From the Society for Vascular Surgery

Final results of the Endurant Stent Graft System in the United States regulatory trial

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Objective: **To report the 5-year outcomes from the Endurant Stent Graft System in the U.S. regulatory trial (bifurcated Endurant; Medtronic Santa Rosa, Calif).**

Methods: **The study was a prospective, multicenter, regulatory trial performed at 26 U.S. sites. From June 2008 to April 2009, 150 patients with abdominal aortic aneurysms (AAAs) were treated with the Endurant bifurcated graft. The main inclusion criteria included AAA diameter >5 cm (or 4-5 cm in diameter where the size increased more than 5 mm within the previous 6 months), neck length ≥10 mm, and neck angulation ≤60 degrees. A clinical events committee adjudicated all untoward events, and a core laboratory reviewed available imaging at 1, 6, 12, 24, and 60 months. Outcomes were compared with the Talent enhanced Low Profile System (eLPS) study for regulatory purposes. At 5 years, clinical follow-up was available on 94% and imaging on 87% of 101 eligible patients.**

Results: **At 5 years, all-cause mortality estimate by Kaplan-Meier was 17.7%, and freedom from aneurysm-related mortality was 99.2%. One aneurysm-related mortality was noted in a patient that refused treatment for a type I endoleak and died in year 4 from rupture. There were no endograft migrations, fractures, or open conversions. At 5 years, endoleaks were identified in 7/83 patients (8.4%) and included six type II endoleaks and one of indeterminate origin. Maximum AAA diameter decreased by more than 5 mm in 53/83 patients (63.9%), remained stable in 25/83 (30.1%), and increased >5 mm in 5/83 (6.0%). Eighteen AAA-related secondary interventions were required in 15 patients (11%): 12 for endoleak management, 4 for limb occlusions, 1 for stenosis, and 1 for thromboembolism. Four of 5 limb occlusions reported were in the first 6 months. Survival and reintervention rates were better than the Talent eLPS study, which was conducted under similar inclusion exclusion criteria.**

Conclusions: **The 5-year outcomes of the Endurant Stent Graft System in the U.S. regulatory trial continue to be positive. The device appears to be durable with limited adverse events through 5 years. Comparison with an older generation device suggests improving outcomes with newer devices. (J Vasc Surg 2016;64:55-62.)**

The early benefits of endovascular aneurysm repair (EVAR) are well documented and have made it the preferred choice of treatment in patients with suitable anatomy. The Endurant stent graft (Medtronic Endovascular, Santa Rosa, Calif) has been widely used since receiving U.S. Food and Drug Administration approval in December 2010. The 1-year Endurant U.S. investigational device exemption pivotal trial results were very encouraging and concluded that the device was safe and effective.[1] Since the publication of the Endurant 1-year data, a number of studies including a worldwide registry have confirmed its midterm durability and effectiveness even in challenging anatomies.[2-4] This is the first report of 5-year long-term outcomes from the U.S. Endurant Stent Graft System regulatory trial.

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METHODS

The study design details, inclusion and exclusion criteria, and outcomes have been previously published.[1] In short, the U.S. regulatory study of the Endurant Stent Graft System was a multicenter single arm study performed at 26 sites. During the 11 months between June 2008 and April 2009,150 subjects were enrolled. The primary safety and effectiveness end points were performance targets that were met. The results were also compared with the pivotal trial results of the Talent enhanced Low Profile System (eLPS) device (Medtronic Vascular) at 30 days and 1 year for regulatory purposes. All patients enrolled met strict regulatory study inclusion and exclusion criteria

and fit within device specific instructions for use. Specific endovascular outcomes have been reported in accordance with the updated endovascular reporting guidelines.[5,6]

All participating patients signed informed consent and institutional review boards approved the study protocol and consent forms. One of five independent expert reviewers evaluated computed tomography (CT) scans of prospective patients to verify that inclusion and exclusion criteria were appropriately met. Of specific anatomic interest, proximal neck lengths ≥10 mm, infrarenal neck angulations of ≤60 degree, and iliac sealing zones of ≥15 mm in length were required. Standard implantation procedures of the respective institutions were used, including imaging equipment, type of anesthesia, and perioperative care. The follow-up schedule included a clinic visit with a CT scan and four view abdominal X rays at 1, 6, and 12 months after implantation and yearly thereafter. An independent core laboratory (M2S, West Lebanon, NH) reviewed all imaging studies during the first year. Additional follow-up information was provided by the study sites. The core laboratory reviewed aortic duplex scans at 5 years of follow-up when contrast CT was not available. Throughout the study, review and adjudication of all reportable events were performed by the clinical events committee (Harvard Clinical Research Institute, Boston, Mass). A data safety monitoring committee reviewed study results and allowed the study to progress to completion. The imaging results presented in this article are based on review by the study sites, clinical follow-up from clinical events committee assessments, and audited individual site reports. All source documents were made available to the authors for direct review during manuscript production. The primary study end point was clinical success as described in the reporting standards for EVAR.[5,6] The primary safety end point for the trial was defined as the incidence of major adverse events at 30 days. This included all-cause mortality, myocardial infarction, paraplegia, stroke, bowel ischemia, renal failure, respiratory failure, or blood loss of ≥1000 mL. Primary effectiveness end points included successful aneurysm repair at 12 months, which was defined as freedom from type I and III endoleaks, successful graft implantation, stent graft migration through 12 months, aneurysm rupture, open aneurysm conversion, aortic sac enlargement >5 mm, or stent graft occlusion at 12 months. Secondary end points included overall and aneurysm-related mortality, sac morphology changes, and endoleak occurrence.

