Non-contrast enhanced MRA screening prior to vascular access creation

IRM sans contraste dans le bilan préfistule

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Faculty Disclosure

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I have **no financial relationships** to disclose.

Preoperative assessment before vascular access planning

modality	advantages	disadvantages
Physical examination	Easily and repeatedly performed	Subjective measurement May miss adequate vessels in obese patients Not suitable for central vessels
Duplex ultrasound	Noninvasive and cheap Functional measurement of arterial & venous vessels	Results are operator dependent Not eligible for central vessels
Phlebography	Well-imaging of arm and central vein anatomy	Contrast load with risk on renal function detoriation No arterial imaging
Contrast-enhanced MRA	Adequate imaging of the whole arterial & venous anatomy	Gadolineum load with risk on NSF

Preoperative assessment before vascular access planning
Rationale of NCE-MRA

- MRA allows visualisation of both central and peripheral vessels and sidebranches
- MRA examination prior to VA creation potentially results in a 30% decrease of non-maturing fistulas because of improved depiction of the most suitable site for VA creation
- Gadolinium-based contrast agents in patients with ESRD may induce the development of nephrogenic systemic fibrosis (NSF)
- Therefore, interest in novel non-contrast enhanced techniques are focus of current research to abstain from contrast administration

Preoperative assessment before vascular access planning
Study design NCE-MRA imaging

- **Feasibility of NCE-MRA for preoperative assessment and depiction of upper extremity vessels**
- **Inter-observer variability of NCE *vs* CE-MRA imaging of arterial & venous vessels in the arm**
- **Accuracy of ultrasound versus NCE-MRA measurement of vessel diameters in the upper extremity**
- **Relationship between preoperative vessel assessment by ultrasound and NCE-MRA versus the surgical decision making**

MRA technique
Patient positioning

Surface coils are applied over the complete upper extremity and thorax. The contrast pump is connected to a contra lateral intravenous cannula on the dorsum of the hand. Please note the slightly semi-oblique supine position for reduction of artifacts in NCE-MRA acquisition.

Sequence parameters of NCE-MRA and CE-MRA

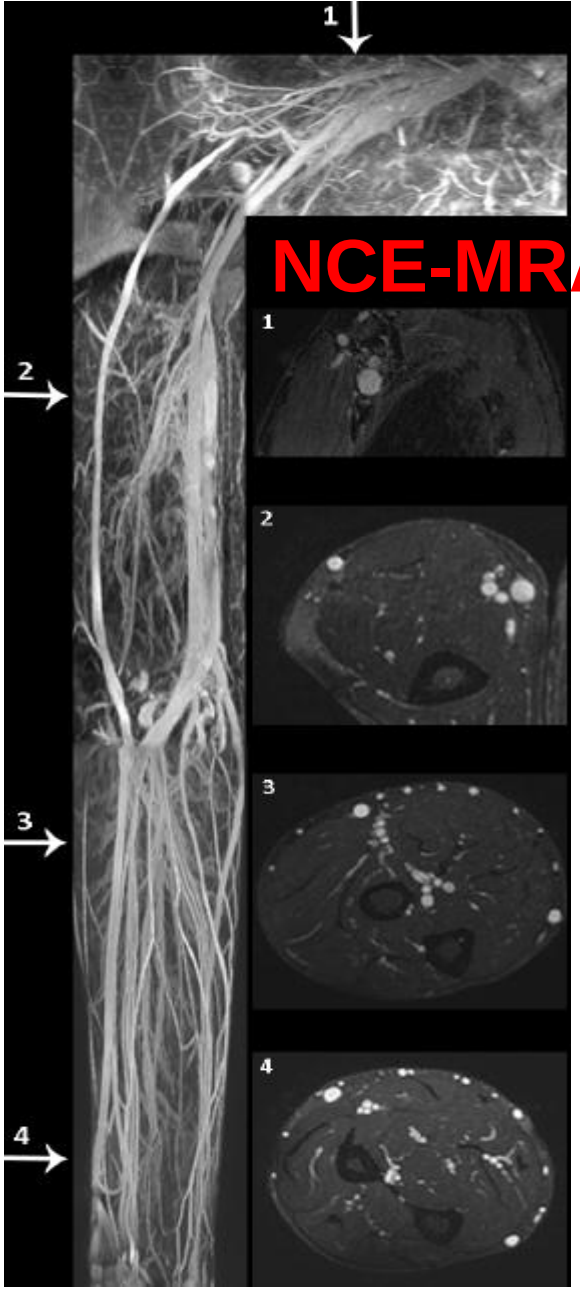
	NCE-MRA			CE-MRA	
	Central	Proximal	Distal	Proximal	Distal
Repetition time (msec)	4.5	5.6	5.8	5.4	5.4
Echo time (msec)	2.2	2.8	2.9	1.61	1.55
Flip angle (degrees)	90	90	90	40	40
Number of stacks	1	2	2	1	1
Field of view (mm)	300	175	175	430	325
Rectangular field of view (%)	65	65	55	85	25
Matrix (scan/reconstruction)	244/384	224/512	224/512	432/512	432/512
Number of slices	125		120	90	125
Slice thickness	0.79	0.79	0.79	1.25	0.84
Acquired voxel size	1.34x0.84x0.78	0.78x0.78x0.79	0.78x0.78x0.79	1.00x1.81x2.50	0.75x1.38x1.68
Reconstructed voxel size	0.78x0.78x0.78	0.34x0.34x0.79	0.34x0.34x0.79	0.84x0.84x1.25	0.63x0.63x0.84
Scan duration	4:45	5:48	4:54	1:52	0:45
Number of phases acquired	1	1	1	4	4

