

Endovascular Repair of Abdominal Aortic Aneurysms: Analysis of Aneurysm Volumetric Changes at Mid-Term Follow-Up

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Abstract

Purpose: To evaluate the volumetric changes in abdominal aortic aneurysms (AAA) after endovascular AAA repair (EVAR) in 24 months of follow-up.

Methods: We evaluated the volume modifications in 63 consecutive patients after EVAR. All patients underwent strict duplex ultrasound and computed tomography angiography (CTA) follow-up; when complications were suspected, digital subtraction angiography was also performed. CTA datasets at 1, 6, 12, and 24 months were post-processed through semiautomatic segmentation, to isolate the aneurysmal sac and calculate its volume. Maximum transverse diameters (Dmax) were also obtained in the true axial plane. Presence and type of endoleak (EL) were recorded. A statistical analysis was performed to assess the degree of volume change, correlation with diameter modifications, and significance of the volume increase with respect to ELs.

Results: Mean reconstruction time was 7 min. Mean volume reduction rates were 6.5%, 8%, and 9.6% at 6, 12, and 24 months follow-up, respectively. Mean Dmax reduction rates were 4.2%, 6.7%, and 12%; correlation with volumes was poor ($r = 0.73\text{--}0.81$). ELs were found in 19 patients and were more frequent ($p = 0.04$) in patients with higher pre-procedural Dmax. The accuracies of volume changes in predicting ELs ranged between 74.6% and 84.1% and were higher than those of Dmax modifications. The strongest independent predictor of EL was a volume change at 6 months $\leq 0.3\%$ ($p = 0.005$), although 6 of 19 (32%) patients with EL showed no significant AAA enlargement, whereas in 6 of 44 (14%) patients without EL the aneurysm enlarged.

Conclusion: The lack of volume decrease in the aneurysm of at least 0.3% at 6 months follow-up indicates the need for closer surveillance, and has a higher predictive accuracy for an endoleak than Dmax.

Key words: Abdominal aortic aneurysm—Aneurysm sac volume—Endoleaks—Endovascular repair

In the last decade, endovascular abdominal aortic aneurysm repair (EVAR) has become a valid alternative to open surgery in selected patients [1–4]. The aim of treatment is to exclude the aneurysm from blood flow, thus preventing rupture [5]. High immediate success rates with low perioperative morbidity and mortality have been demonstrated in several reports [6, 7]. However, as longer follow-up becomes available, several complications have been reported, requiring close surveillance [8, 9], and Computed tomography angiography has been proposed as the best imaging modality to monitor EVAR results [10–13].

Exact definition of the success of the procedure remains a controversial issue [14, 15]. Since aneurysm exclusion is expected to be associated with shrinkage, surveillance of aneurysm dimensions seems to be the most appropriate tool to assess the procedural outcome [14]. Although maximum aneurysm diameter has been used in the majority of initial studies [16, 17], the low reliability of this parameter has been demonstrated, and three-dimensional volume assessment has been proposed as a more valid tool in the early definition of success and in the identification of patients requiring closer surveillance [18–24]. Volume has also been proved to be extremely useful in the decision-making after EVAR, reducing unnecessary and expensive imaging and interventions [25].

The purpose of our study was to retrospectively analyze aneurysm volume modifications after EVAR, to assess the relationship between volume and diameter measurements, and to identify a threshold value of the volume modification rate able to predict the presence of endoleaks (ELs).

Materials and Methods

This retrospective study included 63 patients (male/female = 62/1; mean age 69.8 ± 7.4 years, age range 52–84 years) who underwent EVAR (mean aneurysm diameter 51.8 ± 11.1 mm, range 40–88 mm) using different types of devices. Imaging follow-up was performed by color-coded duplex ultrasound (US; AU5, Esaote Biomedica, Genoa, Italy) at 7 days, 1, 3, 6, 12 months and annually thereafter, and computed tomography angiography (CTA; High-speed and LightSpeedPlus; GE Medical Systems, Milwaukee, WI, USA) at 1, 6, 12 months and annually thereafter. When complications were suspected, closer surveillance was performed by duplex US and CTA; finally, when required, patients underwent digital subtraction angiography (DSA; Multistar, Siemens, Erlangen, Germany) to confirm the EL and provide adequate treatment.

