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2D perfusion angiography to assess the distal effect of revascularization

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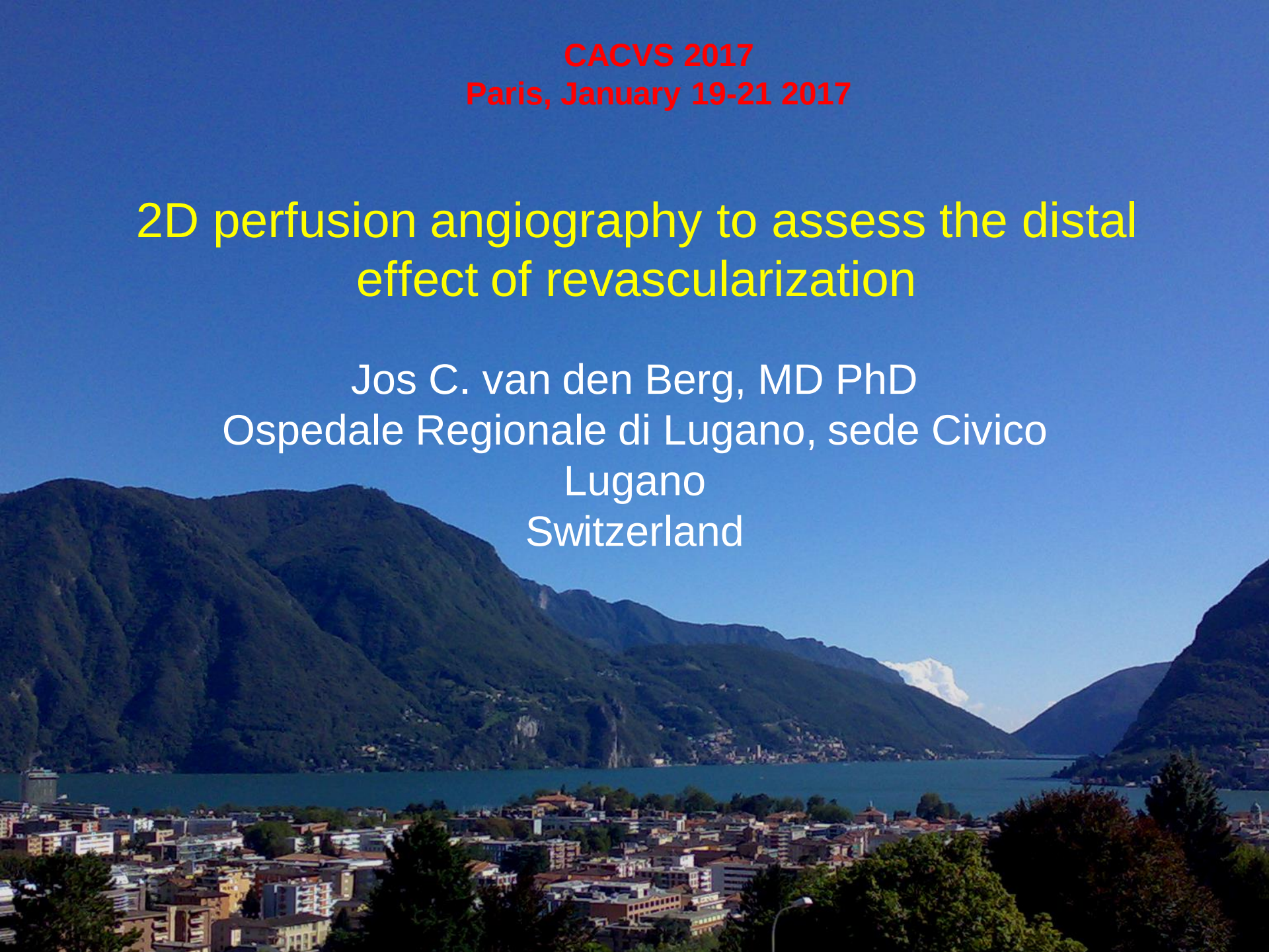

Background

- Angiosome concept favours direct revascularization
- Concept remains controversial
- There is probably also a place for indirect revascularization
  - Theoretical perspective
  - Practical point-of-view (direct revascularization not always possible)
- The more-the-better?: 3 vessel revascularization time-consuming and higher cost
- Restoring the macro-circulation may not be sufficient (in diabetic patients microcirculatory problems play a significant role)

Angiosome concept

Angiosome-targeted Lower Limb Revascularization for Ischemic Foot Wounds: Systematic Review and Meta-analysis

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WHAT THIS PAPER ADDS

The efficacy of angiosome-targeted revascularization to achieve healing of ischemic tissue lesions of the foot and limb salvage is controversial. The results of this meta-analysis suggest that, when feasible, direct revascularization of the foot angiosome affected may improve wound healing and limb salvage rates compared with indirect revascularization.

Objective: The efficacy of angiosome-targeted revascularization to achieve healing of ischemic tissue lesions of the foot and limb salvage is controversial. This issue has been investigated in this meta-analysis.

Methods: A systematic review of the literature and meta-analysis of data on angiosome-targeted lower limb revascularization for ischemic tissue lesions of the foot were performed.

Results: Nine studies reported on data of interest. No randomized controlled study was available. There were 715 legs treated by direct revascularization according to the angiosome principle and 575 legs treated by indirect revascularization. The prevalence of diabetes was >70% in each study group and three studies included only patients with diabetes. The risk of unhealed wound was significantly lower after direct revascularization (HR 0.64, 95% CI: 0.52—0.8, I^2 0%, four studies included) compared with indirect revascularization. Direct revascularization was also associated with significantly lower risk of major amputation (HR 0.44, 95% CI: 0.26—0.75, I^2 62%, eight studies included). Pooled limb salvage rates after direct and indirect revascularization were at 1 year 86.2% vs. 77.8% and at 2 years 84.9% vs. 70.1%, respectively. The analysis of three studies reporting only on patients with diabetes confirmed the benefit of direct revascularization in terms of limb salvage (HR 0.48, 95% CI: 0.31—0.75, I^2 0%).

