were identified. Most were detected within the first 30 days (n = 73 [37.1%]) and through the first year (n = 73 [37.1%]), with the remainder being detected after 1 year of follow-up (n = 51 [25.8%]). Patients with a type II endoleak had a higher incidence of aneurysm growth and more secondary endovascular procedures (15.4% vs 7.5% at 5 years; $P < .001$). Overall survival was higher in the isolated type II endoleak group compared with patients with no endoleak (77.2% vs 67.0% at 5 years; $P = .010$). Twenty-two patients (10%) with a type II endoleak were diagnosed with a late type I endoleak (type IA, n = 10; type IB, n = 12), with a secondary intervention rate of 67.5% through 5 years. There was no difference in health status scores between patients with an early type II endoleak and patients without any type of endoleak at 1-year follow-up.

Conclusions: In the ENGAGE registry, isolated type II endoleaks are present in 15.6% of patients during follow-up. The majority do not require secondary intervention, and an early isolated type II endoleak does not have an impact on health status through 1 year. However, a small group of patients with a type II endoleak will present with a type I endoleak, resulting in a high secondary intervention rate and significant risk of aneurysm-related complications. (J Vasc Surg 2019;■:1-9.)

Keywords: EVAR; Endovascular; Abdominal aortic aneurysm; ENGAGE; Endoleak; Type II

The occurrence of endoleaks after endovascular aneurysm repair (EVAR) remains an issue. Type II endoleaks are most common and arise from retrograde filling of the aneurysm sac through collateral vessels, such as lumbar arteries or the inferior mesenteric artery.[1,2] The incidence of these endoleaks varies considerably by imaging modality and contrast agent used but also because some of them represent a low-flow aspect. The early incidence is usually reported to be around 25%, but most resolve spontaneously during the first

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6 months.[3] Therefore, current treatment guidelines do not recommend prompt treatment at the time of EVAR.

Previous studies on the natural course of type II endoleaks have shown that a conservative strategy is safe for the majority of patients.[4] However, up to 10% of type II endoleaks persist, and a subset of them may cause aneurysm growth, in which case treatment should be considered.[1,3,5] During follow-up, delayed isolated type II endoleaks also occur; these are associated with an increased number of secondary interventions.[6] The exact mechanism of these type II endoleaks is not well understood. In case of a persistent type II endoleak, aneurysm shrinkage is observed in 25%, a stable aneurysm sac in 50% to 70%, and sac enlargement in 15% to 25%. Rupture due to a persistent type II endoleak is rarely reported and is estimated to occur in <1% of all type II endoleaks.[1] To further complicate matters, a systematic review showed that about half of these ruptures occurred in the absence of sac expansion.[2] In case of aneurysm sac enlargement, the presence of another type of endoleak (especially type I or type III) should be suspected. A subset of patients may have an unnoticed type I or type III endoleak as cause of the type II endoleak, whereas some patients with a type II endoleak may go on to develop a type I or type III endoleak. Although the exact underlying mechanism remains unclear, a previous study showed that up to 21% of patients who underwent a reintervention for a type II endoleak had an occult type I or type III endoleak.[7] Current treatment guidelines vary from recommending treatment of all type II endoleaks with sac enlargement to selective intervention based on treatment options and the patient's existing comorbidities.[3,5]

Endovascular treatment options include transarterial catheterization, perigraft arterial sac embolization, transcaval catheterization, and direct translumbar puncture combined with coils or embolic agents to occlude the feeding vessels. Open surgical options include either laparoscopic ligation/clipping of the inferior mesenteric artery or lumbar arteries and open surgical ligation of feeding vessels or conversion to open repair.[8,9] Reports on the outcomes of reinterventions for persistent type II endoleaks (with or without aneurysm growth) unanimously report high technical success rates. This may, however, not be the best measure of success, as shown by a recent review and meta-analysis of secondary interventions for type II endoleaks that again questions when and if treatment is justified.[10]

This study aimed to report the incidence, natural history, and outcome of type II endoleaks in the largest prospective real-world cohort to date, including a health status analysis. Second, an analysis was performed to identify potential risk factors in patients who were initially diagnosed with a type II endoleak and later presented with a type I endoleak.