Contrast *vs* non-contrast MRA

1) central vessels

2) upper arm

3-4) lower arm



CE-MRA acquisition in arterial phase (A) and venous phase (B) with corresponding cross-sectional reformations

NCE-MRA acquisition with corresponding cross-sectional reformations

Contrast *vs* non-contrast MRA
Imaging quality

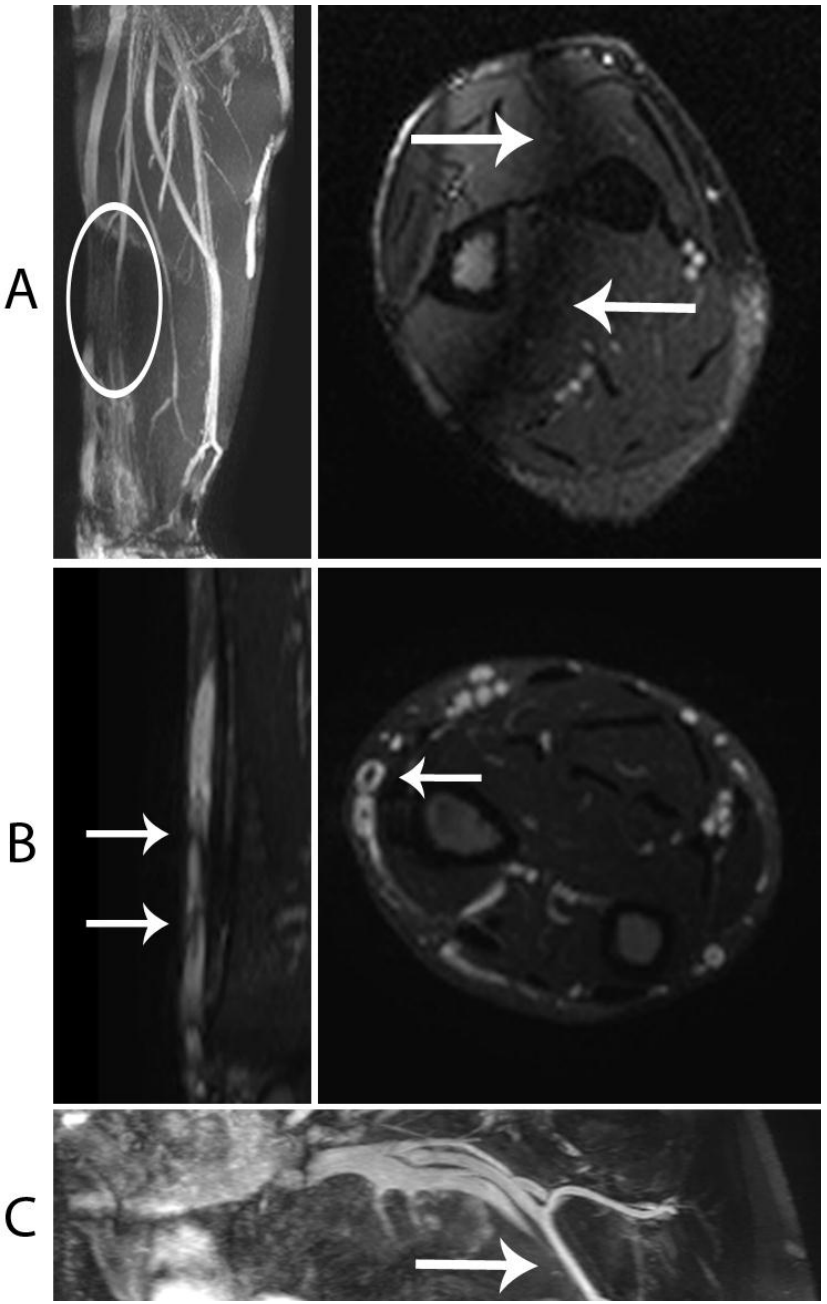
	Observer	Arterial vascular tree			Venous vascular tree		
		NCE-MRA	CE-MRA	P-value	NCE-MRA	CE-MRA	P-value
Visible segments with IQ>0 (%)	1	157/165 (95)	163/165 (99)	0.109	**219/240 (91)**	**197/240 (82)**	**<0.001**
	2	154/165 (93)	164/165 (99)	0.006	**198/240 (83)**	**180/240 (75)**	**0.015**
Image Quality (0-4)	1	**2.25 (±0.97)**	**3.53 (±0.69)**	**<0.001**	2.19 (±1.16)	2.22 (±1.40)	0.701
	2	**2.30 (±1.12)**	**3.81 (±0.55)**	**<0.001**	2.01 (±1.35)	2.09 (±1.53)	0.358
Flow artifacts (0-2)	1	**0.34 (±0.59)**	**0.00 (±0.00)**	**<0.001**	**0.29 (±0.54)**	**0.07 (±0.34)**	**<0.001**
	2	**0.31 (±0.94)**	**0.00 (±0.00)**	**<0.001**	**0.30 (±0.57)**	**0.04 (±0.24)**	**<0.001**
Magnetic field inhomogeneities artifacts (0-2)	1	**0.59 (±0.77)**	**0.04 (±0.19)**	**<0.001**	**0.57 (±0.80)**	**0.05 (±0.25)**	**<0.001**
	2	**0.59 (±0.86)**	**0.00 (±0.00)**	**<0.001**	**0.53 (±0.84)**	**0.00 (±0.00)**	**<0.001**
Compression artifacts (0-2)	1	0.02 (±0.13)	0.00 (±0.00)	0.083	0.15 (±0.48)	0.17 (±0.54)	0.444
	2	0.01 (±0.16)	0.01 (±0.08)	0.655	**0.21 (±0.59)**	**0.33 (±0.72)**	**0.001**
Vessel-to-background ratio		**3.87 (±3.67)**	**6.77 (±3.56)**	**<0.001**	**4.93 (±3.20)**	**3.42 (±1.47)**	**<0.001**

