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HOT TOPICS

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Late Nellix failure in a juxtarenal abdominal aortic aneurysm treated with conversion to open repair: A case report and narrative review of the Nellix system

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EDITORIAL

Cutting Edge or Cutting Back? What ECST-2 Means for the Vascular Surgeon

Ioannis Kakisis

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The Second European Carotid Surgery Trial (ECST-2) addresses a critical question: in patients with carotid stenosis ≥50% (whether asymptomatic or low-to-intermediate risk symptomatic), does adding carotid revascularisation (either carotid endarterectomy or stenting) to optimised medical therapy (OMT) yield better outcomes than OMT alone?[1] The trial was conceived in the context that much of the evidence favouring revascularisation (CEA or CAS) comes from trials several decades old — ECST, NASCET, ACST etc. — and medical therapy (lipids, blood pressure control, antithrombotics, risk factor control) has improved substantially since then.

The trial randomised 429 patients between 2012 and 2019: 215 to OMT alone, 214 to OMT + revascularisation. Both symptomatic and asymptomatic patients were included with a carotid stenosis ≥50%. Symptomatic patients had to have a predicted 5-year risk of ipsilateral stroke of less than 20% by the CAR score (Carotid Artery Risk score).[2] The primary outcome for the 2-year, interim analysis was a hierarchical composite endpoint assessed with a win ratio of (1) periprocedural death, fatal stroke, or fatal myocardial infarction; (2) non-fatal stroke; (3) non-fatal myocardial infarction; (4) new silent cerebral infarction on imaging. Analysis was by intention-to-treat.

The study showed that, at 2 years, there was no significant benefit of adding revascularisation in patients meeting the inclusion criteria. The win ratio was 1.01 (95% CI 0.60-1.70; p = 0.97), meaning nearly equal “wins” for OMT alone vs OMT + revascularisation. No heterogeneity (no subgroup with clear benefit) was found in the predefined subgroups (symptomatic vs asymptomatic, degree of stenosis, etc.). Consequently, the authors support treating patients with asymptomatic carotid stenosis, or symptomatic carotid stenosis at low to intermediate risk (by CAR score), with optimised medical management alone, pending further data (5-year follow-up, etc.).

Strengths of ECST-2 include that it is a contemporary trial, offering current OMT. Given improvements in medical therapy (e.g., statins, better control of hypertension, antiplatelet regimens) over the past decades, it’s highly valid to revisit whether revascularisation still adds benefit in lower-risk populations. The trial is responding to a major gap in current evidence. Morover, the use of the CAR score allows stratification by individual risk, rather than treating all patients above a stenosis threshold equally. This constitutes a step toward personalized medicine. The multicentre design (30 centres across several countries) enhances generalizability, the blinded adjudication of outcomes (particularly imaging outcomes) ensures reliability, whereas the use of the hierarchical composite outcome and the win ratio emphasizes clinically more serious outcomes first. This avoids simply adding up events of unequal clinical meaning.

The low event rates underline how good medical therapy has become. The fact that in both arms, stroke (clinical or imaging) occurrences were modest shows that OMT is effective. This underpins the trial’s utility. In addition, monitoring silent cerebral infarction by imaging adds important nuance; many strokes are clinically silent but may have cumulative effects. Including these in the composite outcome improves sensitivity.

While ECST-2 provides highly informative interim data, there are several important limitations (some acknowledged by authors) that should temper how we apply these findings or draw conclusions. First, the 2-year follow-up is short. The risk of stroke in carotid stenosis tends to accumulate over time. Some benefits of revascularisation may not fully manifest until beyond 2 years. The trial is ongoing with planned 5-year follow-up. In the same context, early perioperative risks (stroke, MI, death) might tip the balance against revascularisation in the short term; whether later benefits outweigh early harm may depend on longer follow-up. It should also be emphasized that ECST-2 deliberately excludes patients with high predicted risk (CAR ≥20%) of ipsilateral stroke. Thus, results do *not* apply to higher-risk patients, where benefit of revascularisation may still be substantial.

Statistical issues and power represent another caveat Because event rates are lower than historical trials anticipated, the trial may be underpowered to detect small but clinically meaningful differences, especially for particular subgroups. Subgroup analyses are especially fragile given small numbers. Similarly, the confidence interval of the win ratio is wide (0.60-1.70) meaning substantial uncertainty around effect-size. A possible moderate benefit (or harm) cannot be ruled out.

The generalisability to revascularisation type and proce-

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dural risk is also under question. ECST-2 included both carotid endarterectomies and CAS procedures. The risks and benefits of these two techniques might differ, especially in certain anatomical subtypes or patient comorbidity profiles. Thus, results may not generalize equally to CEA and CAS.

Risk prediction via CAR score is also questionable. The CAR score was recalibrated, but risk prediction always carries uncertainty; improvements in medical therapy may continue, and baseline population characteristics (older age, comorbidity, imaging features) may shift. Thus, the predictions might drift.

Moreover, imaging markers such as plaque vulnerability (e.g. intraplaque hemorrhage, ulceration) might modulate risk substantially; while ECST-2 plans to examine these, the interim results do not yet allow stratification by these imaging features. Some patients otherwise "low risk" may be misclassified.

While inclusion of "silent cerebral infarction" in imaging is a strength, the clinical impact (on cognition, risk of future symptomatic stroke, functional outcome) is still uncertain. The weight given to silent infarcts in the composite (being lowest in the hierarchy) reflects this. But long-term consequences matter, especially in older patients.

ECST-2 was planned initially for a larger sample size (originally ~2000), but recruitment was smaller. This may limit statistical power. Also, during its protracted recruitment period (2012-2019), standards of medical therapy and patient characteristics may have shifted, potentially introducing heterogeneity across enrolment eras.

Given the strengths and the limitations, what does ECST-2's 2-year interim analysis mean for clinicians managing carotid stenosis? For patients with carotid stenosis ≥50%, but otherwise "low risk" (as per CAR score), especially asymptomatic or in whom symptoms are remote, ECST-2 suggests that optimised medical therapy may suffice without the risks of revascularisation. This could spare patients the operative risks (perioperative stroke, MI, death) and costs or morbidity of surgery.

The trial underlines that medical management today is far better than decades ago. High uptake of statins, better control of BP, antiplatelets etc. These therapies matter; any decision about intervention must assume medical therapy is aggressively optimized.

Not all patients with similar degrees of stenosis are the same. Other factors (age, sex, comorbidities, plaque morphology, time since symptoms) affect risk. ECST-2's use of the CAR score and planned plaque imaging point to a more nuanced decision-making framework. Clinicians should adopt risk scores and imaging to identify who might get benefit from revascularisation. Existing guidelines (national and international) that recommend revascularisation based largely on degree of stenosis and symptomatic status may need revising, or at least specifying thresholds for risk under modern therapy. The ECST-2 findings could prompt societies to incorporate risk scores, imaging markers, patient age, comorbidity, and operative risk more explicitly. Patients with "high stroke risk" by CAR (≥20%), recently symptomatic, or with imaging features of vulnerable plaques, may still benefit from intervention. ECST-2 does not include those, so guidelines should still allow revascularisation in those higher-risk categories.

While ECST-2 is important, there are several unanswered questions and areas for further research.

The longer-term data (5-year follow-up) are crucial. Only then can we see whether the modest early disadvantages of revascularisation (perioperative risk) are offset by longer-term reductions in ipsilateral stroke, and to what magnitude.

Plaque imaging (e.g. intraplaque hemorrhage, ulceration, lipid-rich core) may identify patients with low risk by clinical score but high risk by plaque vulnerability. It remains to be seen whether these subgroups derive greater benefit from revascularisation. ECST-2 includes MRI plaque substudies, but these results are not yet mature.

More work is needed to understand how silent infarcts contribute to long-term neurological, cognitive, or functional impairment, and whether preventing them justifies intervention. The choice of hierarchical composite endpoint is good, but what weights do patients give to silent infarcts vs overt stroke vs MI etc?

Quality of life, cognitive decline, functional status—these are not yet fully addressed, especially in those with silent or subclinical infarcts. Also, durability of revascularisation (late restenosis, procedural durability) matters over longer time.

Interventions (especially surgery or stenting) carry cost and resource use. If OMT alone is non-inferior in many low-risk patients, this could shift resource allocation. Economic analyses will be important.

Many trials are done in high-income countries, in centers with high experience. The benefit:risk ratio may differ in lower-income settings, or in centers with less surgical/interventional expertise.

The CAR score is helpful, but further refinement, validation, perhaps integration of imaging, biomarkers (if any) is needed. Also, tracking secular changes in baseline risk (medical therapy improvements) is vital; what is "low risk" now may shift in the future.

Older patients, those with limited life expectancy or comorbidities, may derive less benefit from revascularisation (given procedural risks) and more from medical management. Tailoring by life expectancy is important.

Revascularisation's appeal lies in the idea of removing or bypassing a stenotic lesion, potentially preventing future strokes. But every revascularisation carries risk — surgical morbidity/mortality; for stenting, risks may differ (embolism, restenosis); procedural MI risk; peripheral complications. Conversely, medical therapy also has cost, side effects, adherence issues, but substantially lower immediate procedural risk.

What ECST-2 shows is that, in patients with lower predicted stroke risk under OMT, the immediate procedural risks may not be balanced by enough prevented strokes in a 2-year span. Over time, this balance may shift, or may not; the trial will tell. Thus, the trade-off is highly sensitive to:

- The magnitude of baseline risk of ipsilateral stroke if untreated (or treated just with OMT)
- The procedural risk and the center/surgeon/interventionalist performance
- Patient preferences: e.g. avoidance of even small stroke risk vs desire to avoid surgery
- Life expectancy: someone with longer life more likely to b

ECST-2 is part of a broader trend of re-examining old assumptions. Earlier trials (ECST, NASCET, ACST) established the benefit of carotid revascularisation in symptomatic high grade stenosis, and in some asymptomatic patients. But medical therapy at the time was much less rigorous. Over time, registries and smaller studies have shown that stroke rates under medical therapy have fallen in asymptomatic stenosis to ~1% per annum or less, sometimes even 0.6% in selected cohorts. Other ongoing trials (e.g. CREST-2, SPACE-2, ACTRIS) also aim to clarify the balance of benefits in asymptomatic or lower risk symptomatic carotid disease. ECST-2's contribution is that it gives us randomized controlled data (rather than observational) in modern medical therapy settings, for a well-defined lower risk population. It helps define what "lower risk" may mean in practice, and challenges the practice of automatically revascularizing stenoses above a fixed degree (e.g. ≥70%) regardless of other risk features.

In conclusion, the ECST-2 2-year interim results are a landmark in carotid stenosis management. They suggest that for many patients with moderate carotid stenosis and low-to-intermediate stroke risk, optimised medical therapy alone may perform as well over 2 years as adding carotid revascularisation, considering the risks, costs, and invasiveness of surgery or stenting. Nonetheless, these are interim observations. Longer follow-up, richer imaging subgroup data, better understanding of silent infarcts, and refinement of risk stratification tools are needed before wholesale changes in practice are made. What the trial does immediately is sharpen our awareness that: *not all carotid stenosis is equal*, that *medical treatment today is far more powerful than a few decades ago*, and that *patient-selection matters critically*. Already, in low-risk patients, a more conservative approach seems justified. As with all such pivotal trials, the devil is in the details — patient selection, operator skill, timing, comorbidity — but ECST-2 moves the field forward by providing modern evidence calibrating when carotid revascularization is truly likely to add value beyond best medical care.

REFERENCES

1 Donners SJA, van Velzen TJ, Cheng SF, Gregson J, Hazewinkel AD, Pizzini FB, et al; ECST-2 investigators. Optimised medical therapy alone versus optimised medical therapy plus revascularisation for asymptomatic or low-to-intermediate risk symptomatic carotid stenosis (ECST-2): 2-year interim results of a multicentre randomised trial. Lancet Neurol 2025;24:389-399.

2 Cheng SF, van Velzen TJ, Gregson J, Richards T, Jäger HR, Simister R, et al. The 2nd European Carotid Surgery Trial (ECST-2): rationale and protocol for a randomised clinical trial comparing immediate revascularisation versus optimised medical therapy alone in patients with symptomatic and asymptomatic carotid stenosis at low to intermediate risk of stroke. Trials 2022;23:606.

A planned vascular surgeon consultation/participation versus emergency vascular surgeon participation in oncologic surgery - a comparative cohort study

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Abstract:

Introduction: Oncologic surgery maybe a challenge, especially when the tumour lies in the proximity of major vascular structures. This study aims to compare main outcomes between a a planned vascular surgeon (VS) consultation/participation versus an emergency VS participation among patients undergoing oncologic surgery.

Methods: This is a retrospective study conducted in a university department of general surgery. All included patients underwent an oncologic surgery within a 6-year period (January 2019-December 2024). Main early outcomes were compared between two groups: Group A (planned VS consultation/participation) versus Group B (emergency VS participation). Main early outcomes included 30-day mortality, intraoparative blood loss, days of ICU stay, days of hospital stay, major cardiac events and major limb events (ischemia or amputation)

Results: A total of 93 patients were included (Group A = 41 versus Group B=53). Demographics were similar between the two groups. Gynaecological tumours and colon/rectal tumours resection were the most frequent types of surgery in Group B. Although Group B presented with 9.6% 30-day mortality compared to null mortality in Group A, this was not statistically significant. Group B was associated with a higher blood loss (6.3 blood units vs 2.2 blood units, p=0.01) and a longer hospital stay (9.8 days vs 6.6 days, p=0.02).

Conclusions: Planned VS consultation/participation to oncologic surgery seems to yield favourable early outcomes compared to emergency VS consultation. This must be verified considering late outcomes as well. This also raises concerns regarding a more extensive vascular training for all oncologic surgeons.

Key-words: oncologic surgery, vascular injury, vascular consultation, vascular participation, comparative study, early outcomes

INTRODUCTION

Iatrogenic vascular injuries have been increased in the last decades, especially with the increase of endovascular procedures.[1,2] Reconstructing any vascular injury can be challenging for surgeons who do not routinely perform vascular reconstruction.[1,2] Vascular surgeons are therefore called to assist other surgical specialties when an injury occurs or preoperatively to plan an oncologic procedure when the tumour lies in the proximity of large vessels.[3] As surgical oncologists, urologists, and colorectal surgeons increasingly resect anatomically complex tumours with curative intent, vascular surgeons are called to reconstruct the associated vascular anatomy, hoping to improve the quality and safety of R0 resections, where margins of the resected specimen are microscopically free of cancer cells, through a multidisciplinary approach.[4,5]

Although the role of a vascular surgeon in the treatment of iatrogenic injuries has been addressed by several studies, there is limited data on a direct comparison of outcomes between a planned and an emergency vascular surgeon consultation. Therefore, aim of this study was to compare outcomes between a planned vascular surgeon consultation/ participation and an emergency call when a vascular injury occurs during an oncologic procedure.

METHODS

This was a retrospective study including patients that were treated with oncologic surgery in our university department. All patients were treated within a 6-year period (January 2019-December 2024). This was a comparative study that compared major outcomes between two Groups of patients: Group A (a planned vascular surgeon [VS] consultation or participation to the procedure was scheduled) versus Group B

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(emergency VS participation to the procedure due to vascular injury). Major outcomes included 30-day mortality, cardiac adverse events (myocardial infarction, acute heart failure or major arrhythmia), limb events (acute limb ischemia or emergency limb revascularization or amputation), mean blood loss, mean ICU (intensive care unit) stay, mean hospital stay.

All main demographics were recorded including mean age, gender, main comorbidities, type of cancer, type of oncologic surgery, type of vascular injury and repair when occurred.

Statistical analysis was conducted using the StatsDirect Statistical software (Version 2.8.0, StatsDirect Ltd, Cambridge, UK). P values were calculated for evaluating statistical significance, with a P of less than 0.05 indicating a statistically significant difference. All variables and outcomes were compared between the two Groups using the x^2 Fischer test for non-numerical parameters and Mann-Whitney test for numerical parameters.

