Endovascular Repair of Thoracoabdominal Aneurysm

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Conflicts of Interest

- COOK Medical - Consulting, Speakers Bureau, IP, Research support
- Medtronic – Advisory Board
- Aortica – Advisory Board
- Cordis – Research Support
- GORE – Research Support, Speakers Bureau

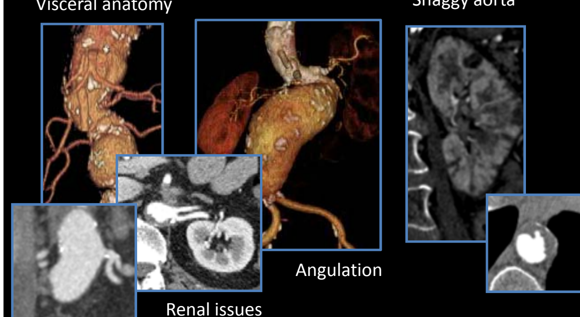
Overview

- Planning for eTAAA
- Staging for eTAAA
- Advanced Imaging Techniques in eTAAA
- Durability of eTAAA

PLANNING

ANATOMIC CONSIDERATIONS FOR COMPLEX AORTIC REPAIR

TOTAL ENDOVASCULAR APPROACH - LIMITATIONS



CrossMark

From the Society for Vascular Surgery

Implications of renal artery anatomy for endovascular repair using fenestrated, branched, or parallel stent graft techniques

Bernardo C. Mendes, MD,[a] Gustavo S. Oderich, MD,[a] Leonardo Reis de Souza, MD,[a] Peter Banga, MD,[a] Thanila A. Macedo, MD,[b] Randall R. DeMartino, MD,[a] Sanjay Misra, MD,[b] and Peter Gloviczki, MD,[a]
Rochester, Minn JVS 2016)

- Renal diameter >4mm
- RA length to bifurcation < 13mm
- Preservation of >75% single kidney OR >60% of 2 kidneys

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- N=520
  - 1009 Main renal arteries
  - 177 accessory renals
- 18% non suitable for endo due to renal issues

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Rochester, Minn JVS 2016)

- 125 patients (24%) excessive downward angle – ChEVAR or BEVAR case???
- 129 patients (25%) at least one upward facing RA – FEVAR???
- Proximal aneurysm extent impacts RA angle

WHEN DO WE USE BRANCHES AND WHEN DO WE USE FENESTRATIONS?

Branches vs. Fenestrations

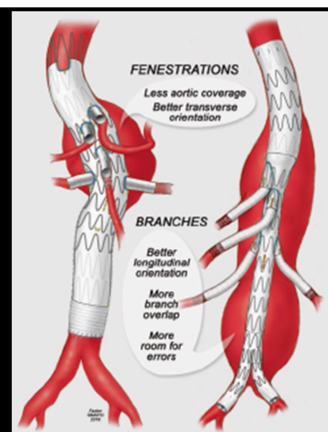
Often A Combination Is The Best Fit – Custom Made Design

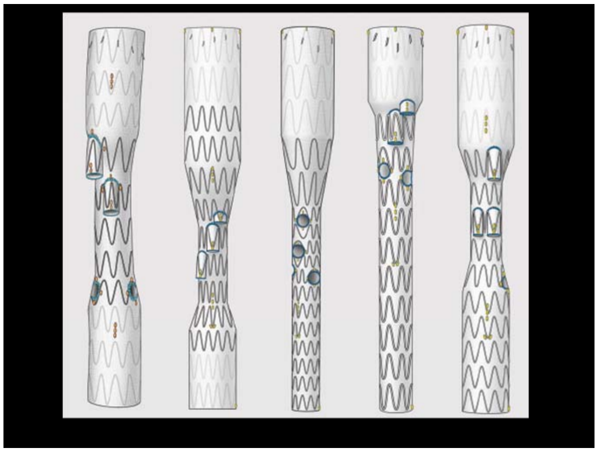
Branches

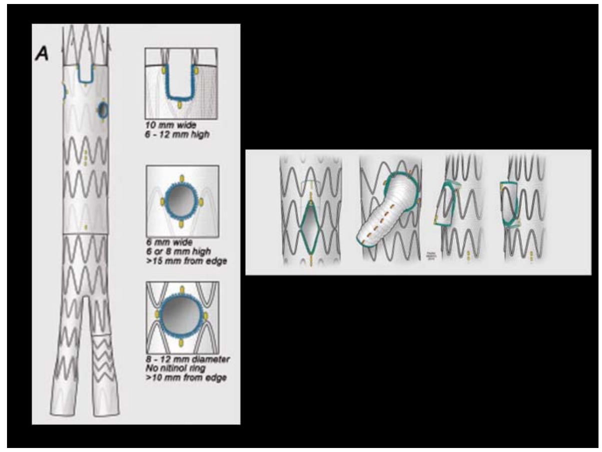
- TV in wide aorta >35
  - TAAA
- Caudally oriented TV
  - SMA, CA
  - Renals in type 4 TAAA
- Emergency cases?
  - Off the Shelf

