Morphological changes in abdominal aorta and iliac arteries post-EVAR

ΤΜΗΜΑ ΙΑΤΡΙΚΗΣ

ΣΧΟΛΗ ΕΠΙΣΤΗΜΩΝ ΥΓΕΙΑΣ

ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ

ΑΓΓΕΙΟΧΕΙΡΟΥΡΓΙΚΗ ΚΛΙΝΙΚΗ

ΔΙΕΥΘΥΝΤΗΣ: ΚΑΘΗΓΗΤΗΣ ΑΘΑΝΑΣΙΟΣ ΓΙΑΝΝΟΥΚΑΣ

ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

" MORPHOLOGIC CHANGES IN ABDOMINAL AORTA AND ILIAC ARTERIES POST-EVAR"

"ΜΟΡΦΟΛΟΓΙΚΕΣ ΑΛΛΑΓΕΣ ΤΗΣ ΚΟΙΛΙΑΚΗΣ ΑΟΡΤΗΣ ΚΑΙ ΤΩΝ ΛΑΓΟΝΙΩΝ ΑΡΤΗΡΙΩΝ ΜΕΤΑ ΑΠΟ ΕΝΔΑΓΓΕΙΑΚΗ ΑΠΟΚΑΤΑΣΤΑΣΗ ΑΝΕΥΡΥΣΜΑΤΟΣ ΤΗΣ ΚΟΙΛΙΑΚΗΣ ΑΟΡΤΗΣ"

ΥΠΟ

ΠΕΤΡΟΥΛΑ ΝΑΝΑ

ΑΓΓΕΙΟΧΕΙΡΟΥΡΓΟΣ

ΕΠΙΒΛΕΠΩΝ

ΚΑΘΗΓΗΤΗΣ ΜΙΛΤΙΑΔΗΣ ΜΑΤΣΑΓΚΑΣ

ΛΑΡΙΣΑ, 2022

Η αίτηση για την εκπόνηση της παρούσης διατριβής έγινε την 15/02/2017

Στις 10/04/2019 ορίσθηκαν ως τριμελής συμβουλευτική επιτροπή οι κ.κ.:

ΜΙΛΤΙΑΔΗΣ ΜΑΤΣΑΓΚΑΣ, τακτικός Καθηγητής Αγγειοχειρουργικής

ΑΘΑΝΑΣΙΟΣ ΓΙΑΝΝΟΥΚΑΣ, τακτικός Καθηγητής Αγγειοχειρουργικής

ΓΕΩΡΓΙΟΣ ΚΟΥΒΕΛΟΣ, επίκουρος Καθηγητής Αγγειοχειρουργικής

Το θέμα της διατριβής ορίσθηκε την 15/02/2017 και την 17/06/2022 η διατριβή κατατέθηκε ολοκληρωμένη.

Curriculum vitae

WORK EXPERIENCE

07/01/2013–08/05/2013

Resident

Department of General Surgery, General Hospital of Kastoria, Kastoria (Greece)

- Primary health services
- Emergency department

14/05/2013–12/04/2015

Resident

Department of General Surgery, University Hospital of Ioannina, Ioannina (Greece)

-Participation in vascular and visceral surgery operations
-Perioperative treatment of patients
-Emergency Department

01/05/2015–31/10/2016

Resident

Hopital du Jura Bernois, site de Moutier, Moutier (Switzerland)

-Participation in operations of visceral, trauma and vascular surgery and orthopedics
-Perioperative management of patients
-Emergency department of General Surgery and Internal Medicine
-Management of patients in the ICU

16/02/2017–31/05/2022

Resident

Department of Vascular Surgery, University Hospital of Larissa, Larissa (Greece)

-Participation in vascular surgery operations
-Perioperative treatment of patients
-Emergency Department

EDUCATION AND TRAINING

26/09/2006–09/07/2012

Degree of Medicine

Faculty of Medicine, Aristotle University of Thessaloniki, Thessaloniki (Greece)

8/10

05/06/2015–06/06/2015 ATLS

American College of Surgeons, Patras (Greece)

15/03/2017–Present PHD Candidate, Vascular Surgery

Faculty of Medicine, University of Thessaly, Larissa (Greece)

"Morphological changes of the aortic anatomy after endovascular repair of abdominal aortic aneurysms"

26/10/2018-31/12/2019 MSc

Faculty of Medicine, University of Thessaly, Larissa (Greece)

“Duplex ultrasound for the prevention and diagnosis of vascular diseases”

02/2021-06/2021 Academic assistant

“Basic principles in Angiology-Vascular Surgery”

University Hospital of Thessaly

12/02/2021-30/06/2022 MSc

Faculty of Medicine, University of Thessaly, Larissa (Greece)

“Thrombosis and antithrombotic therapy”

25/11/2019-Present Sub-investigator, ENCHANT Trial

RCT in the use of chimney EVAR for the treatment of juxta and pararenal abdominal aortic aneurysms, (sponsored by Medtronic)

Vascular societies

-Hellenic Society of Vascular Surgery

-European Society for Vascular Surgery

-European Society for Cardiovascular and Endovascular Surgery

-**Member of Junior Committee of the European Society of Cardiovascular Surgery**

Date: April 2018-June 2019

Strasbourg, France

-Chair of Junior Committee of the European Society of Cardiovascular Surgery
Date: June 2019-present
Istanbul, Turkey

-Organizing committee of the ESCVS-Winter School 2020
Date: 19 December 2020
Virtual meeting

Fellows

Date: 17 August-27 August 2021
Short fellow under the tutorship of Prof Tilo Kölbel
German Aortic Center Hamburg, Department of Vascular Medicine, University Heart & Vascular Center, Hamburg, Germany

Date: 1 June 2022- Present
Clinical fellowship under the tutorship of Prof Stephan Haulon
Aortic Center, Marie Lannelongue Hospital, Le Plessis-Robinson, France

Congress-Prizes

-Date: 19-22 June 2022
70th Congress of the European Society of Cardiovascular Surgery
Liege, Belgium

Oral presentation
Risk factors and adverse events related to supra- and infra-renal aortic dilatation after EVAR
Petroula Nana, George Kouvelos, Konstantinos Spanos, Konstantinos Batzalexis, Metaxia Mpareka, Eleni Arnaoutoglou, Athanasios Giannoukas, Miltos Matsagkas

Impact of conical anatomy on proximal neck adverse events after EVAR
Petroula Nana, Konstantinos Spanos, George Kouvelos, Metaxia Mpareka, Eleni Arnaoutoglou, Athanasios Giannoukas, Miltos Matsagkas

Invited Speaker
Challenges in TAIMH management: Current data

-Date: 26-28 April 2022

CX, Charing Cross Symposium

London, UK

Oral presentation

Meta-analysis of comparative studies between self and balloon expandable bridging stent grafts in branched endovascular aneurysm repair

Konstantinos Spanos, Petroula Nana, Alexandros Brodis, Giuseppe Panuccio, George Kouvelos, Christian-Alexander Behrendt, Athanasios Giannoukas, Tilo Kölbel

-Date: 14-16 April 2022

21st Hellenic Congress of Vascular & Endovascular Surgery-Angiology

Hybrid meeting

Athens, Greece

Oral Presentations

Αντιμετώπιση παρανεφρικών ανευρυσμάτων με τη χρήση της τεχνικής των παράλληλων μοσχευμάτων

Πετρούλα Νανά, Γεώργιος Κούβελος, Κωνσταντίνος Σπανός, Κωνσταντίνος Μπατζαλέξης, Αθανάσιος Χαϊδούλης, Αικατερίνη Μπουζιά, Ελένη Αρναούτογλου, Αθανάσιος Γιαννούκας, Μιλτιάδης Ματσάγκας

Αντιμετώπιση σύνθετων αορτικών ανευρυσμάτων με κλαδωτά και θυριδωτά μοσχεύματα

Πετρούλα Νανά, Κωνσταντίνος Σπανός, Γεώργιος Κούβελος, Κωνσταντίνος Μπατζαλέξης, Γεώργιος Βολακάκης, Ελένη Αρναούτογλου, Αθανάσιος Γιαννούκας, Μιλτιάδης Ματσάγκας

Παράγοντες κινδύνου και επιπλοκές σχετιζόμενες με τη διάταση της υπερ- και υπο-νεφρικής αορτής μετά από ενδαγγειακή αποκατάσταση ανευρυσμάτων

Πετρούλα Νανά, Γεώργιος Κούβελος, Κωνσταντίνος Σπανός, Κωνσταντίνος Μπατζαλέξης, Αθανάσιος Χαϊδούλης, Ελένη Αρναούτογλου, Αθανάσιος Γιαννούκας, Μιλτιάδης Ματσάγκας

Το αντίκτυπο της κωνικής μορφολογίας του κεντρικού αυχένα στις επιπλοκές που σχετίζονται με την κεντρική ζώνη πρόσφυσης μετά από ενδαγγειακή αποκατάσταση ανευρυσμάτων

Πετρούλα Νανά, Γεώργιος Κούβελος, Κωνσταντίνος Σπανός, Χρήστος Καραθάνος, Ελένη Αρναούτογλου, Αθανάσιος Γιαννούκας, Μιλτιάδης Ματσάγκας

Invited speaker

Τα κυριότερα προβλήματα του ειδικευόμενου Αγγειοχειρουργού

-Date: 1-3 December 2021
10th MAC
Virtual meting
Munich, Germany
Invited Speaker
Gender differences in EVAR versus open repair for AAA in the elective and urgent setting

-Date: 7 November 2021
ESVS Travel Grant

-Date: 5-7 October 2021
CX Aortic Vienna
Hybrid meeting
London, UK

Oral presentation (Prize session)
Factors associated to non-infectious fever post endovascular aortic aneurysm repair
Petroula Nana, Konstantinos Dakis, Konstantinos Spanos, George Kouvelos, Miltos Matsagkas, Athanasios Giannoukas

-Date: 28-29 September 2021
ESVS 2021
Hybrid meeting
Rotterdam, Netherlands

Oral presentation
Abdominal aortic aneurysm sac alteration depending on initial diameter, endograft material and presence of endoleak type II (Fast track)
Petroula Nana, George Kouvelos, Konstantinos Spanos, Athanasios Giannoukas, Miltiadis Matsagkas

A comparison on early mortality between EVAR and open aneurysm repair in the female population under urgent and elective settings (Prize session)
Petroula Nana, Konstantinos Dakis, Alexandros Brotis, Konstantinos Spanos, George Kouvelos, Miltiadis Matsagkas, Athanasios Giannoukas

-Date: 25-28 September 2021

CIRSE

Virtual meeting

Posters

Mortality in the female population after open or endovascular repair for abdominal aortic aneurysm

Petroula Nana, Konstantinos Dakis, Alexandros Brodis, Konstantinos Spanos, *George Kouvelos*, Prof Athanasios Giannoukas

Meta-analysis of early outcome of carotid revascularization in retrospective case series

Petroula Nana, *George Kouvelos*, Alexandros Brotis, Konstantinos Spanos, Efthimios Dardiotis, Miltiadis Matsagkas, Athanasios Giannoukas

-Date:10-12 June 2021

LIVE, 2021

Hybrid meeting

Thessaloniki, Greece

Oral presentation

Total endovascular repair using parallel graft technique and iliac branched devices for a pararenal aortic aneurysm extending to the common iliac arteries

Petroula Nana, George Kouvelos, Konstantinos Spanos, Maria Ntalouka, Konstantinos Batzalexis, Athanasios Chaidoulis, Eleni Arnaoutoglou, Miltiadis Matsagkas

Synchronous endovascular management of right internal carotid and subclavian artery stenosis

Petroula Nana, George Kouvelos, Konstantinos Batzalexis, Konstantinos Spanos, Athanasios Giannoukas

Treatment of a non-A non-B chronic dissection with rupture using arch debranching and ch-TEVAR

Petroula Nana, Konstantinos Spanos, George Kouvelos, Konstantinos Batzalexis, Athanasios Chaidoulis, Athanasios Giannoukas

-Date: 3-5 June 2021

20th Hellenic Congress of Angiology- Vascular and Endovascular Surgery

Hybrid Meeting

Athens, Greece

Invited speaker

Chimney Endovascular Aortic Aneurysm Repair: Ch-EVAR

-Date: 26 March-27 March 2021

69th ESCVS annual meeting

Virtual Meeting

3rd prize, Oral presentation

Anatomical differences between intact and ruptured large abdominal aortic aneurysms

E-Poster

External jugular vein aneurysm: case report and review of the literature.

Petroula Nana, Christos Korais, Ourania Karyda, Eleni Gkrinia, Anna Mpouronikou, Vasileios Lachanas, Konstantinos Spanos, George Kouvelos

Oral presentation

Anatomical differences between intact and ruptured large abdominal aortic aneurysms

Petroula Nana, Konstantinos Spanos, George Kouvelos, Konstantinos Mpatzalexis, Miltiadis Matsagkas, Athanasios Giannoukas

10-year single center experience in elective endovascular repair of infra-renal abdominal aortic aneurysms

Petroula Nana, Konstantinos Spanos, George Kouvelos, Konstantinos Stamoulis, Christos Rountas, Eleni Arnaoutoglou, Miltiadis Matsagkas, Athanasios Giannoukas

-Date: 29 September - 2 October 2020

34th ESVS Annual Meeting

Virtual Meeting

Oral presentation

A systematic review and meta-analysis of carotid artery stenting using the transcervical approach.

P. Nana, G. Kouvelos, A. Brodis, K. Spanos, N. Roussas, M. Matsagkas, A. D. Giannoukas

-Date: 25-26 September 2020

LIVE 2020

Larissa, Greece

<u>Oral presentation</u>

Endovascular treatment of distal renal aneurysm

Petroula Nana, George Kouvelos, Konstantinos Mpatzalexis, Metaxia Mpareka, Christos Rountas, Eleni Arnaoutoglou, Miltiadis Matsagkas

One stage endovascular treatment of right internal carotid and right subclavian artery tight stenoses in a female patient

Petroula Nana, George Kouvelos, Konstantinos Spanos, Athanasios Chaidoulis, Konstantinos Mpatzalexis, Athanasios Giannoukas

The unusual case of total occlusion of the three splanchnic arteries and the infrarenal aorta

Petroula Nana, George Kouvelos, Konstantinos Mpatzalexis, Anastasios Maskanakis, Metaxia Mpareka, Eleni Arnaoutoglou, Miltiadis Matsagkas

-Date: 17-18 September 2020

SITE On air-SITE Symposium

Virtual meeting

<u>Poster presentation</u>

Adverse outcome after complex endovascular repair of a para-renal abdominal aortic aneurysm

Petroula Nana, Georgios Kouvelos, Konstantinos Batzalexis, Nikolaos Rousas, Eleni Arnaoutoglou, Miltiadis Matsagkas

Combination of the chimney technique and an iliac-branched device for the repair of a failed EVAR

Petroula Nana, Georgios Kouvelos, Konstantinos Spanos, Konstantinos Mpatzalexis, Eleni Arnaoutoglou, Miltiadis Matsagkas

-Date: 10-12 September 2020

19th National Hellenic Congress of Vascular and endovascular Surgery-Angiology 2020

Athens, Greece

<u>Oral presentation</u>

Ultrasonography guided percutaneous EVAR using the ProGlide® Perclose device. Single center preliminary results

P. Nana, N. Roussas, K. Spanos, M. Mpareka, K. Batzalexis, E. Arnaoutoglou, A. Giannoukas, M. Matsagkas

Initial experience with the CERAB technique

P. Nana, K. Spanos, G. Kouvelos, M. Mpareka, K. Batzalexis, N. Roussas, E. Arnaoutoglou, A. Giannoukas, M. Matsagkas

Endovascular treatment of pararenal abdominal aortic aneurysms

M. Matsagkas, K. Spanos, G. Kouvelos, C. Rountas, A. Bouzia, P. Nana, K. Batzalexis, M. Mpareka, E. Arnaoutoglou, A. Giannoukas

Poster presentation

Popliteal artery cystic adventitial disease : a 2-case presentation

P. Nana, G. Kouvelos, N. Roussas, E. Arnaoutoglou, A. Giannoukas, M. Matsagkas

Endovascular repair of a thoraco-abdominal aneurysm using the sandwich technique

P. Nana, G. Kouvelos, K. Spanos, A. Bouzia, K. Batzalexis, E. Arnaoutoglou, A. Giannoukas, M. Matsagkas

Initial experience using the endovascular sealing device Nellix in patients with abdominal aortic aneurysm: a comparative study

K. Batzalexis, G. Kouvelos, P. Nana, K. Spanos, A. Koutsothymiou, E. Arnaoutoglou, A. Giannoukas, M. Matsagkas

-Date: 8-11 September 2020

CX Aortic Vienna - Charing Cross Symposium

Virtual meeting

Oral presentation

10-year single tertiary center experience in elective endovascular repair of infra-renal abdominal aortic aneurysms

Petroula Nana, Konstantinos Spanos, George Kouvelos, Konstantinos Stamoulis, Christos Rountas, Elena Arnaoutoglou, Miltiadis Matsagkas, Athanasios D. Giannoukas

-Date: 23-25 January 2020

CACVS 2020 - Controversies & Updates in Vascular Surgery 2020

Paris, France

Poster presentation

Systematic Review and Meta-Analysis on the efficacy and safety of the carotid artery stenting with the trans-cervical approach

P. Nana, G. Kouvelos, A. Brodis, K. Spanos, N. Roussas, M. Matsagkas, A. D. Giannoukas

The effect of carotid revascularization on the ophthalmic artery flow assessed with duplex ultrasonography

P. Nana, K. Spanos, G. Antoniou, G. Kouvelos, V. Vasileiou, E. Tsironi, A. Giannoukas

-Date: 24-27 September 2019

33rd Annual ESVS Meeting

Hamburg, Germany

<u>Poster Presentation</u>

EVAR with the use of new generation endografts is a safe and durable procedure

P. Nana, K. Spanos, G. Kouvelos, K. Stamoulis, C. Rountas, M. Matsagkas, E. Arnaoutoglou, A.D. Giannoukas

-Date: 27-30 June 2019

ESCVS Summer School-Anastomosis

Istanbul, Turkey

-Date: 27-29 June 2019

20th EVF

Zurich, Switzerland

1st prize, Poster

A randomized clinical study of radiofrequency ablation versus 1470nm laser for great saphenous vein reflux

<u>Poster presentation</u>

A randomized clinical study of radiofrequency ablation versus 1470nm laser for great saphenous vein reflux

Karathanos C, Spanos K, Nana P, Batzalexis K, Kouvelos G, Giannoukas A.D

-Date: 22-25 May 2019

68th ESCVS Congress

Groningen, Netherlands

3rd Prize, Young Surgeon Award in Vascular Surgery for

Treatment Options of Spontaneous Dissection of Visceral Arteries

<u>Oral presentations</u>

Treatment Options of Spontaneous Dissection of Visceral Arteries

P. Nana[1,2], G. Kouvelos[1,2], K. Mpatzalexis[1], S. Koutsias[2], E. Arnaoutoglou[3,4], A. Giannoukas[1], M. Matsagkas[1,2]

Endovascular Repair of the Aortic Arch Branches' Pathologies

P. Nana[1], G. Kouvelos[1], G. Psarras[1], K. Spanos[1], N. Rousas[1], E. Arnaoutoglou[2], A. Giannoukas[1], M. Matsagkas[1]

DOACs in Vascular Surgery

Joint Resident Forum

P. Nana

Case presentations

A failed EVAR presenting with type I endoleak: treatment options

Meet the expert's session

P. Nana[1], G. Kouvelos[1], K. Spanos[1], K. Mpatzalexis[1], G. Psarras[1], E. Arnaoutoglou[2], M. Matsagkas[1]

Percutaneous chimney EVAR for the treatment of a para-renal aneurysm

ESCVS Cinema session

P. Nana, M. Matsagkas

E-Posters

Sandwich technique with proximal extension for a thoracoabdominal aneurysm

P. Nana[1], G. Kouvelos[1], E. Arnaoutoglou[2], A. Giannoukas[1], M. Matsagkas[1]

A two-stage approach for an abdominal and a thoracic aortic aneurysm

P. Nana[1], V. Bouris[1], M. Peroulis[1], E. Arnaoutoglou[2], M. Matsagkas[1]

-Date: 9-11 May 2019

Leading Innovative Vascular Education, LIVE 2019 Symposium

Larissa, Greece

Oral presentations

The Chimney Technique for Para-renal Aneurysms Repair. Initial Results,

P. Nana [1], G. Kouvelos[1], K. Spanos[1], K. Mpatzalexis[1], E. Arnaoutoglou[2], A. Giannoukas[1], M. Matsagkas[1]

Treatment Options of Spontaneous Dissection of Visceral Arteries

P. Nana [1,2], G. Kouvelos[1,2], K. Mpatzalexis[1], M. Peroulis[2], S. Koutsias[2], E. Arnaoutoglou[3,4], A. Giannoukas[1], M. Matsagkas[1,2]

Chimney EVAR: how we do it , Post-operative management & follow-up

Petroula Nana, Konstantinos Mpatzalexis, Georgios Psarras

Case presentations

Using the sandwich technique for thoraco-abdominal aneurysm repair

Petroula Nana[1], Georgios Kouvelos[1], Aikaterini Bouzia[2], Eleni

Arnaoutoglou[2], Athanasios Giannoukas[1], Miltiadis Matsagkas[1]

Endovascular Approach for the Treatment of a Distal Aortic Arch Aneurysm in an Nonagenarian Patient

Petroula Nana[1], Konstantinos Spanos[1], Konstantinos Mpatzalexis[1], Aikaterini Koutsothymiou[2], Eleni Arnaoutoglou[2], Miltiadis Matsagkas[1]

E-Poster

Endovascular Repair of Aortic Arch Branches' Pathologies

P. Nana[1], G. Kouvelos[1], G. Psarras[1], K. Spanos[1], N. Rousas[1], E. Arnaoutoglou[2], A. Giannoukas[1], M. Matsagkas[1]

-Date: 15-18 April 2019

Charing Cross Symposium

London, UK

Oral presentations

Factors Associated with Elimination of Endoleak Type II During the First Year Post-EVAR

Konstantinos Spanos*, Petroula Nana*, George Kouvelos*, Stylianos Koutsias*, Eleni Arnaoutoglou**, Athanasios D. Giannoukas*, Miltiadis Matsagkas*

E-Posters

The effect of carotid revascularization on the ophthalmic artery flow

P. Nana[1], K. Spanos[1], K. Batzalexis[1], G. Psarras[1], F. Xanthou[2], G. Kouvelos[1], N. Rousas[1], K. Tsetis[3], E. Tsironi[2], G. Antoniou[4], M. Matsagkas[1], A. Giannoukas[1]

Factors associated with increased incidence of rupture in large (>80cm) AAA

P. Nana[1], K. Spanos[1], K. Batzalexis[1], G. Psarras[1], C. Karathanos[1], G. Kouvelos[1], K. Tsetis[2], I. Vasilopoulos[1], E. Arnaoutoglou[3], M. Matsagkas[1], A. Giannoukas[1]

