

Computational Simulation to Predict Maturation



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AVF Complications

- **Short term failure(18-53%) :**
 - Postoperative thrombosis
 - Non-maturation
- **Long term failure:**
 - Development of stenosis (patency)
 - Steal syndrome (20%)
 - Cardiac failure (↑CO 20%)

Citation	N accesses		Primary failures %		Primary (unassisted) survival at 1 year %	
	Fistula	Graft	Fistula	Graft	Fistula	Graft
Kinnaert, 1977 [62]	314		9		80	
Bonalumi, 1982 [63]	177		10		83	
Reilly, 1982 [64]	150		11		80	
Palder, 1985 [65]	154		24			
Winsett, 1985 [66]	273		27			
Kherlakian, 1986 [21]	100	100	12	4	71	75
Churchill, 1992 [67]	227	120			82-87	45-67
Coburn, 1994 [20]	59	47			90	70
Rocco, 1996 [23]	48	40	31	12	55	60
Wong, 1996 [48]	60		30			
Miller, 1997 [34]	75	23			84	47
Hodges, 1997 [68]	87	236	43		43	41
Silva, 1998 [51]	108		26		83	74
Hakaim, 1998 [38]	58		22			
Golledge, 1999 [69]	107		18		69	
Miller, 1999 [25]	101		53			
Konner, 2000 [70]	347		2		77	
Ascher, 2000 [52]	99		18			
Murphy, 2000 [71]	74		32			
Renavur, 2000 [72]	137		22		74	
Wolowczyk, 2000 [45]	208		20		65	
Gibson, 2001 [35]	130	92	23		56	36
Allon, 2001 [13]	139	78	46	21	42	43
Oliver, 2001 [12]	115	80	26	15	65	47
Sedlacek, 2001 [43]	140		25			
Dixon, 2002 [26]	205	117	30	23	53	27
Pisoni, 2002 [18]	177	251			68	49

Primary failure is defined as thrombosis or failure to mature adequately for dialysis, while primary survival is time from access placement to initial intervention.

Table: M. Allon et al. Kidney International 2002

(Patho) Physiology of fistula maturation

Increased Shear Stress

Frictional displacement of cell surface components
Second messengers
Kinase cascades activated

Acute flow change

Sustained flow change

Release of vasodilators

Transcription factors activated
Shear stress response elements
Gene regulation

Endothelial adaptation

Relaxation VSMC

Vessel wall remodeling
& adaptation

(Patho) Physiology of fistula maturation

Hemodynamic Factors

- Radiocephalic AVF: Shear stress, diameter, blood flow and BP at 1, 4 and 12 weeks were assessed

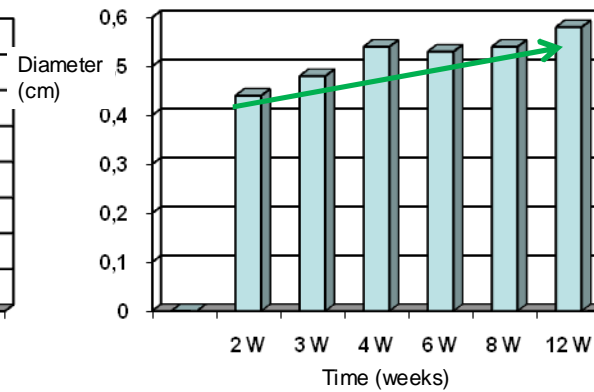
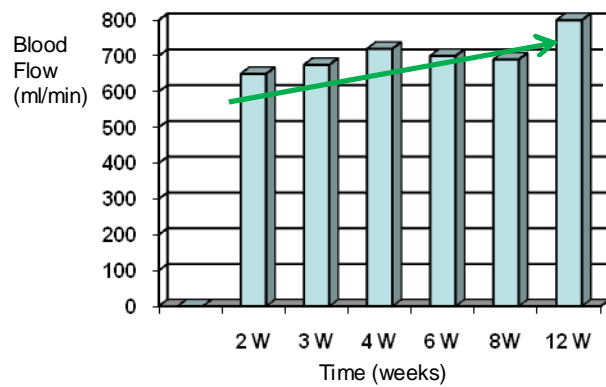
<i>Time:</i>	<i>1W</i>	<i>4W</i>	<i>12W</i>	
• Blood flow:	539	640	750	ml/min
• Shear stress:	24.5	18.1	10.4	dyn/cm ²
• Diameter:	2.3	4.4	5.0	mm
• BP:	144	138	145	mmHg

Corpataux et al:
Nephrol Dial Transplant 17:1057-1062, 2002

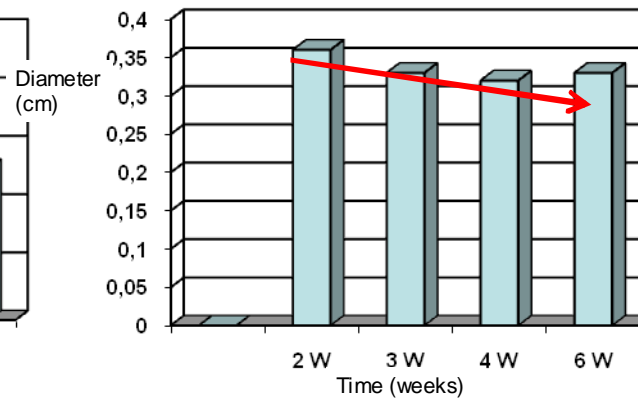
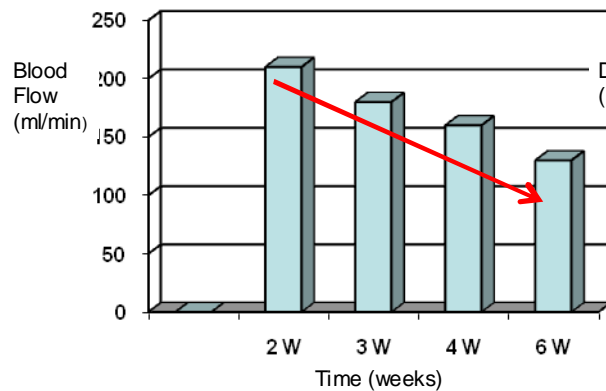
(Patho) Physiology of fistula maturation

