AAWC: Technology Update: Micro and Macro Assessment of Perfusion

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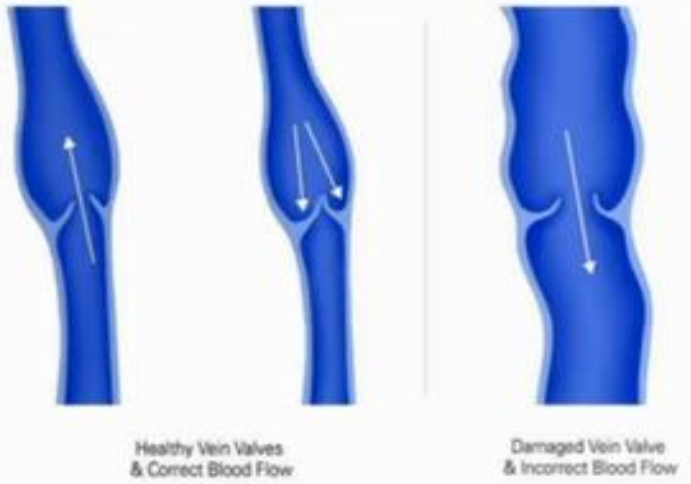
CVI

- Most common vascular disease affecting > 25 million people
- Most common cause of adult leg edema
- Affects 1 out of every 2 females over the age of 50
- Sequelae: edema, varicose veins, skin discoloration, skin thickening, ulceration
- Sx: leg edema, fatigue, cramping, heaviness, pain, itching, achiness

PATHOPHYSIOLOGY

- Disruption of the one way valve system in veins
- Blood flow refluxes due to the incompetent valves and pools in the lower extremities
- Dilation of the veins to accommodate volume results in development of varicosities
- Treatment is focused on the superficial system (the great and small saphenous veins in the leg)



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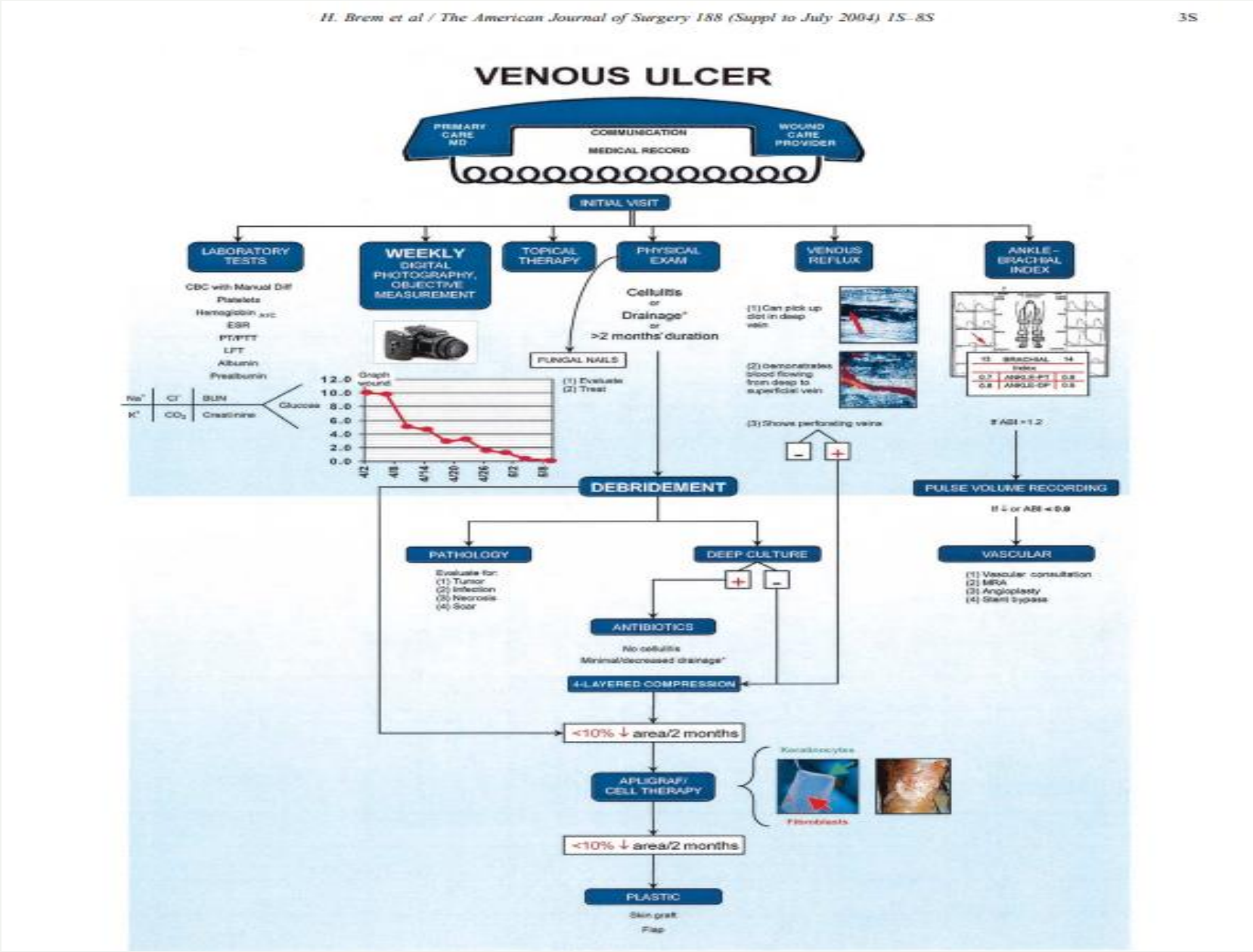
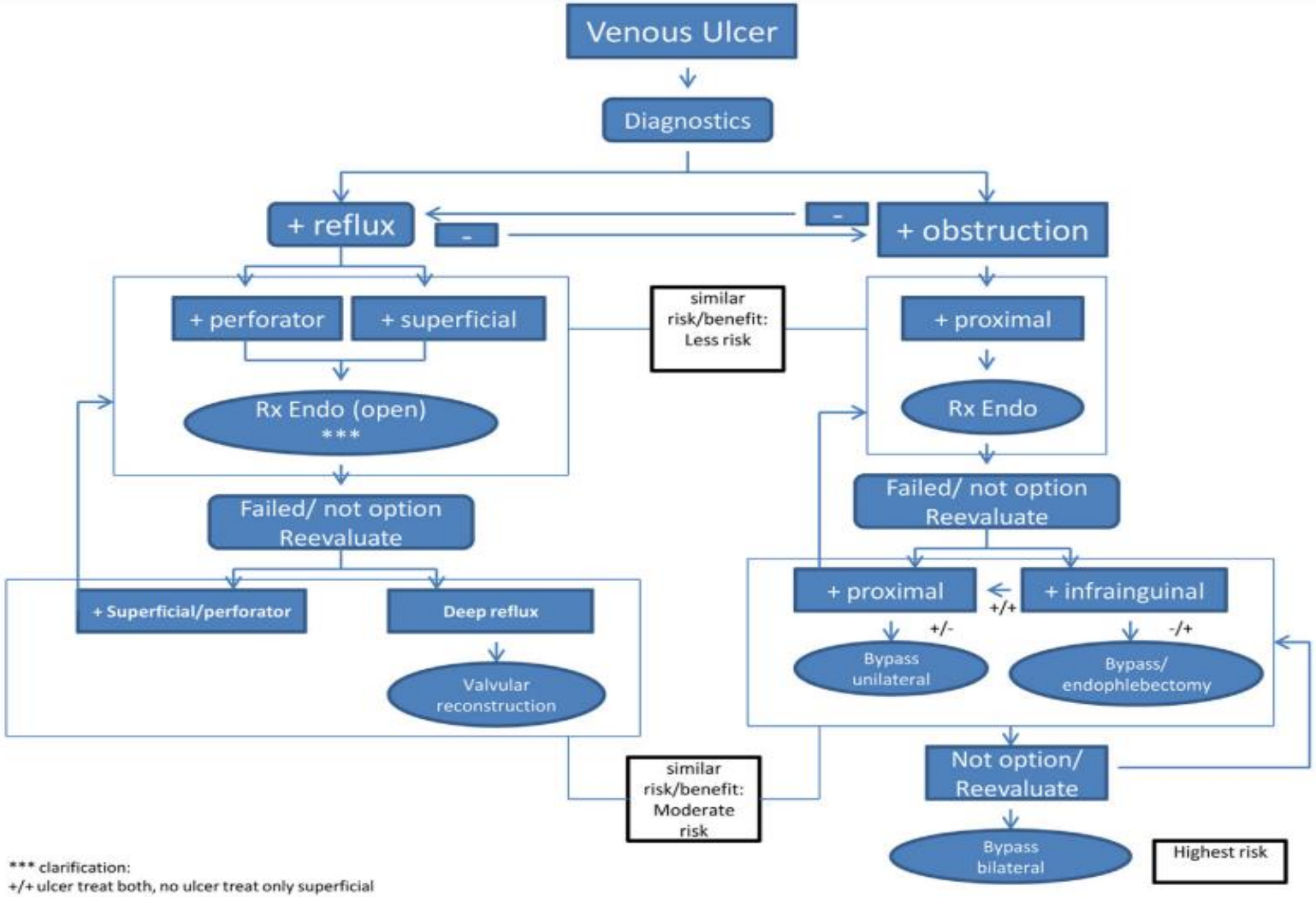
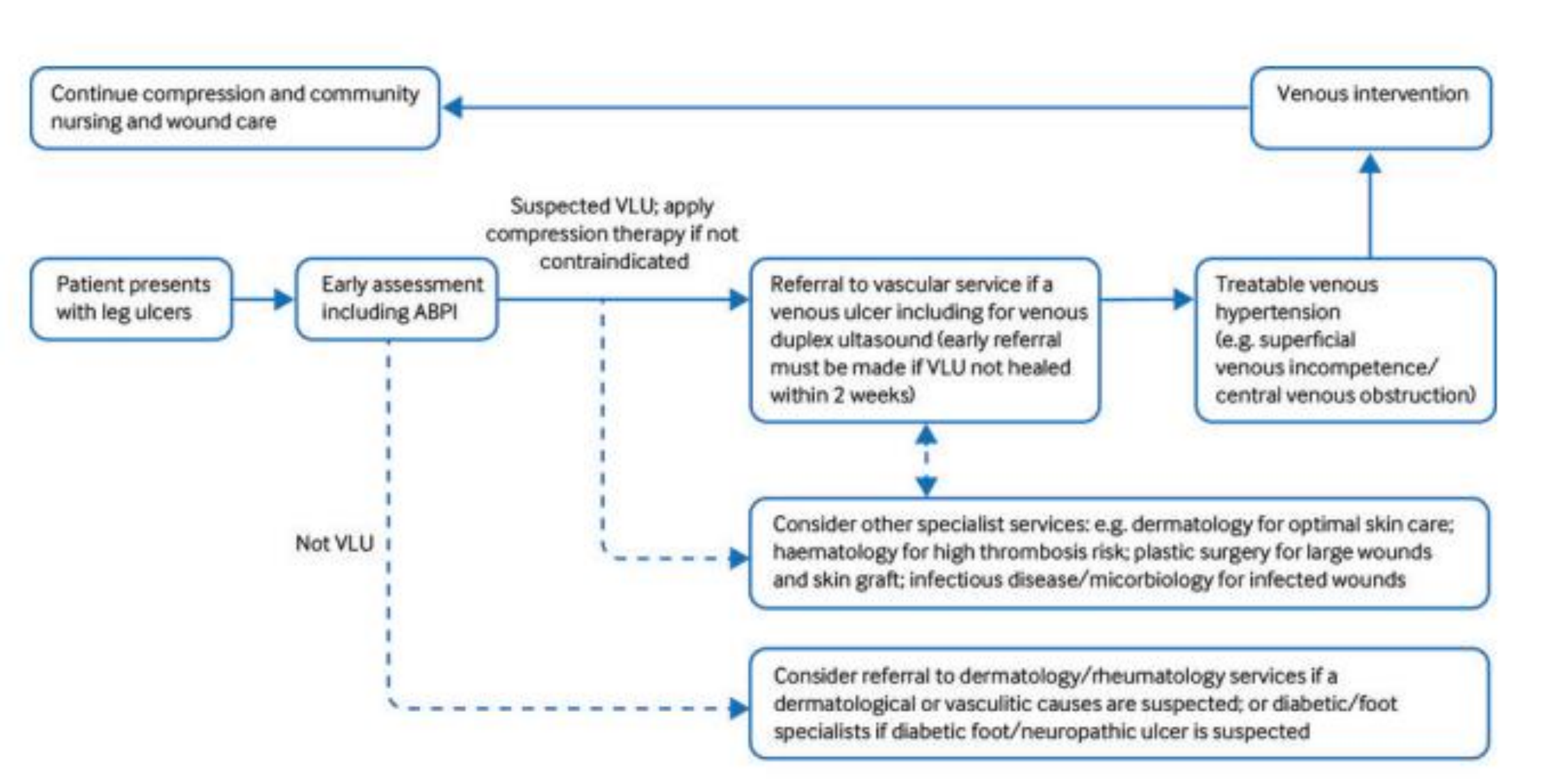


