Brigham and Women's Hospital
Founding Member, Mass General Brigham

Dialysis Vascular Access – Assessment and Complications

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Interventional Nephrology @St. Louis
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Director, Interventional Nephrology

- Clinical focus: Dialysis Access
- Research focus: Dialysis Access Outcomes

DISCLOSURES

- Consultant: Bard, Inari, LaminateMedical, Metronic, Merit Medical, Mozarc, VenoStent, Venofa
- Advisory Board: Nephrodite
- Co-Investigator: Humacyte, WAVE-Trial

OBJECTIVES

Use case vignettes to:

- Connect dialysis access physiology with anatomy and development of dysfunction over time
- Combine tunneled catheter design, positioning, and compartments to understand function, dysfunction, and approach to infection

What is the typical stenosis of this type of access?

Question 1

The typical location of stenosis for this type of access is

a. the juxta-anastomotic segment

b. Needle cannulation segment

c. the cephalic arch

d. the arterial anastomosis

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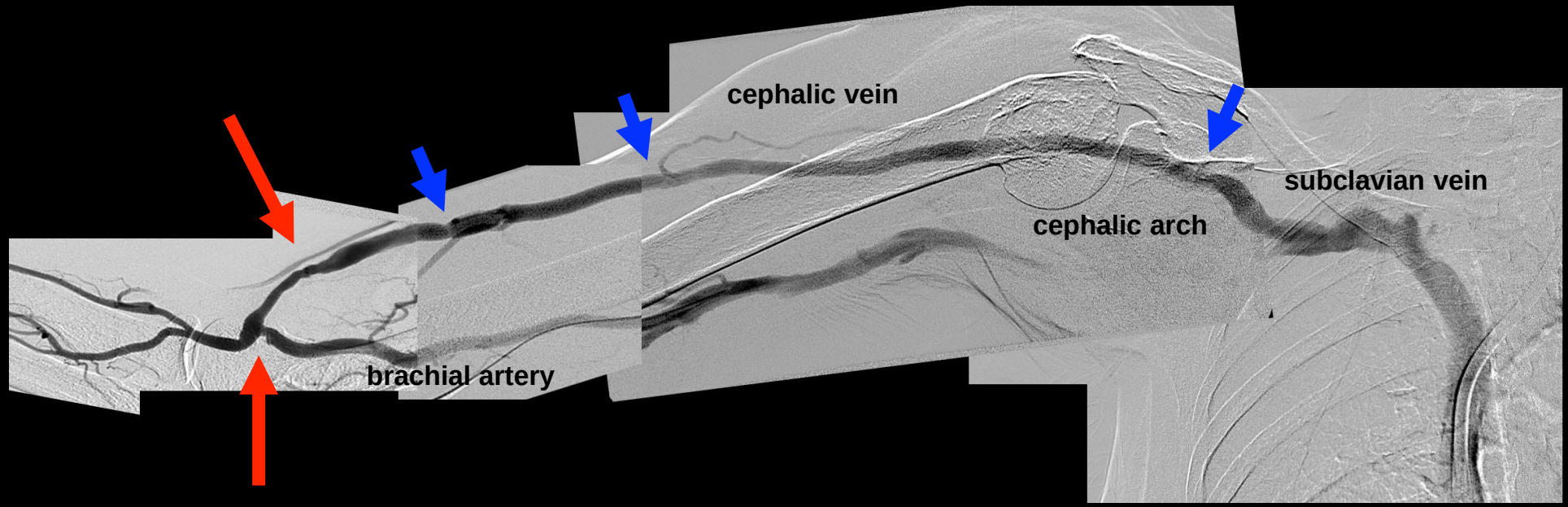
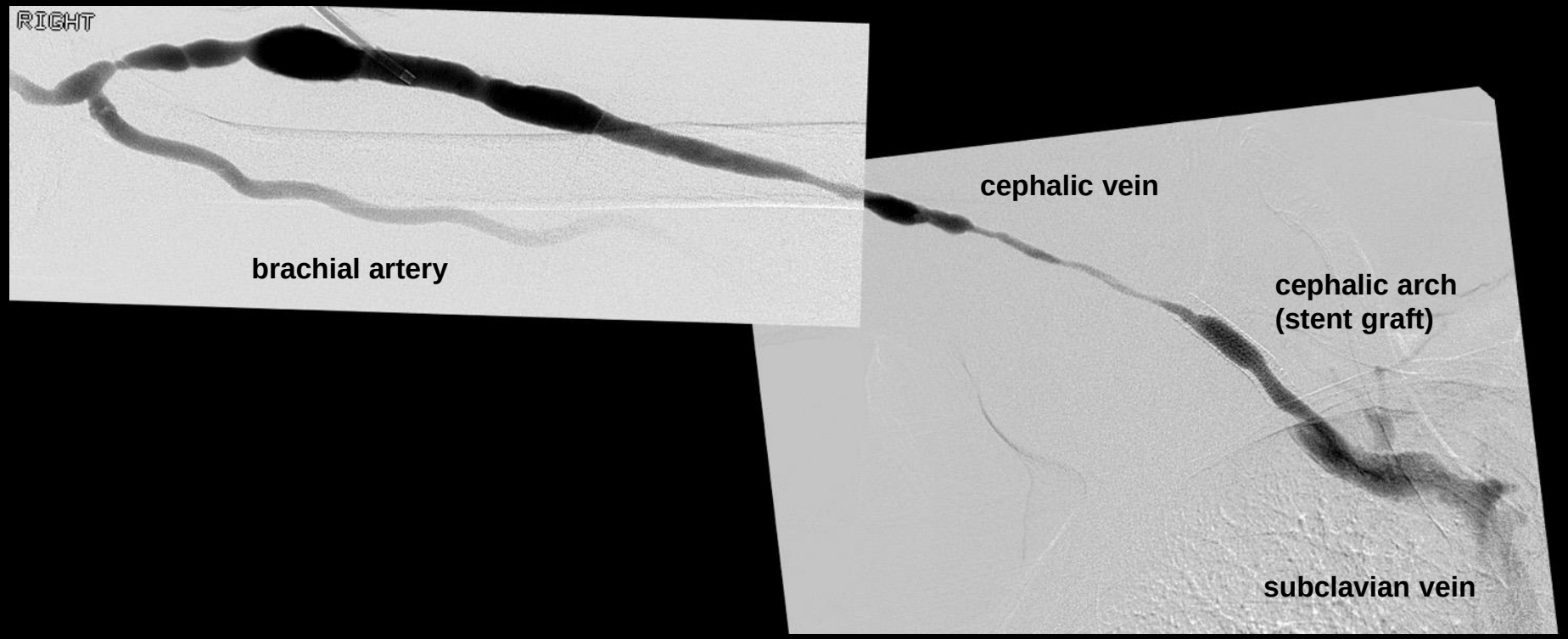

cephalic vein
subclavian vein
cephalic arch
brachial artery

“Chronic Access Disease”



Driven by symptoms and clinical finding during dialysis: angioplasty of cephalic vein and cephalic arch on 1-13-2009, 2-27-2009, 4-17-2009, 6-3-2009; stent graft in cephalic arch on 8-12-2009, and thrombectomy 12-1-2009

Angioplasty on 2-12-2010, 3-12-2010, 7-30-2010, 10-4-2010, 1-14-2011, and 3-11-2011. Cephalic vein stent graft on 6-22-2011.

Question 2

What is the most common site of stenosis in each of the typical types of upper extremity accesses?

1 – Radial-cephalic
2 - Brachial-cephalic
3 - transposed brachial-basilic
4 - prosthetic graft

A - cephalic arch
B - venous anastomosis
C - swing point
D - juxta-anastomotic segment

a. 1C, 2B, 3A, 4D
b. 1C, 2A, 3D, 4B
c. 1D, 2A, 3C, 4B
d. 1A, 2D, 3C, 4B
e. 1D, 2A, 3B, 4C

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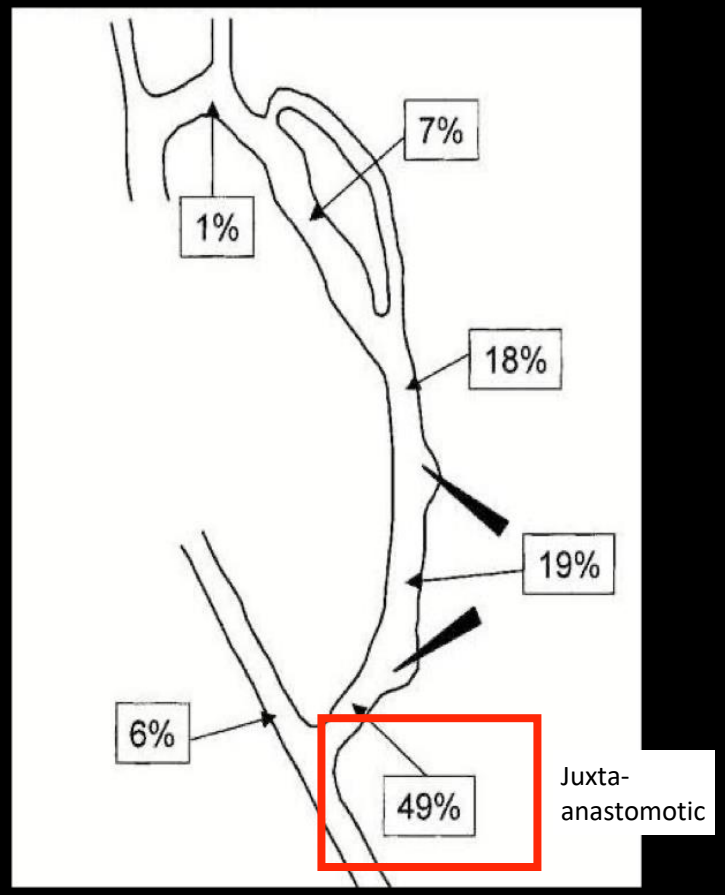
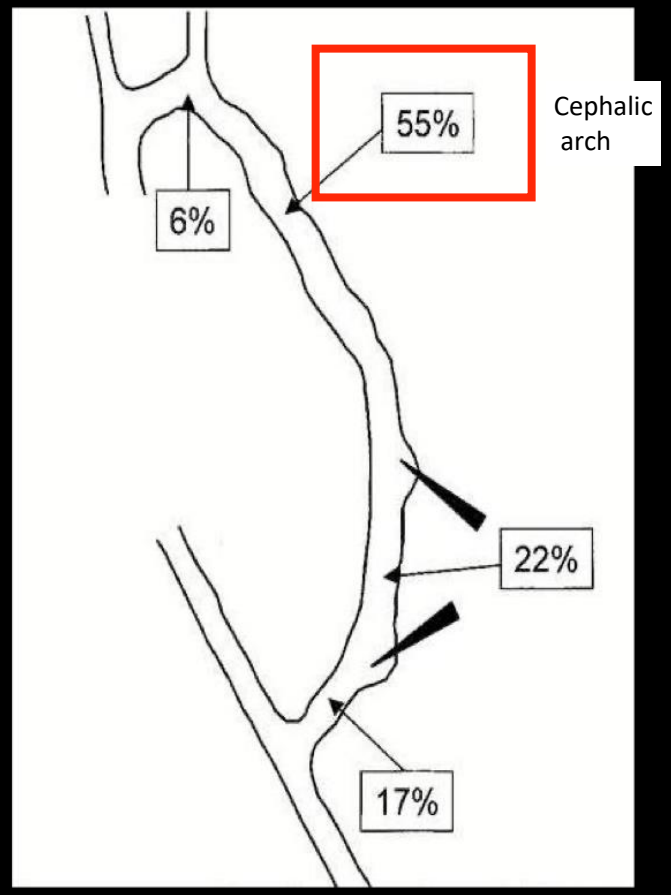
Location of Stenoses in Autogenous Accesses



radial-cephalic



brachial-cephalic

Rx – Cephalic Arch

- Stent grafts superior to angioplasty

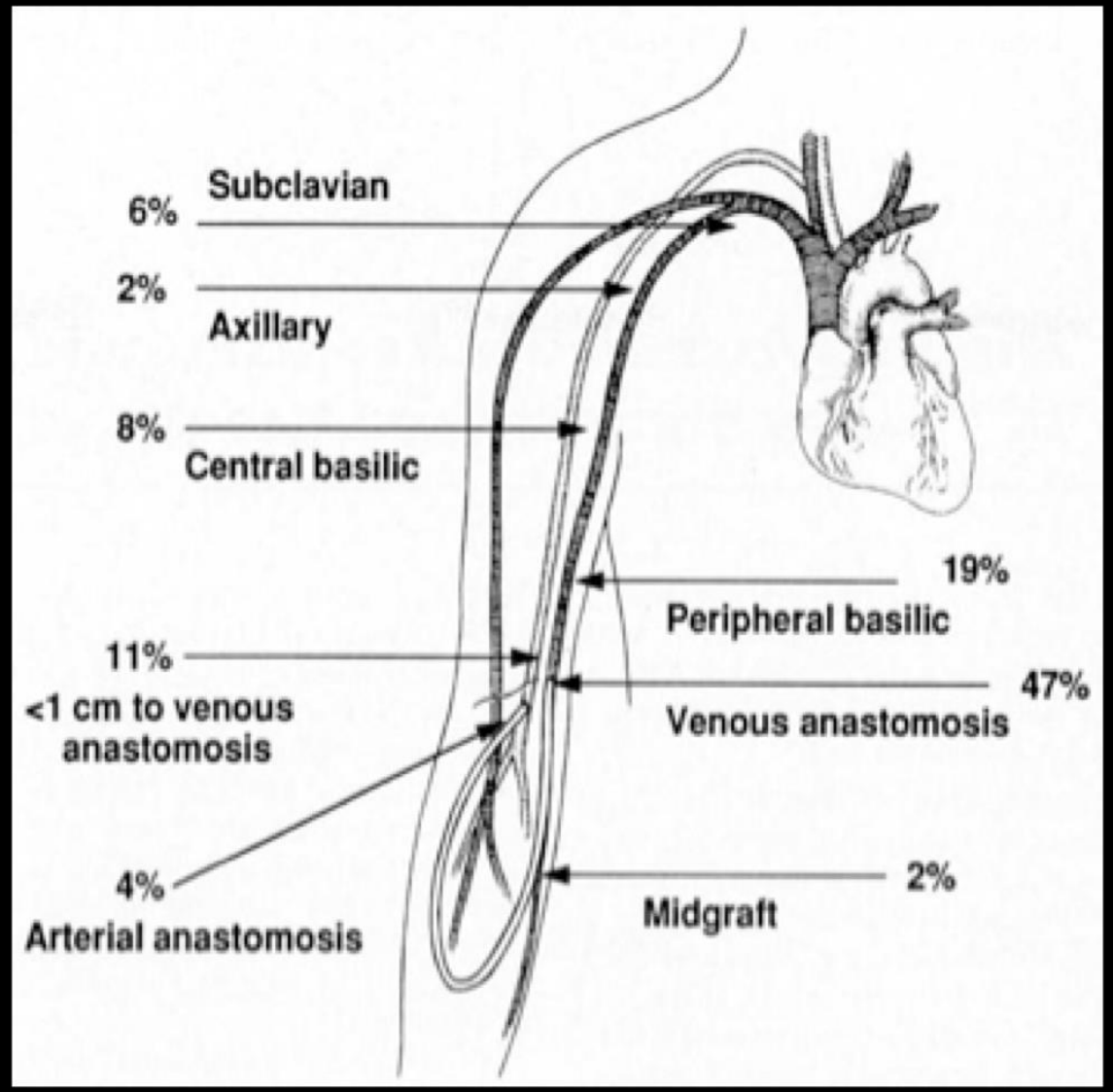
Rx – Juxta-anastomotic

- External Support Devices (Nitinol and absorbable)

Use of drug-coated balloons still unclear

Nephrol Dial Transplant 2000; 15:2029-2036

Location of Stenoses in Grafts



Courtesy TM Vesely

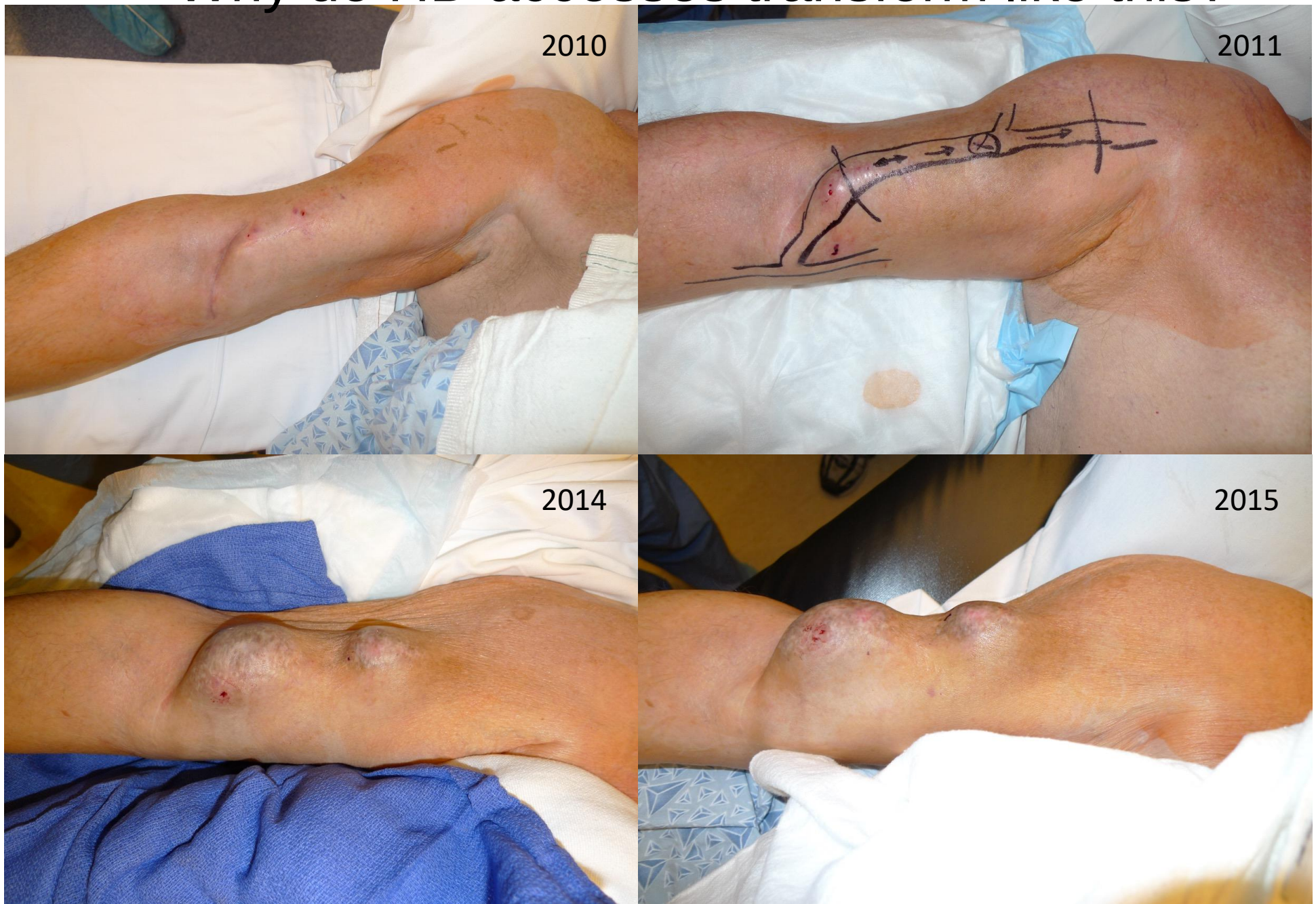
Rx – venous anastomosis

- Stent grafts are superior (2RTCs)

“Chronic Access Disease”

- pre-programmed sites of stenosis:
  - venous anastomotic stenosis (grafts) - AVG
  - cephalic arch - BC or pRC upper arm AVF
  - basilic swing point - tBB AVF
  - sites of side-branch ligations - cephalic vein accesses
  - juxta-anastomotic segment - RC AVF
- increase in flow and shear-stress increases arterial diameter…
- exposure to thrombus induces chronic scarring…
- stenoses recur after angioplasty…
- stent grafts are associated with turbulent flow at edges leading to deposition of “debris”…
- repeated needle insertions lead to enlargement of overlying skin coverage…

Why do HD accesses transform like this?