Mean \pm SD follow-up in this series was 43.2 ± 11.6 months (range 24–60 months). However, the present study refers to the changes found in the initial 24 months of follow-up.

CTA Protocol and Post-processing

CTA was performed from the celiac artery to the common femoral arteries both before and after intravenous contrast administration (Visipaque 320; Nycomed, Oslo, Norway) at a dose of 120 ml with a flow rate of 3 ml/sec. Acquisition parameters for spiral CT were: 3 mm collimation, 1 mm reconstruction spacing, and variable pitch. Multidetector CTA was performed with the following parameters: HighSpeed modality, gantry rotation 0.5–0.6, table speed 7.5 mm/rot, 2.5 mm collimation, and 1.2 mm reconstruction algorithm. Both the arterial phase and a delayed phase were acquired. Scan delay ranged between 20 and 40 sec, according to the patient's circulation time determined by an automated bolus time test (SmartPrep, GE Medical Systems) using 25 ml of iodinated contrast medium. The venous phase was acquired with the same parameters 80 sec after contrast injection.

Images were processed with a dedicated software package on an independent workstation (Advantage Windows 4.1; Sun Microsystems, Mountain View, CA, USA) to generate multiplanar reformations (MPRs), maximum intensity projections (MIPs), and volume renderings (VRs). Volumes were obtained through semi-automatic segmentation, using the summation of area technique. The region of interest was drawn manually at the interface of the outer aortic wall and the extra-aortic tissues, at 5–10 different levels throughout the aorta from the lowest renal artery to the aortic bifurcation. Then, the system automatically determined the boundaries around a class of similar voxel intensity values in the remaining sections and, after proper checking by the operator, the aneurysm sac volume was calculated.

Post-processing and volume assessment of CTA data at 1, 6, 12, and 24 months follow-up were retrospectively performed by a single expert radiologist (I.B.) masked to the follow-up interval and the presence of ELs or other complications. Maximum orthogonal diameter (Dmax) was calculated in the plane perpendicular to the centerline of the aortic lumen. In addition, CTA

images were reviewed by consensus by one of several authors (R.C., A.P., P.P., C.V.) to identify the presence of an EL (defined by contrast enhancement within the sac and outside the stent-graft lumen) and of other complications (such as stent-graft migration or disconnection). CTA image analysis was performed without knowledge of the volume measurements.

Duplex US Evaluation

Color-coded duplex US was performed by a single radiologist (V.N.) masked to the CTA findings. The entire abdominal aorta was scanned from the diaphragm to the iliac arteries in the long axis and cross-sectional views with an abdominal phase array (2.5–3.5 MHz), to visualize possible ELs, using color Doppler and power Doppler US imaging and obtaining a spectral Doppler waveform analysis of the detected leaks. In type II ELs, an attempt was made to identify inflow and outflow vessels.

DSA Evaluation

DSA was performed in the angiographic suite, in a standard fashion, by four experienced interventional radiologists (I.B., P.P., R.C., C.V.) aware of the findings of previous examinations. Aortography was obtained (5 Fr Pigtail catheter) with a bolus of 40 ml of iodinated contrast medium (Visipaque 320). Then, selective angiographies were performed according to the aortographic findings, using appropriately shaped catheters. Images were evaluated by consensus to assess presence of an EL (visualized as spreading of contrast material outside the stent-graft) and to identify its origin (from aortic branches or stent-graft disconnections).

Statistical Analysis

Descriptive statistics (proportions, means, SDs) were calculated for patient characteristics and numeric continuous data.