RESULTS

In total, 93 patients were analyzed in this retrospective study. Group A (planned VS consultation/participation) included 41 patients and Group B (emergency VS participation) included 52 patients. Mean age for all patients was 62 (46-78) years of age and 54.8% were of male gender.

Basic demographics did not differ between the two groups. (**Table I**)

The most common cancer types addressed in Group A were Sarcoma (36.5%) and Pancreas cancer (24.4%). The most common cancer types in Group B were gynecological tumours (36.5%) and colon/sigmoid cancer (19.2%). Sarcomas were more frequent in Group A than Group B, and gynecological tumours were more frequent in Group B than in Group A. (**Figures 1-7**)

Regarding the location of vascular injury, iliac arteries and iliac veins were more frequently injured in Group B compared to Group A. (p = 0.0001)

Regarding the type of vascular injury, ruptures/lacerations (p = 0.0001) and retroperitoneal hematomas (p=0.008) were more frequent in Group B compared to Group A. The other types of injury were similar between the two groups.

Regarding the type of treatment, conservative treatment (p=0.004), suturing (p=0.0002) and ligation (p=0.002) were more frequent in Group B, while other types such as bypass grafting or patch placement were similar between the two groups.

Regarding the main outcomes, 30-day mortality was similar between the two groups (Group A: 0% vs Group B: 9.6%, p>0.05). However, blood loss was higher in Group B (6.3 blood units vs 2.2 blood units, p=0.01) as well as mean hospital stay was higher in Group B (9.8 days vs 6.6 days, p=0.02). Other outcomes such as cardiac events, limb events, DVT/PE (deep venous thrombosis/pulmonary embolism) or ICU stay were similar.

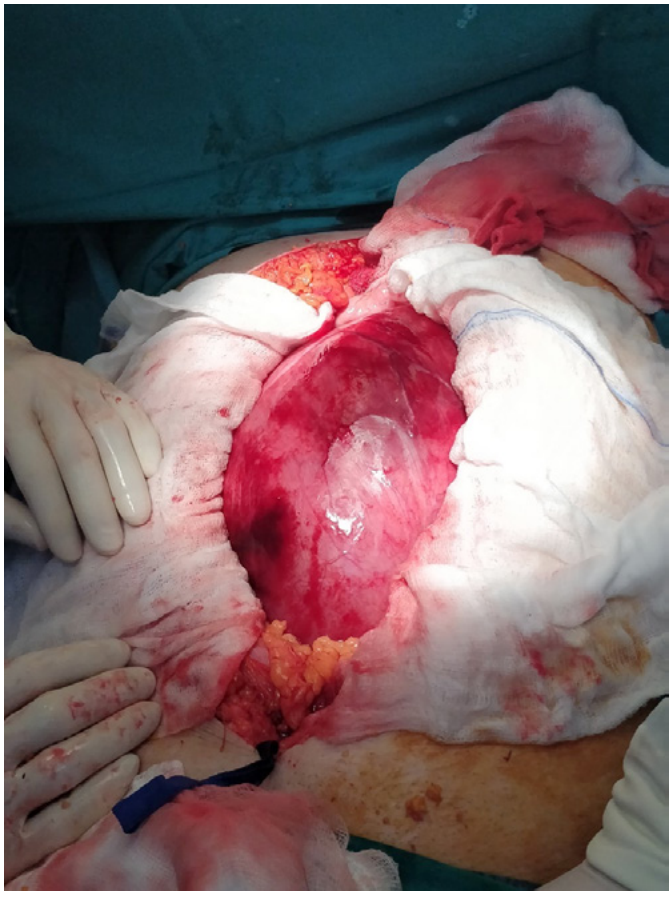

Fig 1. Intra-abdominal teratoma covering the entire abdominal cavity (planned vascular surgeon participation).

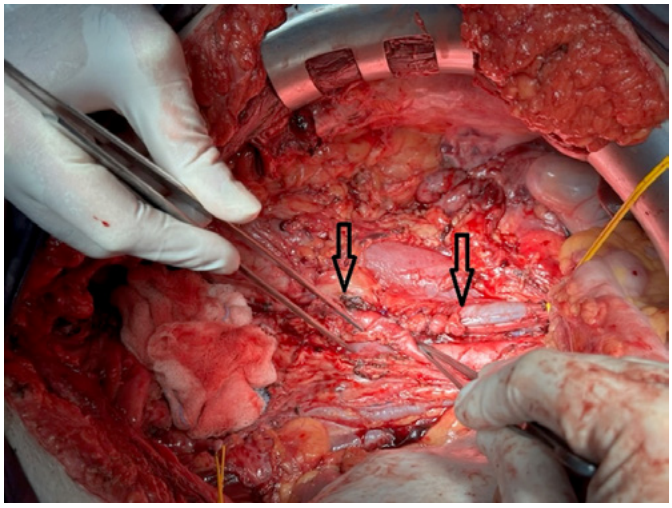

Fig 2. Resection of recurrent retroperitoneal sarcoma – emergency rupture of the inferior vena cava (IVC) and the right common iliac vein (CIV). Emergency vascular surgeon participation – Suturing of the IVC and right CIV (between the arrows).

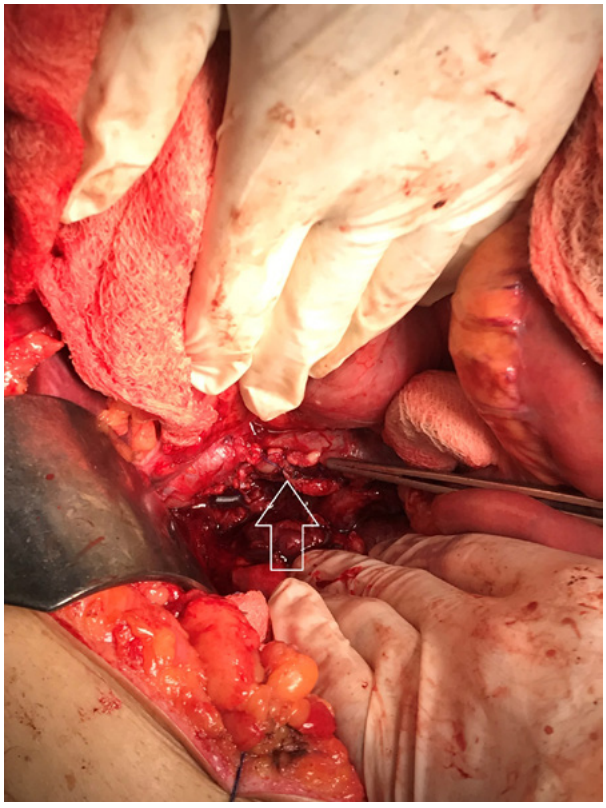

Fig 3. Resection of right renal carcinoma with extensive thrombosis of the right renal vein extending to the inferior vena cava (IVC). Nephrectomy and suturing of the IVC after removal of the kidney (arrow - planned vascular surgeon participation).

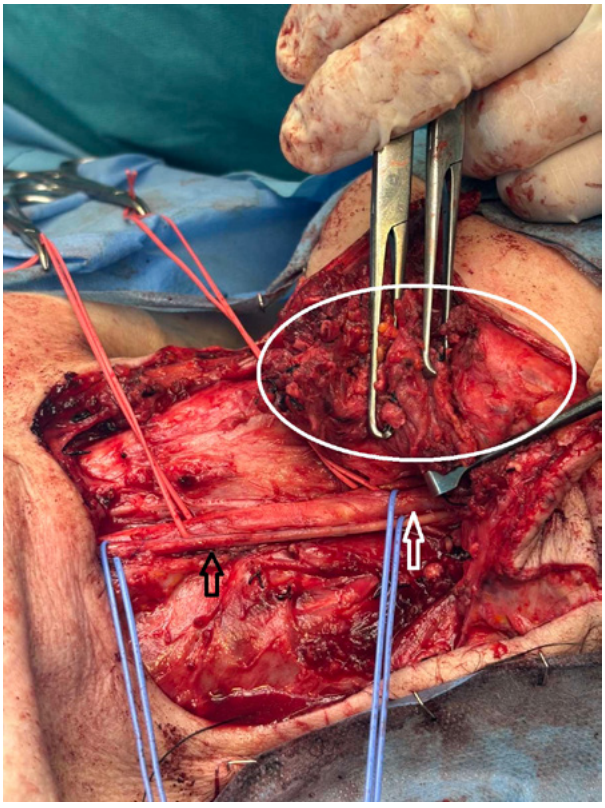

Fig 5. Extensive dissection of the carotid bifurcation due to recurrent tumour of the tongue - The white circle points out the tumour, the white arrow shows the internal carotid artery and the black arrow shows the vagus nerve (planned vascular surgeon participation).

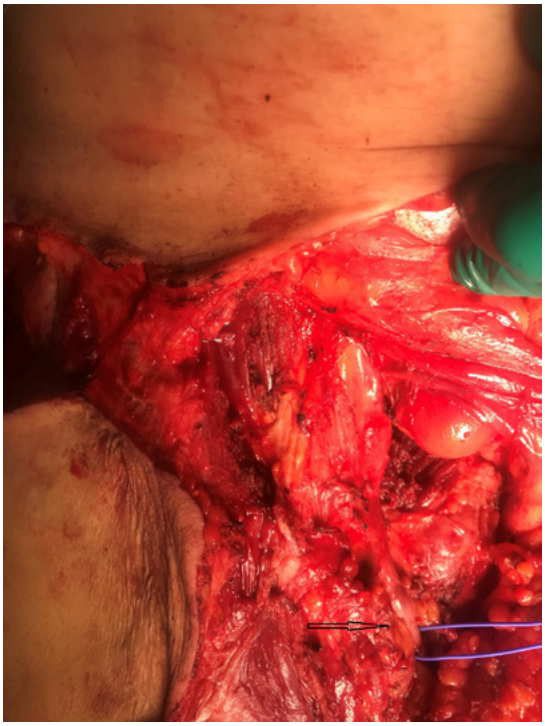

Fig. 4. Extensive resection of a sarcoma located in the right upper femoral area – Arrow shows the superficial femoral artery (planned vascular surgeon participation).

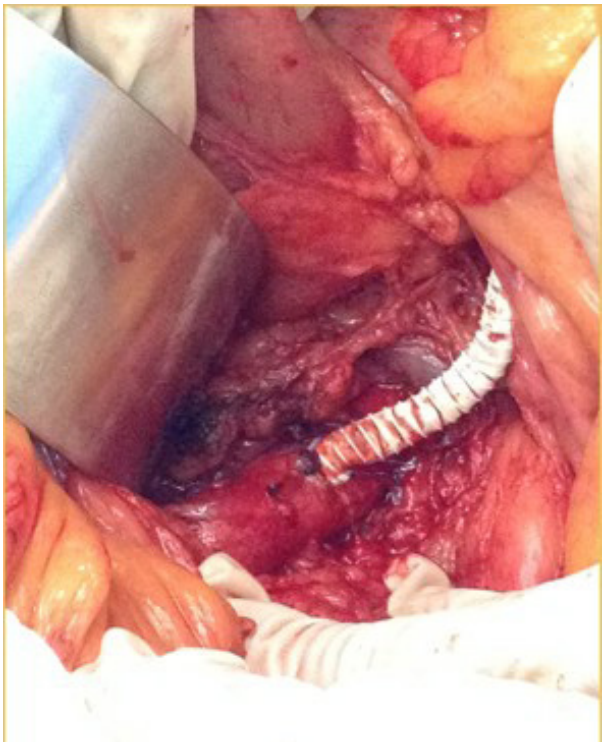

Fig 6. Synthetic aorto-hepatic bypass graft due to hepatic artery transection during a hepatic carcinoma resection. (emergency vascular surgeon participation)

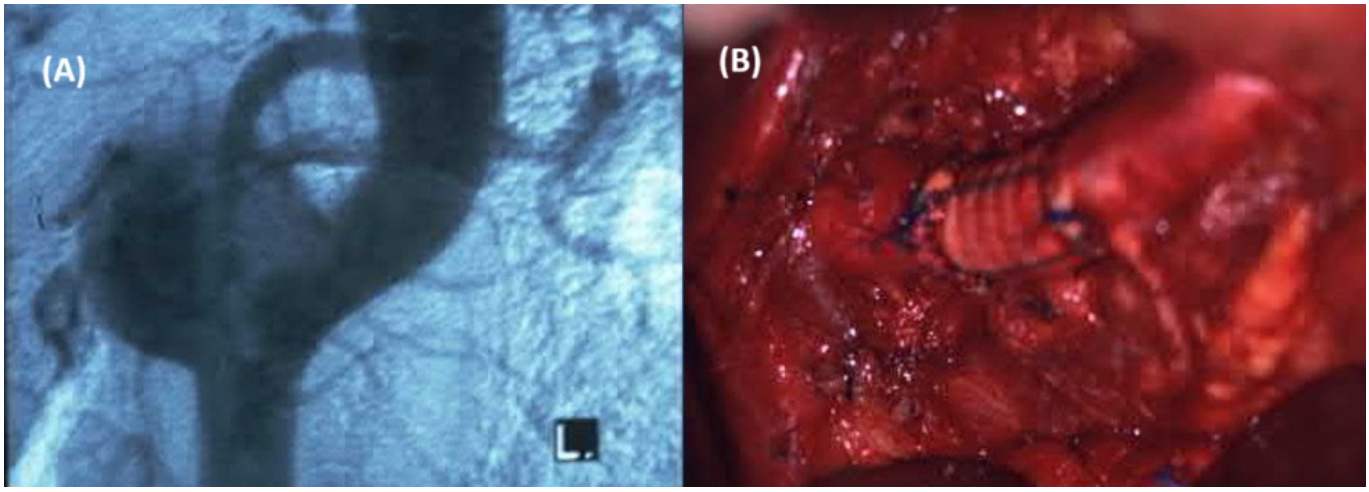

Fig 7. (A) Abdominal aortic pseudoaneurysm formation right after resection of retroperitoneal sarcoma. (B) Emergency vascular surgeon consultation leading to patch placement at the abdominal aorta.

DISCUSSION

In this retrospective study we reported that planned VS consultation/participation to oncologic procedures is associated with better early outcomes compared to emergency VS consultation/participation due to a vascular injury.

Regarding the type of procedure associated with vascular injury, we found that gynaecological procedures were more associated with emergency VS consultations compared to sarcomas where a planned VS consultation was more frequently requested. According to a former cohort study, general surgery procedures were the most frequent procedures associated with iatrogenic vascular trauma followed by the cardiology endovascular procedures.[1] Dancyc et al. reported that 46% of intraoperative consultations referred to surgical oncology compared to other specialties such as orthopedics or urology.[6] This concurs with the present study. However, in a recent cohort study, only 9.6% of all procedures that requested VS consultation referred to surgical oncology, with spinal surgery being the most frequent.[7] In another study by Tomita et al., more than 60% of the cases requested a VS consultation and they were for vascular exposure and avoidance of bleeding, whereas only 14.4% of cases were due to bleeding and a 19% required a vascular reconstruction.[8]

The most frequent type of vascular injury in this study was rupture or laceration and retroperitoneal hematomas in Group B compared to Group A. This could be justified also as iliac arteries and iliac veins were more frequently injured in Group B. Therefore, we found that the most frequent treatments included conservative treatment in case of hematomas and ligation or suturing in case of ruptures/lacerations in Group B compared to Group A.

