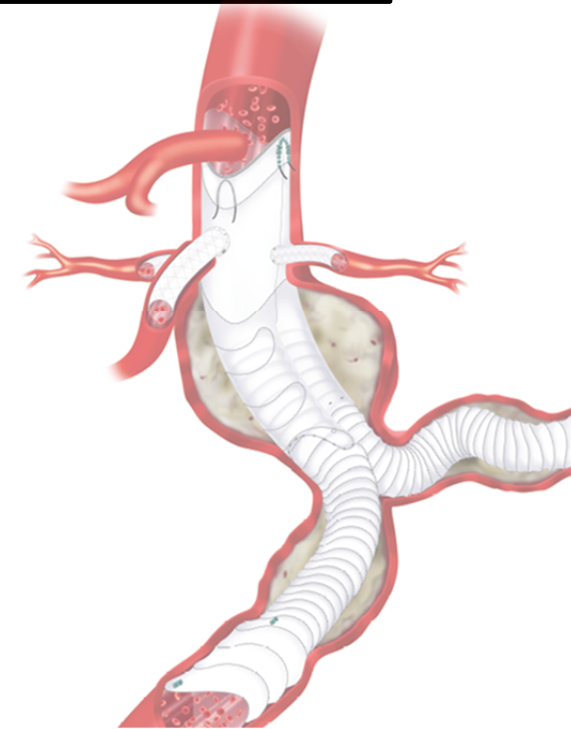


# Mon experience FEVAR avec l'Anaconda Fenetrée (Terumo aortic)



Hospices Civils de Lyon

Antoine MILLON  
Hospices Civils de Lyon



**ARCHIV**  
**St Francois Longchan**  
**29 septembre 2023**



# Complex Abdominal Aortic Aneurysm

Thoracoabdominal AA

Pararenal AA

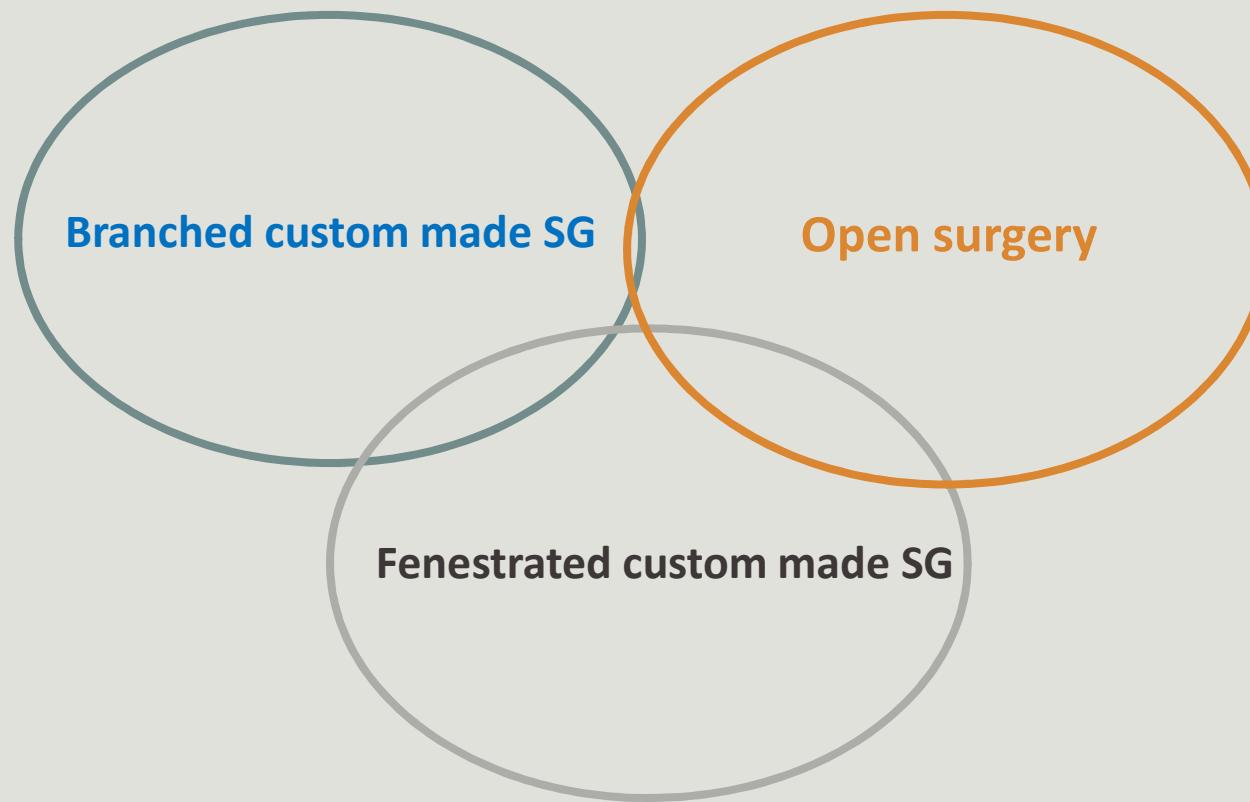
Juxtarenal AA

Infrarenal AA with  
complex proximal neck

Branched custom made SG

Open surgery

Fenestrated custom made SG



# Anatomical limitations for FEVAR

## Iliac access

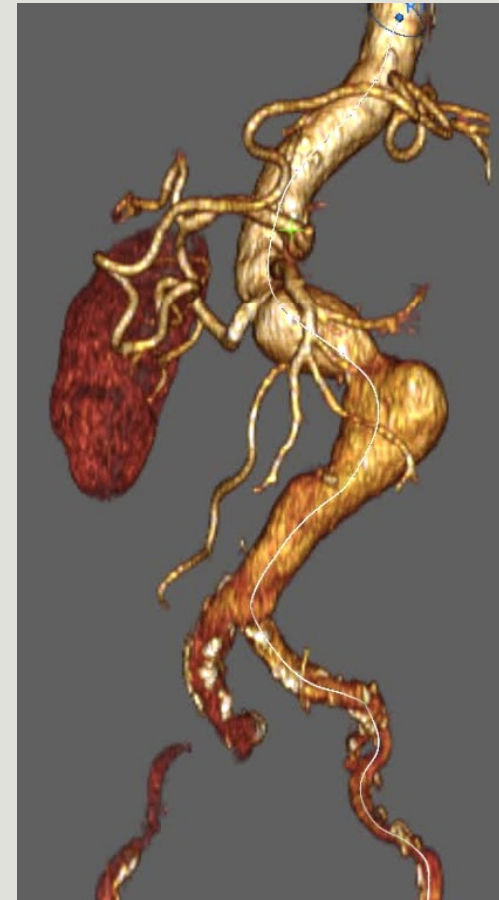
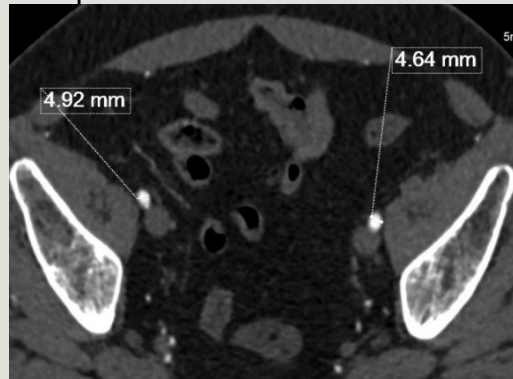
- Calcified and tortuous iliac
- Small and calcified IEA

## Angulation +++

- Aortic
- Iliac

## Target vessels

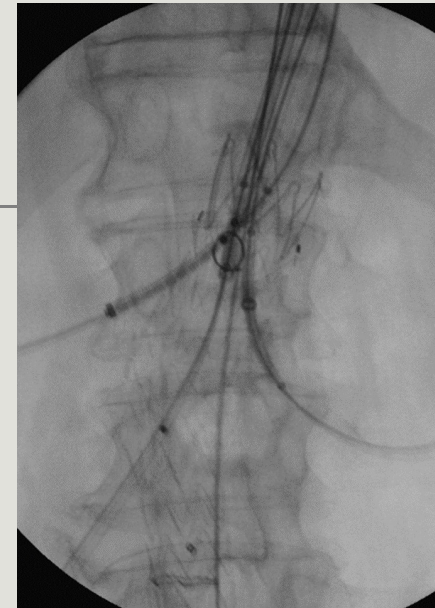
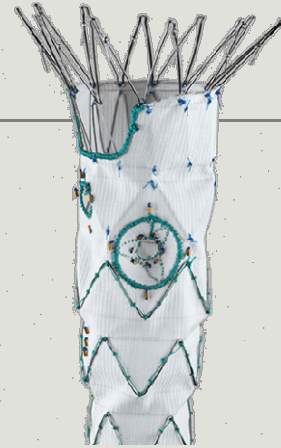
- Small
- Downward facing



# Initial experience

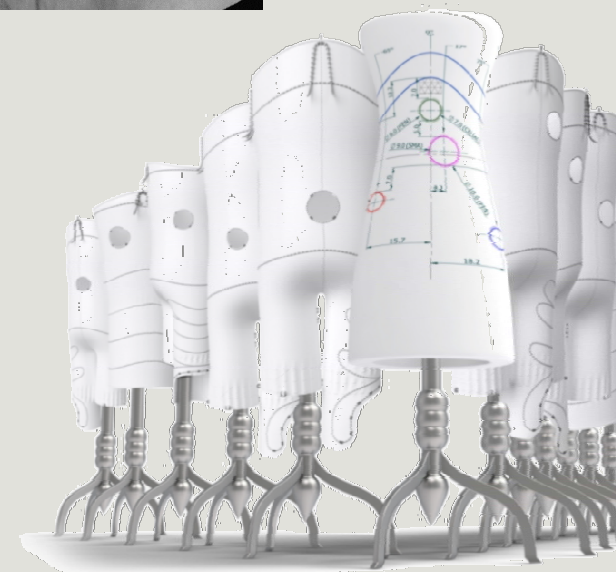
## 2012/ 2016

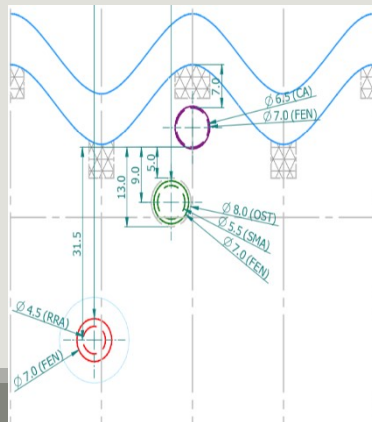
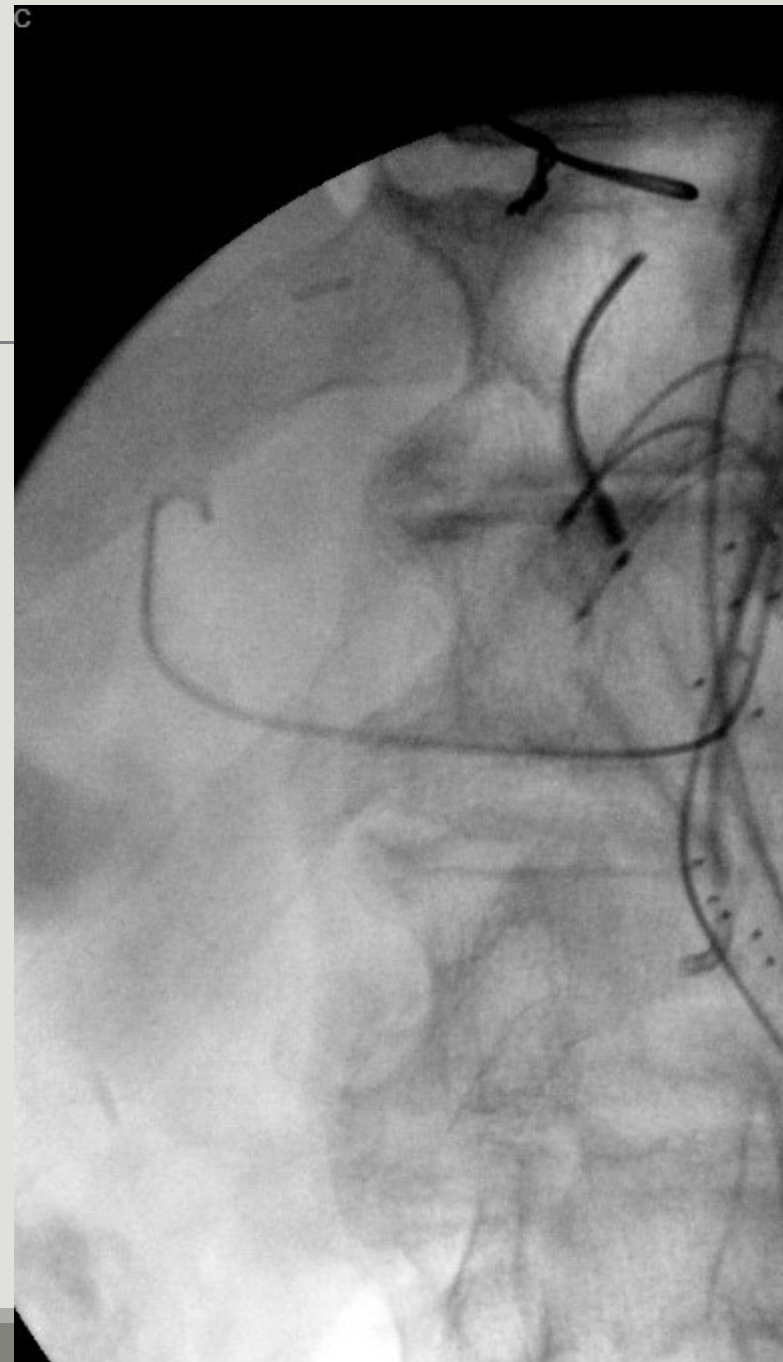
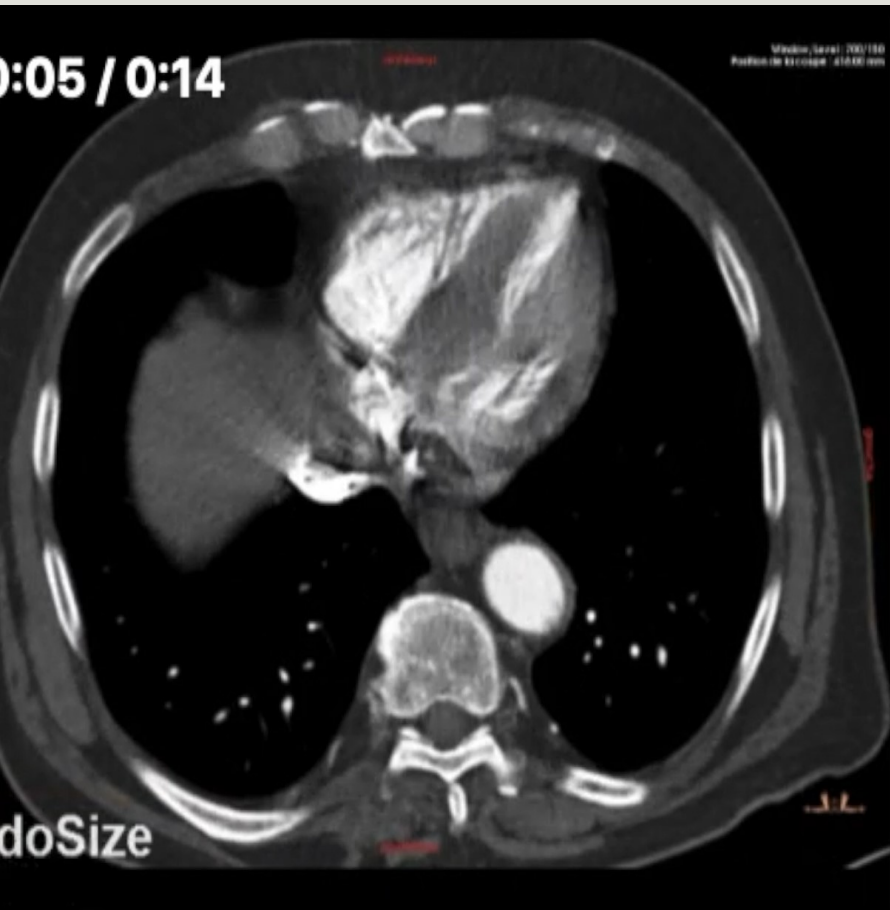
- Custom made Cook device ( >100 patients)
- Home made FEVAR / Chimney
- Hybrid / Open surgery

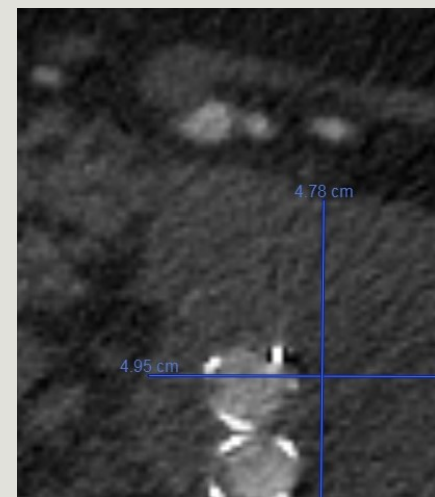
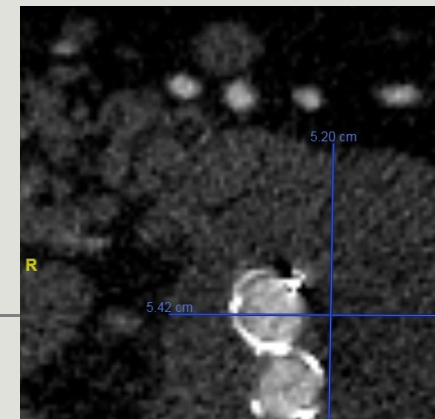
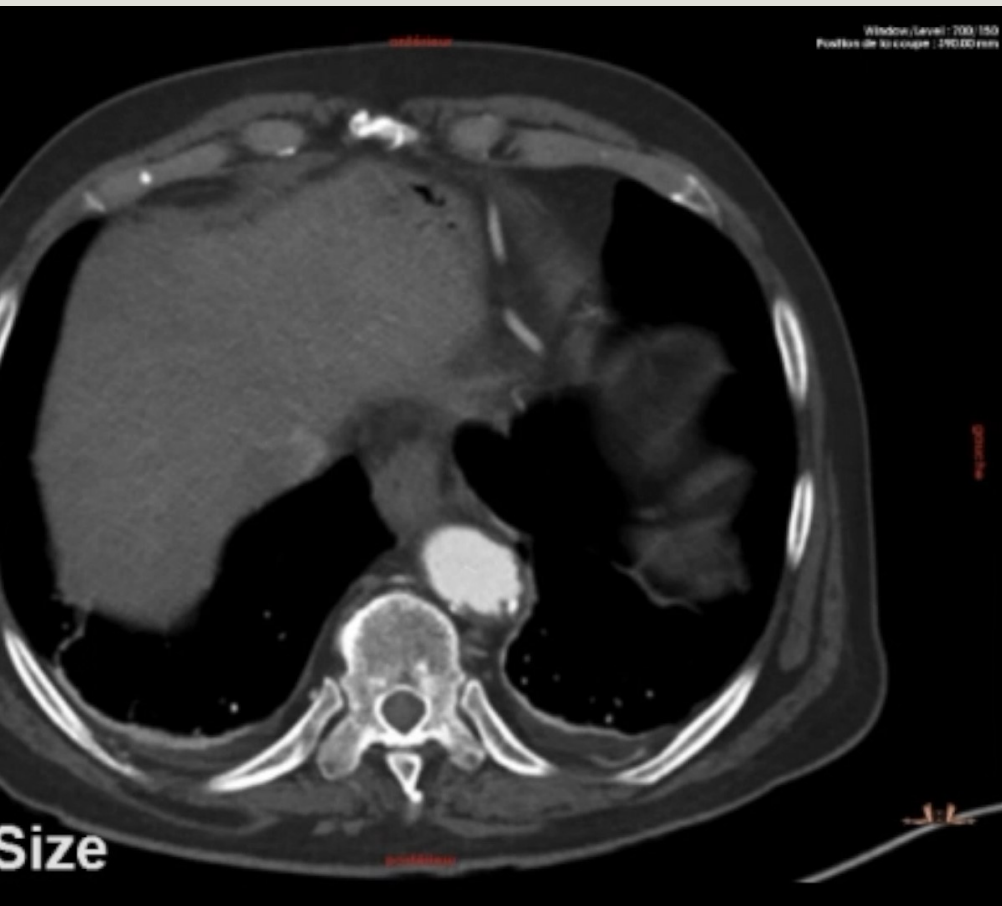


## Fenestrated Anaconda first case in 2016

- 80 yo male, 60mm juxtarenal AAA
- High risk for open repair (CABG, history of stroke, chronic renal failure)
- Severe aortic tortuosity
- Right renal artery downward facing with previous stent







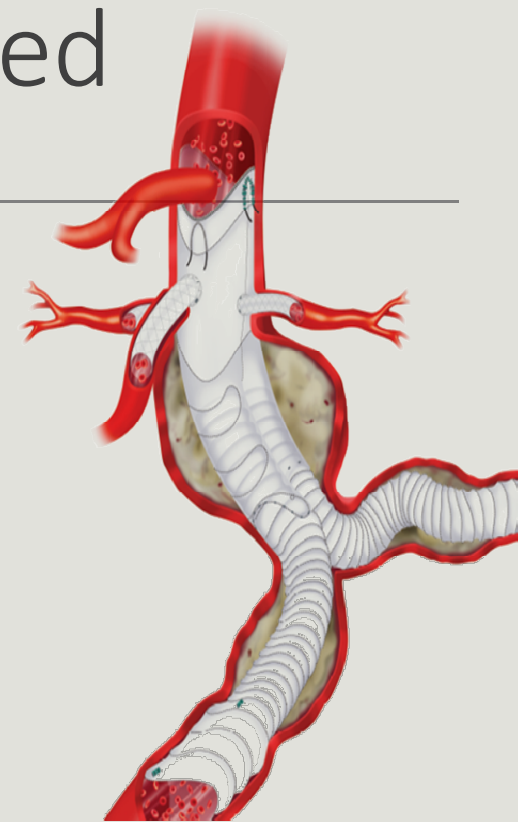
**At 4 years,  
Sac retraction without endoleak  
Without renal function degradation ( creat 142  $\mu\text{mol/l}$ )**

# Personnal experience with fenestrated Anaconda



FEVAR since 2016 n=66  
(2016 = 1 / 2018 = 14 / 2019 = 26 / 2020 = 25...)