Question 3

What are the dominant drivers in aneurysm formation in dialysis accesses?

1 - Outflow stenosis
2 - Focal Needle insertions
3 - High inflow
4 - Gender and Genetics
5 - Race and Age

a. 1, 3, 5
b. 2, 3, 4, 5
c. 1, 2, 3
d. 1, 2, 3, 4, 5
e. 4, 5

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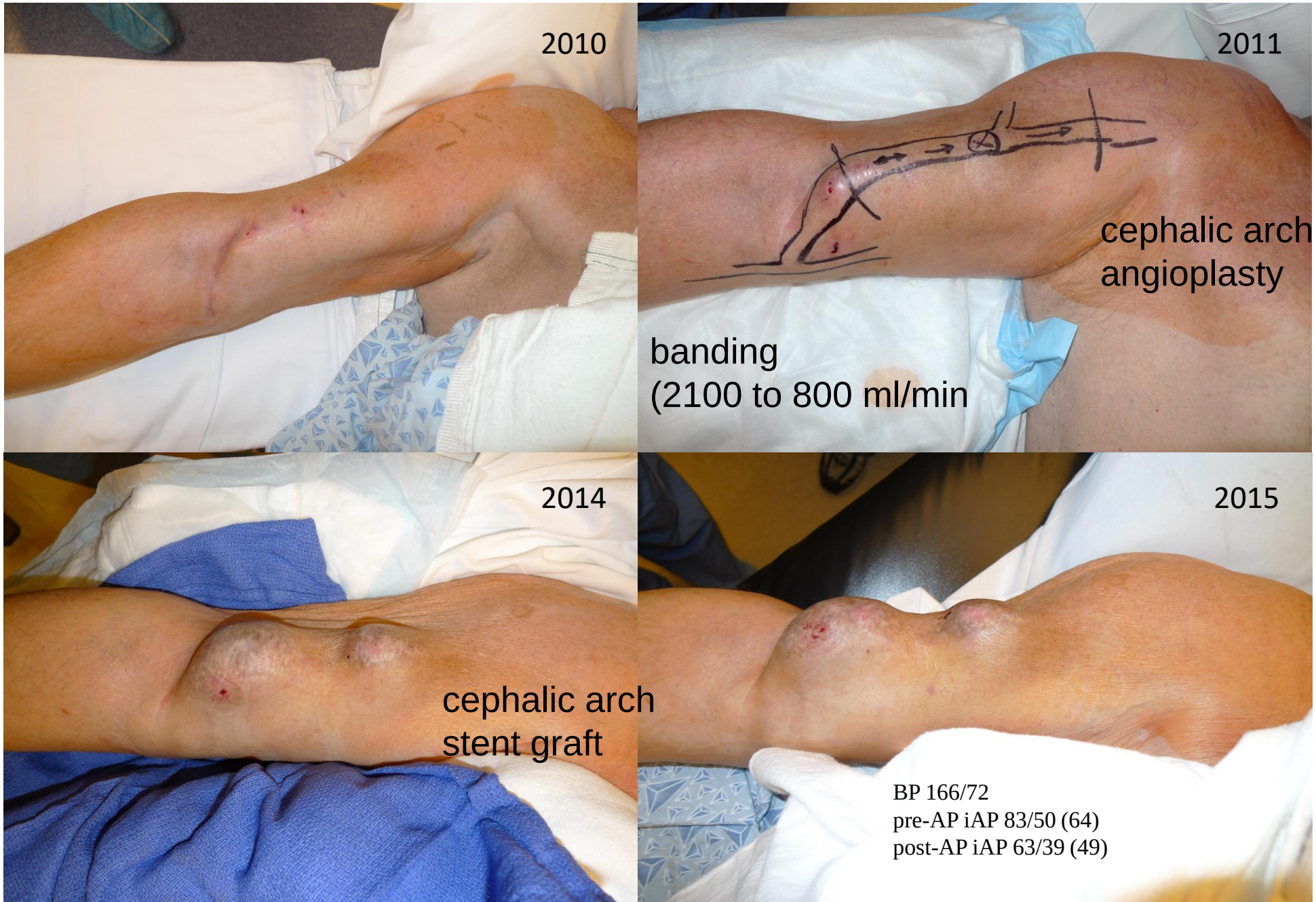
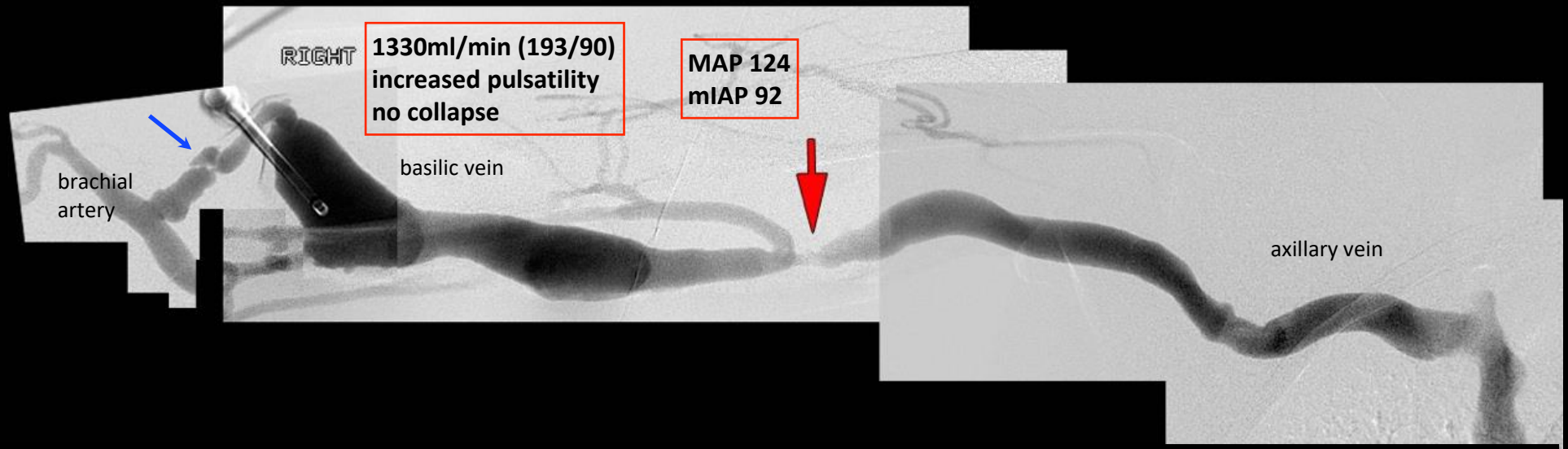
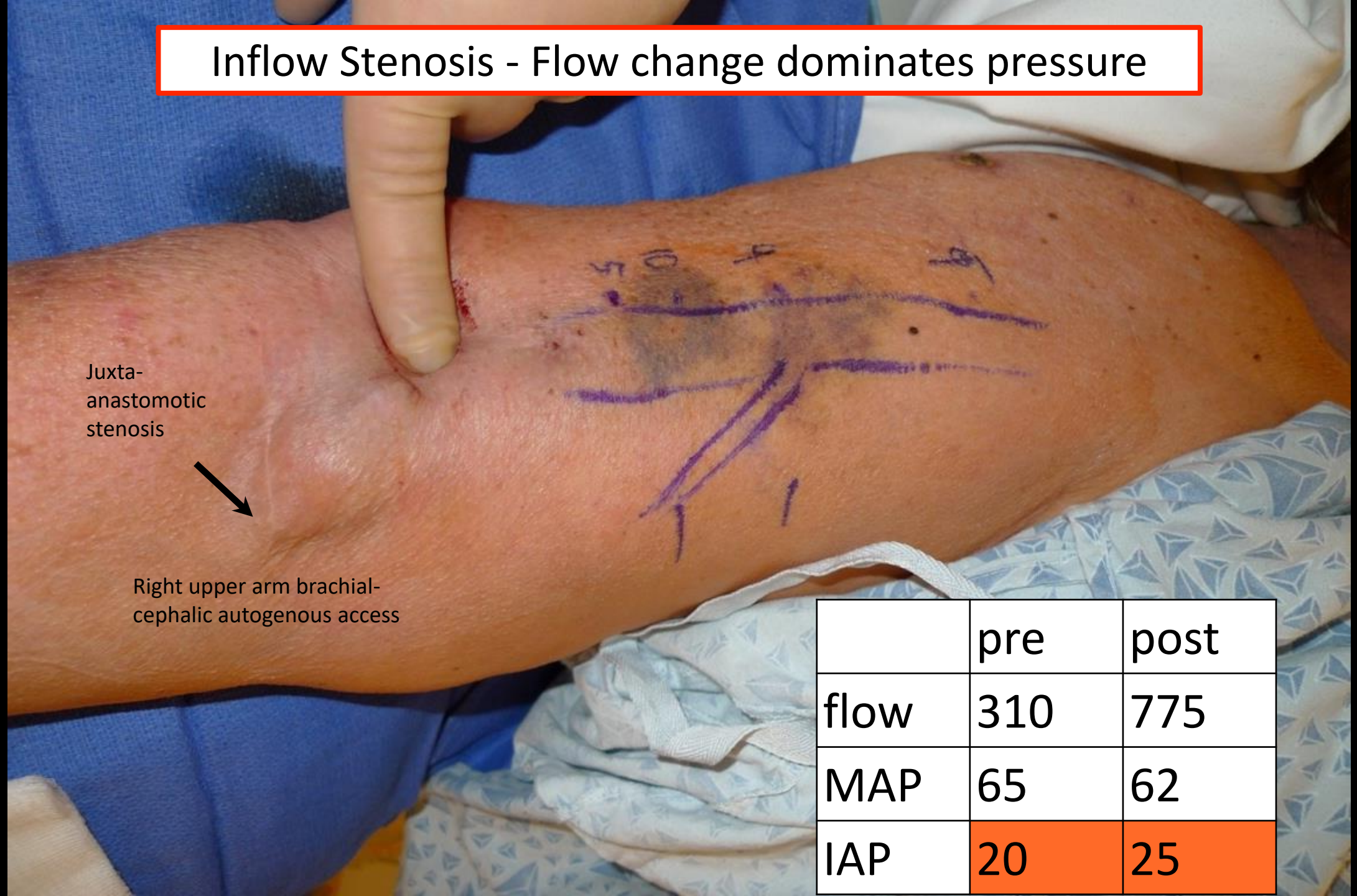
Intra-Access Pressures and Needle Insertion Site Aneurysm



Outflow stenosis: pressure change dominates flow



Inflow Stenosis - Flow change dominates pressure



	pre	post
flow	310	775
MAP	65	62
IAP	20	25

- BC-AVF created in 2007
- initiates dialysis in early 2014

- presents shortly thereafter with
  - ✓ shortness of breath
  - ✓ bleeding after needle removal
  - ✓ L hand numb, occ. painful

Question 4

What clinical condition best fits the presentation ?

1 - Shortness of breath
2 - Hand numbness and pain
3 - Bleeding after needle removal
4 - Initiation of dialysis 7 years after creation of AVF

a. CKD-related coronary heart disease
b. Advanced uremia (cardio-renal Syndrome)
c. Beta-2-microglobulin deposition disease
d. High flow dialysis access

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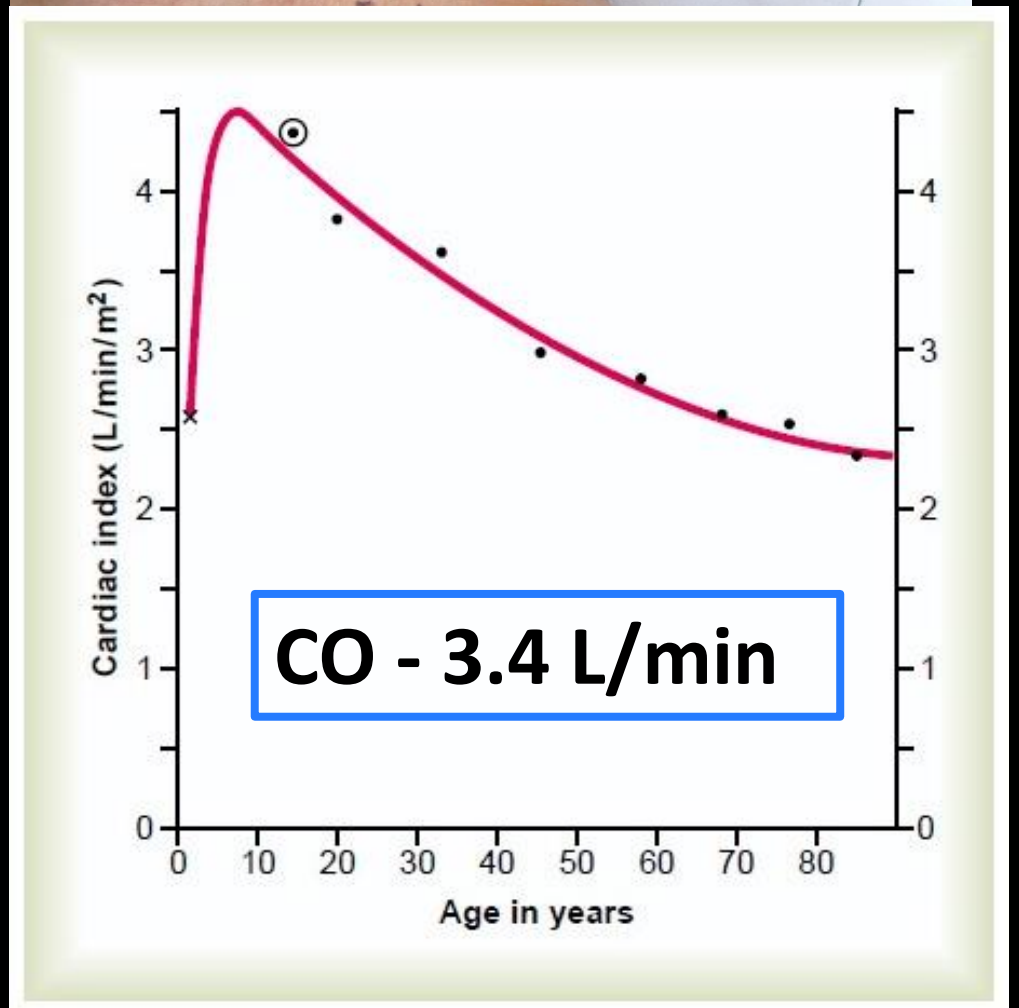


Figure 20–1

Cardiac index for the human being (cardiac output per square meter of surface area) at different ages. (Redrawn from Guyton AC, Jones CE, Coleman TB: Circulatory Physiology: Cardiac Output and Its Regulation. 2nd ed. Philadelphia: WB Saunders Co, 1973.)