The 1-month CT control represented our baseline for evaluating diameter and volume changes, since it was performed in all patients in our institution according to our protocol. In contrast, preprocedural CT was performed elsewhere in 16 patients in this series. Volume changes were expressed as the percentage of the initial volume at referral represented by the volume calculated at 1-month follow-up (V1), using the following formula: $[(V1 - Vx) / V1] \times 100$. Therefore, a positive value indicated AAA shrinkage, whereas a negative value was indicative of a volume increase. An analogous formula was used to assess Dmax changes. Correlation between volumes and diameters was assessed with the Pearson correlation coefficient and 2×2 tables.

By ROC curves, cutoff values were obtained for volume and diameter changes at 6, 12, and 24 months follow-up that best predicted the presence of ELs. Sensitivity, specificity, positive (PPV) and negative (NPV) predictive values, and overall accuracy rates were calculated in predicting ELs.

Volume changes were analyzed with respect to the presence of an EL and the preprocedural diameter by one-way ANOVA, Student's *t*, Fisher and χ^2 tests.

The analysis also included patient age, type of EL, time of follow-up at which the EL was detected (i.e., primary EL when diagnosed within 1 month after treatment, or secondary EL when diagnosed later).

Table 1. Patients' demographic and procedural data

	No leak (<i>n</i> = 44)	Endoleak (<i>n</i> = 19)
Male/female	43/1	19/0
Age (years)	69.4 ± 6.7	70.9 ± 8.9
Preprocedural Dmax (mm)	49.7 ± 9.9	56.8 ± 12.3 ^a
Stent-grafts		
AneuRx	30 (68.2%)	9 (47.3%)
Baxter	1 (2.3%)	0
Endologix	3 (6.8%)	1 (5.3%)
Excluder	4 (9.1%)	3 (15.8%)
Talent	6 (13.6%)	4 (21%)
Vanguard	0	1 (5.3%)
Zenith	0	1 (5.3%)

^a*p* < 0.05, comparing patients without and with an endoleak.

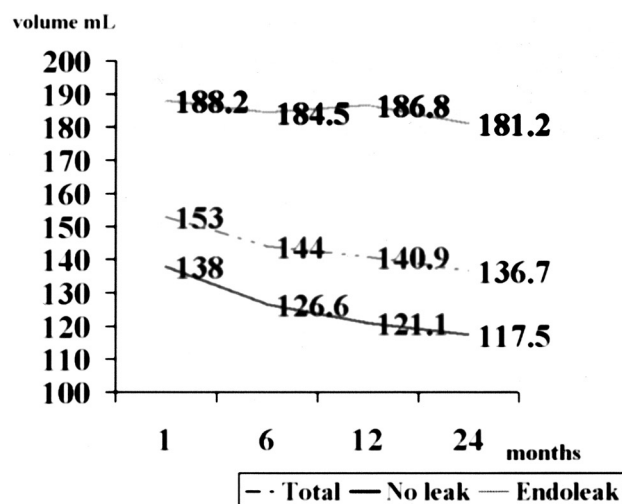


Fig. 1. Changes in aneurysm volume at 1, 6, 12, and 24 months follow-up. A statistically significant difference (*p* < 0.05) was observed comparing patients with and without endoleak.

Stepwise multiple logistic regression analyses were obtained for the evaluation of independent predictors of ELs.

A *p* value < 0.05 was considered statistically significant.

Statistical analysis was performed using JMP software (SAS Institute, Cary, NC, USA).

Results

Patients' demographic and procedural data are detailed in Table 1.

Mean reconstruction time for each dataset was 7 min (range 5–15 min). Volumes calculated on follow-up ranged from 51 to 529 ml (Fig. 1). Mean ± SD volume reduction rates in the entire population were 6.5 ± 11.1%, 8 ± 14.3%, and 9.6 ± 19.4% at 6, 12, and 24 months follow-up, respectively. The rate of volume change was independent of the preprocedural Dmax. Also patient age was not statistically related to volume changes. Mean ± SD Dmax reduction rates were 4.2 ± 7.6%, 6.7 ± 9.6%, and 12 ± 13.7%, at 6, 12, and 24 months follow-up, respectively. Correlation