Statistical analysis was used for comparisons with the Talent eLPS study results for regulatory purposes. End points were evaluated using descriptive statistics by study group. A two-sided 95% confidence interval for difference in rates between the study group and control group was constructed using the exact methods by inverting a single two-sided test. The Cox regression method was applied to the late major adverse event rate to account for subjects that terminated early from the study. Propensity score analysis based on the quintile strata was performed to adjust for the potential biases between the two study groups. Standard data included means, standard deviations, and percentages, where applicable. Kaplan-Meier (KM) life-tables were constructed to assess for differences between the Endurant stent graft and Talent eLPS.

RESULTS

Of the 150 enrolled patients, 149 underwent successful implantation of the Endurant Stent Graft System (99.3%). The single technical device failure was due to an inability to cannulate a contralateral gate that was collapsed in a narrowed distal aorta, and essentially created an aortomonoiliac device. This was successfully treated by creation of a femoral artery to femoral artery bypass, which remained patent in follow-up. The primary safety and primary effectiveness end points were both met at 30 days and 12 months. Through 12 months of follow-up, there were no device migrations, aneurysm ruptures, or open conversions. There were no type I or III endoleaks found at 1 year. Seven aneurysm-related reinterventions were performed during the first year of follow-up, most were for limb thrombosis, limb stenosis, or type II endoleaks. At the 30-day follow-up, there were 9 (6%) arterial adverse events, 4 of which were procedure-related, and 9 (6%) wound complications. The frequency of percutaneous and open femoral artery access was not tracked. At 5 years, clinical site reported follow-up was available on 95 (94%) and imaging follow-up on 88 (87%) of 101 eligible patients. Of the 49 patients who were excluded at 5 years, 25 expired, 6 were lost to follow-up, and 18 withdrew from the study for various reasons. Noncontrast and contrast CT imaging site data at 5 years were reported on 88 subjects, which was processed by the core laboratory on 87 subjects. Twenty patients did not receive a contrast CT scan, and four image files were not sent to the core lab. Duplex imaging was performed on 13 of the 20 patients with noncontrast CT scans; those images were assessed by the core laboratory. At 5 years, the core laboratory was able to evaluate for endoleaks in 64/101 (63%), and the sites assessed for endoleaks in 83/101 (82%) of subjects. No central duplex validation was required for follow-up, and duplex protocols were site dependent. The are many possible explanations for the use of duplex imaging (ie, contrast allergy, additional radiation exposure), however, it is presumed the clinical sites used noninvasive duplex imaging because of the inability to tolerate intravenous contrast.

Death, rupture, and conversion. Twenty-five patients (17.7%) died during the 5 years of follow-up; 6 in the first year, 3 in the second year, 7 deaths each in years 3 and 4, and 2 deaths in year 5. Table I lists the adjudicated causes of death in all patients. There was only one aneurysm-related death, in a patient with type I endoleak who refused treatment and died on postimplant day 1212 from a ruptured abdominal aortic aneurysm (AAA). An intraoperative rupture of the proximal aortic neck occurred after balloon inflation of the main device and was treated successfully with placement of an aortic cuff. No open

Table I. Adjudicated causes of death in the study

Cause of death	*Patients (N = 150), No. (%)*
All	25 (17.7)
AAA-related	1 (0.6)
Cardiac	6 (4)
Carcinoma	6 (4)
Infection	3 (2)
Intracranial hemorrhage	2 (1.3)
Pulmonary	4 (2.6)
Stroke	2 (1.3)
Unknown	1 (0.6)
Multisystem organ failure	1 (0.6)

conversions were performed during the 5-year follow-up. At 5 years, all-cause mortality estimated by KM was 17.7%. Fig 1 and Table II depict KM plots for all-cause mortality ($P < .0103$). Freedom from aneurysm-related mortality was 99.2% ($P = .08$). In comparison, all-cause and aortic-related (Fig 2) survival rates were better than the Talent eLPS study, which was conducted under similar inclusion and exclusion criteria.