ARTICLE HIGHLIGHTS

- **Type of Research:** Prospectively collected registry data (Endurant Stent Graft Natural Selection Global Postmarket Registry [ENGAGE])
- **Key Findings:** In the ENGAGE registry, isolated type II endoleaks occurred in 197 patients (15.6%) through 5 years after endovascular aneurysm repair. Although most do not require secondary interventions, patients with a type II endoleak had a higher incidence of aneurysm growth and more secondary endovascular procedures. Twenty-two patients (10%) with a type II endoleak who were diagnosed with a late type I endoleak had high secondary intervention rates (67.5%) through 5 years. There was no difference in health status scores between patients with a type II endoleak and those without any type of endoleak at 1-year follow-up.
- **Take Home Message:** A small group of patients with a type II endoleak after endovascular aneurysm repair will present with a type I endoleak, resulting in a high secondary intervention rate and significant risk of aneurysm-related complications.

METHODS

Study design. Patients entered in the prospective Endurant Stent Graft Natural Selection Global Postmarket Registry (ENGAGE) were included. There were 79 participating centers worldwide, and ethical committee approval was obtained for the majority of the sites (>75%) and per local law. For the remaining centers, either the ethical committee was notified or approval was waived and standard of care treatment was followed for the patients. The full registry design, inclusion and exclusion criteria, and data collection and a detailed description of the Endurant (Medtronic, Santa Rosa, Calif) stent graft system have been previously published.[11] In short, the ENGAGE is a multicenter nonrandomized single-arm prospective registry. Participating centers were required to perform >20 EVAR procedures per annum. To increase the real-world applicability of the ENGAGE outcomes, both indication for intervention and follow-up protocols were in accordance with standard clinical practice at the participating sites.

The cohort of type II endoleaks was divided into two groups. The first group consisted of patients who had an isolated type II endoleak that was detected during follow-up, excluding those that were present on perioperative angiography. The second group consisted of patients with a type II endoleak who were later diagnosed with a type I endoleak. These groups were separate and analyzed as such. Patients with a type II endoleak and a type I endoleak at some point during follow-up were not in the "isolated" type II group. The control group

consisted of patients who had no endoleak of any type during follow-up. Baseline characteristics and outcomes are reported and compared between these study groups.

Health status scores for patients with an early type II endoleak vs patients without any type of endoleak were obtained using the EuroQol-5 Dimension questionnaire and obtained at baseline, 30 days, and 1 year of follow-up. To limit potential bias in this analysis, patients with a concomitant endoleak of another type (type I or type III) were excluded.

Definitions. Unless otherwise specified, outcomes are reported in accordance with current international treatment guidelines and the Society for Vascular Surgery reporting standards for endovascular aortic aneurysm repair.[3,5,12]

Isolated type II endoleak was defined as persistent aneurysm sac filling through side branches, without signs of either type I or type III endoleak, on duplex ultrasound, computed tomography angiography (CTA), magnetic resonance angiography, or angiography, without signs of any other type of endoleak during subsequent follow-ups.

Early isolated type II endoleak was defined as a type II endoleak diagnosed ≤30 days of the index procedure.

Late isolated type II endoleak was defined as a type II endoleak first diagnosed >30 days of the index procedure.

Statistics. Descriptive statistics for categorical variables were presented as relative frequencies (percentages). Continuous variables were expressed as means, standard deviations, medians, and ranges. For all other continuous variables, the *t*-test was used. For group comparisons, univariate analyses of categorical variables were performed by using Cochran-Mantel-Haenszel test or Fisher exact test; continuous variables were compared using *t*-test or Wilcoxon rank sum test. Testing for normality was not routinely performed; for variables that are skewed by nature, the Wilcoxon rank sum test was used. For the right-censored data, Kaplan-Meier survival estimates were used to estimate the time-to-event and survival rate. Namely, the freedom from conversion to open surgery, secondary endovascular procedures, aneurysm ruptures, and patient mortality (all-cause mortality and aneurysm related mortality) were analyzed using Kaplan-Meier method, and log-rank test was used for subgroup comparisons. For the events observed from the image data, instead of being observed at a specific time point, time to event is reported within a time interval. The survival function for such interval-censored data was estimated using the EMICM algorithm (a combination of expectation-maximization and iterative convex minorant algorithms). The time-to-event comparisons were conducted using log-rank test. Two sided *P* values ≤.05 were considered statistically significant. All statistical analyses were performed with SAS 9.4 software (SAS Institute, Carey, NC).