Table 2. Mean ± SD volume and diameter modifications expressed as percentage of referral initial values at 1 month CTA control, in patients with and without evidence of endoleaks. A statistically significant difference was observed (Wilcoxon rank sum)

	No endoleak	Endoleak	<i>p</i>
Volume change			
6 months	8.4 ± 9.7	2.1 ± 13	0.004
12 months	11.5 ± 12.9	0.07 ± 14.8	0.002
24 months	13.8 ± 15.7	-0.2 ± 23.9	0.006
Diameter change			
6 months	5.5 ± 7.5	1.3 ± 7.5	0.01
12 months	8.7 ± 9.1	2.2 ± 9.5	0.01
24 months	14.9 ± 12.3	5.3 ± 14.6	0.007

between Dmax and volume changes was good (*r* = 0.79, 0.81, 0.73 at 6, 12, and 24 months, respectively).

ELs were detected at CTA and/or duplex US in 19 (31%) patients; 5 cases of type I leak were depicted, due stent-graft disconnection at the proximal (*n* = 4) or distal (*n* = 1) neck; the remaining leaks were classified as type II (*n* = 14), with 7 lumbar and 7 internal mesenteric artery (IMA) and lumbar leaks. Nine ELs were detected within the first month of follow-up, whereas the remaining cases were secondary ELs depicted at 3 (*n* = 1), 6 (*n* = 4) or 12 (*n* = 5) months follow-up.

The number of ELs detected in follow-up ranged from 14 at 6 months to 17 at 12 months and 8 at 24 months. ELs were significantly more frequent in patients with higher preprocedural Dmax; the mean Dmax was 56.8 mm in the group of patients with EL and 49.8 mm in patients without EL (*p* = 0.04) (Table 1).

The type of stent-graft did not affect the presence of perigraft flow, although this is a very inhomogeneous series; even when comparing AneuRx stent-grafts on the one hand with all the other types of endograft on the other, no statistically significant difference was observed in the incidence of ELs (Table 1).

The presence of an EL was significantly associated with the rate of volume change and, to a lesser extent, with the rate of diameter change (Table 2). No statistically significant differences in volume modifications were observed between different types of ELs. In particular, volume changes did not differ significantly between IMA ELs and lumbar ELs. Moreover, the time of EL detection (i.e., primary and secondary ELs) did not affect the rate of volume change.

Using ROC statistics, cutoff values of volume and diameter changes for predicting ELs were assessed (Tables 3, 4). The predictive accuracies of volume changes were higher than those of Dmax modifications, ranging between 74.6% and 84.1% for volumes and between 63.5% and 79.4% for diameters.

When evaluating the cutoff value obtained considering all the ELs independently of their time of detection on follow-up, a change was observed in the threshold values of Dmax at 6 months follow-up (from -1.1% to 4.9%) and of the volume at 24 months follow-up (from 1.1% to -6.7%) (Table 4).

Table 3. ROC curves and predictive accuracies of cutoff values of volume and diameter modification rates in detecting endoleaks at 6, 12, and 24 months follow-up

Follow-up	6 months (ELs <i>n</i> = 14)		12 months (ELs <i>n</i> = 17)		24 months (ELs <i>n</i> = 8)	
	V ≤ 0.3%	D ≤ -1.1%	V ≤ -2.2%	D ≤ 1.4%	V ≤ 1.1%	D ≤ 1.8%
No. of patients	19	17	15	20	22	19
AUC	0.80	0.78	0.82	0.76	0.85	0.80
Sensitivity (%)	78.6	64.3	64.7	64.7	87.5	87.5
Specificity (%)	83.7	83.7	91.3	80.4	72.7	78.2
PPV (%)	57.9	52.9	73.3	55	31.8	36.8
NPV (%)	93.2	89.1	87.5	86	97.6	97.7
Accuracy (%)	82.5	79.4	84.1	76.2	74.6	79.4

ELs, endoleaks; V, volume; D, diameter; AUC, area under the curve; PPV, positive predictive value; NPV, Negative predictive value.