Conclusions: The results of the present meta-analysis suggest that, when feasible, direct revascularization of the foot angiosome affected by ischemic tissue lesions may improve wound healing and limb salvage rates compared with indirect revascularization. Further studies of better quality and adjusted for differences between the study groups are needed to confirm the present findings.

Biancari F et al EJVES 2014;47:517-522

Angiosome concept

Wound healing

Study or Subgroup	log[Hazard Ratio]	SE	Direct revascular. Total	Indirect revascular. Total	Weight	Hazard Ratio IV, Random, 95% CI	Year
Varela 2010	-0.29	0.27	45	31	13.9%	0.75 [0.44–1.27]	2010
Azuma 2012 a	-0.2	0.2	59	51	25.3%	0.82 [0.55–1.21]	2012
Azuma 2012 b	-0.59	0.22	67	41	20.9%	0.55 [0.36–0.85]	2012
Kabra 2013	-0.6	0.29	39	25	12.0%	0.55 [0.31–0.97]	2013
Söderström 2013	-0.58	0.19	121	129	28.0%	0.56 [0.39–0.81]	2013
Total (95% CI)			**331**	**277**	**100.0%**	**0.64 [0.52–0.78]**	

Heterogeneity: Tau² = 0.00; Chi² = 3.05, df = 4 (p = 0.55); I² = 0%
Test for overall effect: Z = 4.46 (p < 0.00001)

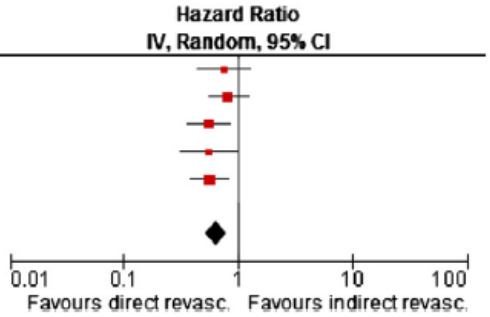

Figure 2. Forest plot for effectiveness of direct revascularization versus indirect revascularization according to the angiosome concept in wound healing in patients with ischemic tissue lesions of the foot.

Biancari F et al EJVES 2014;47:517-522

Angiosome concept

Limb salvage

Study or Subgroup	log[Hazard Ratio]	SE	Direct revascular. Total	Indirect revascular. Total	Weight	Hazard Ratio IV, Random, 95% CI	Year
Varela 2010	-0.28	0.5	45	31	12.7%	0.76 [0.28–2.01]	2010
Alexandrescu 2011	-0.65	0.4	134	98	15.1%	0.52 [0.24–1.14]	2011
Blanes Ortí 2011	-0.59	0.88	18	16	6.6%	0.55 [0.10–3.11]	2011
Ferrufino-Mérida 2012	-4.16	0.92	23	9	6.2%	0.02 [0.00–0.09]	2012
Iida 2012	-0.36	0.25	200	169	19.0%	0.70 [0.43–1.14]	2012
Kabra 2013	-0.69	0.67	39	25	9.4%	0.50 [0.13–1.86]	2013
Lejay 2013	-1.17	0.42	36	22	14.6%	0.31 [0.14–0.71]	2013
Söderström 2013	-0.48	0.36	121	129	16.2%	0.62 [0.31–1.25]	2013
Total (95% CI)			**616**	**499**	**100.0%**	**0.44 [0.26–0.75]**	

Heterogeneity: $Tau^2 = 0.32$; $Chi^2 = 18.21$, $df = 7$ ($P = 0.01$); $I^2 = 62\%$
Test for overall effect: $Z = 3.02$ ($P = 0.002$)

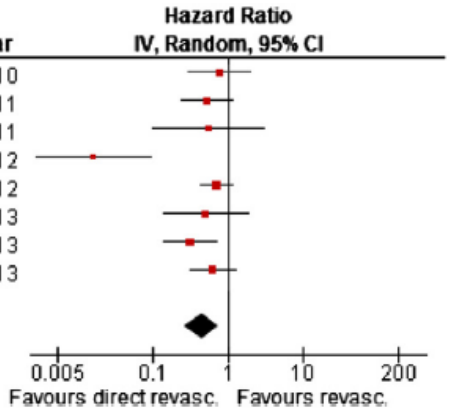

Figure 4. Forest plot for effectiveness of direct revascularization versus indirect revascularization according to the angiosome concept in limb salvage in patients with ischemic tissue lesions of the foot.

Biancari F et al EJVES 2014;47:517-522

Angiosome concept

INVITED COMMENTARY

Commentary on "Angiosome-targeted Lower Limb Revascularization for Ischaemic Foot Wounds: Systematic Review and Meta-analysis"

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Forsythe R et al EJVES 2014;47:523

Angiosome concept

The angiosome concept was developed in healthy patients. Very little consideration has been given to the distribution of angiosomes in patients with critical limb ischaemia or diabetes. Recent evidence suggests that the traditional angiosome model may not accurately predict the distribution of blood flow in an unselected group of patients with critical ischaemia, whose pattern of perfusion is distorted by abnormalities of the vascular bed, development of collaterals (especially in patients with diabetes) and atrophy of existing microvasculature.[5] Therefore, the topographical location of an ulcer may not actually correlate accurately with the source artery supplying that area of tissue. With standard angiography,

Forsythe R et al EJVES 2014;47:523

Angiosome concept

Clinical implications of the angiosome model in peripheral vascular disease

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Vascular surgery has seen a revolutionary transformation in its approach to peripheral vascular disease over the last 2 decades, fueled by technological innovation and a willingness by the field to adopt these changes. However, the underlying pathology behind critical limb ischemia and the significant rate of unhealed wounds and secondary amputations despite apparently successful revascularization needs to be addressed. In seeking to improve outcomes, it may be beneficial to examine our approach to vascular disease at the fundamental level of anatomy, the angiosome, to better dictate reperfusion strategies beyond a simple determination of open vs endovascular procedure. We performed a systematic review of the current literature concerning the significance of the angiosome concept in the realm of vascular surgery. The dearth of convincing evidence in the form of prospective trials and large patient populations, and the lack of a consistent, comparable vocabulary to contrast study findings, prevent recommendation of the conceptual model at a wider level for guidance of revascularization attempts. Further well-structured, prospective studies are required as well as emerging imaging strategies, such as indocyanine green dye-based fluorescent angiography or hyperspectral imaging, to allow wider adoption of the angiosome model in vascular operations. (J Vasc Surg 2013;58:814-26.)