77-year old Caucasian Women

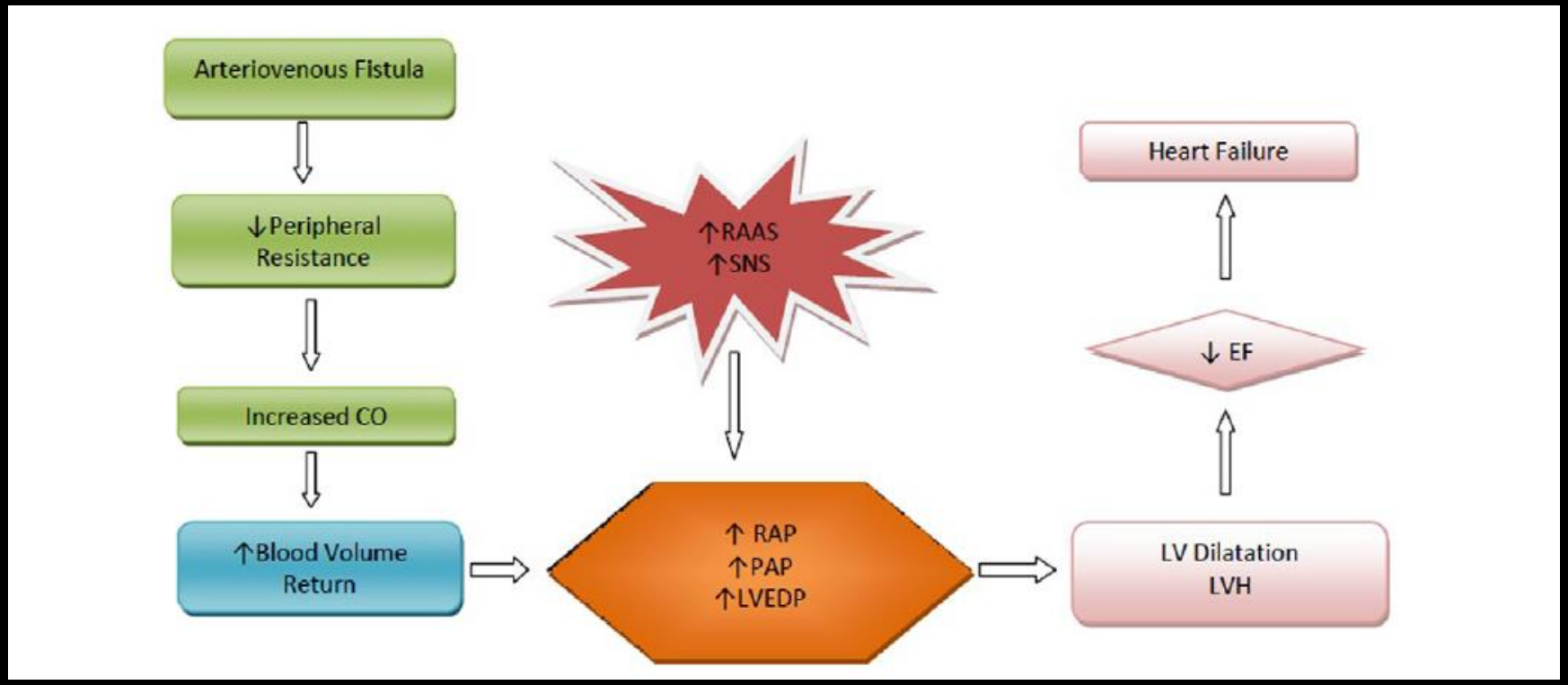
- BC-AVF created in 2007
- initiates dialysis in early 2014

- presents shortly thereafter with
  - ✓ shortness of breath
  - ✓ bleeding after needle removal
  - ✓ L hand numb, occ. painful

Access flow 2,400 ml/min

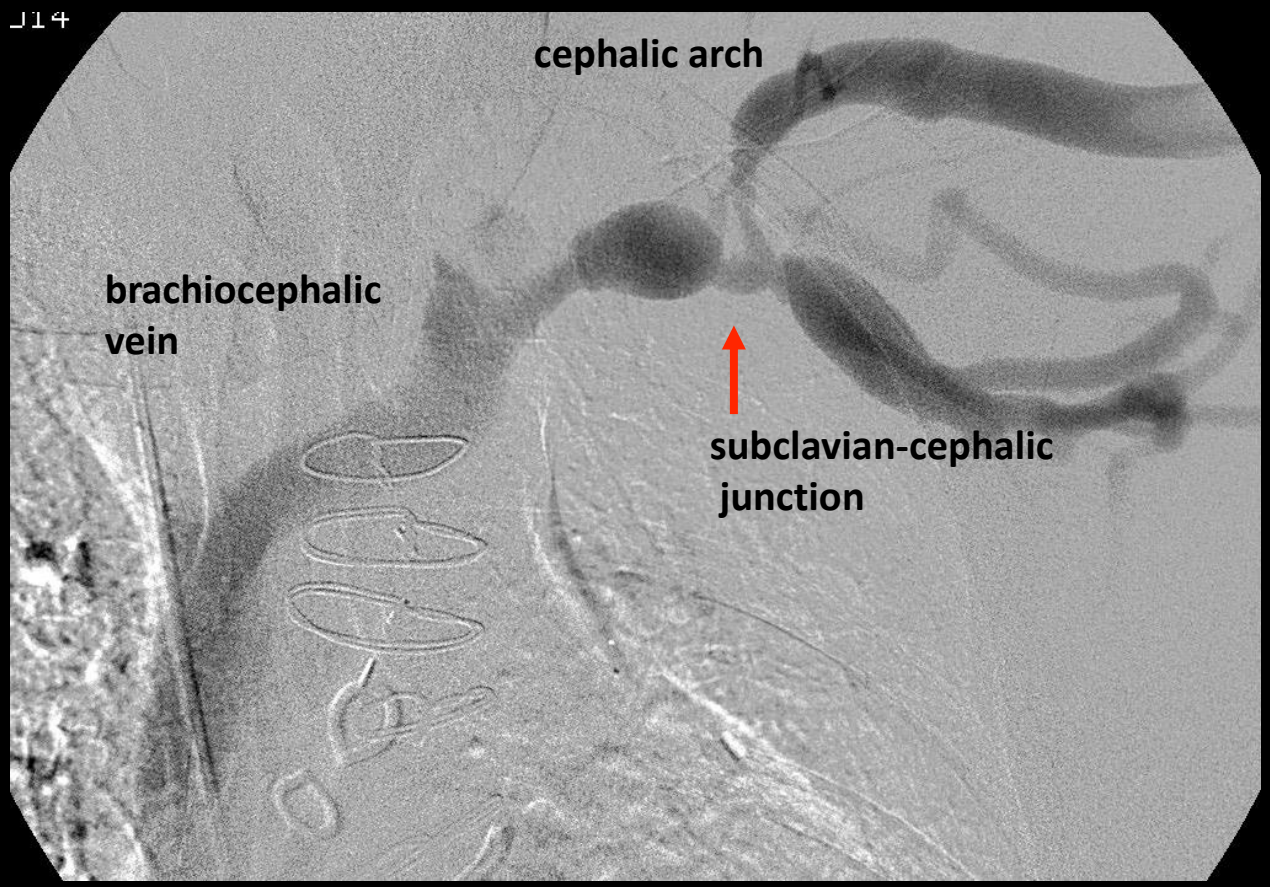
Dose of Dialysis Access

High output cardiac failure

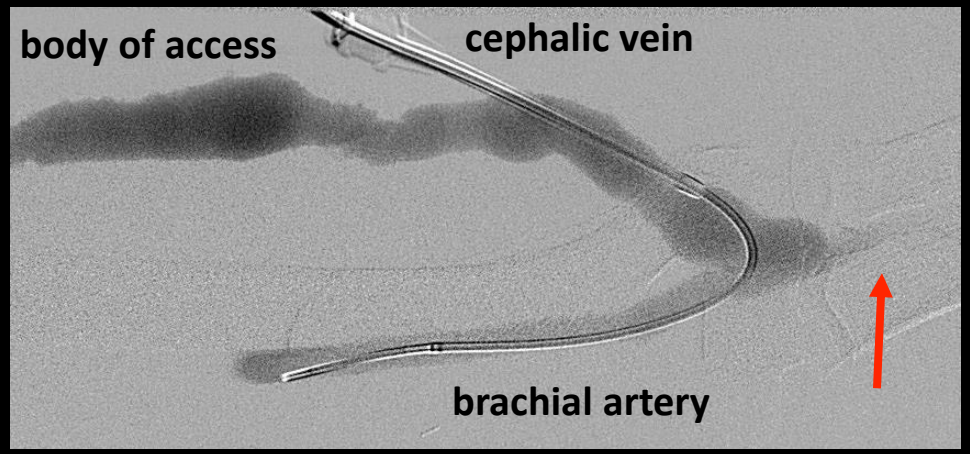


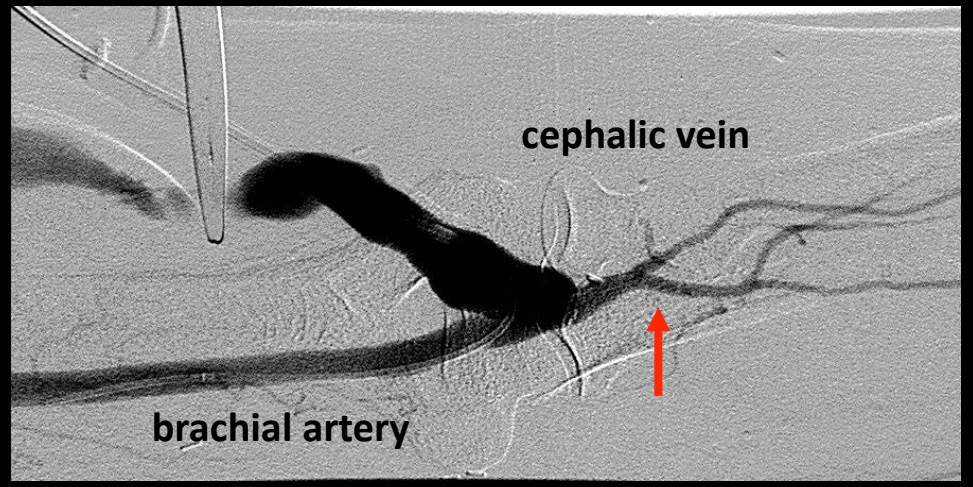
↑ pulmonary artery pressures
right atrial pressures
left ventricular end-diastolic pressures

Inflow-Outflow Balance



Treatment with angioplasty and stent graft placement



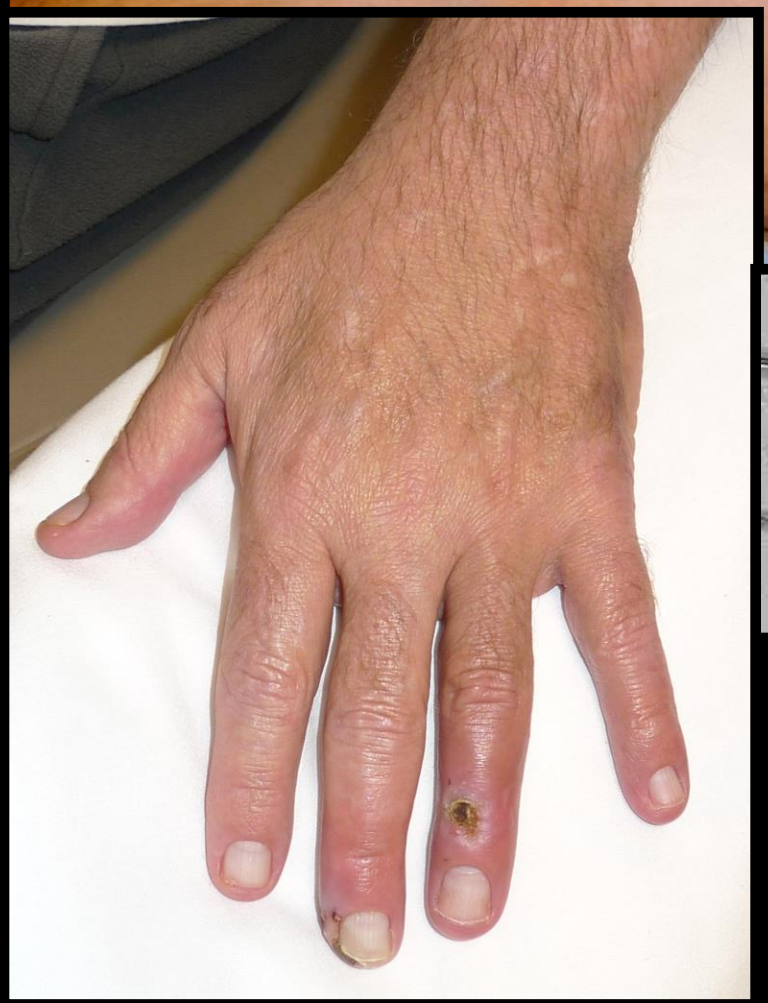


Treatment with inflow banding

Case 2

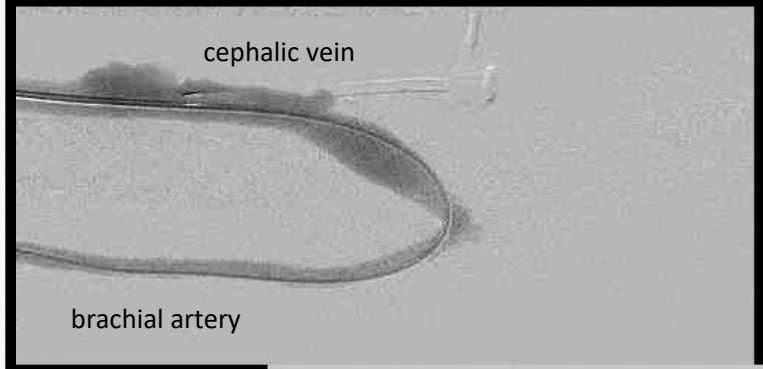
DMII, HTN, CAD, PVD

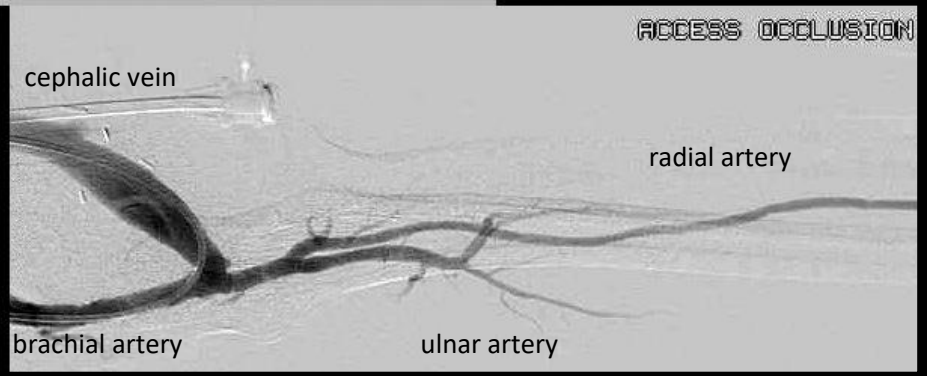
"STEAL"