Table 4. ROC curves and predictive accuracies of threshold values of volume and diameter modification rates in predicting any endoleak

Follow-up	6months		12months		24 months	
	V ≤ 0.3%	D ≤ 4.9%	V ≤ -2.2%	D ≤ 1.4%	V ≤ -6.7	D ≤ 1.8%
No. of patients	19	36	15	20	12	19
AUC	0.73	0.70	0.75	0.70	0.72	0.71
Sensitivity (%)	68.4	84.2	57.9	57.9	52.6	63.2
Specificity (%)	86.4	54.5	90.9	79.5	95.5	84.1
PPV (%)	68.4	44.4	73.3	55	83.3	63.2
NPV (%)	86.4	88.9	83.3	81.4	82.4	84.1
Accuracy (%)	80.9	63.5	80.9	73	82.5	77.8

V, volume; D, diameter; AUC, area under the curve; PPV, positive predictive value; NPV, Negative predictive value

Testing the threshold values obtained in Table 3, the sensitivity, specificity, PPV, NPV, and accuracy rates in identifying any EL were 52.6%, 84.1%, 58.8%, 80.4%, and 74.6% for a diameter ≤ -1.1% at 6 months follow-up, and 68.4%, 79.5%, 59.1%, 85.4%, and 76.2% for a volume ≤ 1.1% at 24 months follow-up. Classifying the aneurysms as increased or decreased according to the threshold values specified above, a poor correlation was observed between classifications according to volumes and diameters ($\kappa = -0.14$ to 0.66), particularly at 6 months follow-up and in patients with an EL (Fig. 2).

We tested the 10% threshold value to assess the relationship between a significant volume decrease and the absence of an EL [24–27] and compared the accuracies with those obtained with our own values (Table 5). A low predictive accuracy was obtained due to low sensitivity of the 10% decrease rate, although a high PPV was observed, particularly at 12 and 24 months follow-up.

On the multiple logistic regression analysis, the volume changes at 6 month and 24 months follow-up were both significant independent predictors of an EL ($p = 0.005$, OR 7.8, 95% CI 0.32–1.78 for the 6 months increase rate ≤ 0.3%; and $p = 0.007$, OR 12.2, 95% CI 0.4–2.3 for the 24 months increase rate ≤ -6.7%).

Using the 6 months increase rate ≤ 0.3%, we observed 6 patients without an EL at any time in whom the aneurysm volume either remained stable ($n = 1$) or increased ($n = 5$). In contrast, in 6 cases with evidence of an EL, no significant volume enlargement was observed at 6 months follow-up (Table 6). These cases included 3 type I ELs (2 primary and

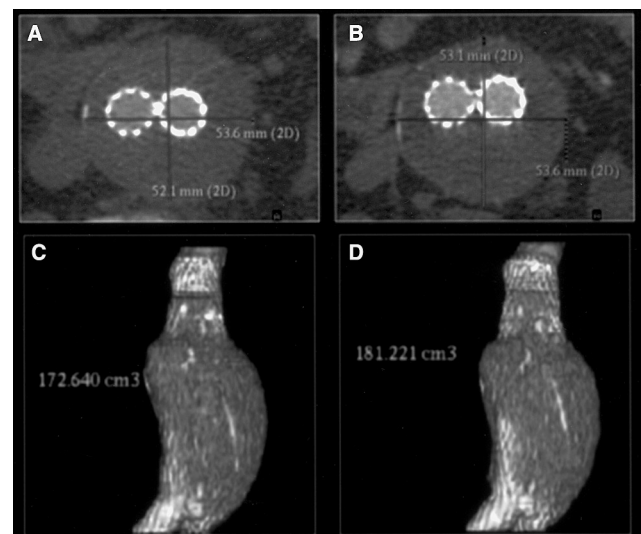


Fig. 2. A–D. One month and 6 months CTA follow-up in a patient with primary type II lumbar endoleak. The maximum orthogonal diameter appeared identical 6 months after the procedure (B) compared with the 1 month control (A), whereas the volume measurement demonstrated significant aneurysm enlargement (D), with an increase of 5.23% over the 1 month volume (C) (from 172 to 181 ml). CTA depicted a type II lumbar endoleak.