Endoleaks and sac size changes. Primary endoleaks occurred infrequently, and the majority of early endoleaks resolved by year 2. A detailed list of endoleaks is located in Table III. There were no type I or III endoleaks reported in the first year. On follow-up, two type I endoleaks were reported in two patients, both were diagnosed and treated in year 2. The first was a presumed type II endoleak that was later identified to be a type Ib endoleak, 406 days after graft implant. This was caused by placement of a short iliac limb in the common iliac artery. It was successfully treated with an iliac limb extension 14 months after initial endograft implant. An enlarging aortic sac because of a type Ia endoleak occurred in a second patient 618 days after endograft implant. This was successfully treated by placement of bilateral renal artery stents using a chimney technique and Talent aortic cuff extension. At the 36-month follow-up, the type IA endoleak returned, and the aortic sac had increased in size. The patient refused additional surgical intervention and requested hospice care. This patient died on day 1212 as a result of aortic aneurysm rupture. Type II endoleaks were described in 23 of 143 patients (16.1%) at 30 days, 12 of 132 (9.1%) at 1 year, and 3 of 73 (4.1%) at year 5. One indeterminate endoleak was found at 12 months (0.8%), 2 indeterminate endoleaks (2.2%) were found at year 3, and 2 at year 5 (2.7%).

The baseline aortic aneurysm diameter was determined by measuring the largest orthogonal diameter on the CT scan. Baseline average aneurysm size was 57 ± 8.3 mm (range, 44-97 mm). A detailed listing of aortic sac diameter changes is located in Table IV. One patient (0.7%) developed sac enlargement at 12 months. At 1 year, a decrease in sac size by more than 5 mm was observed in 65 of 135 (48.1%), and no significant change noted in 69 of 135 (51.1%) of patients. At 2 years, the maximum AAA diameter decreased by more than 5 mm in 80/131 patients (61.1%) and remained stable in 47/131 (35.9%). It

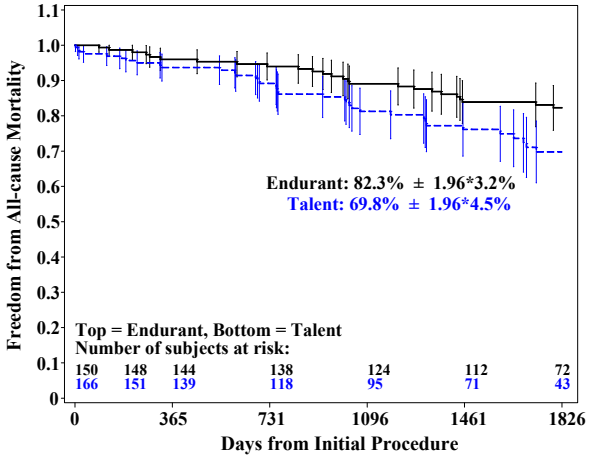

Fig 1. Depict Kaplan-Meier (KM) plots for all-cause mortality.

increased >5 mm in only four patients (3.1%). At 5 years, the maximum AAA diameter decreased by >5 mm in 53/83 patients (63.9%), remained stable in 25/83 (30.1%), and increased >5 mm in 5/83 (6.0%).

Device integrity. There were no observed endograft migrations, anchoring pin fractures, suprarenal bare stent fractures, or component separations. There were no stent graft wire form fractures resulting in a clinical event through 5 years.

Secondary interventions. Eighteen AAA-related reinterventions were required in 15 patients, 12 for endoleak management, four for limb occlusions, one for limb stenosis, and one for thromboembolism. Seven of the interventions were performed in the first year: four endovascular and three open procedures. Three additional early interventions were performed for vascular complications associated with the procedure. At 5 years, secondary intervention rate estimated by KM was 11.0%. Freedom from secondary interventions are listed in Table V and Fig 3 and tended to be better than the Talent eLPS study, which was conducted under similar inclusion exclusion criteria ($P < .1330$).[7] A comprehensive list of secondary interventions is listed in Table VI. Two patients required more than one procedure for recurrent or new type II endoleaks associated with aortic sac enlargement, and all other procedures were determined to be successful at the time of completion. One major adverse event was indirectly associated with a secondary intervention. On postoperative day 618, a type Ia endoleak was successfully repaired with an aortic cuff and bilateral renal artery stents. At the 36-month follow-up, the type Ia endoleak recurred. As previously mentioned, the patient refused further intervention was placed in hospice and expired on day 1212 as a result of a ruptured AAA. There were no other major complications associated with the secondary interventions. In the study, 7 of 18 (38%) secondary procedures were performed in the first year and of those cases, four were performed for limb occlusions, and 1 for limb stenosis.

Limb patency. Four of 5 limb occlusions occurred in the first 6 months and have been previously reported.