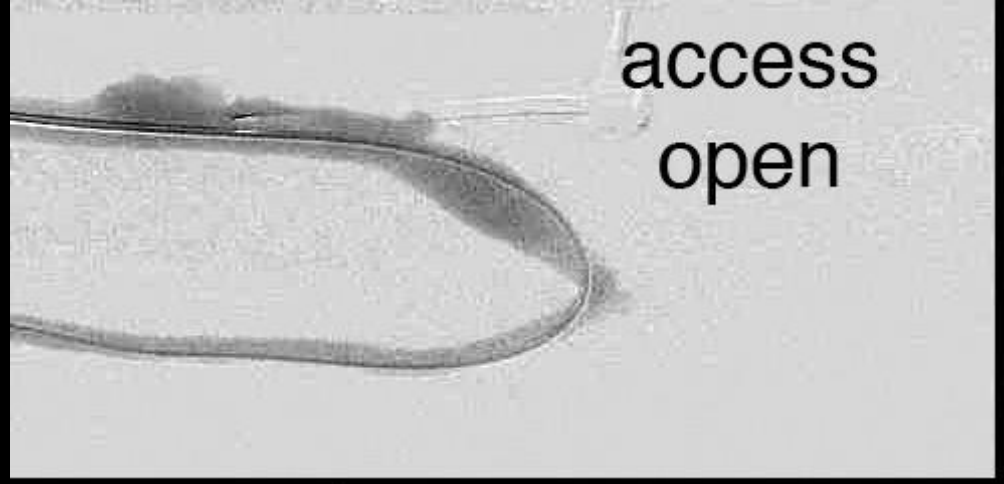
flow 1400ml/min

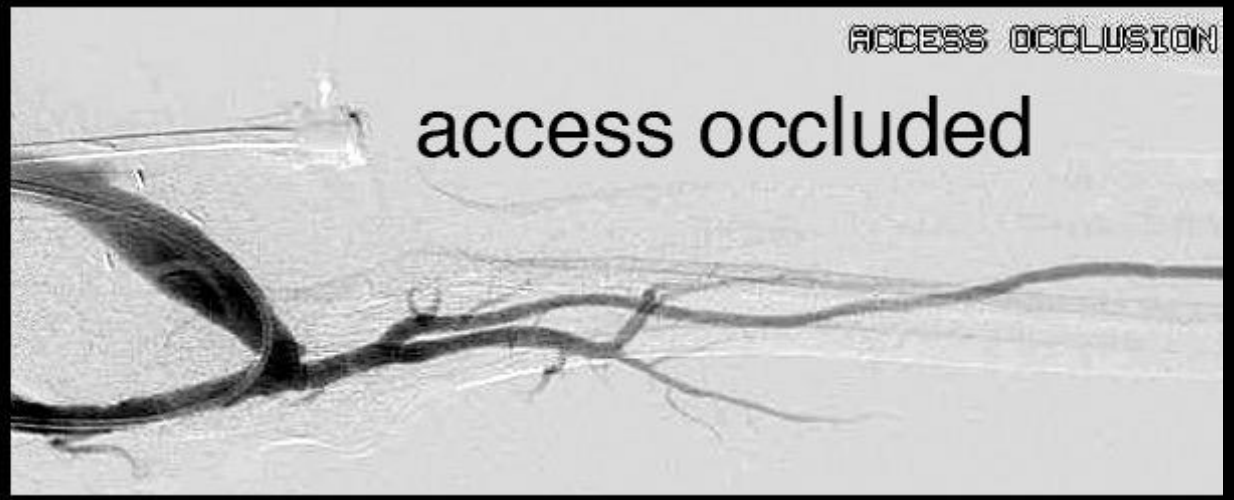
@blood pressure 146/65



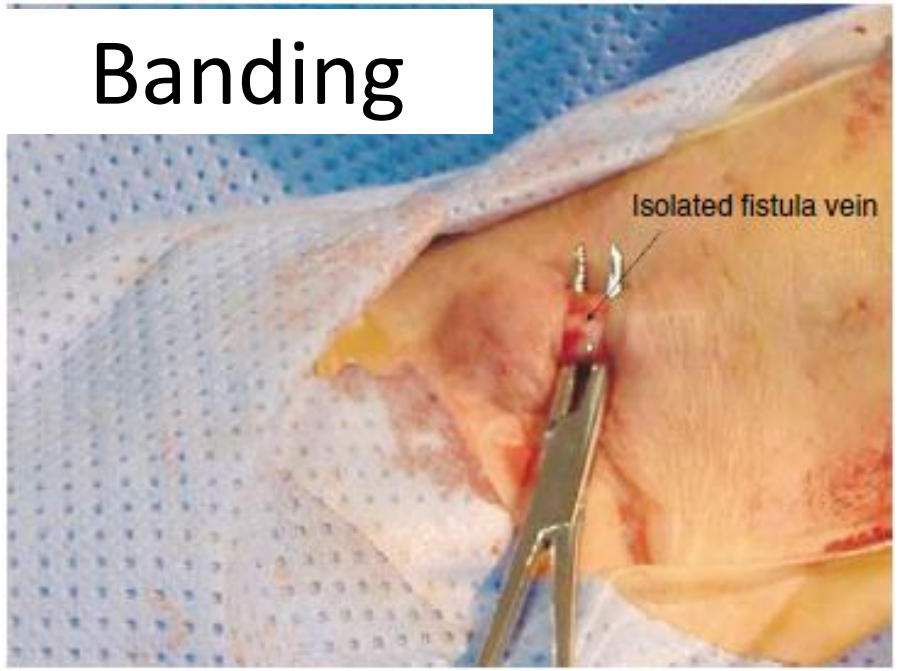


Case 2



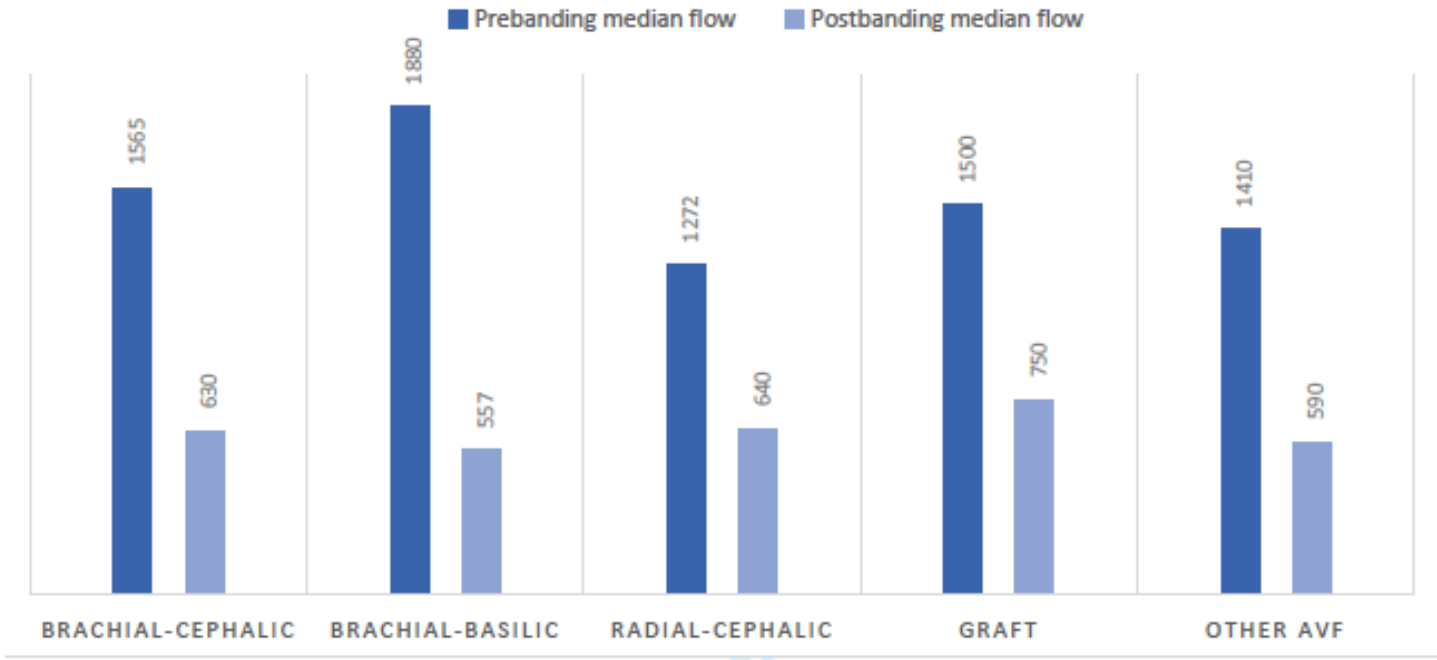


Banding



Banding is effective for inflow control

(Soo Hoo, Scully J Vasc Access 2022)



n = 180 **n = 37** **n = 41** **n = 27** **n = 12**

- **297 patients, 398 banding procedures**
- **Indication: Flow Imbalance 222 (51%), Ischemic Steal 134 (34%), Overt Heart Failure 42 (11%)**
- **30-thrombosis rate 3.8%, re-banding @ 1 year 14% (median 134 days)**

L BC-AVF 2008 with 2nd interposition biograft in 2017

L BC-AVF in 1995 with continuous self-cannulation

How does the physical exam likely differ?

Left

Right

Question 5

What do you expect for the physical exam?

1 - pulsatility	increased, normal, decreased
2 - thrill	location; continuous, discontinuous
3 - flow murmur	pitch; continuous, discontinuous
4 - augmentation	absent, weak, moderate, strong
5 - collapse against gravity	none, partial, complete

a. Left – Pulsatility increased, outflow thrill

b. Left – Pulsatility increased, complete collapse

c. Right – Increased pulsatility, juxta-anastomotic thrill

d. Right – Increase pulsatility, no collapse

Question 5

What do you expect for the physical exam?

1 - pulsatility	increased, normal, decreased
2 - thrill	location; continuous, discontinuous
3 - flow murmur	pitch; continuous, discontinuous
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b. Left – Pulsatility increased, complete collapse

c. Right – Increased pulsatility, juxta-anastomotic thrill

d. Right – Increase pulsatility, no collapse

Pulsatility (increased)

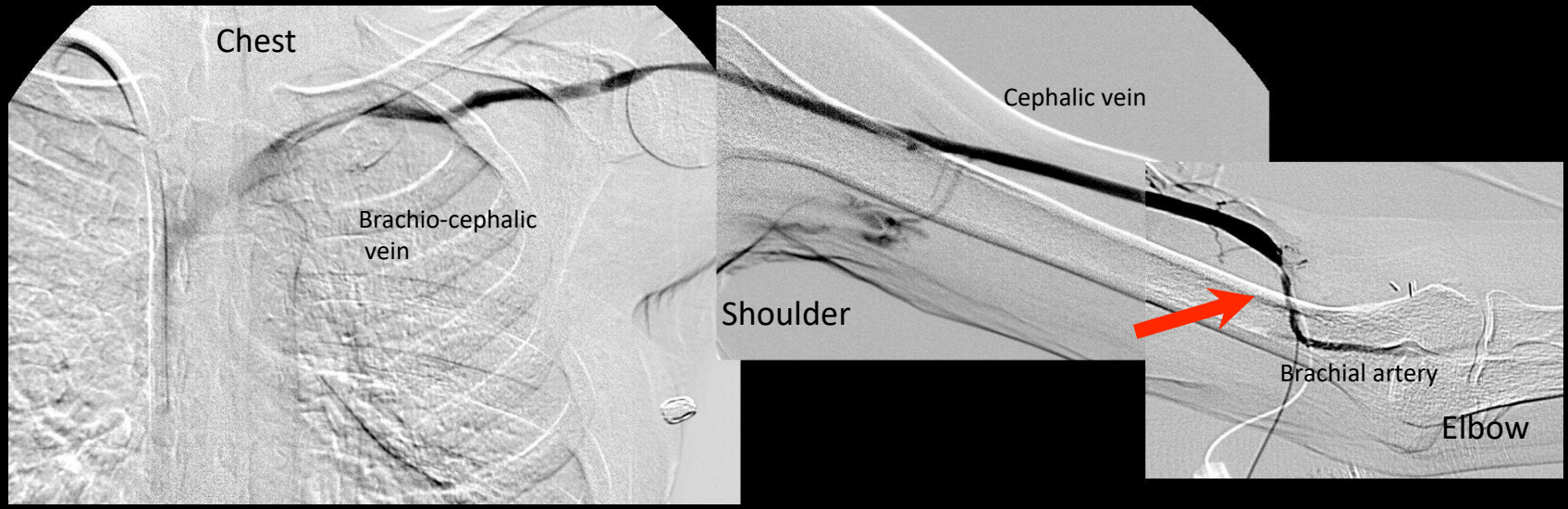
Non-maturing left upper arm autogenous brachial-cephalic access

juxta-anastomotic stenosis

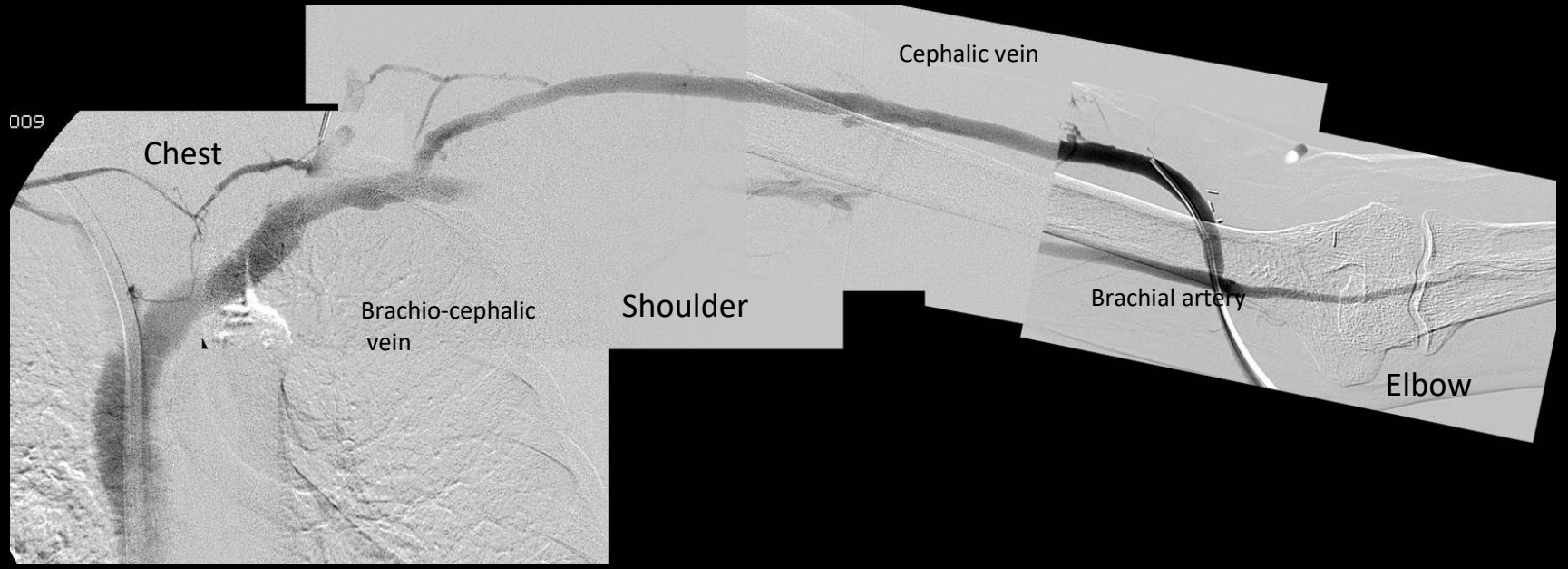
1. Increased pulsatility at anastomosis
2. Thrill just after anastomosis
3. Diminished augmentation
4. Discontinuous flow murmur in juxta-anastomotic segment

Left upper arm autogenous brachial-cephalic access 7/27/09

9/25/09 - flow <400ml/min



10/8/09 - flow 1100ml/min



Insufficient Augmentation

Successful Augmentation

Segmental Sidebranch Ligation - Functional Stick Zone

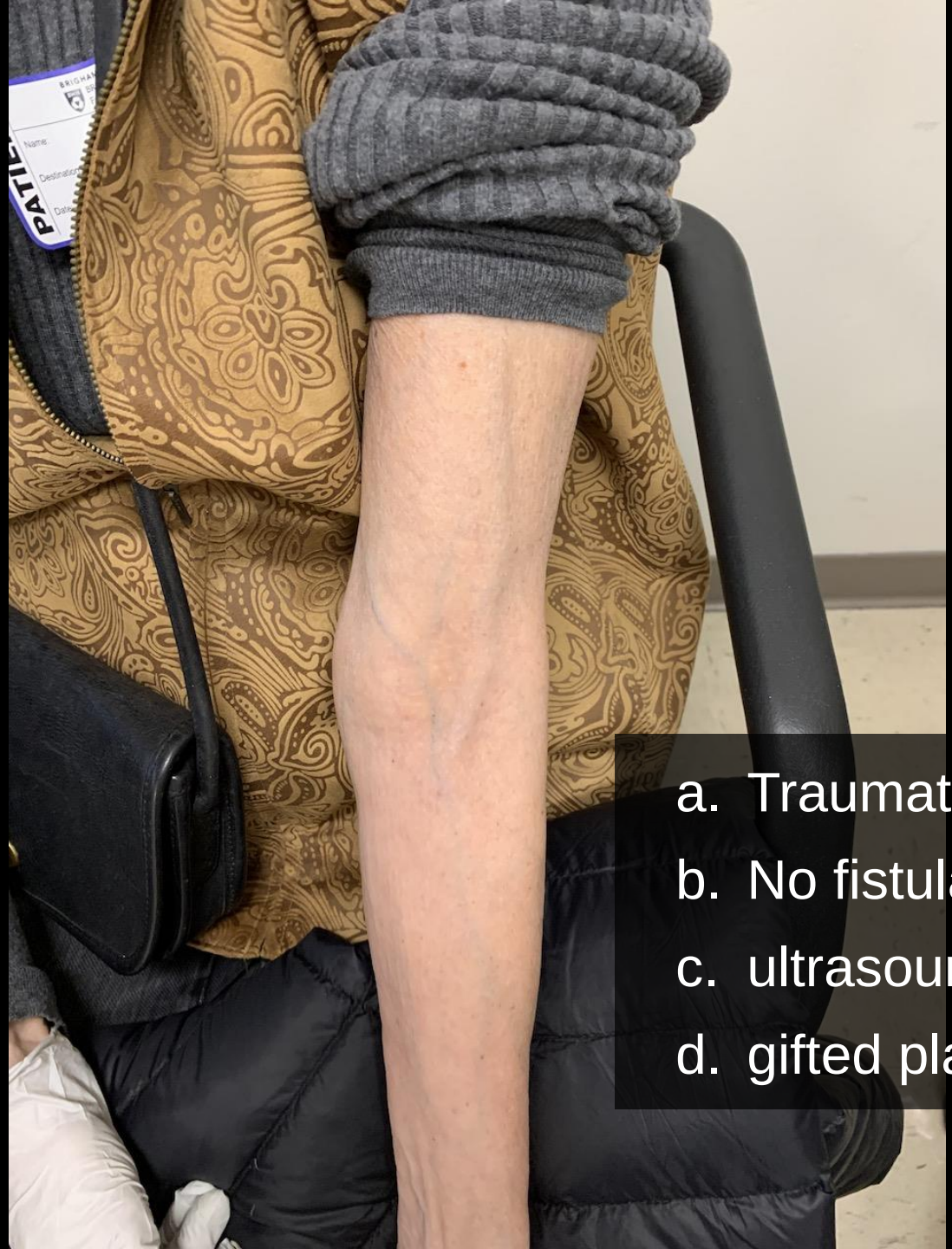
Segmental Sidebranch Ligation - Functional Stick Zone

63-year-old ESRD patient with left forearm autogenous radial-cephalic access created 15 years ago

Arm Elevation

increase pulsatility
thrill @ outflow stenosis
discontinuous flow murmur
moderate-strong augmentation
no collapse (AVG segment)