RESULTS

The ENGAGE registry included 1263 patients (89.5% men; mean age, 73.1 years [range, 43-93 years]). At completion angiography (t = 0), 181 (14.3%) type II endoleaks were identified, of which 105 (58.0%) had spontaneously resolved at the first follow-up imaging. Follow-up data on endoleaks were available for 1090 (86.4%) patients. During follow up (t = 1 and onward), a total of 197 (15.6%) patients with isolated type II endoleaks were identified and 893 (70.8%) patients without any endoleak. Baseline characteristics are shown in Table I. The majority of patients were detected within the first 30 days (early type II endoleaks, n = 73 [37.1%]; Table II) and through the first year (n = 73 [37.1%]) after surgery (Fig 1). Several imaging modalities were used, including CTA (n = 138 [70.1%)], duplex ultrasound (n = 54 [27.4%]), angiography (n = 4 [2.0%]), and magnetic resonance angiography (n = 1 [0.5%]).

Isolated type II endoleak vs no endoleak. Indication for EVAR did not differ between the isolated type II and the no endoleak groups. Hypertension and hyperlipidemia incidences were significantly higher in the isolated type II endoleak group, whereas the incidence of smoking was higher in the no endoleak group. Aneurysm characteristics were mostly similar, with a slightly smaller proximal neck diameter (23.1 mm vs 23.7 mm; $P = .032$) in the isolated type II endoleak group. There was a higher incidence of short neck aneurysms in the no endoleak group (12.7% vs 6.1% in the isolated type II group; $P = .009$; Table I).

During follow-up, there was a significant difference in aneurysm diameter change between the two groups. Patients with an isolated type II endoleak had a higher incidence of aneurysm growth, and this steadily increased during follow-up and reached significance after 3 years of follow-up ($P < .001$; Table III). Freedom from secondary endovascular procedures was 94.3%, 91.0%, 89.1%, 84.6%, and 79.2% in the isolated type II group compared with 94.9%, 94.5%, 94.1%, 93.6%, and 92.5% in the no endoleak group through 1, 2, 3, 4, and 5 years, respectively ($P < .0001$; Fig 2). A secondary endovascular procedure that aimed to correct an isolated type II endoleak was performed in 34 patients (17.3%). Two aneurysm ruptures were reported. One occurred in a patient with an isolated type II endoleak who had stable aneurysm size during follow-up, and one occurred in a patient who initially had no endoleak but developed a type IA endoleak with growth seen on follow-up imaging 3 years after the initial procedure. Freedom from aneurysm-related mortality through 5 years was 99.5% in the isolated type II group compared with 99.0% in the no endoleak group ($P = .57$). Overall survival was 95.4%, 90.2%, 85.9%, 80.4%, and 77.2% (through 1, 2, 3, 4, and 5 years, respectively) in the isolated type II group compared with 93.5%, 86.9%, 79.5%, 73.1%, and 67.0%

Table I. Baseline characteristics, isolated type II endoleak vs no endoleak

	Isolated type II endoleak (n = 197)	No endoleak (n = 893)	*P* value
Age, years	73.8 ± 8.1	72.7 ± 8.1	.078
Male sex	88.8 (175/197)	89.9 (803/893)	.694
Smoking	35.4 (68/192)	53.4 (465/871)	<.001
Hypertension	81.0 (158/195)	73.8 (649/879)	.036
Hyperlipidemia	68.9 (131/190)	59.4 (498/838)	.015
Diabetes	18.4 (36/196)	19.6 (172/878)	.695
Cardiac disease	56.3 (111/197)	53.1 (474/892)	.414
Pulmonary disease	24.2 (47/194)	25.9 (227/877)	.632
Renal insufficiency	15.9 (31/195)	14.9 (132/885)	.729
Aneurysm characteristics			
Maximum diameter, mm	59.3 ± 9.7	59.7 ± 11.3	.633
Proximal neck diameter, mm	23.1 ± 3.4	23.7 ± 3.5	.032
Proximal neck length, mm	27.5 ± 11.6	27.0 ± 12.6	.585
Proximal neck angle, degrees	31.2 ± 23.0	29.2 ± 23.2	.284
Proximal neck length <15 mm	6.1 (12/197)	12.7 (112/883)	.009

Continuous data are presented as mean ± standard deviation and categorical data as % (n/N).

Table II. Baseline characteristics, early vs late type II endoleak

	Early (≤30 days) type II endoleak (n = 73)	Late (>30 days) type II endoleak (n = 124)	*P* value
Age, years	74.6 ± 8.3	73.3 ± 7.9	.269
Male sex	87.7 (64/73)	89.5 (111/124)	.692
Smoking	26.8 (19/71)	40.5 (49/121)	.055
Hypertension	78.9 (56/71)	82.3 (102/124/)	.563
Hyperlipidemia	73.5 (50/68)	66.4 (81/122)	.309
Diabetes	15.3 (11/72)	20.2 (25/124)	.396
Cardiac disease	57.5 (42/73)	55.6 (69/124)	.797
Pulmonary disease	20.8 (15/72)	26.2 (32/122)	.398
Renal insufficiency	11.1 (8/72)	18.7 (23/123)	.163
Aneurysm characteristics			
Maximum diameter, mm	59.6 ± 11.1	59.2 ± 8.3	.798
Proximal neck diameter, mm	22.9 ± 2.9	23.3 ± 3.7	.411
Proximal neck length, mm	29.4 ± 11.6	26.4 ± 4.1	.076
Proximal neck angle, degrees	31.4 ± 25.6	31.0 ± 21.5	.918
Proximal neck length <15 mm	1.4 (1/73)	8.9 (11/124)	.034