H. Brem et al / The American Journal of Surgery 188 (Suppl to July 2004) 1S–8S


Venous Ulcer
Diagnostics
+ reflux
-
-
+ obstruction
+ perforator
+ superficial
similar risk/benefit: Less risk
+ proximal
Rx Endo (open) ***
Rx Endo
Failed/ not option Reevaluate
Failed/ not option Reevaluate
+ Superficial/perforator
Deep reflux
+ proximal
+/+
+ infrainguinal
+/-
-/+
Valvular reconstruction
Bypass unilateral
Bypass/ endophlebectomy
similar risk/benefit: Moderate risk
Not option/ Reevaluate
Bypass bilateral
Highest risk
*** clarification:
+/+ ulcer treat both, no ulcer treat only superficial



BMJ 2018;362:k3115 doi: 10.1136/bmj.k3115 (Published 14 August 2018)

Advanced Wound Care Dressings

- Determined by wound location
- Size
- Depth
- Exudate amount
- Bioburden or biofilm
- Frequency of dressing change
- Payer source or cost, and availability

depth map not available

post-debridement

	Δ 3/22/2021
Total Area	10.84 cm² +6.14%
Length	4.69 cm +1.58%
Width	4.32 cm -1.74%
Perimeter	16.96 cm +10.5%
Total Tunneling	0 cm 0%
Total Undermining	0 cm 0%
Maximum Depth	0.2 cm +100%

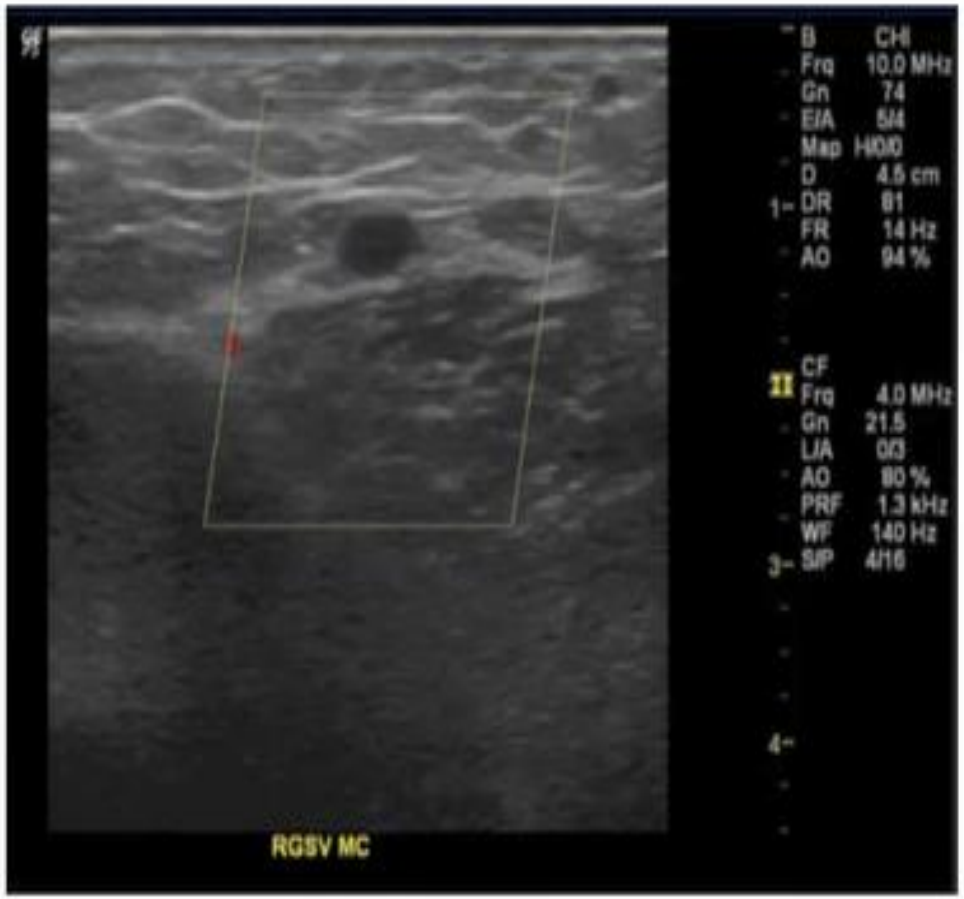
Red Tissue	4.88 cm²	45%	-13.27%
Black Tissue	1.02 cm²	9%	-12.93%
Yellow Tissue	0.06 cm²	1%	-5.33%
Other Tissue	0.72 cm²	7%	+5.04%
Pink Tissue	4.16 cm²	38%	+26.49%

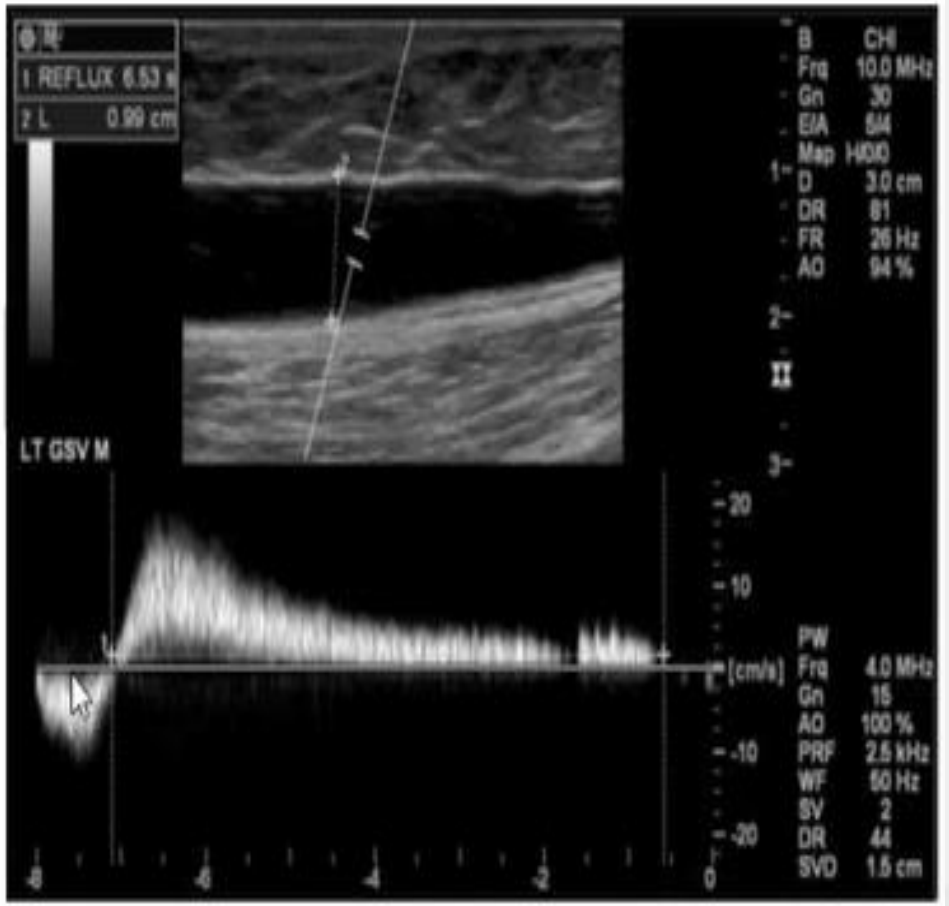
DVT Y/N	N

SUPERFICIAL	SIZE (mm)	REFLUX (sec)
SFJ	8.9	> 2
GSV PT	6.3	
GSV MT	7.6	
GSV DT	5.5	
GSV PC	5.0	
GSV MC	4.0	
GSV DC	3.3	
AGSV PT		
AGSV MT		
AGSV DT		
SSV SPJ	2.6	
SSV P	2.0	

PTV/PV	
DVT Y/N	N

SUPERFICIAL	SIZE (mm)	REFLUX (sec)
SFJ		N/V
GSV PT		
GSV MT		
GSV DT		
GSV PC		
GSV MC		
GSV DC		
AGSV PT		
AGSV MT		
AGSV DT		
SSV SPJ	3.3	
SSV P	4.1	

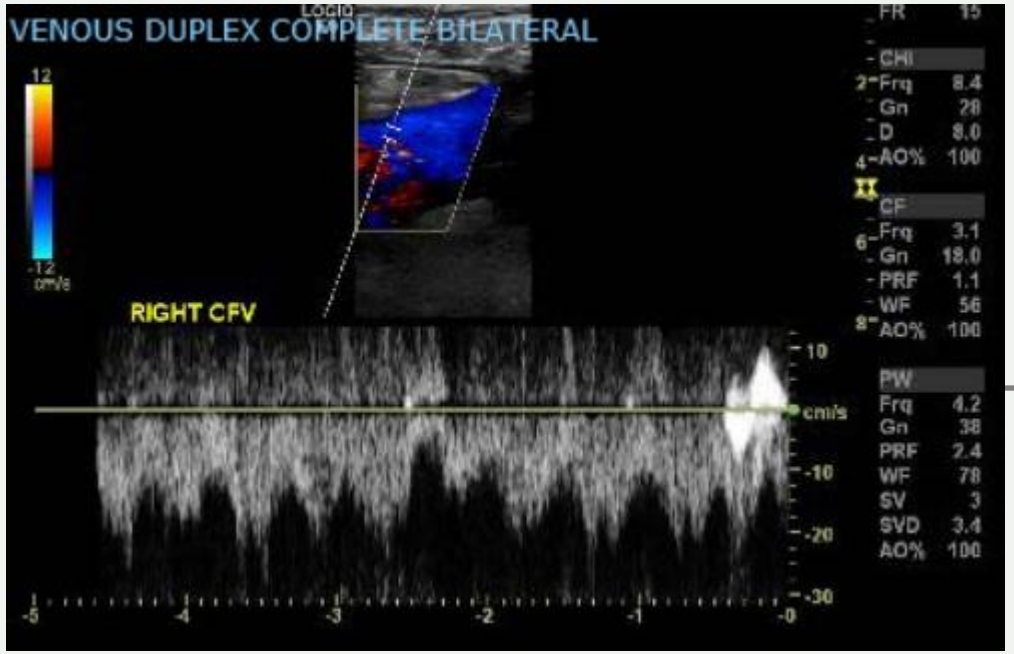

B CHI
Frq 10.0 MHz
Gn 74
EIA 5/4
Map H0/0
D 4.6 cm
DR 81
FR 14 Hz
AO 94 %
CF
Frq 4.0 MHz
Gn 21.5
LIA 0/3
AO 80 %
PRF 1.3 kHz
WF 140 Hz
S/P 4/16
RGSV MC