-Date: 27-29 March 2019

SITE, International Symposium on Endovascular Therapeutics

Barcelona, Spain

Case presentations

Sandwich technique with proximal extension for a thoracoabdominal aneurysm

Petroula Nana[1], Georgios Kouvelos[1], Eleni Arnaoutoglou[2], Athanasios Giannoukas[1], Miltiadis Matsagkas[1]

A two stage approach for an abdominal and a thoracic aortic aneurysm
Petroula Nana[1], Vassilios Bouris[1], Michail Peroulis, Eleni Arnaoutoglou[2], Miltiadis Matsagkas[1]

E-Poster
Tailoring of ch-evar with the currently available endografts: a single center experience
Petroula Nana1, Georgios Kouvelos1, Konstantinos Spanos1, Eleni Arnaoutoglou2, Athanasios Giannoukas1, Miltiadis Matsagkas1

Factors associated with the elimination of endoleak type II during first year post EVAR
Konstantinos Spanos[1], Petroula Nana[1], Georgios Kouvelos[1], Eleni Arnaoutoglou[2], Athanasios Giannoukas[1], Miltiadis Matsagkas[1]

-Date: 7-10 March 2019
HSO, Hellenic Stroke Organization Congress
Athens, Greece

Oral presentation
The effect of carotid revascularization on the ophthalmic artery flow
P. Nana[1], K. Spanos[1], K. Mpatzalexis[1], G. Kouvelos[1], G. Antoniou[2], M. Matsagkas[1], A. Giannoukas[1]

-Date: 17-21 January 2019
Winter School of ESCVS
Kapaonik, Serbia

-Date: 27-29 September 2018
6th Hellenic Congress on Thrombosis & Antithrombotic Therapy
Institute of Thrombosis & Antithrombotic Therapy of Greece
Athens, Greece

Oral presentation
The effect of fiber tip distance from saphenofemoral junction on outcomes after endovenous thermal ablation
Christos Karathanos[1], Petroula Nana[1], Konstantinos Spanos[1], Nikolaos Rousas[1], Athanasios Giannoukas[1]

-Date : 28-30 June 2018

European Venous Forum

19th EVF Annual Meeting

Athens, Greece

E-Poster

The effect of fiber tip distance from saphenofemoral junction on outcomes after endovenous thermal ablation

Karathanos C, Nana P, Spanos K, Rousas N, Giannoukas A.D

-Date: 24-26 May 2018

Leading Innovative Vascular Education, LIVE 2018 Sympocium

ESCVS Summer School 2018

Patras, Greece

First Prize for Oral presentation

"Factors associated with elimination of Endoleak type II during 12-month period post-EVAR"

Oral presentations

Tailoring of Ch-EVAR to various anatomic challenges with the currently available endografts is feasible and effective treatment

Petroula Nana[1], George Kouvelos[1], Konstantinos Spanos[1], Christos Karathanos[1], Athanasios Giannoukas[1], Miltiadis Matsagkas[1]

Factors associated with elimination of Endoleak type II during 12-month period post-EVAR

Petroula Nana[1], Konstantinos Spanos[1], Georgios Kouvelos[1], Stylianos Koutsias[1], Eleni Arnaoutoglou[2], Athanasios Giannoukas[1], Miltiadis Matsagkas[1]

Early experience with the Nellix endovascular aneurysm sealing device: a preliminary comparative study

Petroula Nana[1,2], George Kouvelos[1,2], Konstantinos Spanos[1], Athanasios Giannoukas[1], Miltiadis Matsagkas[1,2]

Comparison of the primary patency between open and endovascular repair of popliteal artery aneurysms

Petroula Nana [1,2], Konstantinos Mpatzalexis [1], Georgios Kouvelos[1,2], Nikolaos Rousas[1], Katerina Drakou[1], Ioannis Vasilopoulos[1], Athanasios Giannoukas[1], Miltiadis Matsagkas[1,2]

Large diameter (>29 mm) proximal aortic necks are associated with increased complication rates after EVAR for AAA

Petroula Nana[1,2], George Kouvelos[1, 2], Konstantinos Spanos[1], Stylianos Koutsias[1], Athanasios Giannoukas[1], Miltiadis Matsagkas[1, 2]

E-Poster

Carotid Stenting Versus Endarterectomy for the treatment of carotid artery stenosis: Contemporary results from a single center study

Petroula Nana[1], Georgios Kouvelos[1], Vasileios Bouris[1], Dimitris Xanthopoulos[1], Michail Peroulis[1], Eleni Arnaoutoglou[2], Georgios Papadopoulos[2], Miltiadis Matsagkas[1]

-Date: 12-14 April 2018

67th International Congress of the European Society of Cardiovascular & Endovascular Surgery

Strasbourg, France

Oral Presentations

Tailoring of ch-EVAR to various anatomic challenges with the currently available endografts is feasible and effective treatment

Petroula Nana[1], Georgios Kouvelos[1], Konstantinos Spanos[1], Christos Karathanos[1], Athanasios Giannoukas[1], Miltiadis Matsagkas[1]

Factors associated with elimination of Endoleak type II during 12-month period post-EVAR

Konstantinos Spanos[1], Petroula Nana[1], Georgios Kouvelos[1], Stylianos Koutsias[1], Eleni Arnaoutoglou[2], Athanasios Giannoukas[1], Miltiadis Matsagkas[1]

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Early experience with the Nellix endovascular aneurysm sealing device: a preliminary comparative study

Petroula Nana[1,2], George Kouvelos[1,2], Konstantinos Spanos[1], Athanasios Giannoukas[1], Miltiadis Matsagkas[1,2]

Comparison of the primary patency between open and endovascular repair of popliteal artery aneurysms

Petroula Nana [1,2], Konstantinos Mpatzalexis [1], Georgios Kouvelos[1,2], Nikolaos Rousas[1], Katerina Drakou[1], Ioannis Vasilopoulos[1], Athanasios Giannoukas[1], Miltiadis Matsagkas[1,2]

-Date: 15-18 March 2018

Hellenic Society of Vascular and Endovascular Surgery

17 Hellenic Congress of Vascular and Endovascular Surgery

Thessaloniki, Greece

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-Date: 19-22 September 2017

European Society of Vascular Surgery, ESVS, 31st Annual Meeting

Lyon, France

-Date: 26-28 May 2016

LIVE 2016-Leading Innovative Vascular Education

Ioannina, Greece

-Date: 14-15 February 2014
5th Educative Conference of Thrombosis and Antithrombotic Treatment
Alexandroupolis, Greece

-Date: 17-20 May 2012
12th National Congress in Gynecology and Obstetrics
Thessaloniki, Greece

-Date: 8-10 December 2011
10th Congress of the Society of General Surgery of Nothern Greece
Thessaloniki, Greece

-Date: 7-9 April 2011
6th Scientific Conference of the Faculty of Medicine of Aristotle
Thessaloniki, Greece

-Date: 2-5 April 2009
5th Scientific Conference of the Faculty of Medicine of Aristotle
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Abstract

Objectives: Supra- and infrarenal aortic remodeling and its effect on neck-related adverse events after endovascular abdominal aortic aneurysm repair (EVAR) has not been systematically investigated while other anatomic factors, as conical neck, which is defined as one of the hostile neck's characteristics and may also affect EVAR outcomes. While most interest focuses on the proximal sealing zone in EVAR cases, the distal landing zone may also play a role in EVAR's durability. The aim of this study was to assess aortic diameter alterations from the supra-renal to its infra-renal part, investigate the risk factors and consequences to proximal sealing zone and present EVAR proximal neck adverse events in patients with conical neck compared to patients with non-conical neck during the 12-month follow-up. Regarding the distal landing zone, the iliac anatomy, its modifications and the potential correlation to iliac related adverse events after EVAR were also investigated during the 12-month follow-up.

Methods: A retrospective analysis of prospective data of consecutive elective standard EVAR patients, treated between 2017 and 2019, in a single tertiary center, was undertaken. All patients underwent computed tomography angiography, preoperatively, at the 1st and 12th month post-operatively. The database included patients' demographics and comorbidities, pre-operative, and post -operative aneurysm anatomical characteristics (supra-renal and infra-renal aortic diameter measurements, aneurysm diameter, neck angle, thrombus, and calcification). The infrarenal diameter was measured at three levels: just below the lowest renal artery, at 7mm and 15mm. The suprarenal aorta was measured just above the highest renal and superior mesenteric artery (SMA) and just below the celiac trunk. Neck-related adverse events included migration of ≥10mm, and ET Ia. Regarding the distal landing zone, the common iliac artery (CIA) diameter was assessed in three levels: origin (just below the aortic bifurcation), distally (just above the iliac bifurcation) and in the middle of the distance

between these two landmarks. Common iliac artery (CIA) angle to the aorta, tortuosity indexes of the CIA and pelvic artery, relining and oversizing were also analysed. Distal landing zone-related adverse events included any limb related re-intervention, endoleak type Ib (ET Ib), graft migration, limb stenosis and occlusion.

Results: A hundred fifty patients were included in the analysis of the proximal neck. At 12-month follow-up, all infra-renal diameters were significantly increased ($p<0.001$), while regarding the supra-renal aorta, the diameter above the highest renal and SMA were also augmented ($p=.024$ and $p=.007$, respectively). Pre-operative neck diameter >29mm ($p<.001$), supra-renal active fixation ($p=.002$) and oversizing >20% ($p=.017$) were significantly associated to just below the lowest renal aortic dilatation while neck diameter >29mm ($p<.001$ and $p=0.001$) and supra-renal fixation ($p<.001$ and $p=.016$) were associated to 7 and 15mm diameter increase. Regarding the supra-renal aorta, neck diameter >29mm affected diameter increase just above the highest renal artery and SMA. Neck-related adverse events were significantly associated to diameter alterations at the level just below the lowest renal artery ($p=.017$). At 7 and 15mm, no correlation to neck adverse events was found ($p=.11$ and $p=.09$, respectively). Regarding the supra-renal diameter alterations, diameter differences at the highest renal artery and SMA were related to adverse events ($p=.007$and $p=.05$). Diameter difference at the CT level was not related to neck adverse events ($p=.05$). The same cohort (150 patients) included 66 (44%) patients with conical proximal neck characteristics. No significant differences were detected in patients' anatomic characteristics between the conical and non-conical group. Only distal (15mm) neck diameter was wider in patients with conical neck ($p<.001$). Supra-renal active fixation was used in 63.3% of the total cohort; 59.5% in non-conical necks and 68.2% of the patients with conical anatomy ($p=.275$). Graft oversizing was 19% and 26.5% in patients with non-conical and conical neck group, respectively (p=0.004). Oversizing >20% and >30% was more common in patients with conical neck [63.6 vs 36.9% (p<.001) and 11.9% vs. 43.9% (p<.001) respectively]. Regarding EVAR outcomes, no difference was recorded between patients with non-conical and conical neck. In a sub-analysis, among patients with conical neck, aggressive oversizing >30% was associated to lower graft migration rate during the 12-month follow-up (p=.011). From these 150 patients, 124 cases were further analysed in terms of the iliac anatomy. In total, 248 iliac limbs were included. In all three levels, iliac diameters increased. At the level of origin, the diameter increased from 18.9±10.8mm to 20.4±10.5mm (p=.02), at the middle portion, it changed from 15.8±6.0mm to 17.5±6.3mm (p<.001) and at the distal CIA, it altered from 14.6±4.2mm to 15.1±3.9mm (p=0.05). Iliac angle altered from 34.1±18.1° to 32.2±16.2° (p<.001). CIA index increased from 0.83±0.12 to 0.88±0.1 (p<.001). The mean value of oversizing was 19.7±13.3% and affected distal iliac diameter increase (p<.001). In 65 cases, a distal iliac diameter ≥18mm was recorded. The estimated oversizing was lower (16.8±11.7%) compared to non-aneurysmal arteries (22.5±14.8%, p=.02). At 12-month follow-up, iliac diameters remained stable in the aneurysmal group. ET Ib was more common in iliac arteries ≥18mm [4 (6.0%) vs 1 (0.5%)] at 12-months.

Conclusions: Post-EVAR aortic dilatation may be detected from the supra-renal aorta to the total length of the aortic neck down to the CIA arteries. Proximal dilatation may be attributed to multiple factors such as large neck diameter, supra-renal fixation, and aggressive oversizing while aggressive oversizing may be related also to iliac dilation. Compared to neck-related adverse events, which are more common in patients with infra-and supra-renal aortic dilatation, distal landing zone adverse events were not affected by the iliac dilatation during the 12-month follow-up. EVAR may offer similar good early outcomes in patients with conical and non-conical neck anatomy. Aggressive oversizing (>30%) may have a preventive role of graft migration in patients with conical neck during the 12-month period after EVAR. Aggressive distal oversizing (>15%) may also prevent ET Ib formation in iliac arteries ≥18mm during the 12-month follow-up.

Περίληψη

Σκοπός: Η αναδιαμόρφωση της υπερ- και υπονεφρικής αορτής και το αντίκτυπο της στις επιπλοκές που σχετίζονται με την κεντρική ζώνη πρόσφυσης μετά από ενδαγγειακή αποκατάσταση ανευρύσματος της κοιλιακής αορτής τελούν υπό διερεύνηση. Ταυτόχρονα, άλλοι ανατομικοί παράγοντες σχετιζόμενοι με τον κεντρικό αυχένα, όπως η κωνική μορφολογία, η οποία χαρακτηρίζεται ως ένα από τα «εχθρικά» χαρακτηριστικά για την ενδαγγειακή αποκατάσταση, μπορεί να ασκούν επιπλέον επίδραση στα αποτελέσματα της ενδαγγειακής αποκατάστασης. Ενώ το ενδιαφέρον της έρευνας επικεντρώνεται στην κεντρική ζώνη πρόσφυσης, η άπω ζώνη στην περιοχή των λαγονίων μπορεί επίσης να παίζει σημαντικό ρόλο όσον αφορά στις επιπλοκές και τις επανεπεμβάσεις που ακολουθούν την ενδαγγειακή αποκατάσταση. Ο στόχος της παρούσας ανάλυσης είναι να προσεγγίσει τις μεταβολές της διαμέτρου του κεντρικού τμήματος της κοιλιακής αορτής από την υπερνεφρική μοίρα ως και τον υπονεφρικό αυχένα και να διερευνήσει τους παράγοντες που τις επηρεάζουν αλλά και τις επιπτώσεις αυτών, όπως οι ενδοδιαφυγές τύπου Ια και η μετάθεση του μοσχεύματος, στην κεντρική ζώνη πρόσφυσης, σε ασθενείς που υποβλήθηκαν σε ενδαγγειακή αποκατάσταση ανευρύσματος της κοιλιακής αορτής κατά τον πρώτο χρόνο παρακολούθησης. Επιπλέον, ανάλογα αποτελέσματα θα προσεγγιστούν, όσον αφορά την κεντρική ζώνη πρόσφυσης, σε ασθενείς με κωνικό και μη κωνικό αυχένα. Σχετικά με την περιφερική ζώνη πρόσφυσης, η ανατομία των λαγονίων αρτηριών, οι μεταβολές της και η επίπτωση αυτών σε ανεπιθύμητα γεγονότα θα μελετηθούν κατά τον πρώτο χρόνο παρακολούθησης.

Μεθοδολογία: Συνετάχθει μια αναδρομική μελέτη, προοπτικά συγκεντρωμένων δεδομένων ασθενών που αντιμετωπίστηκαν σε τακτική βάση ενδαγγειακά για υπονεφρικό ανεύρυσμα της κοιλιακής αορτής από το 2017 ως το 2019 σε ένα τριτοβάθμιο κέντρο. Όλοι οι ασθενείς υπεβλήθησαν σε αξονική αγγειογραφία της κοιλιακής αορτής και των λαγονίων αρτηριών προεγχειρητικά και κατά τον 1ο και 12ο μετεγχειρητικό μήνα. Η βάση δεδομένων περιελάμβανε δημογραφικά στοιχεία, συννοσηρότητες, προεγχειρητικά και μετεγχειρητικά ανατομικά χαρακτηριστικά (υπερ- και υπονεφρικές μετρήσεις της διαμέτρου, τη διάμετρο του σάκου, τη γωνία, το αθηρωματικό φορτίο και το θρόμβο του αυχένα). Η υπονεφρική μοίρα του αυχένα εκτιμήθηκε σε τρία επίπεδα: άμεσα κάτωθεν της κατώτερης νεφρικής, στα 7 και 15χιλ. Αντίστοιχα, η υπερνεφρική μοίρα εκτιμήθηκε πάνω από την ανώτερη νεφρική, την άνω μεσεντέριο αρτηρία και άμεσα κάτωθεν της κοιλιακής αρτηρίας. Τα ανεπιθύμητα συμβάντα που σχετίζονται με τον αυχένα συμπεριελάμβαναν τη μετάθεση του μοσχεύματος πάνω από 10χιλ. και την ενδοδιαφυγή τύπου Ια. Σχετικά με την περιφερική ζώνη πρόσφυσης, η διάμετρος της κοινής λαγόνιας αρτηρίας μετρήθηκε σε τρία επίπεδα: στην έκφυση (άμεσα κάτωθεν του αορτικού διχασμού), το άπω τμήμα (άμεσα άνωθεν του λαγόνιου διχασμού) και στη μεσότητα της απόστασης από αυτά τα δύο ανατομικά σημεία. Η γωνία της λαγονίου ως προς την αορτή, οι δείκτες ελίκωσης της κοινής λαγονίου και όλου του λαγόνιου άξονα, η χρήση ενδονάρθηκα για τον ευθειασμό των λαγόνων σκελών (relining) και η υπερμεγέθυνση του μοσχεύματος (oversizing) αναλύθηκαν επίσης. Τα ανεπιθύμητα συμβάντα της περιφερικής ζώνης πρόσφυσης συμπεριελάμβαναν κάθε επανεπέμβαση σχετιζόμενη με αυτή, τις ενδοδιαφυγές τύπου Ιβ, τη μετάθεση μοσχεύματος και τη στένωση και απόφραξη του λαγόνιου σκέλους.

Αποτελέσματα: Εκατό πενήντα ασθενείς συμπεριλήφθηκαν στην ανάλυση του κεντρικού αυχένα. Στους 12 μήνες παρακολούθησης, όλες οι υπο-νεφρικές διάμετροι αυξήθηκαν ($p<0.001$), όπως και η άμεσα υπερνεφρική και η διάμετρος στο επίπεδο της άνω μεσεντερίου αρτηρίας ($p=.024$ και νp=.007, αντίστοιχα). Ο προεγχειρητικός αυχένας με διάμετρο >29χιλ ($p<.001$), η υπερνεφρική στήριξη ($p=.002$) και η υπερμεγέθυνση (oversizing) του μοσχεύματος >20% (p=.017) σχετίστηκαν με την υπο-νεφρική διάταση, άμεσα κάτωθεν της κατώτερης νεφρικής. Επιπλέον, ο προεγχειρητικός αυχένας με διάμετρο >29χιλ (p<.001 και p=0.001) και η υπερ-νεφρική στήριξη (p<.001 και p=.016) σχετίστηκαν με τη διάταση στα 7 και 15χιλ. Σχετικά με την υπερνεφρική αορτή, ο ευρύς αυχένας >29χιλ φάνηκε να επηρεάζει τη διάταση της. Οι επιπλοκές που σχετίζονται με τον κεντρικό αυχένα σχετίζονταν με στατιστική σημαντικότητα με της μεταβολές της διαμέτρου άμεσα κάτωθεν της κατώτερης νεφρικής αρτηρίας (p=.017). Η διάταση της διαμέτρου στα 7 και 15χιλ κάτωθεν της νεφρικής δε σχετίστηκε με τις ανωτέρω επιπλοκές (p=.11 and p=.09, αντίστοιχα). Σχετικά με την υπερνεφρική διάταση, η διαφορά της διαμέτρου στο επίπεδο άμεσα ύπερθεν της ανώτερης νεφρικής και της άνω μεσεντερίου σχετίστηκε με την εμφάνιση επιπλοκών της κεντρικής ζώνης πρόσφυσης (p=.007 και p=.05, αντίστοιχα). Η διάταση στο επίπεδο της κοιλιακής αρτηρίας δε σχετίστηκε με τα ανεπιθύμητα συμβάντα (p=.05). Στην ίδια ομάδα ασθενών (150 περιπτώσεις), 66 (44%) εμφάνιζαν κωνικό κεντρικό αυχένα. Καμία στατιστικά σημαντική διαφορά δε διαπιστώθηκε μεταξύ των δύο ομάδων ασθενών, εκτός από την περιφερική διάμετρο του αυχένα στα 15χιλ, η οποία ήταν ευρύτερη της ασθενείς με κωνικό αυχένα (p<.001). Μόσχευμα με υπερνεφρική στήριξη χρησιμοποιήθηκε στο 63.3% επί του συνόλου; 59.5% σε μη κωνικούς αυχένες και 68.2% σε ασθενείς με κωνικό αυχένα (p=.275). Η υπερμεγέθυνση (oversizing) του μοσχεύματος ήταν 19% και 26.5% σε ασθενείς με μη και με κωνικό αυχένα, αντίστοιχα (p=0.004). Η υπερμεγέθυνση του ενδομοσχεύματος (oversizing) >20% και >30% χρησιμοποιήθηκε ευρύτερα σε ασθενείς με κωνικούς αυχένες [63.6 έναντι 36.9% (p<.001) και 11.9% έναντι 43.9% (p<.001), αντίστοιχα]. Όσον αφορά της επιπλοκές της κεντρικής ζώνης πρόσφυσης, δεν παρατηρήθηκε διαφορά μεταξύ των δύο ομάδων ασθενών. Σε υπο-ανάλυση της ομάδας των ασθενών με κωνικούς αυχένες, η επιθετική υπερμεγέθυνση (aggressive oversizing) >30% σχετίστηκε με λιγότερο συχνή μετάθεση μοσχεύματος κατά τους 12 μήνες παρακολούθησης ($p=.011$). Από την ομάδα των 150 ασθενών, 124 συμπεριλήφθηκαν στην ανάλυση της ανατομίας των λαγονίων. Συνολικά, 248 λαγόνιοι άξονες μελετήθηκαν. Και στα τρία επίπεδα καταγραφής της διαμέτρου της κοινής λαγονίου αρτηρίας, παρατηρήθηκε στατιστικά σημαντική διαφορά. Στην έκφυση η διάμετρος μεταβλήθηκε από 18.9±10.0χιλ. σε 20.4±10.5χιλ. ($p=.02$), στη μεσότητα, από 15.8±6.0χιλ. σε 17.5±6.3χιλ. ($p<.001$) και στην άπω λαγόνιο, από 14.6±4.2χιλ. σε 15.1±3.9χιλ. ($p=0.05$). Η γωνία της λαγονίου ως προς την αορτή μειώθηκε από 34.1±18.1° σε 32.2±16.2° ($p<.001$) ενώ ο δείκτης ελίκωσης της κοινής λαγονίου αυξήθηκε από 0.83±0.12 σε 0.88±0.1 ($p<.001$). Η μέση τιμή υπερμεγέθυνσης του μοσχεύματος (oversizing) ήταν 19.7±13.3% και φάνηκε να επηρεάζει τη διάταση της περιφερικής διαμέτρου της κοινής λαγονίου ($p<.001$). Σε 65 περιπτώσεις (από τις 248 λαγόνιες αρτηρίες), η άπω διάμετρος προεγχειρητικά ήταν ≥18χιλ. Η εκτιμώμενη υπερμεγένθυση (oversizing) ήταν μικρότερη στις ανευρυσματικές λαγόνιες (16.8±11.7%) σε σχέση με τις μη ανευρυσματικές (22.5±14.8%, $p=.02$). Στους 12 μήνες παρακολούθησης, οι διάμετροι των ανευρυσματικών λαγονίων παρέμειναν σταθερές. Η ενδοδιαφυγή τύπου Ιβ ήταν πιο συχνή στην ομάδα των ασθενών με τις ανευρυσματικές λαγόνιες άνω των ≥18χιλ. [4 (6.0%) vs 1 (0.5%)] στους πρώτους 12 μήνες μετά από ενδαγγειακή αποκατάσταση.