Continuous data are presented as mean ± standard deviation and categorical data as % (n/N).

in the no endoleak group ($P = .010$; Fig 3). There were no differences in health status scores between patients with an early type II endoleak vs patients without any endoleak at any time point (Table III).

Early vs late isolated type II endoleak. A subanalysis of isolated type II endoleaks that were first identified within 30 days after EVAR vs those that were first identified after 30 days showed a higher incidence of shorter neck aneurysms in the delayed type II group (n = 11 [8.9%]) compared with the early type II group (n = 1 [1.4%]; $P = .034$); however, the difference in mean neck length did not reach statistical significance (29.4 mm vs 26.4 mm; $P = .076$; Table II). There was no significant difference in the remaining baseline characteristics or aneurysm morphology.

Isolated type II vs type II and late type I endoleak. Twenty-two patients with a type II endoleak were diagnosed with a late type I endoleak (type IA, n = 10; type IB, n = 12) during follow-up. These were analyzed separately from the group that had an isolated type II endoleak. The late type I endoleaks were diagnosed at a median of 1205 days after the initial procedure (822-

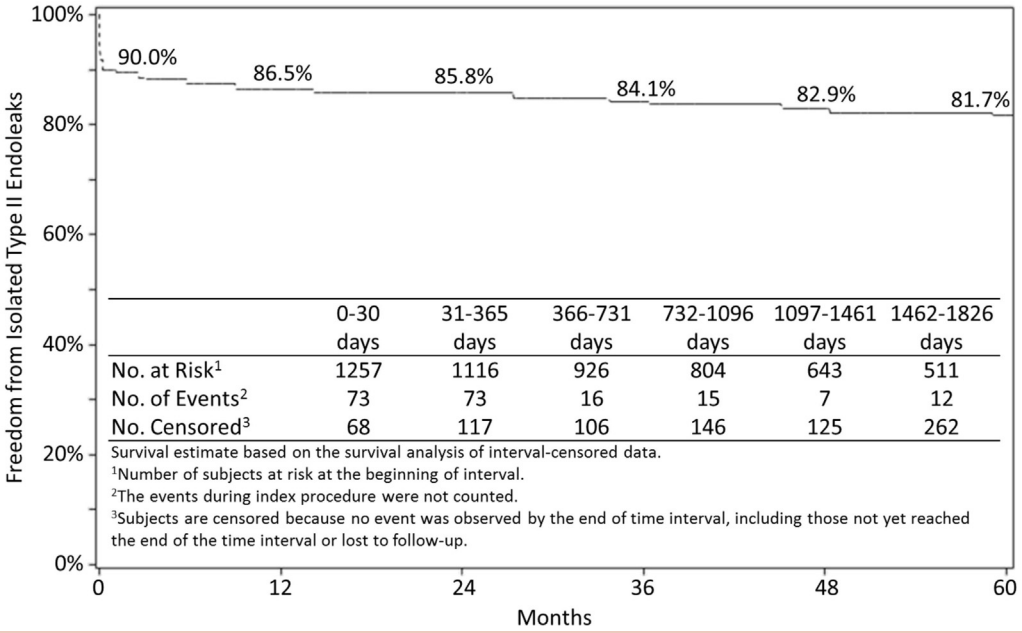


Fig 1. Kaplan-Meier analysis, freedom from isolated type II endoleak.

1716 days) using CTA (n = 18 [81.8%]) and duplex ultrasound (n = 4 [18.2%]). The median time between diagnosis of the type II endoleak and the type I endoleak was 969 days (631-1451 days).