Male n=58 Mean Age=74 yo  
High risk for open repair 100%  
Mean AAA Diameter=62 mm (50-97)



thoracoabdominal AA n=3

Pararenal AA n=13

Juxtarenal AA n=50

4 fenestrations n=47  
3 fenestrations n=14  
2 fenestrations n=3  
1 fenestration n=2

# Personnal experience

## Access

- Femoral artery access : n = 23
- Femoral + Axillary artery access : n = 43
  - 19 surgical axillary access
  - 24 percutaneous axillary access



# Percutaneous axillary artery access



N = 24

23 left and 1 right access

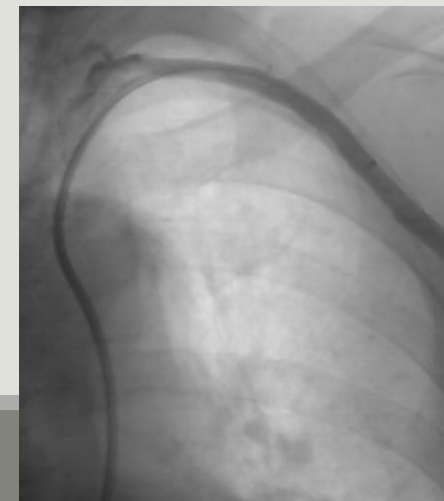
11 arterial blush

- 1 covered stent
- 10 balloon occlusion

1 arterial stenosis (ballon angoplasty)

Complications :

- 1 open conversion (arterial dissection)
- 1 False Aneurysm -> open surgery



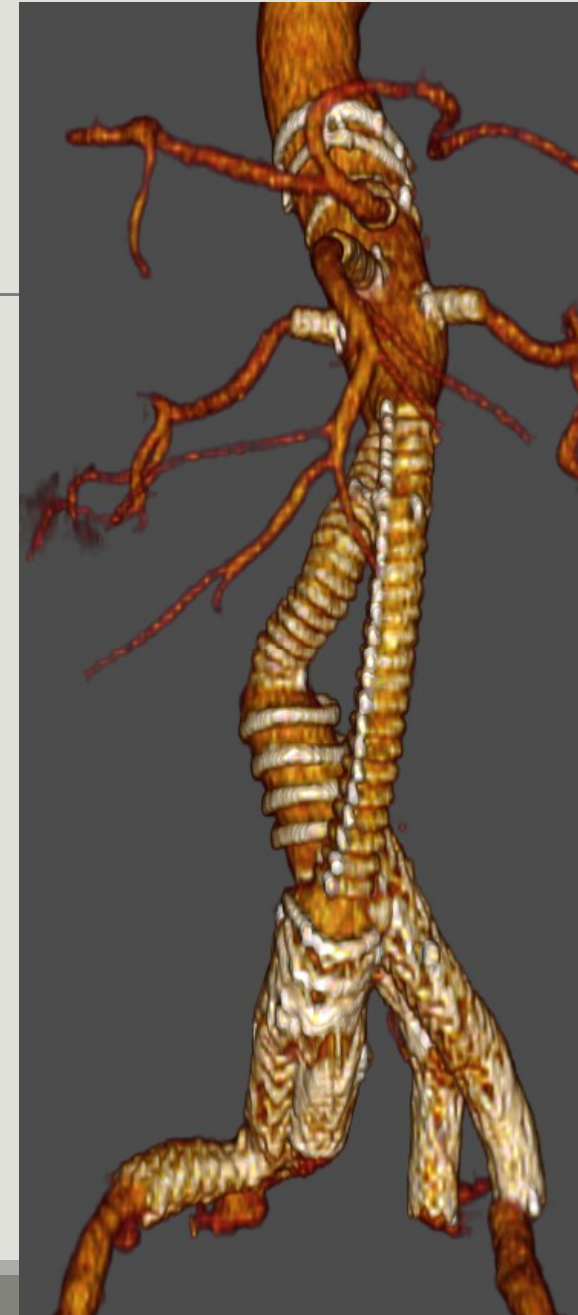
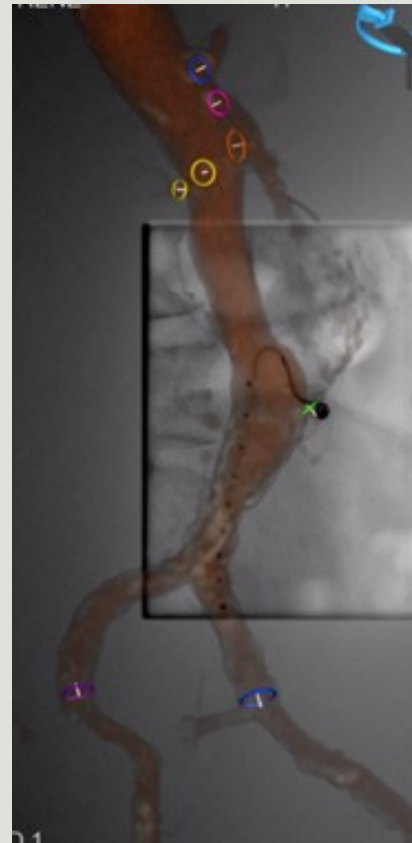
# Personnal experience

## Associated Procedures

- *Embolization* : 26 Pts, 36 arteries  
=>Polar renal or inf mes artery
- *Iliac banch procedure* : 3 Pts

## Procedural details

- Mean fluoroscopy time=75 min
- Mean contrast load=107 cc
- Mean irradiation dose= 319 Gy.cm<sup>2</sup>



# Index hospitalisation

---

Mean Length of Stay = 10,5 days

Complications N = 11 (17%)

Limb ischemia (2)/ Wire injury (3)/ acute pancreatitis (1)/ paraplegia (1)

Femoral or axillary false aneurysm (4)

Reintervention n = 3 (4,5%)

- supplemental stenting or flaring

In-hospital mortality n = 3 (4,5%)



# Midterm results

Mean follow up = 10,2 +/- 8,6 months

ndoleak / Sac retraction

	6 months	12 months	24 months
Patients	38	19	10
ndoleaks	11 (29%) / 7 (24%)	4 (21%) / 0	3 (30%) / 0
c Retraction	7 (18%)	5 (26%)	5 (50%)

◦ 6 (32%) at 12 months

- Global survival = 89,4%
- Stent patency = 99,5%
  - 1 occlusion CA stent / 237 target vessels
- 1 asymptomatic leg stentgraft occlusion

# How the Fenestrated Anaconda has changed my practice ?

---

Increase the range of patients suitable for FEVAR

Simplify the procedure +++

- Lower / Upper arterial access
- Stent Graft easily repositionnable
- Flexibility of the Stent Graft
- Fenestration easy to cannulate and to adjust
- Fenestrated bifurcated body
- Leg length adjustment

Decrease operative time / complications



# PRISE EN CHARGE DES ANEURISMES AORTIQUES COMPLEXES PAR ENDOPROTHÈSE FENÊTRÉE SUR MESURE ANACONDA® RÉSULTATS À MOYEN TERME D'UNE EXPÉRIENCE MONOCENTRIQUE

THESE D'EXERCICE EN MÉDECINE

Soutenue publiquement le 22 Septembre 2022

Marine BORDET

Sous la direction du Pr Antoine MILLON



# - PLAN -

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INTRODUCTION

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MATÉRIEL ET MÉTHODES

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RÉSULTATS

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DISCUSSION

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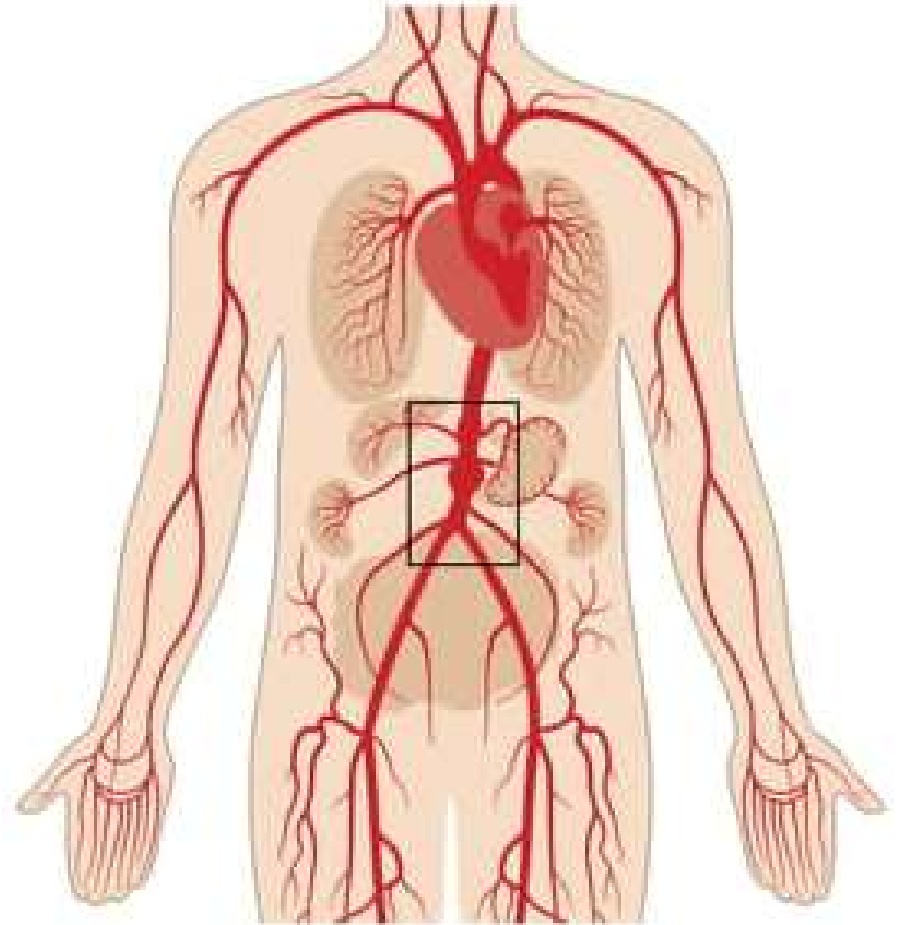
CONCLUSIONS

- INTRODUCTION -

# Anévrisme Aortique

- Dilatation
- Perte de parallélisme paroi
- Décès par rupture

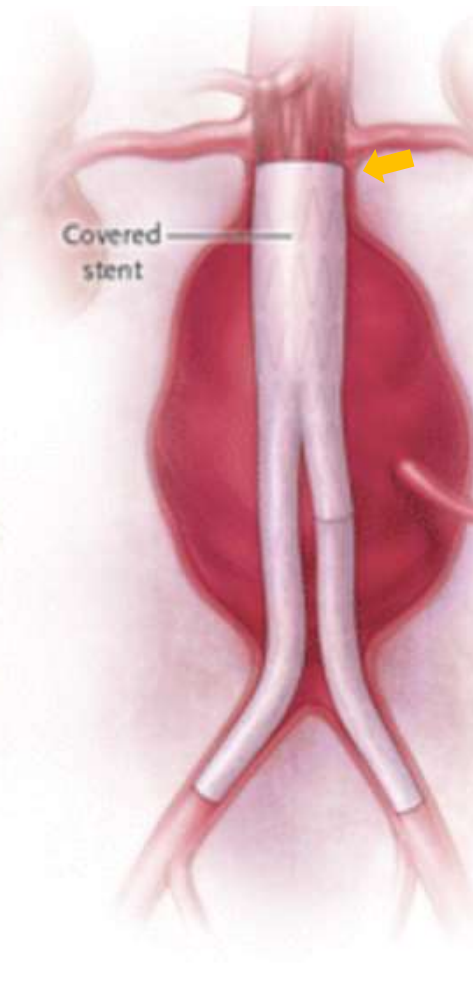
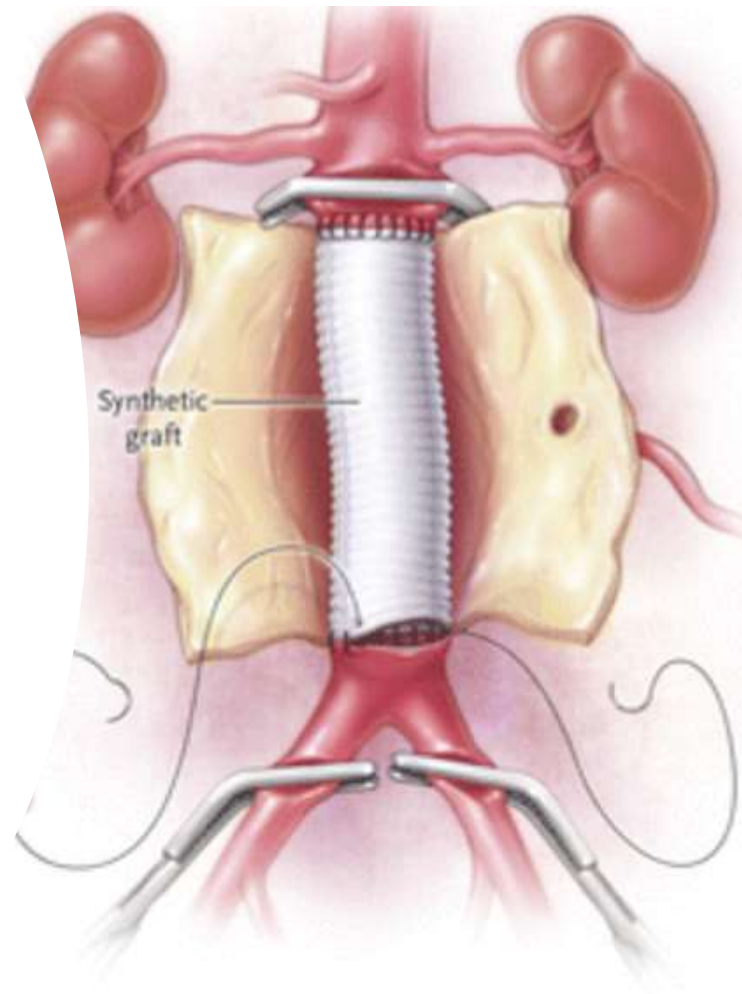
➔ Traitement préventif



## Prise en charge

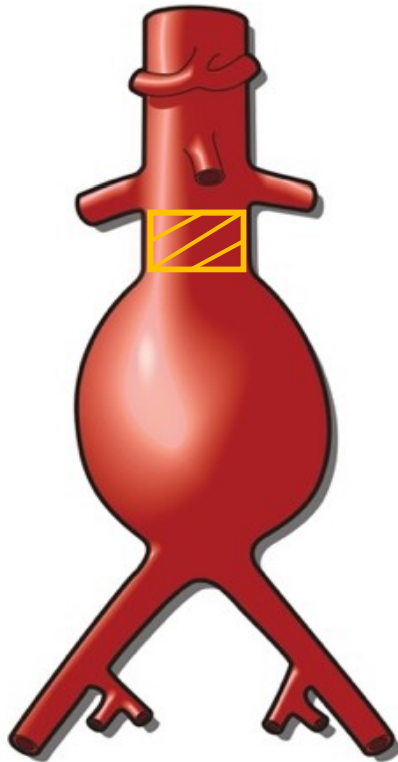
- Chirurgie ouverte
- Exclusion endovasculaire

➔ Landing zone proximale (LZP)

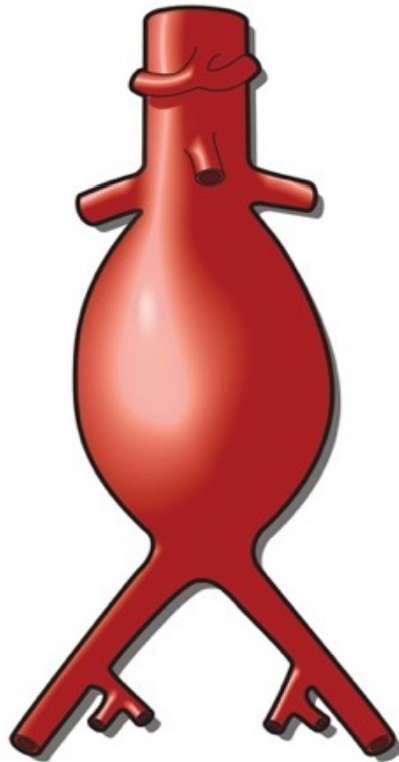


# Anévrismes aortiques complexes

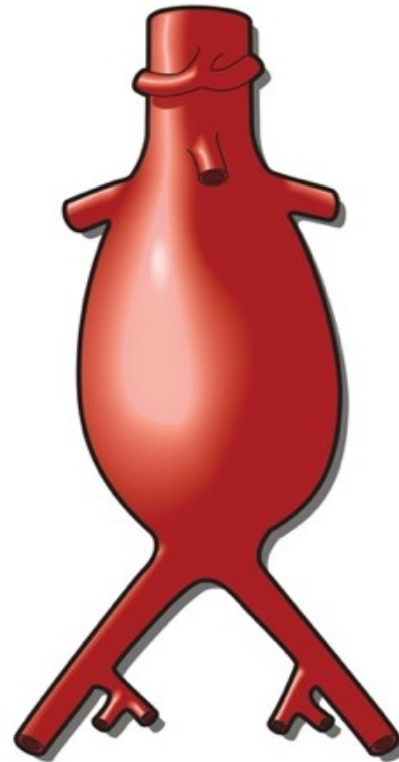
Infrarenal AAA



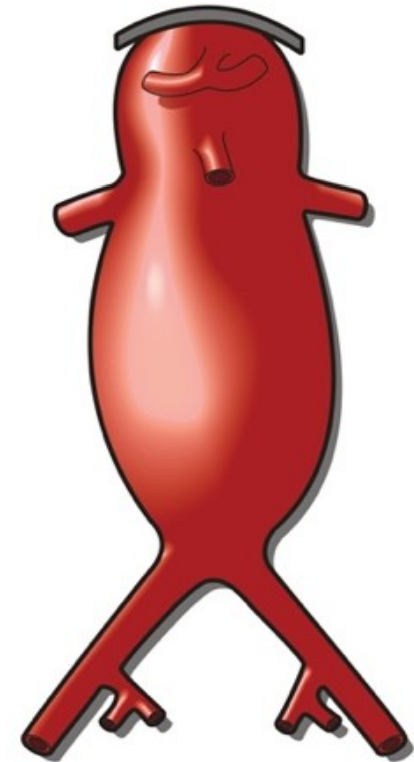
Juxtarenal AAA



Pararenal AAA



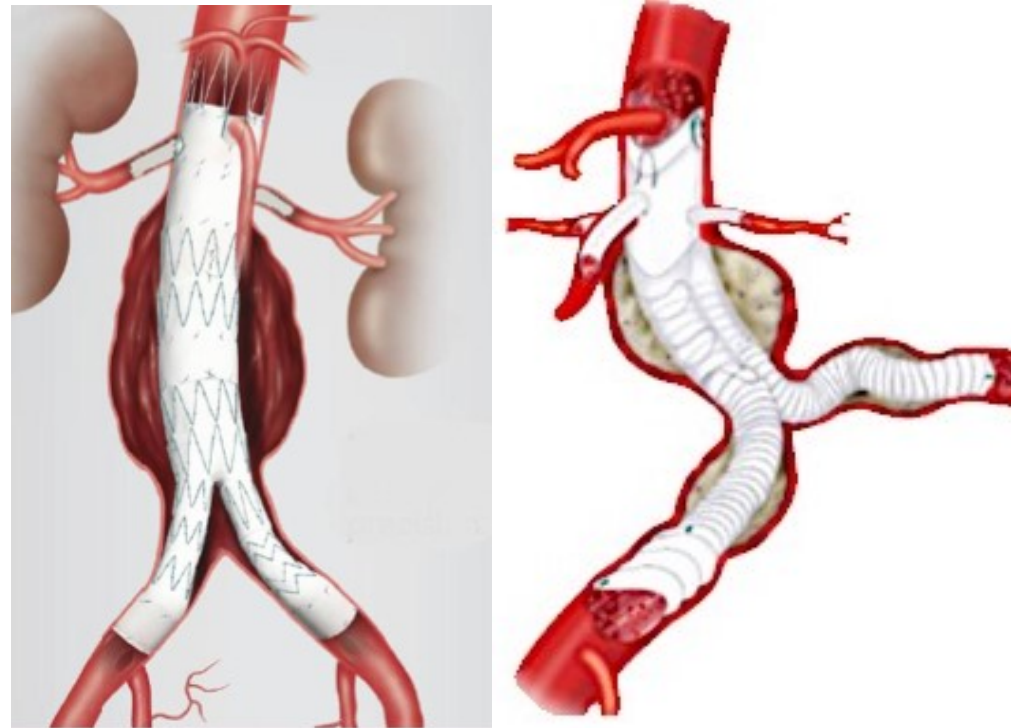
Suprarenal AAA



## Endoprothèses fenêtrées

- LZP au-delà artères viscérales
- Maintien de leur perfusion
- Réduction de la morbi-mortalité <sup>(1,2)</sup>

➡ 2 endoprothèses disponibles



1. Girsowicz E, Dubois L, Gill HL. A systematic review and meta-analysis of endovascular juxtarenal aortic aneurysm repair demonstrates lower perioperative mortality compared with open repair. *J Vasc Surg.* 2019;69(6):1670-1678.

2. KHJ, Pothof AB, De Guerre LEVM, Verhagen HJM, Schermerhorn ML. Fenestrated endovascular aneurysm repair is associated with lower perioperative morbidity and mortality compared with open repair for common iliac aneurysms. *J Vasc Surg.* 2019 Jun;69(6):1670-1678.

# Endoprothèse Anaconda

- Avantages

- Pro
- Lib

- Incon

- Enc
- Perméabilité artères cibles ?
- Déconnexion fenêtres ?

But de l'étude :

**Evaluer les résultats de la prise en charge des anévrismes complexes aortiques par l'endoprothèse fenêtrée Anaconda.**



- MATÉRIEL ET MÉTHODES -

## Sélection des patients

- Etude rétrospective et mono centrique
- FEVAR Anaconda
- 1<sup>er</sup> janvier 2018 au 1<sup>er</sup> mars 2022
- Indication :
  - Anévrismes complexes
  - EF type Ia après EVAR



# Données collectées

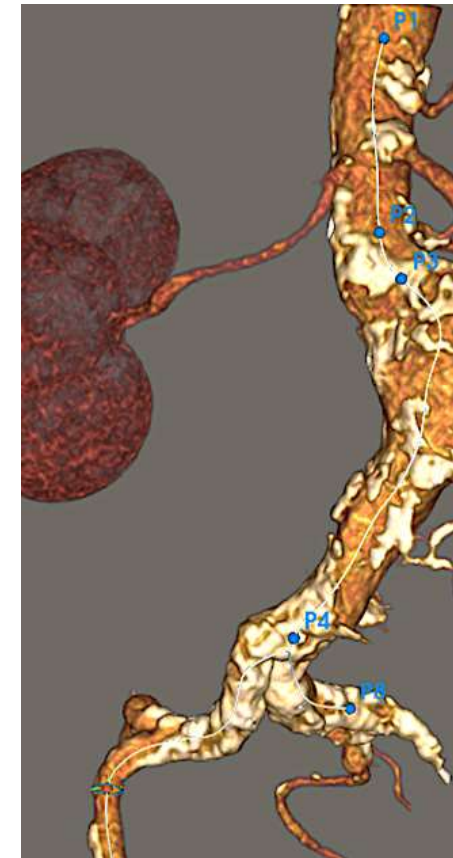
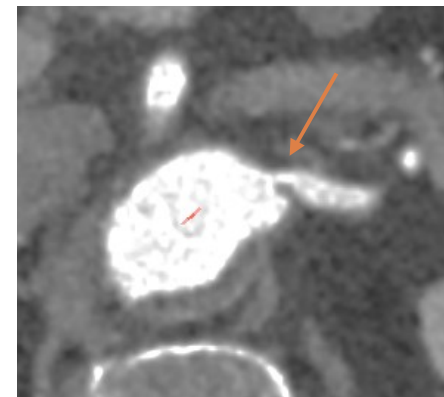
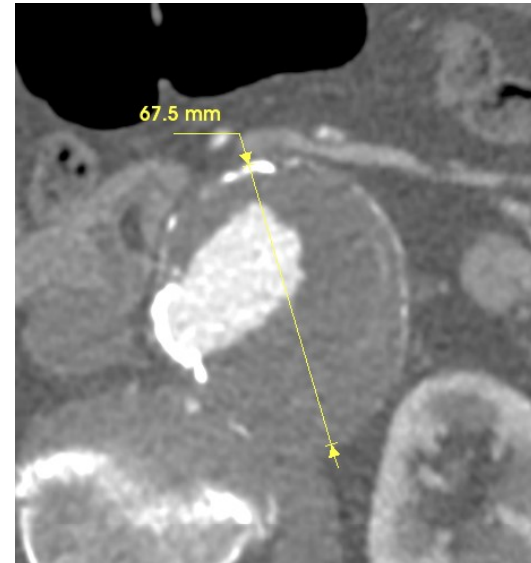
## Sizing pré opératoire (Endosize)

Type anévrisme

Diamètre maximal anévrisme

Nombre d'artères cibles

Caractère pathologique (<5mm ou sténose)



# Données collectées

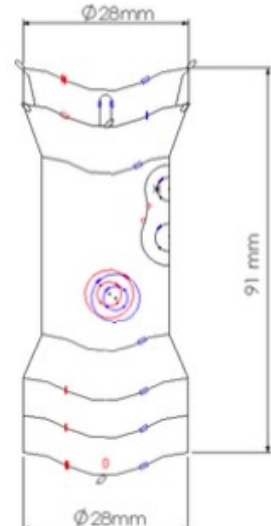
## Graft Plan

Type endoprothèse

Nombre de fenêtres

Oversizing

Angle déploiement



Delivery System: 20F ID, 22F OD  
Markers: Valley Hook on patient's left  
Distal marker between last two distal rings on patient's right.