Regarding early outcomes, we found similar 30-day mortality between groups although emergency VS consultation/participation was associated with 9.6% mortality compared to null deaths after planned VS participation. This concurs with Blackwood et al. who found a 7.2% 30-day morality in their cohort.[9] However, we found more blood loss and a larger hospital stay associated with emergency VS interference. This concurs with the study by Bobadilla-Rosado et al. where the authors found almost twice the loss of bleeding during a retroperitoneal oncologic resection when a VS was requested in an emergency setting. Additionally, the authors have associated the emergency VS interference with low long-term survival too.[10] This raises the question if an oncologic surgeon should receive a training in vascular surgery as well. Raj et al. have highlighted in their study that there is a visible 'gap' in skills training of an oncologic surgeon that could be filled with proficiency in vascular surgery.[10]

A scientific approach and international collaboration are needed, so that we can better identify which patients should be operated, what problems to anticipate and could be avoided with better planning, and which solutions improve patient outcome.[12] Degano et al. have conducted a systematic review evaluating vascular complications during oncologic ovarian surgery and reported almost 2.7% pooled rate of vascular injury during such type of surgery.[13] Ovarian cancer surgery is characterized by a comparatively low risk of vascular complications, as it involves an intraperitoneal pathology, with nearly all surgical interventions occurring at the peritoneal-intraperitoneal interface. There are some exceptions: debulking of lymphadenopathy in advanced ovarian cancer and recurrences, often retroperitoneal, usually in patients who have undergone surgery or other treatments, leading to higher surgical complication risks or any type of pelvic and para-aortic lymph node dissection. Therefore, the authors proposed a risk classification system that classified the patients into low, medium and high risk for vascular complications.[13] High-risk patients have experienced major vascular complications, display significant imaging anomalies, and have undergone multiple previous surgeries. There is a high probability of necessitating lymphadenectomy or advanced abdominal retroperitoneal surgery, with a body-mass-index below 16 or exceeding 30, alongside severe coagulation abnormalities alterations. A vascular surgeon should be present or immediately available, and advanced vascular surgical instruments should be on hand. We believe that such cases of increased risk for vascular com-

plications should be discussed preoperatively before every type of oncologic surgery, and a vascular surgeon should be present and help dissecting major vascular structures.

There are several limitations in this study. First, this is a retrospective study associated by certain bias of data collection. Second, this study underestimates the overall contribution of vascular surgical expertise to the operative management of primarily non-vascular patients. Third, any vascular surgical participation in the management of iatrogenic injuries occurring outside the operating room such as in the angiography suite or cardiac catheter laboratory was not included. Finally, no late outcomes were reported. The advantage regarding later outcomes should be verified by studies with longer follow-up.

To conclusion, vascular surgeons are essential supporting staff to all surgical specialists, and a diverse vascular-oriented skill set in open training coupled with broad anatomic knowledge is necessary for all oncologic surgeons. The emergency intraoperative VS consultation/participation to an oncologic operation seems to be associated with more blood loss and longer hospital stay compared to planned VS consultation/participation, although early mortality seems similar.

REFERENCES

1 Galyfos G, Kerasidis S, Stefanidis G, Stamatatos I, Kastrisios G, Giannakakis S, et al. Iatrogenic and non-iatrogenic arterial injuries in an urban level I trauma center in Greece. Int Angiol. 2016;35:526-530.

2 Filis K, Arhontovasilis F, Theodorou D, Albanopoulos K, Lagoudianakis E, Manouras A, et al. Management of early and late detected vascular complications following femoral arterial puncture for cardiac catheterization. Hellenic J Cardiol. 2007;48:134-142.

3 Filis K, Sigala F, Stamatina T, Georgia D, Zografos G, Galyfos G. Iatrogenic Vascular Injuries of the Abdomen and Pelvis: The Experience at a Hellenic University Hospital. Vasc Endovascular Surg. 2019;53:541-546.

4 Zamora C, Castillo M, Puac-Polanco P, Torres C. Oncologic Emergencies in the Head and Neck. Radiol Clin North Am. 2023;61:71-90.

5 Khanna L, Vargas D, Menias C', Katabathina V. Oncologic Emergencies in the Chest, Abdomen, and Pelvis. Radiol Clin North Am. 2023 Jan;61(1):91-110.

6 Danczyk RC, Coleman J, Allensworth J, Azarbal AF, Mitchell EL, Liem TK, et al. Incidence and outcomes of intraoperative vascular surgery consultations. J Vasc Surg. 2015;62:177-182.

7 Soto C, Tarabey S, Hamilton C, Ciaramella MA, Malanowski A, Rahimi SA, Beckerman et al.. Intraoperative Vascular Assistance: Essential to an Institution's Ability to Provide Surgical Care. Ann Vasc Surg. 2022 May;82:112-119.

8 Tomita TM, Rodriguez HE, Hoel AW, Ho KJ, Pearce WH, Eskandari MK. Implications of Intraoperative Vascular Surgery Assistance for Hospitals and Vascular Surgery Trainees. JAMA Surg. 2016;151:1032-1038.

9 Blackwood SL, O'Leary JJ, Scully RE, Lotto CE, Nguyen LL, Gravereaux EC, et al.#. Emergency intraoperative vascular surgery consultations at a tertiary academic center. J Vasc Surg. 2020;71:967-978.

10 Bobadilla-Rosado LO, Lopez-Pena G, Verduzco-Vazquez AT, Laparra-Escareno H, Anaya-Ayala JE, Azcorra H, et al. Five-year survival after retroperitoneal oncologic resection with and without vascular surgeon intervention. Vascular. 2023;31:868-873.

11 Raj P, Losty PD, Corbally MT. Should Pediatric Surgical Oncologists Receive Training in Vascular Surgery ? A Practice Survey Report From the International Society of Paediatric Surgical Oncology (IPSO). J Pediatr Surg. 2024;59:1605-1610.

12 Vikatmaa P. Emergencies during oncovascular surgery: Strategies and pitfalls. Semin Vasc Surg. 2023 ;36:157-162.

13 Degano M, Arcieri M, Frigatti P, Scrivere P, Zermano S, Driul L, et al. Exploring Vascular Complications in Ovarian Cancer Surgery: A Narrative Literature Review with a New Management Proposal Algorithm. Healthcare (Basel). 2025;13:270.

Beyond the point of no return - the contemporary role of major limb amputation in the treatment of extremity arteriovenous malformations

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Abstract:

Introduction: Extremity arteriovenous malformations (AVM) are rare, congenital, fast-flow vascular anomalies characterized by abnormal shunts between arteries and veins. Despite advances in endovascular and surgical techniques, many lesions remain refractory to treatment, causing severe pain, bleeding, ulceration, and functional loss. In selected advanced cases, limb amputation remains a legitimate, life-saving, and function-restoring option.

Methods: A narrative review of the literature (MEDLINE, 2000–2025) was conducted to analyze the epidemiology, pathophysiology, management strategies, and particularly the indications and outcomes of amputation in patients with extremity AVM. Only verified peer-reviewed studies were included.

Results: Endovascular embolization and combined surgical excision are the mainstays of treatment, but often fail to achieve durable cure in diffuse, high-flow lesions. Recurrence rates may exceed 80% at five years, particularly in lower limb AVM. Major limb amputation is required in up to 22% of patients with Schobinger stage III–IV disease, most commonly for uncontrollable pain, bleeding, infection, or tissue necrosis. When appropriately indicated, amputation provides rapid pain relief, resolution of hemorrhage and infection, and significant improvement in quality of life. Early prosthetic rehabilitation and psychological support are critical for favorable functional recovery. Preoperative embolization, meticulous operative planning, and multidisciplinary postoperative care can minimize complications and recurrence at the stump.

Conclusion: Although a last resort, major limb amputation retains an essential role in the management of advanced or refractory extremity AVM, offering life-saving and function-restoring potential, when limb salvage is no longer achievable.

Key words: arteriovenous malformation, vascular malformation, amputation, quality of life, multidisciplinary approach

INTRODUCTION

Arteriovenous malformations (AVM) are congenital, complex vascular anomalies belonging to the isolated, fast-flow subgroup in the International Society for the Study of Vascular Anomalies (ISSVA) classification.[1] These lesions are characterized by direct, high-flow communications between arteries and veins, bypassing the capillary bed, and are inherently complex and heterogeneous.[2,3] While AVM may arise in any anatomical location, the brain, spine, and extremities are most commonly affected.[3,4] Extremity AVM, though less frequent than intracranial lesions, pose significant clinical challenges, due to their potential for progressive growth and expansion, functional impairment, and life-threatening complications.[4,5]

The aim of this narrative review was to critically evaluate the contemporary role of major limb amputation in the management of extremity arteriovenous malformations (AVM). By synthesizing current evidence from peer-reviewed literature, this paper sought to clarify the clinical indications, timing, technical considerations, and outcomes associated with amputation in extremity AVM. Particular emphasis was placed on postoperative quality of life, functional recovery, and the multidisciplinary strategies that optimize patient-centered care.

METHODS

A comprehensive narrative review of the literature was conducted to evaluate the management of extremity AVM, with particular focus on the role and outcomes of limb amputation. A extensive, electronic search of the PubMed, Scopus, and Web of Science databases was performed for studies published between January 2000 and September 2025. The search strategy used various combinations of the following keywords: "arte-

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riovenous malformation", "extremity", "limb", "amputation", "embolization", "surgical excision", "outcome", *and* "quality of life". The last search was run on 09 October 2025. Only articles published in English and indexed in peer-reviewed journals were included. Eligible publications comprised clinical studies, case series, case reports, and review articles reporting on diagnosis, management, and outcomes of extremity AVM in adults or mixed-age populations. Studies focusing exclusively on cerebral, spinal, or visceral AVM were excluded. Reference lists of relevant papers were also screened to identify additional sources. Data were extracted and synthesized narratively, emphasizing the epidemiology, pathophysiology, treatment strategies, and long-term results of amputation, with cross-referencing to original reports whenever possible. The review adheres to the principles of transparency and reproducibility in narrative reviews, though no formal meta-analysis or quantitative synthesis was performed, due to the heterogeneity among the available studies.

RESULTS - DISCUSSION

Epidemiology

The prevalence of extremity AVM is difficult to ascertain precisely due to underdiagnosis, misclassification, overlapping terminology in older series, and variable detection methods, but estimates suggest that extremity AVM represent around 20-30% of all AVM, with an overall prevalence of approximately 1 in 100,000 individuals in the general population.[6,7] Extremity AVM are usually located in the lower limbs, most commonly in the thigh and knee regions, followed by the lower leg and foot.[2] Upper limb AVM are more commonly found in the hand than in the arm, accounting for around 10% of extremity cases.[5]

Pathophysiology

The formation of AVM is attributed to defective vascular morphogenesis during early embryogenesis, typically between the 4th and 10th week of gestation.[2,7] In these lesions, failure of capillary network development results in persistent arteriovenous shunts, which are hemodynamically abnormal and prone to progressive enlargement.[2,7] Histologically and angiographically, AVM consist of hypertrophic and tortuous feeding arteries, a central nidus composed of dysplastic vessels, and dilated, thin-walled draining veins.[2] The low-resistance, high-flow shunting inherent to AVM leads to venous hypertension, tissue congestion, distal ischemia due to steal phenomena, and progressive local tissue destruction.[7,8] Over time, these processes may manifest as pain, edema, ulceration, hemorrhage, and, in extensive lesions, high-output cardiac failure.[7,8]

Unlike many vascular tumors, AVM do not involute, and are distinguished by their capacity for continuous growth, which may be triggered by external or physiological factors, such as trauma, infection, thrombosis, surgery, or hormonal changes during puberty or pregnancy.[7,9] Such stimuli can transform a previously quiescent lesion into a rapidly enlarging, symptomatic, or even life-threatening vascular anomaly.[7,9] This characteristic growth behavior underpins the need for vigilant monitoring and timely intervention, and explain why therapeutic strategies typically aim at durable symptom control rather than guaranteed cure.[3]

Clinical presentation

Clinically, extremity AVM may remain quiescent for long periods or present with a clinical spectrum of extremity that ranges from subtle skin changes to severe deformity and functional impairment.[2] Early-stage lesions may manifest as localized warmth, pink skin blush, or minimal swelling, often remaining asymptomatic for years.[10,11] As lesions progress, patients may present with palpable thrills, pulsatile masses, audible bruits, and dilated superficial veins.[10,11] Advanced disease is characterized by pain, ulceration, bleeding, tissue necrosis, and progressive deformity, whereas high-output cardiac failure can occur due to extensive arteriovenous shunting.[10,11] The Schobinger staging system[12] remains the most widely adopted clinical framework to communicate disease severity, guide follow-up, and determine timing of intervention:

- Stage I (quiescence): pink-blush skin, warm area
- Stage II (expansion): pulsatile mass, thrill, bruit, dilated veins
- Stage III (destruction): pain, ulceration, bleeding, tissue necrosis
- Stage IV (decompensation): high-output heart failure

Importantly, stage correlates with risk: many lesions remain in stages I-II for extended periods, but a substantial proportion progress to destructive (stage III) disease requiring active intervention.[12] Functional impairment in extremity AVM may include reduced range of motion, weakness, and difficulty performing daily tasks, particularly when lesions involve the hand or wrist.[10,11] Steal phenomena can exacerbate distal ischemia, and large AVM may cause limb hypertrophy or deformity.[10,11] Chronic pain, recurrent bleeding, and repeated infections are common and significantly impact quality of life.[10,11] Figure 1 depicts the ex vivo examination of a hand with an extensive, destructive, Schobinger stage III arteriovenous malformation, showing major digital deformity, extensive skin and soft tissue breakdown, multiple ulcerative lesions, dystrophic nails, and exposed phalanx bones. The patient had presented at our emergency department with spontaneous, major, life-threatening hemorrhage, and underwent an emergent mid-forearm amputation.

Diagnosis

Accurate diagnosis of extremity AVM relies on a combination of clinical assessment and imaging.[2,12] Colored Duplex ultrasonography is often the first-line imaging modality, providing information on flow velocity, direction, resistance, and shunting, as well as serving as a tool for surveillance.[12-14] Magnetic resonance imaging and magnetic resonance angiography are essential for delineating the lesion extent, soft tissue and bone involvement, and relationships to neurovascular structures.[12-14] Computed tomography angiography is particularly useful when skeletal involvement must be assessed.[14] Despite advances in noninvasive imaging, digital subtraction angiogra-

Figure 1. Ex vivo examination of an amputated hand with an extensive, destructive, Schobinger stage III arteriovenous malformation, showing major digital deformity, extensive skin and soft tissue breakdown, multiple ulcerative lesions, dystrophic nails, and exposed phalanx bones.

phy remains the gold standard for detailed mapping of nidus architecture and feeding/draining vessels, particularly when endovascular intervention is being considered.[12,15] Biopsy of suspected AVM is contraindicated due to the risk of significant hemorrhage.[14]

Differential diagnosis should consider low-flow vascular malformations, hemangiomas, pseudoaneurysms, angiosarcomas, or non-vascular soft tissue lesions such as abscesses or tumors.[2] Correct classification using ISSVA criteria is critical to avoid mislabeling and to guide appropriate management.[1]

Treatment strategies

Various treatment modalities exist for extremity AVMs.[16] Conservative management, including compression therapy, analgesia, and close observation, is reserved for small, quiescent, or asymptomatic lesions (Schobinger stage I).[14,16] Interventional therapy is indicated in rapidly progressive lesions, those causing pain, bleeding, ulceration, functional impairment, or systemic complications such as high-output cardiac failure[16,17]. Given the tendency of AVM to grow and recur, early and aggressive treatment is generally recommended, once clinical progression is established, even in younger patients, before the point of no return is reached.[8,16] However, the treatment itself is a major challenge, due to the high rate of failure and recurrence.[8,16] Thus, the primary and rational goal of therapy is symptom amelioration, preservation of function, and prevention of irreversible tissue damage, rather than guaranteed angiographic cure.[11] Multiple series emphasize that outcomes are best when interventional radiology, vascular surgery, orthopedics, plastic surgery and physical rehabilitation specialists collaborate within a vascular anomalies multidisciplinary team.[17]