Table II. Kaplan-Meier (*KM*) plots for all-cause mortality

	Endurant (bifurcated)							*Talent*						
	Treatment to 30	*31-182*	*183-365 days*	*366-731 days*	*732-1096 days*	*1097-1461 days*	*1462-1826 days*	*Treatment to 30 days*	*31-182 days*	*183-365 days*	*366-731 days*	*732-1096 days*	*1097-1461 days*	*1462-1826 days*
No. at risk[a]	150	150	148	144	138	124	112	166	157	151	139	118	95	71
No. of events	0	2	4	3	7	7	2	3	3	4	6	10	5	5
No. censored[b]	0	0	0	3	7	5	38	6	3	8	15	13	19	23
KM estimate[c]	1.000	0.987	0.960	0.940	0.891	0.839	0.823	0.982	0.963	0.937	0.892	0.813	0.761	0.698
Standard error	0.000	0.009	0.016	0.019	0.026	0.031	0.032	0.010	0.015	0.019	0.026	0.033	0.038	0.045

Log-rank test: $\chi^2 = 6.5882$; degrees of freedom = 1; $P = .0103$.
[a]Number of subjects at risk at the beginning of the interval.
[b]Subjects are censored because they withdraw, are lost to follow-up, or die from nonaneurysm-related causes.
[c]Estimate along with its standard error using Greenwood method were made at end-of-time interval.

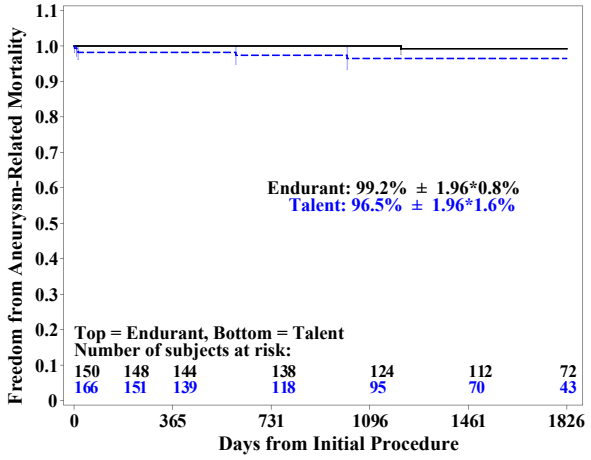

Fig 2. Talent vs Endurant *P* values for freedom from aneurysm-related mortality.

Only one limb occlusion occurred after the first year on day 1281. The patient underwent a successful femoral to femoral bypass. A single stent graft stenosis was observed in the first year because of stent graft kinking at the left iliac gate region and underwent successful angioplasty and stent placement. Most of the limb complications were due to extrinsic compression in a small aorta or iliac artery. A single occlusion not associated with extrinsic compression was due to creation of an acute angle in a tortuous iliac artery following stent graft implantation. These early study results have been previously published.[1]

Comparison to control group. Although the end points of this study were performance targets, a comparison group was provided for regulatory purposes and included another endograft treatment group: the Talent eLPS pivotal trial. Baseline AAA characteristics and comorbidities were nearly identical between the two. The only exceptions were a higher incidence of congestive heart failure, peripheral arterial occlusive disease, and lower incidence of diabetes in the Talent study.[1,7] For all early end points, the Endurant stent graft was found to be superior including utility measures. The lone exception was a slightly higher limb occlusion rate. Fig 3 shows freedom from secondary interventions tended to be better for the Endurant stent graft but was not significant ($P = .1330$).

DISCUSSION

Significant early advantages of EVAR over open AAA repair in anatomically suitable situations has led to its widespread acceptance as the primary treatment modality for infrarenal AAA repair.[8-10] Persistent questions, however, remain, concerning its long-term durability and high reintervention rates. Reporting of long-term outcomes in cohorts with closely monitored and prospectively collected data are, thus, of particular importance. This report provides 5-year data on the regulatory study of one of the most widely used endografts around the world. Prior publications confirmed its excellent early (1 year) and midterm results.[1-3,11,12] The initial report of the Endurant stent graft device at 1 year provided evidence of safety and efficacy in patients with suitable anatomy. The United States Food and Drug Administration provided approval for general use in December 2010, and it remains widely used worldwide. Numerous studies have since shown excellent midterm outcomes and rates of technical success with the device.[2,3,13,14] The data presented in this article confirm the long-term safety and durability of the Endurant system out to 5 years. The observation of only a single rupture at 4 years (day 1212), freedom from open surgical conversion, and freedom from aneurysm-related death (99.2%) supports the excellent long-term durability of the Endurant stent graft.