The sole significant difference found in the baseline characteristics was a proximal neck length of <15 mm. In the group that developed a late type I endoleak, 25.0% (5/20) had a short neck aneurysm vs 6.1% (12/197) in the isolated type II group, although there was no significant difference in absolute infrarenal neck length (27.5 ± 11.6 mm compared with 24.4 ± 10.0 mm; $P = .242$). There was no difference in iliac sealing zone length, infrarenal neck angle, or maximal aneurysm diameter. Aneurysm rupture occurred in 4 of 22 (18.2%) patients with type II endoleak who later developed type I endoleaks. This was fatal in one patient (4.5%) with type II endoleaks. Freedom from aneurysm rupture was 99.5% at 5 years for the isolated type II group vs 80.2% for the late type I group ($P < .0001$). Freedom from aneurysm-related mortality was also lower in the type I group (99.5% vs 90%; $P = .003$).

In this subgroup with a late type I endoleak, the secondary endovascular procedure rate was significantly higher, reaching 67.5% through 5 years vs 21.8% in the isolated type II group ($P < .0001$; Fig 4). In the group with no endoleak, the 5-year reintervention rate was 7.5% (Fig 2). A total of 14 secondary endovascular procedures in 12 patients that aimed to correct the type I endoleak were performed. Of the secondary endovascular procedures, nine (75%) were successful in treating the type I endoleak.

DISCUSSION

The overall incidence of isolated type II endoleaks in the ENGAGE registry is in line with earlier publications.[1,2] The data confirm that the majority of isolated type II endoleaks are clinically not of concern. However, they also show that having a type II endoleak is associated with an increased risk of aneurysm growth and a higher incidence of secondary interventions. Moreover, a small group of patients with a type II endoleak presented with a late type I endoleak during follow-up, which resulteds in a 67.5% secondary endovascular procedure rate through 5 years, increased aneurysm rupture risk, and aneurysm-related mortality. The exact pathophysiologic mechanism is unclear. In the introduction, two possible hypothesizes have been described. First, a type II endoleak may lead to aneurysmal disease progression and subsequent type I (A or B) endoleak. Second, a type II endoleak may be a type I (A or B) endoleak in disguise. Besides the exact pathophysiologic mechanism, the relatively high incidence of late type I endoleak suggests that in these cases, a conservative strategy might be catastrophic. This is supported by the larger subset of patients with aneurysm growth. Larger aneurysms tend to have a shorter neck length. A higher incidence of neck dilation in relation to type II endoleak, however, has not been described in the literature, and based on the current data, neither theory can be proved or dismissed. A recent publication showed that endograft apposition and expansion of the aortic neck may predict late type IA endoleak, but no correlation with type II endoleak was found in that small series.[13] Also, the ability to detect endoleaks varies between imaging modalities

Table III. Follow-up data, isolated type II endoleak vs no endoleak

	Isolated type II endoleak (n = 197)	No endoleak (n = 893)	*P* value
AAA diameter change 1 year			
Decrease	31.5 (52/165)	45.4 (306/674)	.001
Stable	63.6 (105/165)	52.2 (352/674)	.009
Increase	4.8 (8/165)	2.4 (16/674)	.113
AAA diameter change 2 years			
Decrease	42.1 (59/140)	60.4 (337/558)	<.001
Stable	50.7 (71/140)	37.1 (207/558)	.004
Increase	7.1 (59/140)	2.5 (14/588)	.016
AAA diameter change 3 years			
Decrease	43.1 (53/123)	68.6 (310/452)	<.001
Stable	42.3 (52/123)	28.8 (130/452)	.006
Increase	14.6 (18/123)	2.7 (12/452)	<.001
AAA diameter change 4 years			
Decrease	41.3 (45/109)	71.1 (288/405)	<.001
Stable	40.4 (44/109)	25.4 (103/405)	.003
Increase	18.3 (20/109)	3.5 (14/405)	<.001
AAA diameter change 5 years			
Decrease	40.6 (39/96)	72.1 (246/341)	<.001
Stable	37.5 (36/96)	24.6 (84/341)	.014
Increase	21.9 (21/96)	3.2 (11/341)	<.001
EuroQol-5 Dimension index			
Baseline	0.88 ± 0.15	0.86 ± 0.17	.161
12 months	0.90 ± 0.15	0.88 ± 0.16	0428
	Early (≤30 days) type II endoleak (n = 73)	**No endoleak (n = 893)**	***P* value**
EuroQol-5 Dimension index			
Baseline	0.86 ± 0.17	0.86 ± 0.17	.867
12 months	0.88 ± 0.18	0.88 ± 0.16	.938

AAA, Abdominal aortic aneurysm.
Continuous data are presented as mean ± standard deviation and categorical data as % (n/N).