Hemodynamic Factors

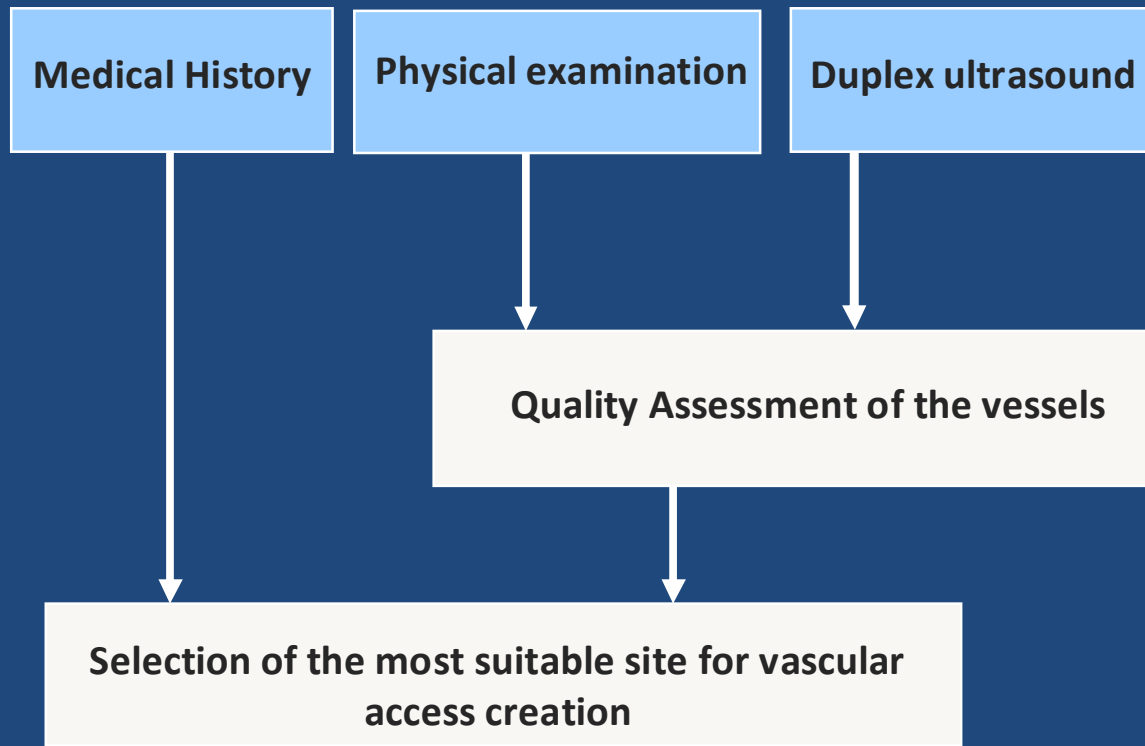
Matured
Fistulae



Failed
Fistulae



Current practice preoperative workup



NON-MATURATION 30-50%

pAtient specific image-based computational modeling for
impRovement of short- and long-term out**C**ome of
vascular access in patients on **H**emodialysis therapy



Consortium organization

Country

Mario Negri Institute
Maastricht University Hospital / TUE
Ghent University
University Medical Centre Ljubljana
University of Sheffield
Philips Medical Systems
Philips Research Europe
ESAOTE Europe B.V.

MNI
AZM
UGENT
KCLJ
USFD
PMS
PRE
ESAOTE

Italy
The Netherlands
Belgium
Slovenia
United Kingdom
The Netherlands
The Netherlands
The Netherlands

Computational Simulation to Predict Maturation

Work package No	Work package title	Type of activity	Lead beneficiary No
WP1	Management	MGT	1-MNI
WP2	Dissemination and exploitation	RTD	2-AZM
WP3	Imaging and functional measurements	RTD	8-ESAOTE
WP4	Image processing	RTD	6-PMS
WP5	Computational modelling	RTD	2-AZM
WP6	Experimental validation	RTD	3-UGENT
WP7	Patient-specific modelling integration	RTD	1-MNI
WP8	ARCH service infrastructure	RTD	7-PRE
WP9	Short-term function (AVF maturation)	RTD	2-AZM
WP10	Long-term VA patency	RTD	2-AZM
WP11	Steal syndrome	RTD	2-AZM
WP12	Cardiac function	RTD	3-UGENT

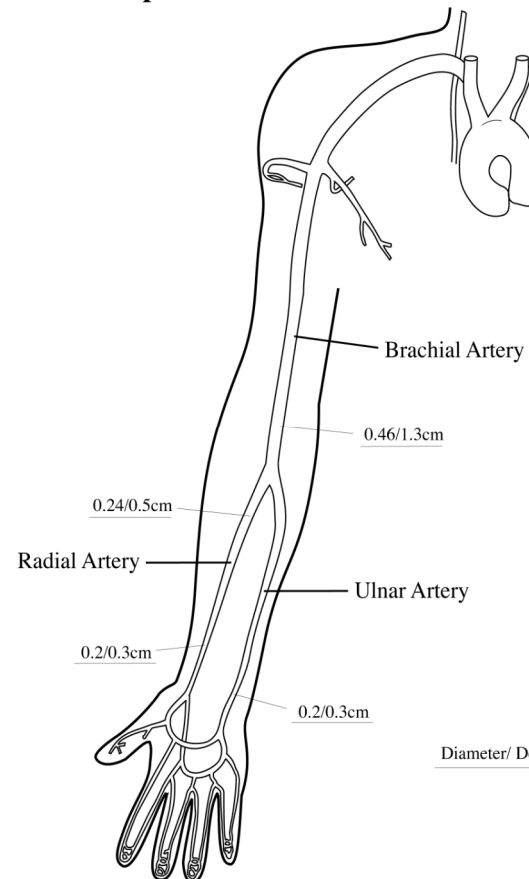
WP9	Short-term function (AVF maturation)
Task 9.1	Protocol definition for use of the computational tool for short-term function
Task 9.2	In-vivo verification of predictions of non maturation
Task 9.3	Definition of major determinants of non-maturation
Task 9.4	Proposal for large scale clinical study on AVF non maturation