Sumpio BE et al JVS 2013;58:814-826

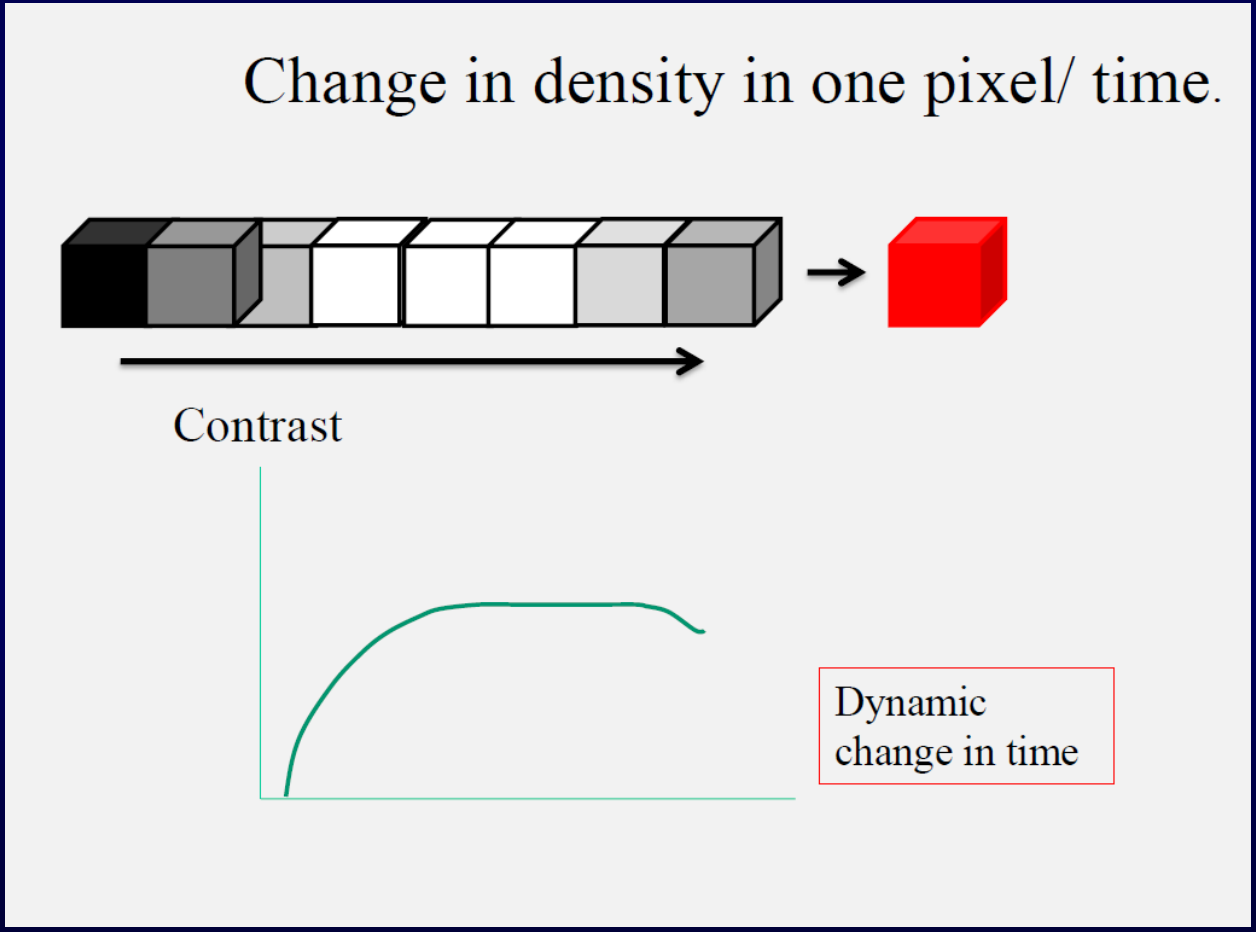
CLI

- Macrovasculature
  - Decreased inflow of blood
- Microvasculature
  - Mismanagement of blood in the foot/limb