and imaging protocols. Nonetheless, the fact that a subset of patients with a type II endoleak later presented with a type I endoleak, some well after the index procedure, confirms the need for meticulous follow-up in these patients. It could also be advocated that patients with a new type II endoleak with duplex ultrasound should undergo further evaluation to make sure this not related to another type of endoleak. Although, given the registry design, no definitive conclusions can be made, patients with short-neck aneurysms and type II endoleaks may be at a higher risk for development of a late type I endoleak, which corresponds with earlier publications on this matter.[14-16] In this study, smoking was associated with a lower incidence of type II endoleaks. Given the retrospective and observational design of this study, the observed difference is not necessarily causal, although there have been previous studies that showed smoking was associated with lower incidence of type II endoleaks.[17] However, even if smoking were to be protective, it would be unwise to have patients smoke to prevent type II endoleaks.

Interestingly, freedom from all-cause mortality was higher in patients with an isolated type II endoleak vs patients without an endoleak of any type (77.2% vs 67.0% through 5 years of follow-up, respectively; $P = .010$; Fig 3). This corresponds with an earlier publication[4] in which the authors found survival to be higher in the type II endoleak group compared with patients with no endoleak, especially in the subgroup of late-occurring type II endoleaks. In this study, no protocol for reintervention was used and was left at the discretion of the treating physician. Only nine reinterventions were performed, mostly for sac expansion >10 mm. No good explanation for this phenomenon was found. A possible reason could be that follow-up in patients with a type II endoleak is more meticulous, which could in turn result in a lower aneurysm-related mortality (also causing lower all-cause mortality). However, loss to follow-up did not differ between groups, and a significant difference between follow-up schemes was not found in the current cohort. Cancer was a common cause of death for patients in both the no endoleak group (24.2%, 65/268

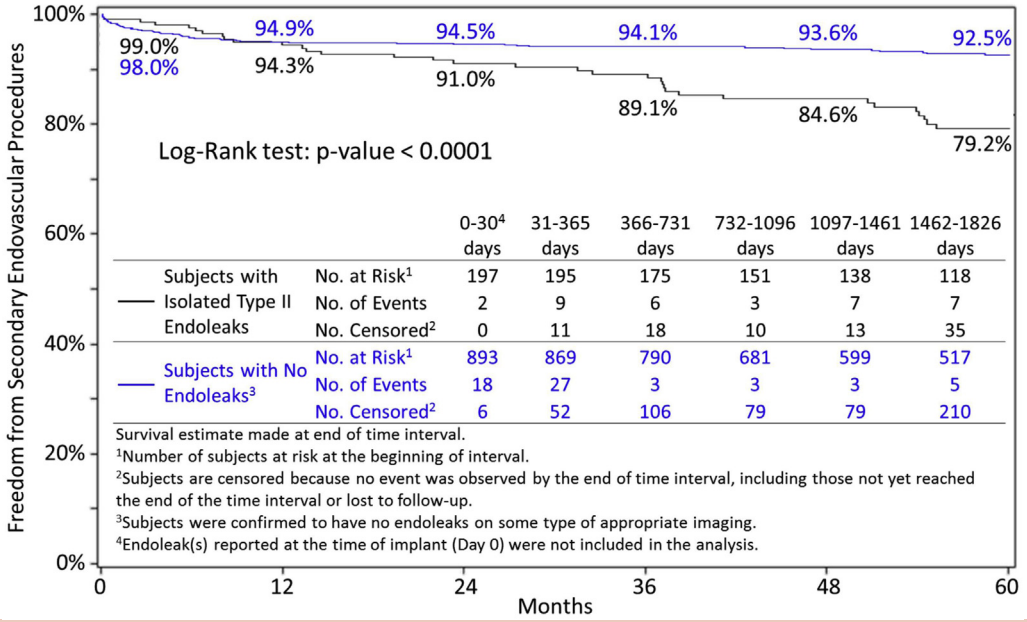


Fig 2. Kaplan-Meier analysis, freedom from secondary endovascular procedures comparing patients with isolated type II endoleak vs no endoleak.