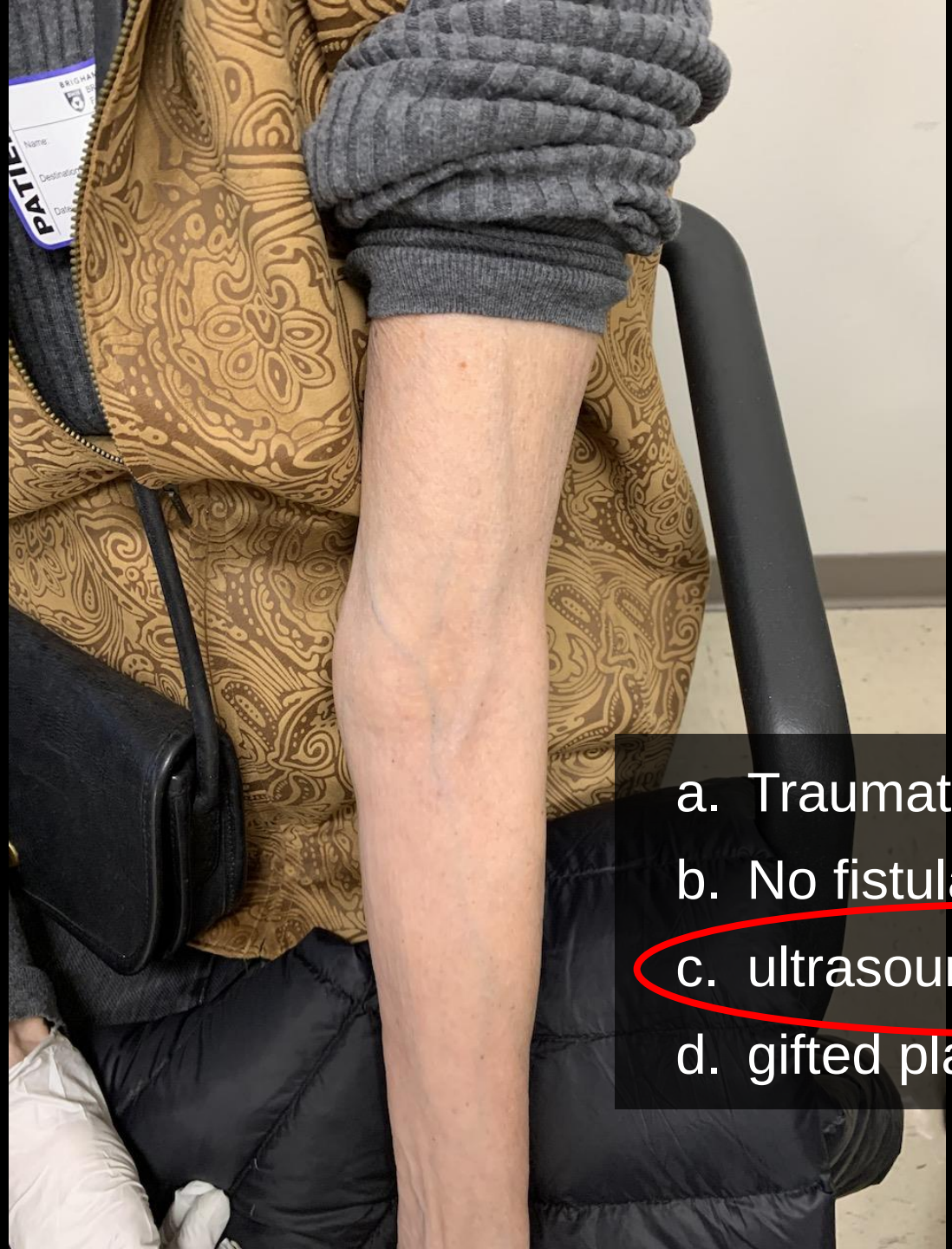
normal pulsatility
thrill @ juxta-anastomosis
continuous flow murmur
moderate augmentation
complete collapse



Question 6

What kind of fistula is this?

a. Traumatic after childhood forearm fracture
b. No fistula - former olympic rower
c. ultrasound guided fistula
d. gifted plastic and vascular surgeon



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endo-AVF Revolution

Usable Cannulation-Zone

- Redirect flow to cephalic vein
  - Band or ligate brachial vein
  - Limit / prevent brachial (deep) venous outflow by coil or ligation
  - New brachial-cephalic anastomosis
- Transpose basilic vein
- Interposition forearm loop graft

Anatomic Type

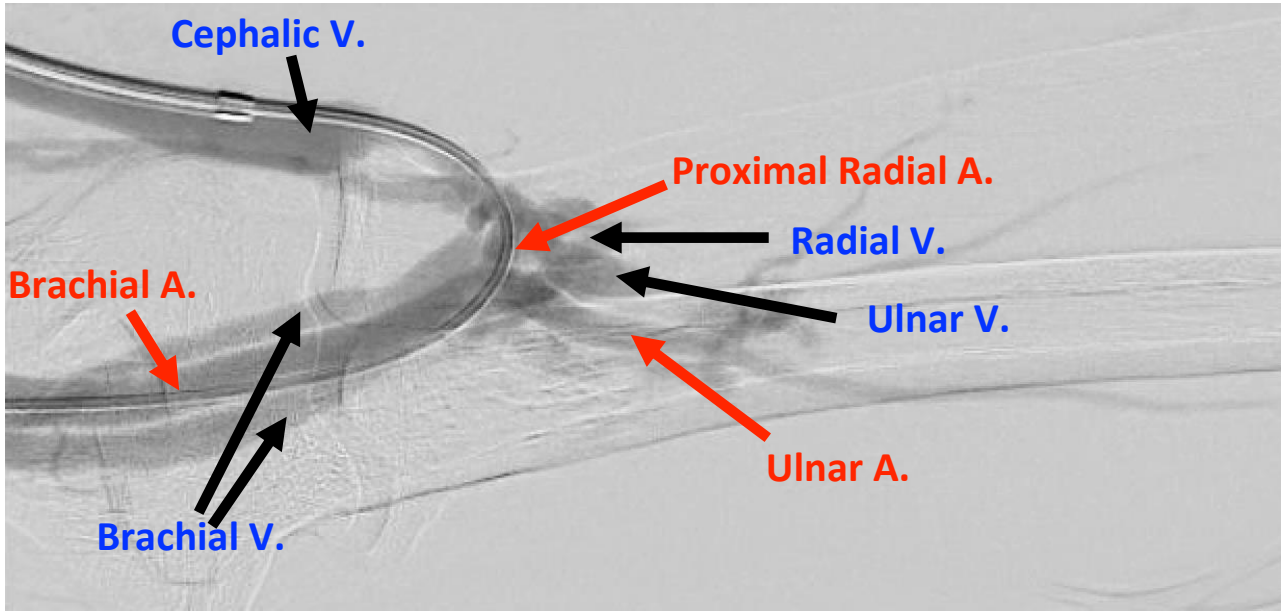
Type 1 - cephalic, basilic, and brachial

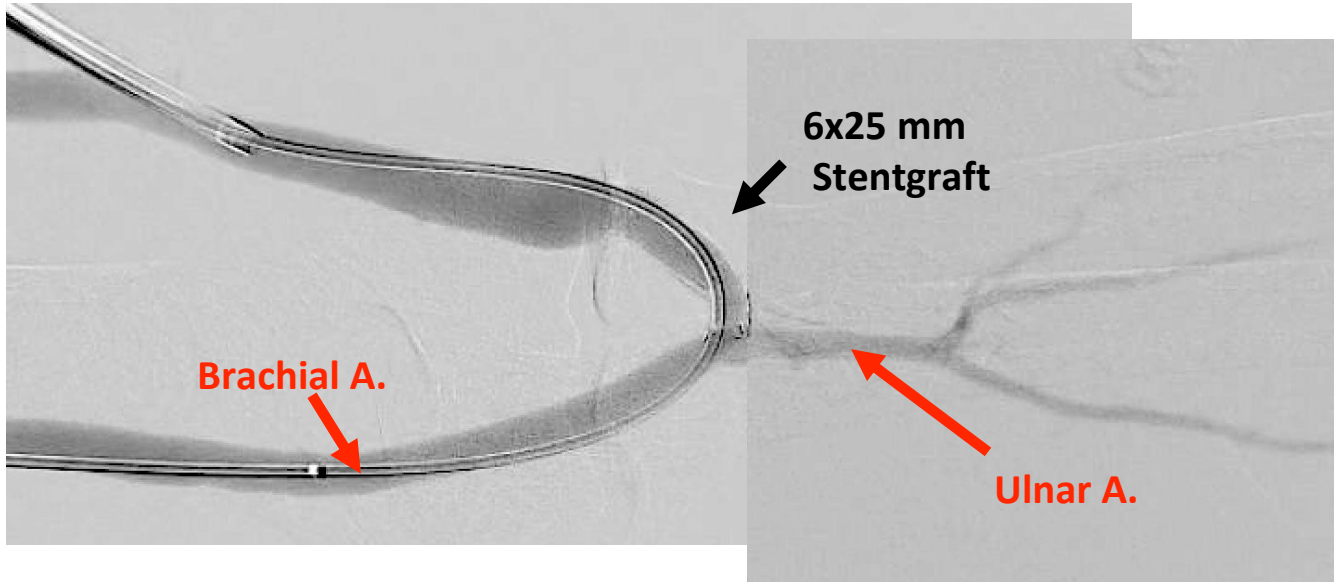
Type 2 - cephalic and brachial

Type 3 - basilic and brachial

Type 4 - brachial alone

Juxta-anastomotic Stent-Graft



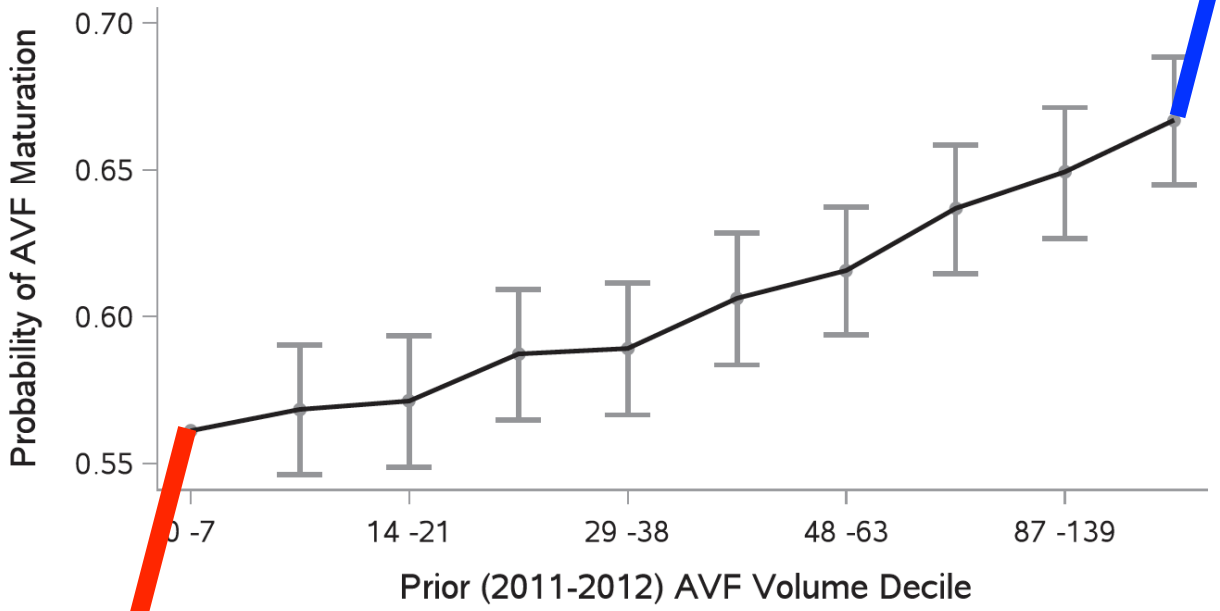


US National Access Landscape - Surgeons

Case Volume correlates with Successful Maturation **(Shahinian AJKD 2020)**

85 %

top 9.7 %



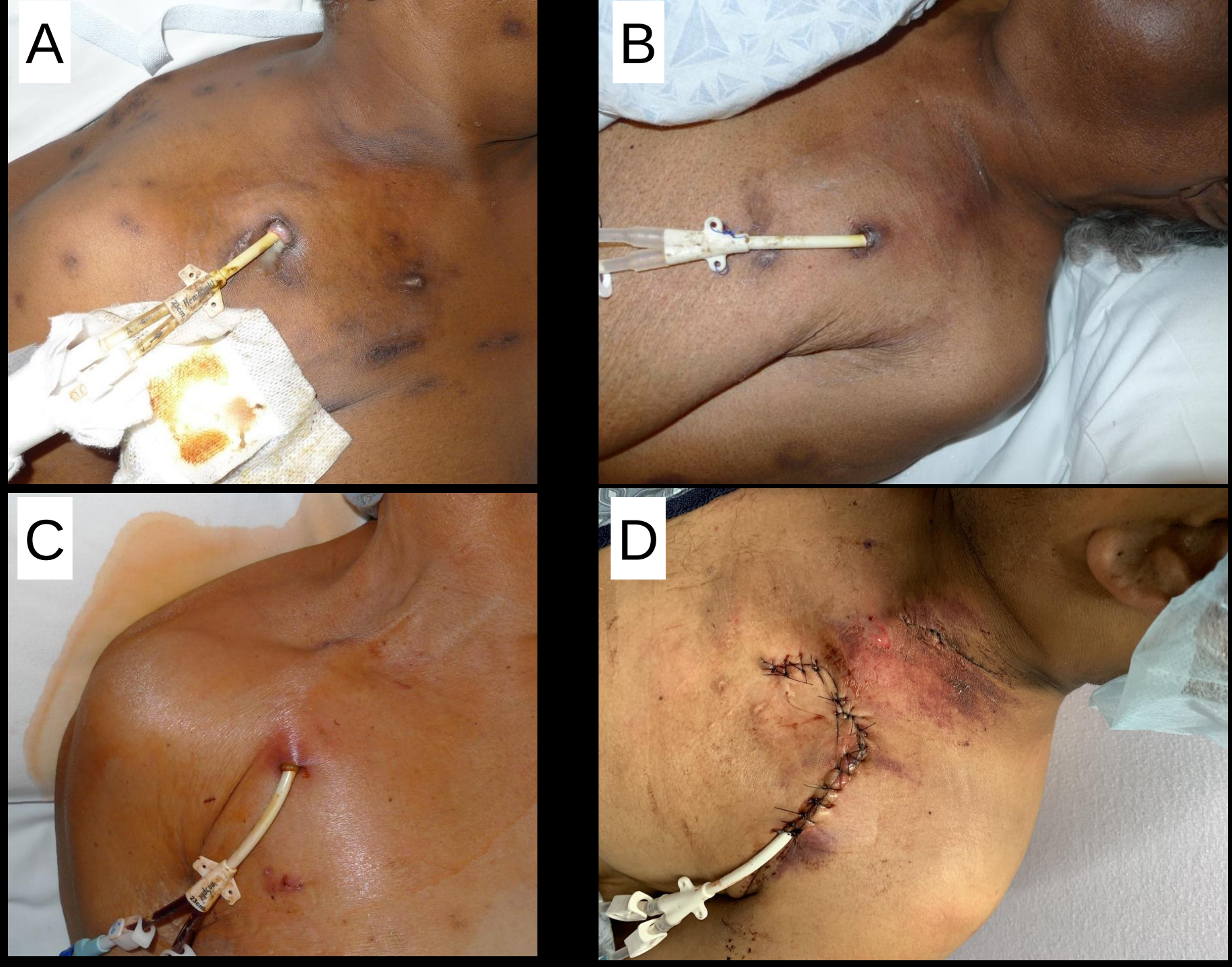
bottom 6.9 %

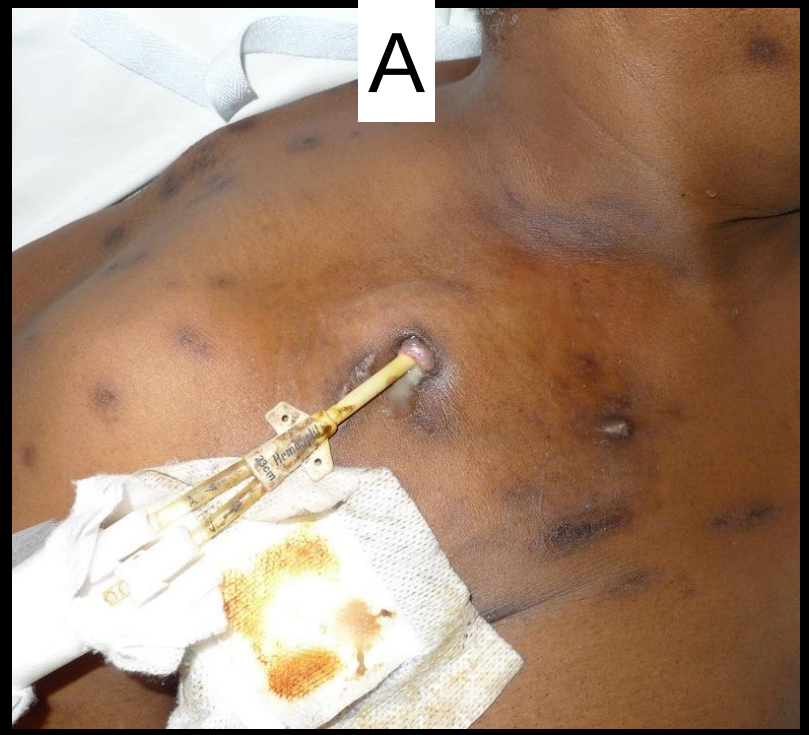
23%

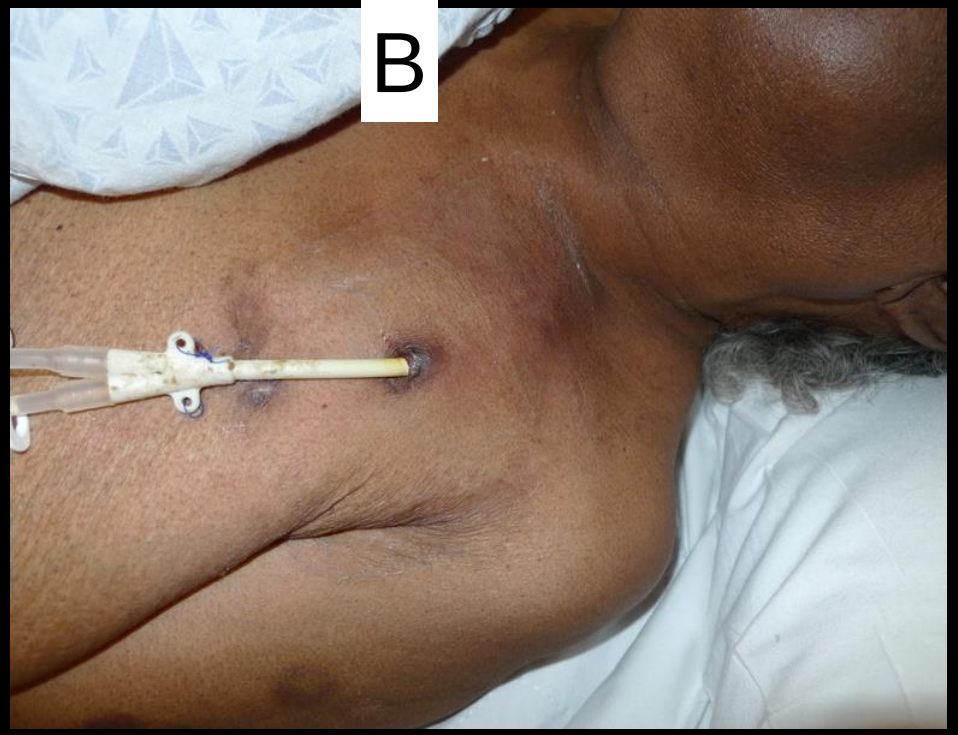
- **2,770 surgeons who placed > 5 AVFs in 2013 and 2014, total 49,826 AVFs in CMS patients**
- **Maturation Success does not plateau**
- **Extremes: top 243 (9.7%) surgeons 85%, bottom 174 (6.9 %) 23 % success rate, ~ 1,500 surgeons < 5 AVF/y**
- **Important to know:**
  - **2016 - 1,251 surgeons placed more than 10 access (AVG or AVF), total 32,767 accesses**
  - **2016 - 3,071 surgeons placed an additional 27,035 accesses**