Συμπεράσματα: Μετά από ενδαγγειακή αποκατάσταση ανευρύσματος της κοιλιακής αορτής παρατηρήθηκε διάταση της κεντρικής της μοίρας, η οποία εκτείνεται από την υπερνεφρική μοίρα μέχρι και όλο το μήκος του κεντρικού αυχένα καθώς και στις κοινές λαγόνιες αρτηρίες. Η κεντρική διάταση μπορεί να οφείλεται σε πολλαπλούς παράγοντες, όπως ο ευρύς προεγχειρητικός αυχένας, η υπερνεφρική στήριξη του ενδομοσχεύματος, και η επιθετική υπερμεγέθυνση του μοσχεύματος (aggressive oversizing) ως προς τον αορτικό αυλό. Ανάλογα η αυξημένη υπερμεγέθυνση (aggressive oversizing) μπορεί να σχετίζεται και με διάταση των κοινών λαγονίων αρτηριών. Σε αντίθεση με τα ανεπιθύμητα συμβάντα του κεντρικού αυχένα, τα οποία είναι πιο συχνά σε ασθενείς με υπερ- και υπονεφρική διάταση, η διάταση της περιφερικής ζώνης πρόσφυσης δε φάνηκε να σχετίζεται με ανεπιθύμητα συμβάντα στο επίπεδο των λαγονίων αρτηριών κατά τους πρώτους 12 μήνες της παρακολούθησης. Επιπλέον, από την ανάλυση των κωνικών αυχένων προέκυψε πως η ενδαγγειακή αποκατάσταση μπορεί να αποφέρει όμοια καλά αποτελέσματα τόσο σε ασθενείς με μη κωνικό όσο και σε ασθενείς με κωνική μορφολογία αυχένα. Η επιθετική υπερμεγέθυνση (aggressive oversizing) πάνω από >30% ίσως έχει προστατευτικό ρόλο όσον αφορά στη μετάθεση του μοσχεύματος κεντρικά σε ασθενείς με κωνική μορφολογία κατά τους πρώτους 12 μετεγχειρητικούς μήνες. Η επιθετική υπερμεγέθυνση (aggressive distal oversizing) στο επίπεδο των λαγονίων >15% ίσως έχει ανάλογα προληπτικό ρόλο στην εμφάνιση ενδοδιαφυγών τύπου Ιβ σε ασθενείς με ανευρυσματικές λαγόνιες ≥18χιλ. κατά τους 12 μήνες παρακολούθησης μετά από ενδαγγειακή αποκατάσταση ανευρύσματος της κοιλιακής αορτής.

Contents

Chapter 1

Foreword

Abdominal aortic aneurysm (AAA) is a fatal, if untreated, vascular disease, causing almost 1.5% of deaths among men elder than 65 years in the western world.[1] The disease has mainly an asymptomatic course, until rupture.[1] Nowadays, open surgical and endovascular repair offer a reliable management, under specific criteria and patients' selection.[1] The history of AAA treatment is remarkable and begins the 2nd century AD when Antyllus provided the first description of aneurysm cause and treatment, followed by Osler who first described aneurysm management using proximal and distal ligation.[2] In 1817, Astley Cooper performed the first abdominal aortic ligation due to an iliac aneurysm rupture and in 1888, Rudolf Matas was the first performing the endoaneurysmorrhaphy technique.[1,3,4]

However, the first open AAA repair using a homograft was reported in 1951 by Dubost, followed a few months later by Cooley and DeBakey in the USA.[5] Fourty years later, Juan Parodi, who conceived the idea of a stent graft with zigzag stents and polyurethane, treated successfully his first patient.[6] A few years later, under the need to address the technique in a larger patient population and expand treatment in iliac arteries, Tim Chuter introduced a unibody bifurcated stent graft which was first applied in 1993.[6] Since then, the endovascular technique evolved and gained popularity among vascular specialists. Despite the tremendous evolution of the technique in the recent years, a few clinical and experimental questions need to be addressed, including novel techniques and material and complication management as well as the pathologic mechanisms affecting AAA formation, expansion and post-operative surveillance and performance. Under this spectrum, this analysis was conducted to estimate aortic morphologic changes of the aorta after endovascular abdominal aortic aneurysm repair (EVAR).

Chapter 2

General information

2.1 Abdominal aortic aneurysm (AAA)

2.1.1 Definitions

An aortic aneurysm is a permanent focal dilatation of the aorta having at least 50% increase in diameter compared its normal diameter.[7,8] The normal values are extracted by studies already available in the literature and referred within ranges to the published reporting standards.[7,8] As this study will report only data regarding the abdominal aorta, supra-renal and infra-renal portion, and iliac arteries, the diameters referred in **Table 1** report only the suspected measurements at these vessels.

Artery	Range of reported mean	Range of reported standard deviation	Sex	Assessment method
Supraceliac aorta	2.10-2.31	0.27	Female	Computed tomography
	2.50-2.72	0.24-0.35	Male	Computed tomography
Suprarenal aorta	1.86-1.88	0.09-0.21	Female	Computed tomography
	1.98-2.27	0.19-0.23	Male	Computed tomography
Infrarenal aorta	1.66-2.16	0.22-0.32	Female	Computed tomography, intravenous arteriography
	1.99-2.39	0.30-0.39	Male	Computed tomography, intravenous arteriography
Common iliac artery	0.97-1.02	0.15-0.19	Female	Computed tomography
	1.17-1.23	0.20	Male	Computed tomography

Table 1. *Normal diameter values referred in the available reporting standards regarding the abdominal aorta and iliac arteries.*

2.1.2 Classification

Aneurysm classification should be interpreted according to the location, etiology, morphology and clinical manifestations.[8] As in all arterial vessels, also in the abdominal aorta, aneurysms may be congenital, mechanical, traumatic, inflammatory, infectious, degenerative and iatrogenic.[8] In this analysis, only degenerative aneurysms were included while any other pathology was excluded. Degenerative aneurysms, which past in the literature, were considered atherosclerotic, are the commonest type. However, the specific pathologic mechanism driving to the presentation and evolution of the disease has not been clarified.[8] Dissection, despite that may be related to many aneurysms' pathophysiologic causes and associates to aneurysm formation, it should be considered a distinct entity.[9]

In terms of morphology, the most significant characteristic is its dimensions including the anteroposterior, lateral and length, as well as the shape.[8] Regarding shape, abdominal aortic aneurysms are dichotomized into fusiform and saccular.[8] In clinical terms, abdominal aortic aneurysms (AAAs) are asymptomatic, when they present a benign nature (pulsatile mass, distortion of adjacent tissues) or symptomatic.[8] Rupture is defined as the extravagation of blood and its presence out of the arterial wall.[8] Rupture should be distinguish to free or contained, or fistulization into an adjacent organ.[8,9] In this aspect, patient's hemodynamic status at diagnosis should be reported, including a distinction between hemodynamically stable, unstable, cardiac arrest and death.[9] Especially in case of AAA rupture, patient's hemodynamic profile, as persistent hypotension of less than 70mmHg and cardiac arrest, seem to affect treatment decision and management outcome, even with endovascular means, as both situations have been related to higher mortality.[7,10-12]

2.1.3 Epidemiology

AAA prevalence increases with age while in younger individuals (<50 years), it remains low through the years.[13] Furthermore, a decreasing rate is recorded the latest decades probably due to the lower smoking incidence in the general population, in developed and developing countries.[13] However, it is of note that smoking remains one of the most important factors affecting the prevalence of the disease; in smokers, the prevalence is four times higher than that in the general population.[14] An analogous important decrease (20-50%) is recorded also regarding the diagnosed and managed ruptured AAA cases.[15-18] Furthermore, screening studies have shown, the prevalence is ranging between 1.3 to 3.3% in Europe, when referring to male population, older than 65 years.[19-22] The disease presents a lower prevalence (0.7%) in the female population, >60 years-old.[23]

As previously referred, smoking is of major interest in AAA formation and probably, the most significant risk factor, affecting especially the female population.[19,24-26] Furthermore, male sex, age, atherosclerotic disease, hypertension and ethnicity may affect AAA evolution while diabetes seem to offer a protective role.[24,26,27-29] A genetic predisposition may also be associated to aneurysm formation, as population studies have reported.[30,31] Positive family history seems to be strongly associated to AAA formation.[31,32] Almost 15% of patients with AAA have ≥1 relatives with aneurysm while the role of screening is also mandatory in these cases, as it prevents rupture and permits an elective management in an especially high-risk population.[33] As in histologic evaluations, aneurysmal wall presents signs of chronic inflammation and degeneration of the extracellular matrix and vascular smooth muscle cells, probably genes related to these physiologic procedures may participate in aneurysm formation and evolution.[33-35] Specifically, modifications in tissue inhibitor of metalloproteinases 1 and 3, matrix metalloproteinases and elastin genes have been detected and related to AAA evolution.[33-35] However, we should note that AAA pathogenesis may be a contribution of genetic and environmental factors and further investigations are needed to prove a specific genetic relationship.

2.1.4 Diagnostic imaging and the role of computed tomography angiography (CTA)

AAA detection and surveillance may be provided by different imaging modalities, including mainly ultrasonography, magnetic imaging resonance and CTA.[7,36] More specific tests as, positron emission tomography-computed tomography (PET-CT) may be used during the diagnostic approach in specific cases, as inflammatory and infectious aneurysms.[7] As aneurysm diameter is the most important factor associated to sac expansion, appropriate diagnostic modalities may be used to assess different anatomic characteristics and detect rapid growth and higher rupture risk.[36] Every modality is characterized by different benefits and weaknesses, however all provide anatomic information valuable for patients' management. As in this analysis, all data are retrieved from CTAs of patients that underwent AAA management using EVAR, a few details will be provided regarding the role of CTA.

CTA is not only able to detect AAA but further, contributes to the therapeutic decision, planning, management and surveillance after repair.[7] Especially, in case of ruptured AAA, CTA provides an early and reliable diagnosis and further information, on aneurysm's anatomy, extension of the disease and relationship with adjacent tissues and organs.[37-39] Even in case of impending rupture, CTA may provide specific characteristics enforcing the clinical criteria, as thrombus heterogeneity, increased aneurysm size; compared to previous studies, low thrombus/lumen ratio.[39] These information and patient's status provide valuable information for urgent intervention.

Regarding measurements using CTA scans with adequate software, intra-observer variability is within the clinically accepted range of 5 mm in most cases. However, the inter-observer reproducibility is estimated at 15% and when considering that diameter is the main indicator for repair, this may hamper safe decisions in the daily clinical practice.[40,41] On the other hand, CTA is advantageous in terms of pre-operative planning, as the total length of the aorta may be evaluated while currently available software three-dimensional analysis, the diameter, length and angle measurements with the application of center lumen line, as well as further details of the aortic anatomy, including side branches' patency, renal artery anatomy and aortic neck anatomy can be estimated.[7] New fully automated software may provide even more accurate details on AAA assessment, including robust lumen detection, infrarenal neck characteristics and presence of thrombus, and decrease inter-observer reproducibility weaknesses.[42] Vascular specialists familiarity with the available software augment the ability to interpret CTA images and improves AAA diagnosis and surveillance after treatment.[41]

CTA limitations include the use of intravenous contrast which may affect renal function, especially in patients with chronic kidney disease.[43-45] It is mandatory to prevent renal failure by the appropriate hydration of the patient pre- and post-CTA, intra-venously or orally. [43-45] The use of oral acetylcysteine has not been proved to provide any benefit in protecting kidneys' function.[45] At the same time, patient's irradiation, when considering the need for future imaging using CT during the post-operative follow-up, especially in young individuals, may increase the risk for malignancies.[46,47] The mean annual cumulative effective dose is 104 mSv per patient-year for EVAR, with a 0.8% average risk of exposure-induced death.[46] Regarding the procedural irradiation and contrast use, the intra-operative use of contrast enhanced cone beam CT, fusion technology and contrast enhanced cone beam CT provide a 50-70% reduction in effective doses during EVAR, by decreasing the operational time and providing immediate technical success assessment.[48,49]

2.1.5 Diameter as the indicator for treatment

Current recommendations suggest aneurysm management when diameter exceeds a specific threshold.[7,50] Other indicator for aneurysm repair are not evaluated, as aneurysm volume.[7] Fusiform AAA should be managed when diameter threshold exceeds 55mm.[7,50,51] A remarkable conformity exists among cardiovascular societies regarding the application of diameter as the most significant indicator for treatment while in most cases, and excluding special populations, the same threshold is applied worldwide.[51] A balance between the risk of operation and rupture should be considered each time an AAA exceeds a specific diameter threshold.[52]

AAA diameter threshold at 55mm was further supported by randomized trials of smaller AAA (40-55mm), that were effectively managed only with surveillance.[53-58] All studies concluded that patients with small AAAs, even when presenting a very low peri-operative mortality rate, are offered scarce benefit when treated while an appropriate surveillance until 55mm is a safe and cost-effective policy.[59] However, it is of note that, despite the wide acceptance and application of threshold diameter at 55mm, current recommendations suggest further investigation in small aneurysm operative treatment.[7] Current clinical evidence have shown that a significant part of patients are managed below 55mm.[60]

However, further than aneurysm diameter, the expansion rate, when exceeding 5mm per 6 months or 10mm per year, may be an indicator for AAA instability, associated to higher risk of rupture.[7,50] Specific imaging features of sac expansion and aneurysm instability, as hyperattenuating mural thrombus and intramural hemorrhage, may be able to detect aneurysm needing repair independent of diameter.[61]Additionally, symptomatic aneurysms associated to abdominal or lumbar pain or embolic events, also require treatment, regardless the diameter threshold.[62,63] However, in this approach, the observer errors should be encountered and these case should be re-assessed to confirm expansion within 14 days.[36,62,63] Additionally, symptomatic aneurysms associated to abdominal or lumbar pain or embolic events, also require treatment, regardless the diameter threshold.[64,65]

As previously mentioned, other factors may be also able to predict AAA risk of rupture, including volume, mechanical and biochemical factors.[66-68] Previous analyses have shown that diameter growth rate did not correlate with baseline diameter while volume growth rate strongly correlated with the baseline value while the peak wall rupture index, assessed using finite element analysis, was related to volume growth rate.[66] These findings support the hypothesis that AAA volume may be a more accurate predictor of aneurysm growth.[66] Biomechanical parameters permit an individualized analysis of factors that may affect AAA evolution and risk of rupture while the correlation of these parameters to the increased diameter may facilitate their application to treatment decision making in the future.[67] Biomarkers, applied in the daily clinical practice, as D-dimers and cholesterol were found to associate to AAA growth rates while more specific factors as osteopontin, haptoglobin polymorphisms, insulin-like growth factor I and neutrophil extracellular traps may be applied to predict the risk of rupture and set the indication for repair, regardless the anatomic parameters of the aneurysm.[68] A more individualized approach may facilitate an even more precise management in the future.

Other patient's characteristics, as sex and general status may also affect decision making. Women present a higher risk of rupture, even in smaller diameters, than men.[69] The risk of rupture in women suffering from AAA with 45mm diameter is equal to that of men with 55mm diameter.[69] These findings suggest that female patients benefit from intervention in <55mm AAA. Thus, current recommendations suggest AAA repair when the diameter threshold exceeds 50mm for the female population.[51]Additional factors, as poor general status and limited life-expectancy should be taken under consideration before treatment, as frail patients present a higher mortality rate, even with the application of minimal invasive techniques.[70-72]

2.2 Elective AAA endovascular management

2.2.1 Anatomy

Endovascular management of AAA is importantly affected by aneurysm's anatomy, as well as aortic branches features.[73] Regarding the pre-operative planning of EVAR, the greatest measurement refer to aneurysm's diameter, as this represents the main indication for treatment.[7,50]

2.2.2 Classification

When a patient is scheduled to undergo endovascular repair, the classification of the abdominal aortic aneurysm should be stratified according to the clinical presentation into asymptomatic (stage I) or intact but symptomatic (stage II), contained (stage III) and free rupture (stage IV), as in the evaluation of any AAA case described previously.[73] Patients suffering for dissecting aneurysm should not be categorized separately, as the nature of the disease and management are more complex and need a more specialized approach.[73]

Further, aneurysm anatomy and especially, sac diameter may classify aneurysms into small when diameter is less than 50mm, medium when diameter ranges between 50-65mm and large when the diameter exceeds 65mm.[73] The extent of the aortic involvement, as well as the tortuosity may be also used for the anatomic stratification (**Table 2**).[73]

Classification	**Extent of involvement**	**Tortuosity**	**Classification**	**Iliac anatomy**
Grade I	Length of proximal neck ≥15mm and distal neck - ≥10mm	180° to 150° (180°=straight aorta without any tortuosity)	**Grade A**	Absence of iliac artery occlusive disease
Grade II	Length of proximal neck ≥15mm, but distal neck <10mm, without iliac aneurysms or aneurysm extension to iliac arteries	150° to 120°	**Grade B**	Presence of iliac artery occlusive disease
Grade III	Length of proximal neck <1.5 cm and distal neck ≥1.0 cm	Less than 120°	**N**	Non-tortuous

Grade IV	Length of proximal neck <15mm and distal neck <10mm or iliac involvement as mentioned previously		**T**	Tortuous

Table 2. *The extent of the aortic involvement, as well as the tortuosity are used to define AAA anatomy and stratify its management.*

2.2.3 Rational of EVAR

As in the conventional open repair, the rationale behind EVAR is the deployment of a stent graft, sealing the sac and excluding the aneurysm from the arterial flow.[7] However, in EVAR, the aneurysm wall remains intact.[7] The presence of intact aortic zones and the use of oversizing are of major importance to permit a long-term efficacy.[7] According to the currently available guidelines, the suggested oversizing ranges between 10 and 25% regarding the proximal sealing zone.[7,9]

2.2.4 Devices

Commercially available endografts provide a modular design, including an aortic bifurcated main body and one or two iliac limbs.[7] In this way, the available devices can be tailored to patient’s specific anatomy, including diameters and lengths, offering an important flexibility in pre-operative planning and accomplishment of the procedure.[7] However, in case of hostile iliac anatomy, limiting access and deployment of a bifurcated device, an aorto-uni-iliac endograft may be deployed.[74] In this analysis, only bifurcated endografts were used. Additionally, each device offers specific characteristics that may conform to AAA anatomy in a better way than others, including graft reposition during deployment, suprarenal fixation, hooks or barbs, and polymer filled rings for proximal sealing.[75-79] Recently, novel devices with lower profile delivery systems have been available and expanded EVAR applicability in patients with small access vessels, as the female population.[80] The use of these devices is suspected to ameliorate EVAR outcomes in women and offer a safer treatment solution.[81] The selection of endograft, further than patient's anatomy, remains at the discretion of operator, as new or renovated devices are available, and the data of the literature may change rapidly. When comparing newer to previous generation endografts, the newer devices have performed better, and their use was related to lower re-intervention rate and need for conversion during the follow-up.[82]

In any case, each specific endograft deployment must follow several anatomical requirements; the instructions for use should be followed to permit a safe and effective outcome.[7] In daily clinical practice, IFUs may be violated. The deployment of endografts outside the IFUs, despite that seems not to affect the overall and aneurysm related mortality, has been associated to adverse events, including higher rates of type I endoleaks.[83] Furthermore, a high reintervention rate has been recorded in the long-term in these patients, estimated at 15%.[84] A comparison between the application of endografts within and out of IFUs, including 4,498 patients, has shown that nonadherence to IFU was related to similar peri-operative mortality, rupture, aneurysm-related mortality, technical failure and re-intervention rates. In this analysis, the overall mortality was higher in patients treated outside the IFU.[85] However, IFU violation may be considered in a specific patient population or under life-threatening conditions.[85]

2.2.5 Definition of successful EVAR

Defining the success of endovascular aneurysm repair remains dependent on a consideration of both clinical and radiographic criteria.[9] The purpose of EVAR, as well as of open repair, is to exclude the aneurysm sac from the systematic circulation.[9] This can be achieved with the use of endograft and if appropriating sealing is achieved, it drives to the complete exclusion of the aneurysm.[9] Despite that the presence of endoleaks may disturb in reporting technical success of EVAR, previous studies have suggested that a persistent endoleak may not lead to sac expansion and rupture.[86] Future investigations may lead to further refinement of technical success.