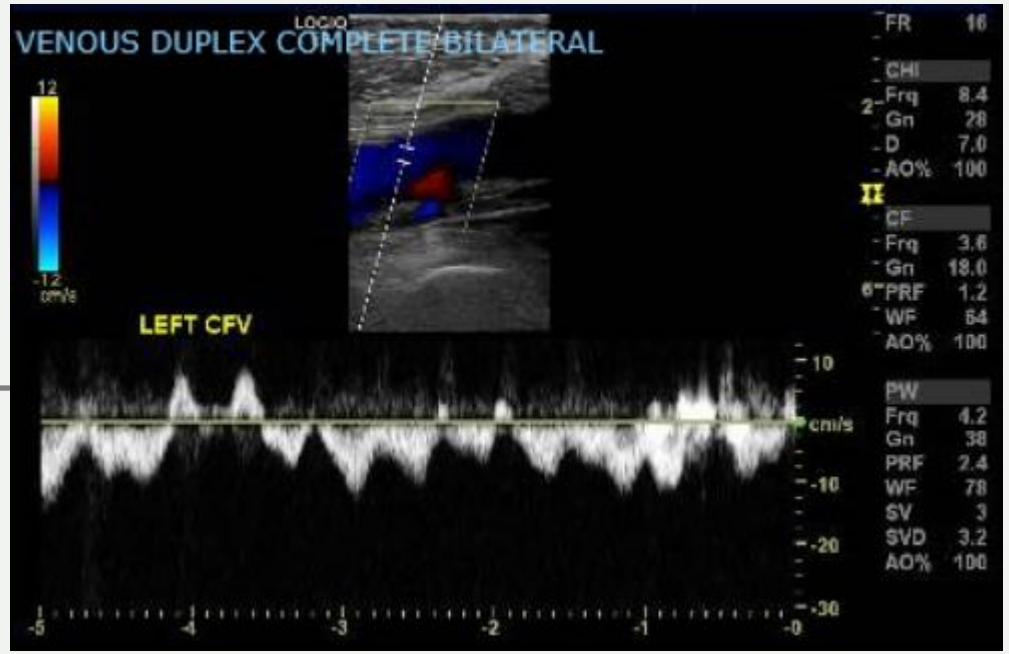

1 REFLUX 6.53 s
2 L 0.99 cm
LT GSV M
B CHI
Frq 10.0 MHz
Gn 30
EIA 5/4
Map H0/0
D 3.0 cm
DR 81
FR 26 Hz
AO 94 %
PW
Frq 4.0 MHz
Gn 15
AO 100 %
PRF 2.5 kHz
WF 50 Hz
SV 2
DR 44
SVD 1.5 cm
(cm/s)

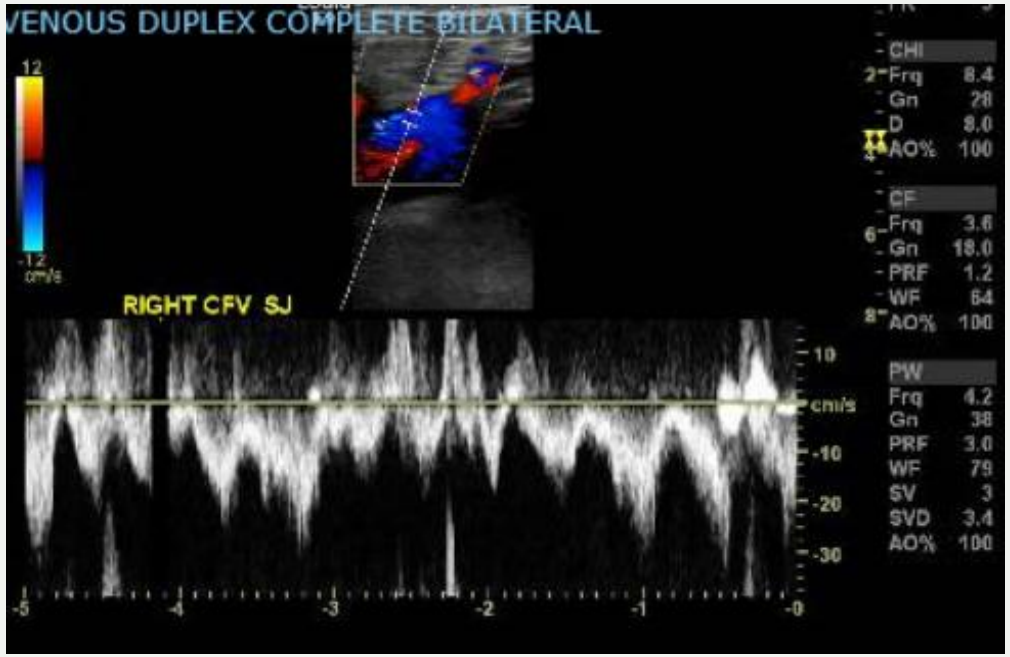
Endovenous Intervention

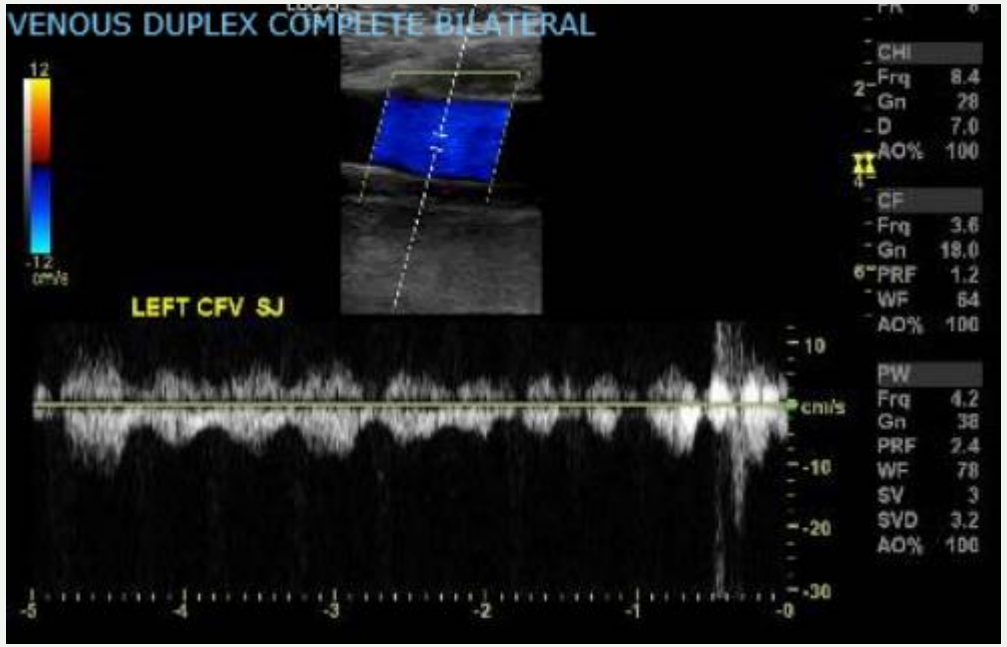
Faster healing rates of venous ulcers when early endovenous ablation to correct superficial venous reflux is performed in conjunction with compression therapy versus compression alone or with delayed intervention of an ulcer that has not reached wound closure after six months

Gohel MS, Heatley F, Liu X, et al.; EVRA Trial Investigators. A randomized trial of early endovenous ablation in venous ulceration. N Engl J Med. 2018;378(22):2105-2114