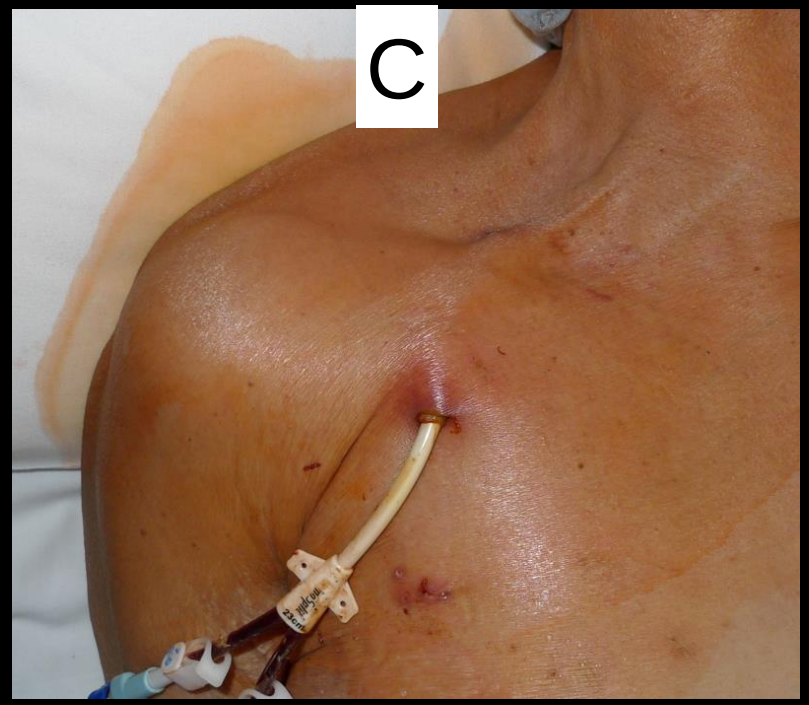
"Develop" Surgeons

- Endo-support
- Team integration
- See in HD unit access use


A
B
C
D







Question 7

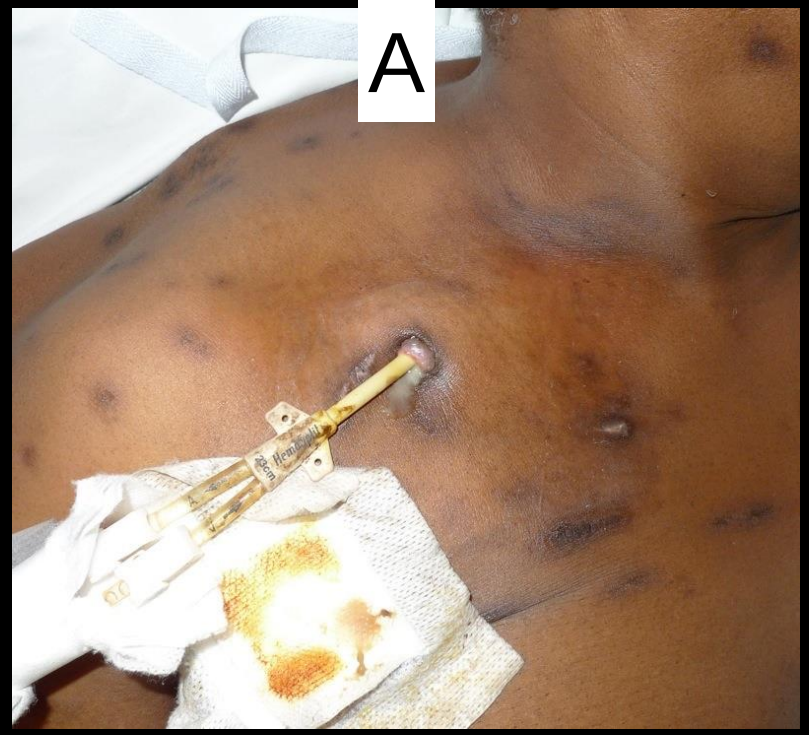
1. Exposed Cuff
2. Operator without catheter experience
3. Tunnel Infection
4. Exit Site Infection