Previously, in the literature, primary technical success is defined on an intent-to-treat basis and requires the identification of four clinical endpoints including, access to the arterial system, deployment of the endograft to achieve proximal and distal fixation, absence of type I or III endoleaks, and stent patency without significant stenosis.[9,73] Sealing is defined as the absence of endoleak within the initial two post-operative days.[73] Every endoleak persisting more than 48 hours is considered a technical failure.[73] The latest phrase relies on the fact that EVAR reporting standards published in 1997 refer to the first generation endografts where porosity of graft material was a common finding with benign outcome.[87,88] The latest decades, the advancement of graft materials has eliminated this phenomenon.[87] The technical success, related to survival and absence of reintervention within the initial 30-days is considered a successful EVAR.[73]

Analogously, the clinical success is defined as the previously mentioned technical, but with the exception of endoleaks.[73] During the initial post-operative period, a percentage of these leaks may disappear without anu further intervention and no clinical impact on patient’s health status.[73] Clinical success may be achieved with or without technical success depicting that patients' survival without any further re-intervention or rupture.[73] Endoleaks that persist and are associated to sac expansion should be considered clinical failures, as they increase the risk for rupture and subsequent intervention.[73] Despite that technical and clinical success are defined in the literature, current data do not adherent strictly with them, as only 20% and 50% of the published studies refer the complication and mortality rate, respectively.[89]

Continuing success is defined as maintenance of the technical and clinical success with no evidence of complications, including thrombosis, migration, infection, or diameter dilatation greater than 20% and sealing zone degeneration and sac expansion more than 5mm.[9,73] If any of these complications is detected during patients surveillance is characterized as intervention failure.[73] In case of type II endoleak, clinical success can be claimed for those cases without aneurysm expansion.[9] As the role of type II endoleaks in late clinical failure remains under investigation, it is recommended that reports should clearly indicate the proportion of patients classified as clinical success, with a concomitant type II endoleak.[9]

Despite that any open re-intervention is counted as EVAR failure, re-interventions using endovascular means could be counted as assisted primary or secondary success.[9,73] When EVAR outcomes refer to the initial 6 months post-operatively are considered as short-term, midterm if maintained for 2 years, and long-term after 5 years.[73] Results reported between the 2nd and 5th post-operative year are intermediate while follow-up less than 6 months should be reported as preliminary.[73] Aneurysm rupture should be reported as either procedure-related, if a perforation of the aneurysm is detected during endograft implantation or as late, if the rupture follows device deployment.[9]

2.2.6 Endoleak

Endoleak is defined as the persistence of flow outside the endograft's lumen but within the sac, determined by an imaging modality.[90,91] Endoleaks may resolve spontaneously while endoleak persistence has been associated to late aneurysm rupture.[92-95] However, some type II endoleaks, due to patent aortic side branches, have been associated to sac shrinkage.[96] The presence of an endoleak depicts incomplete sac exclusion, due inadequate sealing between the graft and aortic or iliac wall, inadequate component connection, fabric defects or porosity, or retrograde flow from patent aortic branches.[91,97]

An endoleak can be classified according to time of occurrence after graft implantation and site of origin.[97] Primary endoleak is defined as an endoleak detected within the initial 30-days post-EVAR while secondary, any endoleak detected after 30-day follow-up.[91] Endoleak recurrence is the reappearance of an endoleak after spontaneous resolution or secondary intervention.[9] Type I endoleak is related to inadequate sealing at the proximal or distal landing zone; subscripts a or b indicate the origin of the endoleak at the proximal or distal zone, respectively.[9] Retrograde blood flow from patent side aortic branches, as lumbar arteries, the inferior mesenteric artery (IMA), or other collateral vessels is characterized as type II.[9] Type III endoleak is related to fabric disruption, component disconnection, or graft disintegration and subscripts a and b are used for the distinction between component disconnection and fabric tear, respectively.[9] Porosity, which describes blood flow through an intact but porous fabric, observed within the initial 30 days of follow-up, is defined as type IV endoleak.[97] If an endoleak is detected in imaging modalities, despite that its origin cannot be identified, it is characterized as an endoleak of undefined origin.[9] If an aneurysm continue to enlarge after EVAR, despite that endoleak detection is not feasible in the available imaging, persistent pressurization of the sac or thrombus may be present.[98,99] This phenomenon is categorized as endotension.[9] Probably, in these cases, the detection of blood flow may be not feasible due to sensitivity limits of the available imaging technology.[98]

2.3 EVAR outcomes in randomized controlled trials and cohort studies

2.3.1 Randomized control trials comparing EVAR and open repair

Four RCTs have been published comparing the conventional open repair to EVAR, including the EVAR 1 trial, DREAM, OVER, and ACE trials.[100-103] Despite that the RCTs have proven a significant early survival benefit for EVAR, this was lost during the mid-term follow-up. In EVAR 1, 1082 patients were enrolled and randomized to elective EVAR or open repair.[100] In all cases aneurysm diameter exceed 55mm. The 30-day mortality was 1.7% for EVAR vs. 4.7% for open repair while the re-intervention rate was 9.8% for EVAR and 5.8% for open repair.[100] After 4 years of follow-up, aneurysm related mortality and re-interventions were increased in the EVAR group.[100] After 8 years, the increased EVAR mortality was attributable to aneurysm rupture (7% vs. 1%).[100] The DREAM trial which enrolled 351 patients, with AAA diameter over 50mm, concluded that EVAR offered a higher 30-day survival advantage but this advantage was lost at the 1st year of follow-up.[101] At 2 years, the survival rate was 89.7% for EVAR compared to 89.6% for open repair. The extended (12-15 years) follow-up showed that the cumulative overall survival rates were comparable between the two techniques while EVAR presented a higher re-intervention rate.[104] The OVER trial included 881 patients (AAA diameter over 50mm) reported a lower peri-operative mortality for EVAR 0.5% (than OSR (3%).[102] This benefit was lost at 2 years of follow-up while the re-intervention rate was comparable between the techniques.[102,105] After 9 years of follow up, survival did not differ between the techniques.[106] The extended follow-up of the OVER trial showed that the long-term overall survival was similar between the techniques.[107] However, EVAR was associated to higher secondary procedure rate.[107] The results of the ACE trial, which randomized 316 patients with AAA diameter exceeding 50mm, showed no difference in the cumulative survival or major events rates and higher re-intervention rate in the EVAR group at 3 years of follow-up.[103]

EVAR provides a survival benefit within the initial six month after the procedure due to the lower peri-operative mortality.[108] However, this advantage was lost in the long-term.[108]After three years, the aneurysm related mortality was higher in the EVAR group and in high-risk patients, the benefit of survival was not met.[108] Furthermore, the re-intervention rate was increased in EVAR compared to open repair.[108] Though, it is of note that patients managed through the RCTs were treated using older devices while novel techniques and material may provide better outcomes. Thus, these RCTs may not be able to depict the today's clinical practice and reality and should be evaluated under this specific spectrum.

2.3.2 Cohort studies presenting EVAR outcomes

Recent studies reported a continued decrease in EVAR mortality and morbidity, even when applied in high-risk patients.[109-115] Recent data of 11,997 patients has shown the widespread use of EVAR over the years and confirmed its survival benefit compared to open repair.[113] The 30-day mortality after EVAR is estimated at 1% in cohort studies and the improved survival rate sustains for at least five years.[113,116] The expanding experience with EVAR seems to further ameliorate its outcomes in terms of survival in elective and ruptured cases.[115,117] However, controversies exists among the published registries and it seems that geographic differences exist in the litearture.[115,118] The increased rate of intact AAA repair, associated to the decreased EVAR mortality, reported in European registries was not met in non-European studies.[118] As EVAR evolves, surgeons' experience and centralization have improved its outcomes and current devices seem to provide a safe, effective and durable solution, as adverse events related to endoleak formation have been limited.[119] The rate of prolonged length of stay in intensive care units has declined considerably over time, from 41.4% to 7.3% in 2013 while elder patients are managed with EVAR and present improved outcomes compared to open repair.[120,121] As novel techniques and devices are applied in the daily clinical practice, before their potential use in RCTs, current data indicate that EVAR development through years, succeeded in offering viable treatment to patients that would be considered unfit for repair and even, with improved survival.

2.4 EVAR complications

Patients treated with EVAR may present late complications, as endoleaks of any type, graft migration, limb occlusion or stenosis, infection or rupture. Limb occlusion is an either early complication, reported mainly during the initial two years of follow-up while graft migration and endoleak may be present at any timepoint.[114] This late EVAR complications are reflected also to higher re-intervention rate compared to open repair.[108]

2.4.1 Endoleak

Endoleak may occur in up to 30% of patients and are classified to primary or secondary; occurring de novo after a previous negative imaging.[122] Type I endoleak should be treated as far as it is diagnosed, with either endovascular means or open repair. [7,123,124] According to patient's anatomy, sealing could be re-achieved using graft balloon dilation, bare metal or stent graft deployment, if there is an appropriate landing zone.[125-127] Other more complex proximal solutions could be the use of parallel graft technique and fenestration cuffs.[128,129] If an endovascular option is not contra-indicated, open conversion could be an alternative solution with acceptable results.[130,131]

Especially for endoleak type II, it seems that it represents a dynamic process while almost 8% of them are detected after the initial year of follow-up.[132]Almost 50% of endoleaks resolve spontaneously, without any further intervention.[122] A variety of techniques and embolic agents may be used to exclude a persistent type II endoleak.[133] Long-term follow up is required and optimizes the management of patients with type II endoleak.[133] Factors associated with endoleak type II persistence and sac expansion are anticoagulant therapy, induced occlusion of the internal iliac artery while the presence and pattern of thrombus.[132,134,1] At the same time, statin use may have a negative effect on endoleak persistence.[134]

As for type I endoleak, type III, which is also related to inadequate graft deployment, migration, or material fatigue, need direct management after diagnosis.[135] Open conversion may be needed if endovascular options have failed.[7] The incidence of type III endoleak is estimated at 2% and may be detected during follow-up imaging or intra-operatively during management of other EVAR complications.[136] Type IV endoleak is quite rare and no cases of rupture have been reported in the literature.[135]

Type V endoleak or endotension is a special condition associated to sac expansion without endoleak detection at imaging.[7,137] A variety of mechanisms has been suggested to relate with endotension as graft material permeability, not visible endoleak due to technical limitations of imaging.[137,138] Endotension may cause rupture and its treatment is indicated when it is associated to sac expansion rate.[7,137,138] In these cases, management can be performed using endovascular means or with open conversion.[138,139]

2.4.2 Limb occlusion

Limb occlusion after EVAR is quite common complication presented in up to 8% of patients, while limb extension to the external iliac artery, iliac atherosclerosis, tortuosity and oversizing exceeding 15%, are the main predictors for limb obstruction.[140-145] Primary limb patency 3 years was estimated at 98.5 ± 0.5%, respectively while freedom from limb reinterventions 3 years was 95.6 ± 0.7%.[142] Limb relining may be a preventive measure in patients presenting intra-operative kinking while specific graft devices have been related to lower limb occlusion rate.[142,143] Approximately one third of stent graft limb occlusions are noted within the first 30 days post-EVAR, and about half of the patients present with symptoms of acute limb ischaemia.[140,145]

In the current recommendations, graft kinking, diagnosed incidentally during follow-up imaging or due to symptoms should be managed operatively with endovascular means or bypass.[7] Thrombectomy with stenting, extra-anatomical bypass, or endovascular thrombolytic treatment could be used to restore patency and revascularized the threatened limb.[7] Currently, new devices performing mechanical thrombectomy may be used as a supplementary option while the available data are encouraging with high technical and clinical success and low peri-operative morbidity.[146]

2.4.3 Migration

Stent graft migration is defined as any stent movement of >10 mm compared to the initial stent position, as this is determined in CT reconstruction using center lumen line, any symptomatic migration, or any migration needing re-intervention.[7,9,147] Active fixation in modern stent grafts has reduced its prevalence while in patients treated with older generation, graft migration is more common.[147-150] Short-neck, excessive oversizing and initial large AAA diameter are associated to migration, which may result to endoleak formation, component separation or kinking, and graft.[147,151] Disease progression with neck dilatation may be a cause of late migration, and is related to initial neck diameter.[152] Graft migration may be also detected at the distal landing zone.[7,153] Iliac limb migration is related to the use of bell-bottom stent grafts, limited oversizing, initial AAA size and aneurysmal common iliac arteries.[153] Distal migration can be resolved using additional iliac stent graft, a safe and effective solution for migration management.[153]

2.4.4 Infection

Infection is a fatal late EVAR complication detected during the mid- to long-term follow-up, with an incidence of 3.5/1000 person-years.[154-156] Graft infection may be complicated with aortoenteric fistula.[154-156] EVAR infection treatment may be palliative, in high risk patients, with long-term antibiotics, endovascular, as a life-saving bridging treatment, in case of fistula or graft explantation, for definitive management.[154,156,157] After graft explantation, in situ reconstruction with cryopreserved allograft, rifampin-soaked silver Dacron graft or vein graft can be used.[154] However, the peri-operative mortality remains high and it is estimated at 40%.[154] Mortality during follow-up for graft infection may be related to cancer or senility.[155] Infection recurrence may occur in up to one third of survivals.[154]

2.5 Patients' follow-up after EVAR

As complications and need for re-intervention is higher after EVAR, a well-defined and regular imaging surveillance is mandatory.[7] Routine surveillance is not always able to detect findings that set the need for re-intervention.[158] However, patients' compliance has been limited to 60%, with a wide range among centers (9-88%).[159] Compliant patients present lower long-term mortality while the re-intervention seems not to be affected by patients' dedication to follow-up, as most patients requiring re-intervention are symptomatic.[159-161] Patients' stratification based on early imaging findings may be used to conform an individualized follow-up protocol according to the risk of late failure.[7]

2.5.1 Early follow up

According to the latest guidelines for AAA management, early imaging follow-up after EVAR is required to estimate the clinical and technical success.[7,50] While duplex ultrasound can detect endoleak and graft patency, its capacity is limited in the detection of graft migration and sealing and components adequate overlap.[7] In this case, a non-contrast CT needs to be performed as a supplementary imaging examination.[7] CTA is the imaging of choice during the early post-operative period.[7] However, repeated CTAs during follow-up expose patients to a high cumulative radiation dose.[162] To resolve this limitation, low radiation CTAs may be used with satisfactory results.[162]

2.5.2 Follow-up protocol after EVAR in the long-term

Early CTA is of high importance as using this imaging evaluation, patients could be stratified in low and high-risk groups for late EVAR failure and need for re-intervention.[7] A variety of findings can be characterized as risk factors for late failure, including endoleak, loss of sealing, and sac expansion.[7] As we have previously mentioned type I and III endoleaks are associated to higher risk of rupture and their identification set the indication for direct management.[163] However, any type of endoleak may be predictive for late EVAR failure.[164] In case of type II endoleak, aneurysm fate is questioned, as they may be benign and resolve spontaneously while in other cases, they are associated to sac expansion and rupture.[163] Therefore, in patients with type II endoleak, a more frequent surveillance is indicated, despite that the indication for re-intervention is set only in case of sac expansion.[163] In these cases, patients' follow-up can be continued using duplex ultrasonography and CTA can be performed if sac size expands more than 10mm.[7,163] The loss of adequate sealing is another important factor for EVAR failure.[7]

Sac regression during follow-up is indicative for aneurysm exclusion and a favorable post-operative course.[165] The prevalence of endoleak in patients with sac shrinkage is low while after 5 years of follow-up, patients with sac regression during the initial follow-up presented higher rates and reintervention-free rate (>95%).[165] A recent analysis of 540 EVAR patients has shown that sac regression to ≤40mm in diameter was associated with improved freedom from rupture and survival.[166] The prognostic value of sac regression should be considered in surveillance strategies and patients presenting stable or expanding sac after EVAR should follow a more strict and regular re-evaluation imaging protocol.[167]

In the latest guidelines, follow-up protocol includes an early post-operative imaging, followed by patient stratification according to the initial findings.[7] In low-risk patients, follow-up could be delayed until the 5th post-operative year.[7] Patients with endoleak type II are considered as intermediate risk group and follow-up is mandatory to detect sac expansion.[7] The high risk group, with type I or III endoleak and inadequate sealing, should be managed immediately while when loss of sealing without endoleak is detected, repeated imaging is suggested, mainly with CTA, to assess endoleaks and AAA expansion.[7]

2.6 Aortic and iliac remodeling

Changes in aneurysm diameter after EVAR have been used as the main marker for clinical efficacy, as aneurysm size is the main indicator for rupture.[168] Aortic neck dilatation, as well as progressive iliac anatomic changes may occur as a result of the technique itself or they may be the outcome of the continuous degenerative process.[9] After endograft deployment, native aortic biomechanical and hemodynamic are modified and this phenomenon results to dynamic changes to aortoiliac anatomy and dimensions.[9] However, the rate and direction of these changes is influenced by a multifactorial process, including graft and aortic properties. For the moment, these late changes have not been used in the definition of clinical success, however they may affect a significant proportion of patients and may be related to adverse EVAR outcomes.[152]

2.6.1 Neck characteristics and morphologic changes

Aneurysm exclusion and device stabilization depend on the maintenance of sealing between the endograft and aortic wall. Thus, aortic dilatation at sealing zones, including the infra-renal aorta and distal common iliac arteries, may lead to device migration or occurrence of endoleak, subsequent sac expansion and rupture.[169-172] Neck dilatation and progressive changes on endograft dimensions, which are associated to increased rates of type I endoleak, migration, and reinterventions, may be detected with the adequate imaging and follow-up protocol early, before aneurysm rupture.[152,173] Aortic neck diameter and graft attachment should be assessed and measurements should be provided perpendicularly to the flow line while an outer-to-outer perimeter of neck wall should be used as the reference point.[9]

2.6.2 Sac morphologic alterations

As in EVAR the aneurysm sac remains intact, this feature may be used to define EVAR outcomes.[9] Changes in sac diameter define the success or failure of the technique, as sac expansion indicates incomplete aneurysm exclusion, continuous risk of rupture, and treatment failure.[174] On the contrary, morphologic alterations in the aortic configuration, because of sac elimination, may jeopardize endograft integrity and provoke graft instability during the follow-up.[9]

As variations in size affect all three dimensions, sac volume and diameter, in collaboration, may be able to define and detect any change in aneurysm size.[175-177] Relatively small diameter changes, difficultly detected in conventional imaging, may be related to more significant volume alterations.[175-177] Thus, aneurysm size should be expressed as either maximum diameter or volume, while the imaging modality used, method and definitions should be detailly described.[9] Maximum sac diameter should be measured perpendicular to the flow line with three-dimensional reconstructed CTA.[9,178] As, the intra- and interobserver variability of CTA measurements range between 2-5 mm or 5-15%, a diameter change of ≥5 mm is considered significant.[9,179,180] Further than diameter, aortic length may be related to aneurysm size and depict endograft deficits, as buckling, kinking, and dislocation.[181] Length measurement should be realized along the flow line, from the inferior renal artery to a reproducible distal endpoint, as the aortic bifurcation, using always a three-dimensional CTA reconstruction.[182-186]

Lately, aneurysm volume has been as studied as a detector of sac variations after EVAR.[9] Total volume is the volume within the native aortic wall, from the inferior renal artery to the aortic or iliac bifurcation while luminal volume represents the volume circumscribed by the endograft and non-luminal, the volume compromising sac thrombus and if present, endoleak.[9] Complete aneurysm resolution should be used if the non-luminal volume is <10% of the volume after endograft deployment.[9] As the intra- and interobserver variability for volume measurements ranged between 3-5%, volume change of ≥5% is considered significant.[176]

2.6.3 Changes of iliac morphology

Progressive curvature of the aortoiliac segment and dilatation of iliac arteries may result in device instability and loss of sealing due to component disruption, limb occlusion, endoleak evolution. Additionally, changes in iliac angulation and tortuosity after EVAR, affecting graft conformability to the aorta, may be important determinants of outcome.[9] As previously mentioned, three-dimensional analysis is of major important when assessing morphologic modifications in the aortoiliac segment.[9]

Chapter 3

Specific issues

3.1 Purpose of this analysis

Along these lines, despite the evolution of the technique, EVAR seems to present a higher re-intervention rate while proximal neck adverse events, including migration and endoleak type Ia are critical to consider a successful EVAR in the long-term.[126,152] Neck dilatation, which is a potentially multifactorial phenomenon, may affect EVAR outcomes, especially when taking into consideration the proximal and distal landing zone.[152,153] Taking into consideration this remark, primarily, the aim of this analysis was to assess the aortic diameter alterations from the supra-renal to its infra-renal part after standard EVAR and relate aortic morphologic changes to neck-related adverse events during the 12-month follow-up.

However, all patients undergoing EVAR do not present the same anatomic characteristics and a few patients in the daily clinical practice may be managed out of the current recommendations and IFUs.[4,85] As this study depicts the daily clinical practice, including patients managed with EVAR in the elective setting, in a secondary approach, we aimed to present EVAR proximal neck adverse events, including ET Ia and graft caudal migration, in patients with conical neck compared to patients with non-conical neck. Factors that may have affect neck adverse events in patients with conical neck during the initial post-operative year will also be analyzed.

Despite that proximal sealing zone is of the higher importance in AAA management, we further provided an analysis regarding the distal landing zone of the iliac arteries.[9] Adverse events associated to distal sealing may also affect the definition of a successful EVAR, as endoleak type Ib (ET Ib) and cranial migration, may impact the re-intervention rate and complicate with aneurysm rupture.[9] The aim of the latest analysis was to assess distal landing zone dilatation at the 12-month follow-up, adverse events related to distal sealing and the factors associated with these phenomena.

3.2 Risk factors and adverse events related to supra- and infra-renal aortic dilatation after endovascular abdominal aortic aneurysm repair (***Submitted to***

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3.2.1 Introduction

Endovascular abdominal aortic aneurysm repair (EVAR), using the currently available endografts, has been proven to be safe and effective, while when being compared to open repair, the associated early morbidity and mortality are significantly lower.[187,188] However, EVAR has been associated with higher graft-related complication and re-intervention rates during the mid- and long-term follow-up, and post-operative surveillance is recommended.[188-190] Along these lines, the need to investigate the factors affecting EVAR performance has emerged over years.[191]

The role of sufficient and durable proximal neck is critical for successful sealing and aneurysm exclusion.[152,192] Aortic neck dilatation after EVAR has been related to worse clinical outcomes due to higher endoleak and migration rates while the impact of anatomic and technical characteristics on diameter expansion is still under investigation.[152,193] A combination of anatomic and technical characteristics seems to be related to aortic morphologic changes after EVAR.[194-198] However, definite conclusions have not been extracted regarding the expansion of the supra-renal aorta and the factors that may affect this process.

Along these lines, the aim of this study was to assess aortic diameter alterations from the supra-renal to its infra-renal part after standard EVAR, investigate the factors affecting this process and relate these changes to neck-related adverse events during the 12-month follow-up.

3.2.2 Methods

3.2.2.1 Study Cohort

Prospectively collected data of consecutive patients treated electively with standard EVAR for infra-renal abdominal aortic aneurysm (AAA), using currently commercially available endografts (Medtronic Endurant, Santa Ana, CA, USA; Cordis Incraft, Dublin, OH, USA; Treovance Bolton, Sunrise, FL, USA; Gore Excluder, W.L. Gore and associates, Flagstaff, AZ, USA; Endologix AFX 2, Irvine, CA, USA; Zenith, Cook Medical, Bloomington, USA) was undertaken in a single tertiary centre. Patients were treated between 2017 and 2019 based on the recent guidelines.[7,199] Cases managed in urgent or emergent setting due to ruptured or symptomatic AAA (27 cases), as well as patients needing more complex repair (34 patients underwent chimney EVAR) were excluded from this analysis. Furthermore, seventeen patients that were managed using the endovascular sealing device (Nellix, Endologix, Irvine, CA, USA), between 2017-2018, were not included.