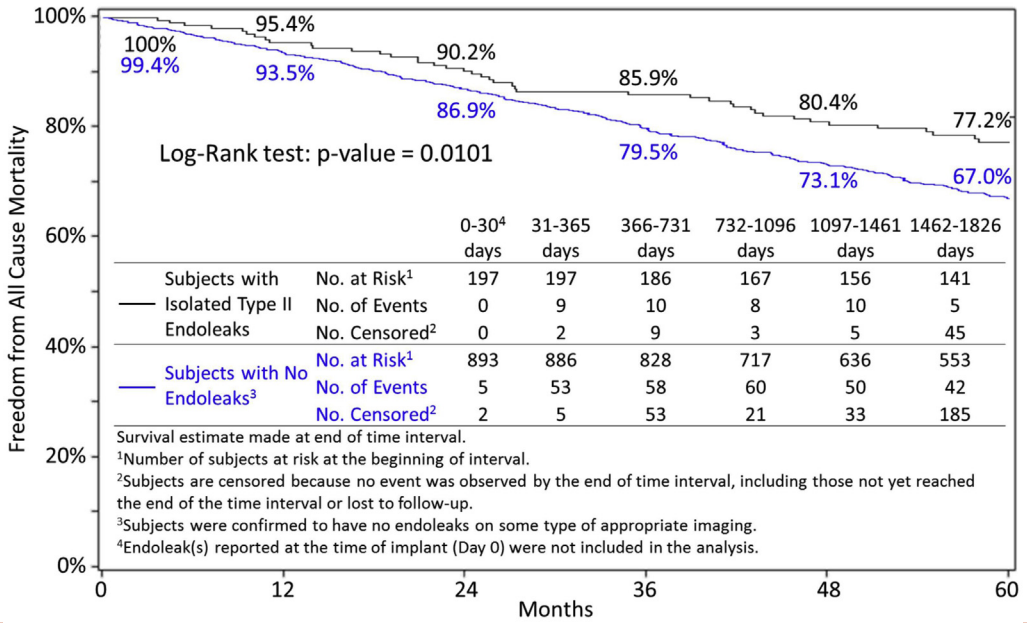
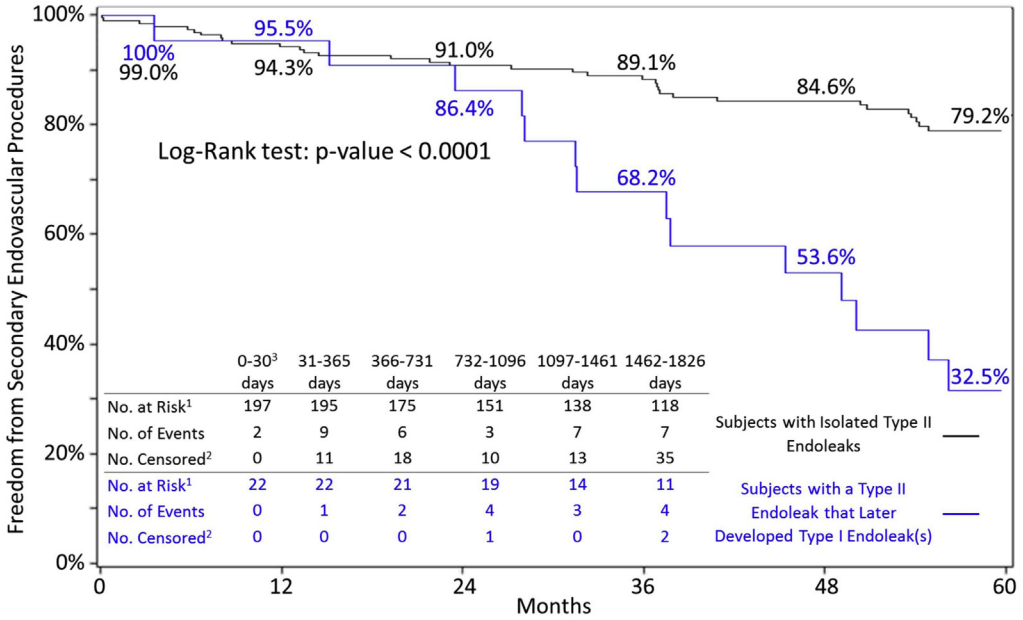


Fig 3. Kaplan-Meier analysis, freedom from all-cause mortality comparing patients with isolated type II endoleak vs no endoleak.

deaths were due to some form of cancer) as well as for those patients with isolated type II endoleaks (28.6%, 12/42 deaths were due to some form of cancer). The overall aneurysm-related mortality is low, and there is no significant difference in aneurysm-related mortality for patients with an isolated type II endoleak compared with those without any type of endoleak. This is in contrast to those who were later diagnosed with a late type I endoleak. Unfortunately, these two groups cannot be distinguished beforehand.