Input parameters modeling tool

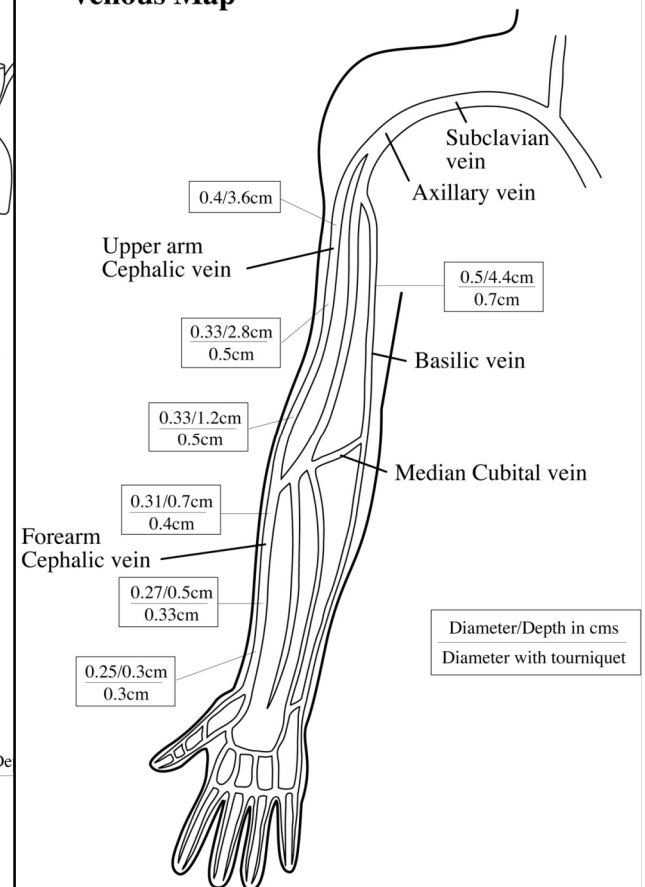
Ultrasonography



Arterial Map

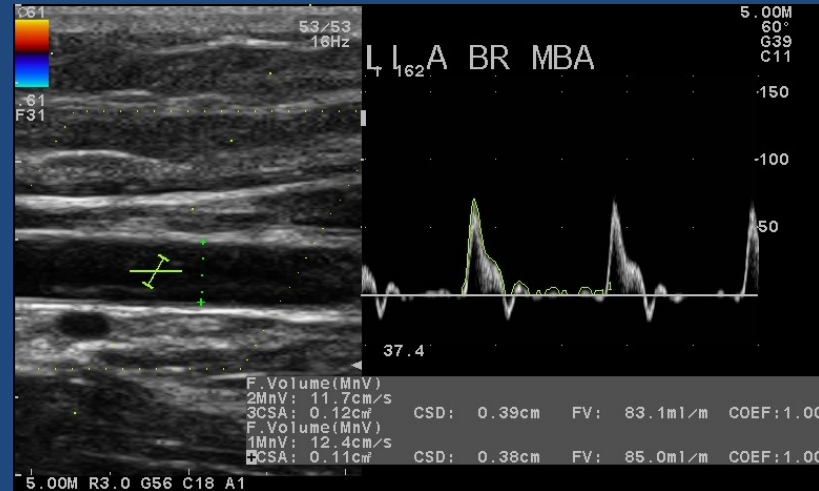


Venous Map



Input parameters modeling tool

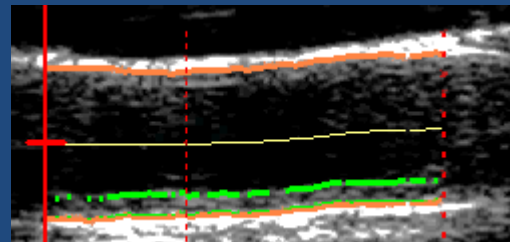
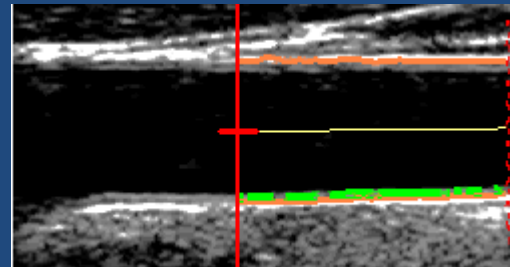
Advanced ultrasonography