Endovascular embolization

Endovascular embolization remains the cornerstone of AVM therapy.[11,17] The target is the nidus, which may be approached transarterially, transvenously, or via direct percutaneous puncture.[2,17] Embolic agents include absolute ethanol, cyanoacrylate adhesives (NBCA), non-adhesive liquid embolic such as Onyx, coils, newer polymer-based agents such as PHIL and Squid, and detachable balloons.[2,17] The choice of agent is lesion-dependent and considers factors including nidus size, venous outflow anatomy, the need to preserve distal perfusion, and the vascular team's experience.[13,16,18] Ethanol achieves permanent endothelial destruction, but carries a risk of systemic toxicity, and requires careful dosing with anesthetic support.[19] Non-adhesive copolymers allow controlled penetration of the nidus, and are preferred in lesions with complex flow patterns or difficult architecture.[20]

Success varies, and reported series indicate that recurrence remains a challenge.[4,11,13,16] Even technically successful embolization often achieves temporary symptom control, particularly in diffuse lower extremity lesions.[13,16] Recurrence rates are high within the first year, and up to 98% of diffuse AVM may re-expand within five years without subsequent intervention.[11,21] While upper extremity AVMs often respond well, lower limb lesions frequently recur, sometimes requiring amputation, despite a technically successful embolization. This highlights the importance of careful angiographic evaluation, nidus-directed technique, and staged procedures.[17]

Surgical excision

Surgical resection is the most definitive approach when complete excision with negative margins is feasible.[2,13] In practice, many extremity AVM are diffuse, infiltrating critical structures, or associated with bone involvement, which makes surgery technically challenging, and functionally risky.[7,21] Even with maximum resection, recurrence rates of 8-9% are reported, particularly in diffuse lesions.[16] Surgery alone carries high risks of blood loss, neurovascular injury, and postoperative morbidity.[2] Multidisciplinary approach and a staged hybrid strategy, combining embolization followed by surgery within 72 hours optimize outcomes by reducing intraoperative bleeding and improving the likelihood of complete resection.[11,17] Reconstruction using local flaps, skin grafts, or free tissue transfer is often necessary to restore both function and form.[2]

Sclerotherapy with sodium tetradecyl sulfate has also been used for low-flow AVM.[22] Pharmacologic agents, particularly mTOR inhibitors, like sirolimus, have emerged as adjuncts for unresectable or recurrent AVM, offering symptom reduction and lesion stabilization in selected cases, although their efficacy remains under investigation.[22]

The role of limb amputation

Major limb amputation remains a legitime, last-resort option for advanced, multifocal, diffuse or functionally devastated extremity AVM (Schobinger stage III-IV).[8] Indications include intractable pain, progressive tissue necrosis, non-healing ulcers, recurrent infections, hemorrhage, ischemia, severe deformity, and, rarely, refractory high-output cardiac failure.[8,23,24] Moreover, it is the ultimate treatment option for cases refractory to multiple embolization/surgical attempts, or the only practical solution when the limb has become severely hypertrophic or deformed and can no longer be considered as functional.[8,23] Finally, amputation is urgent and can be life-saving, when there is major hemorrhage or progressive high-output cardiac failure, unresponsive to other treatments.[8,24] The level of amputation depends greatly on the extent of the AVM, distal tissue viability and functional assessment.[2,8]

It is estimated that up to 22% of AVM patients with advanced Stage III or IV disease may end up needing major amputation, and some studies have shown that even patients with technically successful embolization can undergo amputation within the following years, due to recurrence, particularly in lower extremity AVMs.[21,24,25] According to a large retrospective review of 993 patients with extremity AVM, the median interval from first intervention to amputation was approximately 10 years.[24] Contemporary series emphasize that amputation is reserved only for cases in which less-radical strategies cannot safely or reasonably control symptoms and complications.[22] From an ethical perspective, the decision to amputate should be viewed not as therapeutic failure, but as a legitimate endpoint of disease management when limb salvage no longer serves the patient's best interest.[8,22] Prolonged attempts at salvage in the face of progressive pain, infection, or bleeding can lead to cumulative morbidity, delayed rehabilitation, and psychological exhaustion.[8] Thus, a timely and well-executed amputation in appropriate cases may restore dignity, autonomy, and quality of life, and provide superior long-term outcomes compared to repeated unsuccessful limb salvage procedures.[8]

Amputation carries distinct perioperative and longer-term risks in the AVM population.[2,8] Intraoperative hemorrhage is the principal technical hazard, because vascular malformations often have large, low-resistance channels and thin-walled dilated veins, that will not respond to standard vascular control measures.[24-26] Preoperative planning, pre-amputation angiographic mapping, use of tourniquet, and selective embolization of feeding or outflow vessels can reduce bleeding risk, if time and resources allow; some teams perform pre-operative staged embolization (or proximal ligation) within 24-72 hours before surgery, specifically to lower intraoperative blood loss.[17,18,22,27] In emergent scenarios, such as uncontrollable hemorrhage, tourniquet application, rapid proximal control, and decisive amputation are often required to save life.[23]

Post-amputation problems include delayed wound healing or stump breakdown (particularly where prior radiation or repeated interventions have compromised local tissues), persistent or recurrent AVM at the margin if nidus elements remain, and the usual long-term challenges of phantom limb pain and prosthetic rehabilitation.[8,21,28] Thus, informed consent, preoperative psychological counselling and psychological support are essential components of care.[17] Patients should be fully apprised of the risks, benefits, and alternatives to amputation, and a plan for early prosthetic fitting and rehabilitation should be in place whenever feasible to accelerate functional recovery and to improve quality of life.[17,29,30] Therefore, a multidisciplinary, evidence-based, and patient-centered approach is ideal for sharing the burden of this difficult decision-making process.[17]

Postoperative amputation outcomes are described in small series and case reports, but are generally favorable when amputation is appropriately indicated, and when postoperative rehabilitation is well supported.[24-28] Studies have shown that most patients experience relief from pain, resolution of recurrent bleeding or infection, and improved quality of life.[24-28] Early prosthetic rehabilitation results in good ambulation, and is associated with better functional recovery and independence, and eventual return to daily activities.[29] This is even more favorable in patients receiving timely prosthetic rehabilitation, especially after distal limb amputations (transtibial or transradial).[29]

Regarding quality of life, most studies report improved quality of life and functionality post-amputation, particularly when coupled with prosthetic rehabilitation and psychological support.[29-31] In a multicenter series, patients undergoing amputation for advanced lower limb AVM reported mean pain scores reduced by more than 70%, with 85% achieving satisfactory prosthetic use and significant improvement in quality of life at one year.[32] Similarly, another study found that most patients who underwent below-knee amputation achieved full mobility and independence, while those with more proximal amputations required adaptive aids but still expressed high satisfaction.[33] Thus, multidisciplinary care with psychological support is essential for optimal long-term outcomes.[17] Finally, systematic long-term follow-up is necessary both to monitor for stump complications, and to provide ongoing prosthetic adjustments, psychological evaluation, and pain management, including treatment for phantom limb pain when it arises.[7,17]

Future directions

Despite advances in imaging, embolic agents, hybrid procedures, and adjunctive pharmacologic therapy, substantial gaps in the literature remain. Most published data derive from retrospective single-center studies with heterogeneous outcome definitions. Prospective multi-institutional registries with standardized imaging, staging, outcome metrics, and long-term follow-up are needed to identify predictors of durable response, refine treatment algorithms, and better define the role of amputation in contemporary practice. Additionally, molecular and genetic research may clarify the pathophysiology of AVM and guide the development of targeted therapies.

CONCLUSION

Extremity AVM are rare, biologically active lesions with a po-

tential for progressive local destruction and systemic complications. Management requires a nuanced, multidisciplinary approach. Endovascular nidus-directed embolization, staged or combined with surgical excision, remains central to treatment, with the primary goal of symptom control and functional preservation. Amputation retains a critical, last-resort role for lesions that are refractory to other modalities or life-threatening, providing substantial relief, functional recovery, and improved quality of life, when performed in a controlled, multidisciplinary setting. In all cases, candid patient counselling, comprehensive preoperative planning (including angiographic mapping and consideration of preoperative embolization), perioperative hemodynamic support, and structured postoperative rehabilitation and psychosocial support are essential to optimize outcomes. Future prospective multi-institutional research with standardized definitions and long follow-up is needed to refine indications and to improve prognostication so that the right therapy can be chosen at the right time.

REFERENCES

1 ISSVA Classification of Vascular Anomalies ©2025 International Society for the Study of Vascular Anomalies Available at " https://www.issva.org/classification" Accessed October 09, 2025.

2 Lee BB, Laredo J, Sidawy AN. Congenital Vascular Malformations: General Considerations. In: Sidawy AN, Perler BA, eds. Rutherford's Vascular Surgery and Endovascular Therapy, 10th ed. Philadelphia: Saunders Elsevier, 2023.

3 Schimmel K, Ali MK, Tan SY, et al. Arteriovenous Malformations-Current Understanding of the Pathogenesis with Implications for Treatment. Int J Mol Sci. 2021 Aug 21;22:9037.

4 Park KB, Do YS, Kim DI, et al. Endovascular treatment results and risk factors for complications of body and extremity arteriovenous malformations. J Vasc Surg. 2019 Apr;69:1207-1218.

5 Pinheiro M, Carreira M, Rocha-Neves J. Management of the upper limb arteriovenous malformations. Port J Card Thorac Vasc Surg. 2022;29:45-51.

6 Tasnadi G. Epidemiology and etiology of congenital vascular malformations. Semin Vasc Surg. 1993;6:200-3.

7 Lee BB, Lardeo J, Neville R. Arterio-venous malformation: how much do we know? Phlebology. 2009;24:193-200.

8 Lee BB. Can 'amputation' be justified for arteriovenous-shunting malformations? Phlebology. 202035:445-6.

9 Weinsheimer S, Kim H, Pawlikowska L, et al. EPHB4 gene polymorphisms and risk of intracranial hemorrhage in patients with brain arteriovenous malformations. Circ Cardiovasc Genet. 2009;2:476-82.

10 Szilagyi DE, Smith RF, Elliott JP, Hageman JH. Congenital arteriovenous anomalies of the limbs. Arch Surg. 1976;111:423-9.

11 Lee BB, Baumgartner I, Berlien HP, et al; International Union of Angiology. Consensus Document of the International Union of Angiology (IUA)-2013. Current concept on the management of arterio-venous management. Int Angiol. 2013 Feb;32:9-36.

12 Schmidt VF, Masthoff M, Czihal M, et al. Imaging of peripheral vascular malformations - current concepts and future perspectives. Mol Cell Pediatr. 2021 Dec 7;8:19.

13 Hyodoh H, Hori M, Akiba H, Tamakawa M, Hyodoh K, Hareyama M. Peripheral vascular malformations: imaging, treatment approaches, and therapeutic issues. Radiographics. 2005 Oct;25 Suppl 1:S159-71.

14 Lee BB, Antignani PL, Baraldini V, et al. ISVI-IUA consensus document diagnostic guidelines of vascular anomalies: vascular malformations and hemangiomas. Int Angiol. 2015;34:333-74.

15 Sofocleous CT, Rosen RJ, Raskin K, Fioole B, Hofstee DJ. Congenital vascular malformations in the hand and forearm. J Endovasc Ther. 2001;8:484-94.

16 Shiraishi M, Narushima M, Banda CH, et al. Treatment Effectiveness and Recurrence of Extracranial Arteriovenous Malformations Following Surgical Operations: A 15-Year Retrospective Cohort Study. Ann Plast Surg. 2024 Jun 1;92:688-693.

17 Lee BB, Do YS, Yakes W, Kim DI, Mattassi R, Hyon WS. Management of arteriovenous malformations: a multidisciplinary approach. J Vasc Surg. 2004;39:590-600.

18 Osuga K, Yamamoto K, Higashihara H, et al. Endovascular and Percutaneous Embolotherapy for the Body and Extremity Arteriovenous Malformations. Interv Radiol (Higashimatsuyama). 2023 Jun 3;8:36-48.

19 Nassiri N, Cirillo-Penn NC, Crystal DT. Direct stick embolization of extremity arteriovenous malformations with ethylene vinyl alcohol copolymer. J Vasc Surg. 2017 Apr;65:1223-1228.

20 Saeed Kilani M, Lepennec V, Petit P, et al. Embolization of peripheral high-flow arteriovenous malformations with Onyx. Diagn Interv Imaging. 2017 Mar;98:217-226.

21 Liu AS, Mulliken JB, Zurakowski D, Fishman SJ, Greene AK. Extracranial arteriovenous malformations: natural progression and recurrence after treatment. Plast Reconstr Surg. 2010;125:1185-94.

22 Seront E, Hermans C, Boon LM, Vikkula M. Targeted treatments for vascular malformations: current state of the art. J Thromb Haemost. 2024 Nov;22:2961-2975.

23 Kim Y. Indications for amputation in patients with arterio-venous malformations. In: Lee BB, Gloviczki P, Blei F, eds. Vascular Malformations: Advances and Controversies in Contemporary Management, 1st ed. CRC press, 2019.

24 Conway AM, Qato K, Nguyen Tran NT, et al. Major Limb Amputations in Patients with Congenital Vascular Malformations. Ann Vasc Surg. 2020;68:201-8.

25 Lee YD, Lee SY, Kim DI, et al. Multidisciplinary approach to hand arteriovenous malformations: Treatment strategies and clinical outcomes - insights from a 25-year expe-

rience at a single vascular anomalies center. J Vasc Surg Venous Lymphat Disord. 2025;13:101964.

26 Lee YO, Hong SW. Treatment of large arteriovenous malformation in right lower limb. Korean J Thorac Cardiovasc Surg. 2014 Feb;47:66-70.

27 Park UJ, Do YS, Park KB, et al. Treatment of arteriovenous malformations involving the hand. Ann Vasc Surg. 2012 Jul;26:643-8.

28 Jupiter DC, LaFontaine J, Barshes N, Wukich DK, Shibuya N. Transmetatarsal and Minor Amputation Versus Major Leg Amputation: 30-Day Readmissions, Reamputations, and Complications. J Foot Ankle Surg. 2020 May-Jun;59:484-490.

29 Esquenazi A. Amputation rehabilitation and prosthetic restoration. From surgery to community reintegration. Disabil Rehabil. 2004;26:831-6.

30 Nguyen HL, Bonadurer GF 3rd, Tollefson MM. Vascular Malformations and Health-Related Quality of Life: A Systematic Review and Meta-analysis. JAMA Dermatol. 2018;154:661-9.

31 He B, Sun MS, Liu JW, Nie QQ, Fan XQ, Liu P. Major Limb Amputation in Parkes-Weber Syndrome With Refractory Ulceration: A Case Report and Literature Review. Int J Low Extrem Wounds. 2023 Mar;22:168-173.

32 Linden E, Peers K, Kiekens C. Amputation for chronic pain and/or functional impairment of a limb. J Rehabil Med. 2021 Nov 7;53:jrm00237.

33 Webster JB, Hakimi KN, Williams RM, Turner AP, Norvell DC, Czerniecki JM. Prosthetic fitting, use, and satisfaction following lower-limb amputation: A prospective study. J Rehabil Res Dev. 2012;49:1453-1504.

Perspectives of Vascular Surgery in Greece: Bridging Local Realities with Global Trends

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Abstract:
The challenges that a modern vascular surgeon must face in Greece have been well established. These challenges refer not only to proper education and training as well as the future professional perspectives. This review written by medical students aims to concentrate data and information on this issue and produce useful conclusions for the future vascular surgeons.

INTRODUCTION

The purpose of this review is to succinctly present the opportunities and the existing training programs in the specialty of vascular surgery, as they are formed in the cradle of the vast technological revolution and scientific progress we witness in the present, all from the perspective of graduate students.