The presented data corroborate previous publications showing that the risk of aneurysm rupture for type II endoleaks is low. Patients with an isolated type II endoleak did show a higher incidence of aneurysm growth during longer term follow-up, but rupture may have occurred only once in the isolated type II endoleak group. This should be interpreted with caution, however; a reliable cause of death is notoriously difficult to obtain, and the incidence of rupture may be higher. Secondary endovascular procedures were more common in the type II



Survival estimate made at end of time interval. [1]Number of subjects at risk at the beginning of interval. [2]Subjects are censored because no event was observed by the end of the time interval, including those not yet reached the end of the time interval or lost to follow-up. [3]Endoleak(s) reported at the time of implant (Day 0) were not included in the analysis.

Fig 4. Kaplan-Meier analysis, freedom from secondary endovascular procedures comparing patients with late type I endoleak vs isolated type II endoleak.

group and might be in part responsible for this result. Secondary endovascular procedures were performed for type II endoleaks in 21.8% of patients vs a secondary endovascular procedure rate of 7.5% in the group without endoleaks. The main indication for secondary intervention was aneurysm sac expansion. In patients that developed a type I endoleak, secondary endovascular procedures were even more frequent. For a type I endoleak, which is considered a high-pressure and therefore high-risk endoleak, there is no arguing that this needs to be resolved if there is a suitable treatment option for the patient. For an isolated type II endoleak, this is far less clear. In this series, 34 patients with isolated type II endoleaks underwent a secondary endovascular procedure. However, only a subset of patients with an isolated type II endoleak and sac expansion will go on to experience clinical sequelae or even rupture. It is unknown which patients will benefit from secondary endovascular procedures. The current European guidelines advocate a more "relaxed" surveillance protocol in "low-risk" patients (no endoleak, good seal) but yearly follow-up in case of an isolated type II endoleak.[18] Based on the presented data, a less strict follow-up scheme might be safe, although further studies are needed to confirm these findings and to justify a change in surveillance strategy.

In a broader perspective, risk factors for the development of an isolated type II endoleak have been identified, but the exact pathophysiologic mechanism remains unknown. This is especially frustrating in late type II endoleaks. These late type II endoleaks do occur, but seemingly without cause. The literature on these endoleaks is scarce, but recent publications have suggested that these "late" type II endoleaks might be less benign compared with "early," leading to more sac expansion and high reintervention rates. This could warrant more vigilant follow-up protocols.[19] It is important to note in the referred study, late type II endoleaks were defined as those occurring >1 year after EVAR compared with >30 days in this study.

There was no difference in health status scores between the no endoleak group and the early isolated type II endoleak group both at 30 days and at 1 year (Table III). Apparently, having a type II endoleak and the potentially intensified follow-up do not have an impact on health status, at least in the short term.

This study has limitations. First, the inherent limitations of registries apply, and not all patients had follow-up data on the occurrence of type II endoleaks available. The follow-up protocols were not dictated by the ENGAGE registry and varied between participating centers, which could have influenced outcomes. Data available for analysis are limited to the data as reported on the case report forms. The ENGAGE case report form has broad categories for additional devices used during the implantation procedure. Because the "other" category could include anything from aortouni-iliac devices to cuffs, coils, and limb extensions, a direct comparison of specific additional devices was not possible. In this study, patients who showed signs of an isolated type II endoleak on completion angiography that had disappeared on the first postoperative follow-up imaging were considered benign and excluded from further analysis. On the other

hand, the possibility of this subgroup of patients also having a higher risk of aneurysm growth or the development of a late type I endoleak remains unknown as we do not have these data. Specifically for the health status analysis, follow-up was modest and limited to 1 year. The ENGAGE registry does not use a core laboratory for image analysis. The sensitivity of duplex ultrasound scans in detecting type II endoleaks may differ between sites, which could affect our results. However, previous publications have shown that both duplex ultrasound and contrast-enhanced duplex ultrasound have good sensitivity and specificity in detecting type II endoleaks compared with CTA.[20] The decision to perform a secondary endovascular procedure aimed to correct an isolated type II endoleak was at the treating physician's discretion. Ultimately, the registry data are descriptive and not designed to prove or disprove a hypothesis; it is a tool to gain more insight and to guide further research.

CONCLUSIONS

In the ENGAGE registry, isolated type II endoleaks are present in 15.6% of patients during follow-up. The majority are clinically not of concern. Having an early isolated type II endoleak does not have an impact on health status through 1 year. A small group of patients with a type II endoleak will present with a type I endoleak that is associated with a high secondary intervention rate and risk of aneurysm-related complications.

AUTHOR CONTRIBUTIONS

Conception and design: MD, CZ, MR
Analysis and interpretation: MD, CZ, HV, JT, AP, DB, PP, VR, JB, MR
Data collection: MD, CZ, MR
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Critical revision of the article: MD, HV, JT, AP, DB, PP, VR, JB, MR
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