**Device Parameters**

Device Type:  Bifurcated  Cuff  AUI  Leg  
 Other Specify: \_\_\_\_\_

Number of Fenestrations:  0  1  2  3  4  5  6

Proximal Rings Configuration:  Standard  Augmented Valley  Fenestrated Valley  
Based on: OLB28  Not Applicable

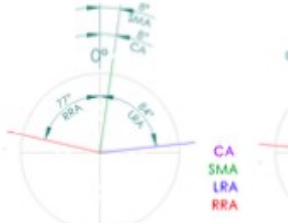
Orientation:  Valleys A/P  Peaks A/P  Not Applicable/specified  
Comments: \_\_\_\_\_

Leg Orientation:  A/P  Lateral  Not Applicable

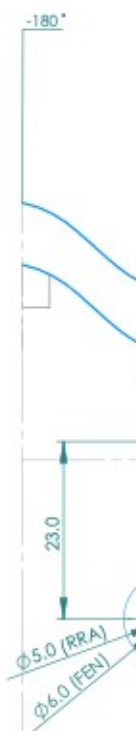
Thru-Support (stentless):  
 Contralateral:  Standard  Reduced  Not Applicable  
 Ipsilateral:  None  Standard  Reduced  Not Applicable

**Measurements**

L1	Bottom of CA to top of SMA ostium	4
L2	Bottom of the CA to the proposed centre of the SMA	9
L3	Bottom of the CA to the bottom of the SMA ostium	12
L5	Bottom of the CA to the proposed centre of the LRA fenestration	24
L6	Bottom of the CA to the proposed centre of the RRA fenestration	23



are based on the image. diameter and orientation



# Données collectées

## Procédure

Données opératoires

Hospitalisation

Complications

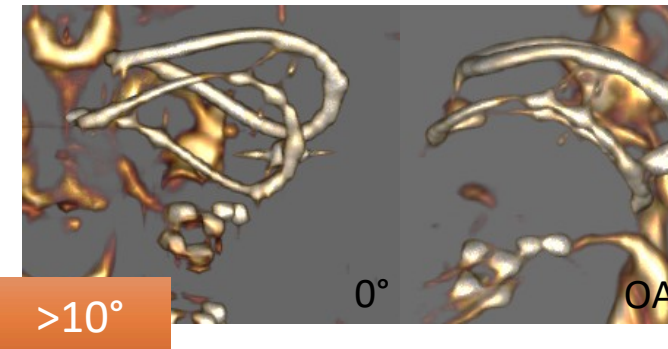
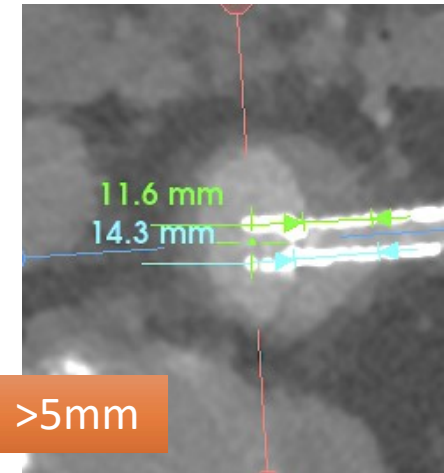
Réinterventions précoces

Scanner post opératoire

Endofuite de type la

Angle EDP

Distance fenêtres-ostia



# Données collectées

Suivi : M1, M6, M12 puis 1/an

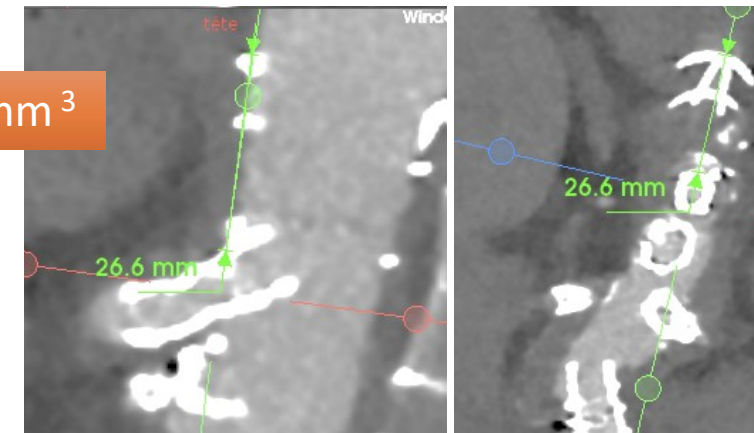
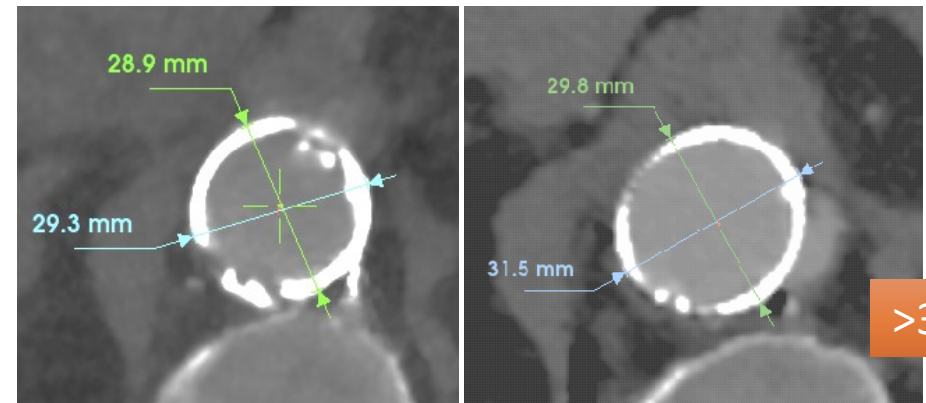
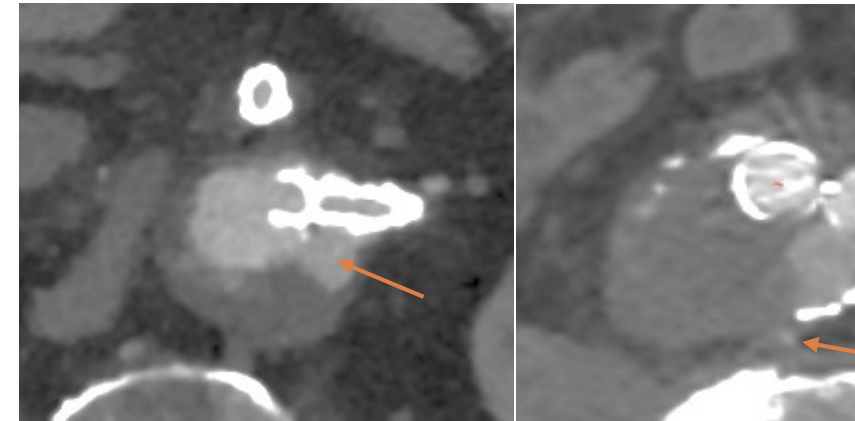
Diamètre maximal

Endofuites<sup>3</sup> : primaires ou secondaires

Collet proximal<sup>3</sup>

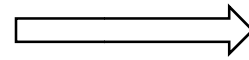
Réinterventions<sup>3</sup> : majeures ou mineures

Survie

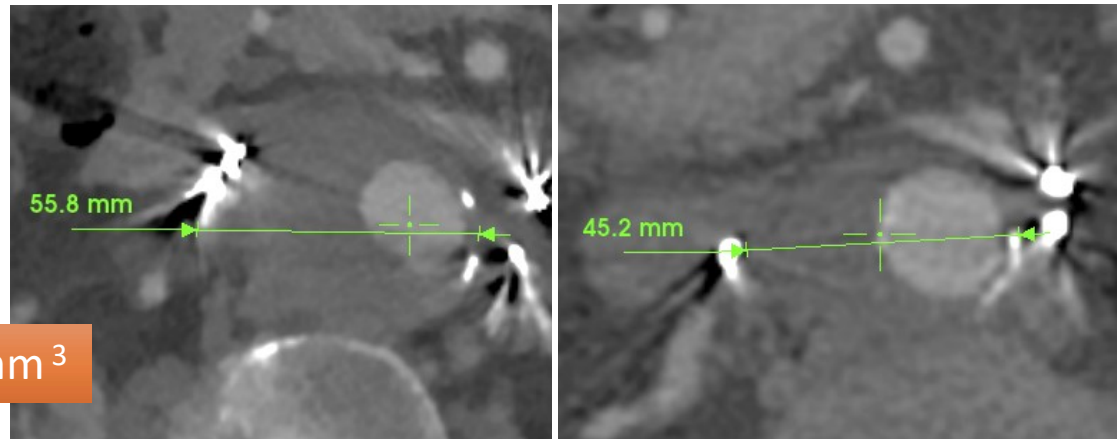


## Critères de jugement

Critère de jugement primaire



Evolution du sac



# Critères de jugement

## Critères de jugement secondaires



### Analyses court terme

- Succès technique
- Complications
- Réinterventions précoces
- Mortalité intra hospitalière

### Analyses moyen terme

- Survenue EF type I ou III
- Perméabilité art. cibles
- Réinterventions
- Evolution collet proximal
- Survie

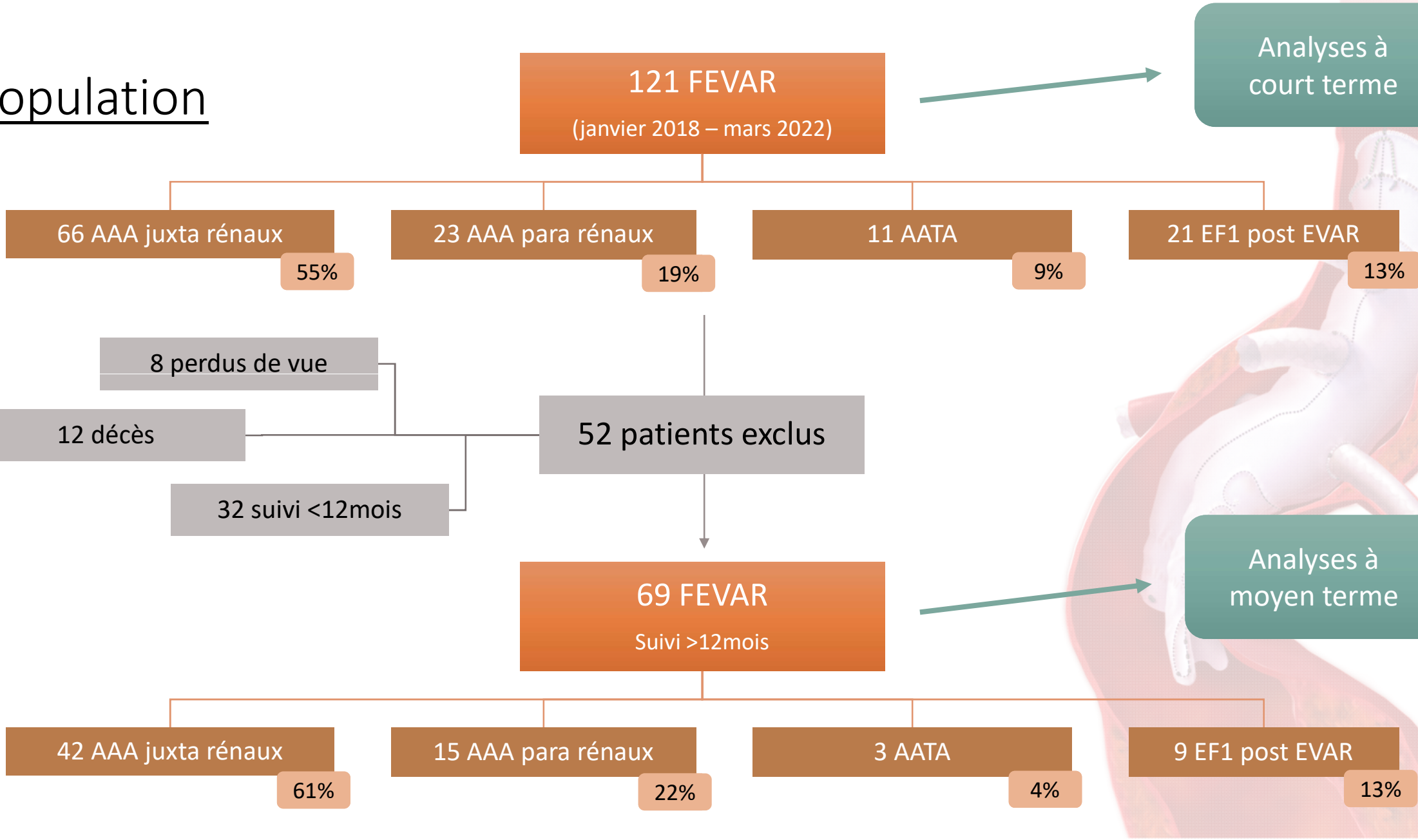


Suivi  
radiologique  
> 12 mois

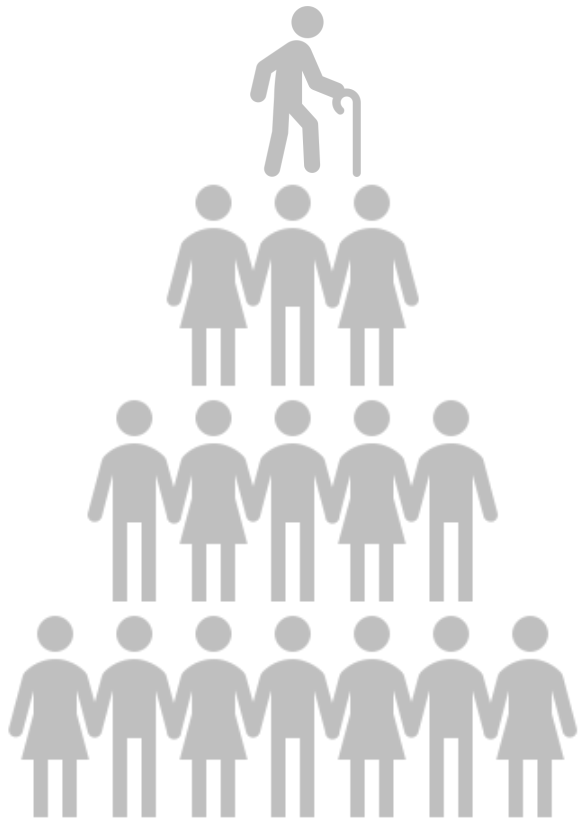
- RÉSULTATS -

- RESULTATS -

Population



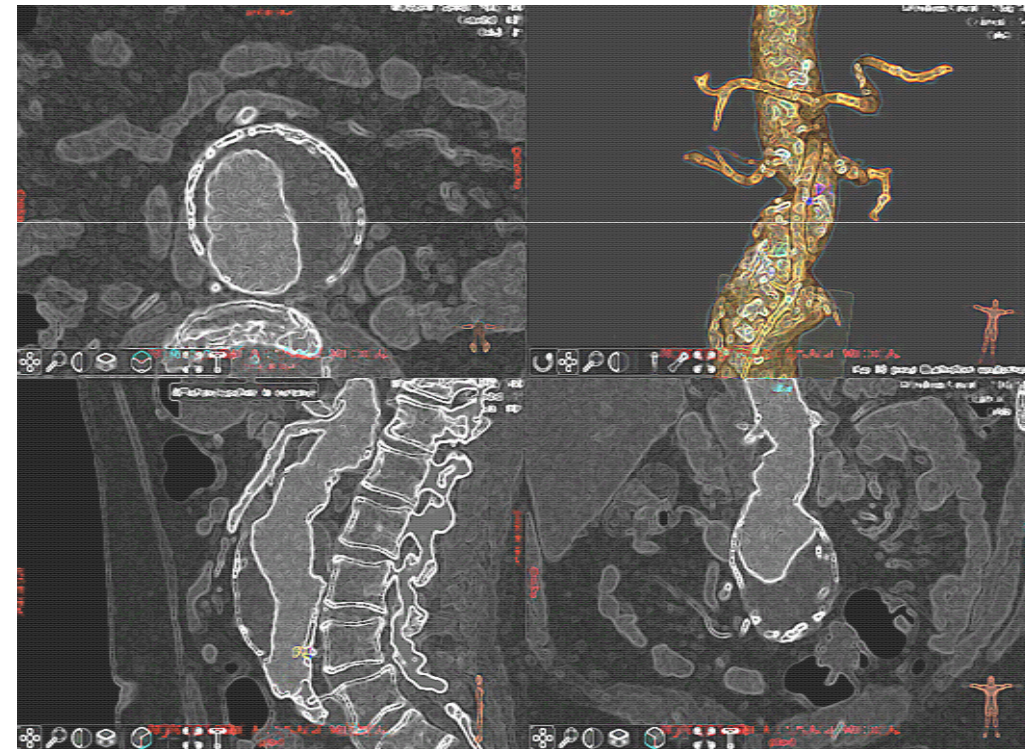
# Données pré opératoires



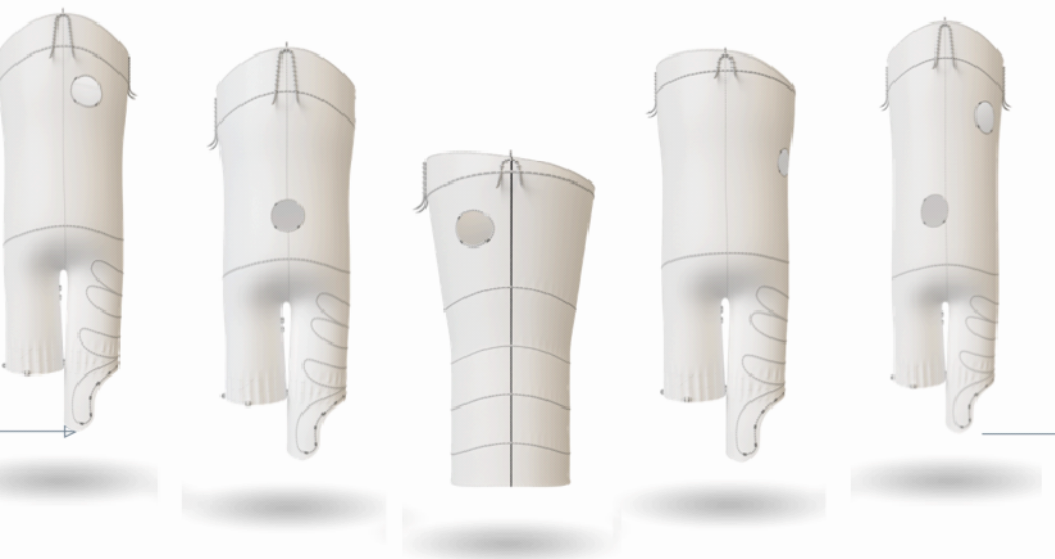
	FE	(N)
Age, moyen +/- DS	73,2 +/- 7,6	
Sexe masculin, n (%)		101
Hypertension artérielle, n (%)		88
Diabète, n (%)		21
Dyslipidémie, n (%)		72
Coronaropathie, n (%)		44
DFG (ml/min/m <sup>2</sup> ), moyen +/- DS		69,3
IRC, n (%)		5
Antécédent chirurgie aortique		32
EVAR, n (%)		20
ASA		
II, n (%)		21 (1
III, n (%)	96 (79,3)	
III, n (%)		96 (7

# Données pré opératoires

Diamètre max de l'anévrisme (mm), médiane [IQR]	58 [55-60]
Anévrisme juxta rénal, n (%)	66 (54,5)
Anévrisme juxta rénal, n (%)	6
Anévrisme para rénal, n (%)	2
<del>Thoraco abdominal, n (%)</del>	
Endofuite type Ia sur EVAR, n (%)	21 (17,4)
Post dissection aortique	
Endofuite type Ia sur EVAR, n (%)	2
Vaisseaux cibles,	455
Vaisseaux cibles pathologiques, n (%)	
Diamètre <5mm, n (%)	
51 - 55 - 700% - (0%)	



# Données pré opératoires



455 fenêtres

<b>Type endoprothèse</b>	
Cuff fenêtrée, n (%)	2
Aorto bi iliaque, n (%)	9
Aorto mono iliaque, n (%)	1
<b>Type échancrure proximale</b>	
Standard, n (%)	1
Oversizing théorique moyen (%) +/- DS	16,2 +/- 3,4
Nombres fenêtres	3,8 +/- 0,7
<b>Oversizing théorique moyen (%) +/- DS</b>	
16	
<b>Nombres fenêtres</b>	
3	
1 fenêtre, n (%) *	
2 fenêtres, n (%)	
3 fenêtres, n (%)	
4 fenêtres, n (%)	
<b>Landing zone proximale</b>	
Supra rénal, n (%)	
Supra cœliaque, n (%)	114 (94,2)

# Données opératoires

	<b>FEVAR (N = 121)</b>
Durée opératoire (min), moyenne +/- DS	243 +/- 68
Dose (Gy.cm <sup>-2</sup> ), moyenne +/- DS	300 +/- 179
Temps de scopie (min), moyenne +/- DS	71 +/- 25
Contraste (ml), moyenne +/- DS	99 +/- 73
Accès fémoral percutané	107 (88,4)
Accès fémoral chirurgical	14 (11,6)
Accès axillaire	81 (66,9)
Percutané	58 (71,6)
Chirurgical	23 (28,4)
Procédures complémentaires	
Embolisations associées, n (%)	42 (34,7)
TEVAR ou Cuff proximale, n (%)	13 (10,7)



Succès technique : 97%

- Échec stenting TC (n=3)
- Thrombose stent rénal (n=)

## Scanner post opératoire

- N=121 (100%)

### Complications

- 3 FA (2,5%)
- 4 ischémies (3 MI et 1 MS) (3,3%)
- 2 complications hémorragiques (1,6%)
- 5 pancréatites aiguës (5,2%)

### Endofuites 1<sup>ères</sup>

- Aucune EF type Ia
- 7 EF type III (10%)

### Artères cibles

- 1 thrombose TC (<1%)
- 1 sténose AR (<1%)

## Scanner post opératoire

- N=121 (100%)

### Instabilité fenêtres (>5mm)

- 84 fenêtrés (69%)
- 61 patients (50%)
- AR dans 92% des cas
- 41% des AAA juxtaR

### Angle EDP (>10°)

- Non conforme (>10°) dans 49 cas (40%)
- 2 cas d'échec de stenting
- Pas plus d'EF type III (8,2% vs 9,7% p =

## Hospitalisation et complications

- Hospitalisation : 7 jours [5-10]
- USC : 1 jour

### Complications

- Ischémie médullaire : 4 patients dont 1 permanente (3,3% / 0,8%)
- Cardiovasculaires : 4 patients (3,3%)
- Sepsis : 3 patients (2,5%)

## Hospitalisation et complications

- Réinterventions précoces = 12 patients (9,9%)
  - 7 complications abords (5,8%)
  - 4 artères cibles (3,3%)
  - 1 laparotomie exploratrice (0,8%)
- Décès : 5 patients (4%)
  - 1 ischémie sus méso colique
  - 1 pneumopathie
  - 1 DMV
  - 2 ACR

## Suivi

- 69 patients (57%)
- Suivi médian : 23,4 mois [16,0 - 31,7]
- 307 scanners analysés
- Sous population = cohorte globale

Endoprothèse	$p = NS$
Anatomie AAA	$p = NS$
Démographie	$p = NS$



# Evolution du sac

## Rétraction du sac

1 an	2 ans	3 ans
21/69 (30%)	24/54 (44%)	24/36 (67%)

## Croissance du sac

1 an	2 ans	3 ans
3/69 (4%)	5/54 (9%)	4/36 (11%)

	Avec rétraction (n = 25)	S
Type d'anévrisme		
AAA juxta rénal, n (%)	15 (60,0)	
AAA para rénal, n (%)	7 (28,0)	
Thoraco abdominal, n (%)	2 (8,0)	
EF type Ia sur EVAR, n (%)	1 (4,0)	
Diamètre moyen AAA +/- DS	55,8 +/- 3,8	
Angle supra rénal moyen +/- DS	23,0 +/- 15,0	
Angle infra rénal moyen +/- DS	24,9 +/- 17,1	
Nombre fenêtres, n (%)	3,3 +/- 1,0	3,9 +/- 0,4
Taille endoprothèse moyenne +/- DS	31,8 +/- 2,1	
Oversizing théorique (%) +/- DS	16,9 +/- 4,3	
Nombre fenêtres, n (%)	3,3 +/- 1,0	
LZP supra rénal (<3F)	3 (12,0)	
LZP supra cœliaque (≥ 3F)	22 (88,0)	

Analyses en sous groupes

## Perméabilité

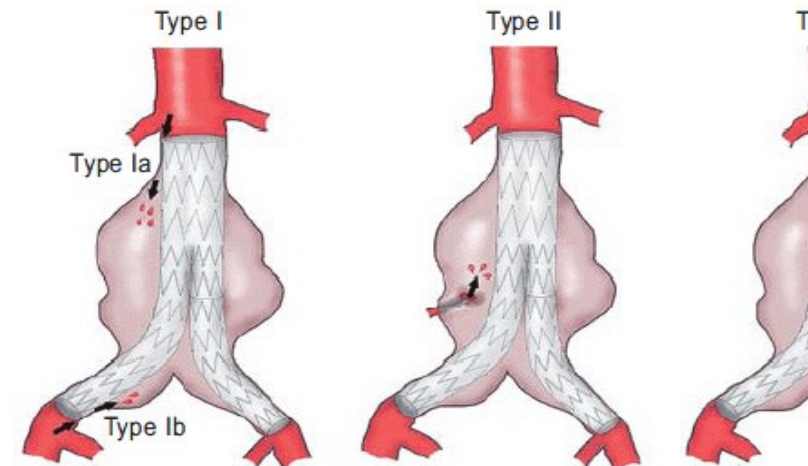
### Artères cibles (N = 253)

- 2 angioplasties/stenting (0,8%)
- 2 thromboses (0,8%)
- Perméabilité primaire : 98,4%
- Perméabilité primaire assistée/secondaire : 99,2%
- Aucune de ces 4 artères n'était pathologique



# Endofuites

- Endofuites type Ia :
    - 1 EF secondaire (1,4%)
- 18 mois  
AAA para rénal  
Collet proximal 33,2mm  
OS théorique 13%
- Endofuites type III :
    - 5/7 primaires spontanément résolutive (71%)
    - 7 secondaires : 6 bridging-stent (2,4%)  
1 déconnexion jambage (1,4%)

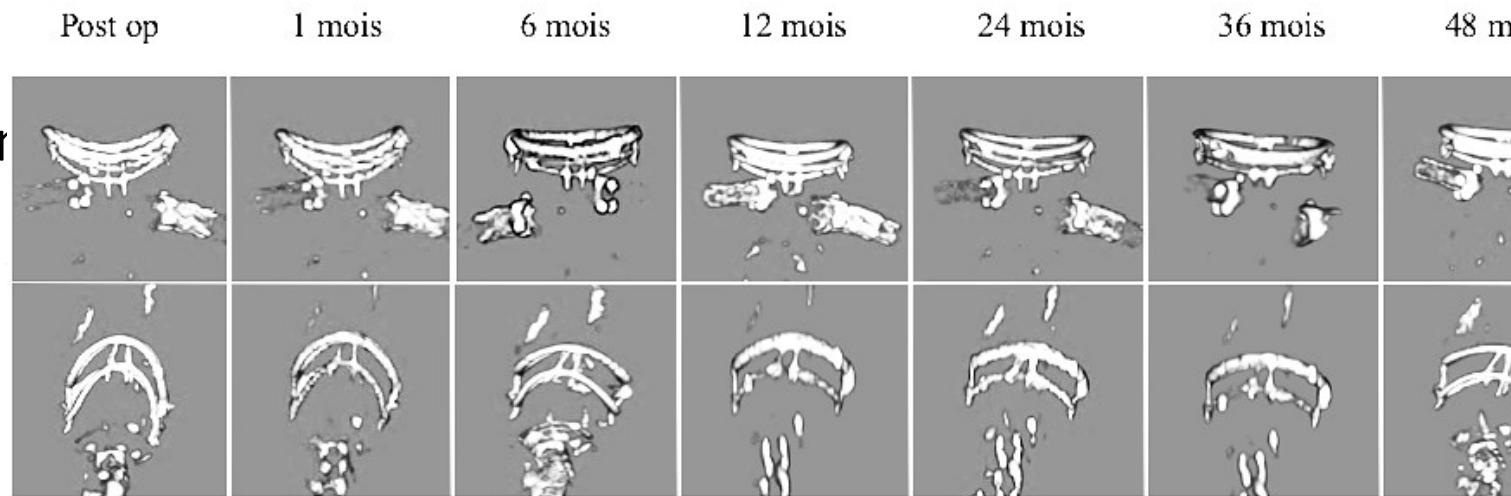


## Réinterventions

<b>Réinterventions mineures</b>	<b>15 (21,7)</b>
Embolisations (EF type II)	
Artères cibles	
Artères cibles	
EF type III	
Débord/Flairing insuffisant	
Relining complet	
Angioplasties	
<b>Réinterventions majeures</b>	
Collet proximal	3 (4,3)
<b>Réinterventions majeures</b>	
Aneurismorrhaphie	