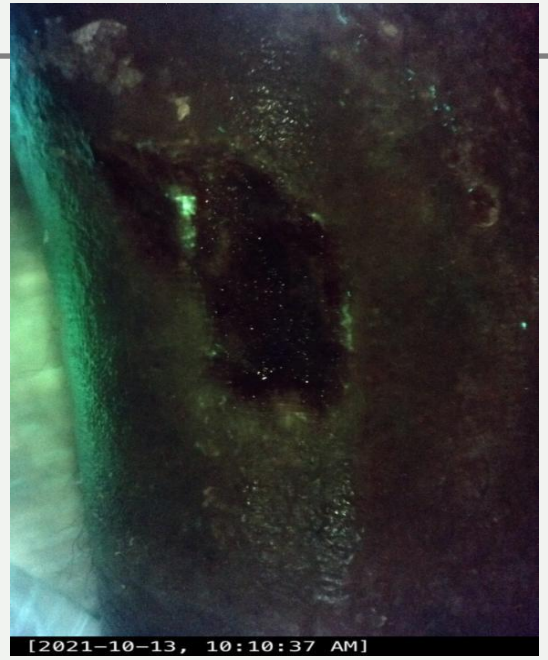

VENOUS DUPLEX COMPLETE BILATERAL
RIGHT CFV
cm/s


VENOUS DUPLEX COMPLETE BILATERAL
LEFT CFV
cm/s


VENOUS DUPLEX COMPLETE BILATERAL
RIGHT CFV SJ
cm/s


VENOUS DUPLEX COMPLETE BILATERAL
LEFT CFV SJ
cm/s


[2021-10-13, 9:40:42 AM]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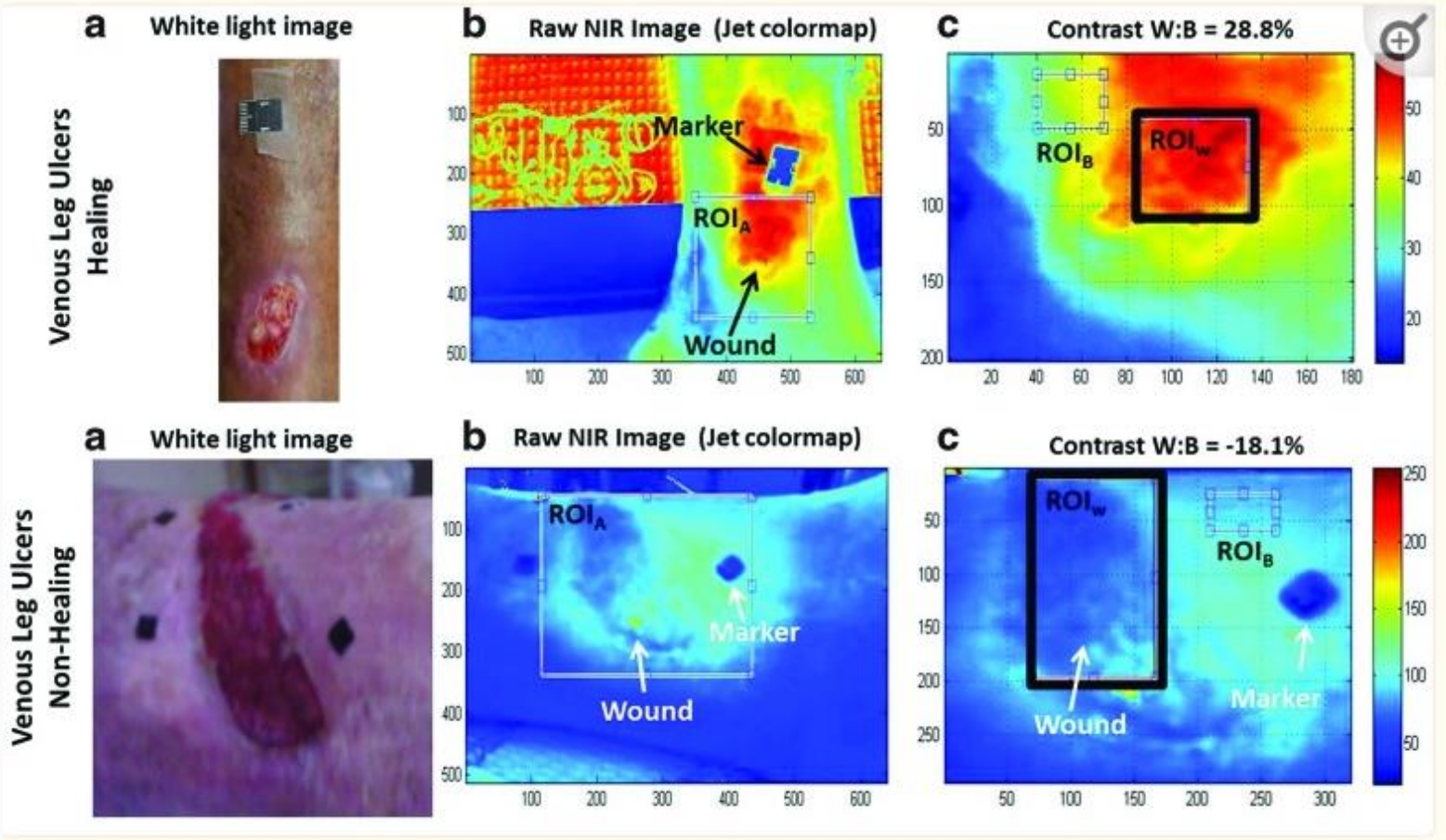
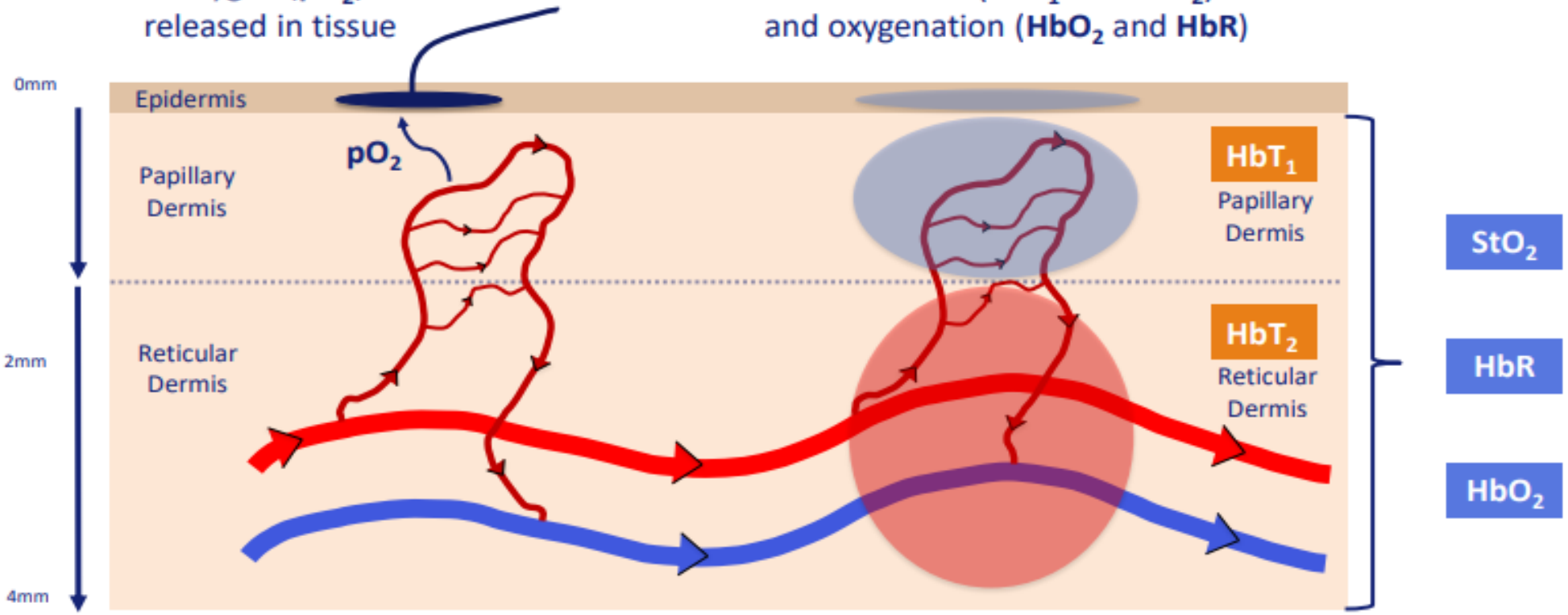


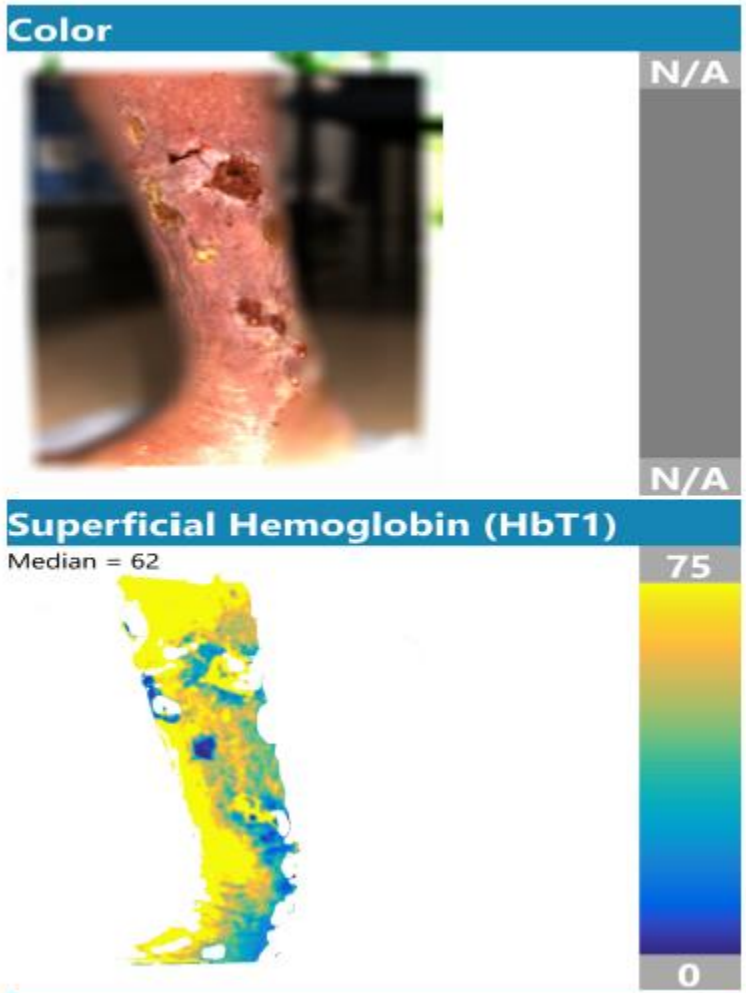
Lei, J., Rodriguez, S., Jayachandran, M., Solis, E., Epnere, K., Perez-Clavijo, F., Wigley, S., & Godavarty, A. (2018). Assessing the Healing of Venous Leg Ulcers Using a Noncontact Near-Infrared Optical Imaging Approach. *Advances in wound care*, *7*(4), 134–143.

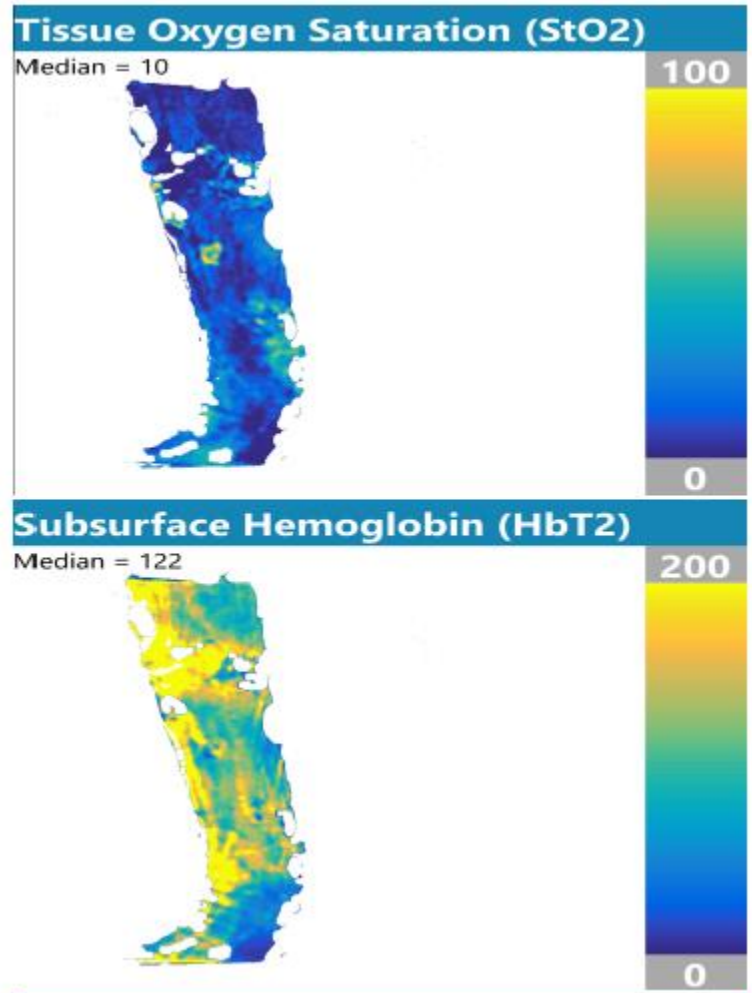
SFDI compared to TCOM

TCOM
Superficial, measures partial pressure of oxygen (pO_2) released in tissue

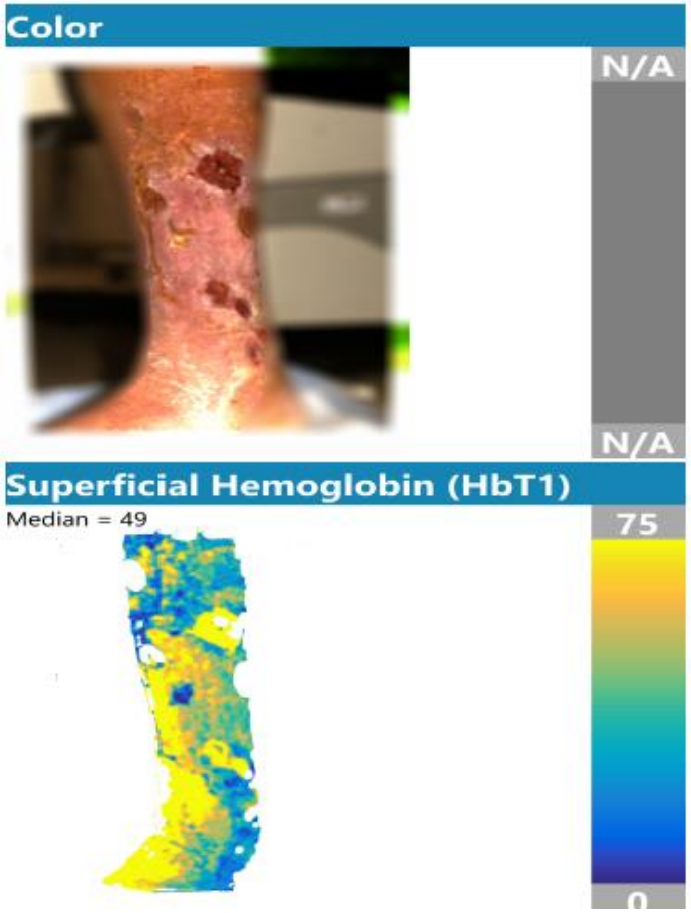
SFDI
Superficial & subsurface, measures tissue oxygen saturation (StO_2) hemoglobin distribution (HbT_1 and HbT_2) and oxygenation (HbO_2 and HbR)




Color
N/A
N/A
Superficial Hemoglobin (HbT1)
Median = 62
75
0


Tissue Oxygen Saturation (StO2)
Median = 10
100
0
Subsurface Hemoglobin (HbT2)
Median = 122
200
0