1 secondary ELs) and 3 type II ELs (1 primary and 2 secondary ELs). Nevertheless, 4 of 6 patients showed enlargement later on follow-up. Among patients with type I

Table 5. Predictive accuracies of absence of endoleak comparing our own referral values with the proposed 10% volume decrease

	No. of patients	Sensitivity	Specificity	PPV	NPV	Accuracy	<i>p</i>
6 months (No EL = 49)							
Vol ≥ 10%	19	38.8%	85.7%	90.5%	28.6%	49.2%	0.08
Vol > 0.3%	44	83.7%	78.6%	93.2%	57.9%	82.5%	<.0001
12 months (No EL = 46)							
Vol ≥ 10%	26	52.2%	88.2%	92.3%	40.5%	61.9%	0.003
Vol > -2.2%	48	91.3%	64.7%	87.5%	73.3%	84.1%	<.0001
24 months (No EL = 55)							
Vol ≥ 10%	31	56.4%	100%	100%	25%	61.9%	0.003
Vol > 1.1%	41	72.7%	87.5%	97.6%	31.8%	74.6%	0.0008

EL, endoleak; Vol, volume change rate

Table 6. Lack of volume increase at 6 months follow-up in patients with endoleak

Patient no.	EL detection time (months)	EL type	Site/Branches	Aneurysm volume (ml)			
				Vol 1 1 month	Vol 6 6 months	Vol 12 12 months	Vol 24 24 months
1	12	1	Proximal	117	99	99	137 ^a
2	1	2	IMA	261	256	267 ^a	262
3	1	1	Proximal	223 ^a	196	192	190
4	12	2	IMA	179	124	130	161 ^a
5	1	1	Proximal	200	129	125	108
6	12	2	Lumbar	230	207	229	255 ^a

EL, endoleak; IMA, inferior mesenteric artery

^aTreatment either by extensive cuffs (type 1 EL) or by intra-arterial coil embolization (type 2 EL)

EL, one case (#3) was treated immediately by an extensive cuff, with no volume increase; another case (#1) was initially misdiagnosed as a type II EL and treated as soon as the volume enlarged. The last patient with primary type I EL (#5) did not show any aneurysm enlargement; an excessive oversizing of the proximal neck had caused the stent-graft to fold at this level, with incomplete sealing to the aortic wall and presence of a posterior EL; nevertheless, the EL was no longer depicted at 6 months follow-up and later the aneurysm progressively shrank (Fig. 3).

Discussion

EVAR has become an appealing alternative to open surgery in patients with AAA [1–4]. Its high immediate technical success and low perioperative morbidity and mortality have been proved in several studies [6, 7]. Nonetheless, concern has been expressed regarding the incidence of mid- and long-term complications [9], such as continued pressurization of the sac through ELs, which might occur in up to 45% of patients, and stent-graft complications, due to disconnections and material consumption, with the frequent need for secondary interventions [28, 29]. Therefore strict surveillance is needed, with an attendant increase in postoperative costs [7, 30].

CTA represents the best imaging modality in the follow-up of patients after EVAR, allowing assessment of both aneurysm and endograft morphology [10–13, 24]. Since aneurysmal sac reduction represents the main goal of treatment, several early reports have focused on maximum

aneurysm diameter changes [16, 17]. However, recent studies have questioned the reliability of this parameter in the assessment of EVAR results, and more detailed three-dimensional reconstruction methods have been proposed [18, 22–31]. In fact, several studies have proved volume assessment to be more accurate than diameter in the early detection of aneurysm growth [23], allowing efficient patient management and avoiding unnecessary, risky, and expensive examinations and interventions, particularly in the first 12-months of follow-up [25].