Examples of artifacts associated with NCE-MRA

A) off-resonance ‘black-banding’ artifact (arrow) caused by magnetic field inhomogeneities resulting in loss of signal (oval)

B) example of a flow artifact (arrow) in the distal cephalic vein

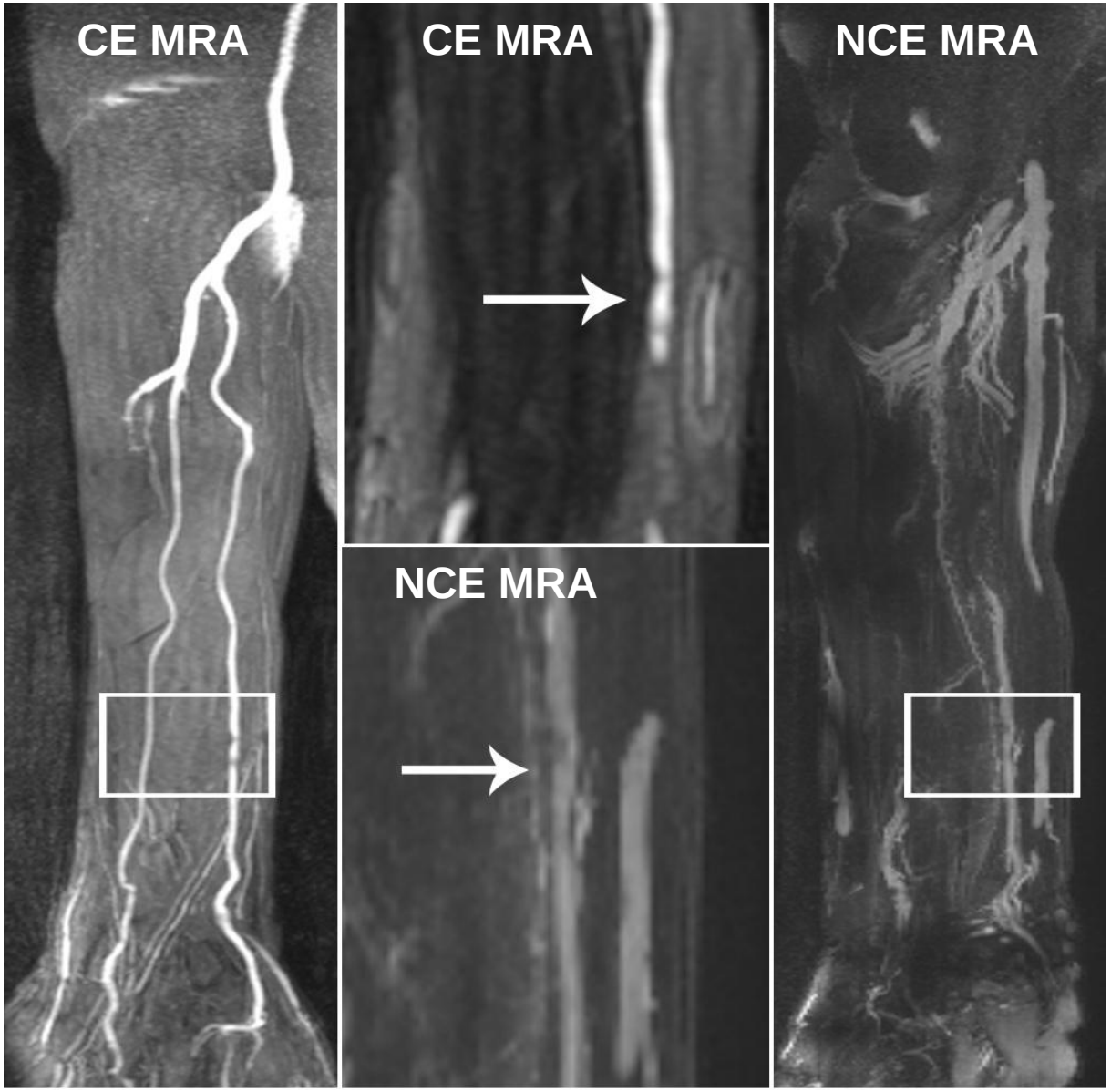
C) example of a compression artifact (arrow) in the distal subclavian vein caused by the sideways positioning of the subject.