## Evolution du collet proximal

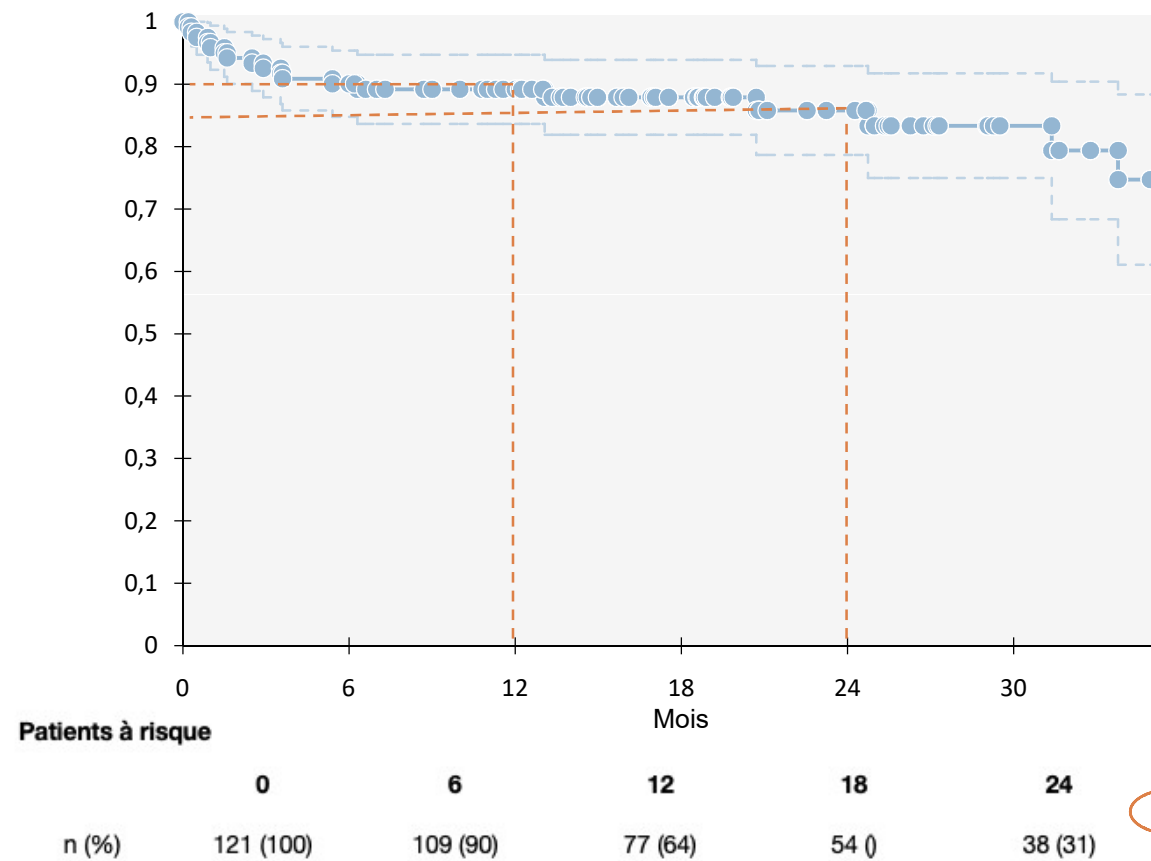
- Augmentation diamètre r
- Dilatation >3mm : 11 pat
- Première année +++



- Migration EDP : 3 patients (4%)
  - Associée : dilatation collet (33%), préparation collet (0%), angle non conforme (100%)
  - Sans répercussion (EF Ia, EF III et perméabilité art. cibles)

# Survie

- 5 décès au cours du suivi (7%)
- Aucun décès en lien avéré avec l'anévrisme
- Mortalité globale 17%



*Estimation de la survie par Kaplan Meier*

- DISCUSSION -

- DISCUSSION -

Littérature

3,8 f/p

Auteurs	Journal Année	Nb.	SN / JR	PR	AAFA	Art. cibles	Nb. F/P	ST %	EF Ia*	Mortalité 30 jrs %	Suivi mois	Survie %
De Niel et al.	JVS 2020	335	289	27	19	920	2,7	88	6,9	4,2	15	30
→ Piny et al.	EJVES 2020	127	77	37	13	342	2,7	88	3,9	3,9	21	18
Colgan et al.	AVS 2018	101	26	-	--	311	3,1	86	9,9	3,0	12	9
→ Falkensammer et al.	JVS 2017	94	-	-	8	-	-	84	-	5,3	10	11,7
Blankensteijn et al.	JVS 2017	60	60	-	-	140	2,3		11,7	3,3	16	7
Shahverdyan et al.	EJVES 2016	48	36	11	1	129	2,7	94		4	24	-
Kotelis et al.	JET 2016	39	23	12	4	106	2,7	95	-	13	33	23

## Littérature

- Taux succès technique satisfaisant : 94%

*Succès technique FEVAR après EVAR : 58,3% vs 87,8%  
P = 0.02<sup>4</sup>*

Auteurs	Journal Année	Nb.	SN / JR	PR	AATA
De Niel et al.	JVS 2020	335	289	27	19
Piny et al.	EJVES 2020	127	77	37	13
Colgan et al.	AVS 2018	101	26	-	--
Falkensammer et al.	JVS 2017	94	-	-	8
Blankensteijn et al.	JVS 2017	60	60	-	-
Shahverdyan et al.	EJVES 2016	48	36	11	1
Kotelis et al.	JET 2016	39	23	12	4

## Littérature

- Taux succès technique satisfaisant : 94%
- Pas d'EF de type I primaire
- Réinterventions précoces : 10%
- Mortalité intra hospitalière : 4%

Auteurs	Journal Année	Nb.	SN / JR	PiTA	Articles	Nb. F/I
De Niel et al.	JVS 2020	335	289	2'9	920	2,7
Piny et al.	EJVES 2020	127	77	3'3	342	2,7
Colgan et al.	AVS 2018	101	26	--	311	3,1
Falkensammer et al.	JVS 2017	94	-	-8	-	-
Blankensteijn et al.	JVS 2017	60	60	-	140	2,3
Shahverdyan et al.	EJVES 2016	48	36	11	129	2,7
Wang et al.	JET	20	20	14	100	2,7

## Littérature

- Rétraction du sac : 67% à 3 ans
  - Analyse en sous-groupes : 3,3 vs 3,9 f/p ( $p = 0.01$ )

➔ EF type III infra radiologique ?

- Taux d'EF type I : 1,4%
  - Diamètre collet proximal > moyenne
  - OS théorique < moyenne

*Midy et al : 70% de rétraction à 2ans <sup>5</sup>  
Amiot et al : 75% de rétraction à 3ans <sup>6</sup>*

*Supériorité FEVAR ≥ 3F en terme  
d'EF Ia ( $p = 0,01$ ) <sup>7,8</sup>*

*EF type Ia :  
1 à 5% selon les études <sup>5,9,10</sup>*

## Littérature

- Taux de réinterventions élevé : 30%
  - Nombre moyen de f/p élevé
  - Prise en charge agressive

*Taux de réinterventions proportionnel au nombre de fenêtrés. <sup>11,12</sup>*

- EF de type III :
  - Primaires : spontanément résolutive (71%)
  - Secondaires : réinterventions nécessaires (83%)

Auteurs	Journal	Nb.	SN / PR	EF	Mortalité	Suivi
De Niel et al.						
Piny et al.						
Colgan et al.	JVS 2018	101	26	-	9,9	3,0
Falkensammer et al.	JVS 2017	94	-	-	-	5,3
Blankenbiller et al.	JVS					

*Kärkkäinen et al <sup>13</sup> :  
Résolution spontanée 79% des EF 1<sup>aire</sup>  
réintervention 72% des EF 2<sup>aire</sup>*

## Littérature

- Taux de réinterventions élevé : 30%
  - Nombre moyen de f/p élevé
  - Prise en charge agressive
- Perméabilité artères cibles : 99%
- Survie à 1an concordante

Auteurs	Journal Année	Nb.	SN / JR	PR	EF Ia*	Mortalité 30 jrs %	Suivi mois
De Niel et al.	JVS 2020	335	289	27	6,9	4,2	15
Piny et al.	EJVES 2020	127	77	37	3,9	3,9	21
Colgan et al.	AVS 2018	101	26	-	9,9	3,0	12
Falkensamm er et al.	JVS 2017	94	-	-	-	5,3	10
Blankensteijn et al.	JVS 2017	60	60	-	11,7	3,3	16
Shahverdyan et al.	EJVES 2016	48	36	11		4	24

## Littérature : Stabilité des fenêtres

*Squizzato et al : Instabilité fenêtrées  
si > 5mm = augmentation  
évènements art. cibles  
 $p = 0.033$ <sup>14</sup>*

- Fenêtre à risque d'instabilité : 50%
- Pas de différence en terme :
  - EF type III
  - Perméabilité
  - Réintervention

➡ Absence de branche sans répercussion ?

Nécessité évaluation  
à plus long terme

## Littérature : Evolution du collet

*Koenrades et al : dilatation collet proximal jusqu'au diamètre nominal de l'ANP <24mois. <sup>15</sup>*

*de Niet : Dilatation collet proximal de 10% après FEVAR Zenith Cook >12mois. <sup>16</sup>*

- Dilatation du collet : 11 patients (16%)
  - Pas d'EF type I
  - 1 cas de migration
  - Première année +++

➔ Expansion ANP sans évolution pathologie aortique

Nécessité d'une  
étude dédiée

*Koenrades MA, Klein A, Leferink AM, Slump CH, Geelkerken RH. Evolution of the Proximal Sealing Rings of the Anaconda Stent-Graft After Endovascular Aneurysm Repair. J Endovasc Ther. 2019;25(4):480-491.*

*de Niet A, Donselaar EJ, Holewijn S, Tielliu IFJ, Lardenoije JWHP, Zeebregts CJ, Reijnen MMPJ. Endograft Conformability in Fenestrated Endovascular Aneurysm Repair for Complex Abdominal Aneurysms. J Endovasc Ther. 2020 Oct;27(5):848-856.*

## Littérature : Précaution déploiement

- Angle de déploiement de l'endoprothèse :
  - Risque échec de cathétérisme art. cibles
  - Risque de migration (OS réel < OS théorique)

*Pas de donnée  
dans la littérature*

➔ Impact du repositionnement per opératoire ?

Intérêt d'une  
étude dédiée ?

## Limites de l'étude

- Etude rétrospective
- Manque de puissance (N=69)
- Mesures scanner : simple opérateur
- Analyses en sous-groupes



Pour conclure :

Faisabilité et Sécurité de la technique



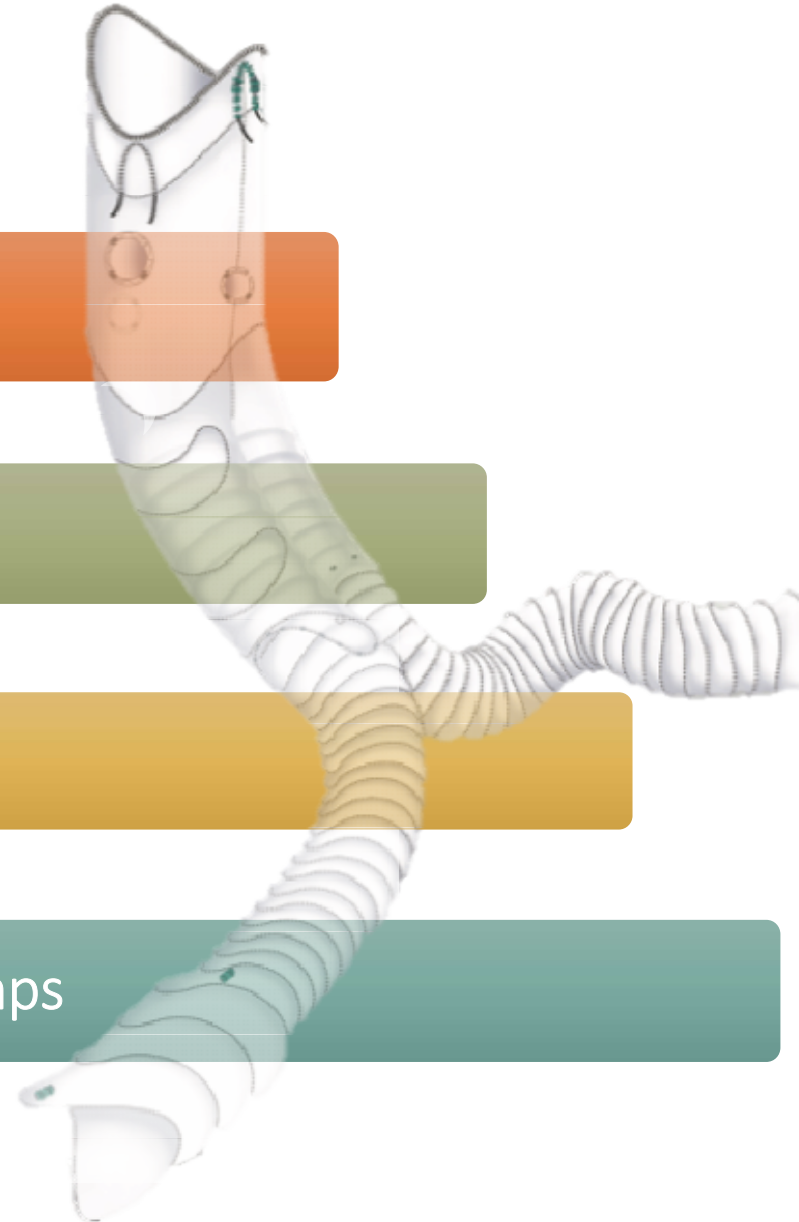
Efficacité de l'exclusion



Stabilité des bridging-stents



Faible taux d'EF type I au cours du temps



# Références :

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6. de Niet A, Donselaar EJ, Holewijn S, Tielliu IFJ, Lardenoije JWHP, Zeebregts CJ, Reijnen MMPJ. Endograft Conformability in Fenestrated Endovascular Aneurysm Repair for Complex Abdominal Aortic Aneurysms. *J Endovasc Ther.* 2020 Oct;27(5):848-856.

Merci pour votre attention.

# Addressing thoracoabdominal morphology with artificial landing zones

Antoine MILLON  
Hospices Civils de Lyon



# Disclosures

- Terumo Aortic
- Gore
- Medtronic

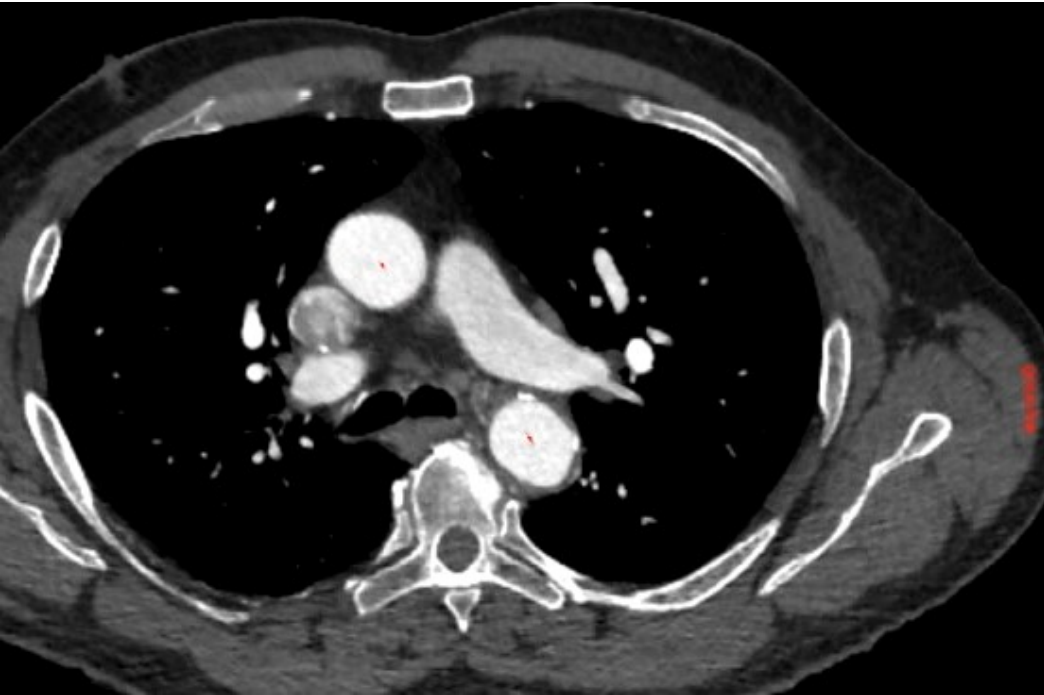
# Juxta-Renal Aortic Aneurysm

- 4fen CMD the most used endovascular strategy
- Required healthy supraceliac landing zone for durable seal
  - Length 20-30 mm
  - Diameter < 32 mm
  - No thrombus
  - No diffuse calcification
  - No severe angulation

# UPRACELIAC PROX LANDING ZONE

Irregular  
Thrombus +++

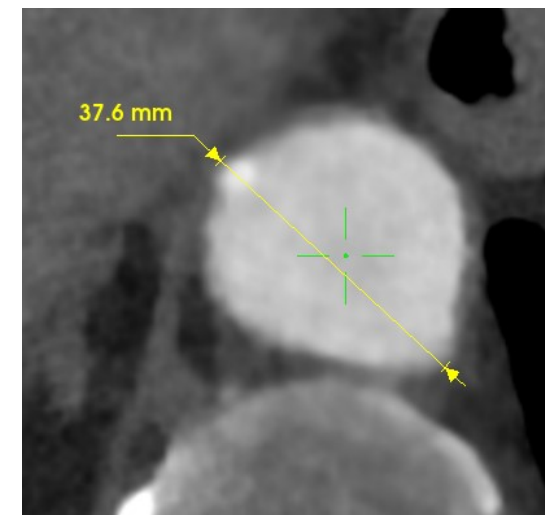
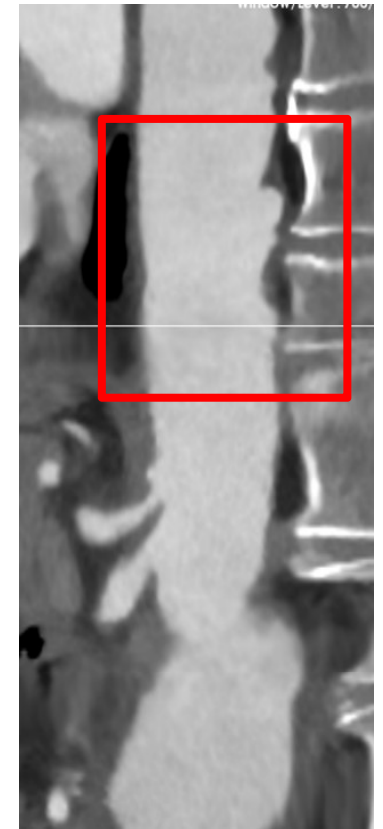
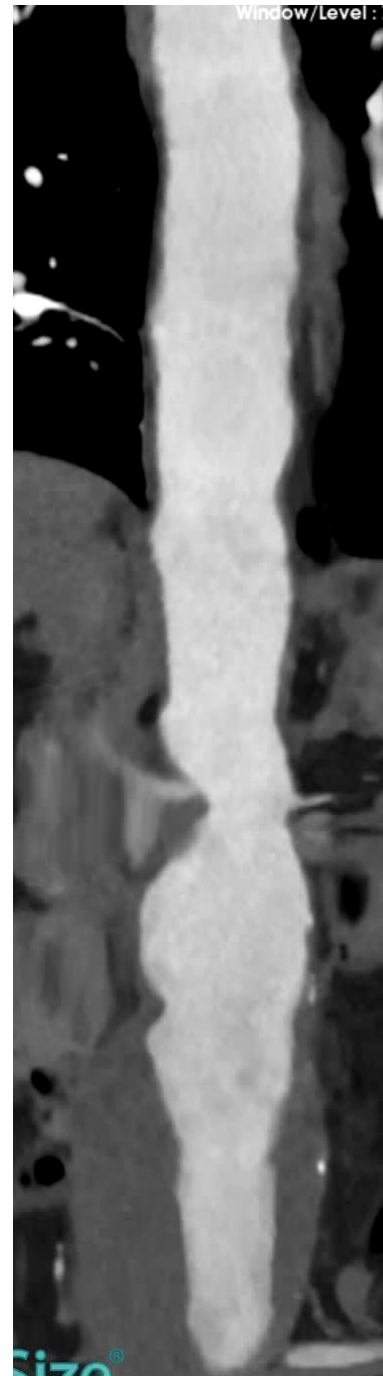
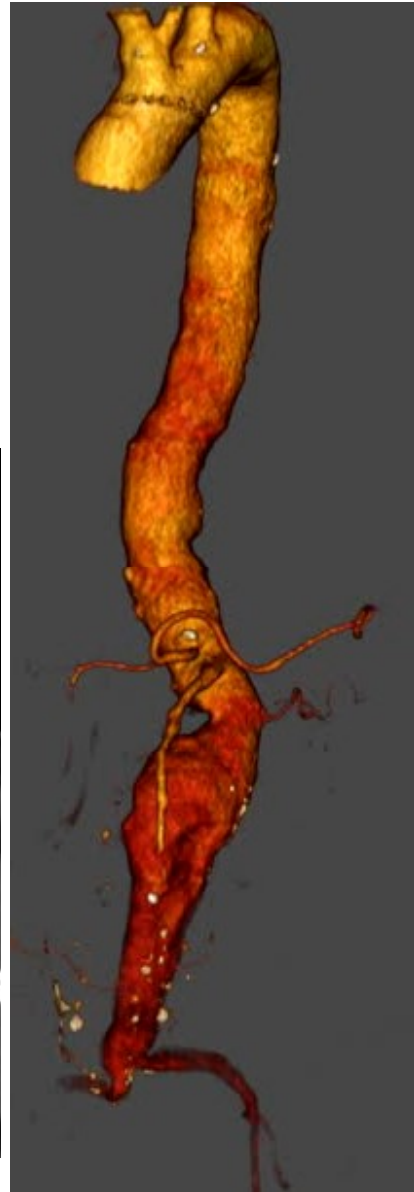
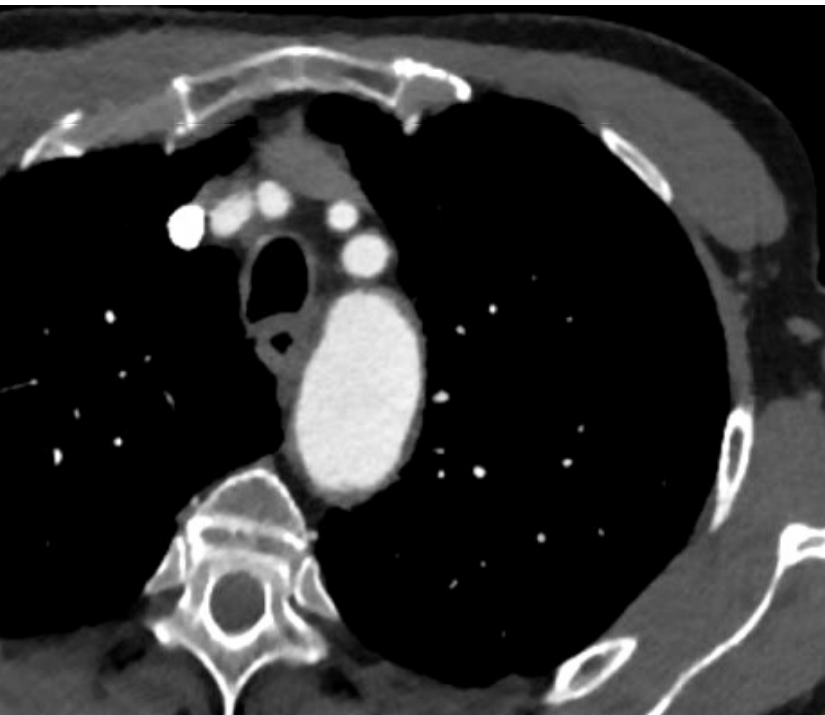
Efficient and durable sealing zone ?  
How far should we go proximally ?



