Intra-aneurysm pressure measurements in successfully excluded abdominal aortic aneurysm after endovascular repair

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Purpose: **This study was performed to determine intra-aneurysm sac pressure of abdominal aortic aneurysm after endovascular aneurysm repair in patients considered successfully treated with aneurysm shrinkage and absence of endovascular leakage.**

Methods: **In 10 patients with median aneurysm shrinkage of 12 mm (range, 7 to 22 mm) and median follow-up of 19 months (range, 14-43 months), a percutaneous translumbar intra-aneurysm pressure measurement was made with a 0.014-inch guide wire-mounted pressure sensor and compared with intra-aortic pressure.**

Results: **Median intra-aneurysm systolic/diastolic/mean pressure was 19/18/19 (ramge, 17-35/13-33/17-31) compared with median intra-aortic pressure of 135/75/99 (range, 126-199/60-95/84-129). Mean intra-aneurysm pressure was 20% of mean intra-aortic pressure (range, 13%-33%). Pulsatility was negligible.**

Conclusion: **Successful endovascular aneurysm repair of abdominal aortic aneurysm results in considerable pressure reduction in the aneurysm sac. The ability to monitor intra-aneurysm pressure provides hemodynamic information within the sac, which can be used in conjunction with imaging to determine whether a secondary intervention is warranted. (J Vasc Surg 2003;37:733-8.)**

Successful endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm (AAA) is defined as complete exclusion of the aneurysm sac from the systemic pressure. However, at present only indirect methods, eg, contrast material-enhanced spiral computed tomography (CT), are available to define EVAR success, including shrinkage of the aneurysm sac in the absence of endovascular leakage, ie, there is no radiologic evidence for persistent circulation in the aneurysm. Direct pressure measurement in the excluded aneurysm sac would be a better method for determining how well the aneurysm is excluded from the systemic pressure. In addition, information on the pressure level in an excluded AAA after EVAR can serve as a reference in decision-making regarding possible further treatment.

Until now, the data available in the literature regarding actual pressure in the aneurysm sac after EVAR has been limited to measurements obtained either in conjunction with stent graft placement or in aneurysms exposed to various types of endovascular leakage.[1-3]

Our purpose was to establish the relationship between systemic blood pressure level and pressure level in the aneurysm sac after successful EVAR of AAA, according to long-term follow-up with CT.

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Competition of interest: none.

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MATERIAL AND METHODS

Patients. In our endovascular center all patients undergoing catheter-based intervention to treat AAA are entered prospectively in a data bank. From June 1993 to June 2002, we treated 300 patients with several different stent graft devices. Patients with successfully excluded AAAs after EVAR were identified from our data base, and their contrast material-enhanced CT scans were reviewed. Our follow-up protocol includes spiral CT before and after contrast medium enhancement at 1 month and 1 year after stent graft placement, and spiral CT performed annually thereafter. Eligibility for the study included aneurysm shrinkage of more than 6 mm at 1-year follow-up or later,[4] absence of endovascular leakage, and anatomy suitable for translumbar percutaneous access for pressure measurement.

AAA diameter was measured with calipers and calibrated against a centimeter scale on hard-copy films. The shortest maximum AAA diameter was obtained by measuring from wall to wall, on the assumption that this represented the true diameter of a potentially tortuous vessel. Patients who gave informed consent to the study underwent additional spiral CT before and after administration of intravenous contrast medium within 1 month before intrasac pressure measurement. Data for the first 10 patients (8 men, 2 women) included in the study are reported. Another three patients otherwise eligible for the study were excluded because the space between the aneurysm wall and the stent graft was inadequate to be safely entered. Stent grafts used were Zenith (custom-made bifurcated stent