10 minutes post radiofrequency ablation



Compression Therapy

Elastic: bandages conforming to the size and shape of the leg

Inelastic: multi-layer

Stockings or custom garments: 30mmHg to 40mmHg

Pneumatic compression pumps: three types of pumps delivering variances of pressure gradient, inflation, and deflation cycles

Leg elevation above heart level

O'Donnell TF Jr., Passman MA, Marston WA, et al.; Society for Vascular Surgery; American Venous Forum. Management of venous leg ulcers: clinical practice guidelines of the Society for Vascular Surgery® and the American Venous Forum. J Vasc Surg. 2014;60(2)(suppl):3S-59S

Types of Skin Replacement Products

- Allografts
  - Harvested from and transplanted between the same species
    - Cadaveric skin
- Xenografts
  - Different species.
    - Porcine products
    - Bovine
    - Equine
- Allogeneic matrix
    - placenta, umbilical cord, amnion, and chorion
- Composite matrix
- Acellular matrix

Treatment Modalities

- Conservative management
- Vein ablation (closure)
    - Radiofrequency ablation
    - Laser
    - Chemical adhesive
- Injectable foam
- Stab avulsion/phlebectomy
- Sclerotherapy
- YAG laser therapy

Conservative Management

- Trial of > 3 months
- Compression stockings/ compression therapy
- Leg elevation
- Pain management
- Exercise
- Weight loss

Radiofrequency (RFA) or Laser (EVLT) Vein Ablation

- Thermal Ablation
- In-office procedure, takes 20-30min
- Local Tumescent Anesthesia
- Closure rate is approximately 98%
- Improvement of quality of life
- Reduction and/ or resolution of patient's symptoms
- Risk is low: less than 1% occurrence of DVT or infection

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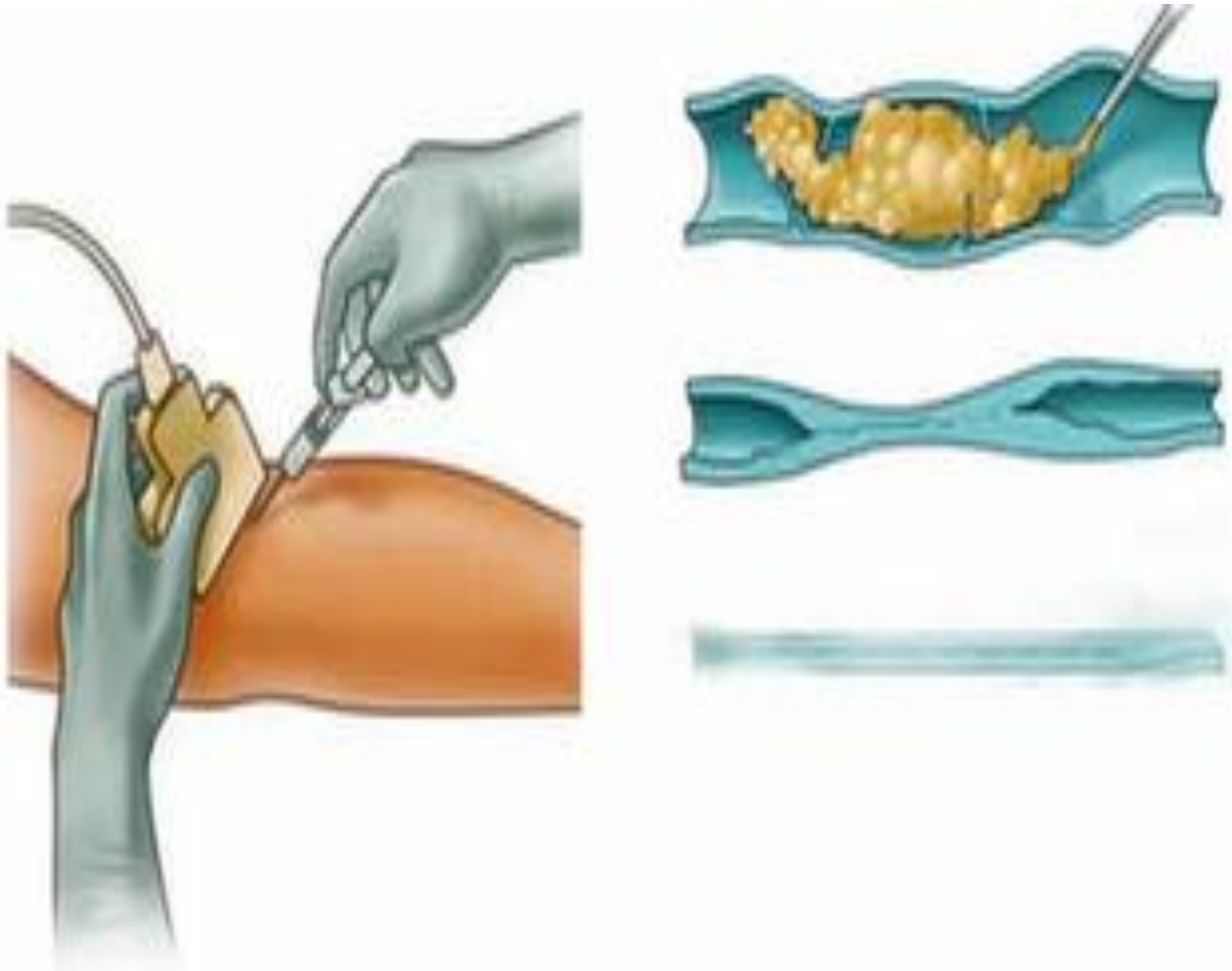
(non-thermal / non-tumescent / non-sclerosant ablation)

Endovascular embolization with coaptation

The system delivers a small amount of specially formulated medical adhesive (cyanoacrylate) to the incompetent vein. The adhesive (glue) permanently seals the vein and blood is rerouted into the deep venous system.

The key is to deliver the cyanoacrylate and compress the leg manually for optimal coaptation of the vein walls using recommended timed intervals



A small amount of "foam" is injected in to the incompetent vein, displacing the blood, effectively filling the lumen for circumferential contact. There is endothelial destruction with very low polidocanol concentration. The vein contract, narrowing the lumen, and collapsing the vein.

- Ablation
- Laser
- Glue

Disadvantages	Complications	Sheath Size	Closure Rate	Capital Equipment	Cost of catheter	Insurance Coverage	RVUs
Tumescent	DVT Thermal injury (nerves/skin)	7F	91.9% at 5y	$30,000 $3,700	$450	All insurances	39
Tumescent	DVT Thermal injury (nerves/skin)	4F	95.5% at 5y	$20,500 $3,700	$395	All insurances	30
Implantable device	DVT Allergic rx to cyanoacrylates	4F	94.6% at 5y	0	$838	Medicare and Managed Medicare only	54

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Patient Outcome and Satisfaction

- Closure rates for vein ablations (98%)
- VCSS improvement of QOL
- Reduction of recurrence of ulcerations
- Improvement in ulcer healing rates
- Complication risk: Low (<1% DVT or infection)

Phlebectomy

- In-office procedure
- Local anesthesia
- Veins marked with skin marker with patient standing
- Small skin incisions using a vein hook
- Post procedure return to normal activity

One month follow-up pictures

- VIRTUS, a prospective, multicenter trial demonstrates a twelve-month safety and effectiveness using of a dedicated venous stent for ICVO
- Demonstrate improvements in clinical symptoms and quality of life using the Venous Clinical Severity Score (VCSS), through 1-year follow-up

Razavi MK, Black S, Gagne P, et al. Pivotal Study of Endovenous Stent Placement for Symptomatic Iliofemoral Venous Obstruction. Circ Cardiovasc Interv. 2019;12(12):e008268. doi:10.1161/CIRCINTERVENTIONS.119.008268

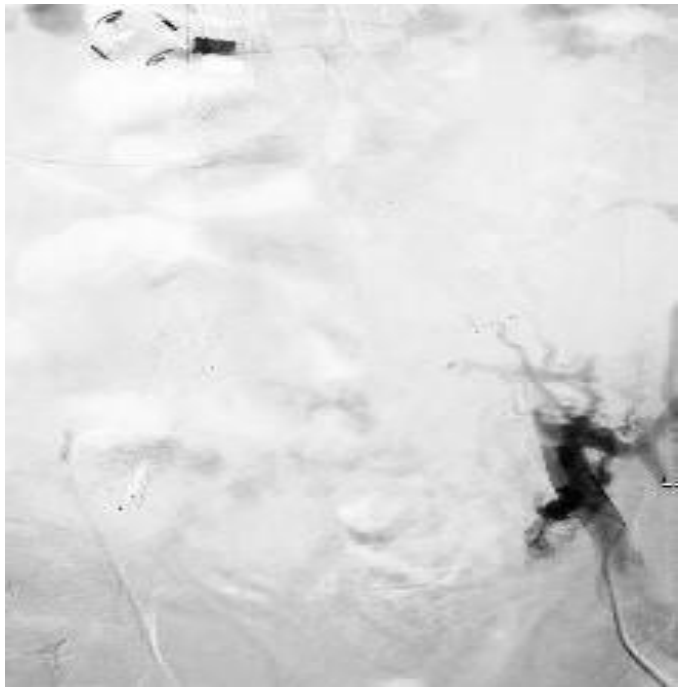
Double blinded RCT

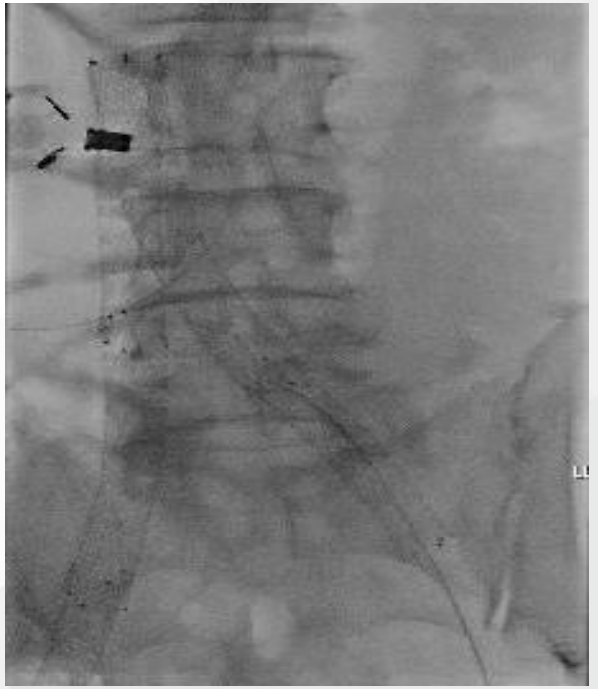
- Demonstrates pain relief via visual analogue scale
- Significant clinical improvement in the VCSS and in SF-36 quality of life in patients randomized to iliac vein stenting versus best medical management
- Although not statistically significant, the rate of venous leg ulcer healing improved

Rossi FH, Kambara AM, Izukawa NM, et al. Randomized double-blinded study comparing medical treatment versus iliac vein stenting in chronic venous disease. J Vasc Surg Venous Lymphat Disord. 2018;6(2):183-191. doi:10.1016/j.jvsv.2017.11.003

- Despite successful endovenous thermal ablation vein closure, a 5-year symptom recurrence rate of 20.9% after endovenous thermal ablation
- Could be due to the presence of underlying ICVO
- In a retrospective study, symptoms persisting during a mean of four months post EVTA that underwent vein stent placement result in further symptomatic relief in about one-third of patients treated with venous stenting

Wallace T, El-Sheikha J, Nandhra S, et al. Long-term outcomes of endovenous laser ablation and conventional surgery for great saphenous varicose veins. Br J Surg. 2018;105(13):1759-1767. doi:10.1002/bjs.10961





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Conclusion

- Surgical approach to venous insufficiency with ulcerations vary
- Initial History and Physical examination
- Prior history
- Vascular testing
- Early intervention