We are a group of sixth year medical students of the National and Kapodistrian University of Athens, very intrigued and interested in the specialty of vascular surgery, who had the luck and privilege to complete a three moth elective course in the Vascular Unit of the 1st Department of Preparatory Surgery in "Hippoctateion" General Hospital of Athens. As a result, the interest was born to study the existing literature concerning the curriculum of the specialty in the pioneer countries in medicine, the distribution of vascular surgeons worldwide, their work satisfaction and, last but not least, the remodeling of the specialty the preceding years through the effect of technology and the future it creates for a vascular surgeon. We strongly believe that our research will be of paramount importance for our personal choice of specialty and enlighten the most suitable professional and educational road for each one.

BASIC TRAINING IN USA AND EUROPE

To present the training programs provided to a new doctor who opts for the residency of vascular surgery, we have to take a quick look back to its past in the United States. Before the period of 1960-1982 there was not specific training in vascular surgery, and the relevant procedures were a part of the cardiothoracic and general surgery. A better touch with vascular surgery practices was possible through apprenticeships with early pioneers. It was not until 1977 that the American Board of Surgery agreed to the creation of the subspecialty of vascular surgery and 1982 that the first officially qualified surgeons existed. Additionally, in the following period of 1983-2006, the credentials of a vascular surgeon required a one year dedicated vascular training, after the completion of an accredited general surgery residency (5-1 pathway), or after an accredited cardiothoracic surgery program, if the number of the vascular cases was deemed adequate. In the following years, an additional year was added, primarily for research (5-2). By that time, general and vascular surgery did not have distinct boundaries, despite the fellowship. General surgery thought to prepare surgeons for simple vascular operations, whereas the fellowship prepared for more complex ones. Still the public was unable to distinguish between a general and a vascular surgeon. The great imbalance between general and vascular training in addition to the rapidly increasing endovascular landscape, led to the creation of the specialty of vascular surgery in 2006 and novel educational programs. Currently, there are two programs, leading to dual board certification, the Independent Vascular Surgery Fellowship, consisting of 5 years of general surgery and 2 years of vascular surgery fellowship (5-2, duration 7 years) and the Early Specialization Program, consisting of the combination 4-2 (duration 6 years) accordingly. Lastly, the Integrated Vascular Residency program exists with a combination of 0-5 (5 years duration) accordingly, leading to vascular certification alone[1].

On the other side of the Atlantic, specialty training in vascular surgery in Europe varies significantly by country, but it has been increasingly standardized under the influence of the European Union of Medical Specialists (UEMS) and the European Board of Vascular Surgery (EBVS). The duration is usually 5-6 years, depending on the country, with a core surgical

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training of 1-2 years and a dedicated vascular surgery training of 3-4 years[2].

Specifically, in Greece, the total duration of residency training in vascular surgery is seven years, comprising two years in general surgery, followed by five years dedicated to the core specialty. There are seven university-affiliated hospitals, along with several other accredited institutions nationwide, which experience significant demand for residency positions, due to the high standards of healthcare and education provided. Trainees receive comprehensive exposure to both open surgical and endovascular techniques. Moreover, vascular surgeons have access to a wide range of postgraduate programs, many of which are specifically tailored to vascular surgery. These programs encompass advanced training in endovascular techniques, management and treatment of vascular surgery emergencies, vascular access for patients with end-stage renal disease, the application of vascular ultrasound in diagnosis and clinical management, as well as thrombosis and antithrombotic therapy. The academic career can be further enriched through additional postgraduate education (fellowship) or the pursuit of a doctoral degree (PhD), either within Greece or internationally[3].

WORK SATISFACTION

When analyzing the general opportunities of a medical specialty, one must take into close consideration the degree of work satisfaction the physicians have. Unfortunately, according to a U.S. study including 14 surgical specialties, vascular surgeons have the second highest burnout incidence and the lowest degree of career satisfaction. At this day and age, burnout is a work-related syndrome increasingly affecting physicians and their ability to treat their patients. It has been linked to medical errors, decreased patient satisfaction and lower career longevity. The Society of Vascular Surgery Wellness Task Force conducted a survey which included 872 active vascular surgeons, using the Maslach Burnout Inventory. The percentages were concerning, with 41% of them experiencing at least one symptom of burnout, 37% having symptoms of depression last month, and 8% having considered suicide in the last 12 months. The survey showed that the factors significantly associated with burnout symptoms were the clinic work hours, the on-call frequency, the electronic medical record and documentation requirements, the work-home conflict and, last, the work-related physical pain[4]. Another survey was conducted relating to the physical pain of vascular surgeons6. Of the 263 total participants, 87% operate 3 or more times per week and 4 or more hours per day, while 48.4 % wear led garments daily. Pain was present in 74.7% of surgeons before beginning an operation, in 92.3% during an operation, and in 96.8% at completion. Professional satisfaction among vascular surgeons was linked to lower pain levels. Surgeons who reported being satisfied with their profession experienced less pain both before and two days after performing surgery. Despite the previous discouraging data, undoubtedly, the progress of the technology and the revolution of the artificial intelligence with the databases created, will aid the vascular surgeon both in the operating room, with less energy consuming instruments, and out, with less time-consuming documentation procedures.[4,5]

Comparative Distribution of Vascular Surgeons Across Five High-Income Countries

Substantial international heterogeneity exists in the density and distribution of vascular surgeons, reflecting differences in national workforce planning, postgraduate training output, and models of vascular care delivery. An analysis of five high-income countries—Greece, France, Germany, the United Kingdom, and the United States—highlights marked disparities in vascular surgeon availability.

Greece exhibits the highest workforce density, with 3.11 vascular surgeons per 100,000 inhabitants and a patient-to-surgeon ratio of approximately 1:32,150[1]. Germany also demonstrates relatively high capacity, with 1.89 surgeons per 100,000 and one surgeon serving every ~52,869 individuals[2]. The United States reports 1.14 vascular surgeons per 100,000 population, corresponding to a ratio of approximately 1:88,072[3].

In contrast, France and the United Kingdom maintain considerably lower vascular surgeon densities. France records 0.73 surgeons per 100,000, with each vascular surgeon responsible for approximately 137,712 individuals[4]. The United Kingdom follows closely with 0.77 surgeons per 100,000 and a surgeon-to-population ratio of 1:129,345[5].

A consideration arising from the observed disparities in vascular surgeon density pertains to the career decision-making process of medical students and junior doctors. In countries where the ratio of vascular surgeons per 100,000 population is disproportionately high—such as Greece—there may be growing concern among medical trainees regarding future job market saturation, limited operative exposure during training, and constrained long-term career prospects. The perception of an oversupplied specialty can deter new graduates from selecting vascular surgery as a preferred career path, regardless of interest or aptitude. This phenomenon may be further compounded by institutional bottlenecks in academic advancement or public sector employment. Consequently, highly qualified candidates may increasingly explore residency or fellowship opportunities abroad, particularly in health systems where the demand for vascular specialists is greater and long-term workforce planning is more balanced. Such migration trends could lead to a paradoxical scenario in which an initially oversupplied domestic workforce drives talent out of the country, further complicating national retention and training policies. Addressing these issues requires not only regulation of training entry points but also alignment of national workforce planning with actual procedural and population needs. (**Table 1**)

Over the past 15 years, vascular surgery worldwide has undergone a marked shift toward minimally invasive and endovascular management. For example, U.S. Medicare data show open abdominal aortic aneurysm (AAA) repairs fell by 76% from 2003 to 2013 while EVAR volumes nearly doubled[11]. Innovations such as fenestrated and branched stent grafts have

Table 1. International Comparison of Vascular Surgeon Density and Coverage Ratios

Country	Number of Vascular Surgeons	Surgeons per 100,000 Population	Population per Surgeon
Greece[6]	326	**3.11**	**~32,150**
France[9]	472	**0.73**	**~137,712**
Germany[7]	1,574	**1.89**	**~52,869**
United Kingdom[10]	518	**0.77**	**~129,345**
United States[8]	3,908	**1.14**	**~88,072**

expanded endovascular treatment to complex aortic and peripheral lesions, aided by advanced imaging (CT/MR angiography, duplex ultrasound) and hybrid operating rooms. Vascular residency slots in the U.S. grew from 161 to 202 between 2012 and 2022 and integrated 5year programs more than doubled from 41 to 84 positions, reflecting emphasis on endovascular skills[12]. In Greece, vascular surgery was established as an independent specialty in 1989 and early incorporated endovascular training. Greek vascular surgeons now perform all aortic and peripheral endovascular procedure. The 2009 financial crisis strained Greece's health budget, however, highlighting the high cost of new endovascular devices and challenging widespread adoption of all new technologies. Overall, the past decade has seen endovascular and percutaneous approaches become the main choice for many vascular conditions, with open surgery reserved increasingly for anatomically complex cases[11,13].

Looking ahead, the field of vascular surgery is expected to undergo further sub-specialization, driven by advances in technology, increasing disease complexity, and evolving healthcare demands. Academic and tertiary care centers are increasingly organizing clinical services around specific pathologies or patient populations. For example, dedicated limb-salvage clinics for patients with chronic limb threatening ischemia, particularly in the context of diabetes—are now recommended by the Global Vascular Guidelines as part of a multidisciplinary strategy to improve limb preservation rates and reduce amputation risk[14]. In parallel, specialized fellowships and focused training pathways in areas such as complex aortic pathology, advanced peripheral arterial disease, venous disorders, and hemodialysis vascular access are emerging in both North America and parts of Europe[15]. These trends reflect a broader shift toward precision care and technical specialization.

At the same time, the role of classic open vascular surgery is becoming more concentrated within the high-volume centers. In the United States, for instance, vascular surgery trainees now perform a limited number of open abdominal aortic aneurysm (AAA) repairs, typically between five to ten over the course of their residency, a consequence of the increasing preference for endovascular aneurysm repair (EVAR)[16]. Nevertheless, data from major academic hospitals indicate that approximately one-third of AAA cases are still managed with open repair, particularly in anatomically complex or younger patients, with some centers reporting 20 to 30 open AAA procedures annually[17]. As leading experts have emphasized, "open aortic surgery is still necessary in a large number of patients," underscoring the importance of preserving open surgical skills[18]. In Greece, as in many other countries, it is anticipated that complex open procedures will be increasingly centralized in specialized referral centers, while interventional and endovascular subspecialties continue to expand and evolve. The future direction of vascular surgery is anticipated to follow two main trends: a steady advancement of minimally invasive, image-assisted procedures, and the continued necessity for open surgical capabilities in particular cases and specialized institutions, according to both worldwide guidelines and the specific requirements of regional healthcare systems.

USE OF MODERN TECHNOLOGIES IN VASCULAR SURGERY

At the beginning of the 20th century, Carrel and Leriche developed the technique of vascular anastomoses, marking the birth of vascular surgery as a distinct specialty. The next revolutionary shift came in the 1990s with the development of endovascular interventions, while today, numerous new techniques complement and improve the field of vascular surgery. Below, we will analyze the main technologies used today, such as hybrid operating rooms, intraoperative angiography (C-Arm), 3D fusion imaging, artificial intelligence, robotic surgery and the application of regenerative medicine in vascular surgery.[19]

A) Hybrid Operating Rooms

In the past two decades, there has been a significant shift from open surgeries to percutaneous interventions. However, neither the classic operating room nor the conventional angiography suite alone, allow the simultaneous performance of both approaches. Hybrid operating rooms offer a solution by combining a standard operating theater with a fixed, high-end angiography system, enabling the integration of open and endovascular techniques simultaneously, in a sterile environment. This approach reduces overall operative time, the need for follow-up procedures, and the risk of infection. Nevertheless, establishing a hybrid OR requires significant financial investment and appropriately trained surgeons to make optimal use of this technology.

B) Intraoperative Angiography

Modern angiography systems (C-Arm) provide high-definition fluoroscopic guidance in real-time during endovascular procedures, allowing precise placement of stents, catheters, and other devices while reducing complications. In a study of 155 procedures, it was found that in 27 or 17% of cases, complications were detected that could be corrected. These included technical errors in suturing, platelet and atherosclerotic debris accumulation, or unrecognized lesions in the runoff.

These findings justify the routine use of intraoperative angiography as a complementary technique in vascular surgery.[20]

C) 3D Fusion Imaging

3D Fusion Imaging technology allows the integration of preoperative imaging data (CT, MRI) with intraoperative imaging, providing the surgeon with a "navigation map" of the patient's vascular anatomy. Initially, a 3D model is created from the preoperative imaging (usually a CT scan). This model is then used to plan the surgery, placing specific markers and storing C-arm angles for intraoperative guidance. During the procedure, a cone-beam CT is performed, and the 3D model is aligned with the patient's anatomy on the table, for real-time navigation. Fusion imaging has been shown in various studies to reduce radiation dose, contrast usage, and procedure time. In the future, fusion models may account for vessel deformation caused by rigid wires and devices, and user-dependent steps may become more automated. In its current form, fusion imaging has already proven to be an essential component in the planning and success of complex endovascular interventions.[21]

D) Artificial Intelligence in Vascular Surgery

Artificial intelligence (AI) is emerging as a transformative tool in vascular surgery, offering the ability to analyze vast amounts of clinical and imaging data, recognize patterns, and predict outcomes in ways that surpass human capabilities. AI technologies, including machine learning, natural language processing, artificial neural networks, and computer vision, are being explored to assist vascular surgeons in diagnostic imaging interpretation, risk stratification, perioperative management, and outcome prediction. By integrating AI into clinical workflows, vascular surgeons can reduce cognitive load, optimize decision-making, and improve patient-centered care. Although most AI applications in vascular surgery remain in the translational research phase, early studies demonstrate their potential in enhancing non-invasive diagnostics, such as the detection of peripheral arterial disease, and providing real-time support during complex procedures. As the field evolves, addressing technical challenges, data quality, algorithm bias, and ethical considerations will be critical to ensure safe and effective AI integration into vascular practice.[21]

E) Robotic Vascular Surgery

With the assistance of AI, robotic surgery represents a highly promising new trend, both for vascular and other surgical procedures. It allows the precise manipulation of micro-instruments with sub-millimeter accuracy, reduces radiation exposure for the surgeon, provides enhanced visualization through 3D, high-resolution images of the operative field, and improves ergonomics by enabling the surgeon to operate from a comfortable seated position. However, the absence of haptic feedback may lead to longer operative times, extended learning curves, and an increased risk of surgical errors. Furthermore, robotic systems can apply forces that exceed tissue tolerances, potentially creating a hazardous environment in the absence of haptic feedback.[22]

F) Regenerative Medicine and Tissue Engineering

Perhaps the most innovative and promising trend in vascular surgery is the application of regenerative medicine and tissue engineering. Research in this field focuses on finding ways to repair or replace damaged blood vessels using the patient's own cells. This may involve creating new vessels in the laboratory or stimulating the body's natural regenerative mechanisms to rebuild tissue on its own. Although these techniques are still in their early stages of development, they offer exciting prospects for creating more durable and biocompatible grafts, overcoming the limitations of synthetic materials.[23]

In conclusion, recent years have seen the emergence of numerous promising new technologies that offer fresh perspectives for surgery as we know it. These technologies enable greater precision, shorter operative times, fewer complications, and a more personalized approach to medicine — whether through tissue regeneration using the patient's own body or via precise micro-adjustments tailored to each patient's specific needs. However, all these advancements come at a cost, both in terms of financial investment and the need for specialized surgical training. In our country, unfortunately, the public sector often lacks the resources to acquire such advanced technologies, while in the private sector; access is frequently limited to patients of higher socioeconomic status, creating disparities in healthcare provision.

PERSPECTIVES OF A VASCULAR SURGEON IN GREECE

Vascular surgery, a highly specialized and demanding field, requires extensive training, technical expertise, and the ability to manage complex and often life-threatening conditions. Despite these requirements, remuneration for vascular surgeons in Greece remains disproportionately low. Specialists employed in public hospitals typically earn between €1,200 and €1,800 per month, a figure that fails to correspond with the responsibilities and intensity of their clinical duties. In stark contrast, vascular surgeons in other European countries, such as the United Kingdom and Germany, earn significantly higher salaries—averaging approximately £99,700 (€116,000) annually in the UK and exceeding €7,300 per month in Germany. This pronounced wage disparity contributes to growing professional dissatisfaction and is a key factor behind the emigration of Greek medical professionals seeking more favorable working conditions abroad. Ultimately, such economic imbalances not only devalue the profession but also pose a serious threat to the long-term viability and quality of vascular surgical care within the Greek healthcare system.