The Endurant stent graft has shown good device-related long-term durability. There were no observed

Table III. Detailed list of endoleaks by visit, defined by the core laboratory

Endoleaks	*1 Month (1-90 days), % (m/n)*	*6 Month (91-304 days), % (m/n)*	*12 Month (305-548 days), % (m/n)*	*2 Year (549-913 days), % (m/n)*	*3 Year (914-1278 days), % (m/n)*	*4 Year (1279-1644 days), % (m/n)*	*5 Year (1645-2009 days), % (m/n)*
Type I	0.0 (0/143)	0.0 (0/131)	0.0 (0/132)	0.8 (1/121)	0.0 (0/93)	0.0 (0/2)	0.0 (0/73)
Type II	16.1 (23/143)	11.5 (15/131)	9.1 (12/132)	9.1 (11/121)	8.6 (8/93)	0.0 (0/2)	4.1 (3/73)
Type III	0.0 (0/143)	0.0 (0/131)	0.0 (0/132)	0.0 (0/121)	0.0 (0/93)	0.0 (0/2)	0.0 (0/73)
Type V	0.0 (0/143)	0.0 (0/131)	0.0 (0/132)	0.0 (0/121)	0.0 (0/93)	0.0 (0/2)	0.0 (0/73)
Indeterminate	0.0 (0/143)	0.0 (0/131)	0.8 (1/132)	0.0 (0/121)	2.2 (2/93)	0.0 (0/2)	2.7 (2/73)
Endoleaks of any type	16.1 (23/143)	11.5 (15/131)	9.8 (13/132)	9.9 (12/121)	10.8 (10/93)	0.0 (0/2)	6.8 (5/73)

Table IV. Detailed list of aortic sac diameter changes following Endurant repair

Change in maximum aneurysm diameter	*1 Year (305-548 days), % (m/n)*	*2 Year (549-913 days), % (m/n)*	*3 Year (914-1278 days), % (m/n)*	*4 Year (1279-1644 days), % (m/n)*	*5 Year (≥1645 days), % (m/n)*
Increase more than 5 mm	0.7 (1/135)	3.1 (4/131)	4.5 (5/111)	2.0 (2/100)	6.0 (5/83)
Stable	51.1 (69/135)	35.9 (47/131)	33.3 (37/111)	36.0 (36/100)	30.1 (25/83)
Decrease more than 5 mm	48.1 (65/135)	61.1 (80/131)	62.2 (69/111)	62.0 (62/100)	63.9 (53/83)

endograft migrations, anchoring pin fractures, suprarenal bare stent fractures, or component separations. Limb compression and subsequent early occlusion rates were comparable to other studies and multicenter device trials.[15-17] The early incidence of limb occlusion supports the need for meticulous imaging post-EVAR implantation and more liberal use of balloon endoflation early on. Beyond the first year, only a single case of limb occlusion occurred. Presumably limb occlusion rates are directly impacted by the development of lower endograft delivery profiles and increased limb flexibility.[18,19] Procedure-related changes need to be considered and emphasis placed on postimplantation balloon endoflation of the flexible limbs, use of kissing balloons in tight aortic bifurcations, and selective stent placement for additional endograft support. It is assumed that had these techniques been used in the early phases of this study, the majority of limb thromboses may have been avoided. Our results showed excellent device durability with freedom from secondary intervention probabilities of 91.6%, 90.0%, and 89.0% at 3, 4, and 5 years, respectively. In the study, 7 of 18 (38%) secondary procedures were performed in the first year and of those cases, 4 were performed for limb occlusions, and 1 for limb stenosis.

The incidence of sac enlargement, endoleaks, and secondary interventions were very favorable in comparison with other device trials. There was a very low incidence of type I, III, and IV endoleaks and an overall incidence of late endoleaks of <12% at all-time points studied, which compares favorably to other studies.[15,20-22] Sac shrinkage remains a surrogate marker for successful aneurysm exclusion. Houbballah et al[23] showed that following EVAR AAA shrinkage of >5 mm significantly increased patient survival. The risk of sac enlargement was very low in the study; 0.7% at 1 year, 3.1% at 2 years, 4.5% at 3 years, 2.0% at 4 years, and 6.0% at 5 years. After the first year, nearly two-thirds of AAA sacs decreased >5 mm in diameter. In a similar study that evaluated the Endurant stent graft, Bisdas et al[2] reported an overall rate of sac shrinkage (>5 mm) of 58%. This compares favorably with our study that showed rates of sac shrinkage of 48.1%, 62.2%, and 63.9% at 1, 3, and 5 years. Of the small number of patients with enlarging aortic sacs, 5 of 7 (71.4%) were found to have either type I or II endoleaks all of which were treated. Type III and IV endoleaks were notably absent during follow-up. As calculated and represented in the KM curves, 11.0% of the patients in the study were at risk for development of late endoleaks and the indication for secondary interventions was lower than the expected rate in the Talent eLPS study group (84.2%). Reassuringly, throughout the study the vast majority of endoleaks were type II in nature. The overall number of type II endoleaks trended down during the course of the study. Secondary interventions were generally successful, particularly those interventions for type I and II endoleaks. In the majority of cases, aneurysm growth was controlled. This underlines the importance of meticulous post implant follow-up.