2D-perfusion angiography technique

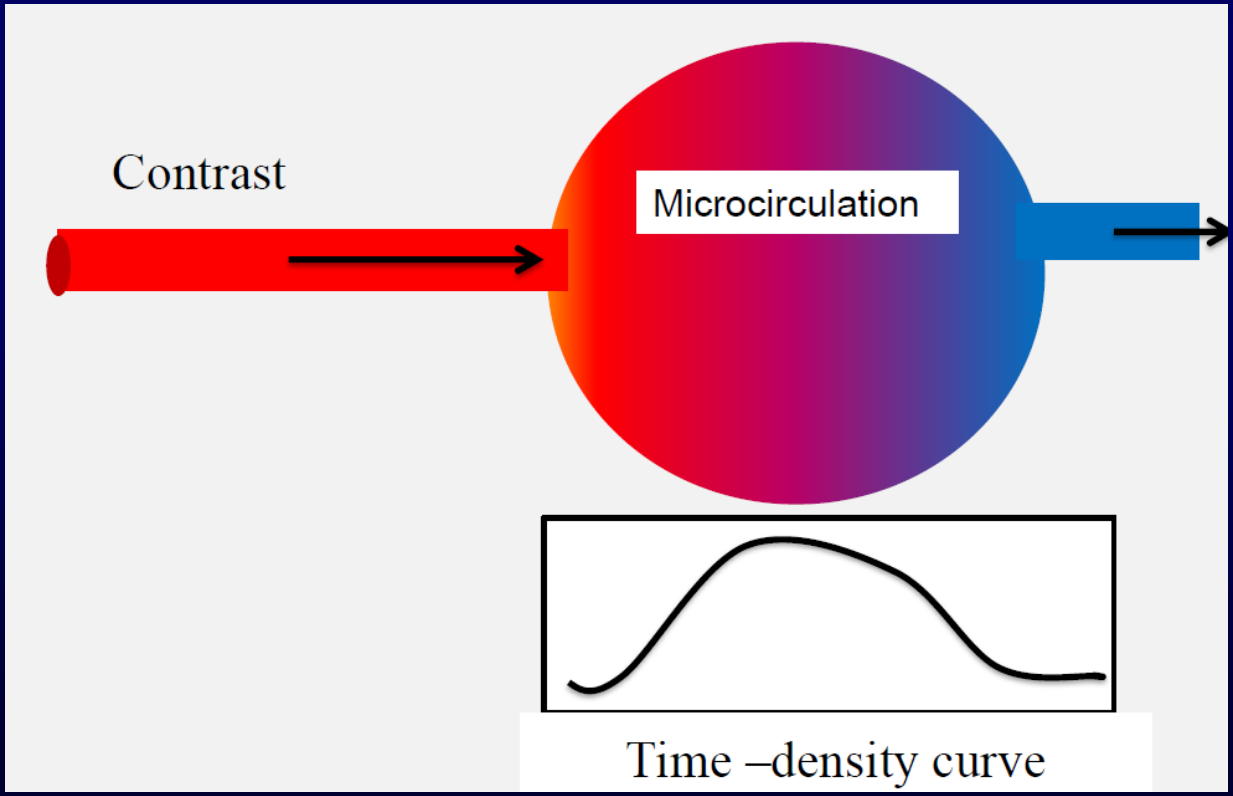
- Standard angiography (DSA 3 fps)
- Standardized contrast injection
- Immobilized limb/foot
- Software elaboration of DSA

2D-perfusion angiography-how does it work?



2D-perfusion angiography

- Measures volume flow in the whole foot
  - Macro-circulation
  - Micro-circulation