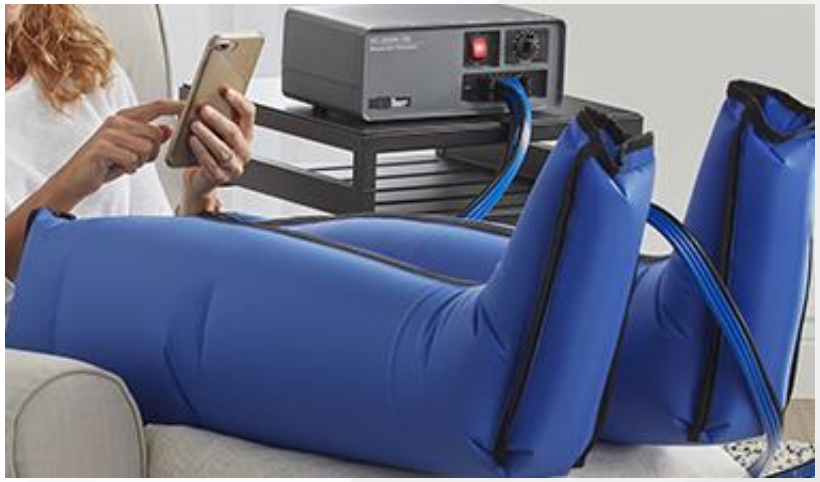
Medications

- Pentoxifylline: hemorheologic agent affects microcirculation and oxygenation
- Fibrinolytic enhancers (stanoolol and defibrotide), calcium dobesilate, aspirin, antibiotics
- Statins: vasoactive and anti-inflammatory effects
- Phlebotomics: improved venous tone and decreasing capillary permeability
- Antibiotics: antimicrobials, doxycycline, levamisole), diuretics, cinnarizine, naftazone, and benzarone
- Pentoxifylline
- Flavonoids (diosmin, hidrosmin, rutosides, and micronized purified flavonoid fraction, Vasculera), Red-Vine-Leaf-Extract AS 195, Ruscus, Ginkgo biloba, Centella asiatica, Pycnogenol (French maritime pine bark), escin/horse chestnut extract, nutritional supplements (ie, zinc and magnesium, glycosaminoglycans [sulodexide], mesoglycans), Axaven, cilostazol

Interdisciplinary Team Approach

- Inpatient
- Outpatient
- Rehab
- Hospice
- Home

- Vascular testing
- Nutrition: L-Arginine, L-Glutamine
- Compression therapy
- Negative pressure
- Dressing management
- Oxygen therapy



Williams JZ, et al. *Ann Surg*. 2002;236(3):369-375

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Conclusion

Treatment algorithms:

Workup

Imaging

Vascular intervention

Medications

Topical Dressings/Devices

Compression

Nutrition

Regenerative medicine

Northwell Health℠

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SCHOOL of MEDICINE
AT HOFSTRA UNIVERSITY℠

Thank you

Technology Update
Micro and Macro Assessment of Perfusion

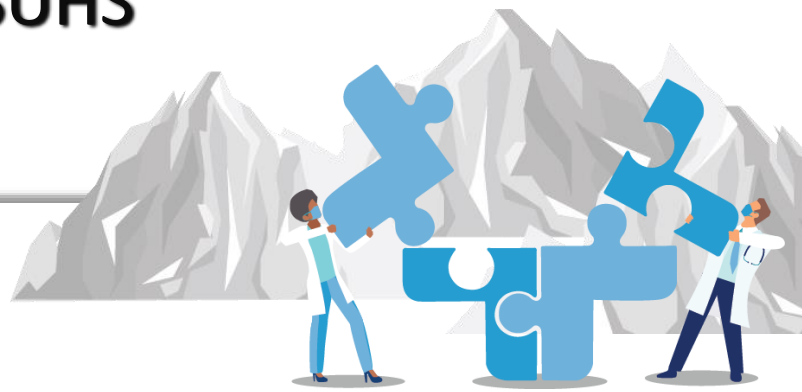
Charles Andersen MD, FACS, FSVS, MAPWCA

Chief Vascular/Endovascular/ Limb Preservation Surgery Service (Emeritus)

Chief of the Wound Care Service

Madigan Army Medical Center

Clinical Professor of Surgery UW, USUHS



AAWC Association for the Advancement of Wound Care®
2022 Annual Conference
Technology in Wound Care

Bias and Disclosures

- Consultant and speaker for Kent Imaging, MolecuLight, Stryker and EO2
- Bias -Vascular Surgeon with a strong interest in limb preservation and wound care
- The opinions voiced in this presentation are the opinions of the author and not the US Army or Department of Defense

Goals of Presentation

- Discuss the importance of assessing tissue perfusion in a limb preservation program and wound care clinic
- Discuss the difference between measuring macro and micro vascular disease
- Discuss the limitations of the non-invasive vascular lab
- Discuss the role of fluorescence angiography and NIRS in assessing tissue perfusion and tissue oxygenation

Measurement of Tissue Perfusion/ Oxygenation

- Helps answer key questions in limb preservation and wound care
  - Is there adequate perfusion to heal a wound or a reconstructive surgical procedure
  - Is there a need for revascularization and is revascularization adequate
    - Pre and post revascularization (Angiosome perfusion)
  - Is debridement adequate
  - Assess response to advanced wound care modalities
    - Topical oxygen therapy
    - Hyperbaric oxygen therapy
  - If an amputation is required, what level will heal
  - Is there adequate perfusion to support tissue products
  - Determine when a wound is really healed vs covered
    - An aid to determining when to stop total contact casts or compressive therapy

Measurement of Tissue Perfusion
Traditional Methods (Non-Invasive Vascular Lab)

- ABIs
- Foot wave forms, Toe Pressures, Toe Wave Forms
- Forefoot PVR
- Duplex scan
- tcP02

Measurement of Tissue Perfusion
Traditional Methods

- Traditional methods utilized to evaluate tissue perfusion/oxygenation are often limited by medial calcinosis, scarring, wounds, prior amputations and infection
- Non-invasive vascular studies measure macro circulation vs microcirculation
- Current methods can be technically challenging, costly and time consuming and don’t measure global perfusion of the foot or focal perfusion in the wound

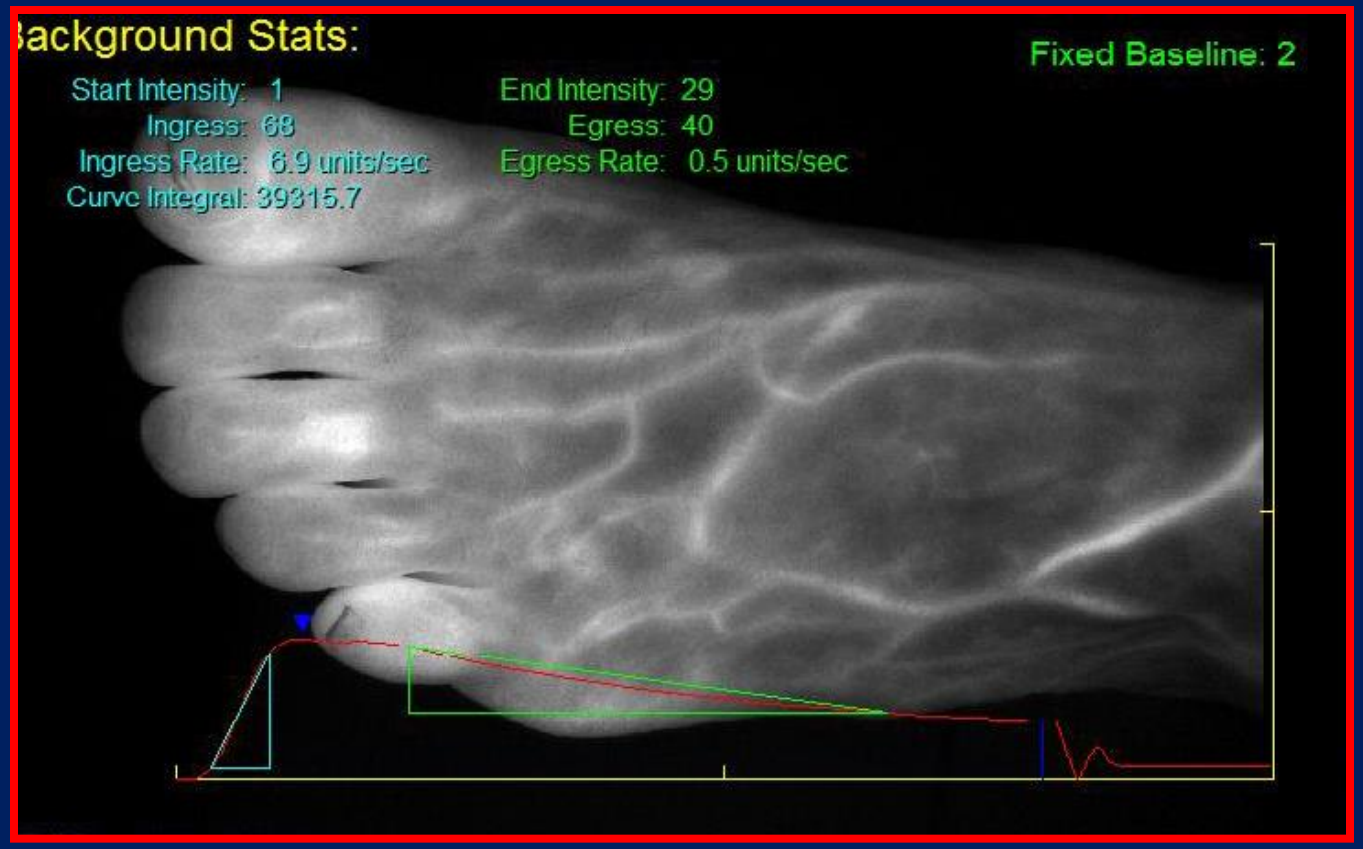
Non-Invasive Vascular Lab - ABIs

- Used as a standard measure of perfusion in many wound care centers
- Limitations of ABIs
  - ABIs can be falsely elevated in calcific vessels (diabetes and renal failure)
  - ABIs measure the pressure where the cuff is located not where the distal signal is heard. In many reports there will be a pressure for the AT, PT and at times the peroneal arteries.
  - ABIs don’t measure pressure or perfusion in the foot

Non-Invasive Vascular Lab - Assessment of Foot Perfusion

- Arterial wave forms in foot, PVRs, digital wave forms and toe pressures or TBIs do measure perfusion in the foot
- Don’t measure global perfusion of the foot
- Can miss regional malperfusion in the area of a wound
- Not provided by many screening labs