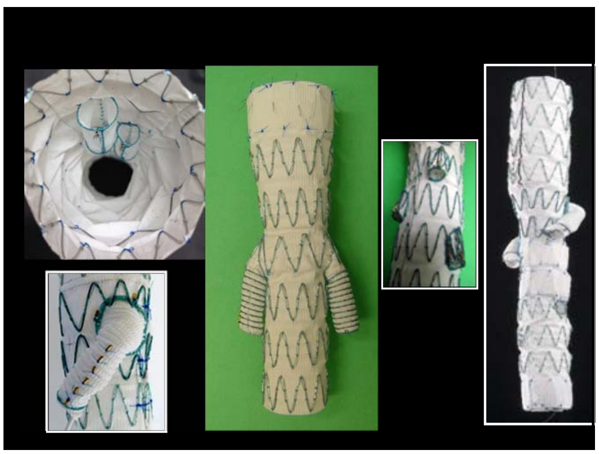
Fenestrations

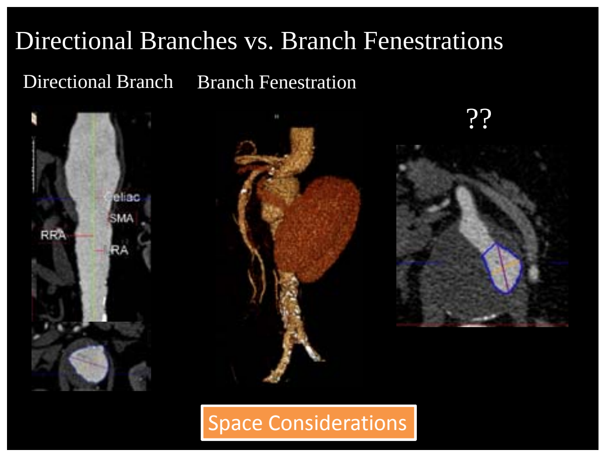
- TV in narrow aorta
  - Juxtarenal/short neck AAA
  - Type 1 TAAA
  - Chronic dissections
- Cranially oriented TV
  - Renals in type 2 TAAA
  - Juxta/Suprarenal AA

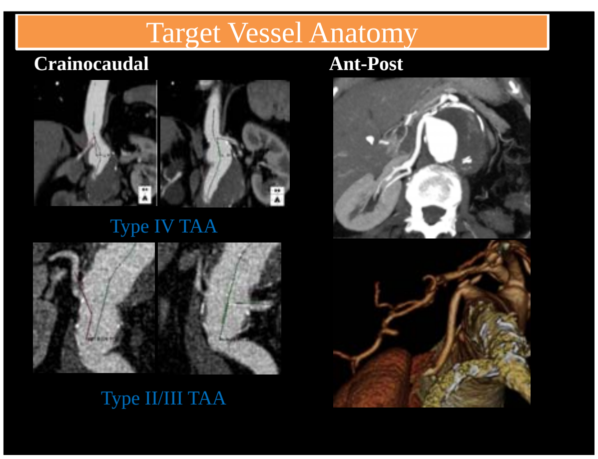


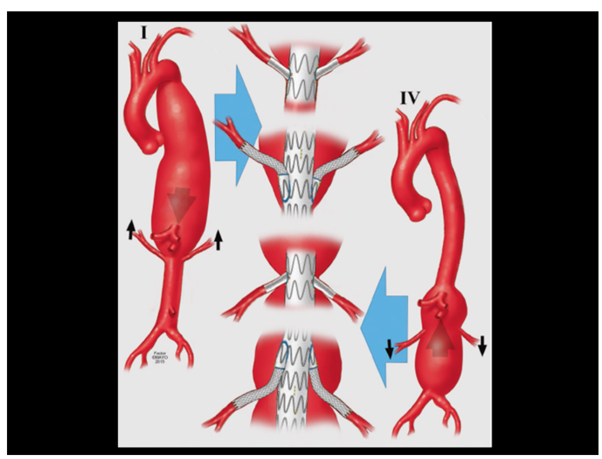



A
10 mm wide
6 - 12 mm high
6 mm wide
6 or 8 mm high
>15 mm from edge
8 - 12 mm diameter
No nitinol ring
>10 mm from edge




Directional Branches vs. Branch Fenestrations
Directional Branch
Branch Fenestration
??
Celiac
SMA
RRA
RA
Space Considerations


Target Vessel Anatomy
Crainocaudal
Ant-Post
Type IV TAA
Type II/III TAA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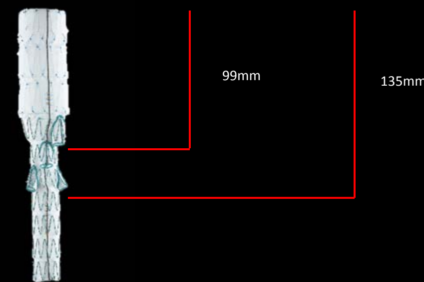
IV

DESIGN IMPLICATIONS FOR AORTIC COVERAGE

Branches in juxtarenal repair?



Lower extremity weakness after endovascular aneurysm repair with multibranched thoracoabdominal stent grafts

Julia D. Sobel, BS, Shant M. Vartanian, MD, Warren J. Gasper, MD, Jade S. Hiramoto, MD, Timothy A. M. Chuter, DM, and Linda M. Reilly, MD, *San Francisco, Calif*

- Lower extremity weakness 21%
  - 13% full recovery
  - 8% persistent deficit
- No Bias based on Crawford extent of aneurysm
  - Included Type II-IV aneusyms and juxta/suprarenal

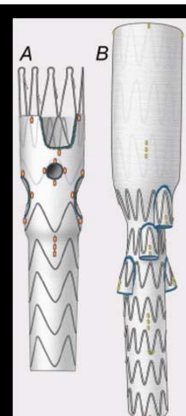
Table III. Branch outcomes[a]

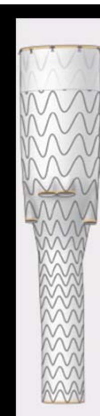
Branch	*No.*	*Insertion injury No. (%)*	*Patent No. (%)*	*Occluded No. (%)*	*Stenosed No. (%)*	*Stented No. (%)*	*Stenosed or occluded[b] No. (%)*	*Injured, stenosed, or occluded[b] No. (%)*
Celiac axis	76	2 (2.6)	74 (97.4)	2 (2.6)	0 (0.0)	0 (0.0)	2 (2.6)	3 (3.9)
Superior mesenteric artery	81	1 (1.2)	81 (100)	0 (0.0)	1 (1.2)	1 (1.2)	1 (1.2)	2 (2.5)
Renal artery	148	11 (7.4)	139 (93.9)	9 (6.1)[c]	4 (2.7)	3 (2.0)	13 (8.8)	21 (14.2)
χ^2		5.48	5.85	5.85	2.39	1.6	7.39	15.9
R		0.065	0.054	0.054	0.3	0.45	0.025	0