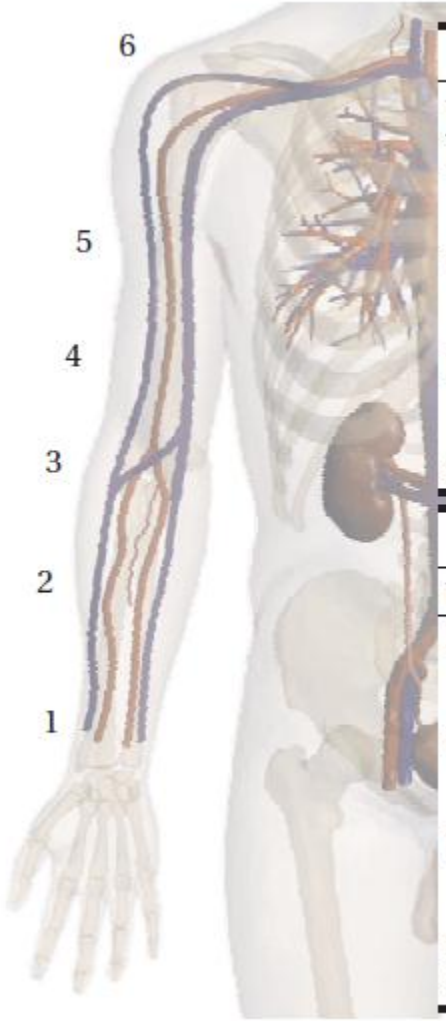
Contrast *vs* non-contrast MRA

Maximum intensity projections of CE-MRA and NCE-MRA in a 76 year old female with end-stage renal failure awaiting AVF creation

Magnified source images confirm presence of two non-significant stenoses in the radial artery



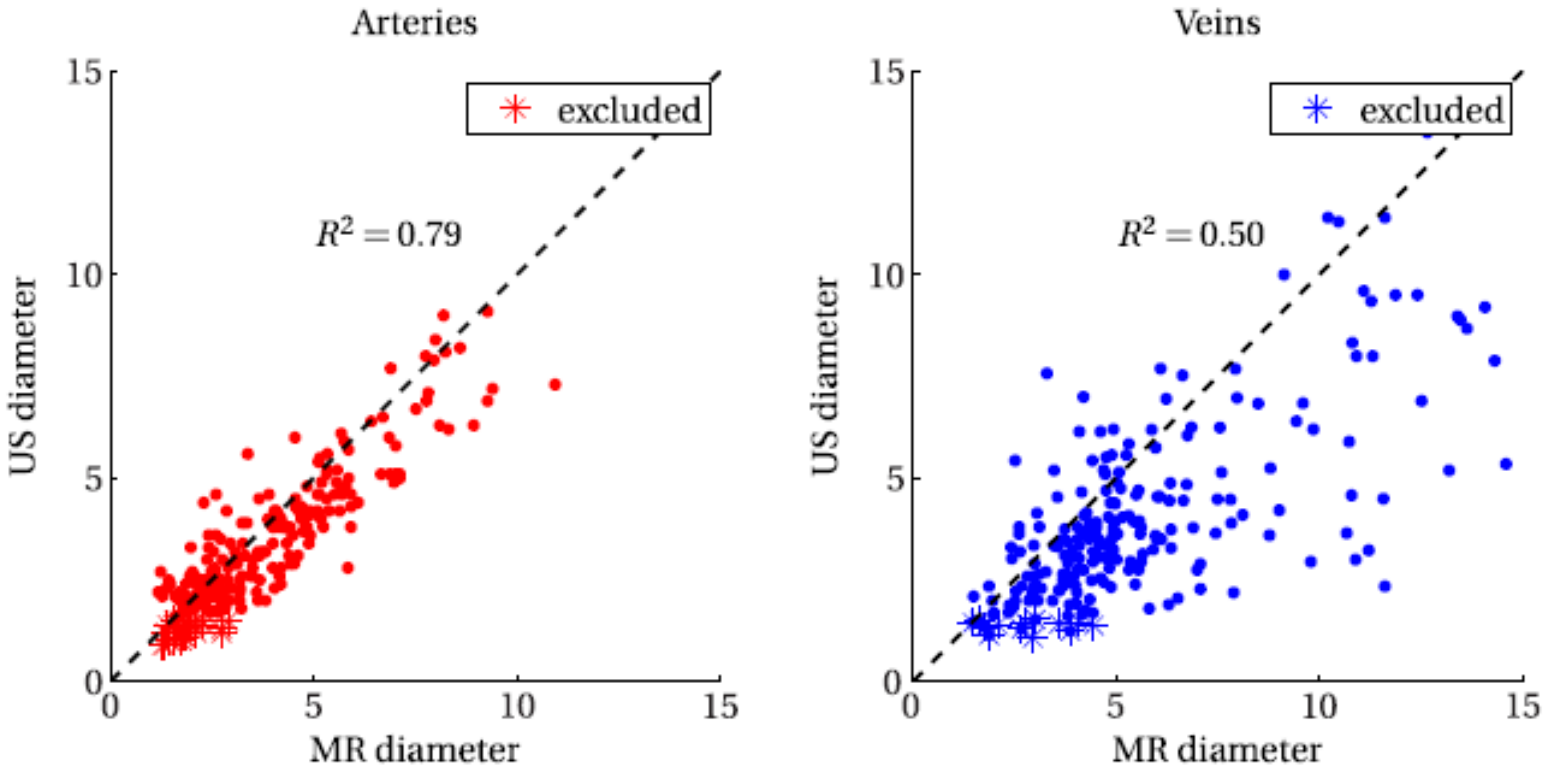
Locations in the upper extremity for vessel diameter comparison between US and NCE-MRA