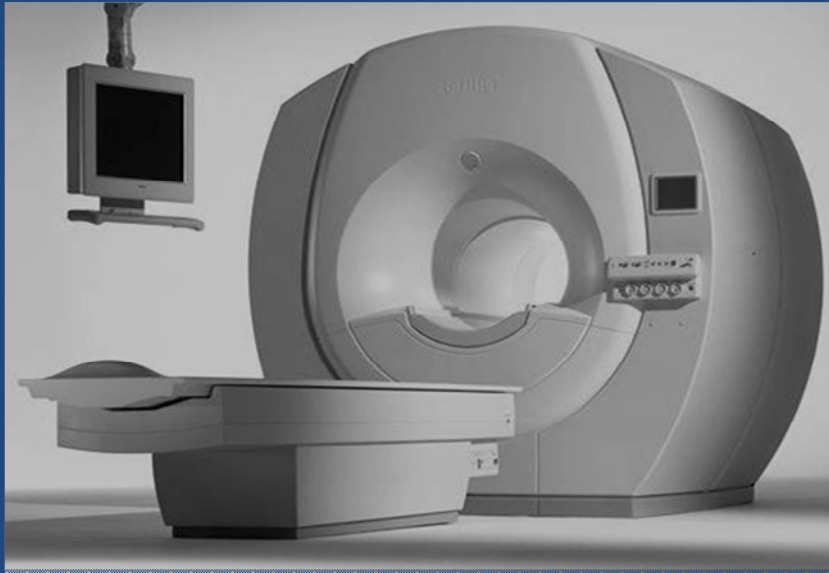
Ø Arterial & venous diameters

Ø Arterial & venous distensibility

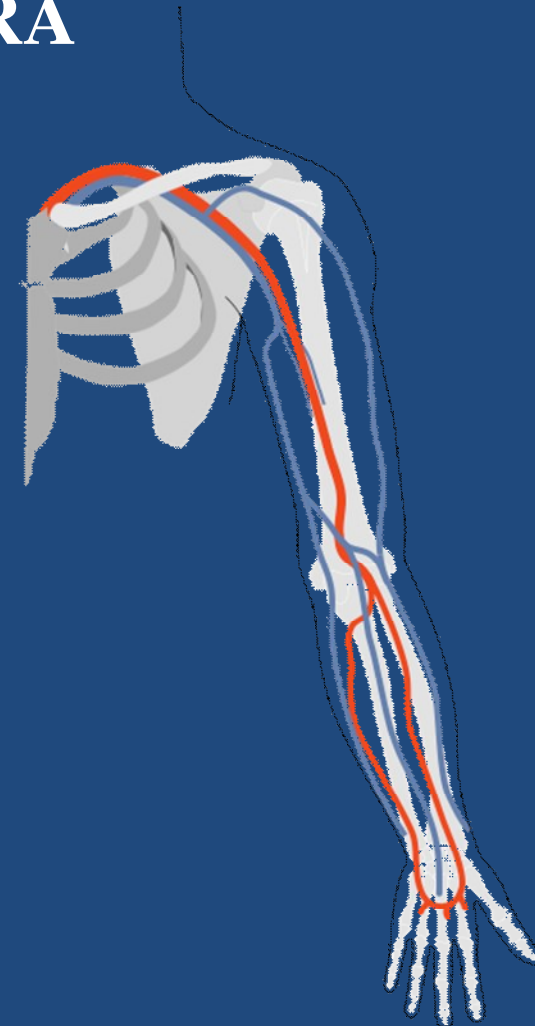
Ø Arterial flow



Input parameters modeling tool



MRA

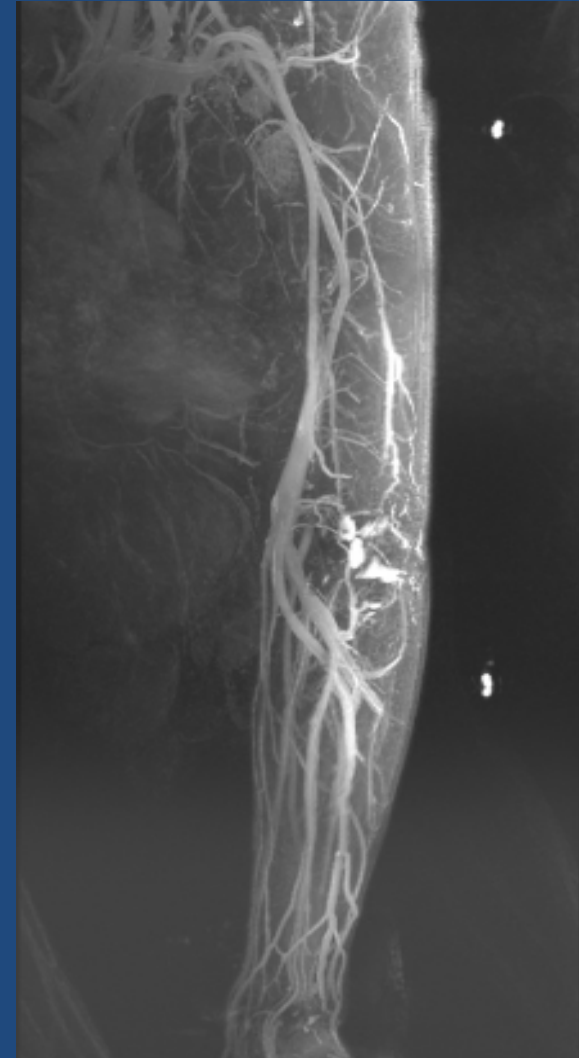


Input parameters modeling tool

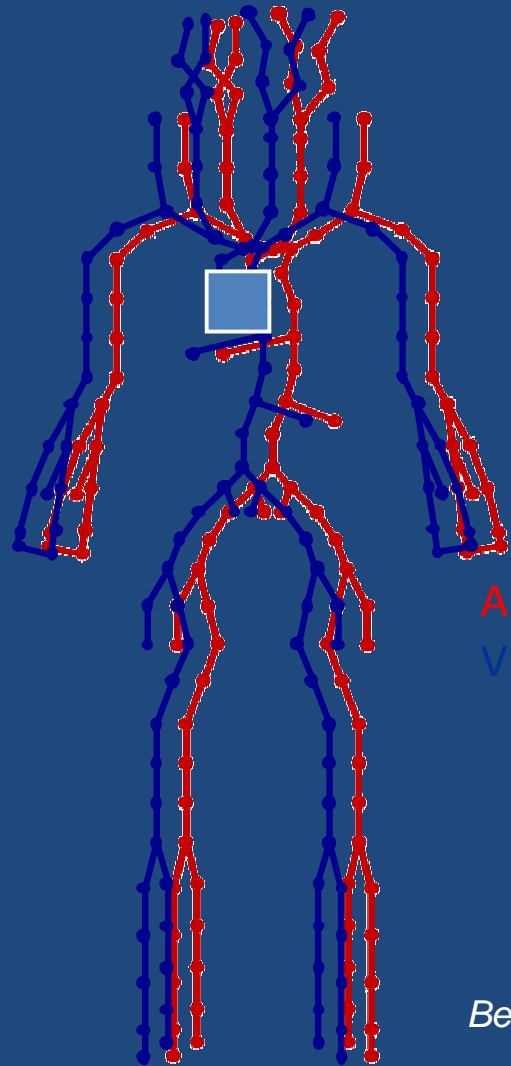
Contrast-enhanced

Non-contrast