Device migration, component separation, open conversion, and device integrity were nonissues during the study. Treating patients with adverse proximal aortic necks (<10 mm) has been reported with acceptable short-term results.[13,14] However, an increased rate of type I endoleaks and mid-to late-term endograft migration is expected. The mean neck length treated in the study was 26.5 ± 12.1 mm and 15 patients (10%) had neck lengths of 10 to 14.9 mm. The shorter neck length threshold in this study appears to be safe out to 5 years as there were no endograft migrations or type Ia endoleaks in patients treated with shorter

Table V. Freedom from secondary intervention rates

	Endurant (bifurcated)							*Talent*						
	To 30 days	*31-182 days*	*183-365 days*	*366-731 days*	*732-1096 days*	*1097-1461 days*	*1462-1826 days*	*Treatment to 30 days*	*31-182 days*	*183-365 days*	*366-731 days*	*732-1096 days*	*1097-1461 days*	*1462-1826 days*
No. at risk[a]	150	148	144	137	129	114	101	166	155	141	123	100	81	59
No. of events	2	2	3	2	3	2	1	2	8	6	3	2	1	0
No. censored[b]	0	2	4	6	12	11	36	9	6	12	20	17	21	23
KM estimate[c]	0.987	0.973	0.953	0.939	0.916	0.900	0.890	0.988	0.936	0.895	0.872	0.853	0.842	0.842
Standard error	0.009	0.013	0.017	0.020	0.023	0.025	0.027	0.009	0.020	0.025	0.027	0.030	0.032	0.032

KM, Kaplan-Meier.
Log-rank test: $\chi^2 = 2.2576$; degrees of freedom = 1; $P = .1330$.
[a]Number of subjects at risk at the beginning of the interval.
[b]Subjects are censored because they withdraw, are lost to follow-up or die from non-aneurysm-related causes.
[c]Estimate along with its standard error using Greenwood method were made at end-of-time interval.

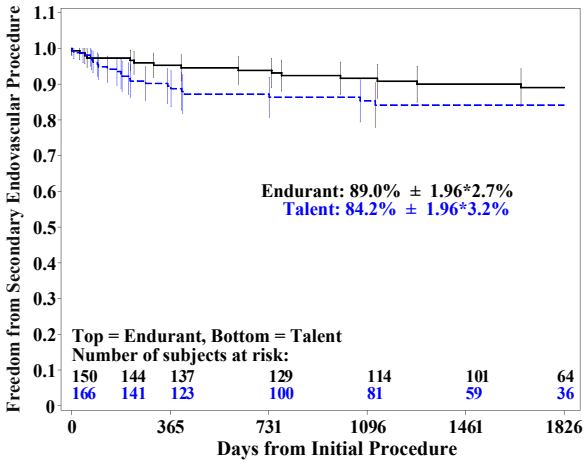

Fig 3. Talent vs Endurant *P* values for freedom from secondary intervention rates.

(10-14.9 mm) proximal necks. These data are consistent with that published from Troiso et al[24] in 2010. It is assumed the success of the device is based on several factors including controlled gradual endograft deployment, sinusoidal M-shaped individual stents, and small amplitude of stent graft rings, active suprarenal fixation, and device flexibility. These characteristics appear to improve sealing in short or angulated necks and may improve device flexibility.[2,13,14]

Conflicting evidence exists regarding deterioration of renal function following EVAR with suprarenal fixation. Patients with baseline creatinine >2.00 mg/dL and those on dialysis were excluded from study enrollment. Of the enrolled subjects, an abnormal baseline renal function was present in 28.7% (43/150) patients, and 12% of patients (18/150) had chronic kidney disease (creatinine >1.4 mg/dL). General renal function complications were defined as a deterioration of renal function >25% above baseline level and occurred in a small number of patients. At 30 days, 1 year, 2 years, 3 years, 4 years, and 5 years the event rates were 4% (6/150), 13% (20/150), 9.7% (14/144), 7.9% (11/138), 0.8% (1/124), and 0.9% (1/112), respectively. The highest incidence of renal function deterioration was apparent in the first year and significantly declined thereafter. Three patients progressed to renal failure and required hemodialysis in this study on postop days 3, 259, and 327. The early renal event at day 3 was procedure related. The frequency of all other renal function events in the follow-up period does not appear to be disproportionate to the baseline characteristics and likely represented progression of underlying chronic kidney disease that was present before study enrollment.