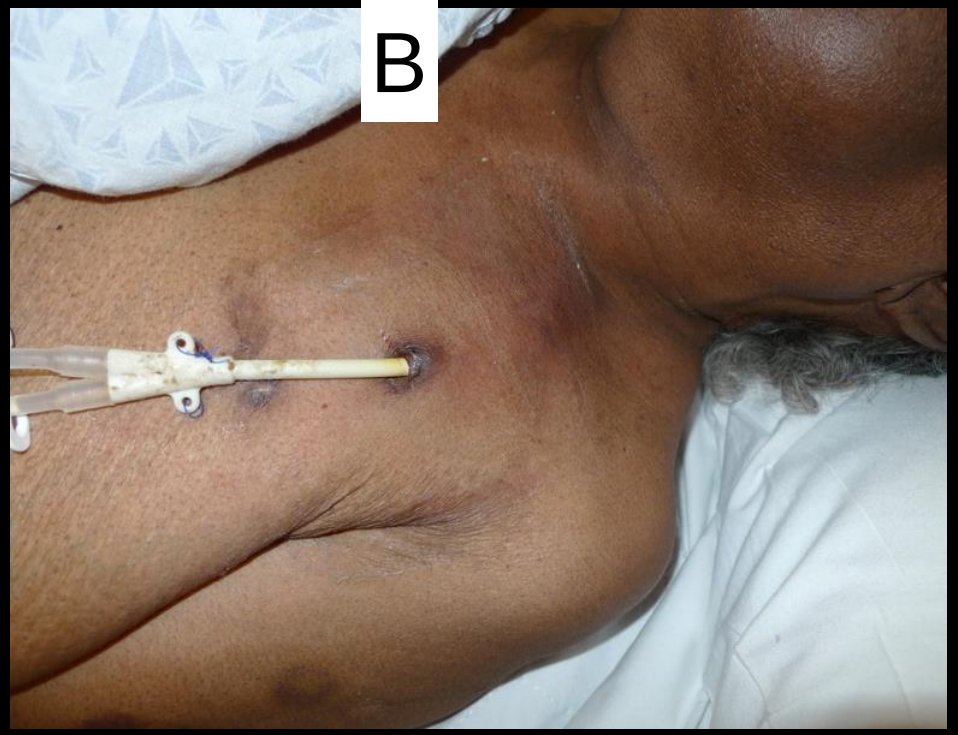
A. 1B, 2C, 3A, 4D

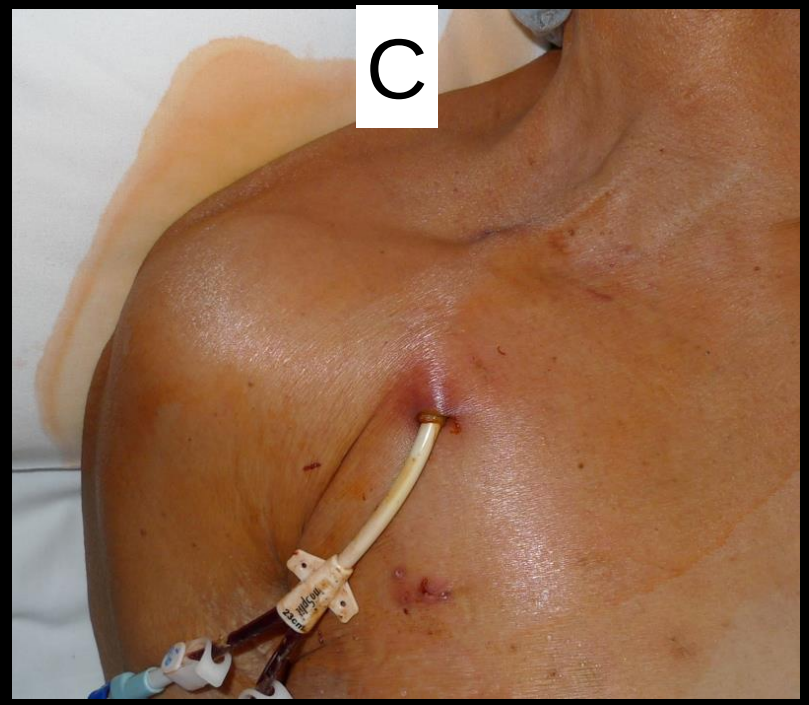
B. 1C, 2B, 3D, 4A

C. 1C, 2D, 3B, 4A

D. 1A, 2D, 3B, 4C







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A. 1B, 2C, 3A, 4D

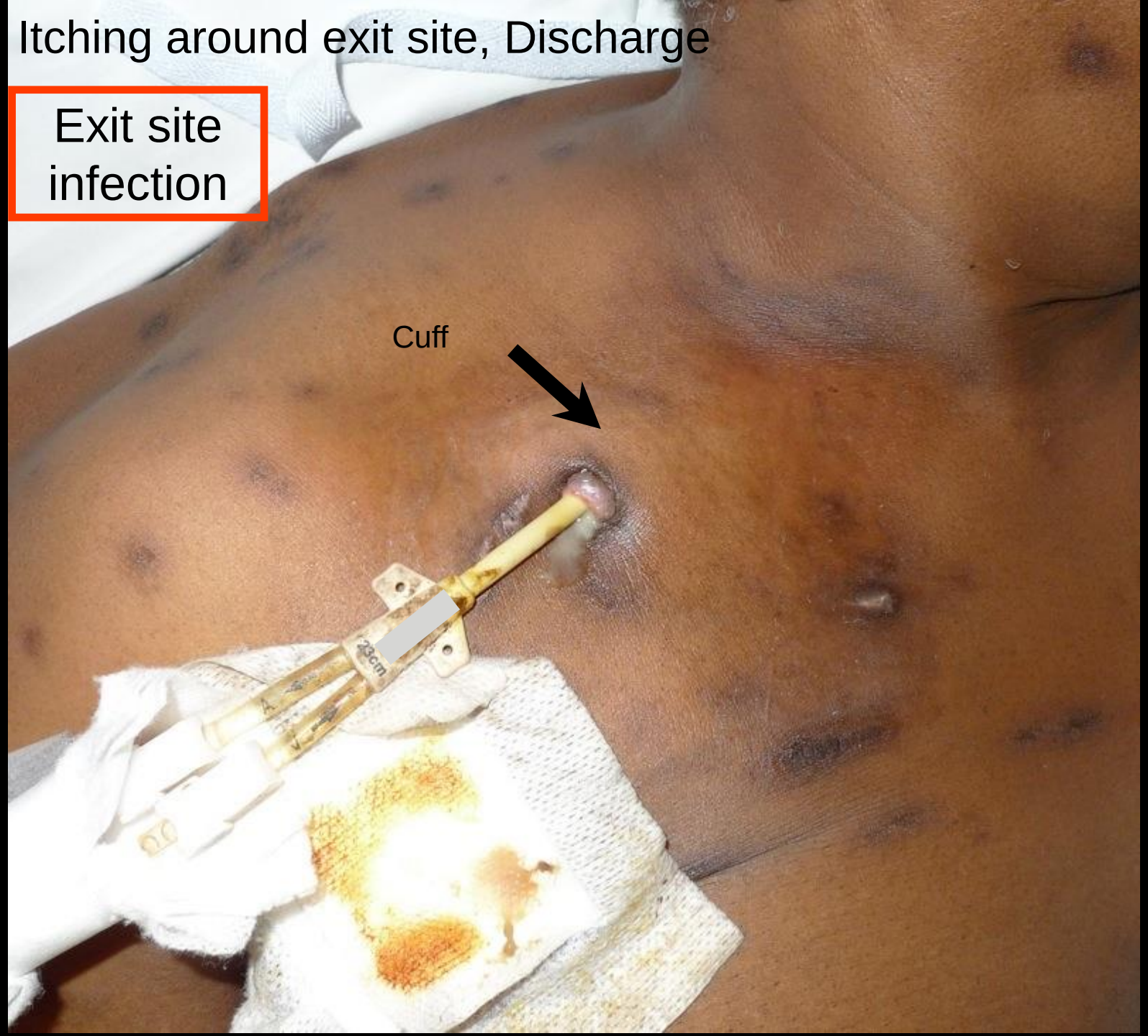
B. 1C, 2B. 3D, 4A

C. 1C, 2D, 3B, 4A

D. 1A, 2D, 3B, 4C

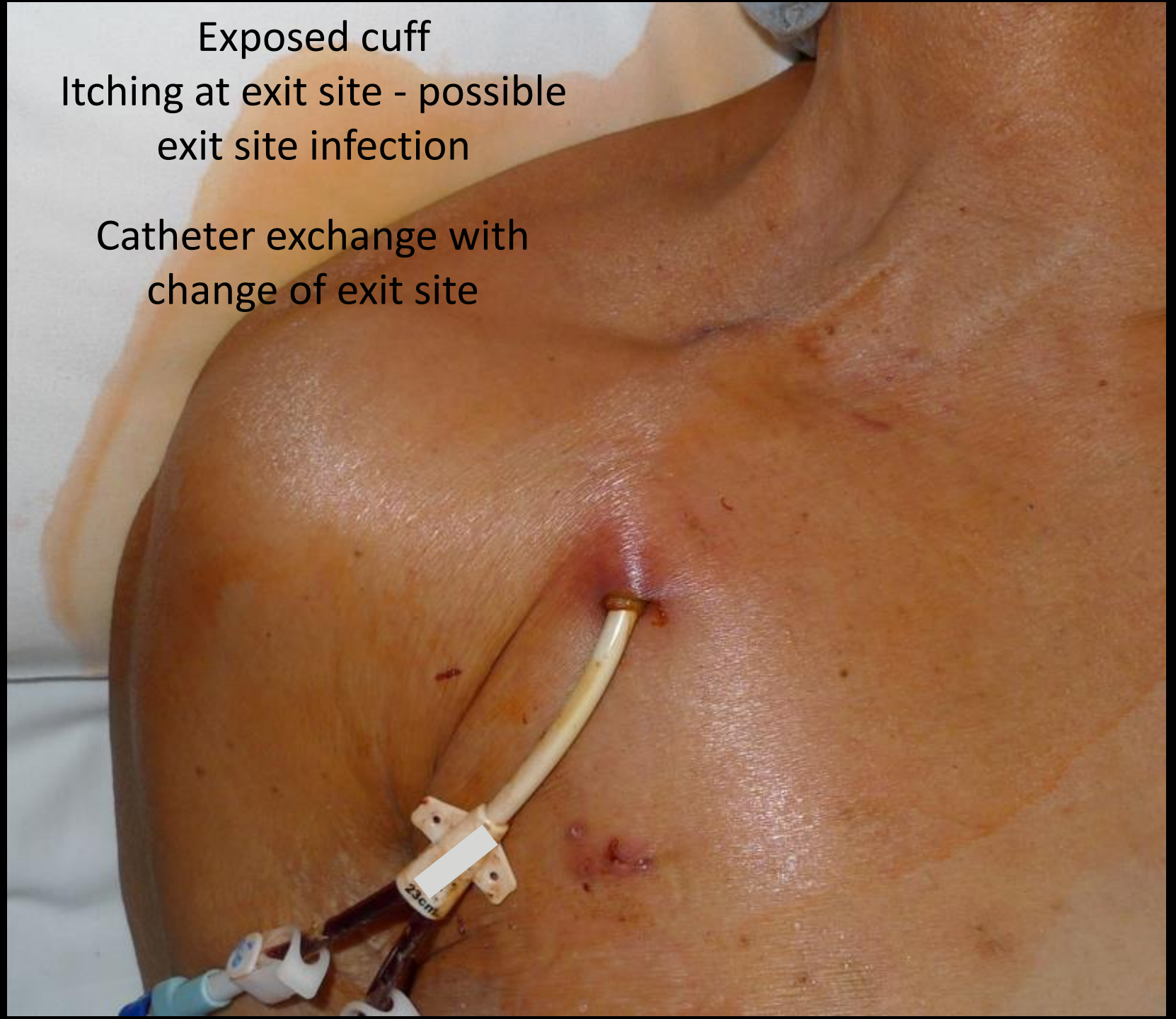
Itching around exit site, Discharge

Exit site infection



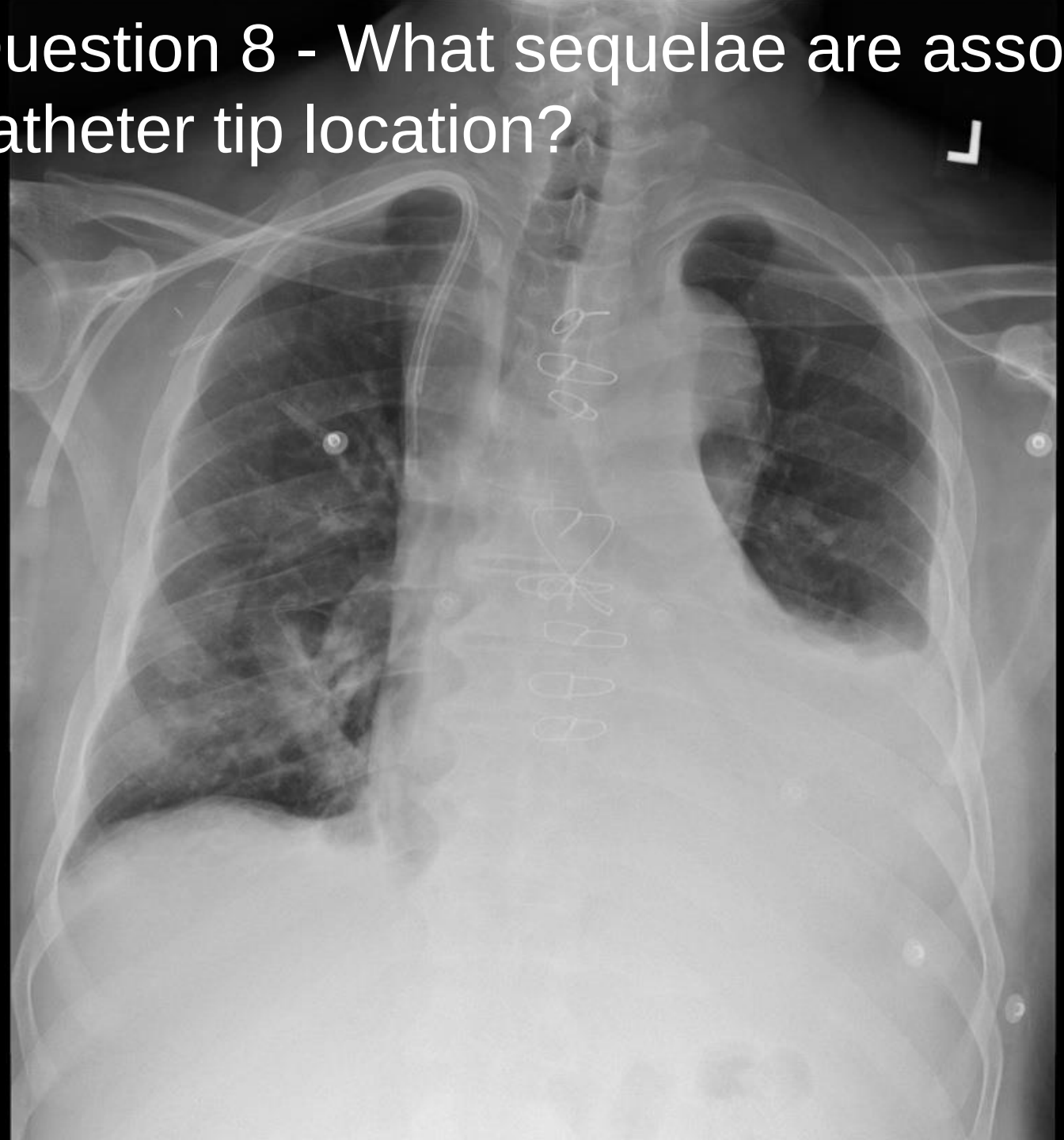

Change in mental status
Tender area over clavicle
Erythema along tunnel


Tunnel infection


Exposed cuff
Itching at exit site - possible exit site infection
Catheter exchange with change of exit site


S
R
L
I
Vitrea®
Zoom:221%
Filter: Medium 15/25
W/L:500/277
Segmented
VR: Multi Color

Question 8 - What sequelae are associate with this catheter tip location?



65-year-old African-American man with DMII and HTN initiates dialysis with a right internal jugular vein catheter on 6/15/2007

Question 8 - What sequelae are associated with this catheter tip location?

1 - catheter dysfunction
2 - central vein stenosis
3 - infection
4 - dialysis access arm edema
5 - fibrinous sheath formation

a. 1, 3, 4
b. 1, 2, 3
c. 1, 2, 4
d. 2, 3, 4
e. 2, 3, 5

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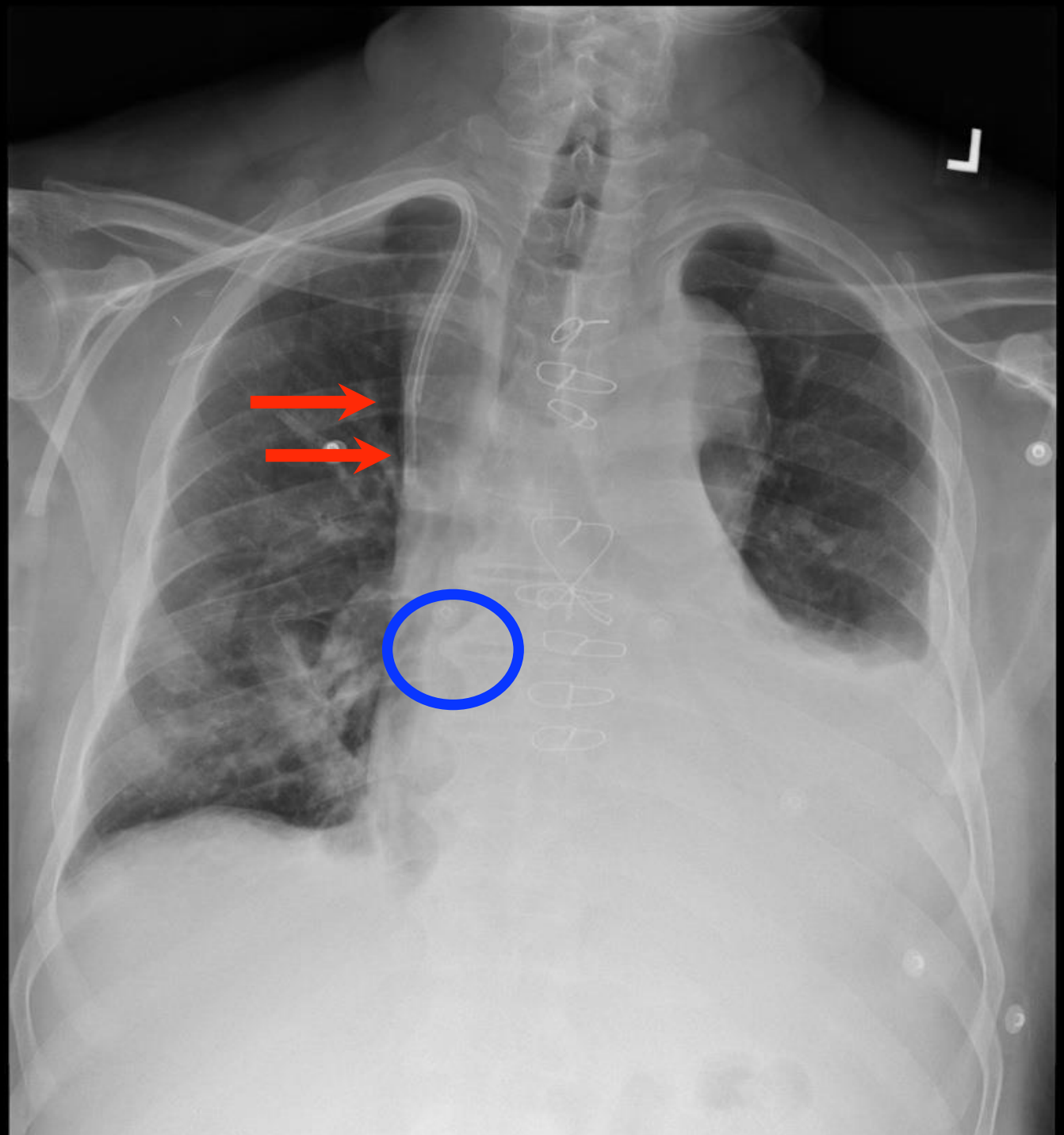
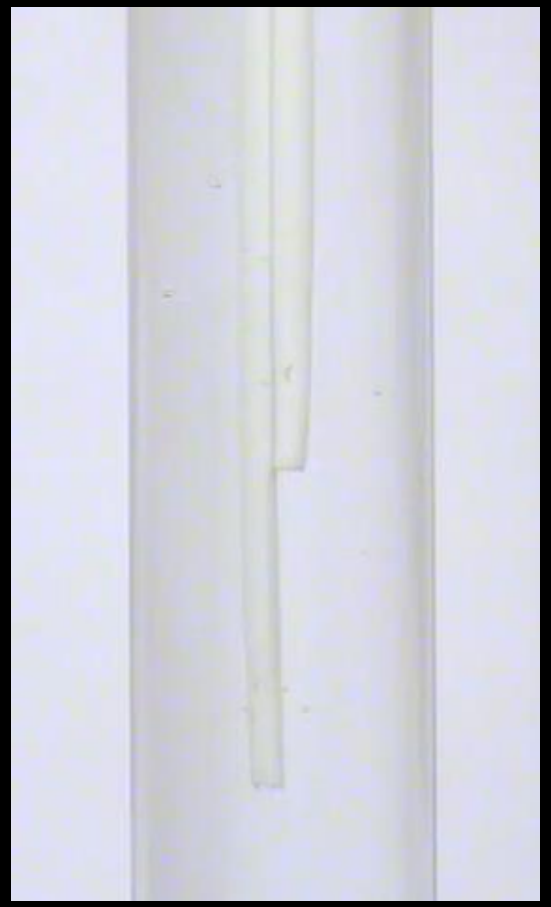


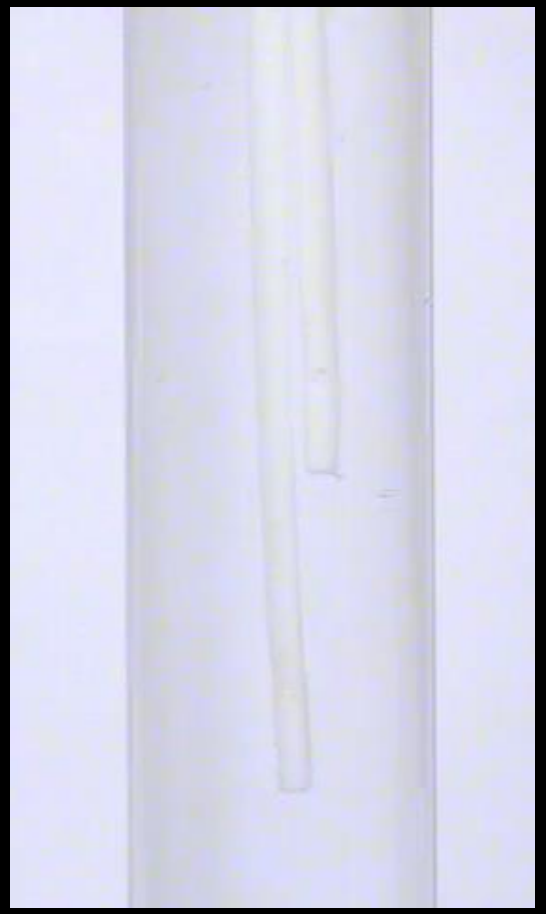
65-year-old African-American man with DMII and HTN initiates dialysis with a right internal jugular vein catheter on 6/15/2007

A right upper arm transposed brachial-basilic access is created on 1/23/08 and first used in May 2008.
He presents with arm swelling in September 2008.