MRA scanning

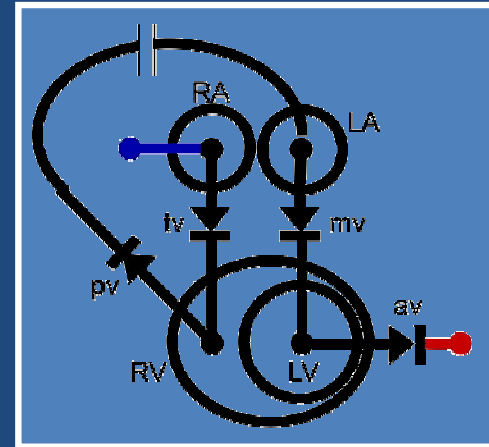


Modeling activities



ARTERIAL SYSTEM
VENOUS SYSTEM

Bessems et al 2007



Arts et al 2005, Bovendeerd et al 2006

Modeling activities

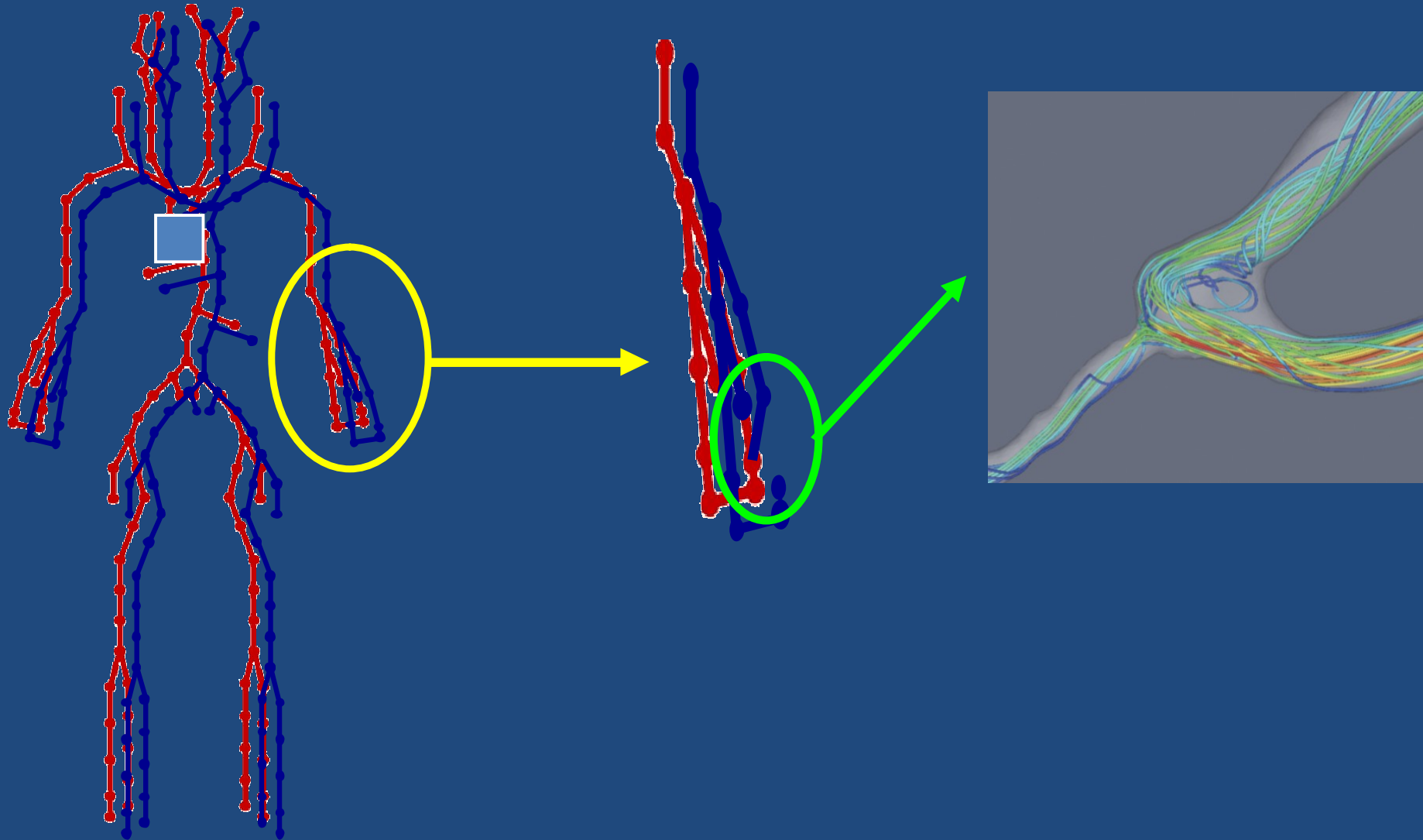
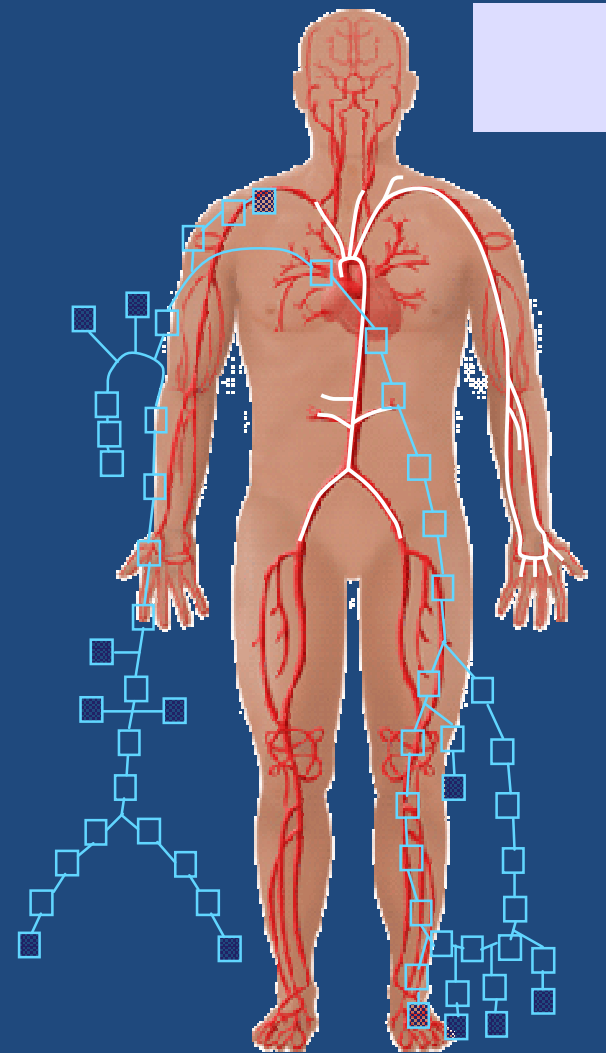
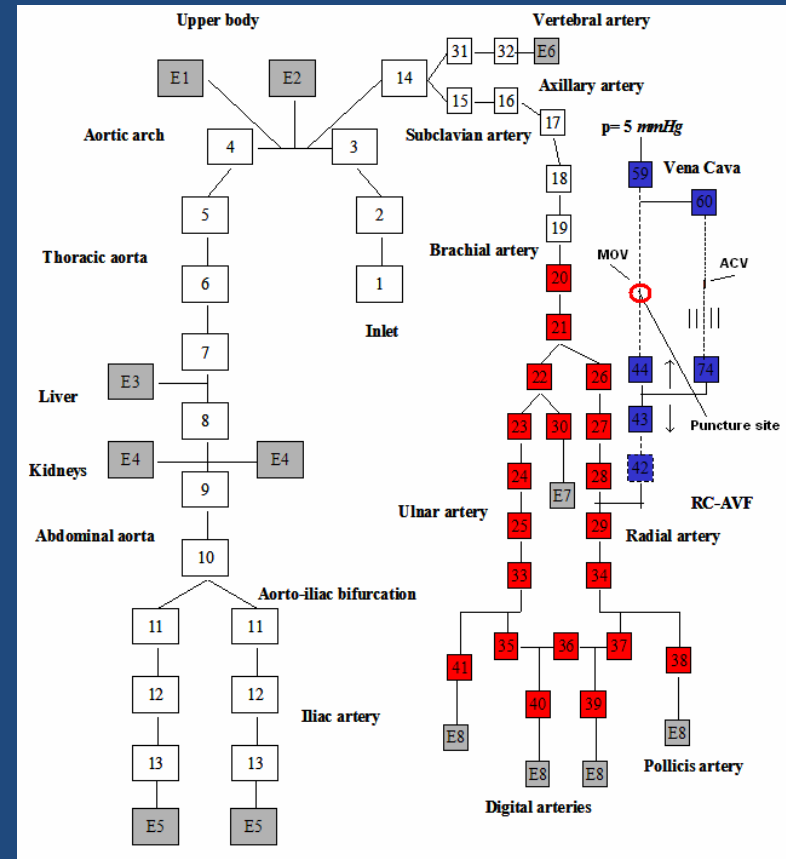
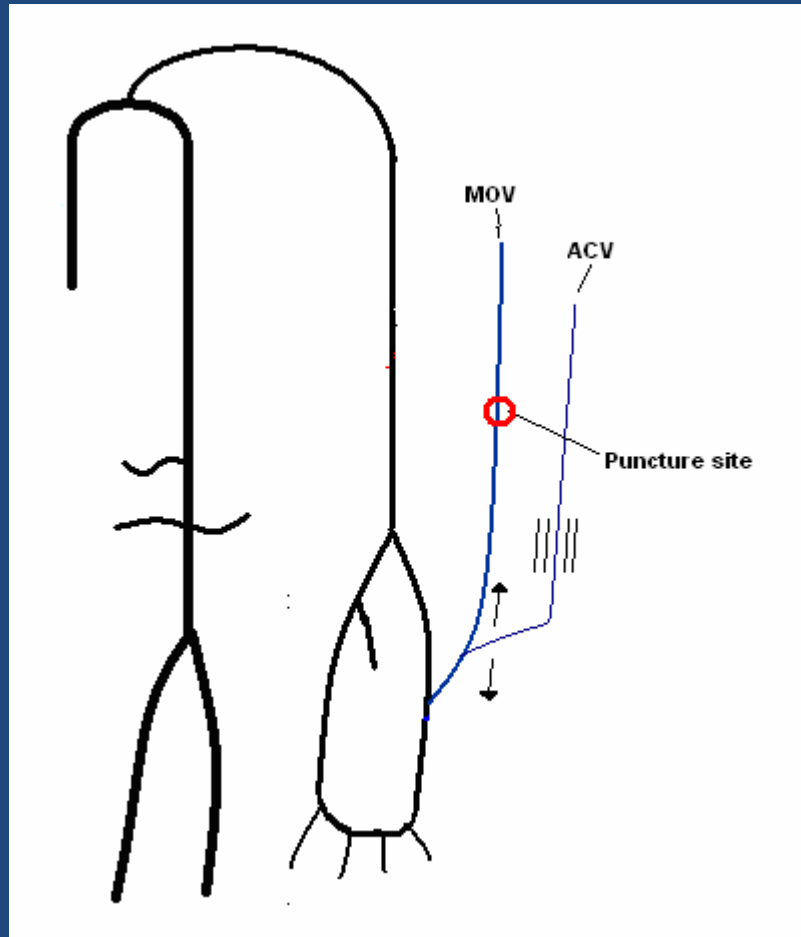