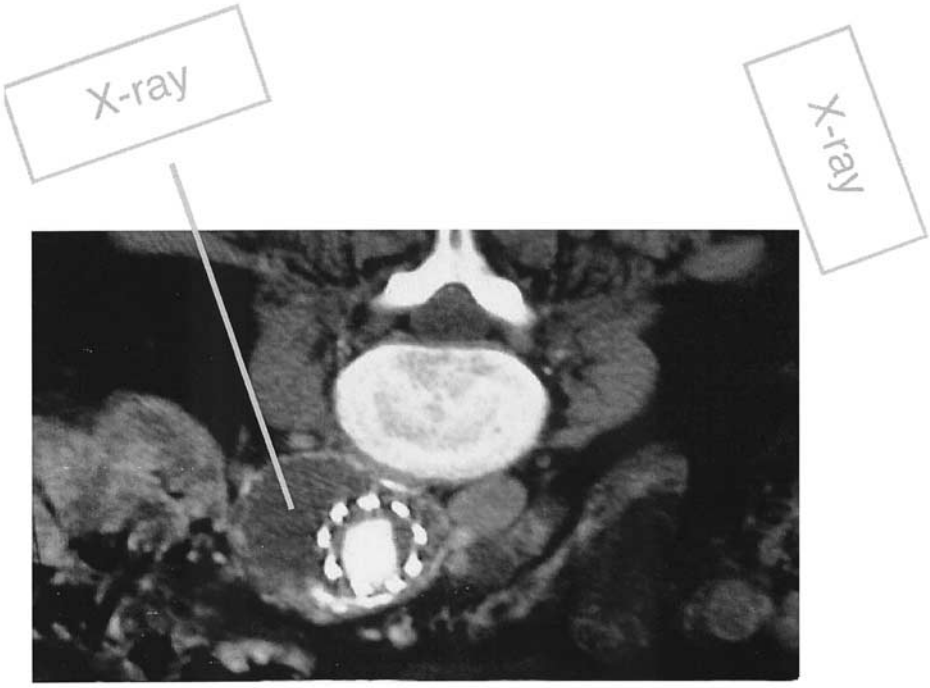

Fig 1. Axial CT scan shows intended line of puncture. *Left,* "Down-the-barrel" position of x-ray tube; *right,* perpendicular position of tube for depth evaluation.

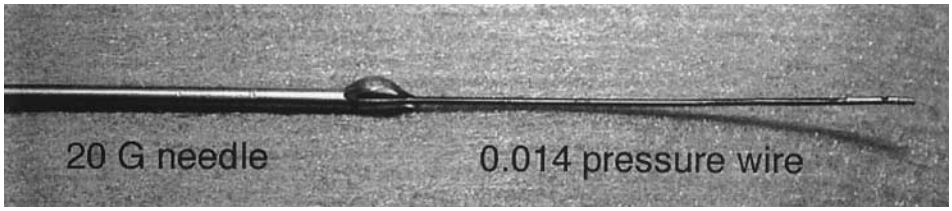

Fig 2. Twenty-gauge needle and 0.014-inch pressure sensor.

graft; William Cook Europe, Bjaeverskov, Denmark), Trifab (Zenith design; William Cook Europe), and Ivancev-Malmö II (aorto-uni-iliac stent graft with femoro-femoral crossover). The study was approved by the Ethics Committee of the University of Lund, Sweden.

Technique. Standard aortography was performed, with a 4F introducer and a 4F catheter placed in standard fashion through the common femoral artery. Whenever there was an increase in serum creatinine concentration, carbon dioxide was used instead of iodinated nonionic contrast medium (Omnipaque; Nycomed Amersham, Lidingö, Sweden). Heparin (Leo Pharma, Malmö, Sweden), 3000 to 5000 U, depending on body weight, was used for anticoagulation. The aortogram was used to confirm adequate position of the stent graft and patency of the aortic branches, including the renal arteries and iliac arteries, and to identify kinks or stenoses in the limbs of the stent graft or in the iliac arteries. Thereafter, a 0.014-inch pressure sensor (PressureWire; RADI Medical System AB, Uppsala, Sweden) was placed through the 4F catheter, with the tip carrying the pressure sensor in the body of the stent graft. This pressure sensor has a radiopaque 30 mm floppy tip beyond the 2.3 mm long sensor tip, which enables precise placement. Before insertion, the pressure sensor was calibrated in saline solution. After the 4F catheter containing the 0.014-inch pressure sensor was secured to the patient, the patient was moved from the supine to the prone position. Based on axial anatomic evaluation, ie, stent graft position and aneurysm size in relation to the vertebral bodies and bony landmarks, as seen on contrast-enhanced axial CT scans, a site of insertion and a fluoroscopic approach were determined (Fig 1). Local anesthesia was applied at the insertion site, which usually was 15 to 20 cm lateral to the spinal process of the vertebral body at a predetermined level. Thereafter a 20-gauge needle (Mediplast; Procurator Medical AB, Malmö, Sweden) was ad-