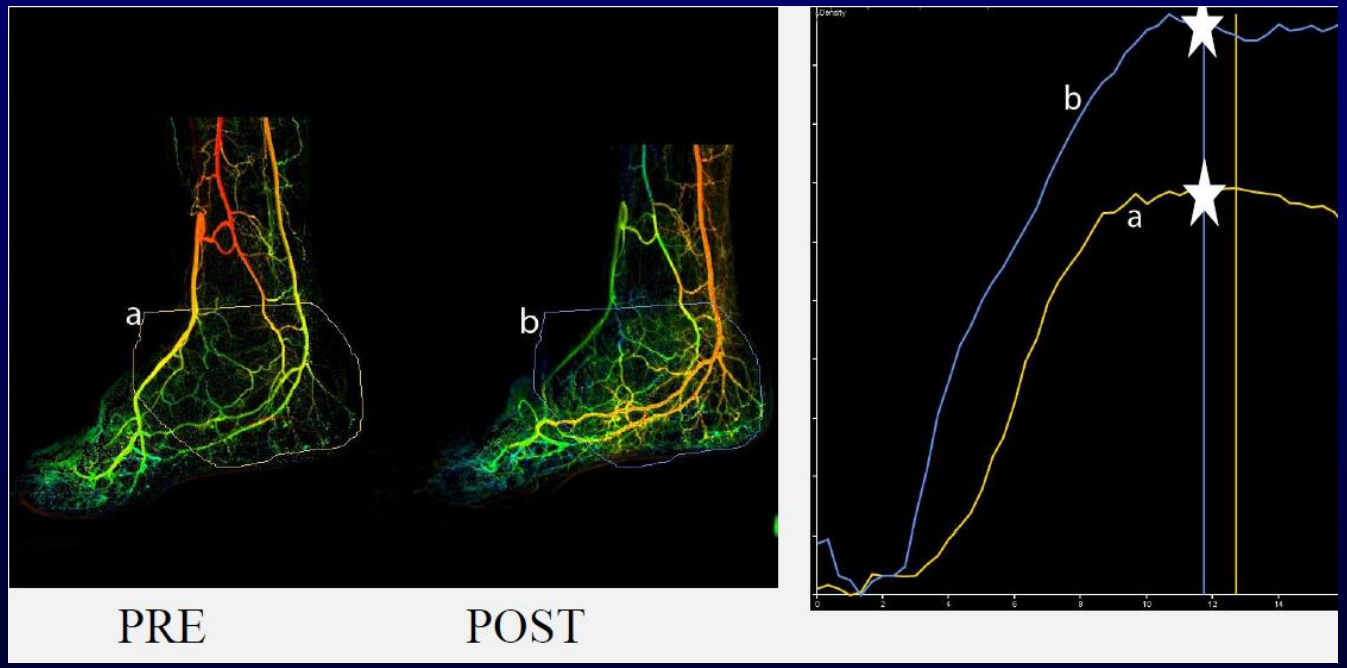


Application 2D-perfusion angiography

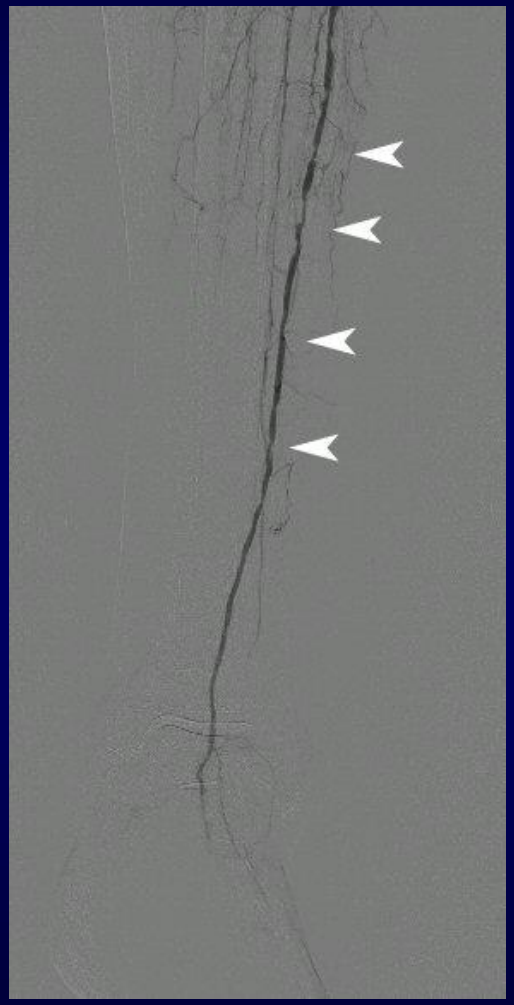
- Determine endpoint for revascularization
  - Evaluation macro-circulation
  - Increase in volume flow
- Test the functionality of the micro-circulation

2D-perfusion angiography

- Increase in volume flow after revascularization
  - Peak density
  - Area under the curve