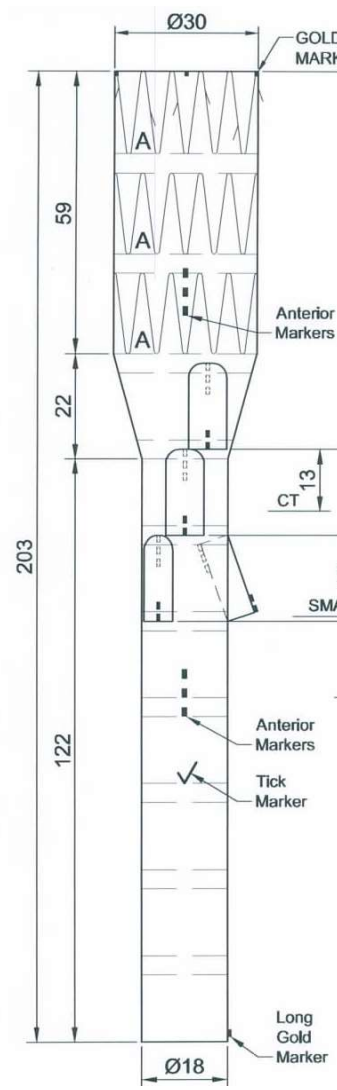
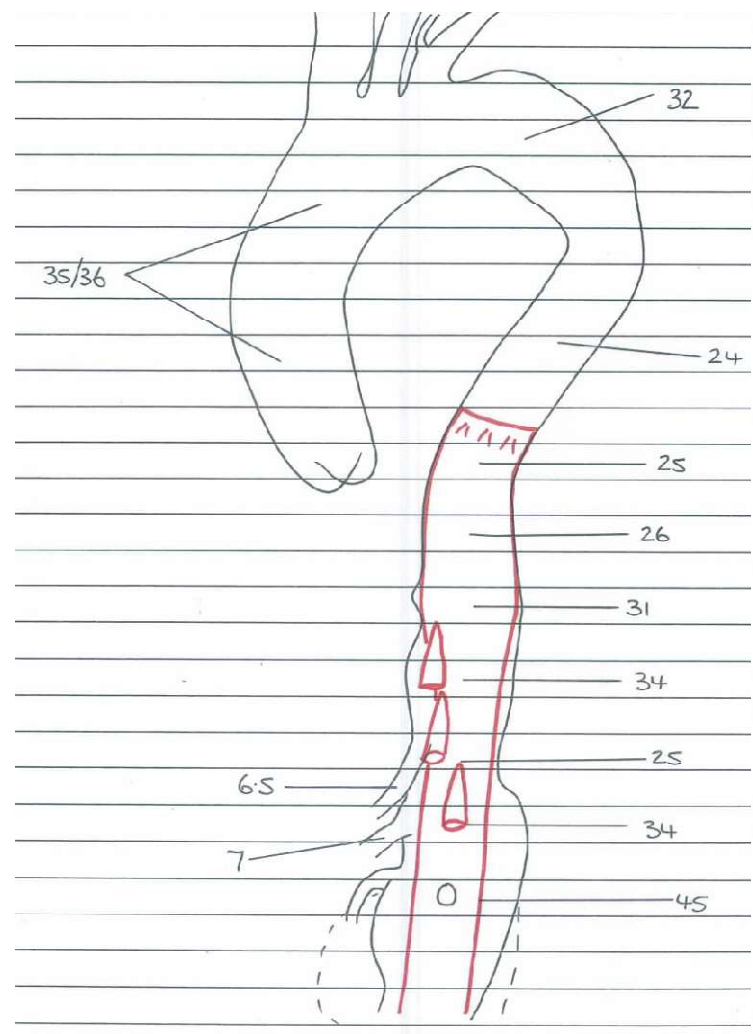
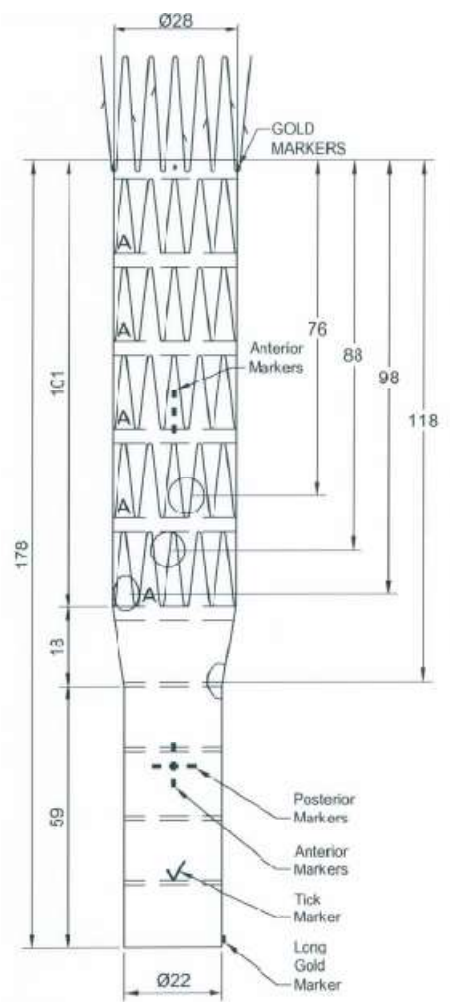
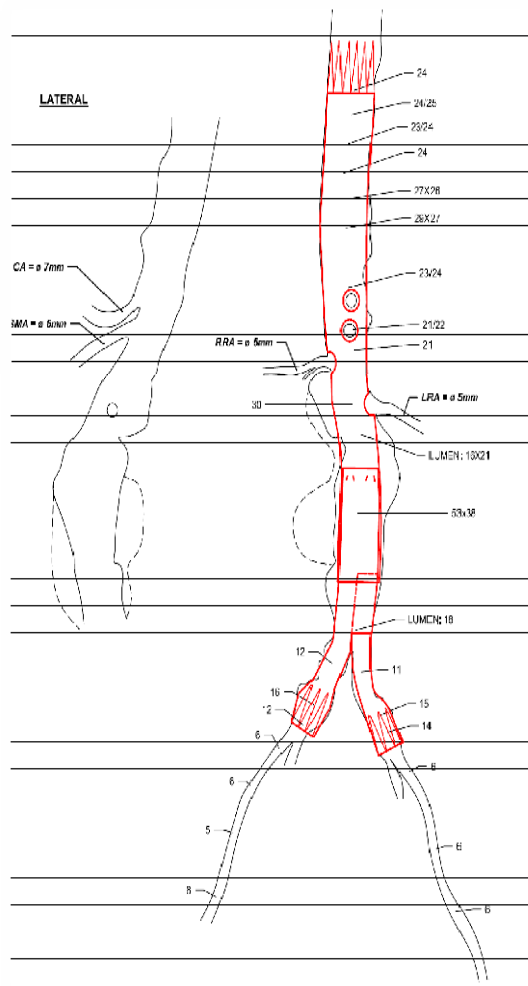
# UPRACELIAC PROX LANDING ZONE

Large D>35mm  
Thrombus

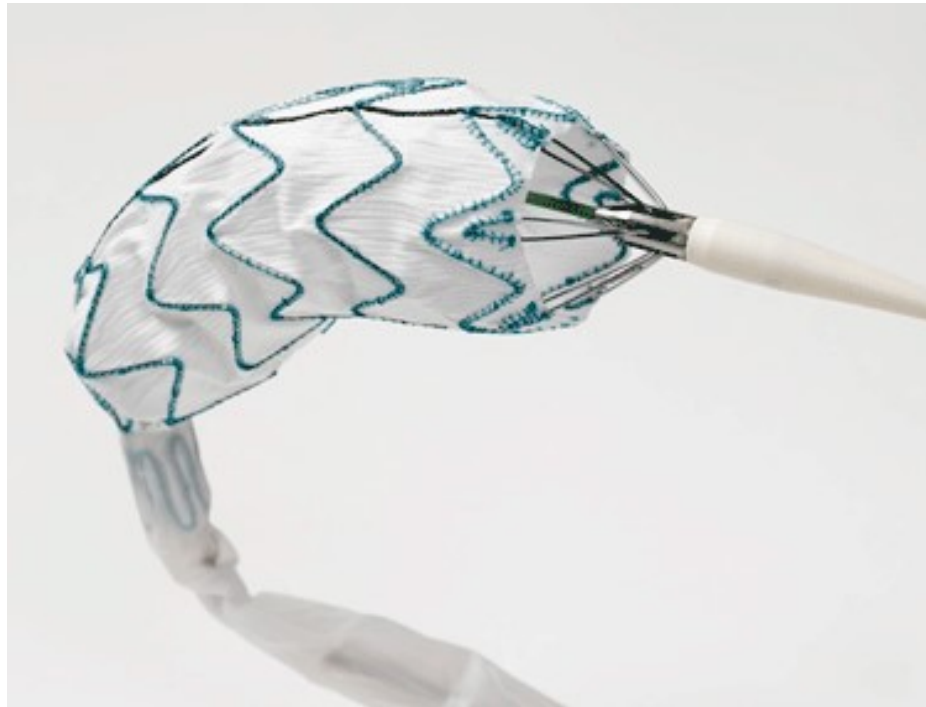
Efficient and durable sealing zone ?  
How far should we go proximally ?



# COOK Custom Made Devices



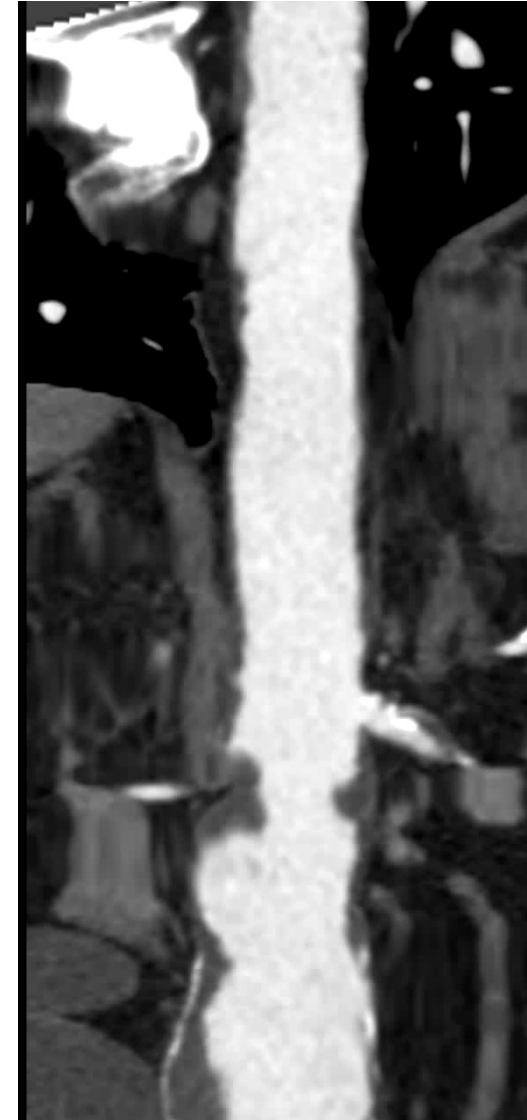
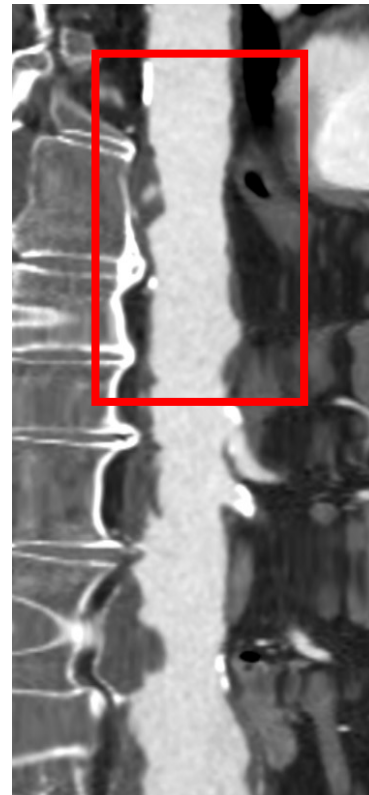
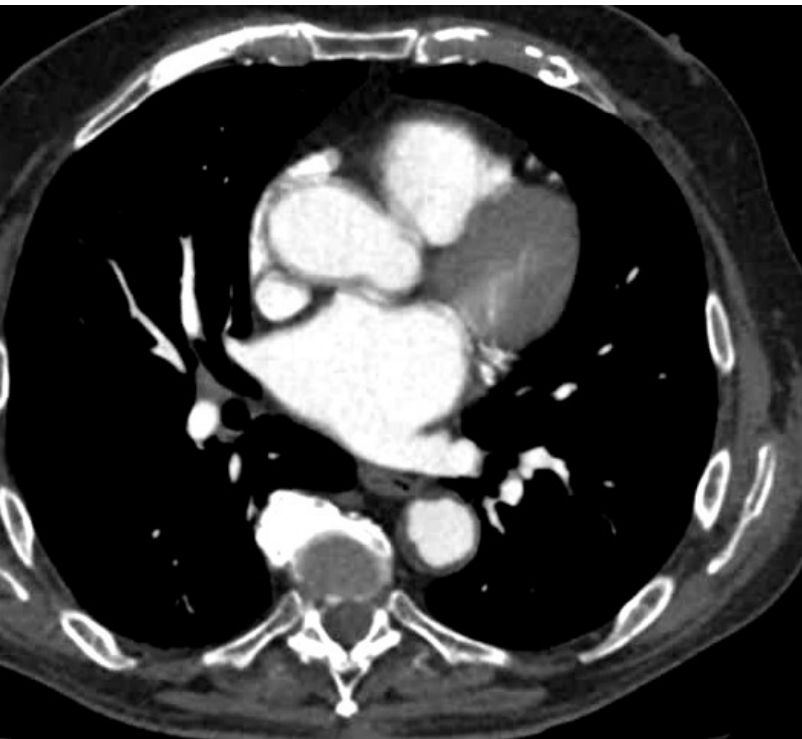
# TERUMO AORTIC Custom Made Devices



# How to create a proximal landing zone for the Fenestrated Anaconda?

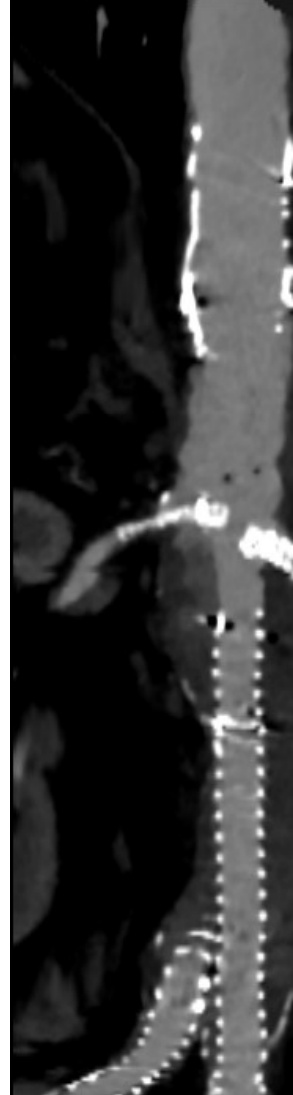
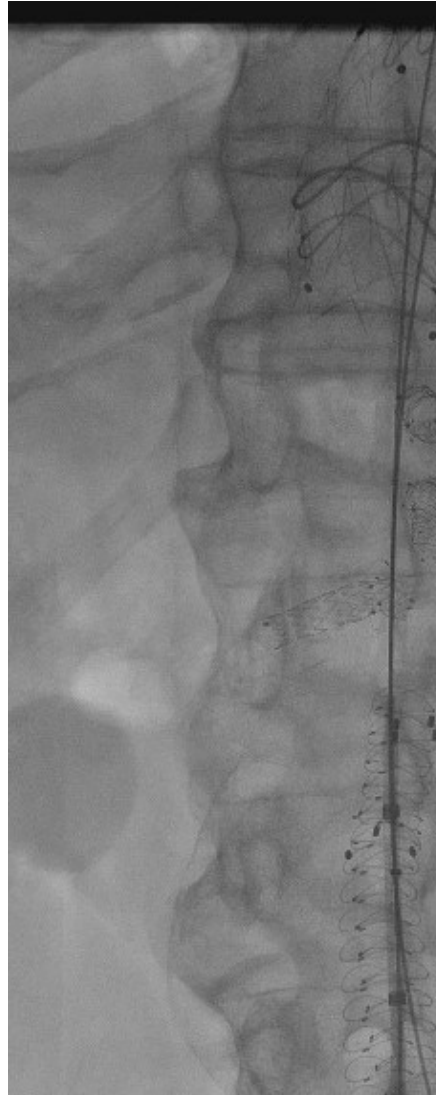
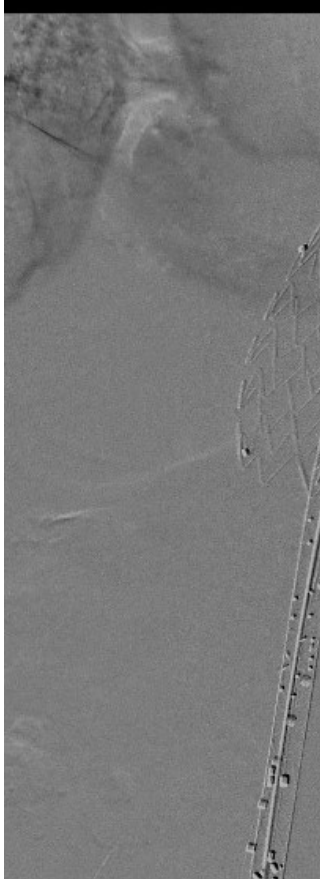
## **SUPRACELIAC PROX LANDING ZONE**

Irregular  
Thrombus +++  
Diameter < 32 mm



# How to create a proximal landing zone for the Fenestrated Anaconda?

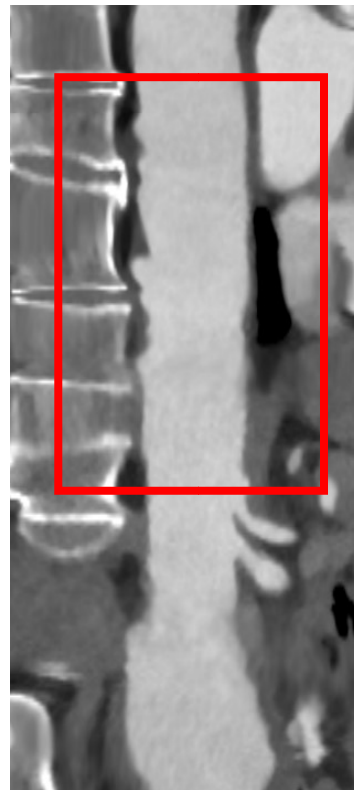
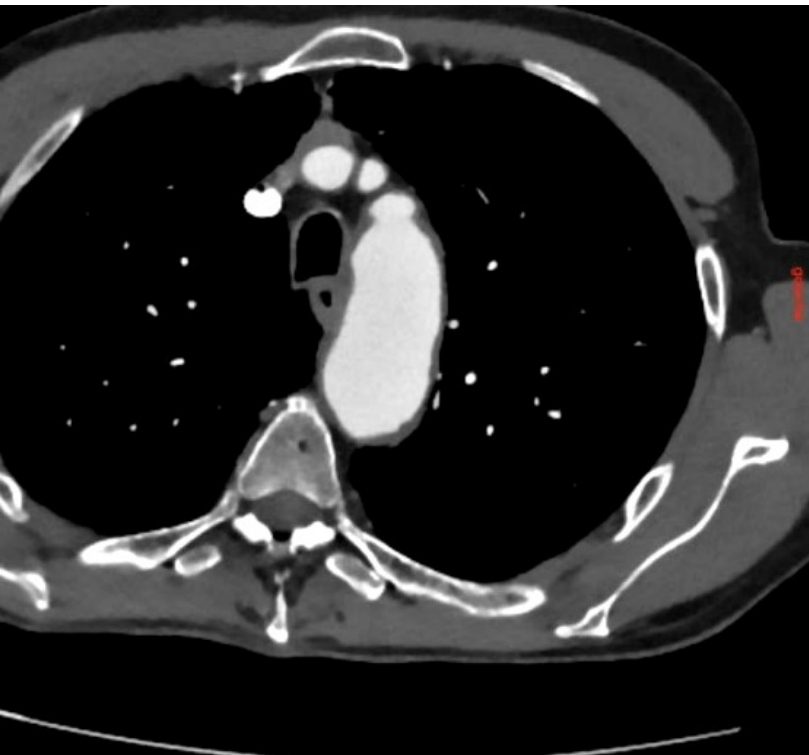
## Electronic Aortic Extension



# How to create a proximal landing zone for the Fenestrated Anaconda?

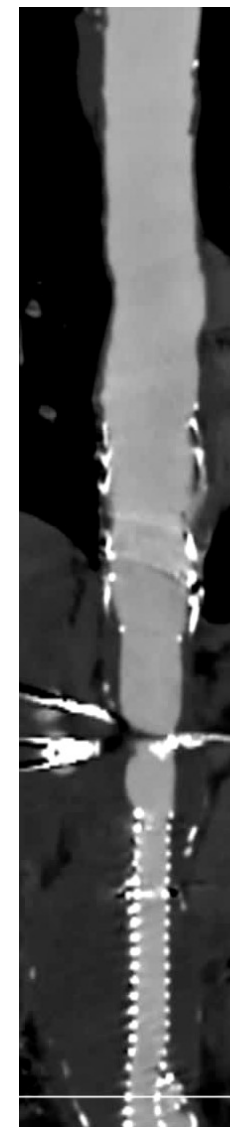
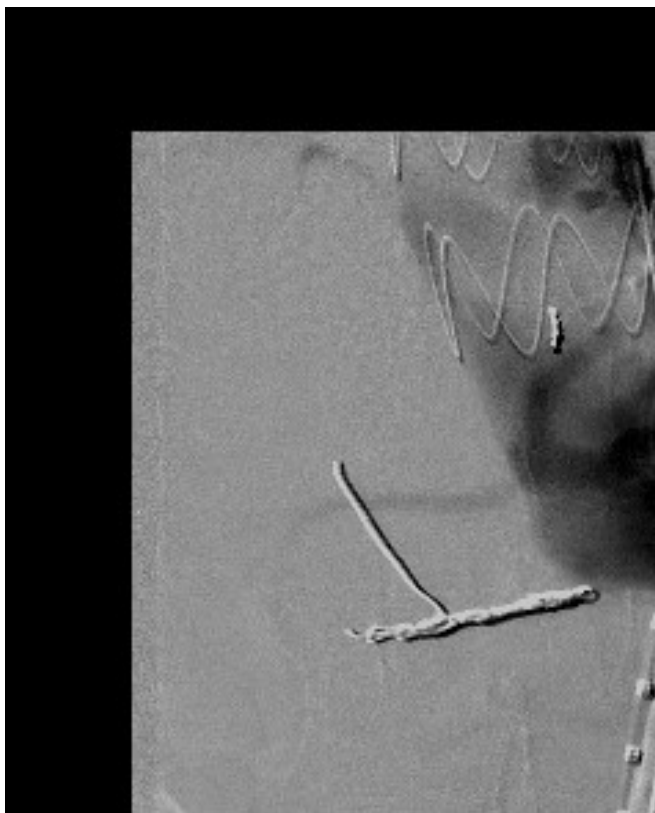
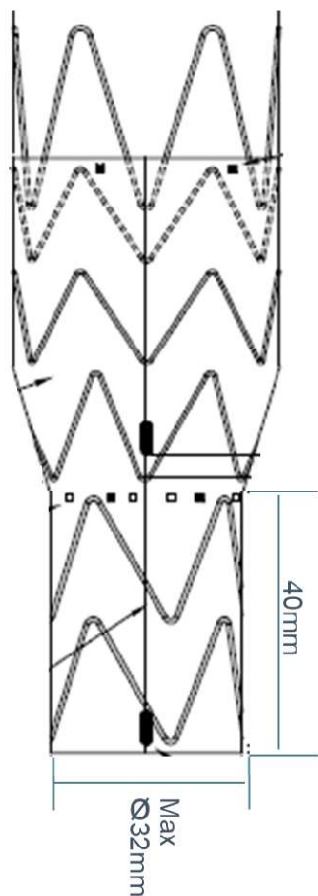
## **SUPRACELIAC PROX LANDING ZONE**

Irregular  
Thrombus +++  
Diameter > 32 mm



# How to create a proximal landing zone for the Fenestrated Anaconda?

## D Tapered Bolton Relay

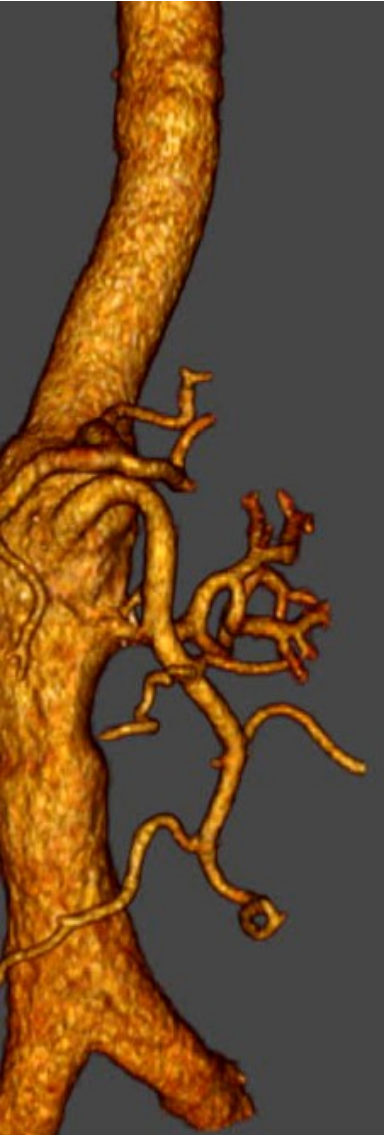


# Thoraco-Abdominal Aortic Aneurysm

- 4 Branch or 2Br/2Fen CMD the most used endovascular strategy
- Patency of the renal branch ?
- Endoleak at the fenestration ?