Tip and Sheath effect on central veins



Split tip
Standard



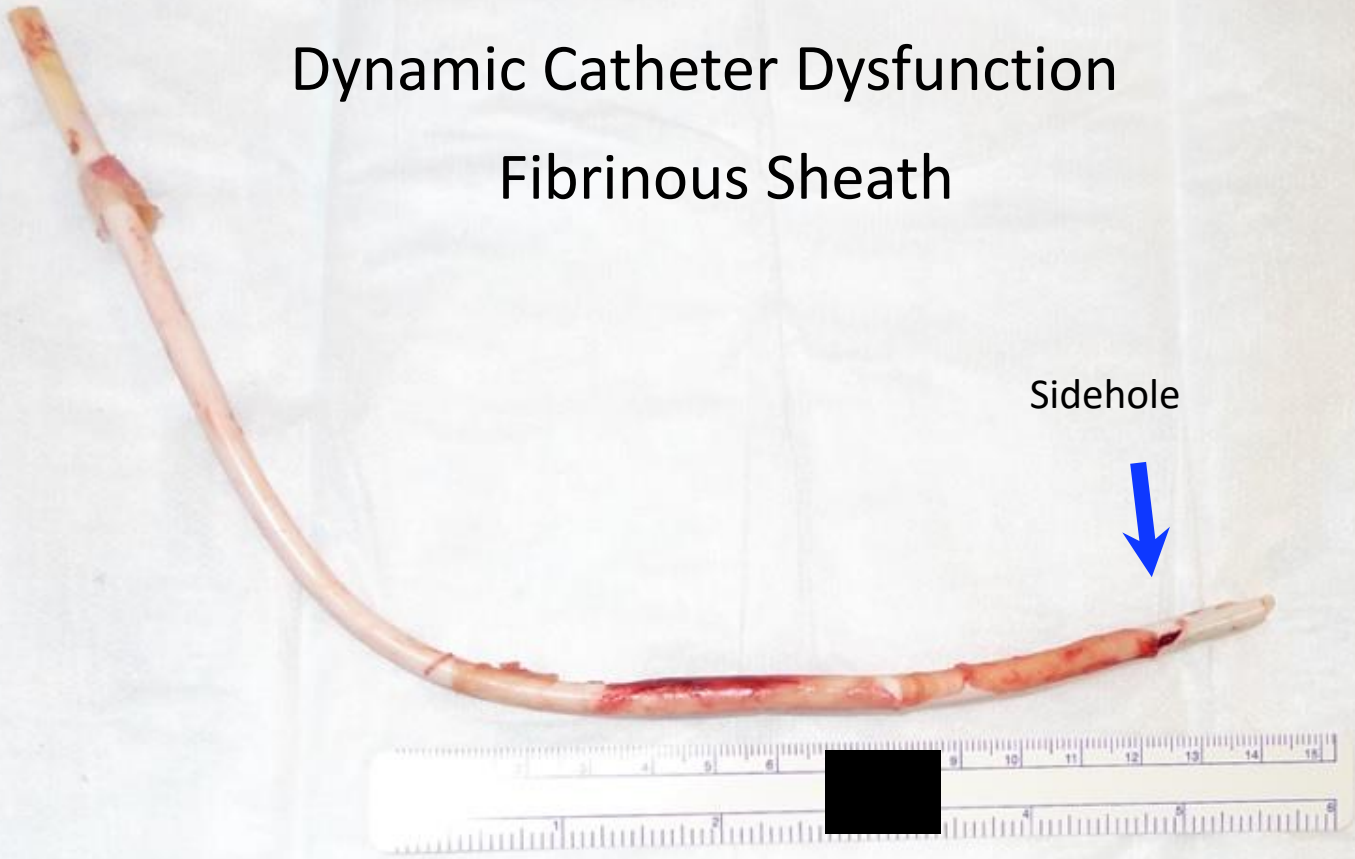
Split tip
Reversed

Symmetric tip
Reversed

Vesely JVA 2016

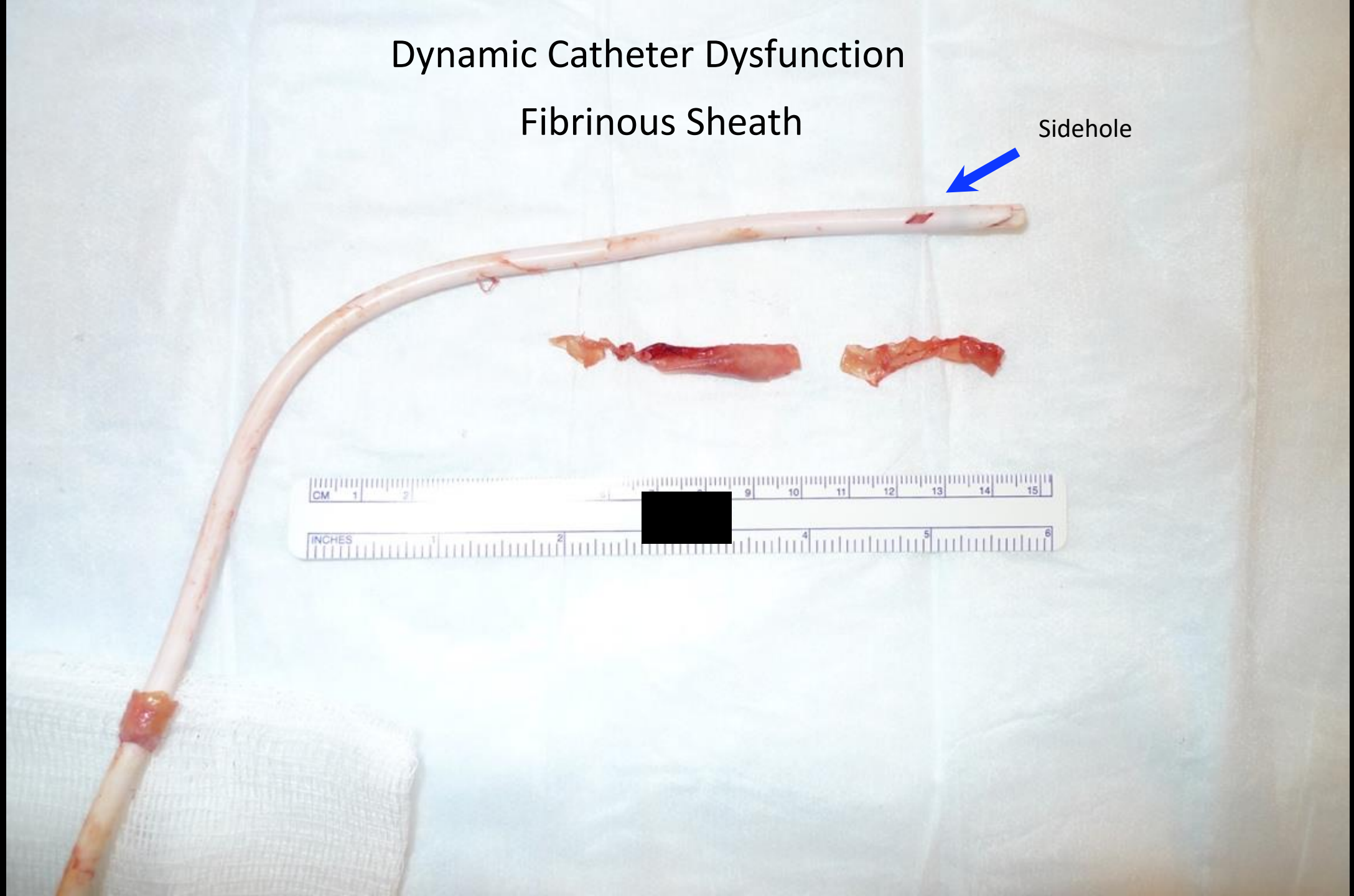
Dynamic Catheter Dysfunction

Fibrinous Sheath

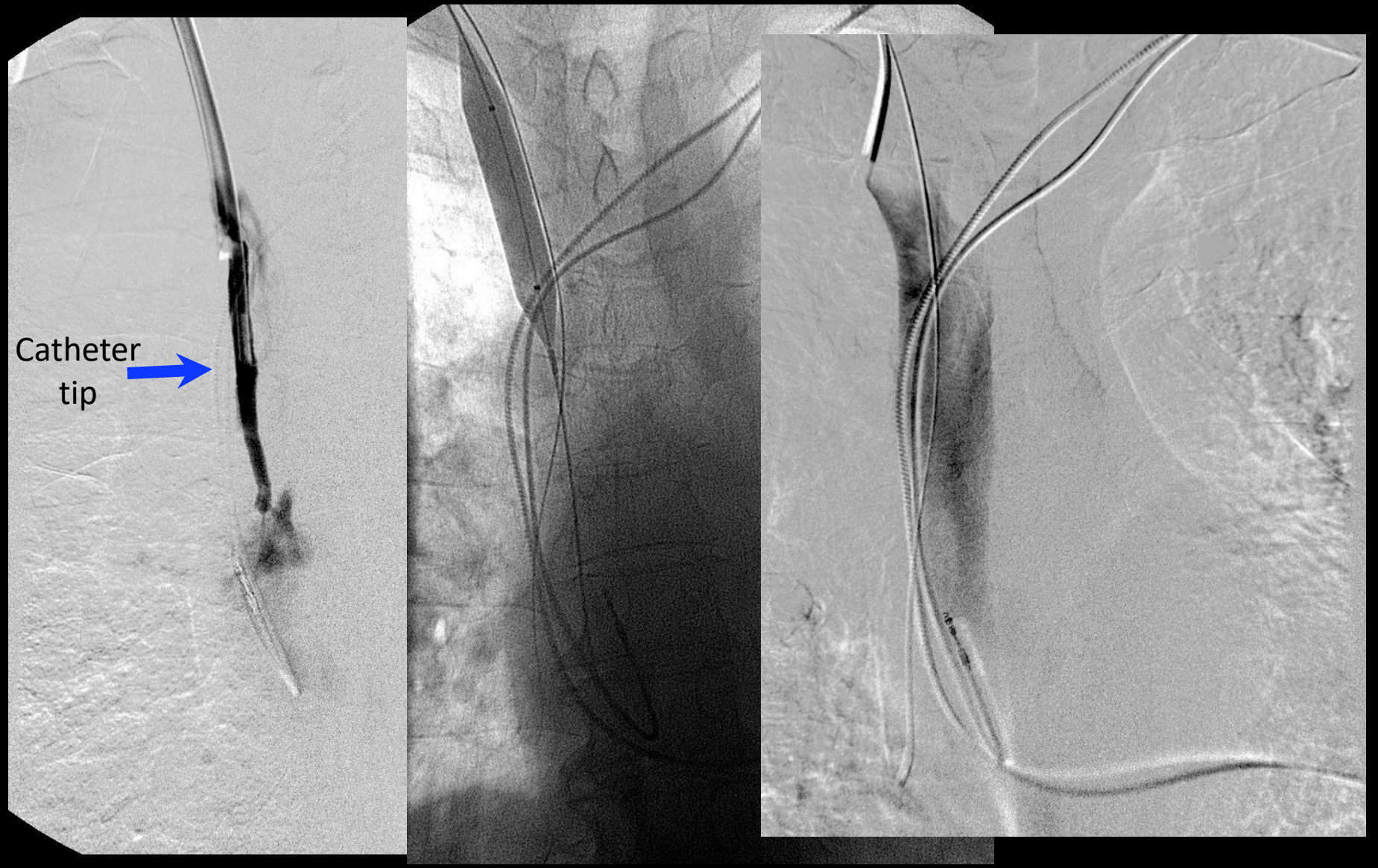


Dynamic Catheter Dysfunction

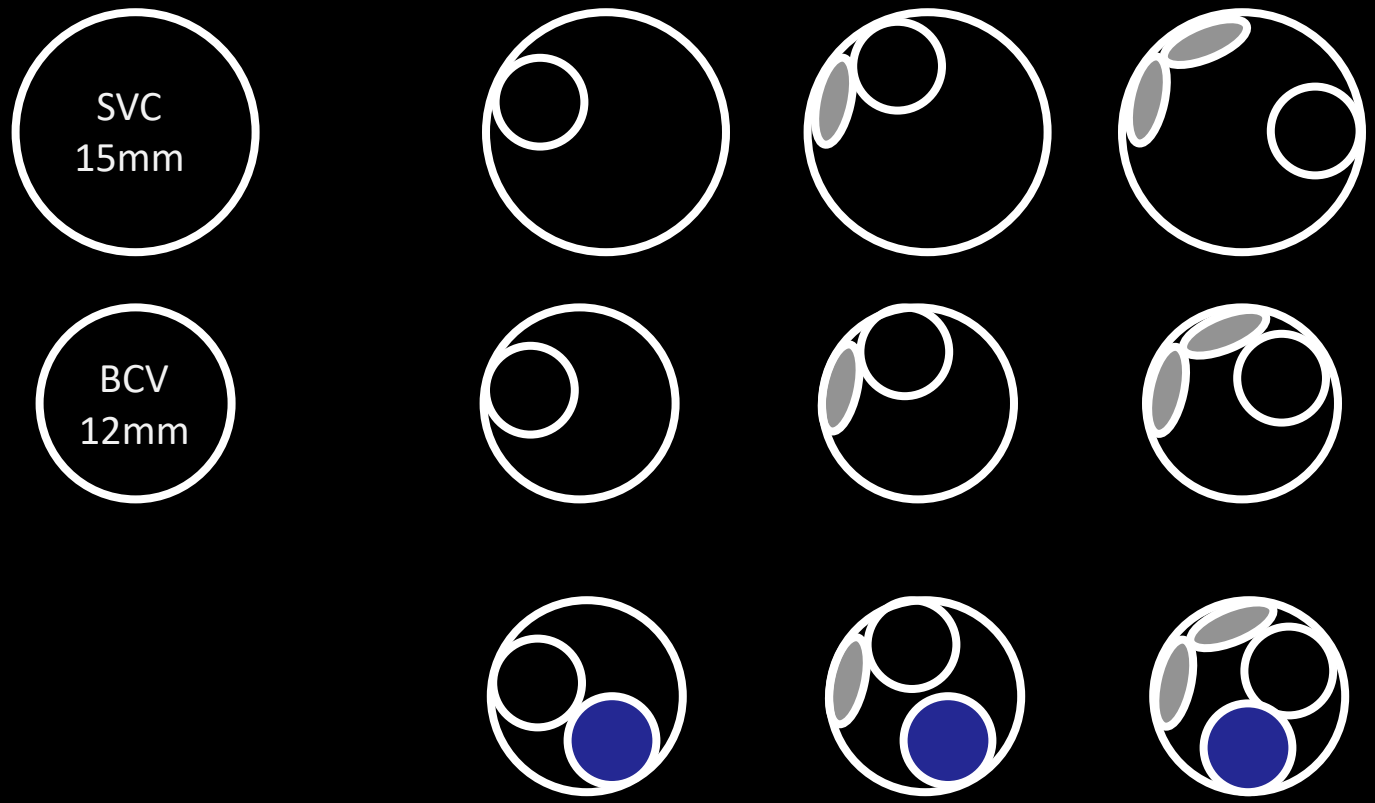
Fibrinous Sheath



Dynamic Catheter Dysfunction
Fibrinous Sheath



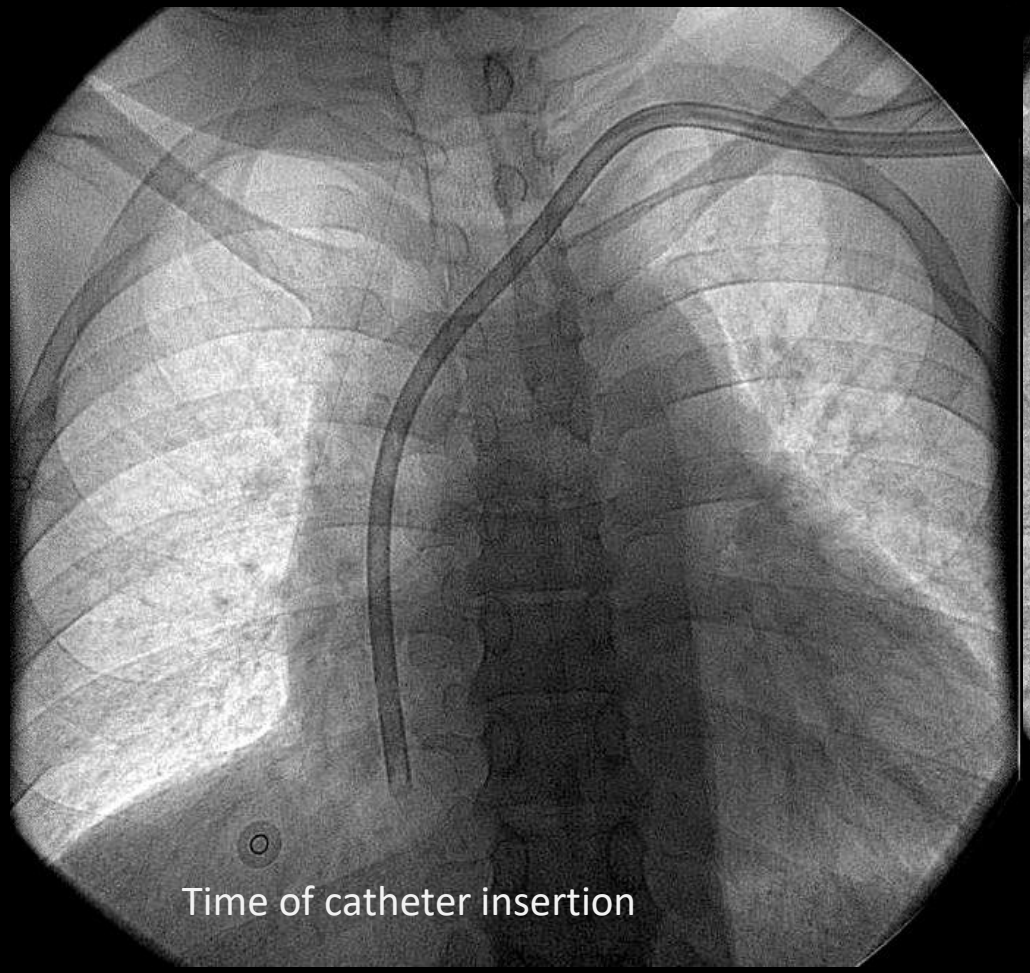
Cumulative exposure to tunneled catheters

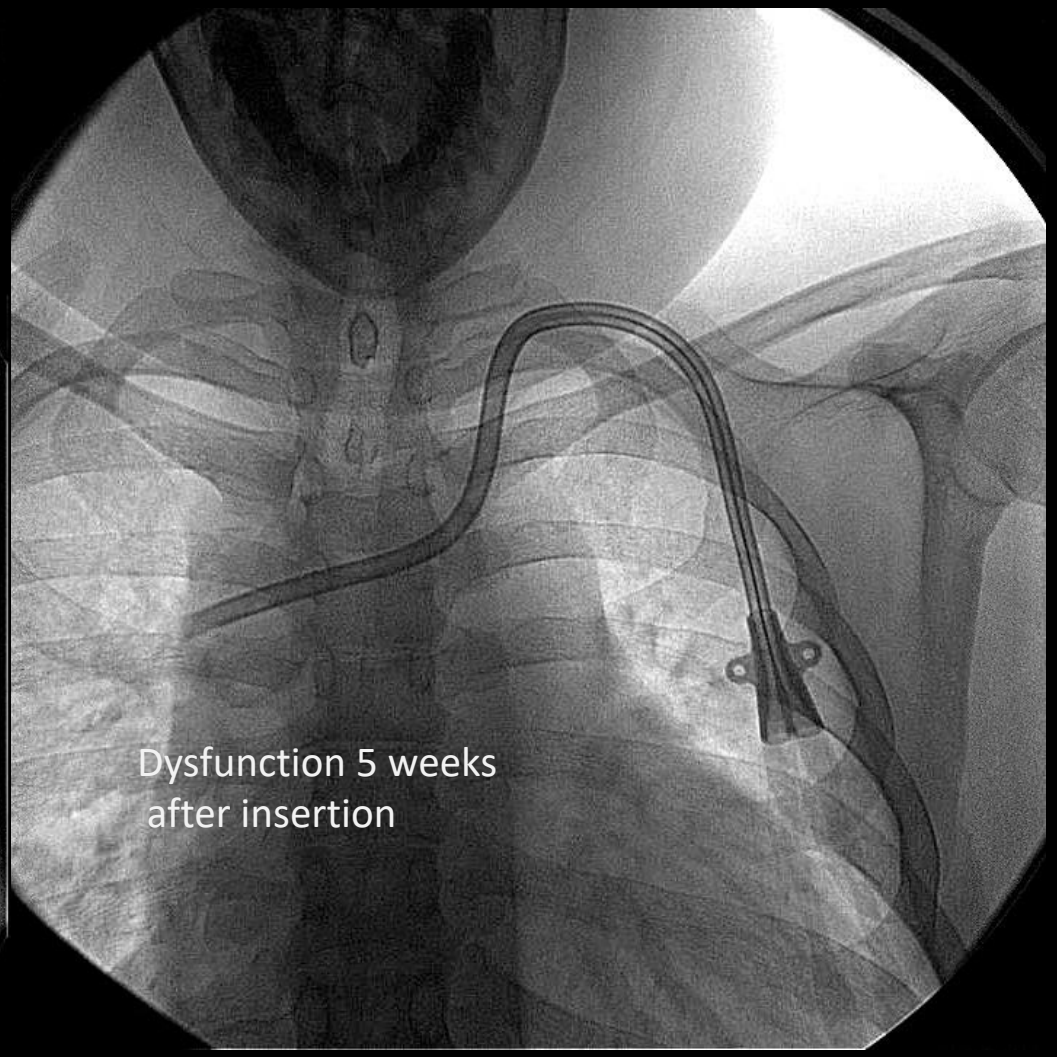


15.5 Fr tunneled catheter (~5mm)

Cardiac Device leads

Dynamic Catheter Dysfunction





Catheter tip position

Success rates of different CRB strategies

(Review of available literature, total of 21 studies reporting on recurrent infections after catheter exchange/removal)

Strategy \ Organism	Overall success	Staph aureus	coag neg Staph	Entero-coccus	GNR	Multiple Organisms	fungus
Abx alone	49% (203/418)	53% (25/47)	67% (84/126)		51% (41/80)	0% (0/10)	100% (1/1)
Abx plus Cath lock	57% (218/381)	40% (54/134)	77% (41/53)	59% (48/81)	66% (53/80)	37% (3/8)	0% (0/1)
Abx plus GW exchange	89% (196/219)	80% (16/20)	88% (29/33)	100% (1/1)	89% (40/45)	70% (7/10)	83% (24/29)
Abs plus Removal and Delayed Reinsertion	88% (174/198)	87% (74/85)	89% (41/46)		88% (64/73)		85% (11/13)

see also: Aslam JASN 2014, Voiculescu JVA 2021


Tunnel infection

Continuous sheath from tunnel into vessel

TAKE HOME MESSAGES

- Access flow has to be sufficient for dialysis
- Limit Access flow to preserve cardiac function and prevent steal
- Intra-access pressure are elevated BEFORE access flow falls significantly
- Aneurysm formation and skin thinning is related to increased intra-access pressures
- Higher flow in setting of outflow stenoses leads to higher intra-access pressures
- Forearm accesses on average have lower flow, lower intra-access pressure, and develop fewer systemic complications
- Tunneled catheter tip position is key to continuous function
- Tunneled catheters are associated with central venous stenosis and infection
- Catheter-related bacteremia may be approached with guidewire exchange if the patient is clinically stable and site preservation important

REFERENCES

J Vasc Access 2023 May;24(3):358-369.

ASDIN white paper: Management of cephalic arch stenosis endorsed by the American Society of Diagnostic and Interventional Nephrology
Gerald A Beathard [1], William C Jennings [2], Haimanot Wasse [3], Surendra Shenoy [4], Abigail Falk [5], Aris Urbanes [6], John Ross [7], George Nassar [8], Dirk M Hentschel [9], Bharat Sachdeva [10], Micah R Chan [11], Loay Salman [12], Arif Asif [13]

Consider limiting flow (e.g. banding) **before** or in addition to treating outflow stenosis

J Am Soc Nephrol 2014 Dec;25(12):2927-41.

Systematic review and meta-analysis on management of hemodialysis catheter-related bacteremia
Saima Aslam [1], Florin Vaida [2], Michele Ritter [3], Ravindra L Mehta [4]

For treatment of Catheter related bacteremia **Guidewire exchange** performs better than catheter lock (in addition to systemic antibiotics)

CLINICAL TRIALS

Clinical Trials	Change in Management	
Haskal et al. NEJM 2010 – Stent graft vs AP for AVG venous anastomosis	Stent graft cost-effective	Open question: across joints? Compared to surgery?
Lockstein JVIR 2023 - IN.PACT AV – drug-coated balloon in AVF	International trial, DCB with improved target lesion patency	DCB use not yet supported by overall evidence.
Trerotola JVIR 2020 - Lutonix AV Randomized Trial of Paclitaxel-coated Balloons	US trial, DCB with variable improvement	target lesion still needs to be identified