Image-based 1D network modelling

Lumped parameter modelling

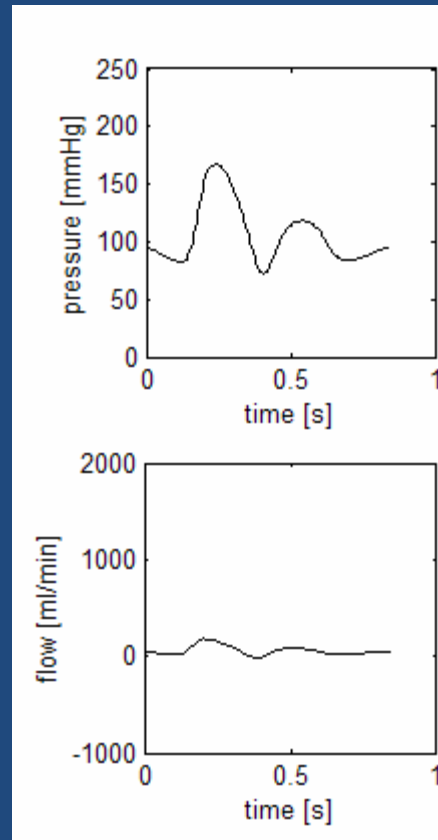
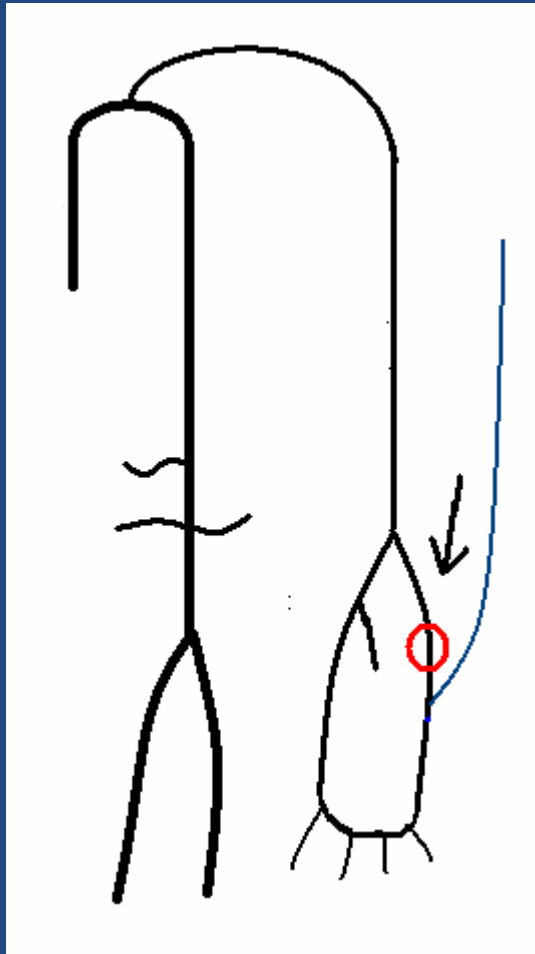