A unique feature of this regulatory study is the comparison data from the Talent eLPS study arm, which is another endograft device from Medtronic Endovascular. As mentioned in the 1-year data analysis, the outcomes of the Endurant cohort were compared with those in the Talent eLPS study.[7] This strategy required the use of nearly identical end points and data collection procedures to permit proper comparisons. Based on all-cause mortality, aortic-related mortality, and freedom from secondary interventions, the Endurant endograft device performed superior to the earlier generation Talent device, although the latter two end points were not statistically significant. This was likely due to device improvements, imaging advancements, and increased operator experience.

The primary weaknesses of this study relate to the nonrandomized design and subject attrition at 5 years of follow-up. At 5 years, there were 25 deaths, 6 patients lost to follow-up, and 18 patients withdrew from study participation. The reasons for withdrawing from the study included: 9 patients who refused continued participation, 4 patients with travel distance-related concerns, 4 patients withdrew for health concerns, and 1 patient was withdrawn

Table VI. Comprehensive list of secondary interventions

Days from implant	*Indication*	*Secondary intervention*
1	Limb occlusion	Thromboembolectomy and stenting
30	Limb occlusion	Femoral to femoral bypass graft
49	Limb occlusion	Thrombolysis and stenting
57	Limb occlusion	Thromboembolectomy and stenting
217	Type II endoleak	Cyanobutulaccrulate glue lumbar artery
231	Type II endoleak	Coil embolization lumbar artery
304	Limb stenosis	Angioplasty and stenting
406	Type Ib endoleak	Iliac extension
569	Type II endoleak	Coil embolization lumbar artery
618	Type Ia endoleak	Bilateral renal stents, Talent aortic cuff
742	Type II endoleak	Coil embolization lumbar artery
779	Type II endoleak	Translumbar cyanobutulaccrulate glue lumbar artery
997	Type II endoleak	Translumbar coil embolization lumbar artery
1134	Type II endoleak	Coil embolization lumbar artery
1281	Embolus, limb ischemia	Femoral to femoral bypass graft
1404	Type II endoleak	Translumbar coil embolization lumbar artery
1470	Type II endoleak	Coil embolization lumbar artery
1666	Type II endoleak	Translumbar coil embolization lumbar artery

by a physician. Imaging data were reported on 88 subjects because six patients were unavailable to attend follow-up visits and seven failed to have imaging studies completed. In comparison other endograft trials, similar attrition rates were seen.[15,17,21,22] The limited number of patients followed out to 5 years to some degree restricts the power of our statistical analyses. These study design issues, although not unique to this study may bring to question conclusions regarding the superiority of the Endurant stent graft compared with Talent.

CONCLUSIONS

The Endurant Stent Graft System has proven to be a safe and effective device based on published 1 year regulatory data and various midterm studies. Long-term data with 5-year outcomes from the Endurant U.S. regulatory trial continue to be very positive even with the inclusion of patients who have shorter aortic necks. The Endurant stent graft appears to be durable with a limited number of adverse events through 5 years. The study results show a high freedom from reintervention, absence of late rupture, need for open conversion, stent fractures, and device migration. The 5-year data continue to support device durability. Iliac limb occlusion rates are comparable with other devices and obtaining a better understanding of its etiology is important. Sac behavior and persistent endoleak rates mandate the need for ongoing endograft surveillance. The results of this study confirm the positive late performance and durability of the Endurant stent graft.

AUTHOR CONTRIBUTIONS

Conception and design: MM
Analysis and interpretation: MS, RF, PA, WJ, TM, RS, MM
Data collection: MS, RF, PA, WJ, TM, RS, MM
Writing the article: MS, MM
Critical revision of the article: MS, RF, PA, WJ, TM, RS, MM
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REFERENCES