A dedicated database existed for the prospective collection of patients' data, including demographics (age, sex) and aneurysm anatomic characteristics [infra-renal diameter at 3 different levels: just below the inferior renal artery, at 7mm, and 15mm; and supra-renal diameter at 3 levels: just above the superior renal artery (SRA), superior mesenteric artery (SMA), and just below the celiac trunk (CT), **Figure 1**]. Furthermore, sac diameter, neck thrombus and calcification; characterized as presence or absence of thrombus or calcification (located at the infra-renal neck), neck angulation, intra-operative details (oversizing, type of endograft fixation, intra-operative endoleak type Ia (ET Ia), additional use of cuff, use of endoanchors) were also recorded. Sizing and planning were performed based on pre-operative computed tomography angiography (CTA), using a workstation with dedicated reconstruction software (3Mensio, Medical Imaging B.V., Bilthoven, Netherlands). All patients underwent EVAR within a month after AAA diagnosis. Regarding aortic diameters, a comparison between the 1st and 12th month to the pre-operative CTA was performed to detect any aortic diameter alteration. All CTAs were evaluated by two independent experienced investigators (P.N., G.K.) and any discrepancies were resolved by a third investigator (M.M.).

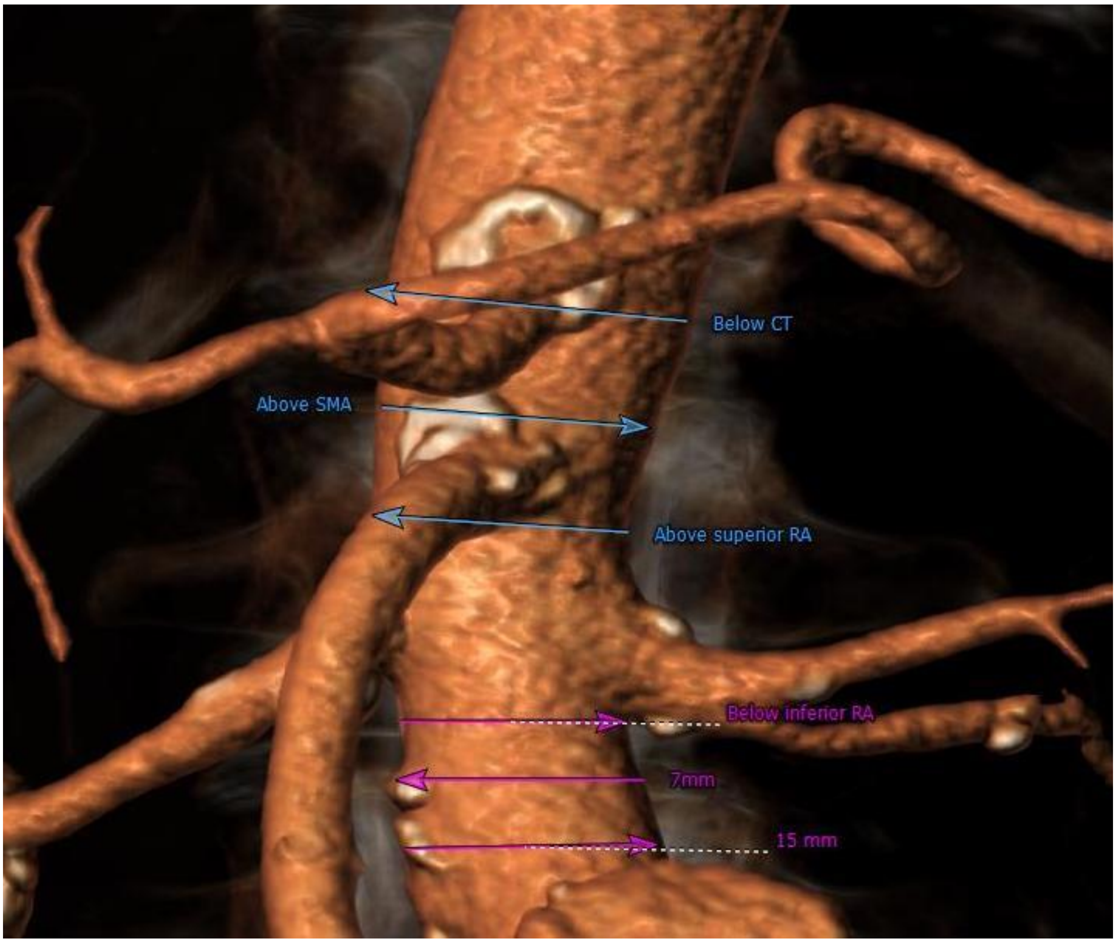

Figure 1. *Three infra-renal and three supra-renal aortic diameters were estimated at the pre-operative and 1st year computed tomography angiography. Infra-renal diameters were calculated at just below the lowest main renal artery, 7mm and 15mm while the supra-renal diameters were estimated just above the superior renal artery, the superior mesenteric artery and just below the celiac trunk. These landmarks were used to permit repetition of the measurements at the CTA of the 1st year. SMA: superior mesenteric artery.*

All patients were treated in an adequately equipped operating room using a moveable radiolucent surgical table and a mobile digital angiographic system (Ziehm

Vision RFD Hybrid Edition, Ziehm Imaging, GE). The final decision for graft selection was at the discretion of senior surgeon, according to their experience and addressed to patient's anatomy. After graft deployment, all endografts were dilatated using the same type of molding balloon (Reliant, Medtronic, Santa Ana, CA, USA) for 10-15 seconds.

Follow-up included an appropriate CTA at 1st and 12th month post-operatively. Post-operative CTAs were assessed using center lumen line (CLL) measurements, which permitted the detailed evaluation of the aorta and graft. All pre-operative measurements were repeated using the previously mentioned landmarks; just below the lower renal artery, at 7 and 15mm, regarding the proximal neck, and just above the SRA and SMA and just below the CT for the supra-renal aorta. All measurements were performed from outer-to-outer wall. All follow-up CTAs were evaluated by two independent experienced investigators (P.N., G.K.) and any discrepancies were resolved by a third investigator (M.M.). Neck-related adverse events included graft migration and ET Ia. Regarding graft position and its potential migration, a comparison between the 1st and 12th month CTA was undertaken. This study involved the collection of existing data and diagnostic tests that have been recorded in such a manner that subjects could not be identified, either directly or through identifiers linked to the subject. The study was approved by the Institutional Review Board (Sector of Surgery, School of Health Sciences, University of Thessaly, 605/14-02-2017).

3.3.2.2 Definitions

Infra-renal diameter was specified as the diameter of the aorta just below the inferior main renal artery.[200] The proximal 15mm of the neck length were considered as the zone of endograft sealing, as the majority of currently available endografts rely on this length to achieve graft fixation. The difference between the pre-operative and 1st month and pre-operative and 12th month aortic diameter, in all six levels, was defined as the result of aortic diameter at 1st month minus the aortic diameter pre-operatively and 12th month diameter minus the aortic diameter pre-operatively, respectively. Neck thrombus and calcification were dichotomized as present or absent characteristic. They were measured and expressed as percentages of the aortic circumference.[201] When the measurement exceeded 25% of the aortic circumference, thrombus and calcification were characterized as present. All diameters were estimated from outer-to-outer wall while in each level they were calculated as the mean value between the maximal and minimum aortic diameter in axial views after the application of CLL.[9] Migration was defined any caudal movement of the endograft ≥10mm from its initial position which was identified compared to the 1st post-operative CTA.[9] Oversizing was defined as the mean percentage between the graft and aortic diameter difference at the proximal neck diameter.[9,200,201] According to the instructions for use, the suggested oversizing at the aortic neck should range between 10 and 20%.[9,200] According to the instructions for use, the suggested oversizing at the aortic neck should range between 10 and 20%.[202]

3.2.2.3 Statistical Analysis

Continuous data were reported as a mean ± standard deviation. Categorical data were expressed as absolute numbers and percentage of prevalence (%) in the study cohort. In the statistical analysis for continuous variables the independent t-test for normally distributed data and the Mann-Whitney U test for nonparametric data were used. The Pearson’s chi square test was used for categorical variables. Repeated measures ANOVA was used to assess neck alterations between the two different time points.; pre-operative and 1st month measurements and pre-operative and 12th month measurements, respectively. Univariate and multivariate Cox proportional hazard regression analysis was used to evaluate the effect of relevant risk factors for neck-related adverse events. The enter method with significance level of 0.05 was used to obtain p values and odds ratios for the main effects and interactions. Statistical analysis was performed by SPSS 22.0 for Windows software (IBM Corp, Armonk, NY).

3.2.3 Results

In total, 150 patients, all males, with a mean age at 72±7.2 years, were treated electively with standard EVAR for infra-renal AAA between 2017 and 2019. Patients' demographics and comorbidities are presented in **Table 3**.

Demographics and comorbidities	**Value**
Age (years)	72±7.2
Males	150 (100%)
Hypertension	123 (82%)
Diabetes Mellitus	19 (12.6%)
Dyslipidemia	123 (82%)
Coronary artery disease	51 (34%)
Chronic obstructive pulmonary disease	54 (36%)
Never smoker	41 (27.3%)
Current smoker	48 (32%)
Previous cerebrovascular event	7 (4.7%)
Peripheral arterial disease	14 (9.3%)
Chronic renal failure(GFR<30ml/min)	4 (2.6%)

Table 3. Patients' demographics and comorbidities.

Among them, 95 were managed using suprarenal fixation (**Table 4**). The distribution of anatomic characteristics among patients managed with supra- and infra-renal fixation is depicted in **Table 5** while no statistical difference was recorded between groups.

Device	**Number of patients (%)**
Endurant, Medtronic Endurant, Santa Ana, CA, USA	48 (32)
Excluder, W.L. Gore and Associates, USA	39 (26)
Cordis Incraft, Dublin, OH, USA	21 (14)
Endologix AFX 2, Irvine, CA, USA	18 (12)
Suprarenal	2
Infrarenal	16
Treovance Bolton, Sunrise, FL, USA	16 (10.7)
Zenith, COOK Medical, USA	8 (5.3)

Table 4. The distribution of the devices among patients.

Anatomic characteristics	**Patients managed with supra-renal fixation graft (n=95)**	**Patients managed with infra-renal fixation graft (n=55)**
Aneurysm diameter (mm)	59.7±11.8	58.6±12.2
Neck length (mm)	24.724.7±9.09.0	25.8±8.8
Neck angulation	26.5±11.8	25.1±12.6

Neck angle >60°	0	5 (9.0)
Conical morphology (number of patients, %)	45 (47.4)	21 (86.6)
Aortic diameter at CT level (mm)	26.9±3.2	25.7±2.3
Aortic diameter at SMA level (mm)	26.4±3.2	25.4±2.3
Supra-renal aortic diameter (mm)	26.0±3.2	24.7±2.3
Infra-renal aortic diameter (mm)	23.9±3.3	22.4±2.1
Aortic diameter at 7mm (mm)	25.0±3.7	22.9±2.1
Aortic diameter at 15mm (mm)	26.1±3.8	24.2±2.8
Presence of calcification (number of patients, %)	34 (35.8)	18 (32.7)
Presence of thrombus (number of patients, %)	46 (48.4)	18 (32.7)

Table 5. Anatomic characteristics' distribution among patients with infra and supra-renal fixation endografts.

All patients have completed the 1st and 12th month of post-operative follow-up. The mean AAA diameter was 58.6±10mm and mean neck length was 25.1±9.8mm. All pre-operative anatomical characteristics are presented in detail in in **Table 6**.

Preoperative anatomical characteristics	**Value**
Aneurysm diameter (mm)	60.7±13.9
Neck length	25.1±9.8
Neck angulation	25.2±18.9

Neck angle >60°	5
Conical morphology (number of patients, %)	66 (44)
Aortic diameter at CT level (mm)	26.5±2.9
Aortic diameter at SMA level (mm)	26.1±2.9
Supra-renal aortic diameter (mm)	25.5±3.0
Infra-renal aortic diameter (mm)	23.3±2.9
Aortic diameter at 7mm (mm)	24.3±3.3
Aortic diameter at 15mm (mm)	25.5±3.6
Presence of calcification (number of patients, %)	52 (34.6)
Presence of thrombus (number of patients, %)	64 (42.6)

Table 6. *All pre-operative anatomic characteristics were presented above. The anatomical characteristics of the aneurysm were estimated at 3 levels of the infra-renal and equal levels of the supra-renal aorta.*

3.2.3.1 Infra and supra-renal aortic measurements

Regarding the infra-renal aortic neck, no statistically significant difference was found between the pre-operative and 1st month diameter at any level, as depicted in **Table 7.** A significant difference was recorded at all three levels at the 12th month of follow-up; the infra-renal diameter increased from 23.3±2.9mm to 24.3±3.6mm, while at 7mm and 15mm, the diameter altered from 24.3±3.3mm to 25.2±4.0mm and 25.5±3.6mm to 27.4±5.2mm, respectively. In all three levels, infra-renal diameter increase was statistically significant ($p<.001$, in all measurements). Regarding the supra-renal diameters, no statistically significant difference in diameter was found at 1st month (**Table 7**). At 12-months, SRA diameter increased from 25.5±3.0mm to 26.0±3.4mm (p=.024), SMA diameter from 26.1±2.9 to 26.5±2.9mm (p=.007) and CT diameter from 26.5±2.9 to 26.7±2.9mm (p=.26).

Level of measurement	**Pre-operative diameter**	**1st month diameter**	**P for 1st month alteration**
Infra-renal aortic diameter	23.3±2.9mm	23.2±3.2mm	.48
Aortic diameter at 7mm	24.3±3.3mm	24.1±3.5mm	.73
Aortic diameter at 15mm	25.5±3.6mm	25.5±3.9mm	.13
Aortic diameter at SRA level	25.5±3.0mm	25.1±3.1mm	.071
Aortic diameter at SMA level	26.1±2.9mm	25.9±3.0mm	.060
Aortic diameter at CT level	26.5±2.9mm	26.4±3.0mm	.061

Table 7. Diameter alterations between the pre-operative measurements and 1st month. *Footnotes: CT: celiac trunk; SMA: superior mesenteric artery.*

3.2.3.2 Factors associated to aortic diameter changes

Regarding the alterations of diameter at 12 months, infra-renal diameter (just below the inferior renal artery) increase was associated with the presence of large neck diameter (p<.001), supra-renal fixation (p=.002), and oversizing >20% (p=.017), while at 7mm and 15mm, the diameter difference was affected by large neck and suprarenal fixation (at 7mm: p<.001 and p=.001, respectively, and at 15mm: p<.001 and p=.016, respectively). Regarding the supra-renal aortic measurements, the presence of large neck affected diameters' increase at all three levels (SRA, SMA and CT; $p<0.001$, $p<.001$ and $p=.015$, respectively). Factors analyzed to aortic diameter alterations for the total cohort are presented in detail in **Table 8**.

Factors analyzed in relation to infra-renal dilatation	**Value**	**P for Infra-renal diameter (0mm)**	**P for 7mm diameter**	**P for 15mm diameter**
Age	72±7.2 years	.32	.32	.08
Aneurysm diameter	60.7±13.9mm	.80	.79	.20
Presence of neck thrombus	64 patients	.90	.90	.36
Presence of neck calcification	52 patients	.46	.20	.59
Neck Angle>60°	5 patients	.49	.23	.64
Neck diameter≥29mm	10 patients	<.001	<.001	<.001
Supra-renal fixation	95 patients	.002	.001	.016
Oversizing >20%	75 patients	.017	.04	.08
Factors analyzed in relation to supra-renal dilatation	**Value**	**P for supra-renal diameter**	**P for SMA diameter**	**P for CT diameter**
Age	72±7.2 years	.23	.18	.15
Aneurysm diameter	60.7±13.9mm	.65	.84	.54
Presence of neck thrombus	64 patients	.72	.33	.80
Presence of neck calcification	52 patients	.40	.73	.76
Neck Angle>60°	5 patients	.54	.06	.25
Neck diameter≥29mm	10 patients	<.001	<.001	.015
Supra-renal fixation	95 patients	.77	.84	.96
Oversizing >20%	75 patients	.32	.88	.57

Table 8. *The role of factors investigated to aortic diameter dilatation at the infra and supra-renal aorta.*

3.2.3.3 Aortic diameter alterations and proximal neck-related adverse events

No patient was lost to follow-up while no death was recorded during the initial 12 months. All neck-related adverse events recorded during the 12-month follow-up are presented in **Table 9**. In total, 29 patients presented with neck-related adverse events; 7 cases of ET Ia and 23 cases of caudal graft migration were detected. In one case with ET Ia, there was a suspicion of its presence at the CTA of the 1st month. None of the patients with ET Ia left the operating room with an endoleak detected at the completion angiography. Only one case presented simultaneous endoleak and graft migration at 12 months. The remaining patients presented either adverse event: migration or endoleak. Six patients underwent re-intervention to provide proximal sealing. Five of them were managed using endovascular means while in one case, an open conversion was performed (**Table 9**). In the latest case, the patient presented signs of peri-aortic inflammation and a biopsy of the aortic wall was performed. Finally, an IgG4 angiitis was diagnosed. He passed away due to pneumonia on the 14th month of follow-up. All the remaining cases, that did not undergo re-intervention during the 12-month follow-up, remained under close surveillance.

Patients' neck-related adverse events during 1st year of follow-up	**Number of neck-related adverse events**	**Re-interventions for proximal sealing during the 1st year of follow-up**

ET Ia at 1 year	7	***1 case*** needed open conversion and proximal cuff ***3 cases*** underwent proximal extension using the parallel graft technique ***2 cases*** underwent proximal extension using cuff *-1 case presented concomitant migration* ***1 patient*** denied any further intervention
Caudal migration >10mm at 1 year	23 (1 case of concomitant ET Ia and migration)	***1 case*** underwent proximal extension using cuff ***22 cases*** are under surveillance using imaging
Composite of ET Ia & migration at 1 year	29 patients with neck-related adverse event	6 re-interventions for proximal sealing in the total cohort

Table 9. *Neck adverse events distribution among patients. In total 29 patients presented neck-related adverse events and 6 of them underwent further re-intervention. Only one patient needed open conversion. ET Ia: endoleak type Ia*

3.3 Impact of conical morphology on proximal neck adverse events after endovascular aneurysm repair (*Submitted to Annals of Vascular Surgery, Number assigned: AVS-D-22-00896, Under Review*)

3.3.1 Introduction

Conical neck represents a hostile characteristic that may have an effect on the efficacy of endovascular abdominal aortic aneurysm repair (EVAR).[203,204] The application of EVAR on patients with conical morphology is out of the instructions for use (IFU) for the available devices.[7] However, in daily clinical practice, a high percentage of patients that are considered non-eligible according to IFU due to neck hostility, are treated using EVAR.[205] There is evidence that specific hostile neck anatomical characteristics, as short length, large diameter, calcification, angulation, and conical morphology are associated with adverse events.[203,204] However, few data exist in the current literature concerning the impact of conical neck in EVAR outcomes.[85, 206-208]

In daily practice, treatment of patients with EVAR out of IFU is not rare (45%) while higher rates of endoleak type Ia and graft-related adverse events may be present in these cases.[83,205] Non-adherence to IFU seems also to have worse long-term survival outcomes in these patients while endografts' evolution may be able to overcome patients' specific anatomy and offer improved EVAR outcomes.[83,85,209-211] Nevertheless, all neck morphological characteristics may not have the same impact on EVAR outcomes.

The aim of this study was to present EVAR proximal neck adverse events, including endoleak type Ia (ET Ia) and graft caudal migration, in patients with conical neck compared to patients with non-conical neck while factors that may affect neck adverse events in patients with conical neck during the initial post-operative year were also analyzed.

3.3.2 Methods

3.3.2.1 Study Cohort

A retrospective analysis of prospectively collected data of consecutive patients treated electively with standard EVAR for infra-renal abdominal aortic aneurysm (AAA) was undertaken. The available devices that were used included Medtronic Endurant (Santa Ana, CA, USA) Cordis Incraft (Dublin, OH, USA), Treovance Bolton (Sunrise, FL, USA), Gore Excluder (W.L. Gore and Associates Flagstaff, AZ, USA), Endologix AFX 2 (Irvine, CA, USA). All patients were managed using currently commercially available devices. Patients were treated between 2017 and 2019 according to the ESVS guidelines.[7,199]

A dedicated database exists for the prospective collection of patients' data, including demographics (age, sex), anatomical characteristics of the AAA (infra-renal diameter, middle neck diameter at 7mm, distal neck diameter at 15mm, aneurysm diameter, neck thrombus or calcification, neck angulation, **Figure 2** intra-operative details (type of endograft; supra or infra-renal fixation, oversizing, additional use of cuff, intra-operative ET Ia). Sizing and planning were performed based on the pre-operative computed tomography angiography (CTA) using a workstation with 3Mensio dedicated reconstruction software (Medical Imaging B.V., Bilthoven, Netherlands). The final decision for graft selection was at the discretion of the senior surgeon according to their experience and addressed to the detailed evaluation of each patient.

Follow-up included CTA at the 1st and 12th month post-operatively. Post-operative CTAs were assessed using centre lumen line (CLL) measurements which permitted the detailed post-operative evaluation of the aortic neck anatomy and graft position. All pre-operative and post-operative CTA measurements and outcomes were provided by two vascular surgeons (P.N., K.S.) and controlled by a third one (M.M.). This study involved the collection of existing data and diagnostic tests that have been recorded in such a manner that subjects could not be identified, either directly or through identifiers linked to the subject. The study was approved by the Institutional Review Board.

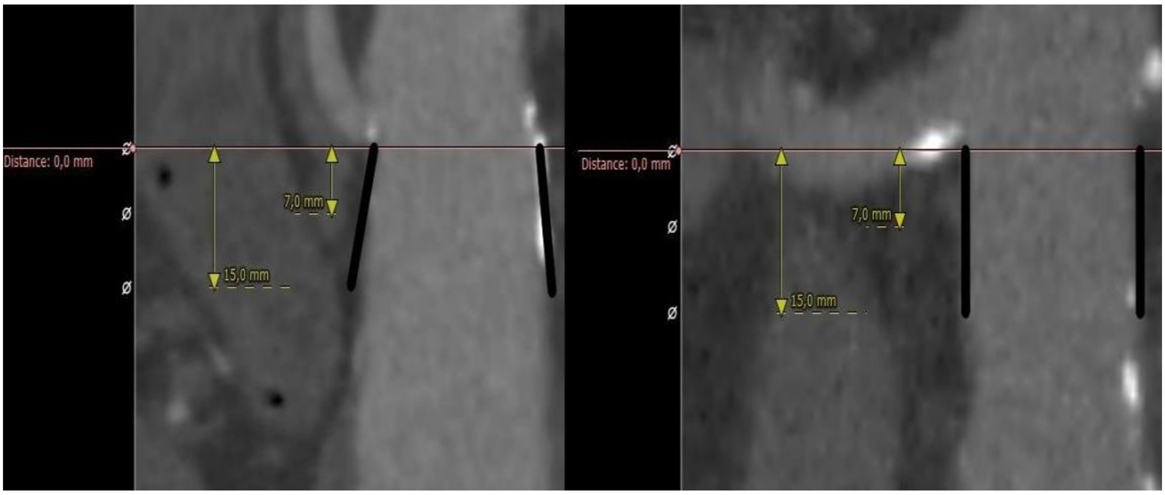

Figure 2. *Patients' cohort was divided in conical and non-conical group. Conical neck was defined as any neck, up to 30mm of proximal diameter, with a diameter increase >2-3mm per cm of length. All necks were measured just below the lowest renal artery, at 7mm and between 10-15mm.*

3.3.2.2 Definitions

Conical neck was defined as any neck with a >2-3mm increase in neck diameter for each centimeter of length (from outer-to-outer aortic wall).[7,200] The proximal 10-15mm of the neck length were considered as the zone of endograft sealing, as the majority of currently available endografts rely on this length to achieve graft fixation and aneurysm exclusion. Neck thrombus or calcification was dichotomized as present (≥25%) or absent characteristic. According to the current Society of Vascular Surgery guidelines, the suggested device oversizing at the aortic neck is 10% to 20%.[50,200] In patients with conical neck, the oversizing was estimated according to the infra-renal diameter just below the renal arteries. Migration was defined as any caudal movement of the endograft >10 mm relative to its position identified at the 1st month post-operative CTA.[9] Proximal neck adverse event was defined as any caudal graft migration or ET Ia.