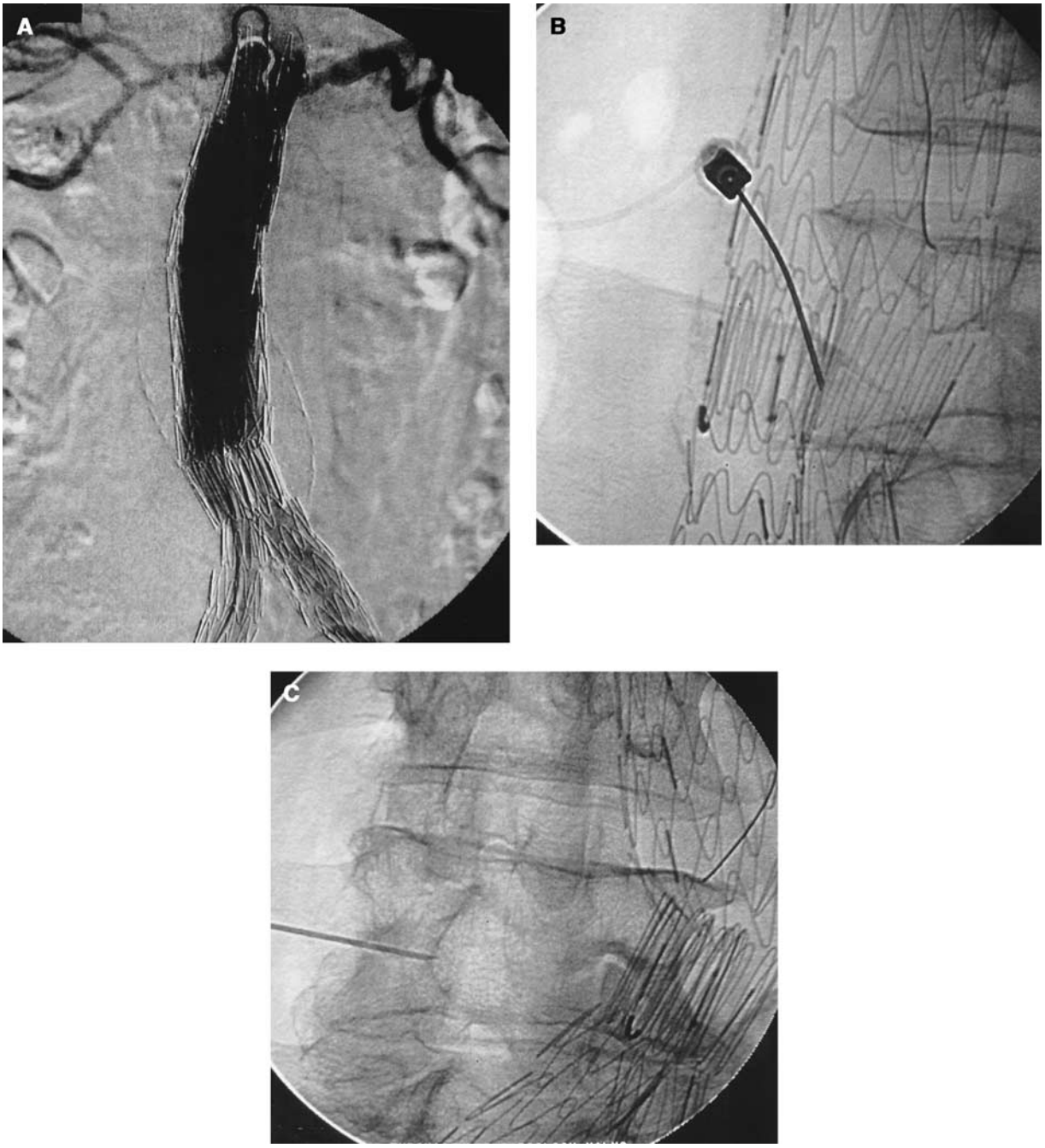

Fig 3. **A,** Aortogram shows calcified aneurysm wall. **B,** Twenty-gauge needle is advanced under fluoroscopic guidance. "Down-the-barrel" image shows axial view of the needle. **C,** For depth evaluation, a view perpendicular to the axial view was used.