Preoperative arterial diameters		
Vessel	Location	Diameter
Radial	1	
	2	
	3	
Ulnar	1	
	2	
	3	
Brachial	3	
	4	
	5	
Subclavian	6	

Preoperative venous diameters		
Vessel	Location	Diameter
Lower cephalic	1	
	2	
	3	
Upper cephalic	3	
	4	
	5	
Upper basilic	3	
	4	
	5	
Median cubital	3	
Subclavian	6	

Vessel diameters
Non-contrast MRA *vs* Ultrasound



Correlation plots for NCE-MRA versus US diameters.
The line of perfect correlation (*y* = *x*) is dashed in each plot, and the resulting *R*2 value is shown.

Surgical decision
Non-contrast MRA *vs* Ultrasound

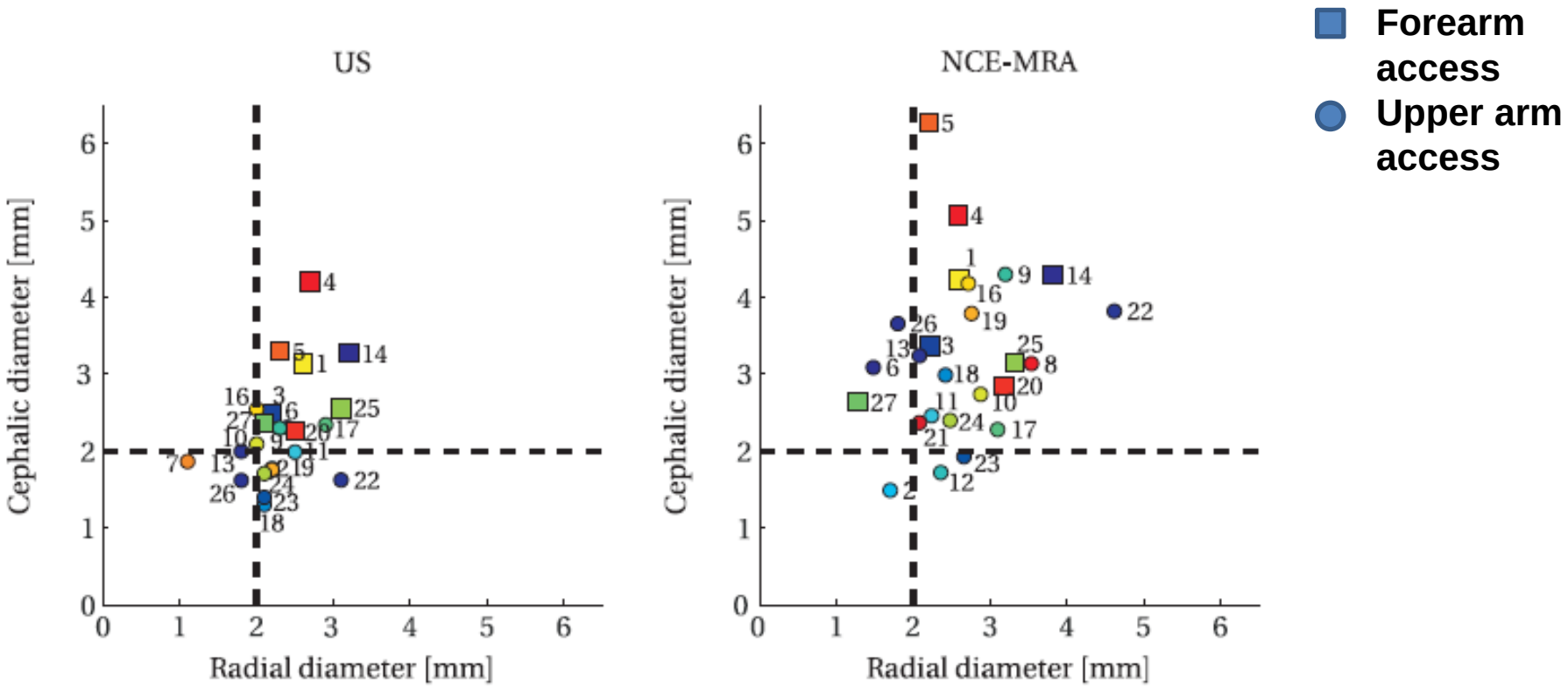
27 patients had ultrasound and NCE-MRA

US \ Surgeon	RCAVF	BC/BBAVF
RCAVF	8	5
BC/BBAVF	0	14

NCE-MRA \ Surgeon	RCAVF	BC/BBAVF
RCAVF	7	12
BC/BBAVF	1	7

Comparison of surgical decision with decision solely based either on US or NCE-MRA measurements. The sensitivity and specificity of the modalities were computed from these values (NCE-MRA sensitivity: 7/8 = 0.88)

Surgical decision and diameter measurements of the radial artery and forearm cephalic vein