3.3.2.3 Inclusion and Exclusion criteria

Symptomatic and ruptured aneurysms were not included. Patients presenting short neck length, less than 15mm were excluded from the analysis. Patients treated with endovascular sealing device were also excluded.

3.3.2.4 Statistical Analysis

Continuous data were reported as a mean ± standard deviation. Categorical data were expressed as absolute numbers and percentage of prevalence (%) in the study cohort. In the statistical analysis for continuous variables the independent t-test for normally distributed data and the Mann-Whitney U test for nonparametric data were used. The Pearson's chi square test was used for categorical variables. P value was considered significant when it was <0.05. Statistical analysis was performed by SPSS 22.0 for Windows software (IBM Corp, Armonk, NY).

3.3.3 Results

A hundred fifty patients were included in the total cohort. Among them, 66 (44%) patients presented conical neck characteristic. All patients were males. The mean AAA diameter was estimated at 58.2±10.0mm in the non-conical and 60.7±13.9mm in the conical group (p=.22). In terms of pre-operative anatomical proximal neck characteristics, no significant differences were documented between patients with conical and non-conical neck [neck length, 26.4±11.1mm vs. 25.4± 10.9mm; (p=0.19) infra-renal diameter, 22.9±2.9mm vs. 23.7±3.0mm; (p=.11) and distal neck diameter 27.5±3.0mm vs. 23.9±3.2mm; (p<.001)], angulation 24.1±16.8° vs. 25.2±18.9°; (p=.72) and the presence of thrombus, 32 (48.5%) vs 32 (38.0%); (p=.20), and calcification, 23 (34.8%) vs 29 (34.5%); (p=.97). All pre-operative anatomical characteristics are presented in detail in **Table 10**.

Preoperative anatomical characteristics	**CG (66 patients)**	**NCG (84 patients)**	**P**
Aneurysm diameter (mm)	60.7±13.9	58.2±10.0	.22
Neck angulation	24.1±16.8	25.2±18.9	.72
Neck angle >60°	1	4	.27
Supra-renal neck diameter (mm)	25.4±3.0	25.7±3.1	.47
Infra-renal diameter (mm)	22.9±2.9	23.7±3.0	.11
Neck diameter at 7mm (mm)	24.8±3.4	23.9±3.3	.12
Distal neck diameter at 15mm (mm)	27.5±3.0	23.9±3.2	<.001
Presence of calcification	23	29	.97
Presence of thrombus	32	32	.20

Table 10. *All pre-operative anatomic characteristics were assessed in the total cohort. No statistical significance was detected, expect distal neck diameter. CG: conical group; NCG: non-conical group*

Supra-renal active fixation system was used in 45 (68.2%) of patients with conical necks and 50 (59.5%) of the non-conical group (95 cases of the total cohort, 63.3%). The rate of the devices with supra-renal active fixation system use was similar between patients with or without conical neck (p=.27). Graft oversizing was 19.1±8.2% in patients without conical neck and 26.5±11.4% in patients with conical neck (p<.001). Aggressive oversizing (>20% and >30%) was more commonly used in patients with conical necks (>20%; 42 (63.6%) in the conical group vs. 31 (36.9%) in the non-conical and >30%, 29 (43.9%) in the conical group vs 10 (11.9%) in the non-conical) compared to patients without conical morphology (p=.001 and <.001, respectively). There was no difference between groups regarding the use of additional aortic cuff and endoanchors technique intra-operatively (use of cuff: 3 (3.7%) in conical vs. 3 (4.6%) in non-conical, p=.08; use of endoanchors: 2 (2.4%) in conical vs. 0 (0%) in non-conical necks, p=21). Patients' specific technical characteristics are presented in **Table 11**.

Patients' neck characteristics	**CG (66 patients)**	**NCG (84 patients)**	**P**
Graft supra-renal active fixation	45 (68.2%)	50 (59.5%)	.27
Polyester material	52 (61.9%)	49 (74.2%)	.11
Oversizing (%)	26.5±11.4	19.1±8.2	<.001
Oversizing>20%	42 (63.6%)	31 (36.9%)	.001

Oversizing>30%	29 (43.9%)	10 (11.9%)	<.001
Use of cuff intra-operatively	3 (3.7%)	3 (4.6%)	.08
Use of endoanchors	2 (2.4%)	0 (0%)	.21

Table 11. *All technical characteristics were assessed in the total cohort. No statistical significance was detected, expect oversizing and oversizing exceeding 30%. CG: conical group; NCG: non-conical group*

No patient was lost to follow-up while no death was recorded during the initial 12 months. The distribution of neck adverse events between the conical and non-conical group is presented in **Table 12**.

Patients' neck adverse events during the 12-month follow-up	**CG (66 patients)**	**NCG (84 patients)**	**P**
ET Ia intra-operatively	0 (0%)	2 (2.4%)	.21
ET Ia at 12 months	2 (3.0%)	5 (6.0%)	.40
Caudal migration >5mm at 12 months	11 (16.7%)	12 (14.3%)	.69

Composite of ET Ia & migration at 12 months	13 (19.7%)	16 (19.0%)	.92

Table 12. *Neck adverse events distribution between patients with conical and non-conical neck. No statistical significance was detected. CG: conical group; ET Ia: endoleak type Ia; NCG: non-conical group*

In the total cohort, 29 patients (19.3%) presented any neck adverse event; 7 (4.7%) patients presented ET Ia while 23 (15.3%) caudal migrations were recorded at the initial year of follow-up. In one case with conical neck morphology, migration and ET Ia were synchronous while in the remaining cases, the events were not related. No difference was found regarding to the composite outcome (ET Ia and migration) between the two groups [13 events (19.7%) vs. 16 (19.0%), p=.92]. When the events of ET Ia and caudal migration were analysed separately, no difference was recorded between the conical and non-conical group, neither regarding ET Ia [2 (3.0%) vs 5 (6.0%), p=.40) nor regarding migration [11 (16.7%) vs. 12 (14.3%), p=.69] during the 12-month follow-up. Regarding the need for re-intervention, six patients underwent re-intervention for proximal sealing: two (3.0%) in the conical and four (4.8%) in the non-conical group (**Table 13**). All the remaining cases, that did not undergo re-intervention remained under close surveillance.

Patients' neck-related adverse events during 12-month follow-up	**Number of neck-related adverse events**	**Re-interventions for proximal sealing during the 1st year of follow-up**
ET Ia		
CG	2	***1 case*** underwent proximal extension using cuff

		** presented concomitant migration* ***1 case*** underwent proximal extension using the parallel graft technique
NCG	5	***1 case*** needed open conversion ***2 cases*** underwent proximal extension using the parallel graft technique ***1 case*** underwent proximal extension using cuff ***1 patient*** denied any further intervention
Caudal migration		
CG	11	***1 case*** underwent proximal extension using cuff **same case reported previously* ***10 cases*** under surveillance using imaging
NCG	12	***12 cases*** under surveillance using imaging
Composite of ET Ia & migration	29 patients with neck-related adverse event	6 re-interventions for proximal sealing in the total cohort

Table 13. The distribution of neck adverse events and need for re-intervention in both groups.

CG: conical group; ET Ia: endoleak type Ia; NCG: non-conical group

3.3.3.1 Subgroup analysis on patients with conical necks

Sixty-six patients presented conical neck characteristics and 13 (19.7%) of them presented neck adverse events during the initial year of follow-up. Two out of 66 patients (3.0%) with conical neck presented ET Ia during the initial year of follow-up while eleven patients presented caudal graft migration (16.7%). The use of additional cuff intra-operatively was related to the presence of ET Ia at the initial year of follow-up (one case (50%) with ET Ia was managed with additional cuff intra-operatively compared to two cases (3.2%) without ET Ia, (p=.002). The use of aggressive oversizing >30% seemed to provide a protective role on graft migration among patients with conical morphology; one case (9.1%) presenting caudal migration was managed with aggressive oversizing compared to 28 cases (50.9%) without migration which were managed with >30% oversizing (OR 0.1, 95% CI 0.012-0.8, p=.01). No statistical significance was recorded in the remaining factors analysed in the conical group, as presented in **Table 14**.

Factors analyzed in relation to ET Ia (conical group only)	**Presence of ET Ia (2)**	**Absence of ET Ia (64)**	**P**
Neck thrombus	2 (100%)	30 (46.9%)	.14
Neck calcification	0 (0%)	23 (35.9%)	.29
Angle>60°	0 (0%)	1 (1.6%)	.86
Neck diameter≥29mm	0 (0%)	4 (6.3%)	.72
Supra-renal fixation	2 (100%)	43(67.2%)	.33
Oversizing (%)	34.0±1.4	26.2±11.5	.34
Oversizing >20%	2 (100%)	40 (62.5%)	.28
Oversizing >30%	2 (100%)	27 (42.2%)	.11
Additional cuff	1 (50%)	2 (3.2%)	.002
Factors analyzed in relation to caudal migration (conical group only)	**Presence of migration (11)**	**Absence of migration (55)**	**P**
Neck thrombus	4 (36.4%)	28 (50.9%)	.39

Neck calcification	3 (27.3%)	20 (36.4%)	.56
Angle>60°	0 (0%)	1 (1.8%)	.65
Neck diameter≥29mm	1 (9.1%)	3 (5.5%)	.64
Supra-renal fixation	6 (54.5%)	39 (70.9%)	.29
Oversizing (%)	21.27±8.5%	27.5±11.7%	.10
Oversizing >20%	5 (45.5%)	37 (67.3%)	.17
Oversizing >30%	1 (9.1%)	28 (50.9%)	.011
Additional cuff	0 (0%)	3 (5.6%)	.42
Factors analyzed in relation to composite neck AE (conical group only)	**Presence of AE (13)**	**Absence of AE (53)**	**P**
Neck thrombus	6 (46.2%)	26 (49.1%)	.85
Neck calcification	3 (23.1%)	20 (37.7%)	.32
Angle>60°	0 (0%)	1 (1.9%)	.62
Neck diameter≥29mm	1 (7.7%)	3 (5.7%)	.78
Supra-renal fixation	8 (61.5%)	37 (69.8%)	.57
Oversizing (%)	23.3±9.1	27.2±11.8	.26
Oversizing >20%	7 (53.8%)	35 (66.0%)	.41
Oversizing >30%	3 (23.1%)	26 (49.1%)	.09
Additional cuff	1 (7.7%)	2 (3.8%)	.55
Aneurysm diameter (mm)	61.8±13.2	60.4±14.3	.74
Infra-renal neck diameter	23.2±1.6	22.8±3.1	.67
Distal neck diameter	28.2±2.3	27.3±3.1	.35

Table 14. *The role of factors investigated to neck adverse events among patients with conical neck. Footnotes: AE: adverse events; ET Ia: endoleak type Ia.*

3.4 The impact of iliac artery anatomy on distal landing zone after EVAR during the 12-month follow-up (*Published to Annals of Vascular Surgery, doi: https://doi.org/10.1016/j.avsg.2022.06.011*).

3.4.1 Introduction

The current trend in clinical practice worldwide is to treat patients with endovascular abdominal aortic aneurysm repair (EVAR) over open repair.[212] EVAR is applied in most patients regardless of sex, age and clinical status.[212] Early EVAR outcomes remain favorable in both elective and emergent setting, although there is a controversy regarding the durability of the procedure and need for re-intervention during the long-term follow-up.[213,214] Common indications for re-intervention are aneurysm rupture caudal graft migration, infections and type I and II endoleaks.[215] Among them limb occlusion, which is mainly an early complication, may be reported in up to 12% of cases.[114,215,216]

While most interest focuses on the remodeling of the proximal landing zone after EVAR and the associated complications, the distal landing zone may also affect EVAR durability.[217] Type Ib endoleak (ET Ib) may be detected during even the initial 6-month follow-up and sets the indication for adjunctive procedures.[217] Technical factors as oversizing or anatomic, as iliac tortuosity, angulation, initial diameter and dilatation during follow-up may affect iliac adverse event rate and the need for re-intervention.[152,218-219] However, the current literature provides only limited data regarding the role of the iliac anatomy, and further studies are need to confirm conclusions.[217]

Under this spectrum, a retrospective analysis of prospectively collected data was performed to assess iliac anatomy and its remodeling after EVAR during the initial year of follow-up and the potential association to distal landing zone adverse events.

3.4.2 Methods

3.4.2.1 Study Cohort

Prospective data of patients treated with standard elective EVAR for infra-renal abdominal aortic aneurysm (AAA), using currently available bifurcated endografts (Medtronic Endurant, Santa Ana, CA, USA; Cordis Incraft, Dublin, OH, USA; Treovance Bolton, Sunrise, FL, USA; Gore Excluder, W.L. Gore and associates, Flagstaff, AZ, USA; Endologix AFX 2, Irvine, CA, USA) was undertaken retrospectively in a single tertiary centre. Patients were treated between 2017 and 2019 based on the recent ESVS guidelines.[17,199] Existing data and diagnostic tests were recorded in a way that subjects could not be identified directly or through identifiers associated to the subject. The study was approved by the Institutional Review Board (605/14-02-2017).

3.4.2.2 Inclusion and exclusion criteria

Only patients managed electively with EVAR using standard bifurcated devices [with distal landing zone only to the common iliac artery (CIA)] were included in this analysis. Cases needing external iliac artery extension as distal landing zone at any side were excluded (8 patients). Patients treated for AAA rupture or symptomatic AAA (27 patients) or with iliac branched devices (14 patients) for the preservation of the internal iliac artery at any side were excluded from this analysis. Furthermore, seventeen patients that were managed using endovascular sealing device (Nellix, Endologix, Irvine, CA, USA), between 2017-2018, were not included. No cases of aorto-uni-iliac devices were applied during the period in elective cases. Furthermore, any patient needing complex endovascular repair of the proximal landing zone was excluded (34 patients).

3.4.2.3 Definitions

The CIA was assessed in three levels: origin; just below the aortic bifurcation, distally; just above the iliac bifurcation and the middle point of the distance between these two landmarks (**Figure 3**). These three measurements were estimated in each CIA at the pre-operative and 12-month post-operative CTA after the application of centre lumen line using a dedicated software (3mensio, Medical Imaging B.V., Bilthoven, Netherlands). The difference between the pre-operative and the 12-month iliac diameter in all levels was define as the result of iliac diameter at 12 months minus the iliac diameter pre-operatively, in each level separately. All measurements were defined from outer-to-outer wall.[9]

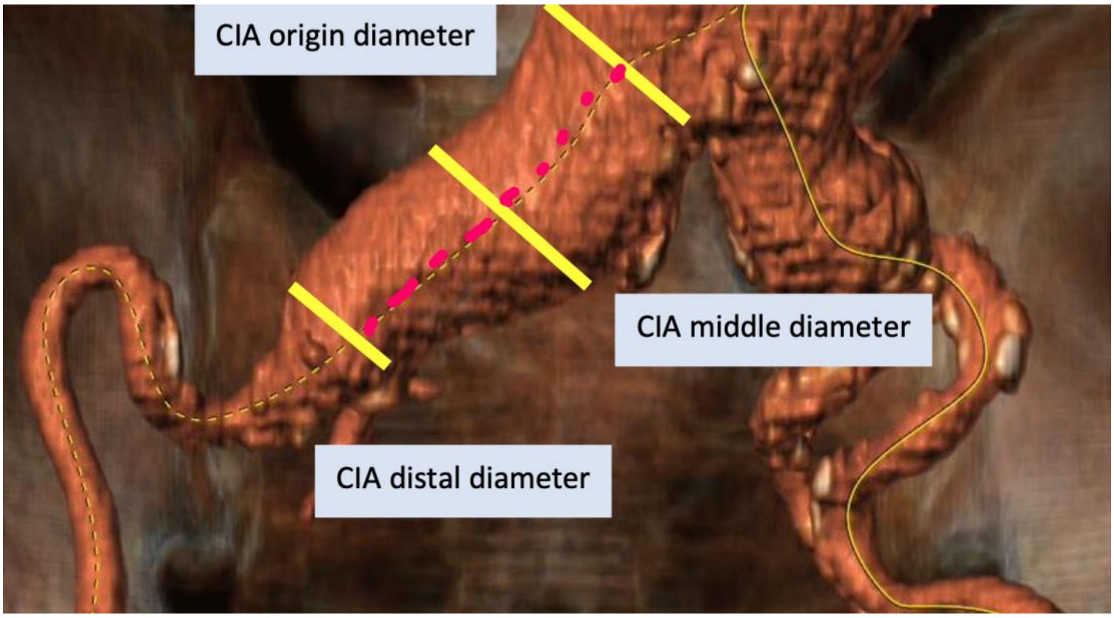

__Figure 3.__ The common iliac artery (CIA) diameter was assessed in three levels: origin; just below the aortic bifurcation, distally; just above the iliac bifurcation and the middle point of the distance between these two landmarks

The length of the pelvic artery (common and external iliac artery) on center-lumen-line from the aortic bifurcation down to the inguinal ligament (origin of the common femoral artery) divided by the length of the shortest distance between the two landmarks was reported as pelvic artery index of tortuosity.[219] The use of the inguinal ligament was decided as it represents the anatomic limit between the external iliac and common femoral artery and its upper limit can be defined using 3D reconstruction and osseous structures as deemed background (3mensio, Medical Imaging B.V., Bilthoven, Netherlands). Similarly, the length of the common iliac artery on center-lumen-line from the aortic bifurcation down to the iliac bifurcation divided by the shortest distance between the two landmarks was reported as common iliac artery index (**Figure 4**).[219]

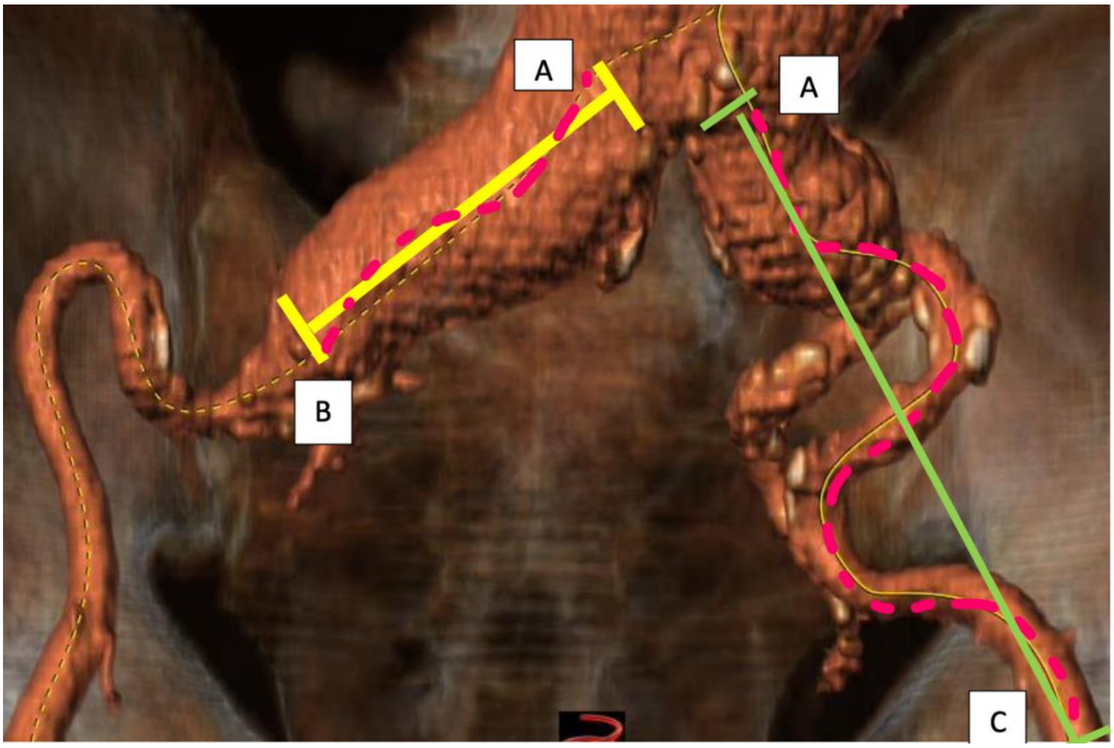

__Figure 4__. The length of the common iliac artery (A to B) on center-lumen-line from the aortic bifurcation down to the iliac bifurcation divided by the shortest distance between the two landmarks (yellow line) was reported as common iliac artery tortuosity index. Pelvic artery tortuosity index was the length of the pelvic artery (A to C, common and external iliac artery) on center-lumen-line from the aortic bifurcation down to the inguinal ligament (origin of the common femoral artery) divided by the length of the shortest distance between the two landmarks (green line).

Double iliac sign is a binary sign (present or absent) and defines the depiction of an iliac artery as doubled on an axial CTA images (**Figure 5A**).[219] Double sign is used to describe the tortuosity of the iliac artery.[219] Any angulation of >90° between the aorta and CIA was characterized as severe.[219] Angle measurements were calculated automatically (referred to the vertical CLL of the aorta) using a dedicated software (3mensio, Medical Imaging B.V., Bilthoven, Netherlands, **Figure 5B**).