- Chuter et al JVS 2012;56
- 81pat, 306 Branches
- Mean FU 21months
- 100% Technical Branch Success

9% renal branch occlusion

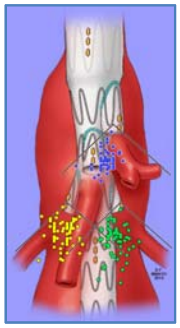
IMPACT OF TIMING





APPLICABILITY OF t-BRANCH®

- 201 patients with TAAAs
- 87% candidates for custom devices
- 47% candidates for t-Branch® device
- Reasons for unsuitability:
  - Visceral artery anatomy 50%
  - Access 26%
  - Proximal landing zone 21%



Compromises

- Long distance to renal arteries
- Upward facing renal arteries
- Repair extended to mid descending aorta

Spandex Rule: "Just Because You Can, Doesn't Mean You should"

T. Mastracci, CCF

STAGING

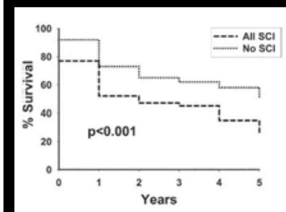
Open **TAAA** Repair

Author	Year	N	Mortality	Paraplegia/Paraperesis	
Svensson	1993	1509	155(10%)	234	16%
Schepens	1996	172	18(10.5%)	24	14.7%
Grabitz	1996	260	37(14.2%)	39	15%
Acher	1998	217	21(9/7%)	17	7.8%
Coselli	2000	1220	93(7.5%)	56	4.6%
Estrera	2001	654	106(16%)	33	5%
Jacobs	2002	184	20(10/8%)	5	2.7%
Van Dongen	2002	118	4(3.4%)	5	4.2%

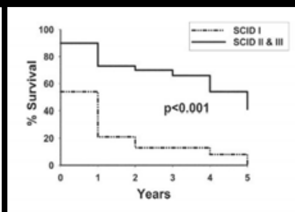
Results Endo

	n	Technical success	30day mortality	SCI	Renal Failure
Malmö	72 (21 emergent)	97%	3.9% (14%)	N=7 (+ 14 transient)	2.9%
Greenberg	406	-	3.2%	4,3% (3-19%)	-
Chuter	81	100%	3.7%	3.7% perm (20% trans)	4.9%
Verhoven	50	93%	8%	N=5 (4 resolved)	6,7%
Haulon	89	96.6%	10%	7%	6,7%

Paraplegia : A Devastating Complication



Conrad MF J Vasc Surg 2008;48:47-53



SCID I : Total paralysis
SCID II & III: Partial function

Risc factors for SCI during eTAAA

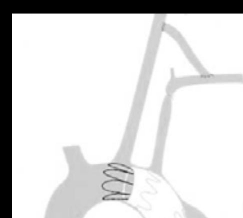
- Simultaneous coverage of 2 vascular supplies to the SC (Czerny et al JEVT 2012)
  - LSA (Cooper et al JVS 2009)
  - Hypogastric artery (Greenberg et al Circulation 2008)
- Length of Aortic Coverage (Feezor ATS 2012)
- (Shaggy Aorta (Patel et al EJVES 2014))
- Perioperative Hypotension (MAP <70mmHg)

Spinal Cord Management

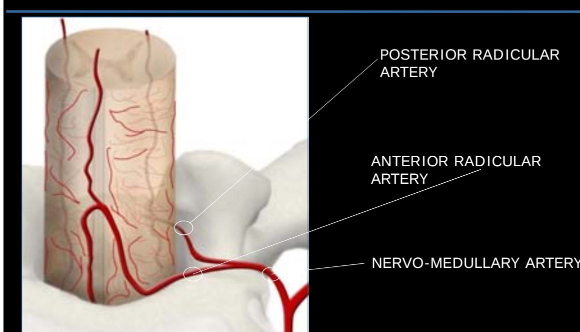
- Spinal Drain preop
  - 10cm H2O continuous drainage
  - <15ml/hour
  - 36-72 Hours
- Intraoperative MEP
  - Perfusion branch option
- Systemic BP
  - MAP >80 (90)
- Hgb >110g/l
- Minimize ischemia time to LE to avoid reperfusion
- Blood product replacement at closure
  - PRC, FFP, Platelets

Staging I

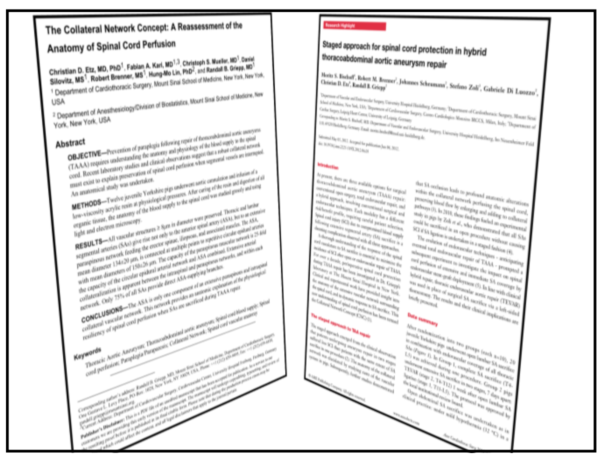
- Carotid Subclavian Bypass
- Iliac Access



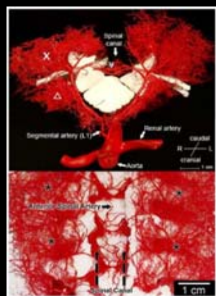
Anterior Spinal Artery



Images courtesy of Dr Mellissano, Milano



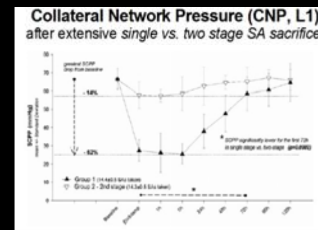
An Intact Collateral Network is more Critical than Single Segmental Arteries