vanced under fluoroscopic guidance while injecting local anesthetic (Fig 2). The position of the needle was verified with the well-established technique of "down the barrel" imaging. For depth evaluation, a view perpendicular to the axial view was used (Fig 3, *C*); ie, the fluoroscopic image was rotated back and forth between different views. When required, intravenous sedation was administered incrementally with 2.5 mg of cetobemidon (Ketogan; Pharmacia, Stockholm, Sweden) and 1 mg of midazolam (Dormicum; Roche, Stockholm, Sweden). On entrance into the aneurysm sac, a small amount of iodinated contrast medium was used to confirm the intra-aneurysm sac position of the

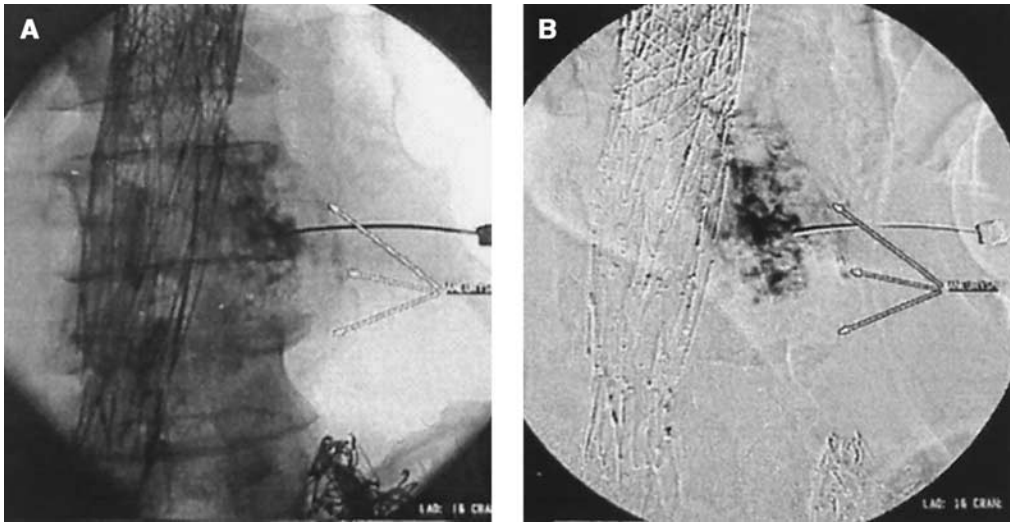

Fig 4. A, Unsubtracted aneurysmogram. **B,** Subtracted view shows distinct distribution of contrast medium in the aneurysm sac.

Table I. Age, sex, shortest maximum AAA diameter, type of stentgraft, and the time between EVAR and intra-sac aneurysm pressure measurement

Patient	*Sex*	*Age (y)*	*Stent-graft type*	*Max AAA diameter (mm)*	*Follow-up (mo)*
1	M	73	Ivancev-Malmö II	50	26
2	M	74	Ivancev-Malmö II	58	24
3	M	77	Zenith	67	14
4	M	81	Zenith	60	19
5	M	80	Trifab	50	19
6	M	82	Trifab	71	14
7	M	66	Trifab	48	19
8	M	78	Zenith	67	14
9	F	68	Ivancev-Malmö II	56	43
10	F	61	Trifab	64	16
Median		75.5		59	19
Range		61-82		48-71	14-43

needle tip (Fig 4). The needle was advanced an additional 1 to 1.5 cm into the thrombosed aneurysm sac. A second 0.014-inch pressure sensor (PressureWire) was inserted through the 20-gauge needle into the anerusym sac after calibration, as described. The standard 30 mm long radiopaque tip on this pressure sensor was shortened by the manufacturer to just 1 mm beyond the pressure sensor. This was necessary because of space limitations in the aneurysm sac and, as a consequence, enables the pressure sensor to stay protected within the needle and not reach beyond its tip. The needle was withdrawn to expose the pressure sensor without damaging it. The pressure sensors, one in the systemic circulation and the other in the aneurysm sac, were connected to an electronic interface for simultaneous pressure recordings. A thorough description of the guide wire-mounted pressure sensor system has been reported previously.[5,6]