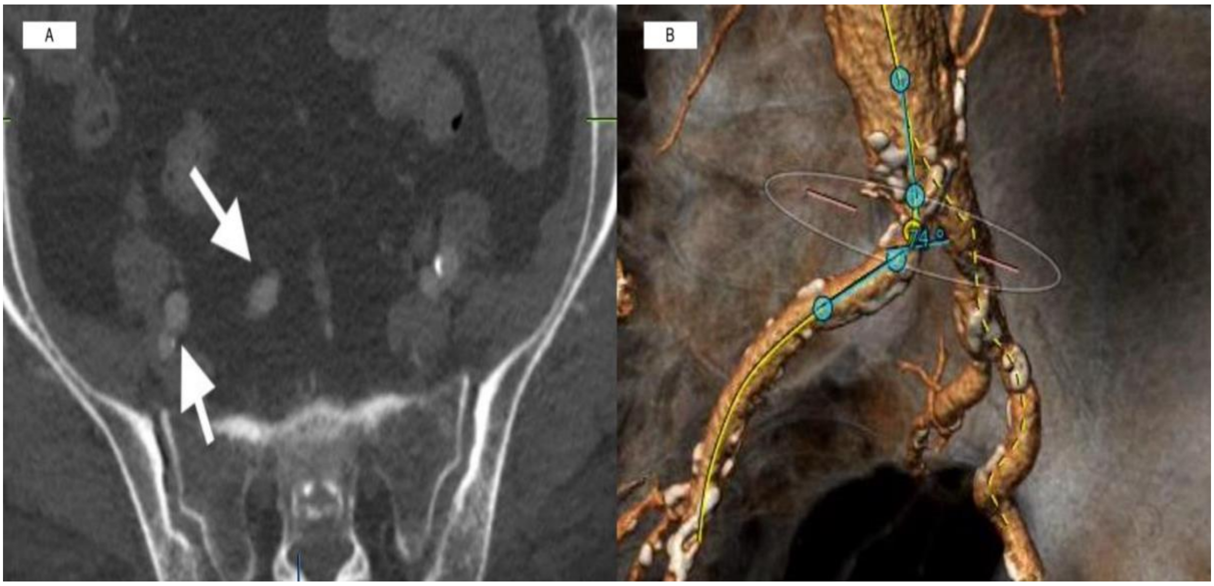

Figure 5. *Double sign of the iliac artery is a binary sign representing high tortuosity, depicted as a doubled iliac artery on axial CTA views (white arrow, Panel A). Angle*

measurements were calculated automatically (referred to the vertical CLL of the aorta) using a dedicated software (3mensio, Medical Imaging B.V., Bilthoven, Netherlands, Panel B).

Any oversizing applied to the distal landing zone exceeding 15% was reported as aggressive oversizing.[218] Oversizing of the device was defined as the mean percentage between the graft and iliac diameter difference at the distal iliac diameter. As relining was reported the application of bare metal balloon expandable stent to correct an intra-operatively recorded kinking or stenosis of the iliac limb (at the level of the aortic bifurcation). Iliac aneurysm was defined as any iliac artery exceeding 18mm at its distal diameter using the 12mm diameter threshold for CIAs referred in the reporting standards for arterial aneurysms.[8]

Distal landing zone-related adverse events were the composite outcome of any limb related re-intervention, ET Ib, cranial graft migration, limb stenosis or occlusion. Adverse events were analysed as the composite outcome and then, each type of event separately. Migration was defined as any cranial movement of the endograft >10mm from its initial position which was identified compared to the 1st post-operative CTA.[9]

3.4.2.4 Data collection

A dedicated database existed for the prospective collection of patients' data, including demographics (age, sex), AAA diameter, iliac anatomy; including iliac diameter in three levels; origin, middle and distal point of the common iliac artery (CIA), calcification, angle to the aorta, pelvic artery, and CIA index. The intra-operative details (oversizing, type of endograft, additional iliac extension) were also recorded. The pre-operative sizing and planning were performed based on an adequate pre-operative computed tomography angiography (CTA) using 3Mensio; a dedicated reconstruction software (Medical Imaging B.V., Bilthoven, Netherlands). All CTAs were evaluated by two independent experienced investigators (P.N., G.K.) and any discrepancies were resolved by a senior investigator (M.M.).

All patients were treated in an adequately equipped operating room with a moveable radiolucent table and mobile digital angiographic system (Ziehm Vision RFD Hybrid Edition, Ziehm Imaging, GE). The final decision for graft selection was at the discretion of the operator and according to patient's anatomic needs and surgeon's experience.

3.4.2.5 Post-operative surveillance

Follow-up included an adequate CTA at the 1st and 12th month post-operatively. Distal landing zone adverse events included cranial graft migration, ET Ib, limb thrombosis or stenosis were recorded. Any iliac limb related re-intervention was recorded. Post-operative CTAs were assessed using centre lumen line (CLL) measurements, which permitted the detailed post-operative evaluation of the aorto-iliac anatomy and graft. All CTAs were evaluated by two independent experienced investigators (P.N., G.K.) and any discrepancies were resolved by a third investigator (M.M.).

3.4.2.6 Statistical Analysis

Continuous data were reported as a mean ± standard deviation. Categorical data were expressed as absolute numbers and percentage of prevalence (%) in the study cohort. In the statistical analysis for continuous variables the independent t-test for normally distributed data and the Mann-Whitney U test for nonparametric data were used. The Pearson's chi square test was used for categorical variables. Repeated measures ANOVA was used to assess iliac anatomic alterations between the two different time points. Univariate and multivariate Cox proportional hazard regression analysis was used to evaluate the effect of relevant risk factors for distal landing zone-related adverse events. The enter method with significance level of 0.05 was used to obtain p values and odds ratios for the main effects and interactions. Statistical analysis was performed by SPSS 22.0 for Windows software (IBM Corp, Armonk, NY).

3.4.3 Results

In total, 134 patients, including 268 iliac limbs, were treated with EVAR between 2017 and 2019 using only standard bifurcated devices. All patients have completed their post-operative follow-up to 12 months. The mean age was estimated at 70.9±8.2 years and the mean pre-operative AAA diameter was 59.3±14.7mm. Regarding the three pre-operative measurements, the mean CIA origin diameter was 18.7±10.5mm, the middle CIA diameter was 15.5±5.1mm and the distal CIA diameter was 14.6±3.3mm. The mean pre-operative angle was estimated 33.8±18.2°. All the pre-operative anatomic characteristics are presented in detail in **Table 15**.

Preoperative characteristics of the study cohort (134 patients, 268 limbs)	**Value**
Age (years)	70.9±8.2
Males (Number of patients)	134
Abdominal aortic aneurysm diameter (mm)	59.3±14.7
CIA diameter at its origin (mm)	18.7±10.5

Middle CIA diameter (mm)	15.5±5.1
Distal CIA diameter (mm)	14.6±3.3
Iliac diameter >18mm	57
Iliac angle (°)	33.8±18.2
Iliac angle >90°(number of limbs)	0
Presence of double signs (number of limbs)	38
CIA tortuosity index	1.17±0.13
Pelvic artery tortuosity index	1.21±0.11
Presence of severe calcification (number of limbs)	12
Presence of moderate calcification (number of limbs)	39
Presence of mild calcification (number of limbs)	103

Table 15. *Pre-operative iliac anatomy characteristics in the total cohort. Footnotes: CIA: common iliac artery.*

3.4.3.1 Iliac artery anatomic measurements at 12-month follow-up

In all three levels, iliac diameters increased. Regarding the level of origin of the CIA, the measured diameter increased from 18.7±10.5mm to 19.9±9.4mm and the difference in diameter recorded during the 12-month follow-up was statistically significant ($p=.04$). At the middle portion of the CIA, the diameter changed significantly ($p<.001$)

from 15.5 ±5.1mm to 17.4±5.4mm. At the distal CIA, the diameter altered significantly from 14.6±3.3mm to 15.1±3.9mm (p=0.03).

Regarding the indicators of tortuosity, iliac angle altered from 33.8±18.2° to 31.9±15.9° (p<.001). Neither pre-operatively, nor post-operatively, an iliac angle >90° was recorded. The presence of double sign remained stable. CIA index was 1.17±0.13 pre-operatively and decreased to 1.11±0.09 post-operatively (p<.001) while pelvic artery index remained stable (1.21±0.11 to 1.21±0.10) at 12-month follow-up (p=.14).

3.4.3.2 Factors associated to iliac diameter and angle changes

Intra-operative details included oversizing and relining with the application of bare metal balloon expandable stent to correct significant kinking of the iliac limb. The mean value of oversizing was 21.5±14.5% while intra-operative relining was performed in seven limbs. In 135 limbs, oversizing exceeded 15% (50.4%). Oversizing affected distal iliac diameter increase (p<.001). Iliac angle alteration was not affected using relining (p=.56).

3.4.3.3 Iliac diameter alterations and distal landing zone-related adverse events

No patient was lost to follow-up while no death was recorded during the initial 12 months. The distal landing zone-related adverse events and need for reintervention recorded during the 12-month follow-up are presented in detail in **Table 16**. In total, 24 limbs presented the composite outcome (8.9%), and fourteen patients underwent re-intervention (5.2%).

The composite outcome of distal landing zone adverse events was not associated to diameter changes at any level; origin of the CIA, p=.66, middle CIA diameter, p=.36, and distal CIA, (p=.06). Angle decrease did not affect the composite outcome of adverse events (p=.54). Further, analysis of the separate outcomes did not prove any statistical significance.

Distal landing zone-related adverse events during 12-month follow-up	**Number of adverse events**	**Re-interventions during the 12-month follow-up**
Limb occlusion	9	***2 cases*** managed with femoro-femoral bypass ***7 cases*** underwent endovascular management with thrombectomy and stenting
ET Ib	4	***4 cases*** underwent distal limb extension *-In 3 cases (3/4), an extension to the external iliac artery*
Stenosis	3	***1 case*** *underwent stenting using bare metal balloon expandable stent* ***2 cases*** *remain under surveillance with no clinical impact*
Cranial limb migration*	8	*No case underwent re-intervention* *All cases remain under surveillance*
Composite of adverse events at 12-month follow-up	24 limbs presented distal landing zone-related adverse event (8.9%)	14 re-interventions were performed (5.2%), 13 were performed using endovascular means

Table 16. *Distal landing zone-related adverse events during the 12-month follow-up. Iliac diameter and angle changes did not affect adverse events. Footnotes: ET Ib: endoleak type Ib.*

3.4.3.4 Sub-analysis of aneurysmatic iliac arteries (diameter≥18mm)

In 57 cases, a distal iliac diameter exceeding 18mm was recorded. The mean age was 71.5±8.5 years and pre-operative AAA diameter was 57.9±15.9mm. The distal iliac diameter was 19.5±1.8mm. Regarding the tortuosity markers, iliac angle was 32.6±17.6° while the pelvic tortuosity index and CIA tortuosity index were 1.27±0.11 and 1.16±0.13, respectively. The pre-operative iliac characteristics between groups are reported in **Table 17.** Compared to non-aneurysmal iliac arteries, large iliac arteries presented more commonly double sign; 9.5% to iliacs <18mm and 34.2% in iliacs ≥18mm (p=.04), and higher pelvic artery index; 1.27±0.11 vs. 1.19±0.10 (p<.001). The estimated oversizing was 16.3±11.8% compared to non-aneurysmal iliac arteries where oversizing was 22.5±14.9% (p=.01). No other difference between the iliac groups was detected.

Iliac artery anatomic and technical characteristics	**≥18mm (57 limbs)**	**<18mm (211 limbs)**	**P**
Origin CIA diameter (mm) 12-month origin CIA diameter (mm)	27.7±16.7 26.3±14.1	16.5±6.3 18.2±6.6	<.001 <.001
Middle CIA diameter (mm) 12-month middle CIA diameter (mm)	23.4±4.6 23.0±7.9	13.9±4.0 15.9±3.7	<.001 <.001
Distal CIA diameter (mm) 12-month distal CIA diameter (mm)	19.5±1.8 19.8±5.2	13.4±2.1 14.0±2.5	<.001 <.001
Iliac angle 12-month iliac angle	32.6±17.6° 34.5±18.4°	31.6±18.2° 31.9±15.3°	.41 .30
Pelvic tortuosity index 12-month pelvic tortuosity index	1.27±0.11 1.26±0.12	1.19±0.10 1.20±0.09	<.001 <.001
CIA tortuosity index 12-month CIA tortuosity index	1.16±0.13 1.12±0.11	1.17±0.13 1.12±0.09	.89 .71

Double sign 12-month double sign	18 (34.2%) 17 (29.5%)	20 (9.5%) 20 (9.5%)	.04 .02
Oversizing	16.3±11.8%	22.5±14.9%	.01

Table 17. *Pre-operative and 12-month anatomic and technical characteristics' distribution between aneurysmal and non-aneurysmal iliac arteries. Footnotes: CIA: common iliac artery.*

At 12-month follow-up, all three levels in iliac diameters ≥18mm remained stable. Regarding the level of origin of the CIA, the measured diameter decreased from 27.7±16.7mm to 26.3±14.1mm, at the middle CIA, the diameter changed from 23.4±4.6mm to 23.0±7.9mm and at the distal CIA, the diameter altered from 19.5±1.8mm to 19.8±5.2mm. No change was statistically significant. For non-aneurysmal iliac arteries, the diameter the level of origin of the CIA changed from 16.3±6.3mm to 18.2±6.6mm, at the middle CIA, the diameter altered from 13.9±4.0mm to 15.9±3.7mm and at the distal CIA, the diameter increased from 13.3±2.0mm to 14.0±2.5mm. All diameter increase were statistically significant ($p<0.5$). At 12 months, compared to non-aneurysmal iliac arteries, iliac arteries ≥18mm presented larger diameters at all three levels. Furthermore, large iliac arteries presented more commonly double sign; 9.5% to iliac arteries <18mm and 29.5% in iliac arteries ≥18mm ($p=.02$) and higher pelvic index; 1.26±0.12 vs. 1.20±0.09 ($p<.001$).

The correlation of an iliac artery diameter exceeding 18mm pre-operatively with distal landing zone-related adverse events (composite outcome) did not present statistical significance ($p=.15$). However, in a further analysis of separate outcomes, endoleak type Ib was more common in iliac arteries exceeding 18mm [3 events (5.3%)

vs 1 event (0.5%), p=.03] at 12-month follow-up. The distribution of distal landing zone-related adverse events between the two groups is presented in **Table 18**.

Distal landing zone related- adverse events during the 12-month follow-up	**≥18mm (57 limbs)**	**<18mm (211 limbs)**	**P**
Limb occlusion	1 (1.8%)	8 (3.7%)	.44
ET Ib	3 (5.3%)	1 (0.5%)	.04
Stenosis	1 (1.8%)	2 (1.0%)	.36
Cranial limb migration	2 (3.5%)	6 (2.8%)	.06
Re-intervention	4 (7.0%)	10 (4.7%)	.62
Composite of adverse events at 12-month follow-up	7 limbs presented distal landing zone-related adverse event and 4 underwent re-intervention	17 limbs presented distal landing zone-related adverse event and 10 underwent re-intervention	.15

Table 18. *Distal landing zone related-adverse events distribution between patients with aneurysmal and non-aneurysmal iliac artery. No statistical significance was detected, except the presence of ET Ib at 12-month follow=up. Footnotes: ET Ib: endoleak type Ib.*

Chapter 4

Discussion

EVAR durability relies on the maintenance of persistent seal between the proximal edge of the stent-graft and aortic wall. Aortic dilatation of the infra-renal aorta has been previously studied.[152,193-195] However, it remains unclear whether it is a part of the continuing aneurysm process or result of stent-graft's radial force.[193-196,220] The occurrence of aortic neck dilatation after EVAR and open repair, with analogous rate, enforces the role of aneurysm progression on aortic dilation.[193,221-224] In the present analysis, aortic expansion was not detected at 1st month follow-up. However, at 12th month, a diameter increase was recorded not only at the proximal sealing zone but the supra-renal aorta up to the level of SMA. Aortic diameters increased by almost one millimetre within a year; a finding suspected to evolve up to three years after EVAR.[197] However, as previously published, the rate of dilatation might be greatest, up to 5.2%, during the initial 12 months after EVAR, with slower growth rate during the midterm follow-up period.[195]

This dilation may not seem significant in net numbers, but it seems that has affected neck related adverse events in this analysis. The rate of adverse events (including ET Ia and migration) was 19%. Nevertheless, similarly high rates of type Ia endoleak have been already described.[225] However, only 4% of patients underwent further intervention for proximal sealing, depicting that neck adverse events might not have a clinical impact in terms of re-interventions during the initial year. Though, they guarantee the need for continuous surveillance. It is of note that supra-renal dilation was related to neck adverse events at 12-months in this analysis while only scarce data exist in the available literature regarding the performance of the supra-renal aorta after EVAR and its association to EVAR outcomes is limited.[169,226,227]

In this analysis, stent-graft related factors, such as supra-renal graft fixation and oversizing >20% affected aortic dilatation.[194,195,200,228-230] Despite that the impact of these EVAR-related factors would be suspected to affect aortic diameter since the 1st month follow-up, no significant difference in diameter was recorded at any level during this period in the current analysis. However, as radial forces continue to oppose to the aortic wall during further follow-up, especially in supra-renal fixation endographs, which are considered to present higher radial force than their infra-renal counterparts, the impact of EVAR-related factors might be recorded at 12 months.[195] The presence of suprarenal stent probably increases the strength opposed to the aortic wall through years and its effect might be seen later on follow-up.[195,231] Additionally, aggressive oversizing may play a role on neck dilatation, probably during the 12-month follow-up, as previously reported.[151,200] Proximal sealing forces may be associated with neck expansion and contribute to loss of stent-graft wall apposition to the most critical zone of sealing.[173,232-234]

Furthermore, in this study, pre-operative neck diameter >29mm was associated with aortic dilatation. Large proximal aortic neck has been characterized as a risk factor of adverse events and has been related to higher reintervention and mortality rates.[167,202,220,235-238] In this analysis, large proximal neck has been associated not only to neck fate but even a dilatation of the suprarenal part at 12-months. Large aortic diameters may be predictive of a generally diseased aorta with a more aggressive aneurysmal progression. However, in the currently available literature, only scarce data exist regarding the supra-renal aortic fate and factors affecting this process.[170] The impact of large necks, stent-graft fixation, and oversizing, detected in this analysis, could explain the potential multifactorial phenomenon of proximal aortic expansion.[202,221]

Aortic dilatation has been shown to increase the risk of adverse outcomes during follow-up, due to the loss of grafts' wall apposition.[152,195] As well, in this analysis, infra-renal and supra-renal aortic expansion was related to neck adverse events. The role of the supra-renal anatomic alterations on EVAR outcomes is limited. Despite that a direct relationship between the supra-renal aorta and EVAR has not been reported in the literature, supra-renal aortic fate probably depicts the presence of an aggressive aneurysmal disease, and this rational association could affect EVAR outcomes.[152] Aortic dilatation effects on EVAR should be under consideration during graft and technique selection, as a future proximal re-intervention could not be excluded. Novel techniques and material, as the use of endoanchors, may affect positively the aortic performance after EVAR and decrease neck adverse events.[198]

Despite that aneurysm progression and graft technical characteristics seem to provide adequate answers on EVAR durability and neck adverse events, other factors, as the pre-operative AAA anatomy may further affect EVAR outcomes. Especially, regarding the proximal sealing zone, specific anatomic characteristics are considered hostile, as large neck diameter, short length, extreme angulation and conical morphology.[7] Under this spectrum, the impact of conical neck morphology was investigated, considering that the available data in the literature are scarce regarding its incidence, role on neck adverse events and potential technical details that may be able to have a preventive role on them.

Conical morphology is a relative contra-indication to perform EVAR, however, patients with conical neck morphology are often managed using standard endovascular devices, presenting conflicting outcomes.[7,206] In this analysis, patients with conical necks performed similarly in terms of neck adverse events with patients having a non-conical morphology. Furthermore, in this study almost 45% of patients who were treated with standard EVAR, presented conical morphology, while the remaining pre-operative anatomic characteristics were similar, except distal neck diameter. Previously reported data referred that in EVAR cohort, the estimated percentage of patients with conical neck was 35%.[206] Conical neck is probably a more common neck characteristic in the daily clinical practice than considered to be, especially when strict definitions are applied in EVAR cohorts.

Neck morphology, evolution, hostility, and its impact on EVAR outcomes has been extensively studied.[173,203,238-240] However, the available data specifically on the conical morphology are scarce.[208,210,240] In this analysis, nearly 70% in the conical group was treated using supra-renal fixation endografts while oversizing was higher in the conical group and in 63.6%, the 20% suggested by the current guidelines was exceeded.[9] Despite that conical neck has been characterized as a significant factor for adverse events and EVAR failure, in this study, conical neck did not affect EVAR proximal neck outcomes, as the results regarding ET Ia and graft migration were similar between patients with conical and non-conical necks.[205,208,209]

In this study, lower migration rate was found among patients with conical neck that were managed with aggressive oversizing (>30%) compared to patients with conical morphology and oversizing less than 30%.. The role of oversizing has not been clarified in patients with conical neck, while it seems rational that a more aggressive strategy might fit better in conical anatomy which is associated to have substantial difference in aortic diameters between the proximal and distal part. In cohorts of patients undergoing EVAR, proximal oversizing up to 25% seems to decrease the risk of ET Ia; on the other side the more aggressive oversizing (>30%) has been related to caudal graft migration., probably due to graft infolding and mis-apposition of the graft to the proximal infrarenal neck.[241-244] In this study, the more aggressive oversizing (>30%) proved to be preventive of migration in the conical group.