Images Courtesy of Dr Etz

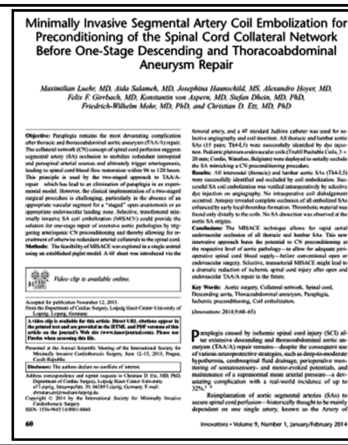
Staging

- Staging of TAAA repair reduces SCI
  - Etz et al JTCS 2010
  - Mastracci et al, JVS 2015



SG Repair Staging

- Extranatomic Bypass and Access Separate
- Segmental Artery Embolisation
- Perfusion Branch
- TEVAR first

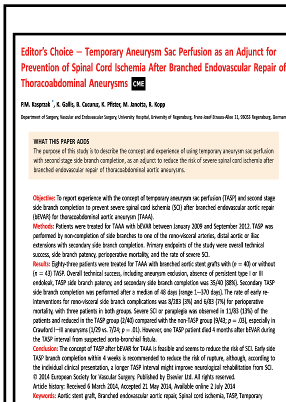


Minimally Invasive Segmental Artery Coil Embolization for Preconditioning of the Spinal Cord Collateral Network Before One-Stage Descending and Thoracoabdominal Aneurysm Repair

Innovations • Volume 9, Number 1, January/February 2014

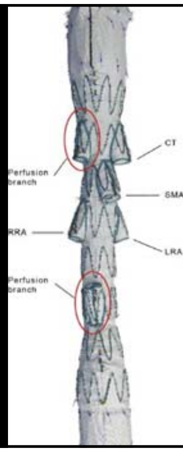
Perfusion Branch Concept

- Chuter Case report
- Ivancev et al J Vasc Surg 2012;55:1202-5
  - 10 patients with Type II TAAA
  - 1 Paraplegia + death
  - 2 SCI with recovery

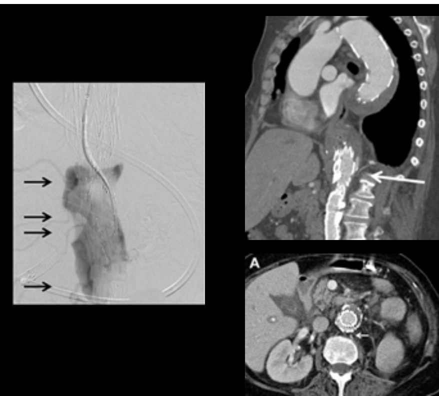


Editor's Choice – Temporary Aneurysm Sac Perfusion as an Adjunct for Prevention of Spinal Cord Ischemia After Branched Endovascular Repair of Thoracoabdominal Aneurysms

Elective sac perfusion to reduce the risk of neurologic events following endovascular repair of thoracoabdominal aneurysms



Journal of Vascular Surgery 2012 55, 1202-1205DOI: (10.1016/j.jvs.2011.10.079)



European Journal of Vascular and Endovascular Surgery 2014 48, 258-265DOI: (10.1016/j.ejvs.2014.05.020)

Perfusion Branch

- Kazperzak EJVES 2014
  - 83 patients (43 without and 40 with perfusion branch)

Table 5. Neurological complications.

Neurological complications	Non-TASP (n = 43)	TASP (all patients) (n = 40)	p[a]	TASP (completed) (n = 35)	p[a]
Acute cerebrovascular events	0 (0)	3 (1)		1 (3)	
Paraesthesia	1 (2)	5 (13)		3 (9)	
Temporary paraparesis[b]	1 (2)	5 (13)	NS	5 (14)	.04
paraplegia (day 30 or discharge)[b]	9 (21)	2 (5)	.03	1 (3)	.02
Subgroup of aneurysm type I—III	n = 24	n = 29		n = 26	
Paraplegia (d 30 or discharge)[b]	7 (29)	1 (3)	.01	0 (0)	<.01

Note. Values are n (%) unless otherwise indicated. TASP = temporary aneurysm sac perfusion; NS = not significant.
[a] All in comparison to the non-TASP group.
[b] Muscle strength 0—2 according to the modified Tarlov scale.

2 Stage Concept

- Separate TEVAR from TAAA Repair
  - Collateral development
  - Shorter procedure

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From the Society for Vascular Surgery

Staged endovascular repair of thoracoabdominal aortic aneurysms limits incidence and severity of spinal cord ischemia

Adrian O'Callaghan, MD, Tara M. Mastracci, MD, and Matthew J. Eagleton, MD, *Cleveland, Ohio*

Objective: Neurologic dysfunction remains a persistent complication of extensive aortic repair owing to disruption of the spinal collateral network. We hypothesized that staged repair might mitigate the incidence and severity of this spinal cord ischemia (SCI).
Methods: We conducted a retrospective cohort study of patients undergoing a Crawford type II repair of a thoracoabdominal aortic aneurysm between January 2008 and July 2013. Baseline demographics, incidence of prior aortic surgery, comorbidities, and outcomes were prospectively recorded. Staged repair was defined as intentional completion of the endovascular repair as two temporally separate procedures, referred to as a two-stage repair. Extent of aortic cover was calculated by three-dimensional imaging and reported as the proportion of the aorta covered between the left subclavian artery and the aortic bifurcation. Primary outcome measures were incidence and severity of SCI and mortality.
Results: The study included 87 patients, divided into the following subgroups: single-stage repair (n = 32; repair in a single procedure, without prior aortic surgery), two-stage repair (n = 27; repair in two separate procedures, without prior aortic surgery), and unintentionally staged repair (n = 28; those with prior aortic surgery, without an intention to stage). Median time between stages was 5 months (range, 1-60 months). All groups were equivalent in terms of demographics and risk factors; however, the staged group had significantly greater proximal aortic cover (P = .001). The overall rates of SCI in the nonstaged and staged groups were 37.5% (12 of 32) and 11.1% (3 of 27), respectively (P = .03). Furthermore, all neurologic injuries in the staged group were temporary. The 30-day survival in the single-stage, two-stage, and unintentionally staged repairs was 18.8%, 0%, and 10.7%, respectively (P = .52).
Conclusions: Staged repair appears both to protect against SCI and to enhance overall survival in extensive aortic repair. (J Vasc Surg 2015;61:347-54.)