DSA



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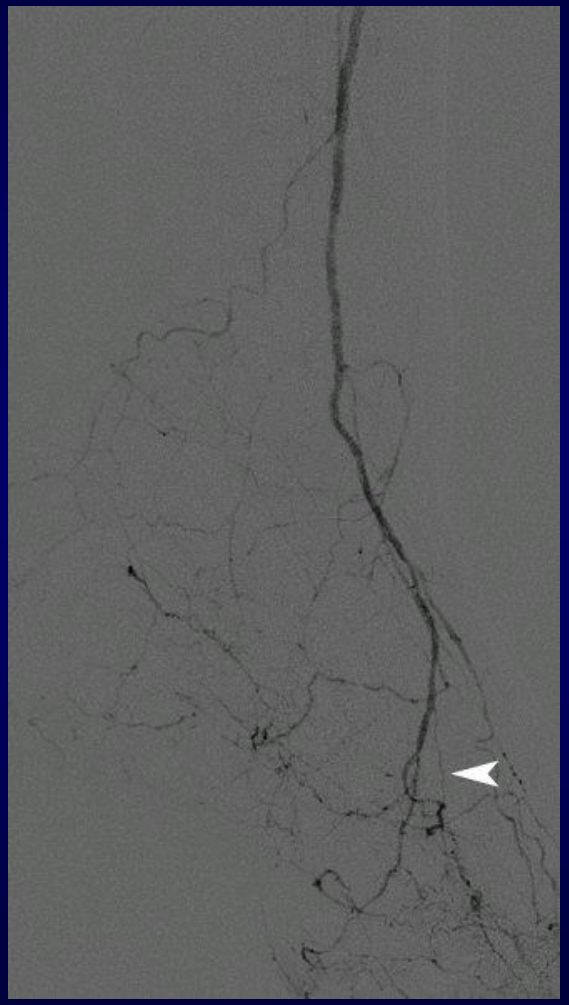
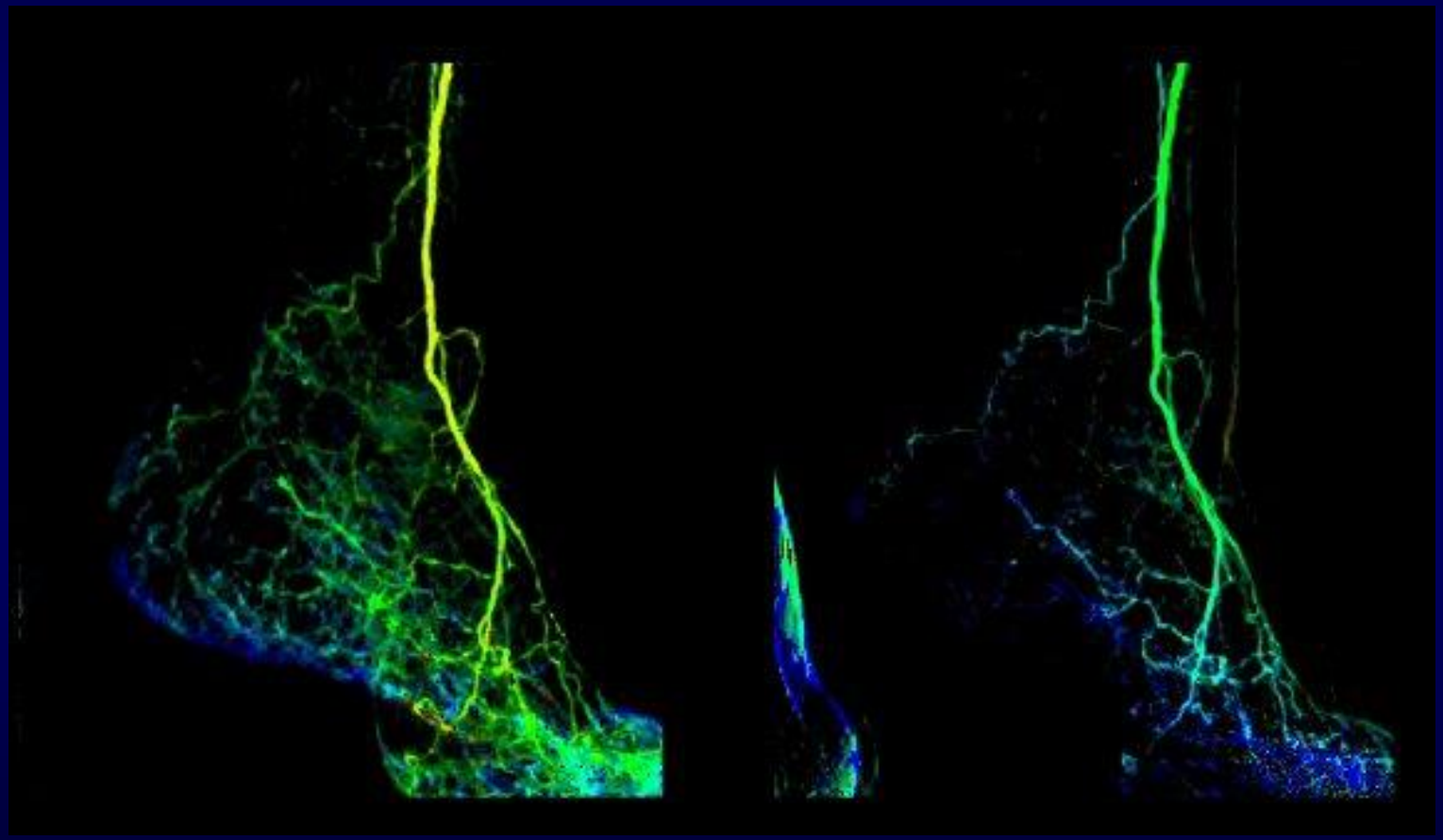
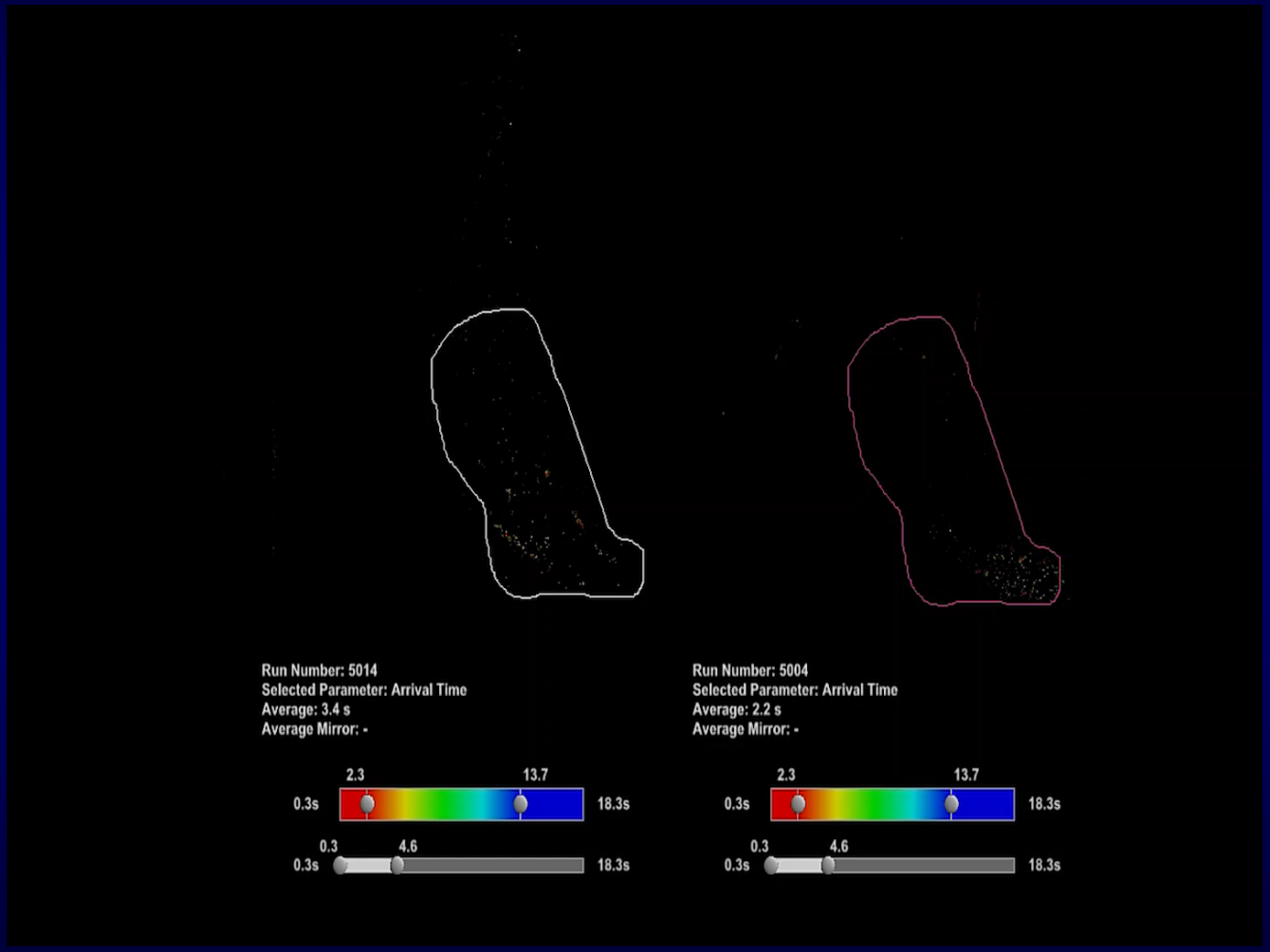