We analyzed AAA volume changes over 24 months of follow-up in a series of 63 consecutive patients and correlated these modifications with diameter changes and with the presence of ELs. In our series, 19 ELs (30%) were detected over the entire follow-up period, with a higher incidence in patients with a higher preprocedural aneurysm diameter [32]. In the entire series, volumes and diameters decreased during follow-up, with a statistically significant difference of both parameters in patients with or without ELs [16, 17, 33]. Yet, volumes seemed to be more efficient in the early detection of ELs, with a higher area under the curve at ROC analysis [20]. In fact, diameter changes seem to occur later in follow-up [20, 34], and the best correlation between diameter and presence of ELs was obtained 24 months after the procedure.

Moreover, our data showed a relatively low correlation between the rates of change of volume and diameter ($r = 0.73–0.81$). Up to 37% of patients with increasing aneurysm volumes showed decreases in aneurysm diameter, particularly at 6 months follow-up and in patients

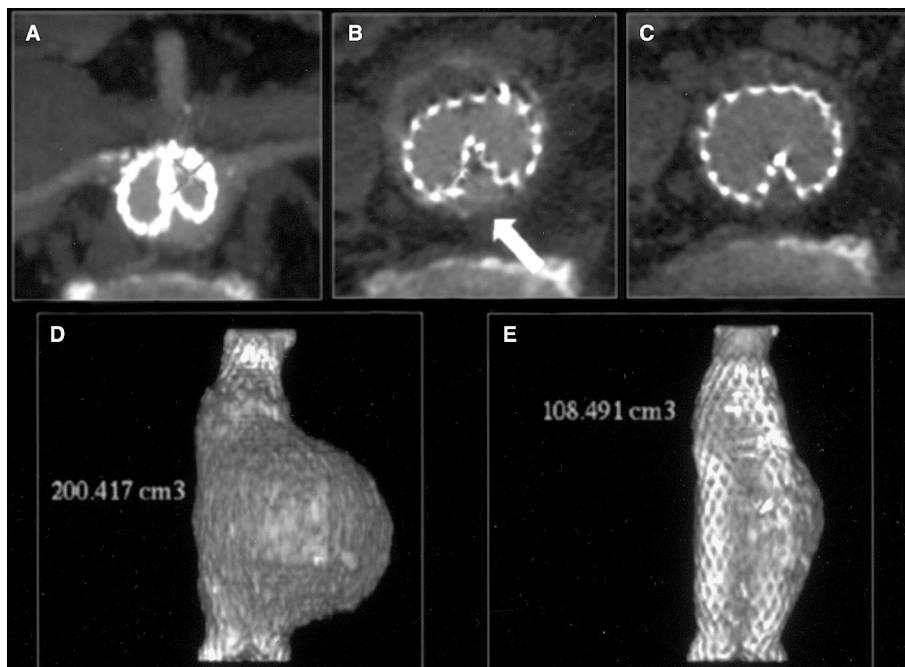


Fig. 3. **A–E.** One month and 24 months CTA follow-up in a patient with primary type I endoleak. The 1 month CT control showed an incorrect deployment of the stent-graft that was folded at the level of the proximal anchorage (**A**), with a proximal endoleak caused by the incomplete sealing of the stent-graft to

the aortic wall (**B**, arrow). The endoleak was no longer visible 6 months after EVAR (**C**); the 24 months volume measurement (**E**) demonstrated a significant reduction of the aneurysmal sac by 46% relative to the 1 month control volume (**D**) (from 200 to 108 ml) confirming the exclusion of the aneurysm from blood flow.

with EL. This phenomenon could cause underestimation of the importance of persisting flow within the sac and, therefore, of the risk of rupture. Diameter is of course the expression of aneurysm changes in only a single cross-section, whereas volume changes involve the aneurysm as a whole [18, 19, 33]. Changes in aneurysm morphology can alter the level corresponding to the maximum diameter at each CTA examination. In addition, the true axial plane perpendicular to the centerline length might change over time, and operator variability seems to be greater in diameter measurement than in the volume assessment [27, 35].