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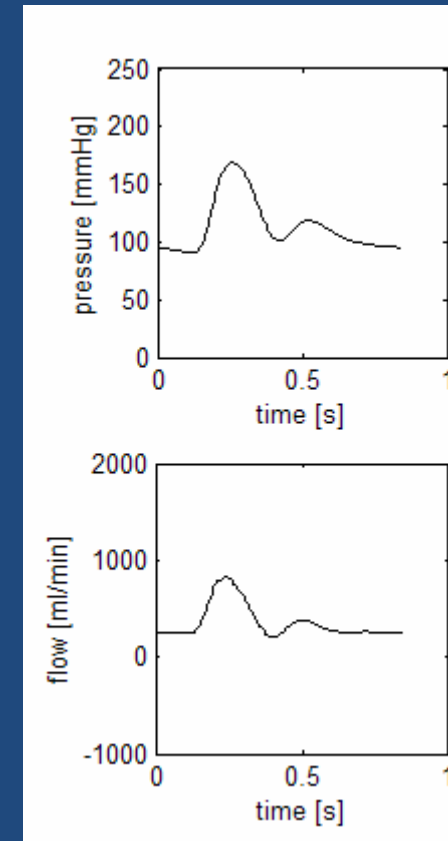


A schematic representation of the model. The location of the ACV in relation to the AV-anastomosis and the caliber of the ACV were adjustable

Computational Simulation to Predict Maturation



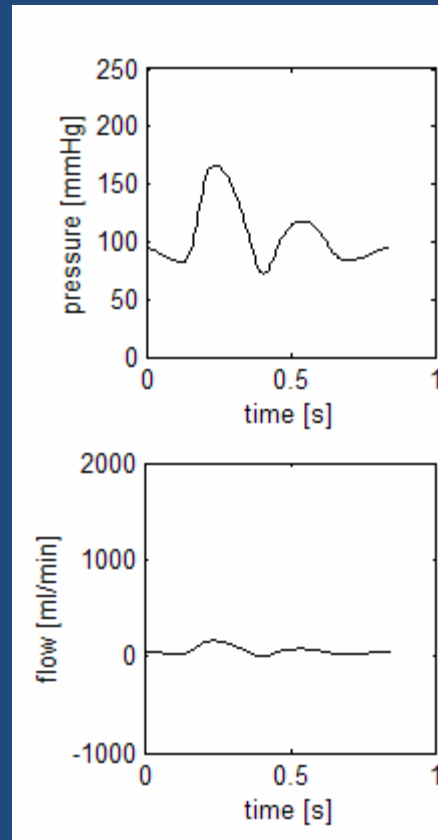
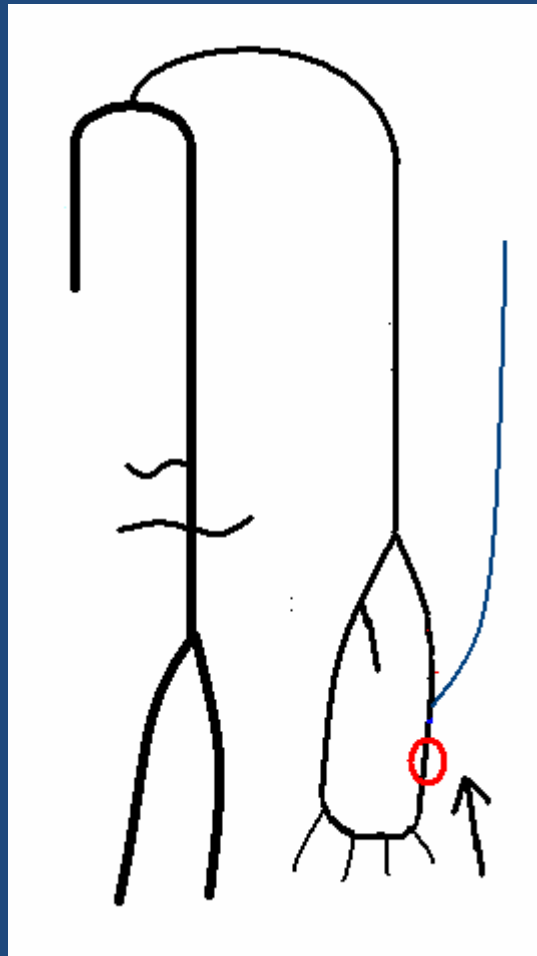
pre



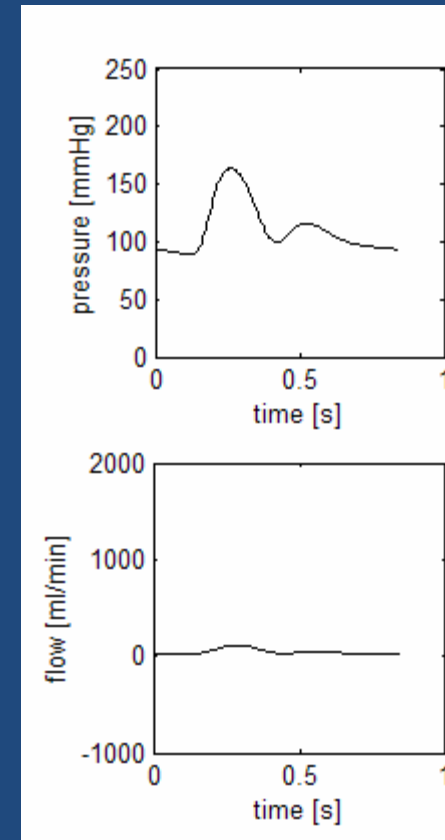
post

Pressure and flow as a function of time in the proximal radial artery before (left) and after (right) RC-AVF construction during one heart cycle