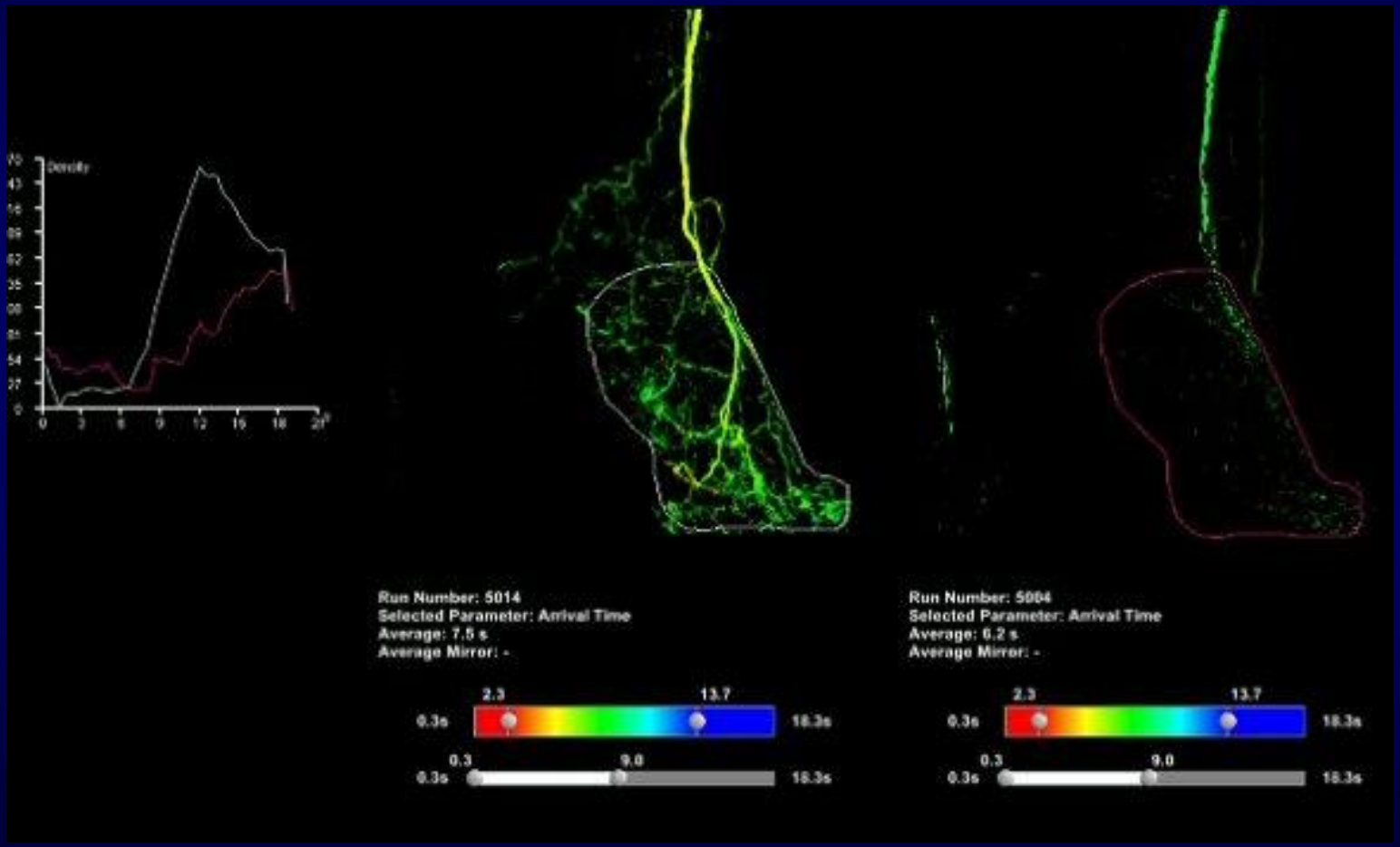
2D-perfusion angiography



2D-perfusion angiography



2D-perfusion angiography



Peak density and area under the curve

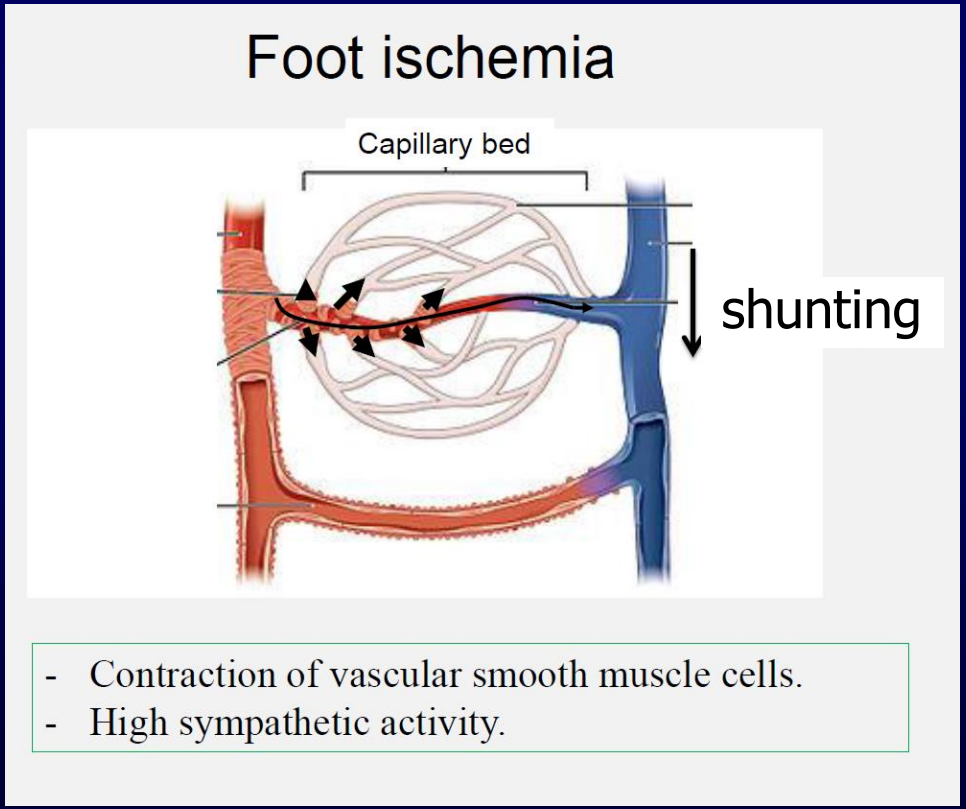
2D-perfusion angiography

- 89 patients
  - N=9 imaging not adequate
  - N=12 no BTK intervention
  - N=68 available for analysis
- Increase in maximal peak density 21%, area under the curve 48% (NB changes, no absolute measures)
- 9/68 no increase
- No relationship to clinical outcome investigated (PALI study will address this)