Except the impact of neck anatomy and proximal aorta on EVAR outcomes, patients may undergo re-interventions during the follow-up due to distal landing zone adverse events. Iliac anatomy is less investigated in the literature, probably due to the easier and minimal management with endovascular means when needed.[217] However, the re-intervention rate after EVAR is related to higher morbidity and mortality and the need to decrease the secondary interventions is of high importance, not only for patient quality of life and survival but also, due to the higher economic effect.[217,245]

Iliac arteries remodeling after EVAR seem to have a similar evolution with the proximal aorta after EVAR.[220,246] Iliac artery expansion is an early finding, mainly detected during the initial six post-operative months, compared to the proximal aorta which expands prominently during the mid-term follow-up period [220] In the current analysis, common iliac arteries dilated in the total cohort during the initial year of follow-up and this alteration in diameter was significant in all levels. Especially, for distal CIA dilation, it could be the result of excessive oversizing and the consequent radial forces affecting the distal iliac wall.[195] The same combination of factors already described affecting the proximal landing zone of the aorta.[195,247]

Regarding the role of oversizing in EVAR cases, a variety of conclusions have been recorded through the years in the literature.[195,218,246-248] However its role has not been completely defined neither for the proximal nor the distal landing zone.[195,218,246-248] In this analysis, the oversizing exceeded the suggested 15% by the literature and approached 20% for the total cohort.[218] This more aggressive application may have affected the CIA distal diameter expansion. Iliac dilatation has been associated to adverse events as cranial migration and clinical adverse events.[248] However, it is of note that this morphologic alteration did not affect the distal landing zone adverse events while it seemed that EVAR reformed the iliac anatomy, with a reduction in angle and

CIA index while the number of double signs remained stable. Potentially, this may be recorded in a longer follow-up period as the aneurysmal progression is a continuous phenomenon and repeated evaluation with an adequate imaging may be able to detect early the fate of the distal landing zone, before the evolution of clinical events.[195,248]

The sub-analysis of the aneurysmal iliac arteries has shown that the diameter remained stable compared to normal arteries during the 12-month follow-up, while the applied oversizing was significantly lower in this group of arteries (16 vs 22%, respectively). Despite that surgeon bias cannot be excluded, the specific iliac limb diameters that combine the main graft may have affected the choice of a lower oversizing in these cases, especially when considering that proximal neck characteristics are the main criterion for graft selection in the daily clinical practice. The lower oversizing may be able to explain the associated stable distal iliac diameter in this group.[249] It has been suggested that in aneurysmal iliac arteries, conservative oversizing between 10-15%, may be able to decrease endoleak Ib.[152] However, in the current analysis, despite that the estimated oversizing was 16.3%, large iliac arteries presented a higher rate of ET Ib compared to the normal group, where a more aggressive oversizing was used (22.5%). An aggressive oversizing and the use of wide (≥24mm) iliac extensions have been reported to have a preventive role for adverse events in aneurysmal iliacs.[247,248] In any case, aneurysmal CIAs represent a diseased area, more prone to further complications.[247,250]

As in hostile proximal necks, further extension is suggested, similarly in a hostile distal landing zone, an additional extension of the landing zone could be an effective solution [236,251] Aneurysmal iliac arteries, despite that are characterized as adequate landing zones, present a higher re-intervention rate due to ET Ib and patients treated with flared limbs should be under a closer follow-up protocol.[236] A recent analysis has shown that external iliac artery extension was associated to higher aneurysm regression compared to the bell-bottom technique.[250,252] However, external iliac artery use as landing zone may be related to greater limb complication and re-intervention rate.[250] The use of devices for the preservation of the internal iliac artery performed with a low incidence of re-interventions associated to endoleaks and occlusions while the primary patency of the IIA remained >90% during the 12-month follow-up.[236,253] Iliac branch endoprosthesis application is further significantly associated to CIA and AAA diameter regression during the initial year after EVAR. Despite that proximal sealing is of major interest during the pre-operative planning and follow-up, distal landing zones should be carefully evaluated as they seem to perform as the proximal aortic neck and may be prone to adverse events and re-interventions during the surveillance period; a fact that increases patients' morbidity and mortality.[254,255]

4.1 Limitations

There are several limitations in the previous analyses, especially their retrospective nature, despite that all data were recorded prospectively. The relatively small number of patients and the short period of follow-up may hamper firm conclusions regarding the impact of proximal aorta alterations, conical neck morphology and distal landing zones. However, all patients adhered to the follow-up protocol with an adequate CTA at the 1st and 12th month and all measurements were confirmed by two investigators (P.N., G.K.). Furthermore, as all patients were males, the results of this analysis depict EVAR outcomes only on male population, which though represents most patients.

Heterogeneity exists because of the variability of the devices used, but on the other hand, these devices were within the commonest applied globally. Regarding the first analysis of aortic infra and supra-renal dilatation, the impact of stent-grafts radial force's impact on aortic wall, only scarce data exist in the literature and a further investigation of each stent type could not provide safe conclusions. Additionally, surgeon's bias cannot be excluded, as patient, technique and graft selection may be affected by the experience of the therapist. However, all patients were treated by the same experienced surgeons (A.G., M.M.).

Longer follow-up is needed to extract firm conclusions regarding aortic morphologic changes after EVAR, their impact on proximal sealing and the durability of standard EVAR in patients with conical neck anatomy. Regarding the distal landing zone, an additional surveillance period up to 4 years could provide adequate data, as most distal events are recorded up to the mid-term follow-up.[114]

Chapter 5

Summary of findings

In this study, the anatomy of the aorta was studied in its total length, from the supra-renal part down to iliac bifurcation. Despite the limited number of patients, all of them followed the surveillance protocol and the CTAs were analyzed by the same investigators. These factors permitted a systematic approach of the aortic alterations after EVAR. According to the results of the three analyses, post-EVAR aortic dilatation may be detected from the supra-renal aorta to the total length of the aortic neck. The measurements included the proximal aortic zone from the celiac trunk to 15mm below the lowest renal artery, the most critical zone of sealing.

According to the findings of the first analysis, proximal aortic dilatation may be attributed to multiple factors, such as large neck diameter, supra-renal active fixation, and aggressive oversizing. Furthermore, neck-related adverse events were more common in patients with infra-and supra-renal aortic dilatation. These factors combine both the anatomic characteristics of the neck and technical features of the procedure, depicting that aortic expansion after EVAR and the related neck-adverse events may be the result of a multifactorial process, including the natural aneurysmal progression and radial forces of the stent-graft on the arterial wall.

A more precise analysis was performed to detect the role of conical anatomy of the proximal neck on neck-related outcomes, including ET Ia and migration. It was found that in terms of neck adverse events, EVAR may offer similar good early outcomes in patients with conical and non-conical neck anatomy. Probably the low number of adverse events in a high-risk group with hostile proximal anatomy, as patients with conical morphology, could be addressed to the more aggressive oversizing (>30%), which may have played a preventive role of graft migration in this group during the initial 12 months of follow-up. Potentially, the wide use of endografts with active supra-renal fixation in both groups have affected these findings. Supra-renal active fixation was used in almost 70% of cases and may protected the conical group from the evolution of neck adverse events. However, statistical significance was not achieved.

The last analysis was performed to evaluate the impact of EVAR on distal landing zone, an aortic part that is less investigated than the proximal aorta. The study showed that iliac arteries followed the proximal aorta evolution and expanded significantly during the 12 months of follow-up. Oversizing affected this iliac dilatation, and it was more aggressive than the one suggested in the literature. However, the expansion was not associated to distal landing zone adverse events. Potentially, a longer follow-up period may be able to detect an association between iliac artery dilatation and distal adverse events.

The sub-analysis of the aneurysmal iliac arteries showed that the oversizing used was lower and the diameters remained stable. Despite that under these findings, a correlation with distal adverse events was not suspected, large iliac arteries were associated to a higher rate of ET Ib during the initial 12 post-operative months. Thus, despite that aggressive oversizing may be related to iliac dilatation, it may have a protective role on endoleak formation in aneurysmal iliac arteries. The role of oversizing is controversial in the literature. However, in selected cases of hostile proximal or distal anatomy, patients may benefit from a more aggressive approach.

Chapter 6

Congress presentations and publications

Abstracts-Presentations

28-29 September 2021

ESVS 2021

Hybrid meeting

Rotterdam, Netherlands

Oral presentation

Abdominal aortic aneurysm sac alteration depending on initial diameter, endograft material and presence of endoleak type II (Fast track)

Petroula Nana, George Kouvelos, Konstantinos Spanos, Athanasios Giannoukas, Miltiadis Matsagkas

Introduction: Aortic aneurysm sac expansion is a factor associated to higher re-intervention and long-term mortality rates after endovascular aneurysm repair (EVAR). On the other hand, aneurysm sac regression is a desirable outcome after EVAR. The aim of this study was to assess the impact of initial aneurysm sac diameter, endograft material and presence of endoleak II on aneurysm sac diameter alteration during the first year of follow up after EVAR.

Methods: A retrospective study of prospectively collected data of patients being treated with standard EVAR was undertaken. Patients' cohort was divided according to the initial sac diameter (<55mm, 55-80mm, >80mm). Sac alteration was defined as the difference between the maximum sac diameter at the pre-operative and 12-month computed tomography angiography (CTA). The outcomes are presented as odds ratio (OR) with 95% confidence interval (CI). P value was considered significant when it was <0.05. The study was approved by the Institutional Review Board.

Results: From 2017-2019, 254 patients were treated with standard EVAR and 203 of them completed the first year of follow-up. The mean pre-operative AAA diameter in CTA was 60.1mm (range 50-108mm) and the mean 12-month diameter was 55.2mm (range 21-96mm). Mean intra-observer and interobserver variability was 0.2±0.55 mm and 0.2±0.6 mm, respectively. Regarding graft material, in the PET group the median aneurysm sac diameter decrease was -4.3mm (range -4.1 to +9mm) while in the PTFE group, the aneurysm sac was increased in diameter (2.6mm; range -3.3 to +13mm).at the 12-month follow-up (p=.004). The absence of ET II in 12-month CTA was associated to sac regression -4.8mm (range -41 to +9.4mm), while its presence was associated with sac increase at 0.6mm (range -2.8 to +13.2) at the 12-month follow-up (p<.001). Median aneurysm sac regression among patients with initial diameter of <55m, 55-80mm and > 80 mm were -3.05 mm (range -16.9 to +9.4), -4.1mm (range - 41.5 to +9.2) and -5.85mm (range -33.8 to +13.2), respectively. Regression rate was significant among all three groups (p<0.001, p<0.001 and p=0.013 respectively). Among group analysis, it was shown that aneurysms with diameter <55mm had a lower regression rate compared to larger aneurysms (p=0.007).

Conclusion: Aneurysm sac regression might be more common in EVAR patients that are treated with endografts using PET compared to PTFE material. Presence of type II endoleak is associated to sac expansion, while smaller aneurysms seem to have a lower regression rate.

14-16 April 2022

21st Congress of the Hellenic Society of Vascular and Endovascular Surgery

Hybrid meeting

Athens, Greece

Παράγοντες κινδύνου και επιπλοκές σχετιζόμενες με τη διάταση της υπερ- και υπο-νεφρικής αορτής μετά από ενδαγγειακή αποκατάσταση ανευρυσμάτων

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Σκοπός: Η αναδιαμόρφωση της αορτής και το αντίκτυπο της στην κεντρική ζώνη πρόσφυσης, μετά από ενδαγγειακή αποκατάσταση ανευρύσματος της κοιλιακής αορτής είναι υπό διερεύνηση. Στόχος της της μελέτης είναι να προσεγγίσει τη μεταβολή της αορτικής διαμέτρου από την υπερ-νεφρική ως την υπο-νεφρική μοίρα, της παράγοντες που την επηρεάζουν και της επιπτώσεις στην κεντρική ζώνη πρόσφυσης.

Υλικό-Μέθοδοι: Συντάχθηκε μια αναδρομική μελέτη, προοπτικών δεδομένων ασθενών που αντιμετωπίστηκαν ενδαγγειακά σε τακτική βάση από το 2017 ως το 2019 σε ένα τριτοβάθμιο κέντρο. Βάσει πρωτοκόλλου, όλοι υπεβλήθησαν σε αξονική αγγειογραφία προ-εγχειρητικά, κατά τον 1^{ο} και 12^{ο} μετεγχειρητικό μήνα. Η υπο-νεφρική διάμετρος μετρήθηκε σε 3 επίπεδα: κάτωθεν της κατώτερης νεφρικής

αρτηρίας, στα 7 και 15χιλ. από αυτή, ενώ η υπερ-νεφρική, άμεσα άνωθεν της ανώτερης νεφρικής και της άνω μεσεντερίου και κάτωθεν της κοιλιακής αρτηρίας. Οι επιπλοκές που σχετίζονται με την κεντρική ζώνη πρόσφυσης συμπεριελάμβαναν τη μετάθεση μοσχεύματος και την ενδοδιαφυγή τύπου Ια.

Αποτελέσματα: Εκατό πενήντα ασθενείς συμπεριλήφθηκαν. Της 12 μήνες, της οι υπο-νεφρικές διάμετροι αυξήθηκαν (p<0.001), της και η άμεσα υπερ-νεφρική και η διάμετρος στο επίπεδο της άνω μεσεντερίου αρτηρίας (p=.024 και νp=.007, αντίστοιχα). Ο προ-εγχειρητικός αυχένας με διάμετρο >29χιλ (p<.001), η υπερ-νεφρική στήριξη (p=.002) και η υπερμεγέθυνση (oversizing) του μοσχεύματος >20% (p=.017) σχετίστηκαν με την υπο-νεφρική διάταση. Σχετικά με την υπερ-νεφρική αορτή, ο ευρύς αυχένας >29χιλ φάνηκε να επηρεάζει τη διάταση της. Οι επιπλοκές που σχετίζονται με τον κεντρική ζώνη πρόσφυσης σχετίζονταν με στατιστική σημαντικότητα με της μεταβολές της διαμέτρου άμεσα κάτωθεν της κατώτερης νεφρικής αρτηρίας (p=.017). Η διάταση της διαμέτρου στα 7 και 15χιλ κάτωθεν της νεφρικής δε σχετίστηκε με επιπλοκές (p=.11 and p=.09, αντίστοιχα). Σχετικά με την υπερ-νεφρική διάταση, η διαφορά της διαμέτρου στο επίπεδο άμεσα ύπερθεν της ανώτερης νεφρικής και της άνω μεσεντερίου σχετίστηκε με την εμφάνιση επιπλοκών της κεντρικής ζώνης πρόσφυσης (p=.007 και p=.05, αντίστοιχα).

Συμπεράσματα: Η διάταση της αορτής μετά από ενδαγγειακή αποκατάσταση ανευρυσμάτων μπορεί να εντοπίζεται τόσο στην υπερ-νεφρική όσο και την υπονεφρική μοίρα. Οι ευρείς αυχένες, η υπερνεφρική στήριξη και το επιθετικό oversizing φαίνεται να επηρεάζουν αυτό το φαινόμενο. Οι επιπλοκές της κεντρικής ζώνης πρόσφυσης είναι συνηθέστερες σε ασθενείς με διάταση της υπερ- και υπο-νεφρικής αορτής.

Το αντίκτυπο της κωνικής μορφολογίας του κεντρικού αυχένα της επιπλοκές που σχετίζονται με την κεντρική ζώνη πρόσφυσης μετά από ενδαγγειακή αποκατάσταση ανευρυσμάτων

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Σκοπός: Η κωνική μορφολογία αποτελεί ένα από τα «εχθρικά» χαρακτηριστικά του κεντρικού αυχένα κατά την ενδαγγειακή αποκατάσταση ανευρυσμάτων της κοιλιακής αορτής. Στόχος της μελέτης είναι να παρουσιάσει της επιπλοκές της κεντρικής ζώνης πρόσφυσης σε ασθενείς με κωνικό και μη-κωνικό αυχένα και της πιθανούς παράγοντες επίδρασης κατά τον 1ο χρόνο παρακολούθησης

Υλικό-Μέθοδοι: Συντάχθηκε μια αναδρομική μελέτη, προοπτικών δεδομένων ασθενών που αντιμετωπίστηκαν ενδαγγειακά σε τακτική βάση από το 2017 ως το 2019 σε ένα τριτοβάθμιο κέντρο. Βάσει πρωτοκόλλου, όλοι υπεβλήθησαν σε αξονική αγγειογραφία προ-εγχειρητικά, κατά τον 1ο και 12ο μετεγχειρητικό μήνα. Οι επιπλοκές που σχετίζονται με την κεντρική ζώνη πρόσφυσης συμπεριελάμβαναν τη μετάθεση μοσχεύματος και την ενδοδιαφυγή τύπου Ια.

Αποτελέσματα: Εκατό πενήντα ασθενείς συμπεριλήφθηκαν. Συνολικά, 66 (44%) εκ των ασθενών εμφάνιζαν κωνικό κεντρικό αυχένα. Καμία στατιστικά σημαντική

διαφορά δε διαπιστώθηκε μεταξύ των δύο ομάδων ασθενών, εκτός από την περιφερική διάμετρο του αυχένα στα 15χιλ, η οποία ήταν ευρύτερη της ασθενείς με κωνικό αυχένα (p<.001). Μόσχευμα με υπερ-νεφρική στήριξη χρησιμοποιήθηκε στο 63.3% επί του συνόλου; 59.5% σε μη κωνικούς αυχένες και 68.2% σε ασθενείς με κωνικό αυχένα (p=.275). Η υπερμεγέθυνση (oversizing) του μοσχεύματος ήταν 19% και 26.5% σε ασθενείς με μη και με κωνικό αυχένα, αντίστοιχα (p=0.004). Oversizing >20% και >30% χρησιμοποιήθηκε ευρύτερα σε ασθενείς με κωνικούς αυχένες [63.6 έναντι 36.9% (p<.001) και 11.9% έναντι 43.9% (p<.001), αντίστοιχα]. Όσον αφορά της επιπλοκές της κεντρικής ζώνης πρόσφυσης, δεν παρατηρήθηκε διαφορά μεταξύ των δύο ομάδων ασθενών. Σε υπο-ανάλυση της ομάδας των ασθενών με κωνικούς αυχένες, το επιθετικό oversizing >30% σχετίστηκε με λιγότερο συχνή μετάθεση μοσχεύματος κατά το 1^{ο} έτος παρακολούθησης (p=.011).

Συμπεράσματα: Η ενδαγγειακή αποκατάσταση των ανευρυσμάτων της κοιλιακής αορτής δύναται να αποδώσει όμοια αποτελέσματα σε ασθενείς με κωνικό ή μη κωνικό αυχένα κατά το 1^{ο} έτος μετεγχειρητικά. Το επιθετικό oversizing (>30%) μπορεί να έχει προστατευτικό ρόλο στη μετάθεση μοσχεύματος σε ασθενείς με κωνικό αυχένα κατά το 1^{ο} έτος μετεγχειρητικής παρακολούθησης.

20-23 June 2022

70th ESCVS Congress

Liege, Belgium

Risk factors and adverse events related to supra- and infra-renal aortic dilatation after EVAR

Petroula Nana, George Kouvelos, Konstantinos Spanos, Konstantinos Batzalexis, Metaxia Mpareka, Eleni Arnaoutoglou, Athanasios Giannoukas, Miltos Matsagkas

OBJECTIVE: Aortic remodeling and its effect on neck-related outcomes after endovascular abdominal aortic aneurysm repair (EVAR) is under investigation. The aim of this study was to assess the supra- and infra-renal aortic diameter modifications after EVAR and investigate the risk factors and adverse events to proximal sealing.

METHODS: A retrospective analysis of prospective data of consecutive patients managed with standard EVAR, between 2017 and 2019, in a single tertiary center, was undertaken. Adequate computed tomography angiography was performed preoperatively, at the 1st and 12th month of follow-up. The database included pre- and post-operative anatomic characteristics (infra- and supra-renal aortic diameters, aneurysm diameter, angle, presence of neck thrombus and calcification). The infrarenal diameter was measured at three levels: just below the lowest renal artery, at 7mm and 15mm. The suprarenal aorta was measured just above the highest renal and superior mesenteric artery (SMA) and just below the celiac trunk. Neck-related adverse events included migration of ≥10mm, and endoleak type Ia (ET Ia).

RESULTS: The analysis included 150 patients. At 12-month follow-up, all infra-renal diameters increased (all $p<0.001$). Regarding the supra-renal aorta, the diameter above the highest renal and SMA were augmented ($p=.024$ and $p=.007$, respectively). Pre-

operative neck diameter >29mm (p<.001), active supra-renal fixation (p=.002) and oversizing >20% (p=.017) were significantly associated to just below the lowest renal aortic dilatation. Neck diameter >29mm (p<.001 and p=0.001) and supra-renal fixation (p<.001 and p=.016) were associated to 7 and 15mm aortic dilatation. Neck diameter >29mm affected also the supra-renal diameter increase. Neck-related adverse events were associated to diameter alterations at the level just below the lowest renal artery (p=.017). Regarding the supra-renal dilatation, diameter differences at the highest renal artery and SMA were related to adverse events (p=.007, and p=.05).

CONCLUSIONS: Post-EVAR aortic dilatation may be detected from the supra-renal aorta to the total length of the aortic neck. Multiple factors may affect this phenomenon, as neck diameter >29mm, active supra-renal fixation, and aggressive oversizing. Neck-related adverse events are more common in patients with infra-and supra-renal aortic dilatation.

Impact of conical anatomy on proximal neck adverse events after EVAR

Petroula Nana, Konstantinos Spanos, George Kouvelos, Metaxia Mpareka, Eleni Arnaoutoglou, Athanasios Giannoukas, Miltos Matsagkas

OBJECTIVE: Conical neck is one of the hostile characteristics that may affect endovascular aneurysm repair (EVAR) outcomes. The aim of this analysis was to present proximal neck adverse events (endoleak type Ia (ET Ia) and graft migration), in patients with conical morphology compared to patients with non-conical neck. Factors that may affect adverse events in patients with conical neck during the 12-month follow-up were also assessed.

METHODS: A retrospective analysis of prospectively collected data, of consecutive elective EVAR patients, treated between 2017 and 2019, was undertaken. Adequate computed tomography angiography was performed preoperatively, at the 1^{st} and 12^{th} month of follow-up. The database included patients' demographics and comorbidities, pre-operative, and post -operative aneurysm anatomical characteristics (supra-renal and infra-renal aortic diameter measurements, sac diameter, neck angle, neck thrombus, and calcification). Neck adverse events included ET Ia and migration.

RESULTS: A hundred fifty patients were included; 66 (44%) presented conical proximal neck characteristics. No significant anatomic differences were detected between the conical and non-conical group. Only distal neck diameter was wider in the conical neck group (p<.001). Supra-renal active fixation endograft was applied in 63.3% of the total cohort; 59.5% of patients with non-conical and 68.2% with conical neck (p=.275). Oversizing was 19% and 26.5% in patients with non-conical and conical morphology, respectively (p=0.004). Oversizing >20% and >30% was more commonly used in patients with conical neck [63.6 vs 36.9% (p<.001), and 11.9% vs. 43.9%

(p<.001), respectively]. Regarding neck adverse events, no difference was recorded between patients with non-conical and conical morphology. In a sub-analysis, among patients with conical neck, aggressive oversizing >30% was related to lower graft migration rate during the 12-month ollow-up (p=.011).

CONCLUSIONS: EVAR may offer similarly good outcomes in patients with conical and non-conical neck anatomy during the early follow-up. Aggressive oversizing (>30%) may have decrease graft migration rate in patients with conical neck during the first post-operative year.

Publications

1. Petroula Nana, George Kouvelos, Konstantinos Spanos, Konstantinos Batzalexis, Eleni Arnaoutoglou, Athanasios Giannoukas, Miltos Matsagkas. **Risk factors and adverse events related to supra- and infra-renal aortic dilatation after endovascular abdominal aortic aneurysm repair.** Journal of Cardiovascular Surgery (Torino), Minerva Medica, Number assigned: J Cardiovasc Surg-12487, Under review

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3. Petroula Nana, Konstantinos Spanos, George Kouvelos, Konstantinos Dakis, Eleni Arnaoutoglou, Athanasios Giannoukas, Miltos Matsagkas. **The Impact of Iliac Artery Anatomy on Distal Landing Zone after EVAR During the 12-Month Follow-up.** Annals of Vascular Surgery, Elsevier, Received 27.02.22, Accepted 06.06.22, Available online 30.06.22, doi: https://doi.org/10.1016/j.avsg.2022.06.011

Chapter 7

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