Despite the current economic limitations, vascular surgeons in Greece possess considerable potential to contribute meaningfully to both national and international healthcare. Greek medical education is rigorous, and surgical training—particularly in vascular surgery—is known for its high standards and emphasis on clinical excellence. Furthermore, Greek surgeons often demonstrate exceptional adaptability and skill, having gained experience in resource-constrained settings that demand efficiency and innovation. With access to improved infrastructure, research opportunities, and finan-

cial support, vascular surgeons in Greece could play a pivotal role in advancing minimally invasive techniques, developing public health strategies for vascular disease prevention, and participating more actively in European collaborative studies. Investing in this specialty not only strengthens the healthcare system but also helps retain talented professionals who are currently compelled to seek better prospects abroad.[24-27]

CONCLUSION

Vascular surgery stands at the crossroads of tradition and innovation—rooted in the legacy of open procedures and rapidly evolving through minimally invasive technologies and subspecialized approaches. As demonstrated in this review, the field continues to transform in response to emerging challenges, technological progress, and shifting patient demographics. While disparities in training structures, workforce distribution, and compensation—particularly in Greece—pose substantial obstacles, they also illuminate opportunities for reform and advancement. Greek vascular surgeons, despite facing systemic limitations, are uniquely positioned to contribute to the global vascular community through their adaptability, strong clinical foundation, and potential for innovation. Addressing structural weaknesses in training, remuneration, and infrastructure will not only enhance local care delivery but also help to retain medical talent and align Greek vascular surgery with international standards. Ultimately, the future of the specialty relies on a balance between embracing technological breakthroughs and safeguarding the fundamental principles of surgical excellence, access, and equity.

REFERENCES

1 Sidawy AN, Perler BA, Rutherford RB, et al. Vascular surgery training in the United States: A half-century of evolution.

2 Alpagut U, Ricco JB, Setacci C, et al. Education in vascular surgery: Critical issues around the globe—training and qualification in vascular surgery in Europe.

3 Christiansen J, Jakobsen J, Madsen MM, et al. A cross-sectional national study of burnout and psychosocial work environment in vascular surgery in Denmark.

4 Hersey AE, Osborne NH, Lin PH, et al. Vascular surgeon wellness and burnout: A report from the Society for Vascular Surgery Wellness Task Force.

5 Smeds MR, Chang TT, Blair LK, et al. Physical discomfort, professional satisfaction, and burnout in vascular surgeons.

6 Hellenic Statistical Authority. Available from: https://www.statistics.gr/el/home

7 Berufsverband der Deutschen Chirurgie e.V. Available from: https://www.bdc.de

8 The American Board of Surgery. Available from: https://www.absurgery.org/

9 Société de Chirurgie Vasculaire et Endovasculaire de Langue Française. Available from: https://www.vasculaire.com/

10 Kiernan A, Boland F, Harkin DW, et al. Vascular Surgery Workforce: Evaluation and Estimation of Future Demand in the United Kingdom. *Ann Vasc Surg.* 2022; PMID: 36126835.

11 Suckow BD, Goodney PP, Columbo JA, et al. National trends in open surgical, endovascular, and branched-fenestrated endovascular aortic aneurysm repair in Medicare patients. *J Vasc Surg.* 2018;67(6):1690-1697.e1. Jayroe H, Weaver L, Velazquez G, et al. Vascular Surgery Training Positions and Applicant 10-Year Trends with Consideration for Further Expansion. *Ann Vasc Surg.* 2023;95:291-296.

12 ResearchGate. Vascular Surgery in Greece in the Wake of Financial Crisis. Available from: https://www.researchgate.net/publication/309333101

13 Nickinson ATO, Dimitrova J, Houghton JSM, et al. Does the Introduction of a Vascular Limb Salvage Service Improve One Year Amputation Outcomes for Patients with Chronic Limb-Threatening Ischaemia? *Eur J Vasc Endovasc Surg.* 2021;61(4):612-619.

14 Lok CE, Yuo T, Lee T, et al. Hemodialysis Vascular Access: Core Curriculum 2025. *Am J Kidney Dis.* 2025;85(2):236-252.

15 Smith ME, Andraska EA, Sutzko DC, et al. The decline of open abdominal aortic aneurysm surgery among individual training programs and vascular surgery trainees. *J Vasc Surg.* 2020;71(4):1371-1377.

16 Wanhainen A, Van Herzeele I, Bastos Goncalves F, et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2024 Clinical Practice Guidelines on the Management of Abdominal Aorto-Iliac Artery Aneurysms. *Eur J Vasc Endovasc Surg.* 2024;67(2):192-331.

17 Cleveland Clinic. Analysis Shows Dramatic Declines in Open Vascular Surgery Training in U.S. Available from: https://consultqd.clevelandclinic.org/analysis-shows-dramatic-declines-in-open-vascular-surgery-training-in-u-s

18 Carrel A. Les anastomoses vasculaires et leur technique opératoire. *Surgery (Experimental)*. 1904.

19 Dardik II, Ibrahim IM, Sprayregen S, et al. Routine intraoperative angiography: An essential adjunct in vascular surgery. *Arch Surg.* 1975;110(2):184-190.

20 Jones DW, Stangenberg L, Swerdlow NJ, et al. Image fusion and 3-dimensional roadmapping in endovascular surgery. *Ann Vasc Surg.* 2018;52:302-311.

21 Antoniou GA, Riga CV, Mayer EK, et al. Clinical applications of robotic technology in vascular and endovascular surgery. *J Vasc Surg.* 2011;53(2):493-499.

22 Evans CE, Iruela-Arispe ML, Zhao YY, et al. Mechanisms of endothelial regeneration and vascular repair and their application to regenerative medicine. *Am J Pathol.* 2021;191(1):52-65.

23 Organization for Economic Co-operation and Development (OECD). Health statistics 2024: Physicians' remuneration by country. (https://stats.oecd.org/index.aspx?DataSetCode=HEALTH_STAT)

24 World Health Organization. Global health workforce statistics. (https://www.who.int/data/gho/data/themes/topics/health-workforce)

25 Pavlopoulos V, Polyzos N, et al. Medical brain drain in Greece: Causes and impacts. *Health Policy.* 2020;124(10):1103-1110.

26 European Society for Vascular Surgery. Workforce and remuneration of vascular surgeons across Europe. (https://www.esvs.org/news-events/publications/)

Single-stage open surgical management of symptomatic abdominal aortic aneurysm and colorectal carcinoma using nais technique: a case report

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Abstract:

Background: The occurrence of simultaneous malignant diseases and abdominal aortic aneurysm (AAA) is reported to be around 5.4-6.7%. Surgical intervention for abdominal cancer can elevate the risk of AAA rupture and infection. Here, we present a case report detailing a single-stage open surgical approach for the treatment of a symptomatic abdominal aortic aneurysm and an advanced colorectal carcinoma using the NAIS technique.

Case Report: A 71-year-old patient with a 7cm symptomatic infrarenal AAA and ileus due to advanced colorectal carcinoma was evaluated. The patient also had comorbid conditions, including arterial hypertension, chronic obstructive pulmonary disease, and diabetes mellitus. A CT scan was performed, and due to the unsuitable anatomy of the AAA for endovascular repair, a synchronous open approach was chosen. The first stage involved a total colectomy with ileo-rectal anastomosis. Subsequently, AAA resection and aorto-biiliac bypass with the NAIS technique were performed, utilizing bilateral femoral veins as graft material. The patient was discharged on the 8th postoperative day. Follow-up CT scans at the first, second, and fourth year showed no residual tumor formation and a patent graft.

Conclusion: Simultaneous open repair of AAA and concurrent malignant diseases demands meticulous attention to detail, considering the higher cumulative morbidity and mortality associated with single-stage operations. Managing patients with this dual pathology poses a significant surgical challenge, particularly in the absence of a clear consensus in the existing literature.

INTRODUCTION

Concurrent presentation of an abdominal aortic aneurysm (AAA) and colorectal carcinoma is rare, with an observed prevalence between 0.5% and 4% among individuals with AAA.[1] The simultaneous management of both pathologies poses substantial surgical challenges—particularly with respect to determining the optimal sequence of interventions and appropriate vascular reconstruction strategies. We present the case of a septuagenarian male who arrived with an acute abdomen secondary to a symptomatic infrarenal AAA and concurrent ileus attributable to advanced colorectal cancer. Given the aneurysm's unfavorable vascular anatomy, endovascular repair was contraindicated, necessitating an open, synchronous surgical approach. In such contaminated operative fields, achieving vascular control requires careful consideration of diverse revascularization options: aortic ligation with extra-anatomic bypass, in situ cryopreserved allografts, antibiotic-impregnated prostheses, or the neoaortoiliac system (NAIS) reconstruction utilizing autologous femoral veins (FVs)—first described by Clagett et al. in 1993[2]. Herein, we report a single-stage open operation employing NAIS for simultaneous AAA repair and resection of advanced colorectal malignancy.

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CASE DISCUSSION

A 71-year-old man presented to the emergency department following one week of lower back and abdominal pain, which had dramatically worsened over the previous three days. He reported intermittent lower back discomfort during the preceding year but had not undergone any diagnostic evaluation. His medical history included arterial hypertension, chronic obstructive pulmonary disease, and type II diabetes mellitus. On examination, he exhibited signs of peritonitis; laboratory studies showed leukocytosis (20,000/mm^3). Contrast-enhanced computed tomography identified a 7 cm infrarenal AAA and evidence of ileus secondary to advanced colorectal carcinoma. Endovascular exclusion was deemed unfeasible due to anatomical constraints, prompting selection of a synchronous open operative strategy.

Under general anesthesia, bilateral femoral veins were harvested to construct a bifurcated venous conduit. Through a midline laparotomy, proximal aortic control was achieved, followed by aneurysmotomy and proximal anastomosis of the NAIS graft to the infrarenal aortic segment. Distal anastomoses were performed on both common iliac arteries. Following extensive peritoneal lavage, an omental flap was mobilized to envelop the graft. Subsequent oncological resection entailed a total colectomy with anterior rectal excision. The patient was transferred to the intensive care unit postoperatively and discharged on 8th postoperative day. Adjuvant chemotherapy consisted of five cycles of capecitabine. Serial surveillance via CT imaging at 1st, 2nd , 3rd and 4th years post-procedure demonstrated no evidence of residual malignancy and confirmed graft patency.

Surgical Technique

Under general anesthesia, the patient was placed in a supine position. Initial dissection focused on the bilateral femoral triangle for femoral vein (FV) harvesting. Great care was taken to preserve the deep femoral vein and its major tributaries. Approximately 25 cm of FV was harvested from each side to construct a bifurcated autologous conduit.

Following femoral vein harvesting, a midline laparotomy was performed. Extensive adhesiolysis was required due to tumor-related ileus. The infrarenal abdominal aorta and bilateral common iliac arteries were mobilized and controlled proximally and distally. After systemic heparinization, aortic clamping was achieved, and aneurysmotomy was performed. A proximal anastomosis between the aortic neck and the NAIS conduit was constructed using 4-0 polypropylene in a continuous fashion.

The autologous FV graft was configured in a pantaloon shape to create a bifurcated conduit, with distal anastomoses performed to each common iliac artery. Following completion of the vascular reconstruction, the aneurysmal sac was reapproximated over the graft, and the conduit was wrapped with an omental flap to enhance graft protection and reduce infectious risk.

Colorectal resection proceeded with oncologic principles. A total colectomy and anterior rectal resection were performed en bloc. Given the extent of the disease and the contamination risk, a terminal ileostomy was created. Extensive peritoneal lavage concluded the abdominal procedure, and the abdominal wall was closed in layers.

DISCUSSION

The coexistence of an AAA and colorectal carcinoma poses a multifaceted surgical dilemma. While staged interventions may reduce operative complexity, they also carry risks of aneurysm rupture in the interim or progression of malignancy. Conversely, synchronous repair confers the advantage of single-anesthetic exposure but raises concerns over increased morbidity, particularly in contaminated fields.

Historically, staged approaches have dominated management paradigms. However, contemporary evidence supports select use of one-stage procedures in appropriate patients. In our case, anatomical constraints precluded endovascular aneurysm repair (EVAR), and oncologic urgency rendered staged intervention inadvisable.

In situ reconstruction with autologous femoral vein—pioneered by Clagett et al.—offers durable outcomes even in contaminated fields, with reduced infection risk compared to prosthetic materials [3]. The NAIS technique is particularly valuable in infected or potentially septic scenarios where prosthetic use would be contraindicated.[4,8] While technically demanding and time-intensive, NAIS reconstruction eliminates the need for synthetic grafts, has demonstrated long-term patency, and exhibits lower reinfection rates[5,6,8].

Our patient's outcome supports the viability of a synchronous open approach in selected high-risk individuals[4]. Despite the inherent complexity, careful planning, multidisciplinary coordination, and meticulous surgical technique facilitated a favorable recovery[7,9,10]. Long-term follow-up has confirmed both oncologic remission and vascular graft durability.

CONCLUSION

This case highlights the feasibility and effectiveness of a synchronous, single-stage surgical approach to managing concurrent abdominal aortic aneurysm and colorectal carcinoma using neoaortoiliac system (NAIS) reconstruction. In anatomically or oncologically complex cases where endovascular repair is not an option and delayed treatment poses significant risk, autologous in situ reconstruction offers a viable alternative. The use of femoral vein grafts minimizes the risk of graft infection in contaminated surgical fields and achieves satisfactory vascular and oncologic outcomes. This case supports the selective application of NAIS in multidisciplinary surgical management strategies for complex coexisting pathologies.

REFERENCES

1 J. Shalhoub, P. Naughton, N. Lau, J.S. Tsang, C.J. Kelly, A.L. Leahy, N.J.W. Cheshire, A.W. Darzi, P. Ziprin,Concurrent Colorectal Malignancy and Abdominal Aortic Aneurysm: A Multicentre Experience and Review of the Literature,European Journal of Vascular and Endovascular Surgery, Volume 37, Issue 5,2009, Pages 544-556

2 Clagett GP, Bowers BL, Lopez-Viego MA, Rossi MB, Valentine RJ, Myers SI, et al. Creation of a neo-aortoiliac system from lower extremity deep and superficial veins. Ann Surg. 1993;218(3):239-48; discussion 48-9.

3 Chung J, Clagett GP. Neoaortoiliac System (NAIS) procedure for the treatment of the infected aortic graft. Semin Vasc Surg 2011;24:220-226.

4 Chris Klonaris, Nikolaos Patelis, Athanasios Katsargyris, Dimitrios Athanasiadis, Andreas Alexandrou, Theodoros Liakakos, Neoaortoiliac System Procedure to Treat Infected Aortic Grafts, Annals of Vascular Surgery, Volume 44, 2017, Pages 419.e19-419.e25,

5 Fatima J, et al. Treatment and outcomes of aortic endograft infection. J Vasc Surg. 2016;63(2):332-40.

6 Perler BA, et al. Management of infected vascular grafts. Vascular medicine. 2016;21(1):53-60.

7 Davila VJ, Stone W, Duncan AA, Wood E, Jordan WD Jr, Zea N, et al. A multicenter experience with the surgical treatment of infected abdominal aortic endografts. J Vasc Surg 2015;62:877 883.

8 Ali AT, Modrall JG, Hocking J, Valentine RJ, Spencer H, Eidt JF, et al. Long-term results of the treatment of aortic graft infection by in situ replacement with femoral popliteal vein grafts. J Vasc Surg 2009;50:30-39.