Fluorescent Angiography



Visualize and quantitate micro circulation

Definitions

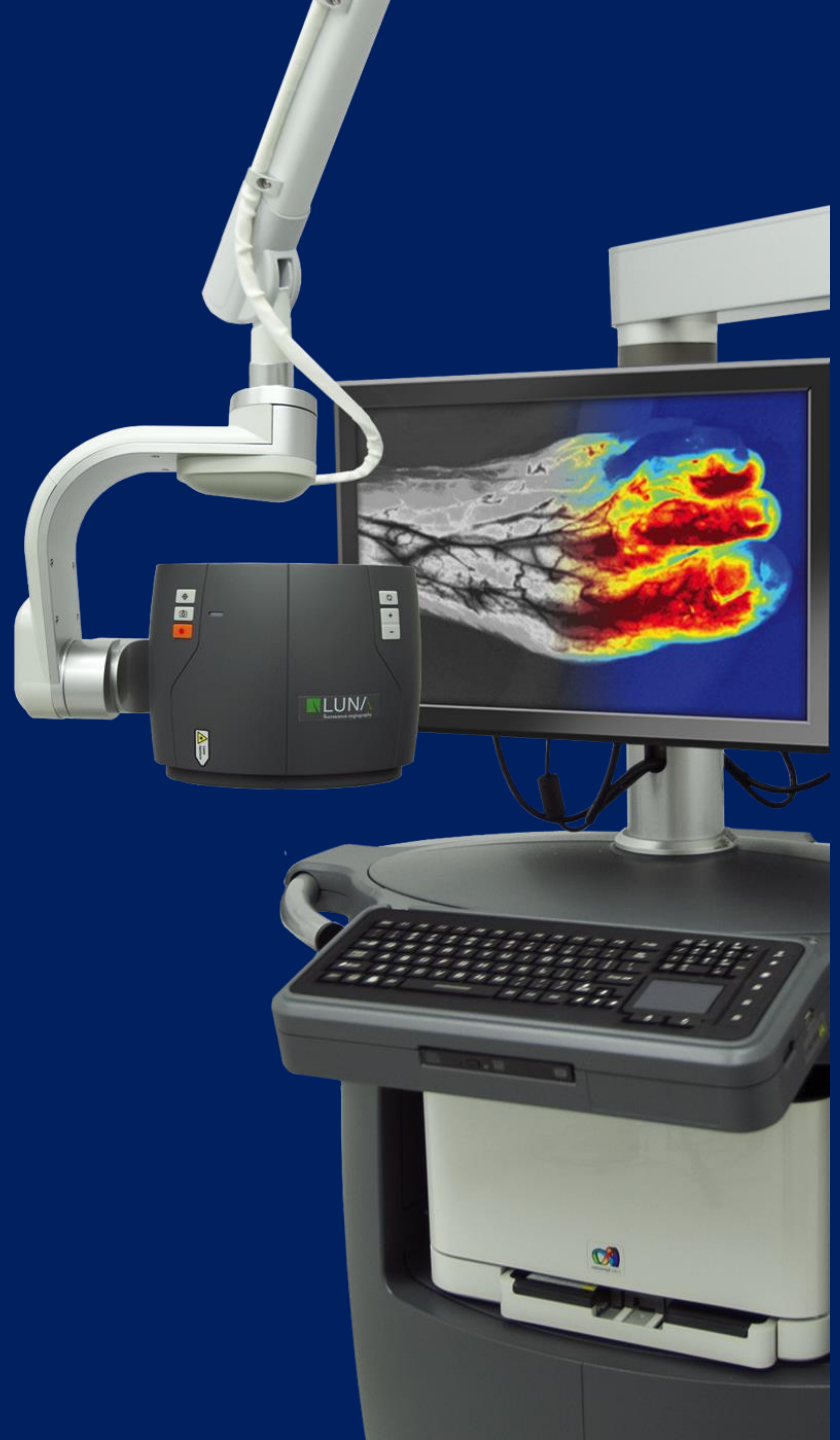
- Fluorescent angiography is a diagnostic technique that uses Indocyanine Green (ICG) a fluorescent dye injected IV to allow the sequential visualization of blood flow
- ICG
  - Strong record of safe clinical use
  - Excreted hepatically – not contraindicated in patients with compromised renal function
  - 3-5 minute half-life – can repeat multiple studies
  - Only contraindication – should be used with caution in patients that have a history of sensitivity to iodides

Fluorescent Angiography

Fluorescent dye ICG) is injected IV

The injected agent lights up blood flowing through the veins and arteries in real time, and the camera captures live images of the patient's vasculature.

These images can be captured on a computer screen, analyzed and saved and printed for medical reference.



Fluorescent Angiography

- Currently not used routinely in our wound care clinic – requires an IV and is time consuming to perform and analyze results
- Utilized selectively in clinic for assessing perfusion to determine amputation level or healing potential for advanced podiatric procedures
- Used in OR – Spy technology
  - Assessing flaps
  - Spy assisted amputation

Case Study - Hallux Amputation

- 92 y/o male with non healing hallux ulcer with osteomyelitis
- Concern for PAD
- ABI unobtainable because of noncompressable distal vessels.
- Hallux toe pressure not available due to hallux ulceration.
- TCPO2 indicated inadequate perfusion 19 mmHg and 23 mmHg base of hallux and second toe

Management Questions

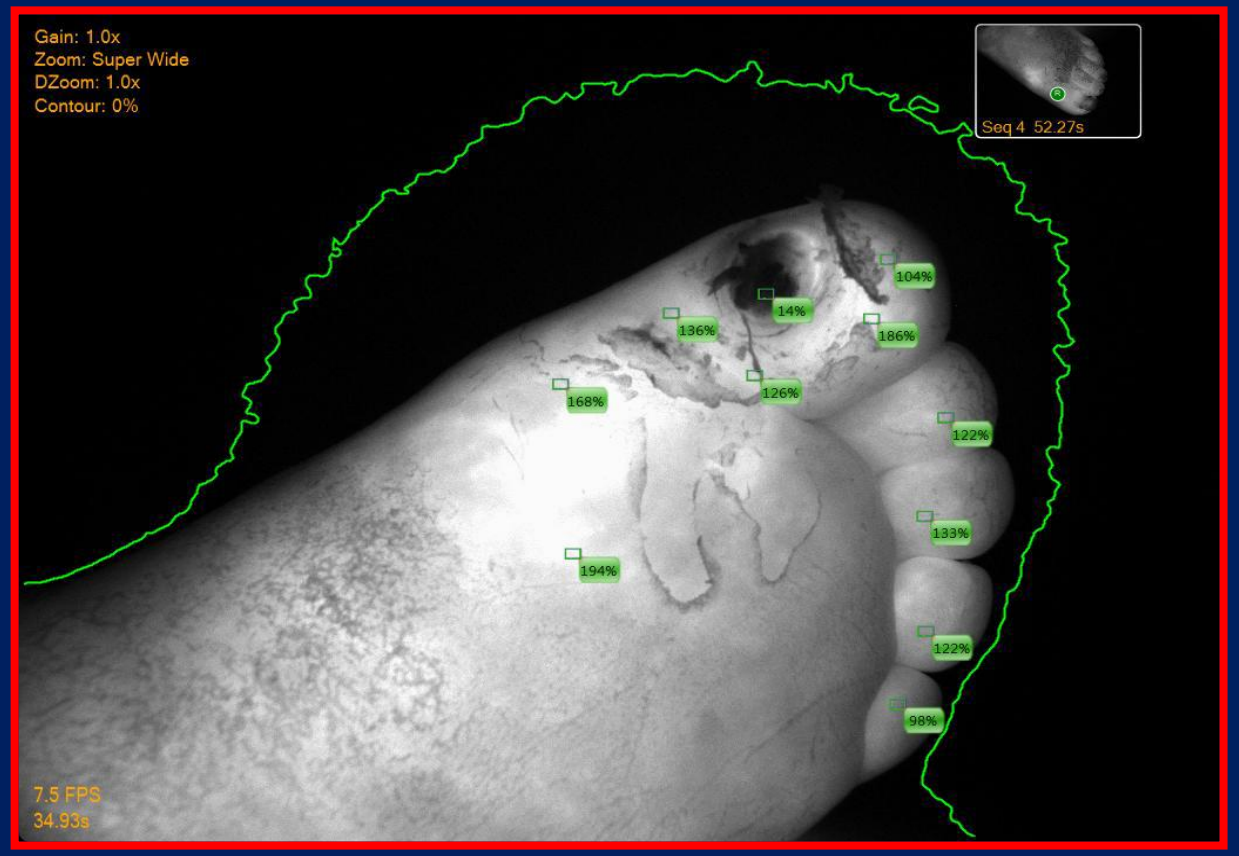
- Does the patient need a CTA, MRA or Arteriogram?
- If these studies are performed, does he need vascular intervention – (vascular disease will be seen)
- Based on the arterial studies should a BK be performed

Case Study - Hallux Amputation

- Fluorescence micro-angiography revealed adequate perfusion to heal a digital amputation.
- No additional diagnostic studies were performed
  - Avoid domino effect
- Patient underwent hallux amputation for osteomyelitis utilizing regional anesthesia
- Uneventful post-operative course.
- Returned to baseline function

Hallux Ulcer with Osteomyelitis

Pre-op Study



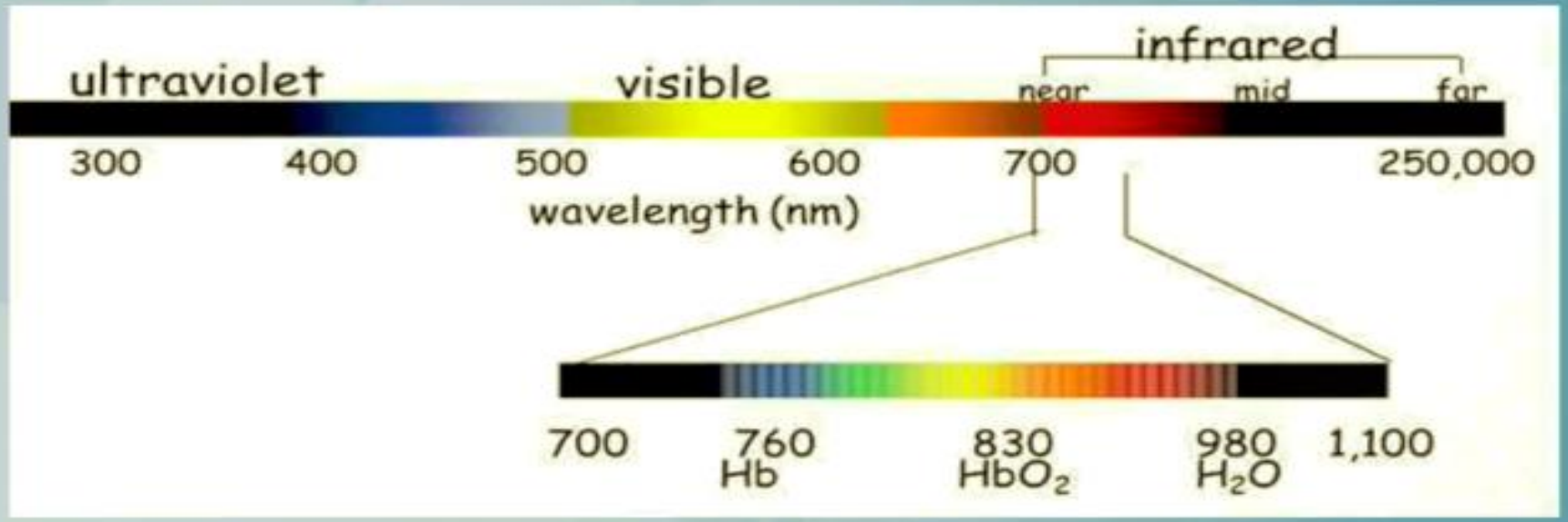
Demonstrates adequate perfusion to heal a toe amputation

Post-op

Patient returned to baseline function with no complications

Near Infrared Spectroscopy

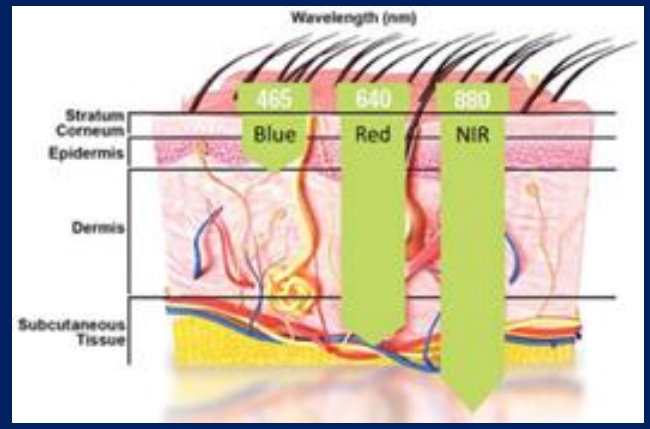
- Near infrared spectroscopy (NIRS) is an imaging technology based on the principle that light is absorbed and reflected differently by oxygenated and non-oxygenated hemoglobin.