However, volume assessment is time-consuming and requires advanced processing, dedicated equipment, and skilled operators [21, 25, 26]. Several specific softwares have recently been introduced to reduce processing time and variability [36]. We used a semiautomatic segmentation technique [21], and all volumes were measured by a single masked operator. Reconstruction time was therefore usually less than 10 min, which in our experience is an acceptable time for CTA data analysis. Measurement variability was limited by the use of a single operator [27] and of semiautomatic segmentation instead of a fully manual technique [21, 33, 36, 37]. Nonetheless, intraobserver variability was not analyzed in our study; we obtained a cutoff referral value by ROC curves and compared our predictive accuracies with results obtained using the cutoff values proposed in other reports [23, 25, 27].

Our threshold values were much lower than the 10% decrease proposed by other authors, according to the reproducibility coefficient [27], although recent studies have reported lower intraobserver variabilities (1.4–3%) using automatic software [36, 38]. A possible explanation for this evident difference might be the relatively higher number of patients in our study with aneurysms only 4–5 cm in diameter. Other studies have focused on patients with AAA at least 6 cm in diameter, and therefore a higher preprocedural volume [25], that might undergo a more evident decrease at 6 months follow-up. However, no data are presently available, nor in our series could a relationship be demonstrated between the volume reduction rate and preprocedural diameter.

According to our data, the use of a 10% volume change is associated with a higher specificity but much lower sensitivity than the 0.3% modification rate at 6 months follow-up. Therefore, underestimation of volume increase might occur. Our predictive values in the detection of ELs compare favorably with the published data, with over 80% specificity, sensitivity, and overall accuracy rates [23]. The strongest predictor of an EL was lack of a volume decrease of at least 0.3% at 6 months follow-up, which had the ability to predict any EL, independent of its detection time. This value points out the importance not only of enlarging aneurysms, but also of almost stable sacs that might be associated with persistent flow and pressurization. Therefore, stable volumes might represent an imminent EL and might require closer surveillance [23, 25, 39].

The existence of patients with an EL and no aneurysm enlargement should be evaluated carefully. We observed 6 ELs in patients with a decrease in aneurysm volume 6 months after EVAR; however, in the majority of cases the volume increased later on follow-up [31], except for 2 cases of type I proximal EL.

No statistically significant differences in volume modification rates were observed on comparing different types of ELs. However, we agree with the general concern expressed regarding the rapid growth caused by type I ELs [41], which requires immediate treatment, and our results could be biased by the immediate successful treatment of type I ELs in the vast majority of our patients.

Six cases of aneurysm increase with no evidence of complications at duplex US and CTA were observed in our series. The term “endotension” has been proposed in these patients, although its nature is still a debated topic [14, 40]. In fact, endotension might be the expression of a nonvisualized EL [41], and alternative imaging modalities have been proposed as more sensitive tools in detecting perigraft flow, such as magnetic resonance angiography [42] and contrast-enhanced US [43, 44].

The present study is limited by its retrospective design. Nonetheless, volume analysis was performed without knowledge of patient follow-up and outcome, and the presence of complications at CTA and duplex US was assessed by different radiologists, masked to the volume measurements. Moreover, only a small number of patients was included in the present study with a relatively short follow-up. However, all patients had identical continuous follow-up with both CTA and duplex US [11].

We used the presence or absence of an EL as the gold standard to evaluate the significance of aneurysm changes. Probably, other parameters, such as the intrasac pressure measurement, would be more appropriate [45]; however, for ethical reasons this parameter was not available in our series.

Nonetheless, our findings are substantially in agreement with previous studies [23, 25], confirming the importance of volume measurement, particularly in the short-term follow-up, to avoid unnecessary imaging and interventions. It might be a time-consuming process, yet it should be performed in all patients at 1 and 6 months follow-up, whenever an EL is detected, to evaluate its significance on AAA pressurization, and when the diameter appears persistently stable on follow-up. The lack of a volume decrease of at least 0.3% at 6 months follow-up indicates the need for closer surveillance, and has a high predictive accuracy for the presence of complications.

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