Open surgical thoracoabdominal aortic aneurysm (TAAA) repair offers patients a durable solution for this devastating disease, provided they can tolerate the morbid procedure. Initial reports of the successful repair of TAAA were soon followed by the recognition that such extensive surgery was associated with an increased incidence of postoperative neurologic dysfunction.[1,2] Over time, the development of protective measures, such as moderate hypothermia, distal bypass, and spinal drainage, mitigated these effects in part. However, maintenance of spinal perfusion, in the form of intercostal reimplantation, has been shown to be a powerful determinant of a positive outcome.[3,4]

Endovascular repair of TAAA affords high-risk patients a therapeutic solution.[5] The absence of aortic cross-clamping and the avoidance of a thoracotomy, among other benefits, conspire to lessen the insult associated with open repair. However, despite these advances, the incidence of postoperative neurologic dysfunction remains stubbornly high. Rates of spinal cord ischemia (SCI) after endovascular repair of TAAA have been reported as high as 20%.[6] Device length, extent of aneurysm repaired, and occlusion of spinal collaterals such as the left subclavian artery or hypogastric artery were shown to be important contributors to the development of postoperative spinal dysfunction and clinical outcomes.[7,8] In spite of the many benefits of endovascular surgery, options are limited with regard to maintenance of perfusion of any excluded intercostal or lumbar vessels.

A combination of clinical and experimental work in the last decade has served to further elucidate the spinal perfusion network and the relative importance of the different contributors. What has emerged is the concept of a collateral network that can potentially lessen the impact of spinal ischemia if it is optimized.[9] This collateral network may behave in a compensatory manner, similar to other vascular beds, and maintain perfusion pressures when contributors are excluded. Separating the ischemic insult into two lesser procedures may facilitate the remaining perfusing elements to compensate and so maintain function. We hypothesized that staging of extensive thoracoabdominal repairs in this

From the Department of Vascular Surgery, Cleveland Clinic.
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Additional material for this article may be found online at www.jvascsurg.org.
Reprint requests: Matthew J. Eagleton, MD, Department of Vascular Surgery, H32, Cleveland Clinic, 9500 Euclid Ave, Cleveland, OH 44195 (e-mail: eagletm@ccf.org).
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0741-5214

http://dx.doi.org/10.1016/j.jvs.2014.09.011

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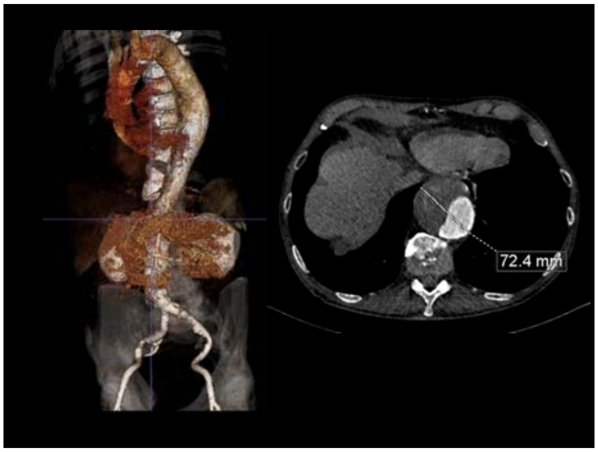
Table III. Outcome results

Factor	Total (N = 87), No. (%)	Single-stage repair (n = 32), No. (%)	Two-stage repair (n = 27), No. (%)	Unintentionally staged repair (n = 28), No. (%)	P value
SCI	19 (21.8)	12 ([illegible]7.5)	3 (11.1)	4 (14.3)	.025[a]
Duration of SCI					[illegible]
None	68 (78.2)	20 ([illegible]2.5)	24 (88.9)	24 (85.7)	
Improved	11 (12.6)	7 ([illegible]1.9)	3 (11.1)	1 (3.6)	
Permanent	8 (9.2)	5 ([illegible]5.6)	0 (0.0)	3 (10.7)	
30-day mortality	9 (10.3)	6 ([illegible]8.8)	0 (0.0)	3 (10.7)	.052[b]
Prolonged intubation (FEVAR)	13 (14.9)	7 ([illegible]1.9)	[illegible]	5 (17.9)	.11[b]
Tracheostomy (FEVAR)	0 (0.0)	0 ([illegible].0)	0 (0.0)	0 (0.0)	
Dialysis (FEVAR)	0 (0.0)	0 ([illegible].0)	0 (0.0)	0 (0.0)	
AKI (FEVAR)	12 (13.8)	7 ([illegible]1.9)	2 (7.4)	3 (10.7)	.26[b]
MI (FEVAR)	5 (5.7)	2 ([illegible].3)	[illegible]	2 (7.1)	.99[b]

AKI, Acute kidney injury; *FEVAR*, fenestrated endovascular aortic aneurysm repair; *MI*, myocardial infarction; *SCI*, spinal cord ischemia.
A significance level of .017 was used for pairwise ad hoc comparisons.
[a] Pearson χ^2 test.
[b] Fisher exact test.