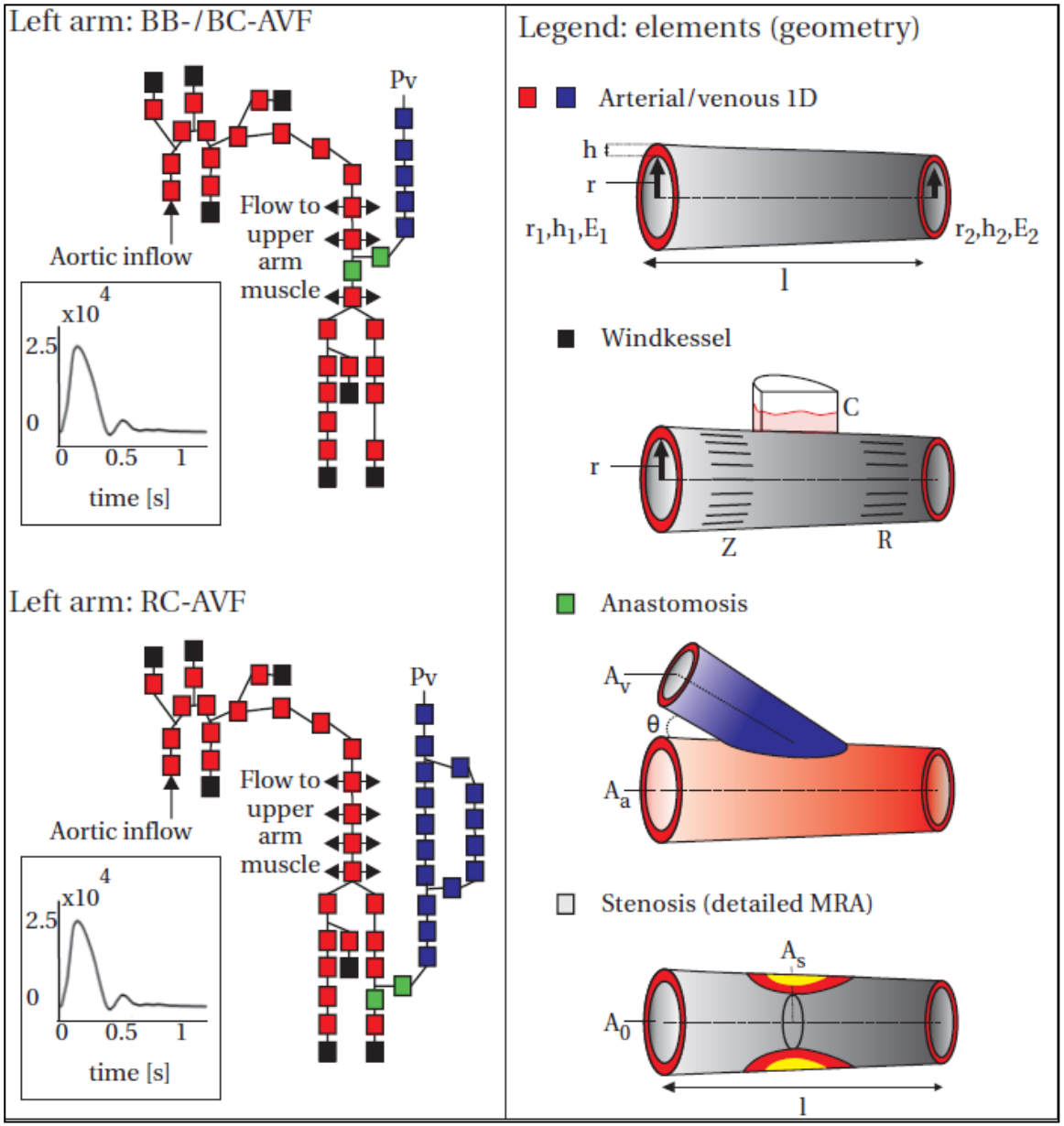
Ultrasound **NCE-MRA**

Computer simulation for access planning

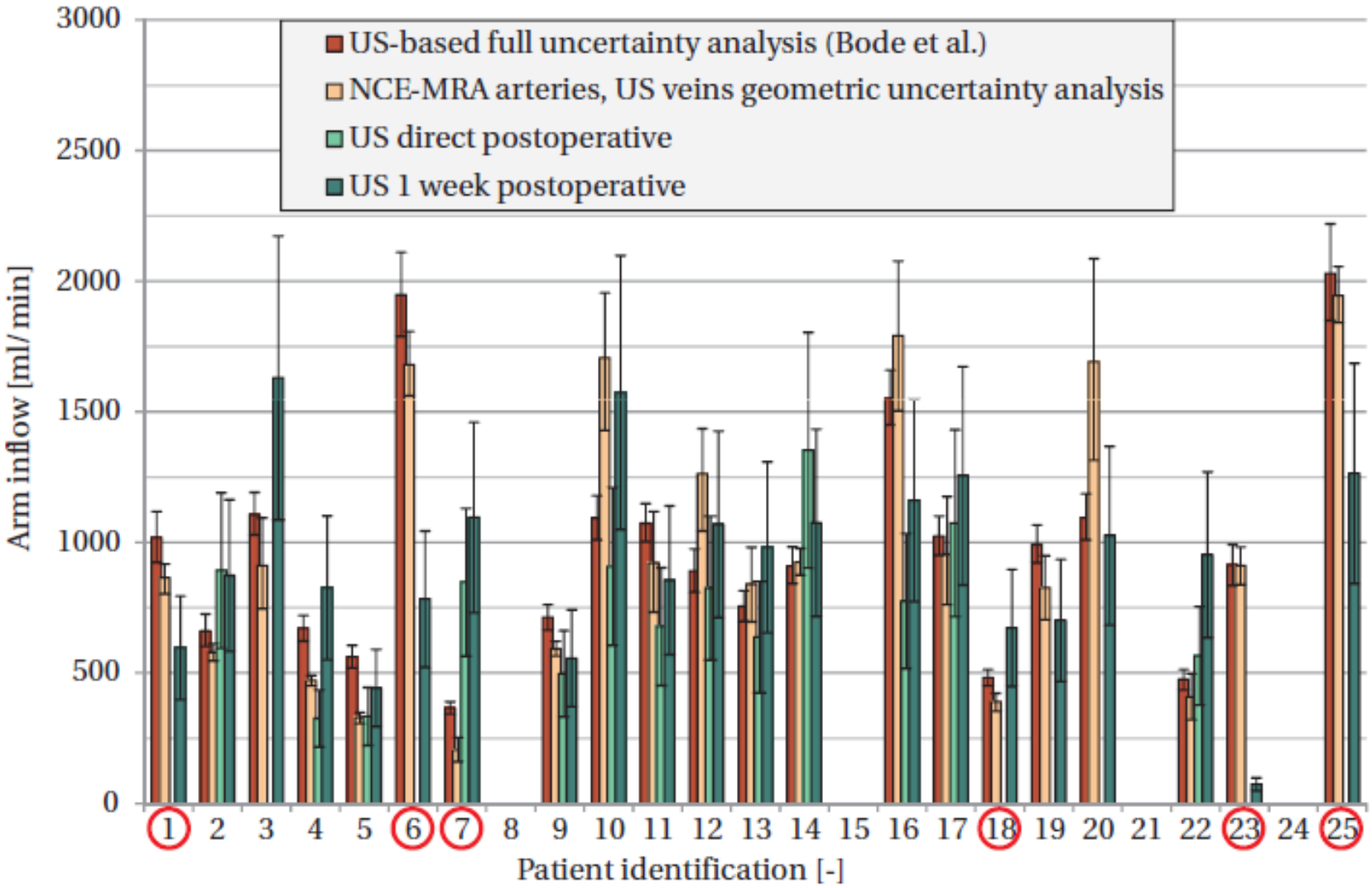
Input parameters

Ultrasound vessel diameters & flow

NCE-MRA vascular geometry



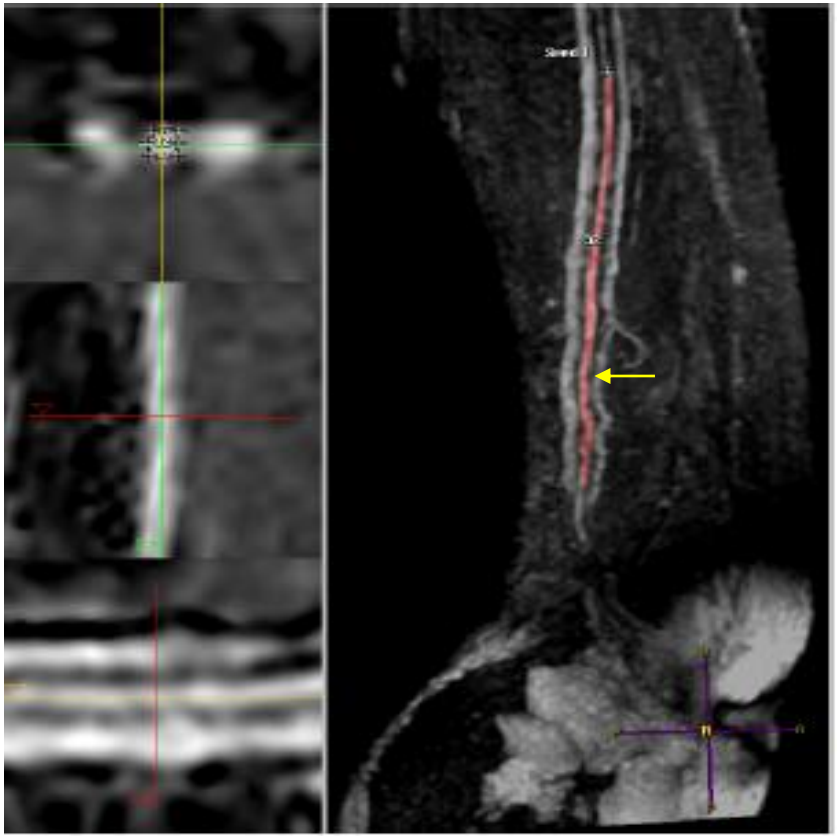
Computer simulation for access planning
NCE-MRA *vs* Ultrasound



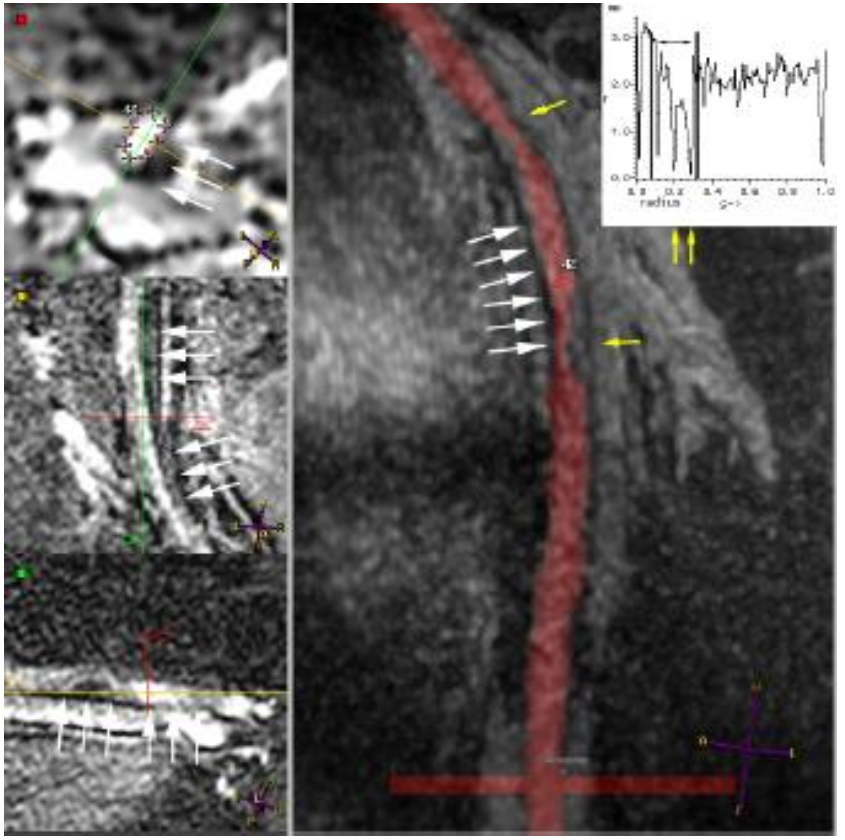
Overlap in predicted flow in 19 out of 25 patients

Computer simulation for access planning
NCE-MRA *vs* Ultrasound

Early thrombosed AVF



A relevant section of the lower arm artery (radial) is displayed. Average radius in this section was 0.71 mm, while US reported 1.12 mm.



A relevant section of the upper basilic vein is displayed with a significant (>75%) stenosis, indicated by the arrows.

Non-contrast enhanced MRA screening prior to vascular access creation

Summary

- NCE-MRA enables imaging of the entire upper extremity vascular tree, instead of just several discrete locations as is achieved with duplex ultrasound
- Venous vessels can be accurately visualised with NCE-MRA
- Vessel diameter is overestimated with NCE-MRA in particular for veins
- NCE-MRA allows for extraction of patient-specific vascular geometry which can be used for personalization of computational modeling tools