# How to address TAA with Fenestrated Anaconda?



## Para-renal AAA



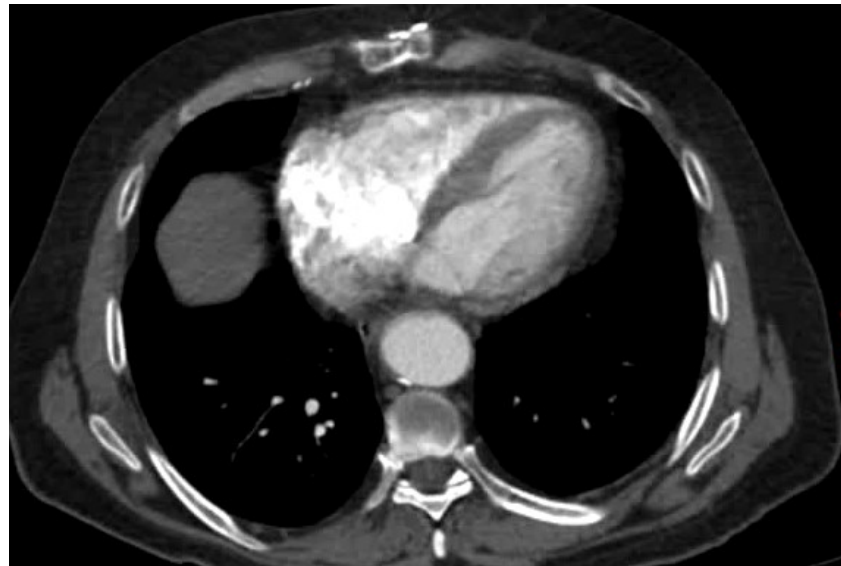
MEDTRONIC AORTIC EXTENSION  
4 FEN ANACONDA  
GORE IBE X2



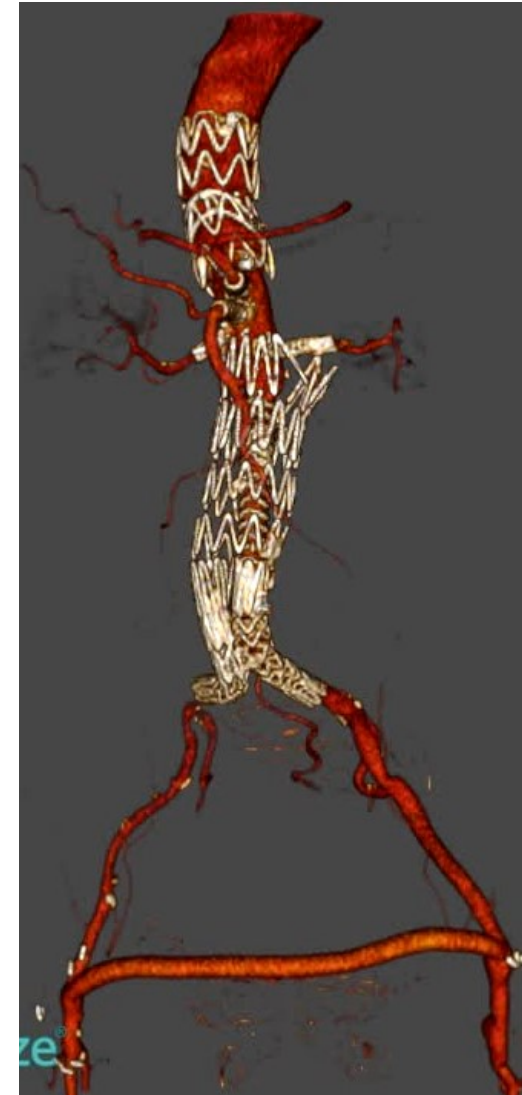
# How to address TAA with Fenestrated Anaconda?



**Para-renal AAA**  
Previous EVAR



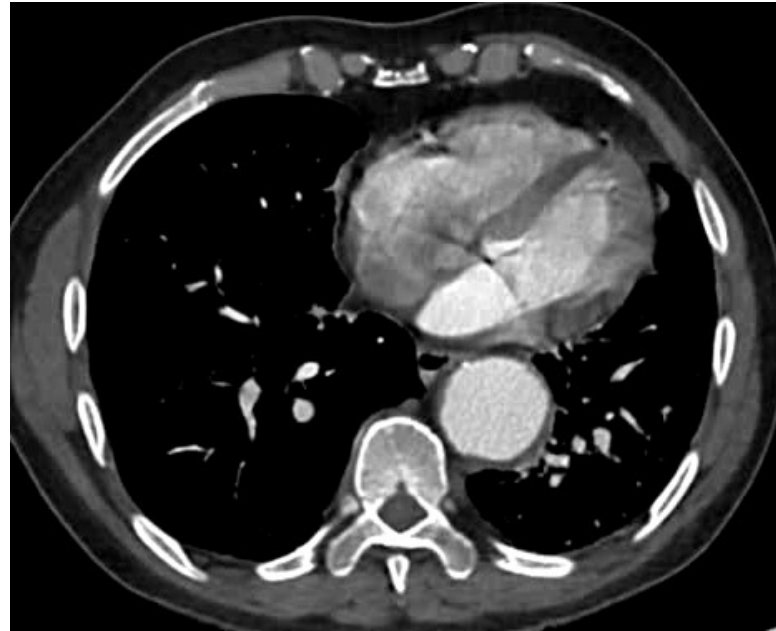
CMD Tapered RELAY  
4 FEN ANACONDA  
Aortouniliac SG



# How to address TAA with Fenestrated Anaconda?

## Type IV TAAA

Solitary kidney



CMD Tapered RELAY  
3 FEN ANACONDA  
1 FEN LIMB



# How to address TAA with Fenestrated Anaconda?

## Type 2 TAAA

Previous Frozen Elephant trunk



RELAY  
CT occlusion  
3 FEN ANACONDA



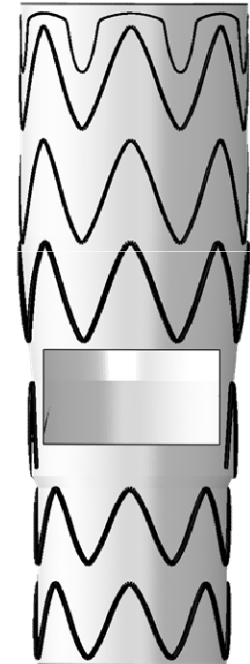
# How to address TAA with Fenestrated Anaconda?



## Type 3 TAAA

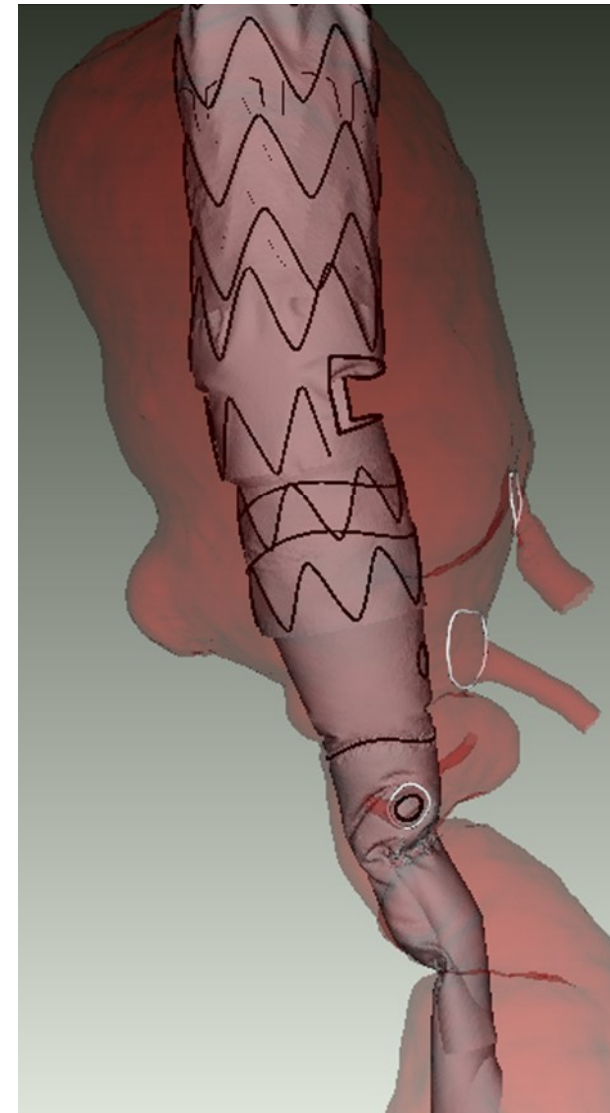
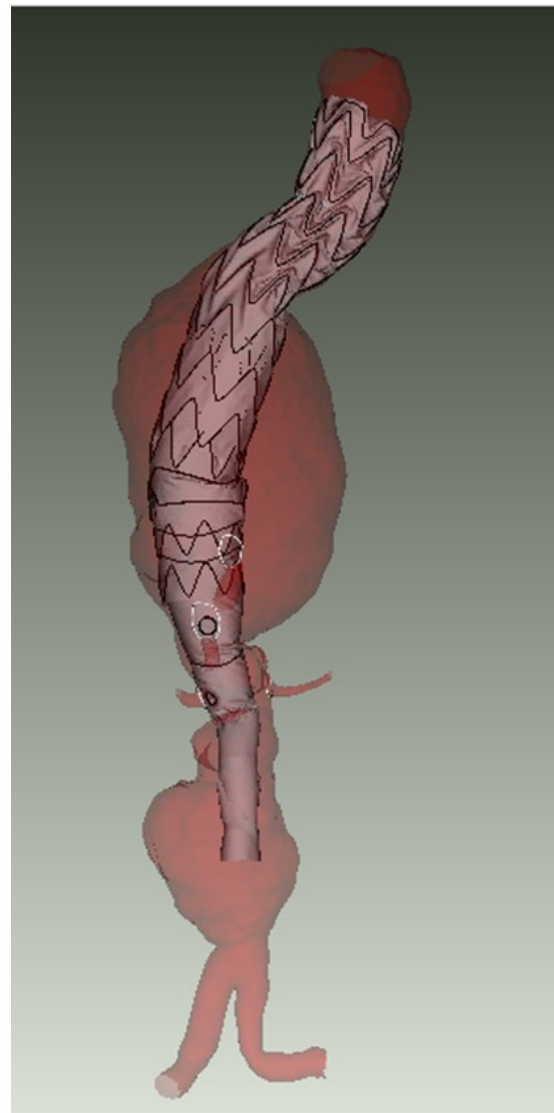
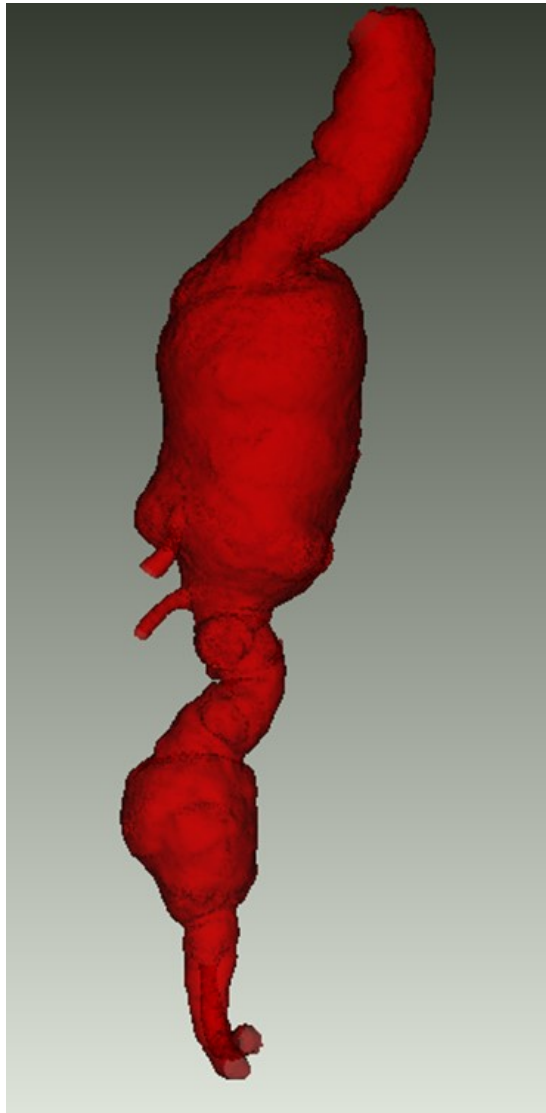


RELAY  
CMD RELAY 1 Branch for th CT  
3 Fen Anaconda

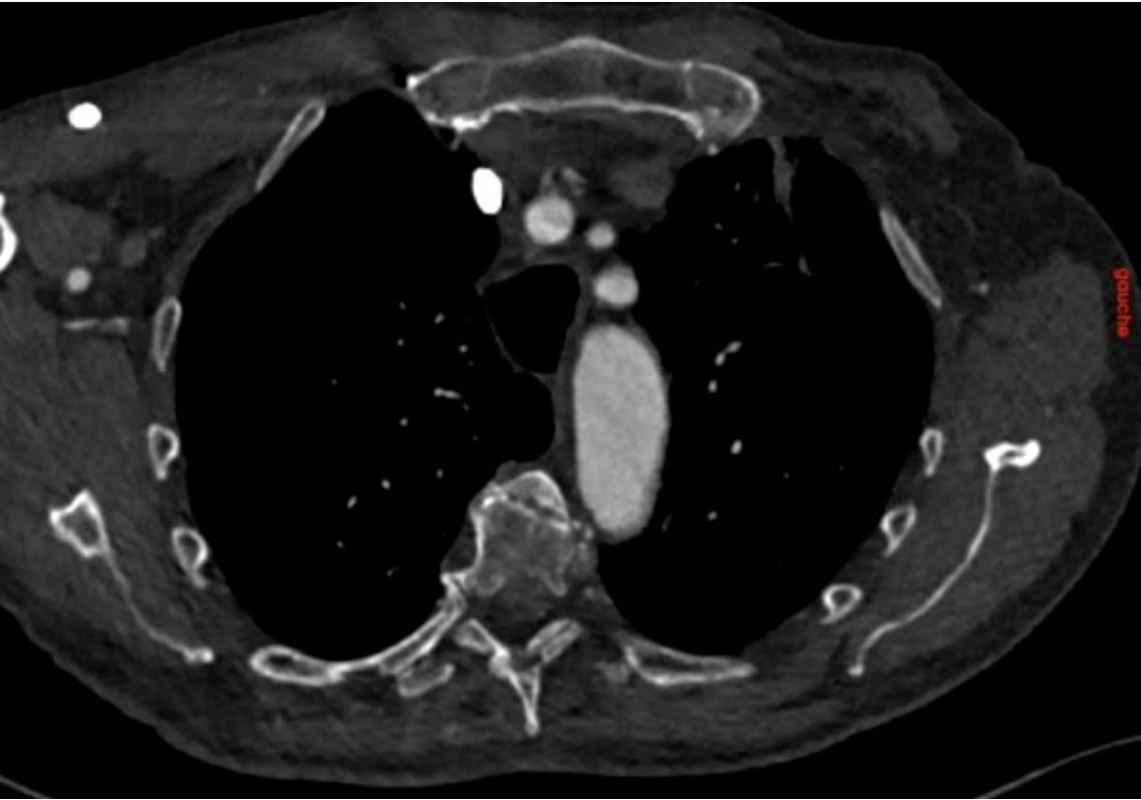


*Courtesy Prof A Duprey / Prof JN Alberti*

# Numerical Simulation

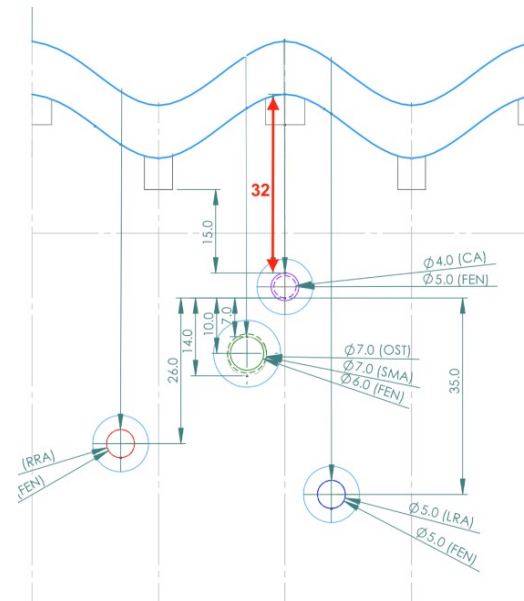


2 years postop CT



# FENESTRATED ANACONDA IN TAAA

- Required artificial landing zone
  - Aortic Extension
  - CMD Tapered RELAY
  - Standard TEVAR
- Overlap > 30 mm
- Preclinical Results of Pull-out Testing have shown good stability

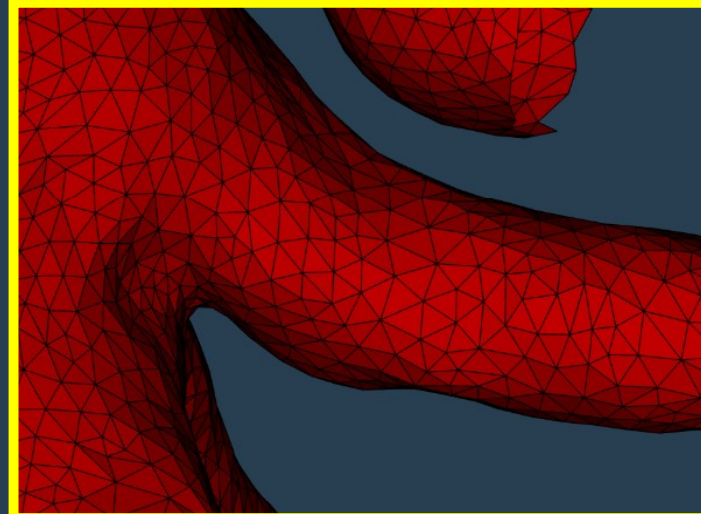
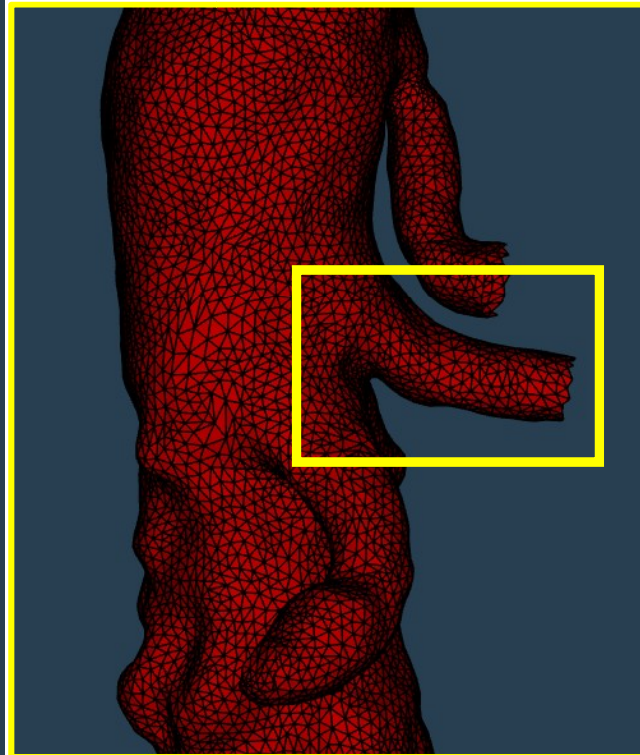
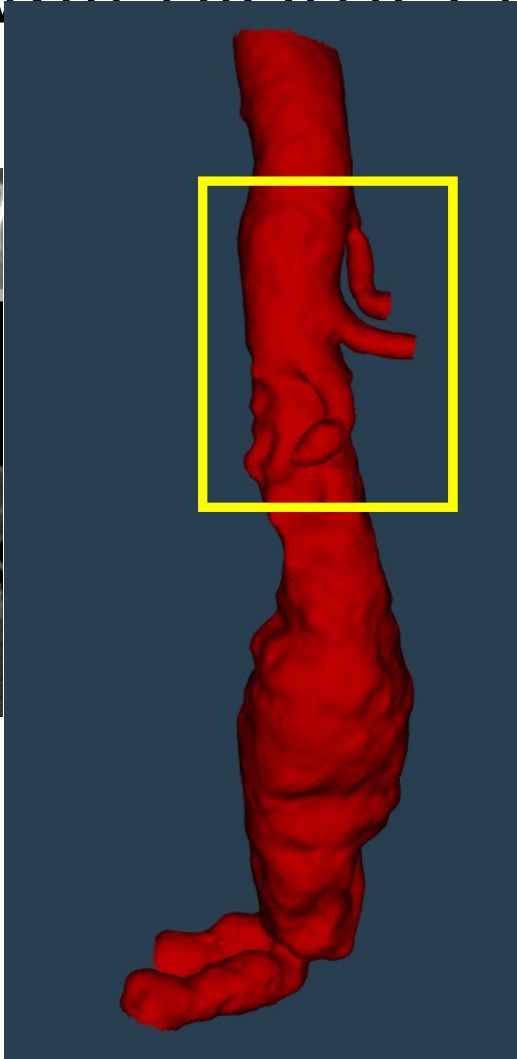
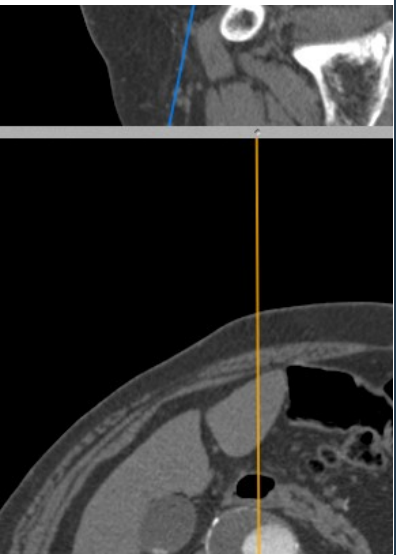


**Assessment of Pull-out Forces in TEVAR and ANACONDA FEVAR Combination and Early Clinical Results: Creation of a Proximal Landing Zone for FEVAR in Patients with Extent I and Extent IV TAAAs**

Jürgen Falkensammer,<sup>1,2</sup> Fadi Taher,<sup>1</sup> Markus Plimon,<sup>1</sup> Miriam Kliewer,<sup>1</sup> Corinna W. Elisabeth Pelanek,<sup>1</sup> and Afshin Assadian,<sup>1</sup> Vienna, Austria

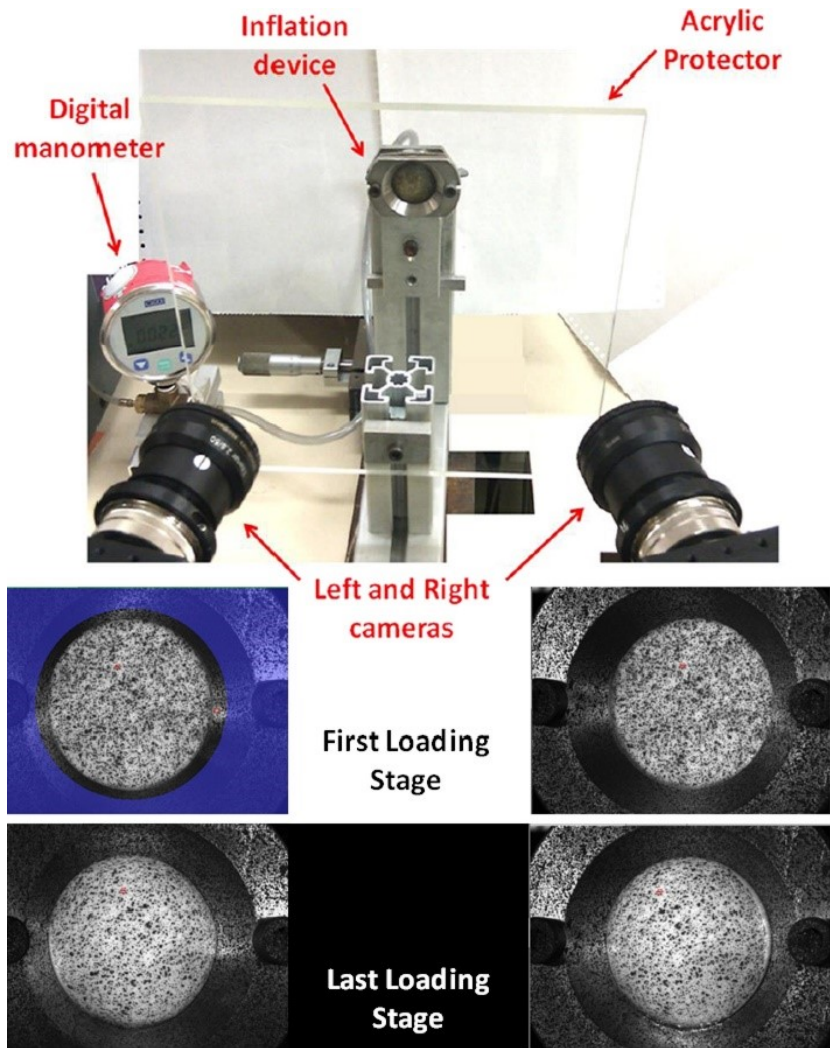
# Patient-specific aortic aneurysm models