Reekers JA et al, CVIR 2016;39:183-189

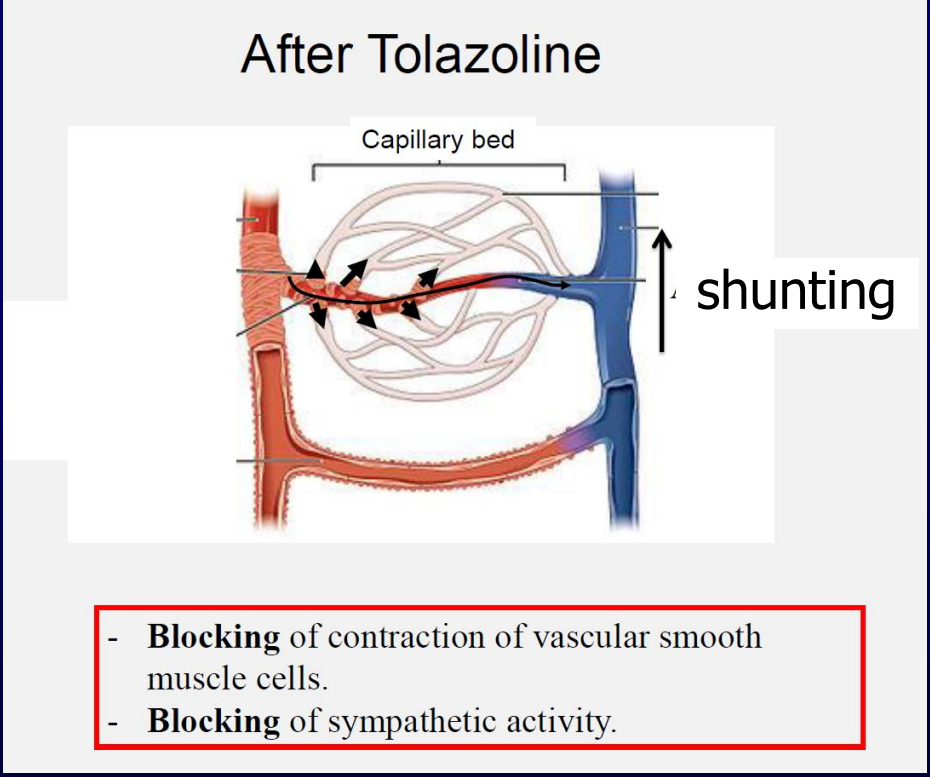
Micro-circulation

- AV-shunting reduced (‘foot wants to keep the blood’)



Micro-circulation

- Tolazoline opens capillaries (vasodilation), increases AV-shunting



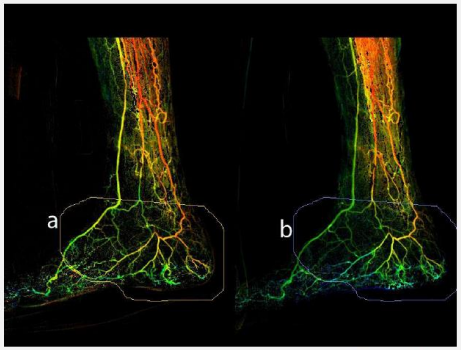
Capillary resistance index (CRI)

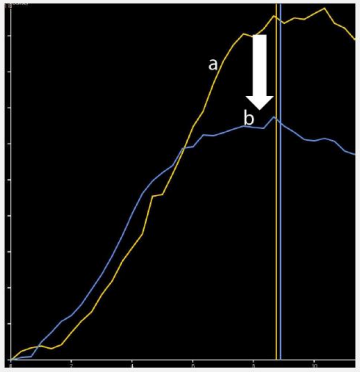
- Maximal peak density post-tolazoline divided by maximal peak density pre-tolazoline
- Measures functionality of micro-circulation

Reekers JA, CIRSE 2015

CRI

- CLI with non-healing ulcer.
- No intervention
- Diabetes type 2

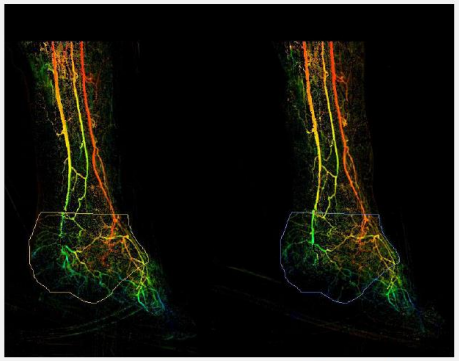


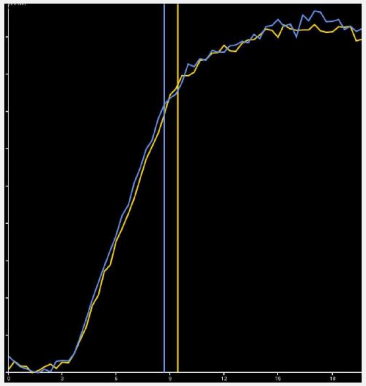


Tolazoline

Capillary Resistance Index (CRI) = b/a = **0,68**

- CLI with non-healing ulcer.
- No intervention
- Diabetes type 2





Tolazoline

Capillary Resistance Index (CRI) = b/a = **1,0**

Reekers JA, CIRSE 2015

CRI

- 21 patients with CLI
  - Group A n=10 revascularization (2 bypass)
  - Group B n=11 no treatment
- 7 early amputations (30%)
  - Group A n=4
  - Group B n=3

Reekers JA, CIRSE 2015

CRI

- 21 patients
  - CRI >0.9 n=6
  - CRI <0.9 n=15
- Amputations
  - CRI >0.9 6 early amputations
  - CRI <0.9 1 early amputation

Reekers JA, CIRSE 2015

CRI

- Patient selection? Cf. FFR (cardiology)
- Patients with CRI <0.9 may have better outcome

Reekers JA, CIRSE 2015

Conclusion

- 2D-perfusion angiography is feasible and can help to determine an endpoint for revascularization
- Allows functional imaging that may help in selecting patients that will benefit from revascularization