9 Nordanstig J, Törngren K, Smidfelt K, Roos H, Langenskiöld M. Deep femoral vein reconstruction of the abdominal aorta and adaptation of the neoaortoiliac system bypass technique in an endovascular era. Vasc Endovascular Surg 2019;53:28-34.

10 Daenens K, Fourneau I, Nevelsteen A. Ten-year experience in autogenous reconstruction with the femoral vein in the treatment of aortofemoral prosthetic infection. Eur J Vasc Endovasc Surg 2003;25:240-245.

Late Nellix failure in a juxtarenal abdominal aortic aneurysm treated with conversion to open repair: A case report and narrative review of the Nellix system

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Abstract:

The EndoVascular Aneurysm Sealing (EVAS) System had been introduced as an alternative solution for the treatment of abdominal aortic aneurysms (AAAs). Unlike endovascular aneurysm repair (EVAR), EVAS with the Nellix device (Endologix, Irvine, Calif, USA) was based on sealing the aneurysm's lumen, by means of two polymer-filled endobags, with the AAA being excluded by two stent grafts. In spite of promising early-term results, late surveillance of the patients treated with EVAS, bore testament to a large number of type Ia endoleaks and sac enlargement, mainly due to device migration, a fact that obliged the company to withdraw Nellix on May 10th, 2022. We present a case of a seventy-six-year-old male, who developed an asymptomatic type Ia endoleak and sac enlargement because of migration of a Nellix endograft placed for a AAA eight years ago at another institution. The patient was considered fit for surgery and had conversion to open repair with transrenal aortic cross-clamping, explantation of the device, common femoral artery endarterectomy, bilaterally, and placement of an aortobifemoral graft on the grounds of significant iliac occlusive disease, which caused moderate intermittent claudication symptoms and precluded intra-abdominal reconstruction. Postoperative course was uneventful and our patient was discharged on the sixth postoperative day. On one-month and one-year follow-up there were no complications, the graft was patent and our patient enjoyed resolution of his claudication symptoms. Due to the high percentage of Nellix device failure, the severity of its complications (e.g. increased risk of rupture) and the large number of patients who underwent the procedure until EVAS withdrawal, holistically informing and surveilling these patients is crucial to achieve in-time diagnosis and proper treatment.

Key Words: Case Report, Narrative Review, EVAS, Nellix, Type Ia Endoleak, Aortobifemoral bypass, Open Conversion.

CASE

A 76 year-old male with a history of 5.6 cm AAA, had an EVAS procedure (Nellix system, Endologix, Irvine, Calif, USA) eight years ago at another institution. He was referred to our outpatient clinic due to aneurysm's sac enlargement, as shown on Computed Tomography Angiography (CTA) scanning during follow-up. He had also moderately severe intermittent claudication (IC) symptoms, affecting both legs, with the right leg being mostly affected. Past medical history included arterial hypertension, dyslipidemia, diabetes mellitus type II, insomnia and smoking (stopped seven years ago). Medications included ramipril 2.5 mg, hydrochlorothiazide 12.5 mg and monoxidine 0.2 mg once daily, metformin 850 mg twice daily, cilostazol 200 mg twice daily and zolpidem 10mg, clopidogrel 75mg and omeprazole 20mg once daily.

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On physical examination, palpation of epigastrium, revealed a non-tender, pulsatile mass, which represented the aneurysm. The only palpable artery of the lower extremities was the left femoral artery and his ABI was abnormal, especially on the right lower extremity, where the symptoms of IC were more intense (Figure 1). Auscultation also revealed

Figure 1: On patient physical examination, there was a pulsatile abdominal mass (aneurysm) and the only palpable artery of the lower extremities was the left femoral artery.

a systolic bruit over the left carotid artery. The rest of cardiovascular (ejection fraction, cardiac contractility and stress response), pulmonary (auscultation, spirometry), renal (urinalysis, creatinine) and remaining laboratory examination and testing was normal.

Imaging

The pre-operative CTA depicted the Nellix (Endologix, Irvine, Calif) device, which appeared displaced and migrated resulting in a type Ia endoleak (Figure 2a, 2b), more accurately corresponding to Is2 endoleak, according to van den Ham classi-

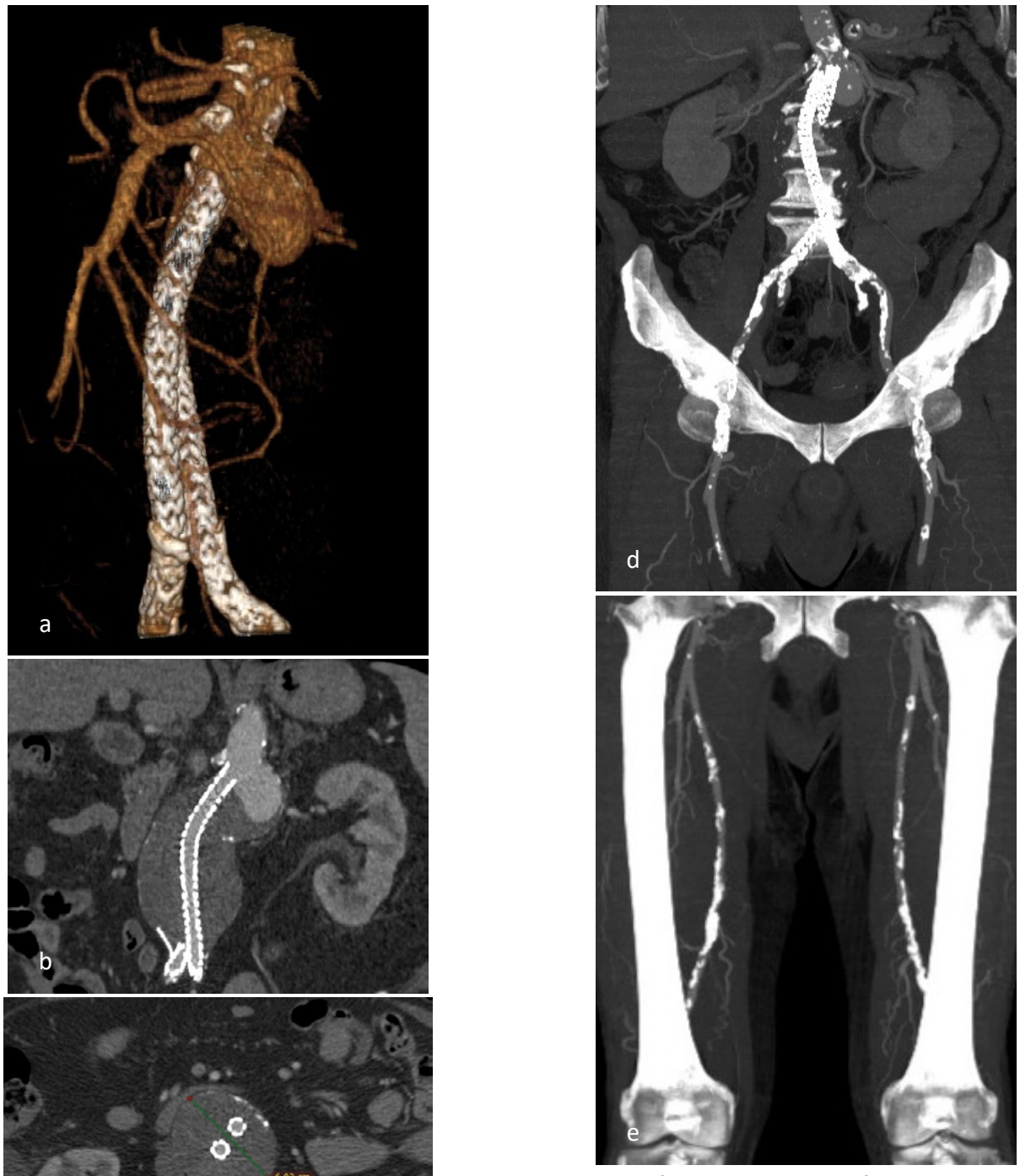

Figure 2: This figure shows results of computed tomography angiography (CTA) scanning (a) Three-dimensional and (b) CT reconstruction, depicting the type Ia endoleak. (c) Axial plane section of the CTA Scan, showing the aneurysm sac expansion to 6.8 cm. (d & e) CTA reconstruction of the lower extremity runoff revealed severe atherosclerotic lesions of the iliac and femoral axes.

fication, causing a juxtarenal bulging aneurysm neck dilatation and expansion of the aneurysmatic sac to the maximum diameter of 6.8 cm (Figure 2c).

The CTA also revealed extensive atherosclerotic lesions with severe stenosis (>90%) of the common and external iliac arteries bilaterally and occlusion of the left internal iliac, right common femoral and superficial femoral arteries bilaterally (Figure 2d, 2e).

As part of the preoperative evaluation and in correlation with the finding of the physical examination, a carotid duplex doppler ultrasound was performed, which revealed approximately 50% stenosis of the common carotid arteries, extending into the internal carotid arteries bilaterally.

Surgical Treatment

The patient was considered fit for open surgery and explantation of the device, which is the treatment of choice according to the most recent guidelines (Figure 3). The presence of severe common femoral atherosclerotic lesions required femoral endarterectomy bilaterally to ensure adequate runoff to the deep femoral arteries bilaterally, while to overcome the bilateral iliac artery occlusive disease, we had to perform aortobifemoral by-pass grafting. Moreover, we had to consider reperfusing the right internal iliac artery (RIIA) to preserve adequate supply to the pelvis.

During the procedure, because of the juxtarenal pathology described above, the aorta had to be crossed-clamped transrenally. The aortotomy revealed the Nellix device, blatantly dysfunctional, with shrinkage of its endobags, likely as a result of polymer dissolution (Figure 4). The extraction of the device proved easy, while difficulties potentially can be present, especially at its distal portion, where the bare-stent graft limbs can form adhesions with the vessel's wall causing intimal flaps when manipulations are inept.

After meticulous dissection and endarterectomy of the common femoral arteries bilaterally, a bifurcated 24x12 mm PTFE aortobifemoral graft (Gore Medical, Flagstaff, AZ, USA) was used and anastomosed end-to-end to the aorta proximally (Figure 5) and side-to-end to the common femoral arteries distally. The initial plan of graft to RIIA by-pass procedure intending its revascularization, was abandoned intra-operatively, because of adequate back-flow to the common iliac and the right internal iliac arteries.

Recommendation 2		
Explantation of failing Endovascular Aneurysm Sealing Nellix prostheses (Endologix) is recommended as the preferred treatment in surgically fit patients.		
Class	**Level**	**References**
I	C	Consensus

Figure 3: ESVS AAA Guidelines Update concerning the treatment of patients with failed Nellix device, published on March 2023, reproduced with permission from Elsevier.

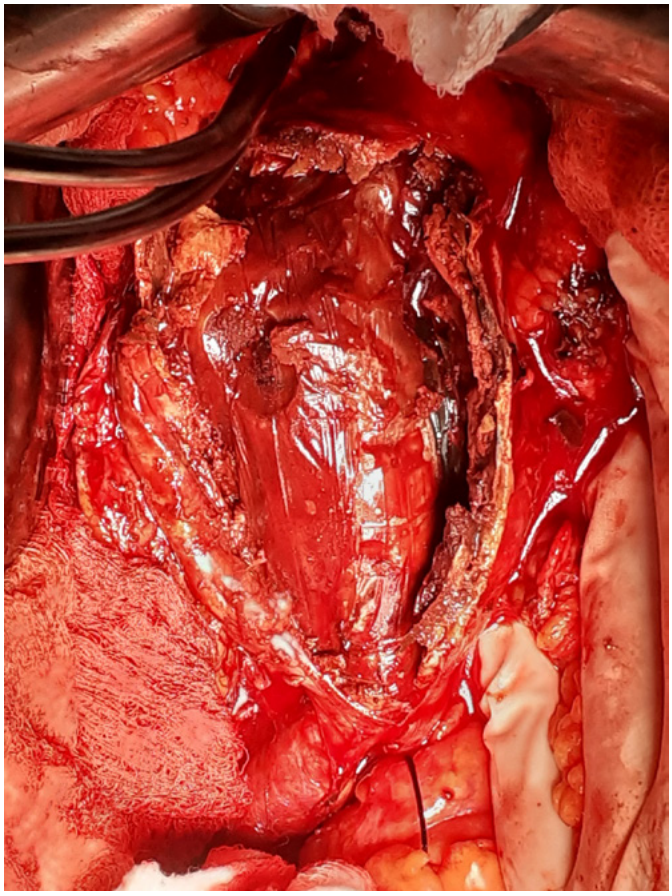

Figure 4: Intraoperative picture of the Nellix device inside the aneurysm lumen. The device endobags are clearly shrank providing inadequate sealing.

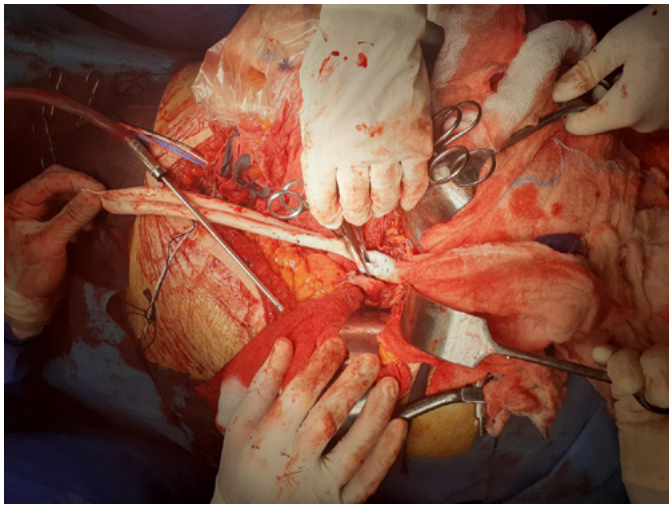

Figure 5: Proximal end-to-end anastomosis between the bifurcated PTFE (24mm x 12mm) graft (Goretex) and the juxtarenal abdominal aorta.

Post-Operatively, One-Month & One-Year Follow-Up

Postoperatively, a transient acute kidney injury, with elevation of creatinine levels (from 0.8 mg/dL pre-operatively to 1.8 mg/dL) due to the transrenal cross-clamping occurred and gradually resolved, reaching normal on 6th postoperative day,

when the patient was discharged uneventful.

On the one month follow up, all wounds had healed, the graft was clinically patent with the patient having a full complement of lower extremity pulses, enjoying relief from his claudication symptoms. On one-year follow up the patient had an ABI_{right}=1 and ABI_{left}=1.1, clearly improved from his last measurement and compatible with his clinical status.

DISCUSSION

The EndoVascular Aneurysm Sealing System (EVAS, Endologix Inc, Irvine, CA, USA) , was introduced as an alternative, to the conventional EVAR , method of endovascular exclusion of an aneurysm sac, sealing its lumen by polymer-filled polyurethane endobags[1].

IFU

Its initial instructions for use (2013)[2] were similar to the most EVAR devices;

- Aortic proximal neck diameter between 18 mm and 32 mm
- Minimum aortic proximal neck length of 10mm
- Aortic neck angulation <60°
- Common iliac arteries diameter between 8 mm and 35 mm.
- Blood lumen diameter of the aortic sac <70 mm.

Although, after the increase of late incidents of Nellix migrations, endoleaks (mainly type Ia) and sac enlargements, the company attempted a modification of the IFU (October 18th, 2016)[2,3,4]:

- Reducing the limit of the maximum proximal aortic neck diameter to 28 mm (trying to prevent type Ia endoleaks and device migrations),
- Restricting the blood lumen´s diameter (8-35mm) measurement, outside the distal zone (aiming the reduction of type Ib endoleaks) and
- Inserting a maximum aortic aneurysm diameter to maximum aortic blood lumen diameter ratio <1.4

Complications of the EVAS System

The Nellix device was introduced as having a unique mechanism for reducing the incidence of endolealks, especially type II [6,7] (whose prevalence may reach 25% of all endoleaks in some cases[5]), by restricting back-flow from the IMA, lumbar and renal accessory arteries via direct sealing. EVAS was initially associated with high technical success rates (98-100%)[1] and low 30-day[8] and one-year[9] complication rates. However, significant adverse effect rates were observed during mid- and late-term surveillance (usually an average of two years after the intervention)[10,11,12].