Computational Simulation to Predict Maturation



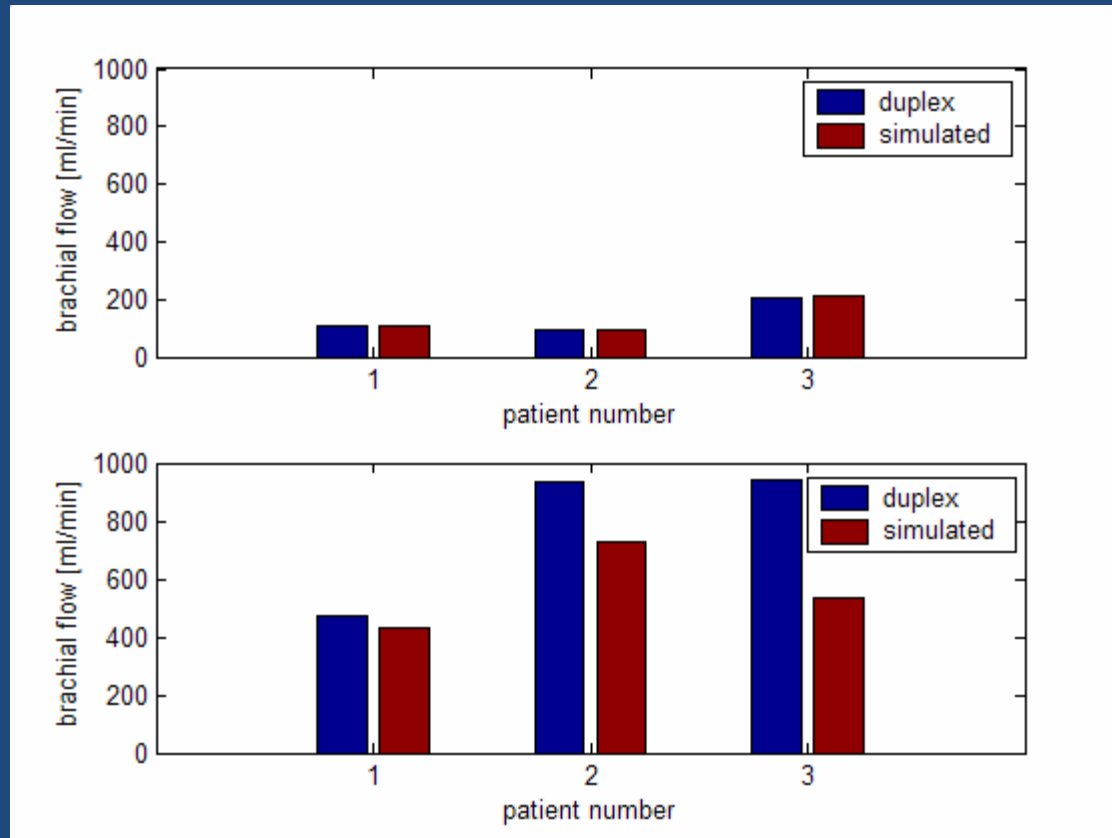
pre



post

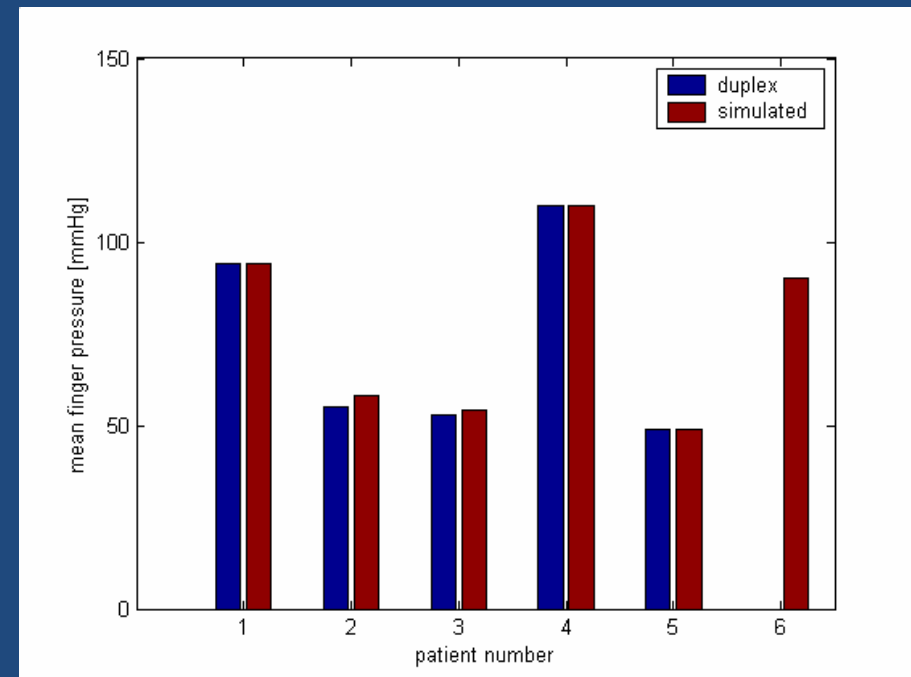
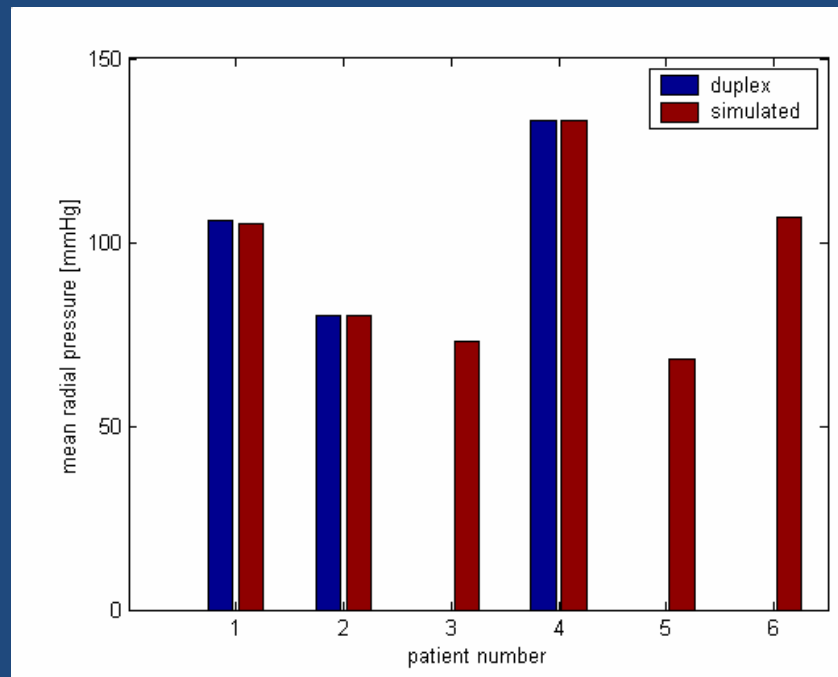
Pressure and flow as a function of time in the distal radial artery before (left) and after (right) RC-AVF construction during one heart cycle

Computational Simulation to Predict Maturation



Brachial artery flow for three simulated RC-AVF patients, determined by the lumped parameter model and measured by duplex scanning before and after AVF construction

Computational Simulation to Predict Maturation



The radial (left) and finger pressures (right) determined preoperatively by the lumped parameter models and measured by respectively tonometry and the Penaz method

Computational Simulation to Predict Maturation

 Summary 

- ü Patient-specific assessment & surgical planning
- ü Multi-scale computational modelling framework
- ü Dedicated preoperative vessel imaging
- ü Input of high quality duplex scanning & MRA parameters
- ü Improvement of Short-term maturation



European Commission
Information Society and Media

Acknowledgement

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