## Aortic wall biomechanical properties



# Artic wall biomechanical properties

## Sample of experimental protocol



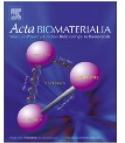
Acta Biomaterialia 42 (2016) 273–285



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Full length article

### Biaxial rupture properties of ascending thoracic aortic aneurysms



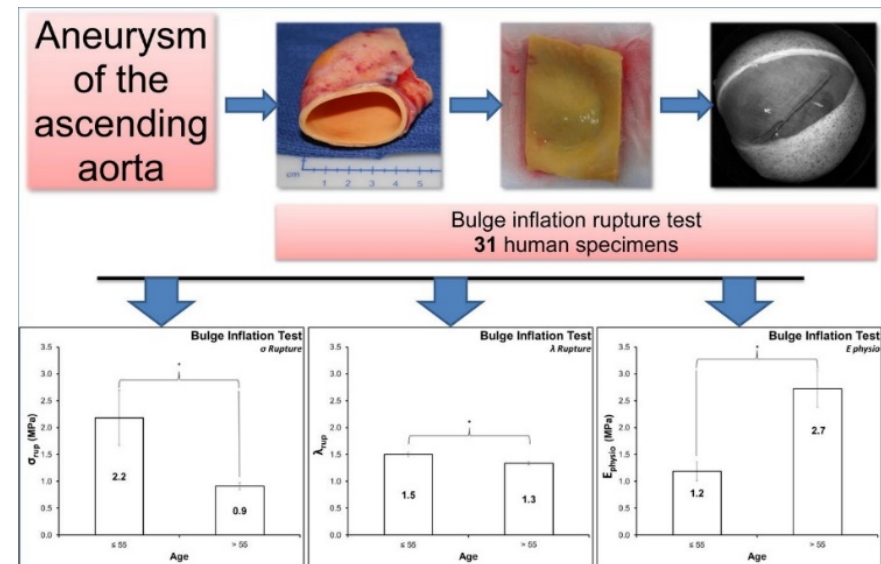
Ambroise Duprey<sup>a,b,c,d,\*</sup>, Olfa Trabelsi<sup>a,b,c</sup>, Marco Vola<sup>d</sup>, Jean-Pierre Favre<sup>b,c,d</sup>, Stéphane Avril<sup>a,b,c</sup>

<sup>a</sup> Ecole Nationale Supérieure des Mines de Saint-Etienne, CIS-EMSE, SAINBIOSE, F-42023 Saint Etienne, France

<sup>b</sup> INSERM, U1059, F-42000 Saint Etienne, France

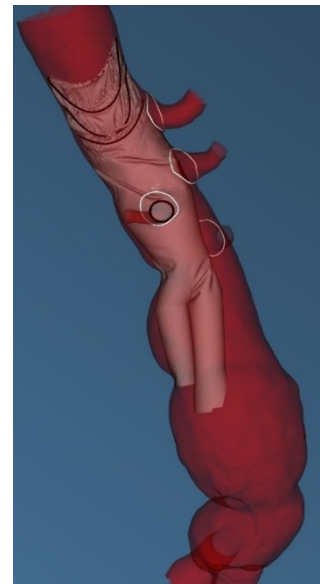
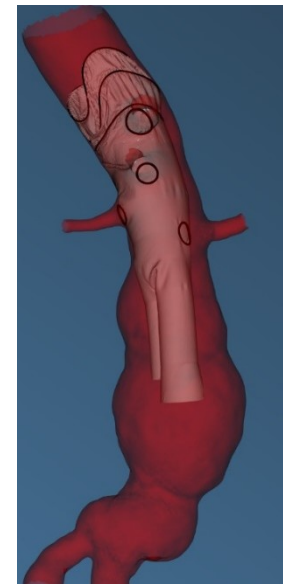
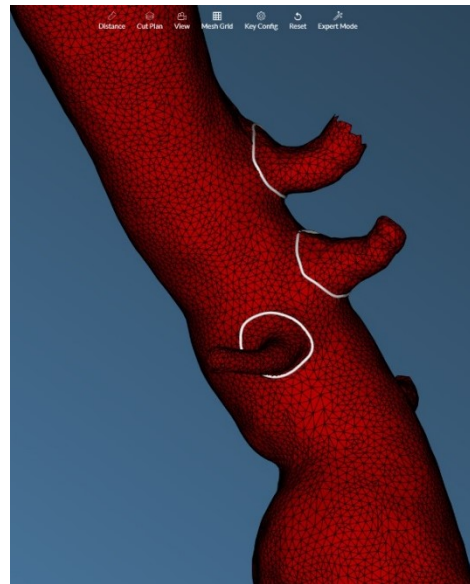
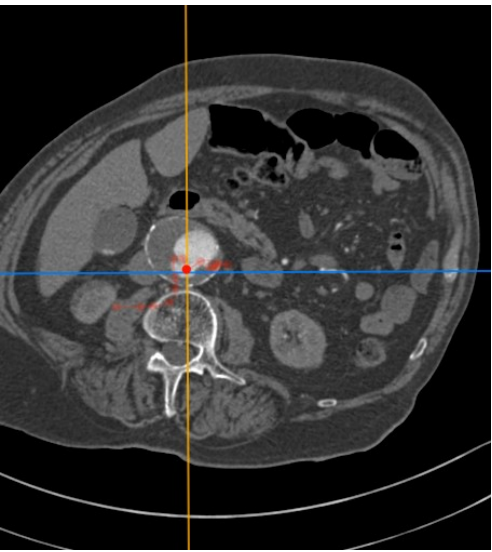
<sup>c</sup> Université de Lyon, SAINBIOSE, F-42000 Saint Etienne, France

<sup>d</sup> University Hospital of Saint-Etienne, Department of Cardiovascular Surgery, F-42055 Saint-Etienne cedex 2, France

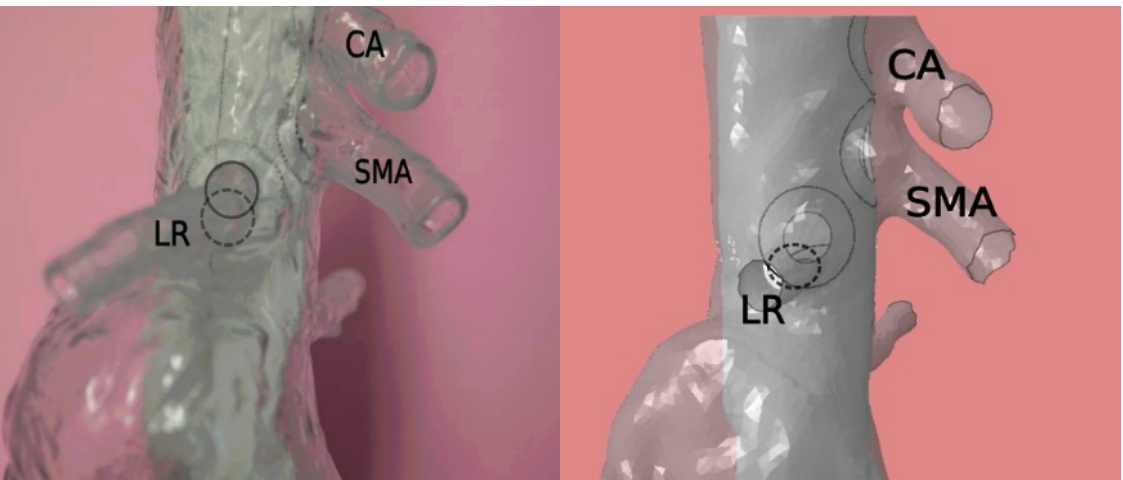


# Simulation Technology

- Finite-element analysis technique (used for decades in car & plane industry)
- Provides patient-specific computational modelling of device implantation
- Deployment simulation is used to validate custom-made device designs

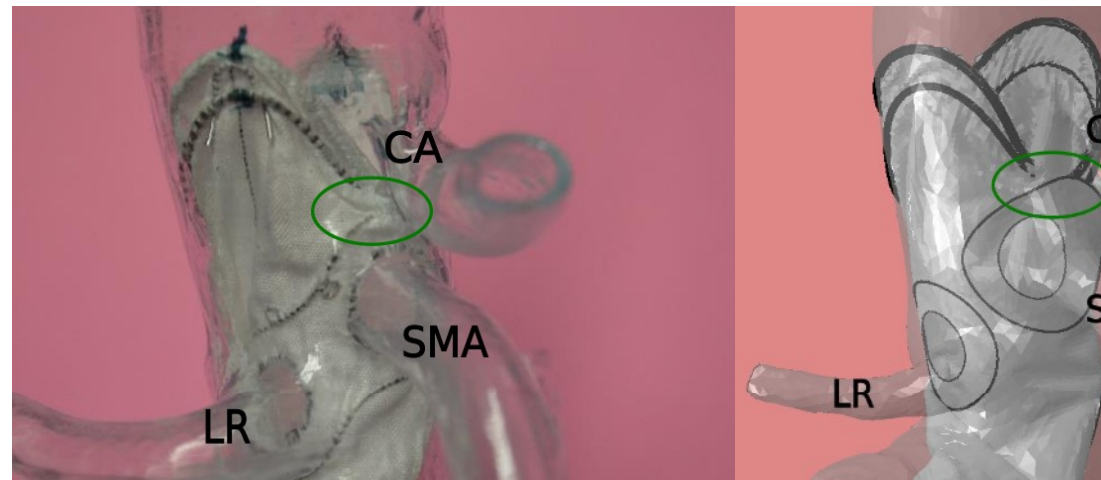


# Fenestrated Anaconda: validation of fenestrations positions numerical simulation vs in-vitro test (Fensim 1 study)



Real aorta model & prototype

Numerical simulation



Real aorta model & prototype

Numerical simulation

**50 patients, 176 fenestrations**

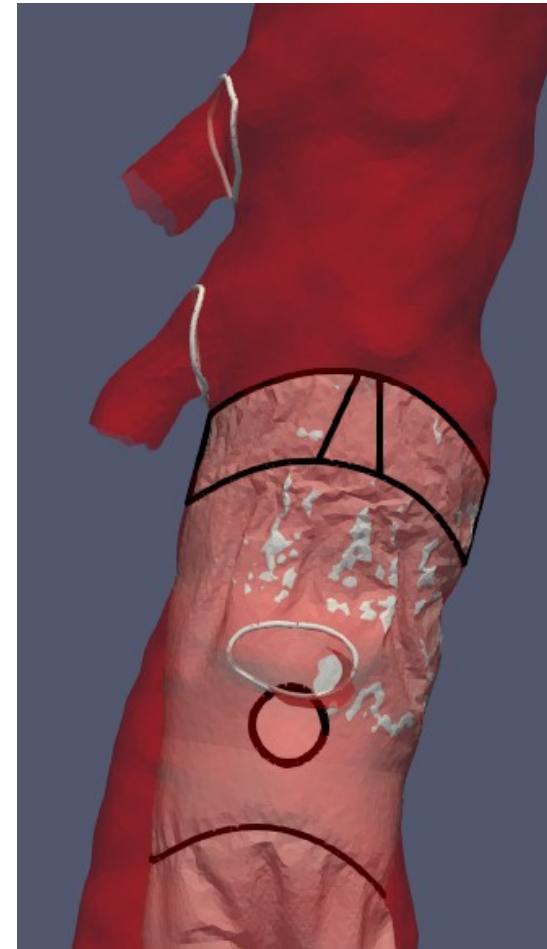
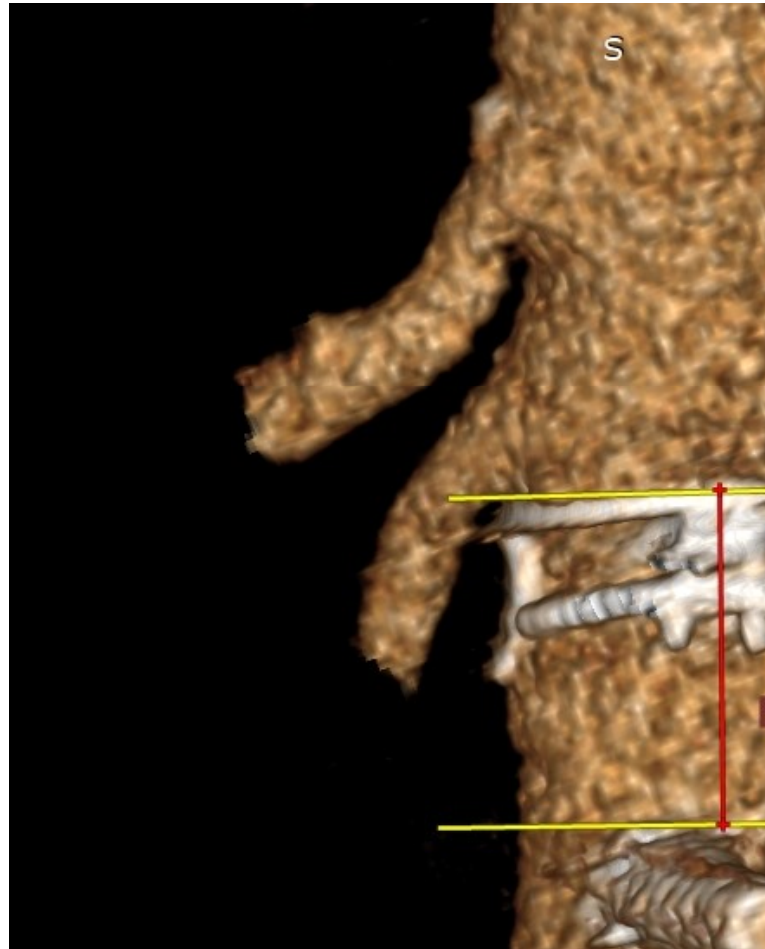
Fenestration position $\leq$	Longitudinal	Circumferential
2 mm	91 %	95 %
<b>2,5 mm</b>	<b>98 %</b>	<b>99 %</b>
3 mm	99 %	99 %

Assessment of fenestrated Anaconda stent graft design by numerical simulation: Results of a European prospective multicenter study

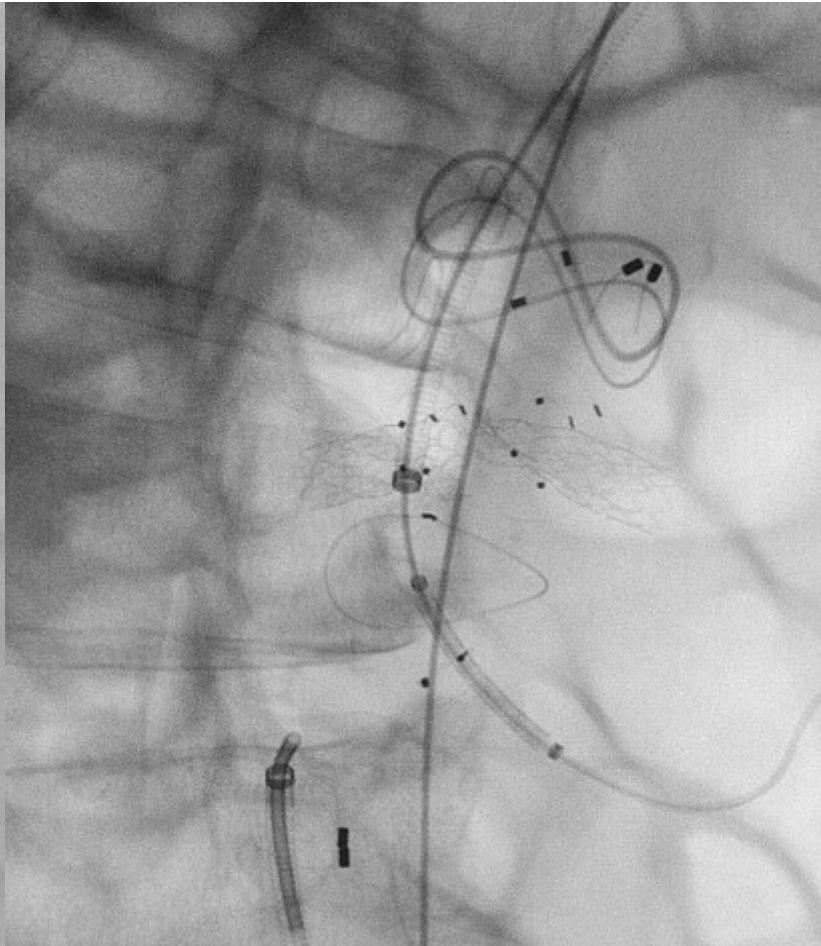
Miriam E. Kliewer, MD,<sup>a</sup> Marine Bordet, MD,<sup>b</sup> Bertrand Chavent, MD,<sup>c</sup> Michel M. P. J. Reijnen, MD,<sup>d</sup> Nicolas Frisch, MD,<sup>f</sup> Dominique Midy, MD,<sup>g</sup> Patrick Feugier, MD,<sup>h</sup> Antoine Millon, MD,<sup>b</sup> Jan-Willem Lardenoije, MD,<sup>d</sup> Afshin Assadian, PD, MD,<sup>a</sup> Jürgen Falkensammer, PD, MD,<sup>a</sup> Christian Müller, MD,<sup>f</sup> Jean-Pierre Favre, MD,<sup>c</sup> Sabrina Ben-Ahmed, PD, MD,<sup>c</sup> and Jean-Noël A. ...  
Vienna, Austria; Lyon, Saint-Etienne and Pierre-Bénite, France; Arnhem, and Enschede, The Netherlands; Bordeaux

**Kliewer et al, J Vasc Surg 2021(A)**

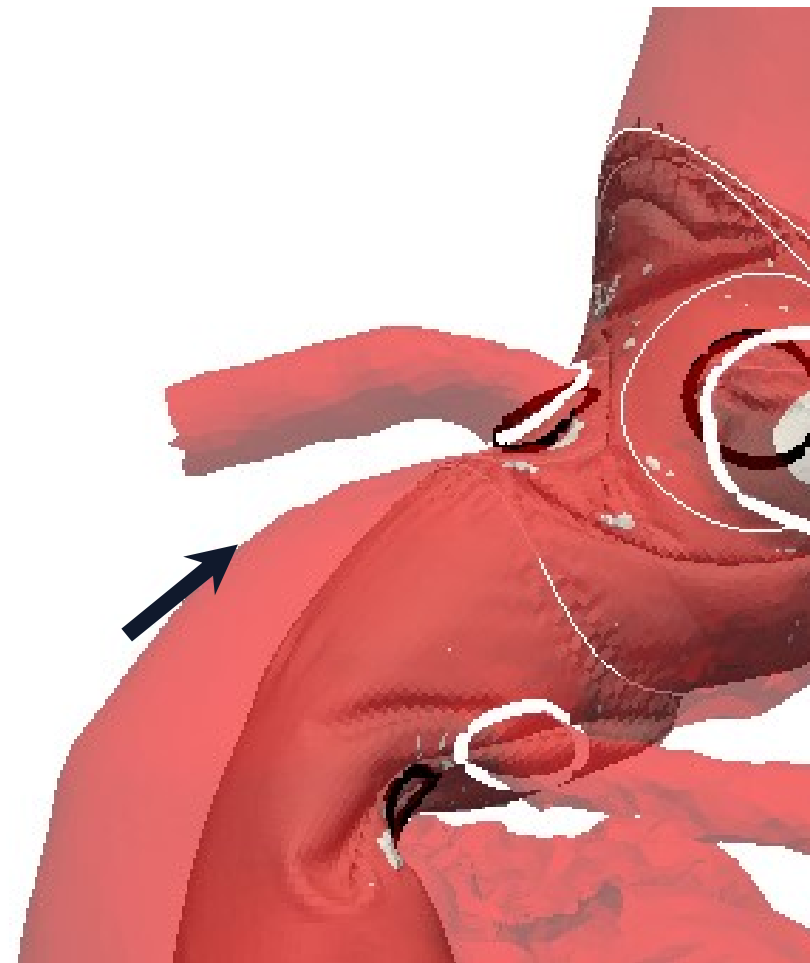
# Validation of simulated proximal stents shape vs in vitro test and post-op CT-scan