All patients were given intravenous injections of 2 g of isoxacillin (Ekvacillin; Astra, Södertälje Sweden) or, if allergic to penicillin, 600 mg of klindamycin (Dalacin; Pharmacia, Stockholm, Sweden). After recording the pressure in the aneurysm sac, on average at two sites per patient, the needle and pressure sensors were withdrawn. Normally, if the patient was calm and relaxed, there was a decrease in pressure on withdrawal from the aneurysm sac. However, if the patient was uncomfortable or stressed, high values could be recorded, probably due to contractions in the psoas or back muscle. After the pressure wires were removed from the patient, they were again calibrated in saline solution to confirm their proper function.

RESULTS

In all 10 patients there was a clear decrease (median, 20%; range, 13%-33%) in intra-sac pressure relative to systemic pressure. In absolute values, this means that mean pressure in the aneurysm sac was as low as 17 mm Hg and never exceeded 31 mm Hg. The tracing was also typically nonpulsatile in all patients.

Table I summarizes patient data, type of stent graft used, maximum AAA diameter, and time between EVAR and intra-sac aneurysm pressure measurement.

Table II summarizes the decrease in maximum AAA diameter and intra-aneurysm sac pressure. In one patient with a relatively large aneurysm, efforts were made to record the intra-sac pressure close to the stent graft (27/27/27) and close to the aneurysm wall (19/18/19). In this case, both values were included, although they are derived from one patient. No complications related to aneurysm sac puncture were noted in this group of patients.

DISCUSSION

This preliminary study shows a marked decrease in pressure in successfully excluded AAAs after EVAR. Abso-

Table II. Decrease in shortest maximum AAA diameter after follow-up and intra-aneurysm sac pressure

Patient	*Change in max AAA diameter (mm)*	*Aortic pressure (syst/diast/mean; mmHg)*	*Intraaneurysm pressure (syst/diast/mean; mmHg)*	*% of mean arterial pressure*	*Pulse pressure (mean; mmHg)*	*Comments*
1	−8	199/90/129	19/14/17	13	5	
2	−14	132/79/100	24/24/24	24	0	
3	−12	135/60/86	19/13/17	20	6	
4	−7	126/60/84	17/17/17	20	0	
5	−8	174/78/115	22/20/21	18	2	
6	−15	139/73/99	27/27/27	27	0	Close to stent-graft
		135/74/99	19/18/19	19	1	Close to aneurysm wall
7	−8	149/81/104	30/26/28	27	4	Inflammatory AAA
						Close to stent-graft
8	−12	135/75/95	35/33/31	33	2	Close to stent-graft
9	−22	175/95/121	18/16/17	14	2	
10	−9	126/70/95	18/18/18	19	0	
Median	−12	135/75/99	19/18/19	20	1	

lute intra-aneurysm sac pressure was low, and there was almost no systolic/diastolic fluctuation, resulting in a nonpulsatile curve.

The translumbar puncture technique for entering the aneurysm sac was consistently successful and associated with little patient discomfort. No complications were noted. A small number of patients considered for the present study on the basis of shrinking AAA after EVAR were excluded because the space between the aneurysm wall and the stent graft was inadequate to be safely entered. Such patients probably benefit least from pressure measurement, whereas patients with endovascular leakage or endovascular tension often have relatively large aneurysms, thus enabling easy application of this technique for intra-sac aneurysm pressure measurement.