1. Makaroun MS, Tuchek M, Massop D, Henretta J, Rhee R, Buckley C, et al. One year outcomes of the United States regulatory trial of Endurant Stent Graft System. J Vasc Surg 2011;52:601-8.
2. Bisdas T, Weiss K, Eisenack M, Austermann M, Torsello G, Donas KP. Durability of the Endurant stent graft in patients undergoing endovascular abdominal aortic aneurysm repair. J Vasc Surg 2014;60:1125-31.
3. Zandvoort HJ, Goncalves FB, Verhagen HJ, Werson DA, Moll FL, de vries JP. Results of endovascular repair of infrarenal aortic aneurysm using the Endurant stent graft. J Vasc Surg 2014;59:1195-202.
4. Broos PP, Stokmans RA, van Sterkenburg SM, Torsello G, Vermassen F, Cuypers PW, et al. Performance of the Endurant stent graft in challenging anatomy. J Vasc Surg 2015;62:312-8.
5. Chaikof EL, Blankensteijn JD, Harris PL, White GH, Zarins CK, Bernhard VM, et al. Reporting standards for endovascular aortic aneurysm repair. J Vasc Surg 2002;35:1048-60.
6. Chaikof EL, Brewster DC, Dalman RL, Makaroun MS, Illig KI, Sicard GA, et al. The care of patients with an abdominal aortic aneurysm: the Society for Vascular Surgery practice guidelines. J Vasc Surg 2009;50:S2-48.
7. Turnbull IC, Criado FJ, Sanchez L, Sadek M, Malik R, Ellozy SH, et al. Five-year results for the Talent enhanced Low Profile System abdominal stent graft pivotal trial including early and long-term safety and efficacy. J Vasc Surg 2010;51:537-44.
8. Lederle F, Freischlag JA, Kyriakides TC, Matsumura JS, Padberg FT, Kohler TR, et al. Long-term comparison of endovascular and open repair of abdominal aortic aneurysm. N Engl J Med 2012;367:1988-97.
9. Schermerhorn MJ, O'Malley AJ, Jhaveri A, Cotterill P, Pomposelli F, Landon BE. Endovascular vs. open repair of abdominal aortic aneurysms in the Medicare population. N Engl J Med 2008;358:464-74.
10. Singh MJ, Hager E, Mapara K, Chaer R, Marone L, Leers S, et al. Ruptured abdominal aortic aneurysms: is open surgery an outdated operation? J Cardiovasc Surg 2014;55:137-49.
11. Van Keulen JW, de Vries JP, Dekker H, Gonclaves FB, Moll FL, Verhagen HJ, et al. One-year multicenter results of 100 abdominal aortic aneurysm patients treated with the Endurant stent graft. J Vasc Surg 2011;54:609-15.

12. Rouwet EV, Torsello G, de vries JP, Cuypers P, van Herwaarden JA, Eckstein HH, et al. Final results of the prospective European Trial of the Endurant Stent graft for Endovascular Abdominal Aortic Aneurysm Repair. Eur J Vasc Endovasc Surg 2011;42:489-97.
13. Matsagkas M, Kouvelos G, Peroulis M, Avgos S, Arnaoutoglou E, Papa N. Standard endovascular treatment of abdominal aortic aneurysm in patients with very short proximal necks using the Endurant stent graft. J Vasc Surg 2015;61:9-15.
14. Donas K, Torsello G, Weiss K, Bisdas T, Eisenack M, Austermann M. Performance of the Endurant stent graft in patients with abdominal aortic aneurysm independent of their morphologic suitability for endovascular aneurysm repair based on instructions for use. J Vasc Surg 2015;62:848-54.
15. Greenberg RK, Chuter TA, Cambria RP, Sternbergh WC, Fearnot NE. Zenith abdominal aortic endovascular graft. J Vasc Surg 2008;48:1-9.
16. Coulston J, Baigent A, Selvachandran H, Jones S, Torella F, Fisher R. The impact of endovascular aneurysm repair on aortoiliac tortuosity and its use as a predictor of iliac limb complications. J Vasc Surg 2014;60:585-9.
17. Maleux G, Claes H, Van HA, Janssen R, Laenen A, Heye S, et al. Ten years of experience with the Gore Excluder stent-graft for the treatment of aortic and iliac aneurysms: outcomes from a single center study. Cardiovasc Intervent Radiol 2012;35:498-507.
18. Faure EM, Becquemin JP, Cochennec F; ENGAGE collaborators. Predictive factors for limb occlusions after endovascular aneurysm repair. J Vasc Surg 2015;61:1138-45.e2.
19. Van Zeggeren L, Goncalves FB, van Herwaarden JA, Zandvoort HJ, Werson DA, Vos JA, et al. Incidence and treatment results of Endurant endograft occlusion. J Vasc Surg 2013;57:1246-54.
20. Mehta M, Valdes FE, Nolte T, Mishkel GJ, Jordan WD, Gray B, et al. One-year outcomes form an international study of the Ovation Abdominal Stent Graft System for endovascular aneurysm repair. J Vasc Surg 2014;59:65-73.
21. Wang GJ, Carpenter JP. The Powerlink system for endovascular abdominal aortic aneurysm repair: six-year results. J Vasc Surg 2008;48:535-45.
22. Tanski W, Fillinger M. Outcomes of original and low-permeability Gore Excluder endoprosthesis for endovascular abdominal aortic aneurysm repair. J Vasc Surg 2007;45:243-9.
23. Houbballah R, Majewski M, Becquemin JP. Significant sac retraction after endovascular aneurysm repair is a robust indicator of durable treatment success. J Vasc Surg 2010;52:878-83.
24. Troisi N, Torsello G, Donas KP, Austermann M. Endurant stent graft: a 2-year, single-center experience with a new commercially available device for the treatment of abdominal aortic aneurysms. J Endovasc Ther 2010;17:439-48.

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