# Suboptimal fenestration position Example 1

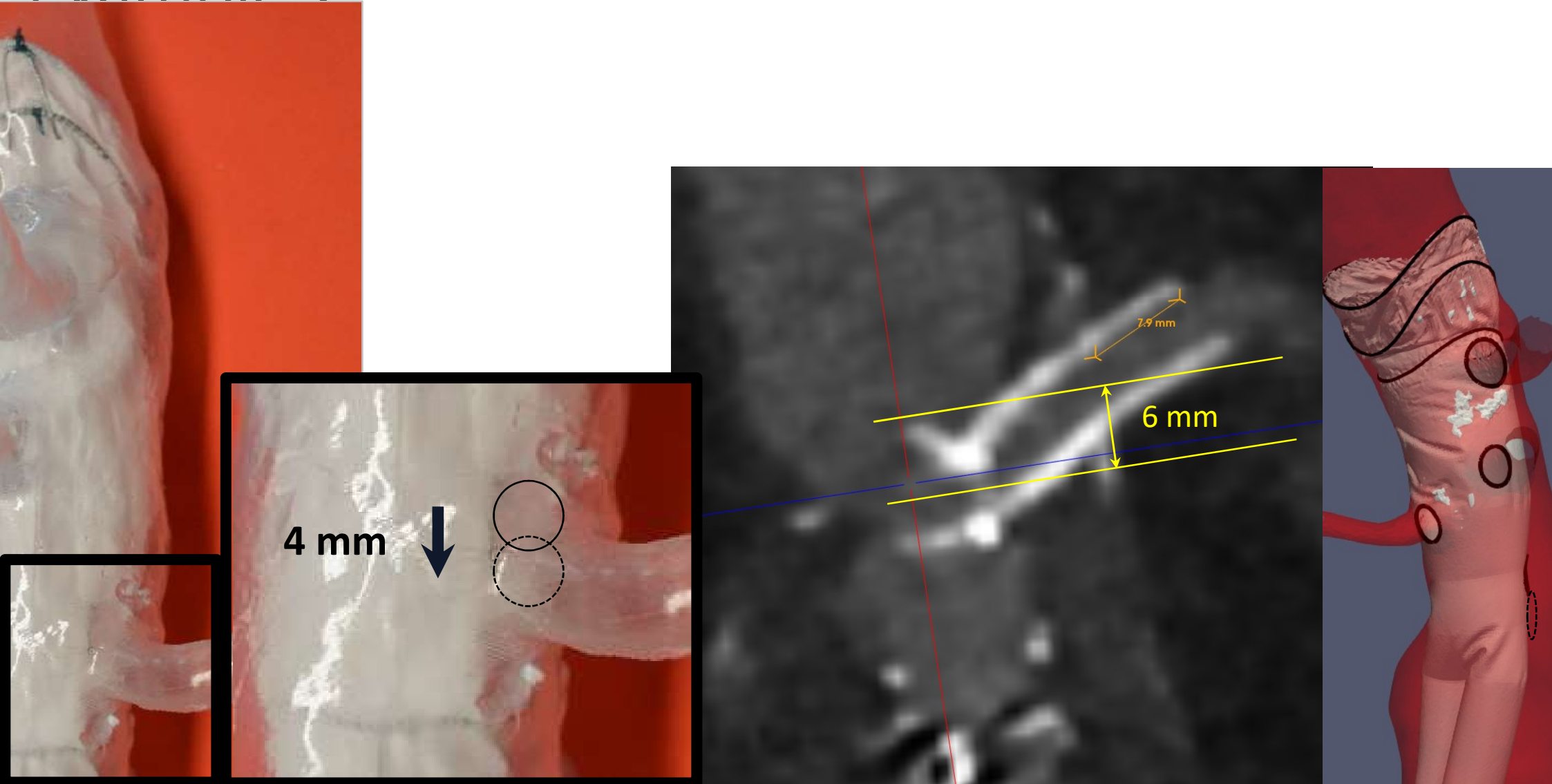


Numerical simulation provides more accurate fenestration position



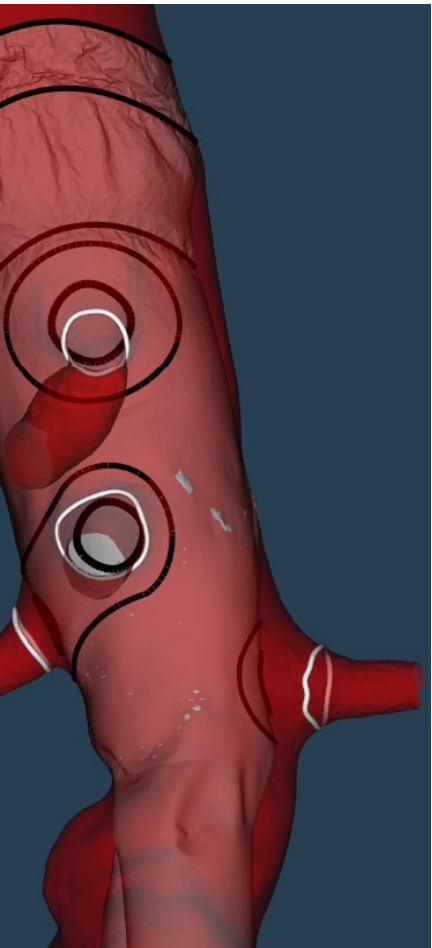
# Suboptimal fenestration position

## Example 2



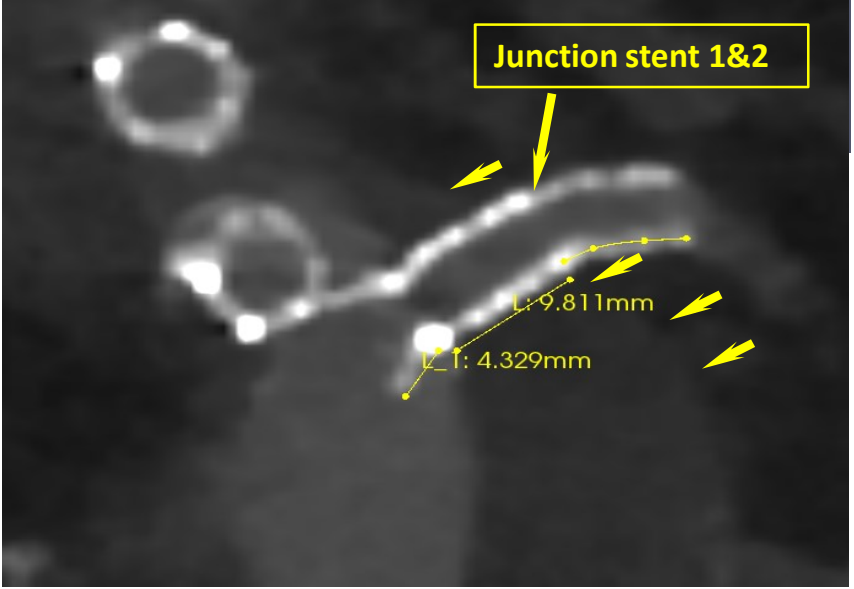
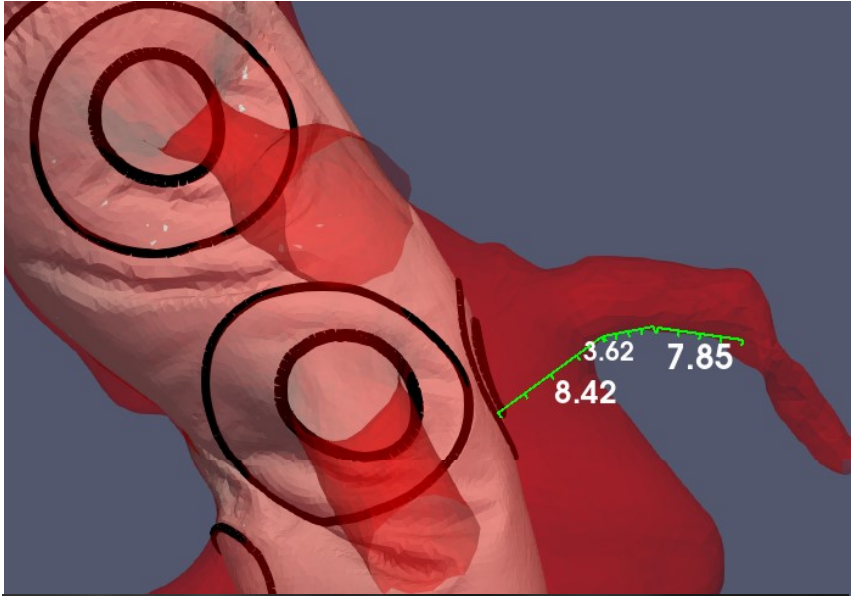
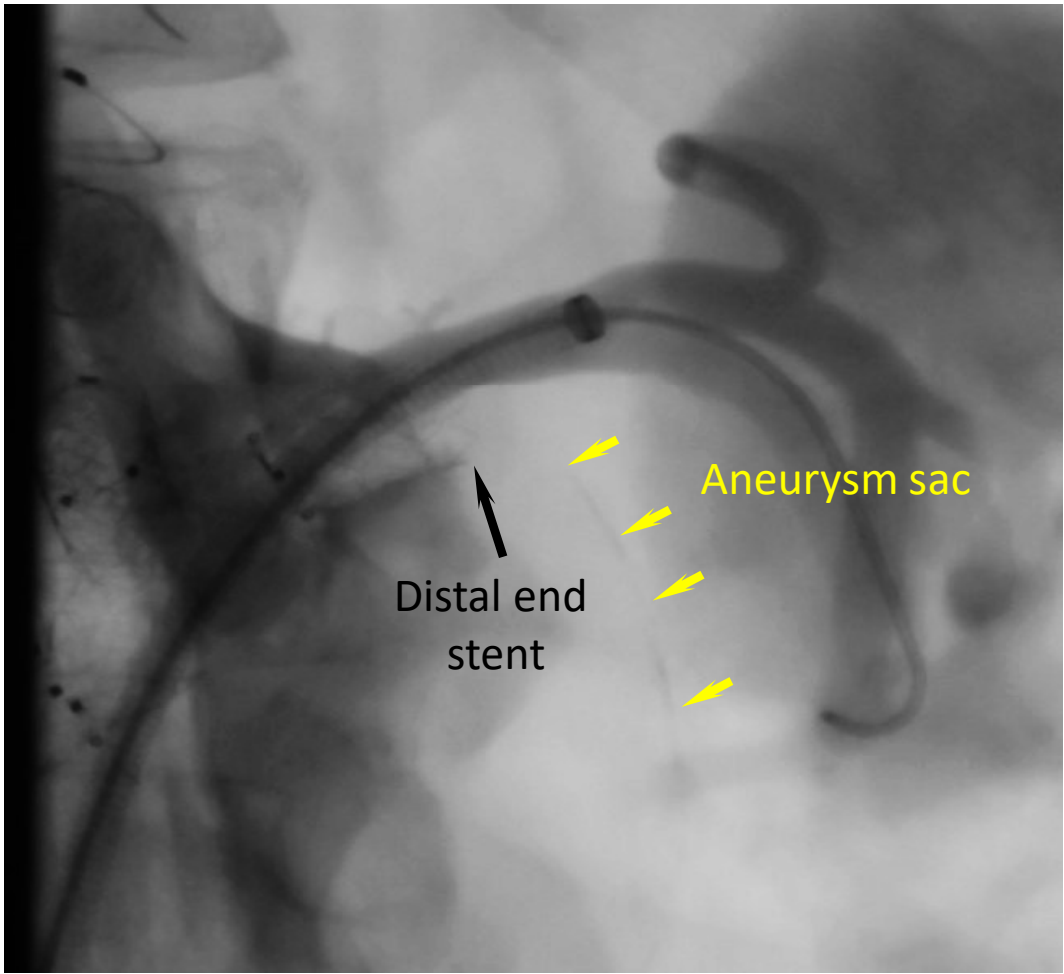
# Anaconda: fenestrations positioned as per numerical simulation

## Analysis of intra operative outcomes

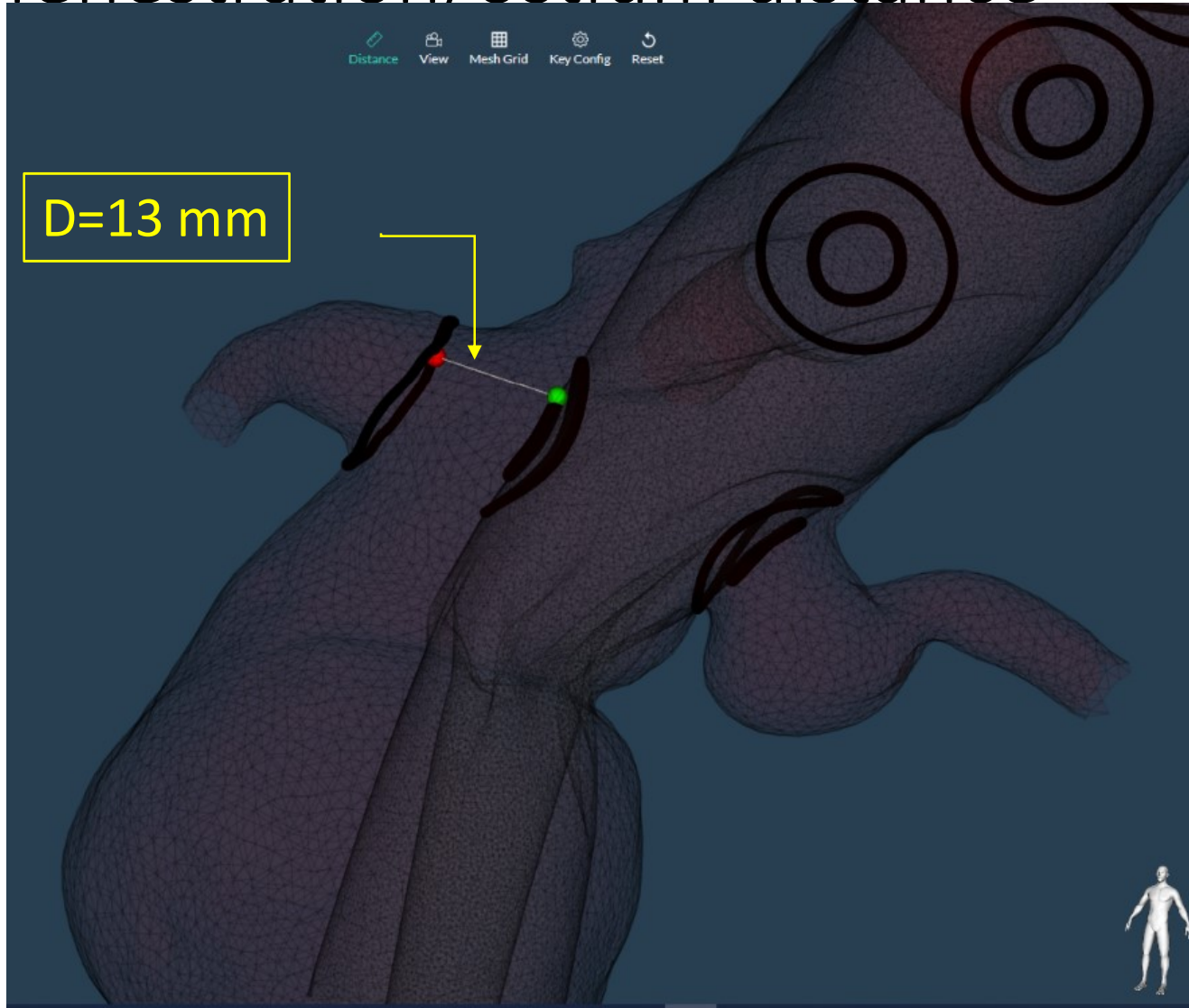


- 95 patients from 40 European centers
- 363 fenestrations
- Technical success (fen. catheterization + stenting) **100%**
- Perfect fenestration alignment **99.7%**
- Median catheterization time **60 sec** (range 5-2100)
- Simulation median delivery time **2 days**

# Type IC endoleak due to wrong estimation of distance fen/ostium

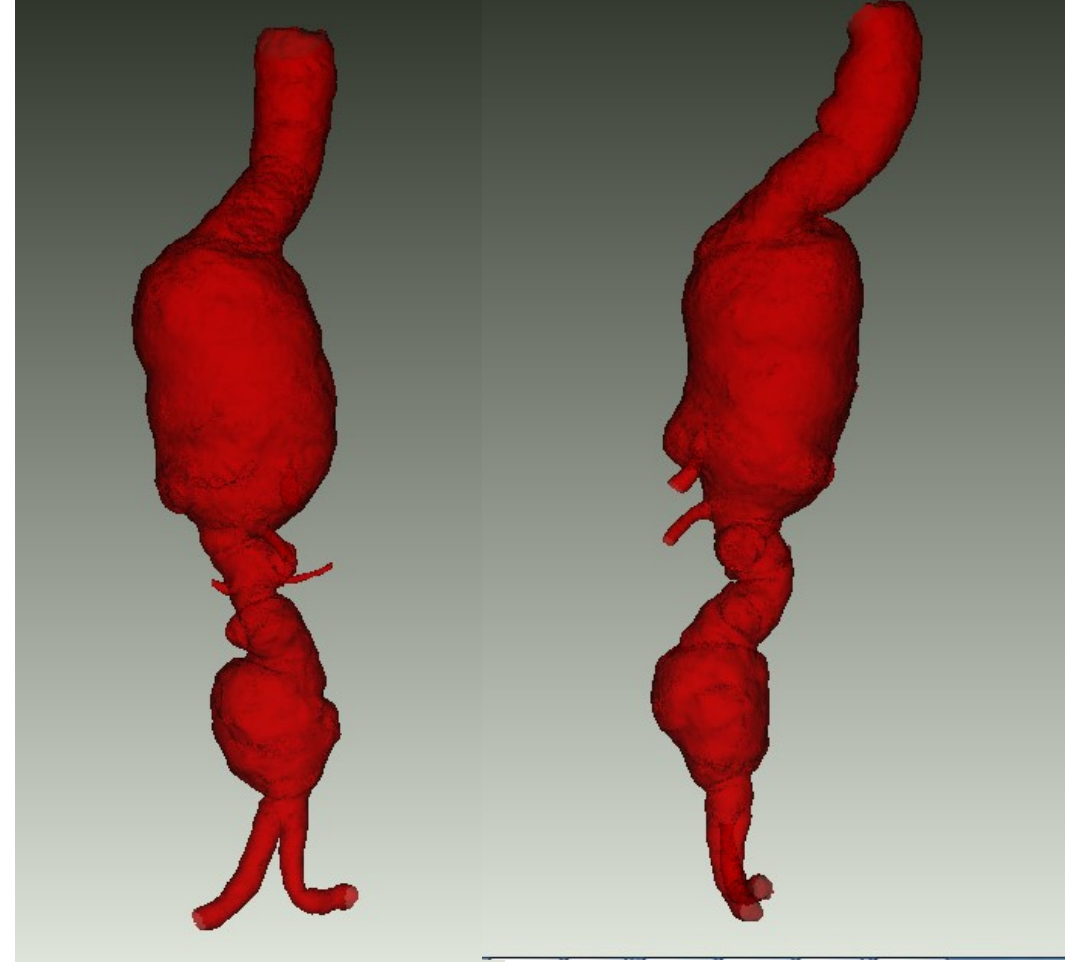
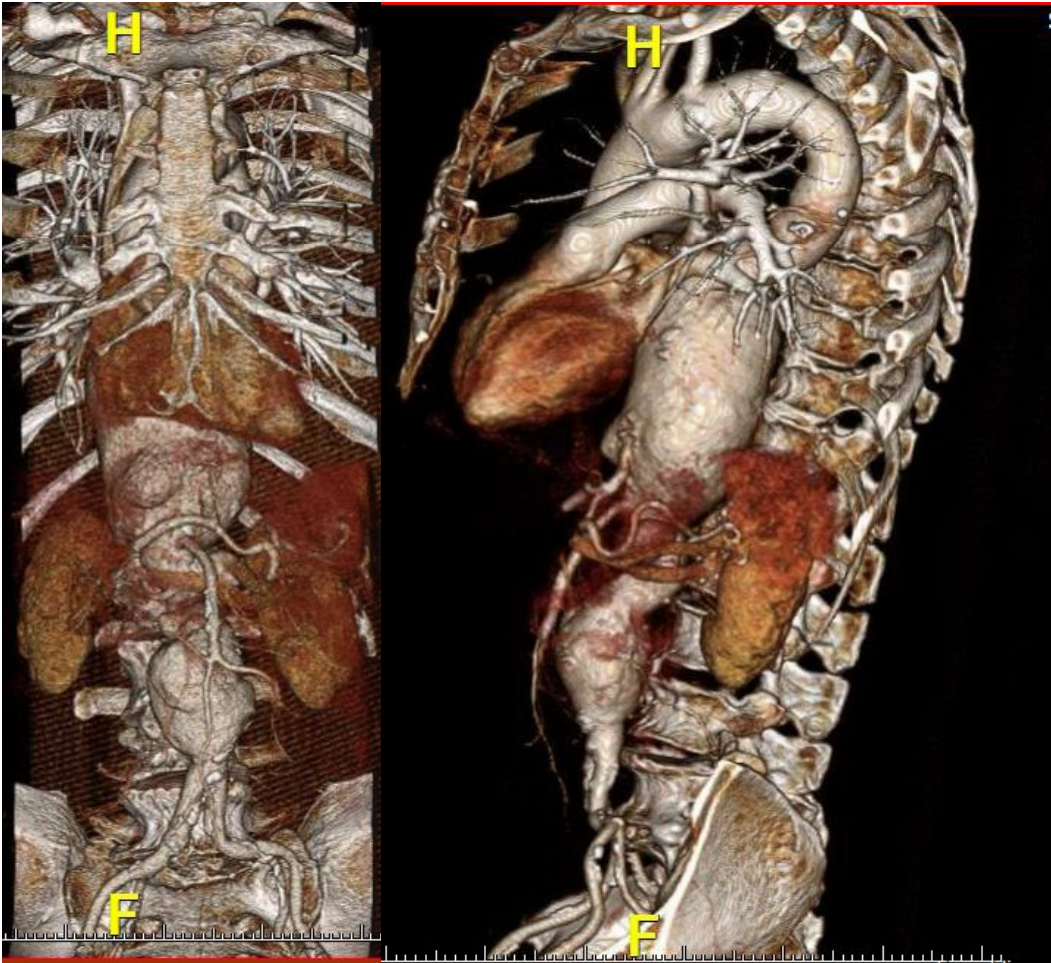


# Use of PlanOp measurement tool to assess fenestration/ostium distance

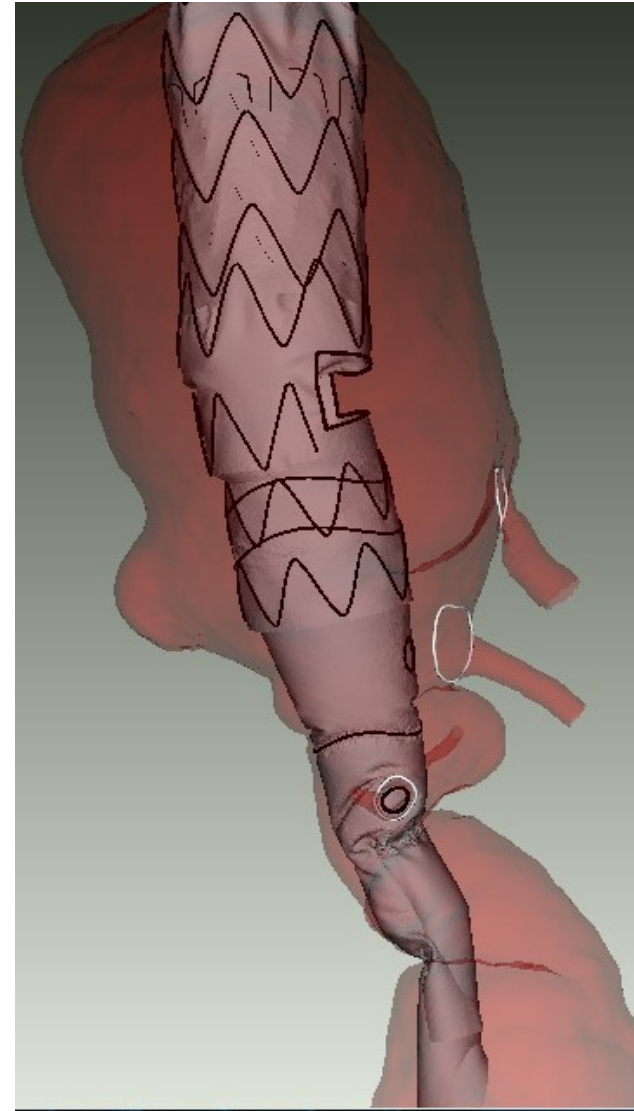
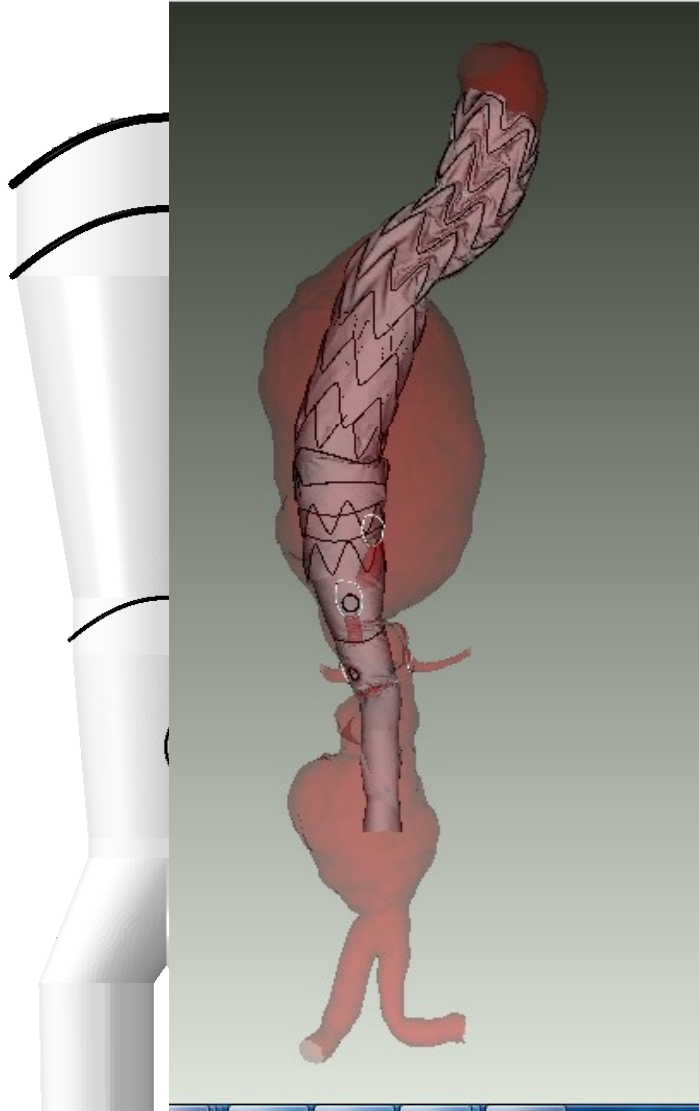
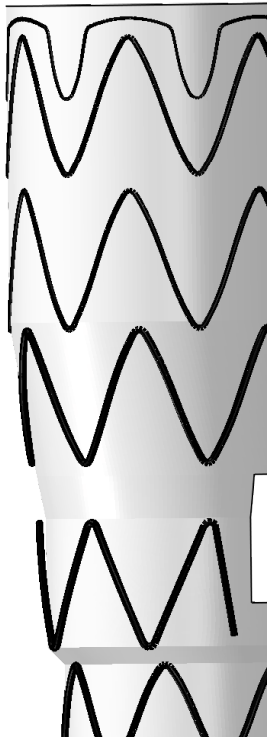
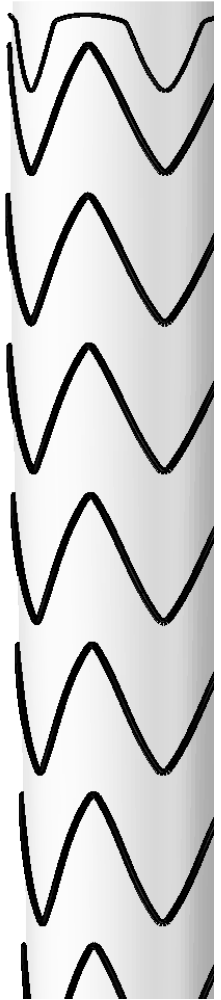


# Branched Relay + fenestrated Anaconda for thoraco-abdominal aneurysm

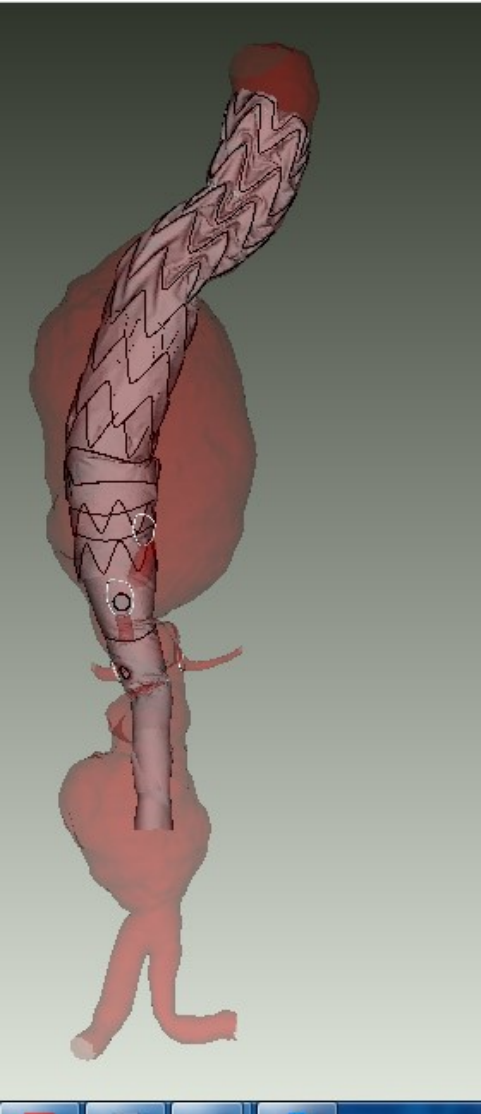
- Courtesy Prof A Duprey University Hospital Reims



# Pre-operative planification of devices with simulation



# Simulation vs post-op CT scan



# Conclusion

- **Numerical simulation provides a streamlined and reliable planning process for complex aortic aneurysm repair**
- **A wide range of devices and anatomies are amenable to this technology**
- **Prediction of complications by numerical simulation becomes a reality with a strong potential for improved clinical outcomes**