Table III. Outcome results

Factor	Single-stage repair (n = 32), No. (%)	Two-stage repair (n = 27), No. (%)
SCI	12 (37.5)	3 (11.1)
Duration of SCI		
None	20 (62.5)	24 (88.9)
Improved	7 (21.9)	3 (11.1)
Permanent	5 (15.6)	0 (0.0)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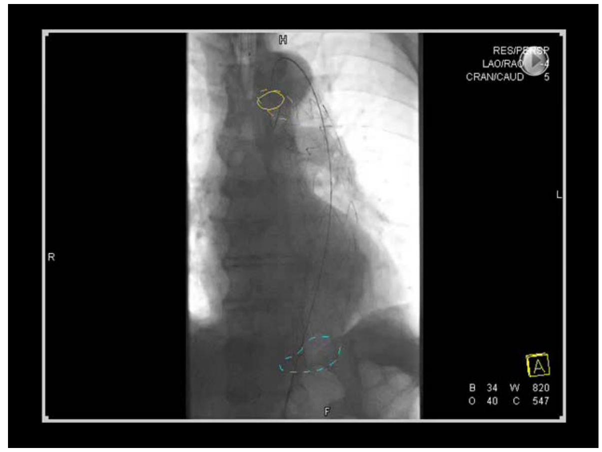
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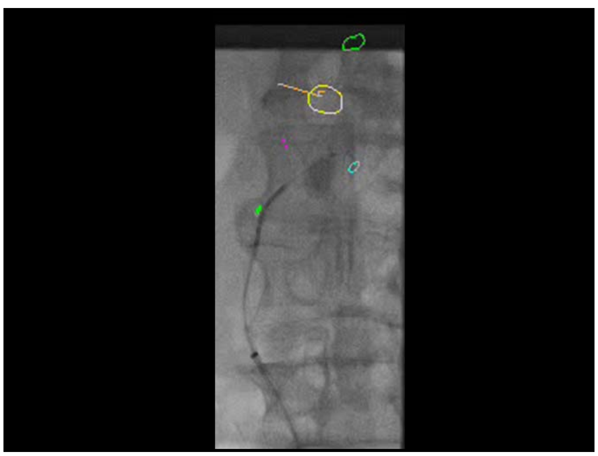

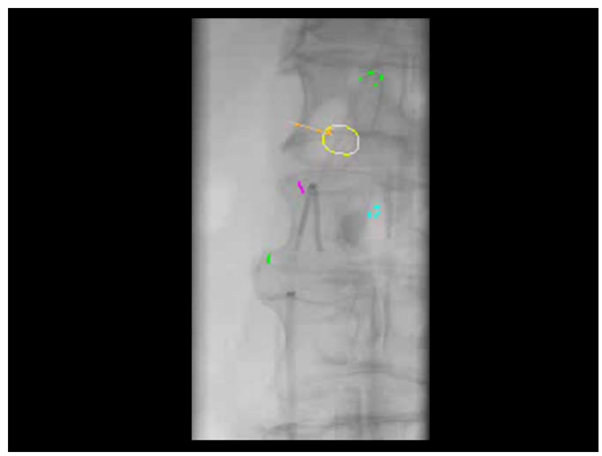

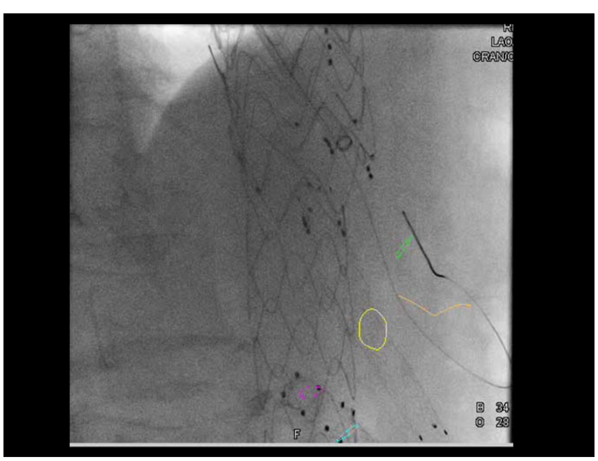
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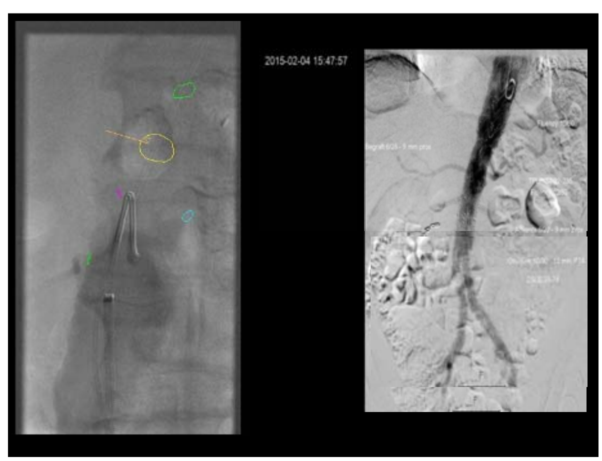
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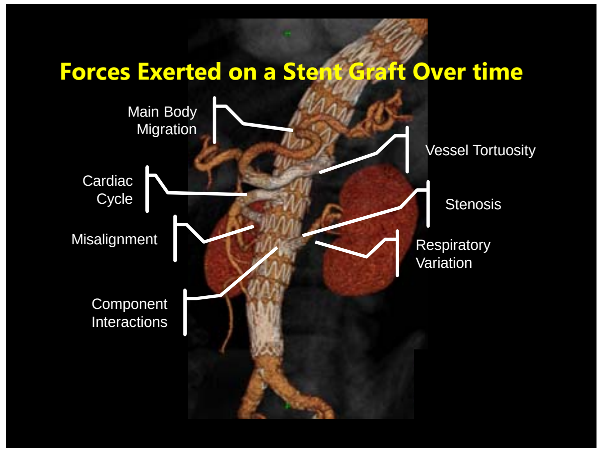
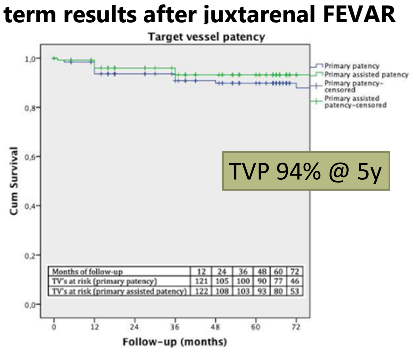
What Do We know About the Long-term Outcome on Branch/Fenestrated Repair?