For several reasons, we used a guide wire-mounted pressure sensor rather than a conventional fluid-filled catheter pressure measurement system. Wire-tipped pressure sensors and catheters are considered the standard for measuring pressure. The pressure sensor is located at the tip of the wire or catheter, and measurements can be obtained without phase and amplitude errors from the source under pressure, ie, the blood stream within the stent graft or the thrombus-filled aneurysm sac. In a fluid-filled pressure system, on the other hand, measurement errors may occur because of damping of the signal, which may be caused by an incomplete fluid column from bubbles or clot. This is an obvious risk factor when measuring the pressure in a thrombus-filled aneurysm sac. In addition, in fluid-filled pressure systems any excess length of catheter is another cause of incorrect measurements. Resonant frequency rapidly decreases with length of catheter, which in turn affects the accurate measuring range.

We took several precautions to ensure accurate measurement. To be included in the study, patients had to demonstrate a decrease in pressure when the pressure sensor system was removed from the aneurysm sac and entering the retroperitoneal space; there also had to be less than 5 mm Hg drift while calibrating the pressure wire system in saline solution before and after the procedure. In addition, as the pressure wire was only 0.014 inch in diameter and placed through a 20-gauge needle, it was possible to puncture the aneurysm sac at multiple sites to obtain reproducible values.

In AAAs that were well excluded after EVAR, we found a mean pressure value of 19 mm Hg and almost no systolic/diastolic pulsatile variation compared with intra-aortic pressure curves. On average, mean intra-aneurysm sac pressure was 20% of mean intra-aortic pressure. To the best of our knowledge, there are no other data from a similar group of patients reported in the literature. However, there are some data on intra-aneurysm sac pressure measurements performed either experimentally in vitro[7] or in vivo[8,9] and clinically in patients.[1-3,10] Treharne et al[2] and Chuter et al[1] used catheters placed in the aneurysm sac from the femoral artery and immediately after deployment of the stent graft. They found a decrease in mean pressure values, from 111 mm Hg to 48 mm Hg and from 73 mm Hg to 35 mm Hg, respectively. However, in the latter study the values do not represent fully excluded intra-sac pressure after stent graft placement, because the contralateral common iliac artery was still patent with collateral flow through the internal iliac artery. Baum et al[3] measured the pressure in the intra-aneurysm sac in five patients before and after embolization of endovascular leaks and found a systolic post-embolization pressure of 20 to 30 mm Hg. There is no comment in the latter report on the degree of pulsatility before and after embolization of the endovascular leak. Baum et al[3] also speculated on different pressure measurements in different sites in the aneurysm sac with regard to the distance to the stent graft and the quality of the thrombus. In this small group of 10 patients, we were able to record in only one patient a minimal difference (8 mm Hg) between the pressure close to the aneurysm wall and the pressure close to the stent graft. It may be that our patients had a well-organized thrombus formation in the aneurysm sac, which may account for the apparently equal distribution of pressure throughout the aneurysm sac.

Our data, though preliminary, establish the intra-aneurysm sac pressure in well-excluded AAAs. This information might serve in the future as a baseline for evaluation of EVAR-treated AAAs and, more specifically, when endovascular leak or endovascular tension is present. For example, there is strong evidence to suggest that perigraft leak, either at the proximal or distal attachment site, should be treated aggressively because of the high risk for rupture associated with these type I endovascular leaks. Conversely, branch endovascular leaks (type II) originating from branches feeding the aneurysm sac in retrograde fashion may be left untreated. The clinical significance of this type of endovascular leak remains uncertain, and controversy exists as to the necessity for intervention to eliminate it. There are also divergent opinions regarding the prognosis for patients with endovascular leakage. Some authors believe that if an endovascular leak is detected but subsequently seals there is still risk for rupture, caused by possible pressure transmission through the thrombus. In all of these unclear situations, intra-aneurysm sac pressure measurement might be helpful in the decision-making process. Another important issue to be addressed is so-called endovascular tension, in which AAAs do not decrease in size after EVAR, or even increase in diameter, without demonstrable endovascular leak. In this situation, too, intra-sac pressure measurement may contribute to determination of the course of treatment, eg, watchful observation, additional endovascular procedures, or conversion to open repair.

In conclusion, the results of intra-sac pressure measurements after successful EVAR of AAAs provide a useful reference for further decision-making in the growing number of patients undergoing EVAR.

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