The most common Nellix complication, that subsequently provoked device failure and aneurysm sac growth, was stent-graft migration, frequently coexisting with limb separation (>5mm)[13,14]. The Society for Vascular Surgery (SVS) has defined stent migration as stent movement of >10mm, or any stent displacement leading to symptoms (endoleaks, sac enlargement, etc)[15]. The most important factor that either causes or allow and intensify especially proximal migration (which is the most often), is the lack of proximal active fixation site to the aortic wall (absence of struts, anchors, barbs, hooks or crowns). Therefore, stability and adhesion of the device to the proximal aortic neck relies only on the polymer-filled endobag sealing[15]. As a consequence, alterations of either the aortic anatomy or the device itself could result in sealing deficits, thus, caudal translocation, endobag separation (>5mm), endoleaks (mainly type Ia) and late aneurysm sac growth. In regard to the polymer/endobag complex, in many cases of open surgical conversion, degradation of PEG and endobag shrinking had been noticed. This dissolution decreases the area of sealing surface and the immobilization of the stent-grafts (especially to the proximal aortic neck, where the paucity of fixation coexists), allowing for caudal migration[16] of the device and resulting to endoleak type Ia and sac growth. It has been reported that not only stent-graft migration can cause the growth of the AAA (due to inadequate sealing and leakage of the blood circulation inside the sac), but it could also be a result of progression of the aneurysmatic disease at the first place. These measurements brought out possible expansion concerning the whole aneurysm, or partially, away from the maximum cross-sectional area and accompanied by changes in shape or volume, without noticed differences in maximum diameter. Another potential cause of this fact is the existence of aneurysmatic regions that underlie different radial force and pressure, which the landing zones exert (e.g. because of polymer dissolution or endobag weakness). This disunion indicates a closer and more detail examination of the AAA anatomy and characteristics, during the follow-up screening and imaging. Histologically, it has been reported that, in some cases, elastolysis existed, likely because of a triggered biological response and interaction between the endobags and the aortic wall[17].

As aforementioned, the most frequent event that follows the device´s proximal migration is type Ia endoleak. The diagnosis of this complication may be challenging, even in CT or DSA, mainly due to the increased density and opacity of the endobags, making it difficult to be spotted. The only detail that implies the presence of a type Ia endoleak is an arcuate and slightly linear area, enhanced by the flow of contrast, between the device´s endobags and the aortic wall[21]. Van den Ham et al. proposed a comprehensive classification of the type Ia endoleaks following EVAS failure[18], depending on the site and the extend of the contrast medium inside the aortic sac:

- Is1: The slit or gutter leakage is observed at the neck, not reaching the aneurysm sac.
- Is2: The endoleak reaches and fills partially or totally the aneurysm sac.
- Is3: The flow is present between the endobags.
- Is4: There is no visible source of endoleak and it is similar to type V post-EVAR endoleak (endotension).

Endovascular Treatment of EVAS Complications

The initial treatment choices to deal with type Ia endoleaks and graft migration were both endovascular and open surgical (Open Conversion - OC), until the withdrawal of the device, when the first one was abandoned. Endovascular methods were preferred and indicated for unfit for OC patients[20], those with low life expectancy and in some urgent cases[19]. Due to EVAS peculiar anatomy, EVAR or FEVAR stent-graft extensions would not match for proximal sealing reinforcement. A common solution to overcome this problem, was the endovascular use of a Nellix extension device, placed in the top of the initial one, while the bare-stent distal limbs were inserted, deployed and stabilized into the main proximal ones (Nellix in Nellix Application - NiNa)[21,22]. In case of inadequate aortic neck length, the Nellix proximal extension required the use of chimney technique (for the Superior Mesenteric Artery and the Renal Arteries) to provide sufficient blood supply to the superior mesenteric and renal arteries[22,23,24]. In persistent cases of type Ia endoleaks, due to the presence of slits or gutters, coil or butyl-cyanoacrylate embolization[25] could potentially stop the leakage and the sac enlargement. In general, Is1 and Is2 endoleaks with correct location of the Nellix endograft, were usually treated with embolization (coils and onyx glue), while for Is3 and Is2 with caudal migration of Nellix stent-grafts, NiNa proximal extension with or without the use of chimney stent-grafts or open surgical conversion were preferred.

Even though endovascular techniques temporarily showed a decent block sealing of the endoleak, long-term surveillance proved a significantly low percentage of success, presenting recurrence of the endoleak and further sac growth. NiNa technique proved ineffective due to the unsolved stent-graft migration problem. Even if the proximal extension achieves transient sealing and endoleak reduction or exclusion, the initial Nellix device is not stabilized, hence the migration continues until the complications reappear.

EVAS Withdrawal and Open Device Explantation

On account of Nellix´s disappointing late results, the company decided its withdrawal on May 10th, 2022. Insecurity of Nellix usage preexisted, since 2019 AAA Guidelines, when its application was not recommended in clinical practice (IIIC). During an update (March 2023) on guidelines concerning EVAS, ESVS recommends the close surveillance of patients treated with Nellix and in case of device failure, the explantation of the prosthesis in fit for surgery patients (IA)[26].

Open surgical conversion and explantation of the Nellix device is the current treatment of choice in fit patients. During surgery, there are advantages, like the tractable removal of the device´s proximal part (due to lack of active fixation) and often the existence of a suitable area for cross-clamping (depending on the neck´s anatomy and length) and some points that could potentially cause serious complications. For example, in most cases, due to the features of the device's distal limbs (which are bare stents, deprived of endobags or graft coverage) and the late onset of the complications, adhesions can be formed, between the stents and the iliac attachment sites. As a result, abrupt or clumsy manipulation could cause vascular damage and later thrombosis or iliac dissection. Mortola et al concluded that constant and stable pulling of the stent-graft limb permits proper removal without harming the artery. Adhesions formation and fibrosis on the aortic wall could also coexist at the endobag attachment sites. Generally, due to an unregulated inflammatory response of the surrounding tissues[22], the device explantation and aneurysm isolation may be challenging. At any rate, the whole procedure of Nellix extraction should be under great care and mild manipulation.

CONCLUSION

In summary, Nellix failure may result in severe complications, such as sac enlargement and aneurysm rupture. The patients treated with EVAS should be closely informed and supervised to prevent imminent device failure and endoleaks. In case the failure is confirmed, fit patients should be treated with open conversion and extraction of the device. Concerning our case, patients with juxtarenal aneurysms due to Nellix failure and concomitant peripheral arterial occlusive disease have to be treated with caution to avoid unforeseen circumstances, like ischemic complications of the kidneys or the lower extremities. In any case, the necessity of timely diagnosis of the failure and the open conversion with explantation of the device in fit patients is crucial for their safety.

REFERENCES

1 Choo XY, Hajibandeh S, Hajibandeh S, Antoniou GA. The Nellix endovascular aneurysm sealing system: current perspectives. Med Devices (Auckl). 2019 Feb 19;12:65-79.

2 Karthikesalingam A, Cobb RJ, Khoury A, Choke EC, Sayers RD, Holt PJ et al. The morphological applicability of a novel endovascular aneurysm sealing (EVAS) system (Nellix) in patients with abdominal aortic aneurysms. Eur J Vasc Endovasc Surg. 2013 Oct;46(4):440-5.

3 Important Field Safety Notice Updated Instructions for Use (IFU), Endologix, October 18th, 2016, Endologix

4 Zoethout AC, Boersen JT, Heyligers JMM, de Vries JPM, Zeebregts CJAM, Reijnen MMPJ. Two-Year Outcomes of the Nellix EndoVascular Aneurysm Sealing System for Treatment of Abdominal Aortic Aneurysms. J Endovasc Ther. 2018 Jun;25(3):270-281.

5 Bryce Y, Schiro B, Cooper K, Ganguli S, Khayat M, Lam CK et al. Type II endoleaks: diagnosis and treatment algorithm. Cardiovasc Diagn Ther. 2018 Apr;8(Suppl 1):S131-S137. 9.

6 Najafi A, Sheikh GT, Wigger P, Binkert CA. Outcome of Nellix-EVAS: single center mid-term results. CVIR Endovasc. 2019 Apr 23;2(1):13.

7 Reduction of Type II Endoleaks with the Nellix® EVAS System, Marwan Youssef.

8 Brownrigg, J.R.W. et al. Endovascular Aneurysm Sealing for Infrarenal Abdominal Aortic Aneurysms: 30-Day Outcomes of 105 Patients in a Single Centre. European Journal of Vascular and Endovascular Surgery, Volume 50, Issue 2, 157 - 164

9 Carpenter JP, Cuff R, Buckley C, Healey C, Hussain S, Reijnen MM, et al. One-year pivotal trial outcomes of the Nel-

lix system for endovascular aneurysm sealing. J Vasc Surg. 2017 Feb;65(2):330-336.e4.

10 Singh AA, Benaragama KS, Pope T, Coughlin PA, Winterbottom AP, Harrison SC, et al. Progressive Device Failure at Long Term Follow Up of the Nellix EndoVascular Aneurysm Sealing (EVAS) System. Eur J Vasc Endovasc Surg. 2021 Feb;61(2):211-218.

11 Ferrero E, Quaglino S, Berardi G, Manzo P, Ferri M, Gaggiano A. First Case of Nellix Stent Rupture in a Huge Symptomatic Abdominal Aortic Aneurysm Who Underwent Endovascular Aneurysm Sealing 7 Years Before. J Endovasc Ther. 2024 Feb;31(1):146-150.

12 Harrison SC, Winterbottom AJ, Coughlin PA, Hayes PD, Boyle JR. Editor's Choice - Mid-term Migration and Device Failure Following Endovascular Aneurysm Sealing with the Nellix Stent Graft System - a Single Centre Experience. Eur J Vasc Endovasc Surg. 2018 Sep;56(3):342-348.

13 England A, Torella F, Fisher RK, McWilliams RG. Migration of the Nellix endoprosthesis. J Vasc Surg. 2016 Aug;64(2):306-312.

14 Stenson KM, de Bruin JL, Loftus IM, Holt PJE. Migration and sac expansion as modes of midterm therapeutic failure after endovascular aneurysm sealing. J Vasc Surg. 2020 Feb;71(2):457-469.e1.

15 Yafawi A, McWilliams RG, Fisher RK, England A, Karouki M, Uhanowita et al. Aneurysm Growth After Endovascular Sealing of Abdominal Aortic Aneurysms (EVAS) with the Nellix Endoprosthesis. Eur J Vasc Endovasc Surg. 2020 Nov;60(5):671-676.

16 Zerwes S, Kiessling J, Liebetrau D, Jakob R, Gosslau Y, Bruijnen HK et al. Open Conversion After Endovascular Aneurysm Sealing: Technical Features and Clinical Outcomes in 44 Patients. J Endovasc Ther. 2021 Apr;28(2):332-341.

17 Bruijn LE, Heyligers JMM, Vriens PW, van Rhijn J, Roy J, Hamming JF, Gäbel G, Lindeman JHN. Histological evaluation of the aortic wall response following endovascular aneurysm repair and endovascular aneurysm sealing. JVS Vasc Sci. 2023 Mar 23;4:100101.

18 Van den Ham LH, Holden A, Savlovskis J, Witterbottom A, Ouriel K, Reijnen MMPJ; EVAS Type IA Endoleak Study Group. Editor's Choice - Occurrence and Classification of Proximal Type I Endoleaks After EndoVascular Aneurysm Sealing Using the Nellix™ Device. Eur J Vasc Endovasc Surg. 2017 Dec;54(6):729-736.

19 Mortola L, Ferrero E, Quaglino S, Ferri M, Viazzo A, Manzo P et al. Management of Nellix migration and type Ia endoleak from proximal endovascular aneurysm sealing relining to late open conversion. J Vasc Surg. 2021 Oct;74(4):1204-1213.

20 Pleban E, Michalak J, Iwanowski J, Szopinski P. The Dilemma after Sealing an Endovascular Aortic Aneurysm - Three Ways Out. Zentralbl Chir. 2021 Oct;146(5):498-505. English.

21 Zoethout AC, Zerwes S, Zeebregts CJAM, Heyligers JMM, De Vries JPJM, Oberhuber et al. Preliminary outcome of Nellix-in-Nellix extensions in patients treated with failed endovascular aneurysm sealing. J Vasc Surg. 2019 Oct;70(4):1099-1106.

22 Quaglino S, Mortola L, Ferrero E, Ferri M, Cirillo S, Lario CV, Negro G, Ricotti A, Gaggiano A. Long-term failure after endovascular aneurysm sealing in a real-life, single-center experience with the Nellix endograft. J Vasc Surg. 2021 Jun;73(6):1958-1965.e1.

23 Pietro Volpe, Antonino Alberti, Vittorio Alberti, Mafalda Massara. A Case of Late Type Ia Endoleak After Endovascular Aneurysm Sealing Using the Nellix System: Proximal Extension with Triple Chimney and Gutter Endoleak Embolization. 2021 Volume 14 Issue 4 Pages 393-395

24 Ketting S, Zoethout AC, Heyligers JMM, Wiersema AM, Yeung KK, Schurink GWH. Nationwide Experience with EVAS Relining of Previous Open or Endovascular AAA Treatment in The Netherlands. Ann Vasc Surg. 2022 Aug;84:250-264.

25 Dinoto E, Ferlito F, Mirabella D, Tortomasi G, Bajardi G, Pecoraro F. Type 1A endoleak detachable coil embolization after endovascular aneurysm sealing: Case report. Int J Surg Case Rep. 2021 Jun;83:106024.

26 Boyle JR, Tsilimparis N, Van Herzeele I, Wanhainen A; ESVS AAA Guidelines Writing Committee; ESVS Guidelines Steering Committee. Editor's Choice - Focused Update on Patients Treated with the Nellix EndoVascular Aneurysm Sealing (EVAS) System from the European Society for Vascular Surgery (ESVS) Abdominal Aortic Aneurysm Clinical Practice Guidelines. Eur J Vasc Endovasc Surg. 2023 Mar;65(3):320-322.

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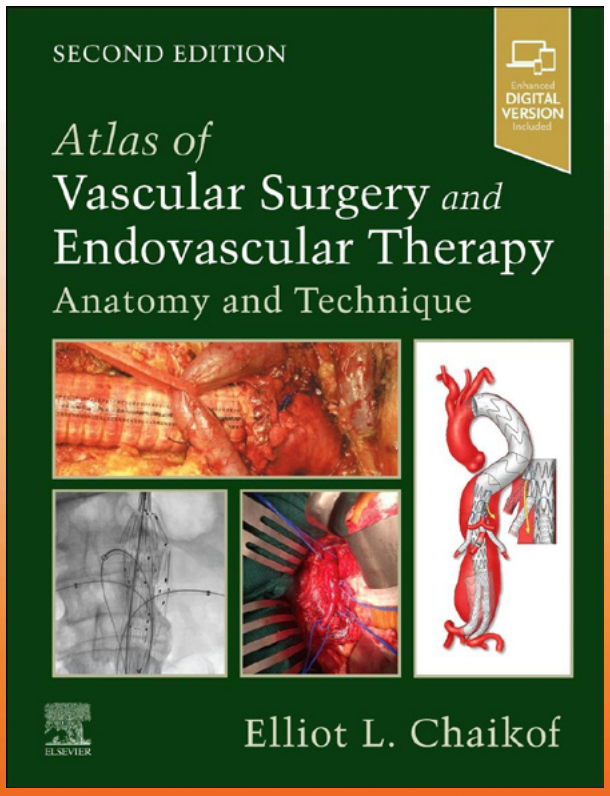

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