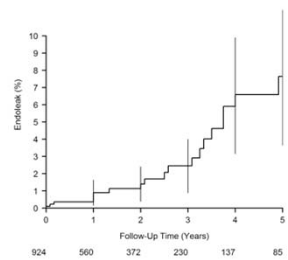
Long term results after juxtarenal FEVAR



Kristmundsson JVS 2014

Type 1a EL after FEVAR

- 924 patients
  - 2.8% Type 1a EL
  - 10/26 > 12month



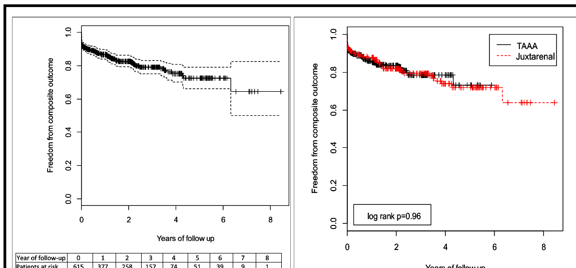
O'Callaghan A, Mastracci TM, Greenberg RK, Eagleton M, Bena J

Durability of branches in branched and fenestrated endografts

Tara M. Mastracci, MD, Roy K. Greenberg, MD, Matthew J. Eagleton, MD, and Adrian V. Hernandez, PhD, *Cleveland, Ohio*

JVS 2013; 57:926

- 650 patients
  - Juxtarenal and TAAA
- Mean FU 3years

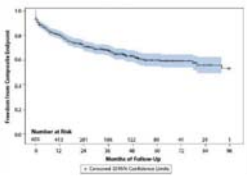


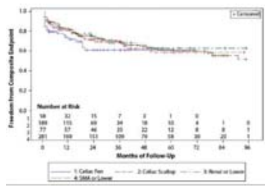
- Reinterventions CA 0.4%, SMA 4%, RA 6%

Table III. Details of renal artery interventions in this cohort

Category	*No. of patients*	*Endoleak vs occlusion*	*Mean preoperative creatinine*	*Last recorded creatinine*	*Earliest and latest day from index procedure to secondary intervention*
Diagnostic angio and intervention for occlusion or stenosis	19	Occlusion/stenosis	1.12	1.35	87-2239
Complete occlusion, recanalization not possible	11	Occlusion/stenosis	1.14	1.90	33-751
Endoleak requiring intervention	28	Endoleak	1.32	1.77	3-1362

Freedom from Composite Endpoint (Overall and by Device Type)



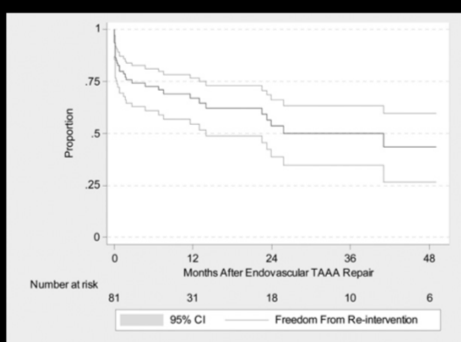


Twelve year experience with fenestrated endografts for juxtarenal and type IV thoracoabdominal aneurysms.
TM Mastracci, MJ Eagleton, Y Kuramochi, S Bathurst, K Wolski

Table III. Branch outcomes[a]

Branch	No.	Insertion injury No. (%)	Patent No. (%)	Occluded No. (%)	Stenosed No. (%)	Stented No. (%)	Stenosed or occluded[b] No. (%)	Injured, stenosed, or occluded[b] No. (%)
Celiac axis	76	2 (2.6)	74 (97.4)	2 (2.6)	0 (0.0)	0 (0.0)	2 (2.6)	3 (3.9)
Superior mesenteric artery	81	1 (1.2)	81 (100)	0 (0.0)	1 (1.2)	1 (1.2)	1 (1.2)	2 (2.5)
Renal artery	148	11 (7.4)	139 (93.9)	9 (6.1)[c]	4 (2.7)	3 (2.0)	13 (8.8)	21 (14.2)
χ^2		5.48	5.85	5.85	2.39	1.6	7.39	15.9
R		0.065	0.054	0.054	0.3	0.45	0.025	0

- Chuter et al JVS 2012;56
- 81pat, 306 Branches
- Mean FU 21months
- 100% Technical Branch Success



[1]Centre Hospitalier Regional Universitaire Lille, France
[2]Vascular Center, Skane University Hospital, Malmo
[3]Guys and St. Thomas' Hospital, Kings College London, UK
[4]Klinikum Nurnberg, Klinikum Nuremberg, Paracelsus Medical University Nuremberg, Germany
[5]Royal Free London, University College London, UK

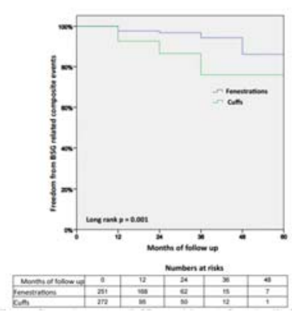
Branched Collaboration

Event Rates: Occlusion or Reintervention

	n	%
Celiac	7/208	3%
SMA	3/234	1.3%
Left Renal Artery	18/215	8.3%
Right Renal Artery	17/222	7.5%
Any Death, Branch occlusion or Branch Reintervention	80/235	34%

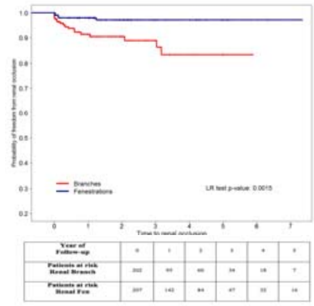
Mastracci et al, 2015

Long Term Outcomes of Fen v Branch



Pannucio et al, EJVES 2015

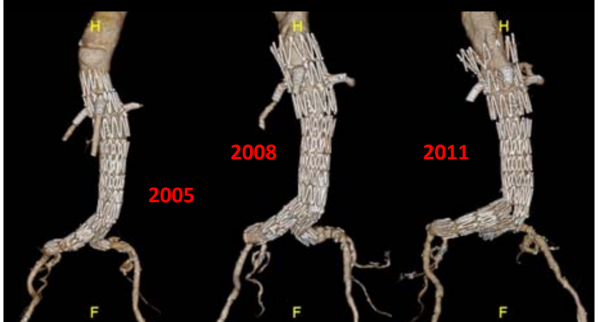
Branch v Fenestrated for Renals: Durability



Martin-Gonzales et al, EJVES 2016

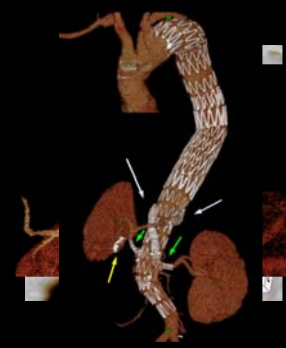
How Do We Improve eTAAA Durability?

Plan With the End In Mind



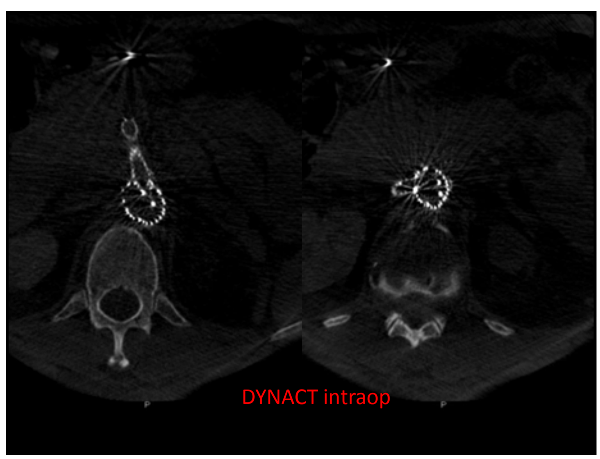
Make Branches Durable

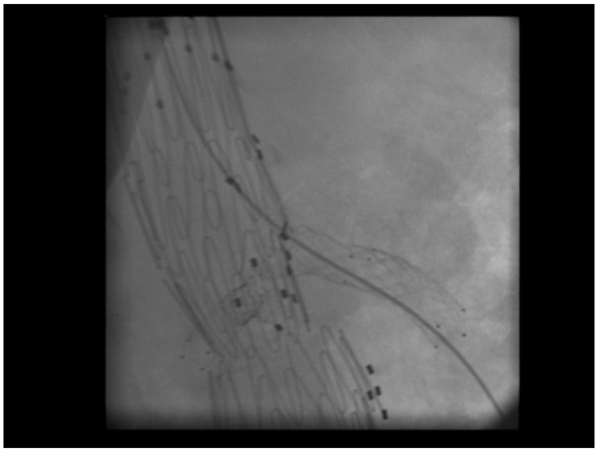
- Make branches as short as possible
- Align branch graft vector in accordance to target vessel native anatomy
- Provide as much overlap as possible between the branch and aortic component as well as the branch and visceral target vessel
- Minimize kinking and angulation in branches

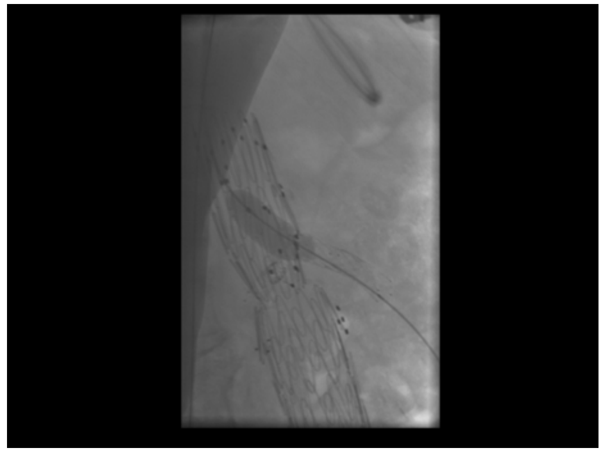


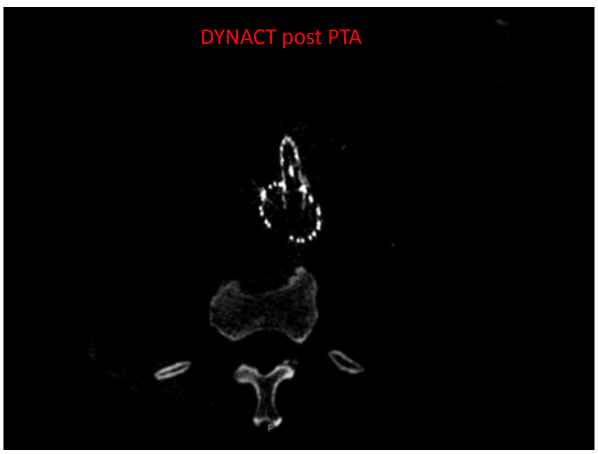
Improve Completion Imaging

	Endoleaks	Limb issues	Branch/Fens
Angiography	++	+	+ (flow)
Discharge CT	+++	+++	+++









Summary

- F/BEVAR is an established therapy for endo Tx of complex aneurysms
- Choice of design depends on anatomy, repair extent, urgency
- Combination of branches and fenestrations in graft design are common

Summary

- SCI is common after OR and Endo
  - Type I-III
- Spinal Collateral Flow Concept might be a Game changer
- Optimal Staging Method and Timing Still to be determined
  - Invasiveness
  - Delay to definitive repair

Summary

- The Natural History of Medically Managed TAAA's is dismal
- The Short-term Outcome of eTAAA is good
  - Comparable to Open Repair?
- ANY TAAA repair must be planned to outlive the patient
- Planning with the end in mind is Key
  - Life long surveillance

Save the date!

Critical Issues in Aortic Endografting

June 29–30, 2018

Malmö, Sweden