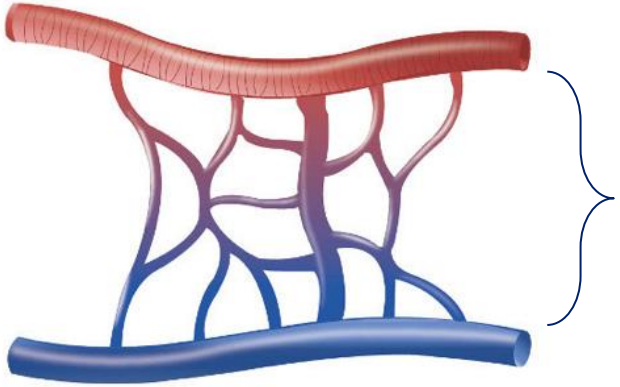


Near Infrared Spectroscopy (NIRS)

- NIRS technology is based on measuring and analyzing light in the near infrared spectrum (600-1000 nm)
- NIRS measures the proportion of oxygen bound to the hemoglobin in the blood of the capillary bed
- NIRS measures site specific tissue oxygenation (StO_2)

  (Wound – area of interest)





S_tO_2 provides information on both the oxygen delivery and oxygen extraction at the cellular level

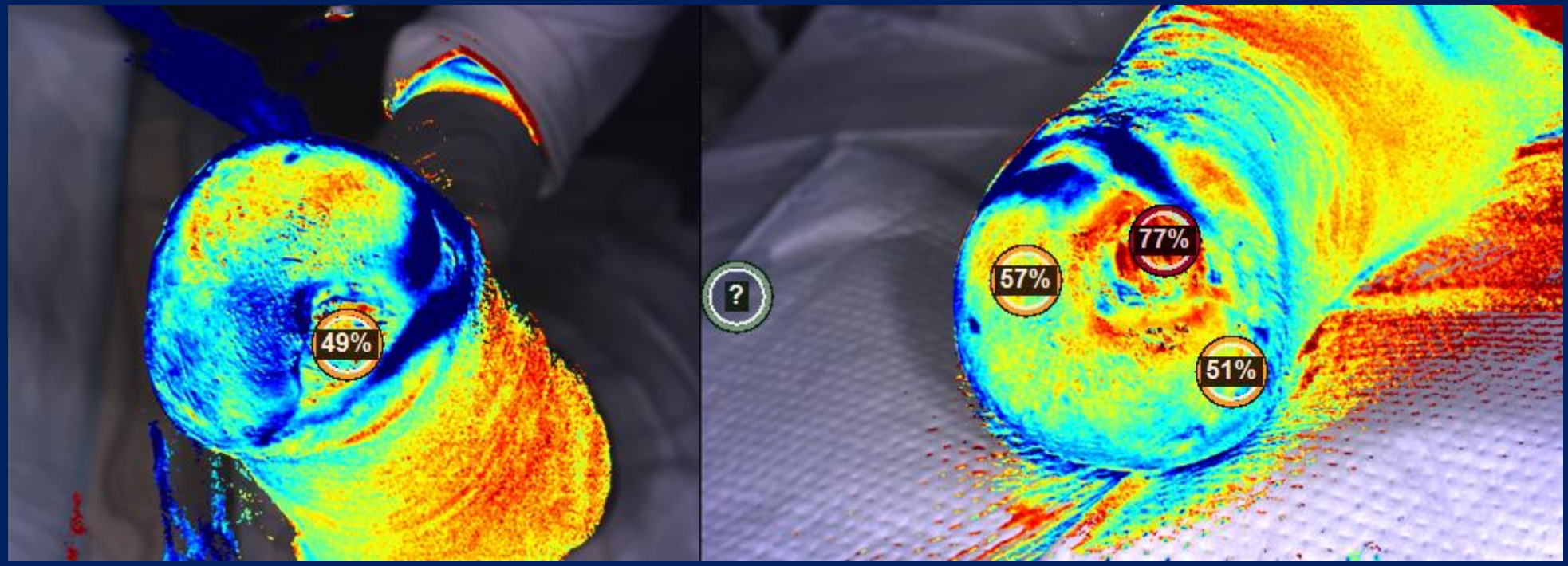
Near Infrared Spectroscopy (NIRS)

- Point-of-care measurement of tissue oxygenation
- No injection required
- Adds minimal time to a tissue encounter

Case Study
Pre and Post Revascularization

- 70 y/o diabetic female with severe PAD status post right BK amputation
- Developed suture line complications with a non-healing ulcer
- Concern for ischemia of stump
- Arteriogram demonstrated SFA occlusion that was recanalized and stented

Post Revascularization of Stump

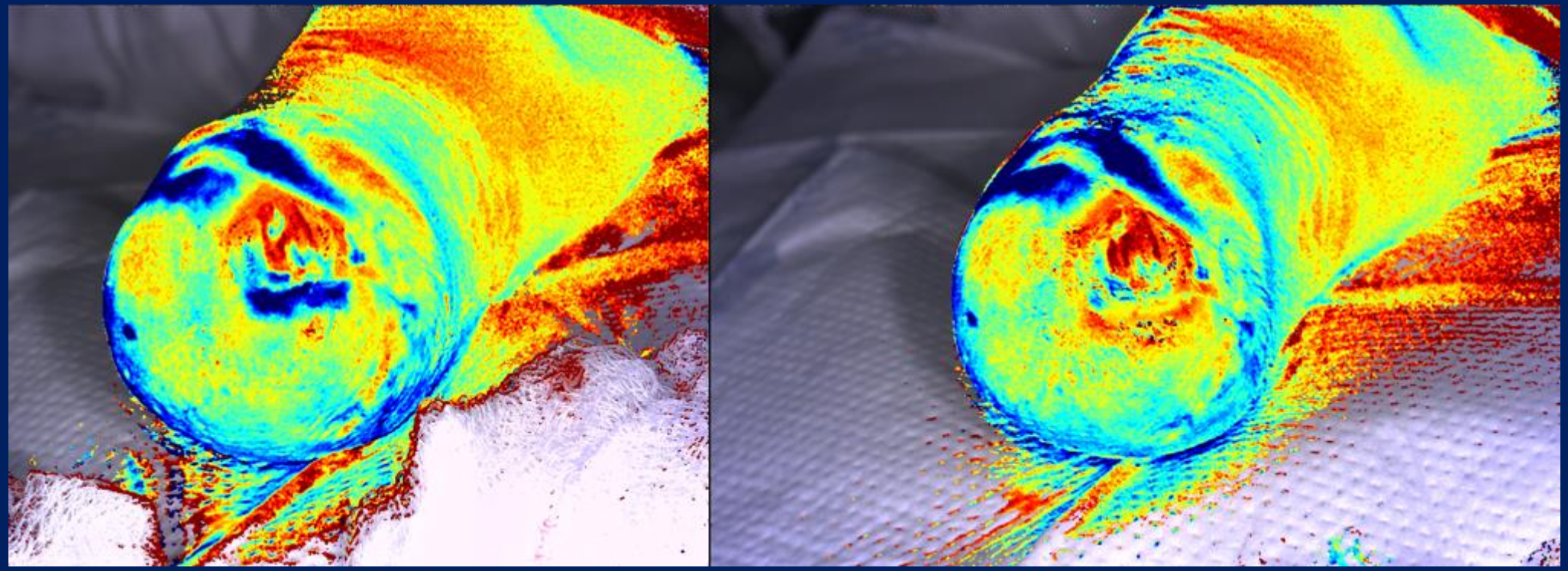


Pre - revascularization

Post - revascularization

Significant improvement in oxygenation in the ulcer

Ulcer Debridement 2 Days Post Revascularization



Pre debridement

Post debridement

Following debridement there is increased oxygenation of the wound bed

Assessing Tissue Oxygenation in the Diabetic Foot Preventing Amputations

- Diabetes is a risk factor for foot ulceration
- Foot ulceration is a risk factor for amputation
- Associated PAD is a significant confounding factor that increases the risk for amputation in a patient with a diabetic foot ulcer
- The timely and accurate assessment of peripheral arterial disease (PAD) is an important component of routine podiatric care and a critical component of a limb preservation initiative

Andersen, JVS 52:125

Near Infrared Spectroscopy (NIRS) Assessment in Patients with Diabetes

- Near infrared spectroscopy (NIRS) utilized to screen patients with diabetes
- S_tO_2 _ 70% or greater – Normal
  - Proceed with treatment
- S_tO_2 _ 40 – 69 %
  - Order vascular studies
- S_tO_2 _ 39% or less
  - Order vascular studies and vascular consult to consider invasive assessment and possible intervention

Assessing DFUs for Healing Potential

- 61 y/o diabetic male with recurrent DFU

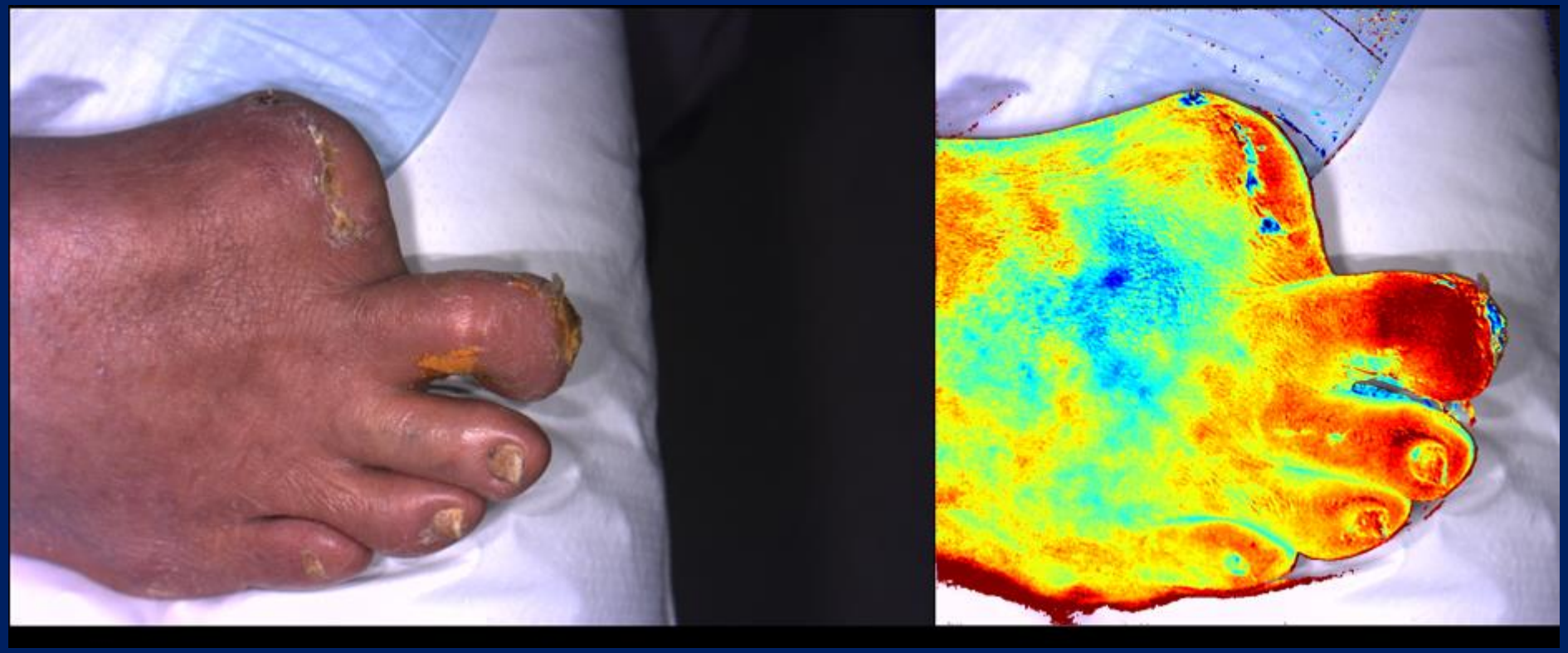
NIRS demonstrates adequate perfusion to heal the DFU

Preoperative Assessments for Healing Potential

Case Study

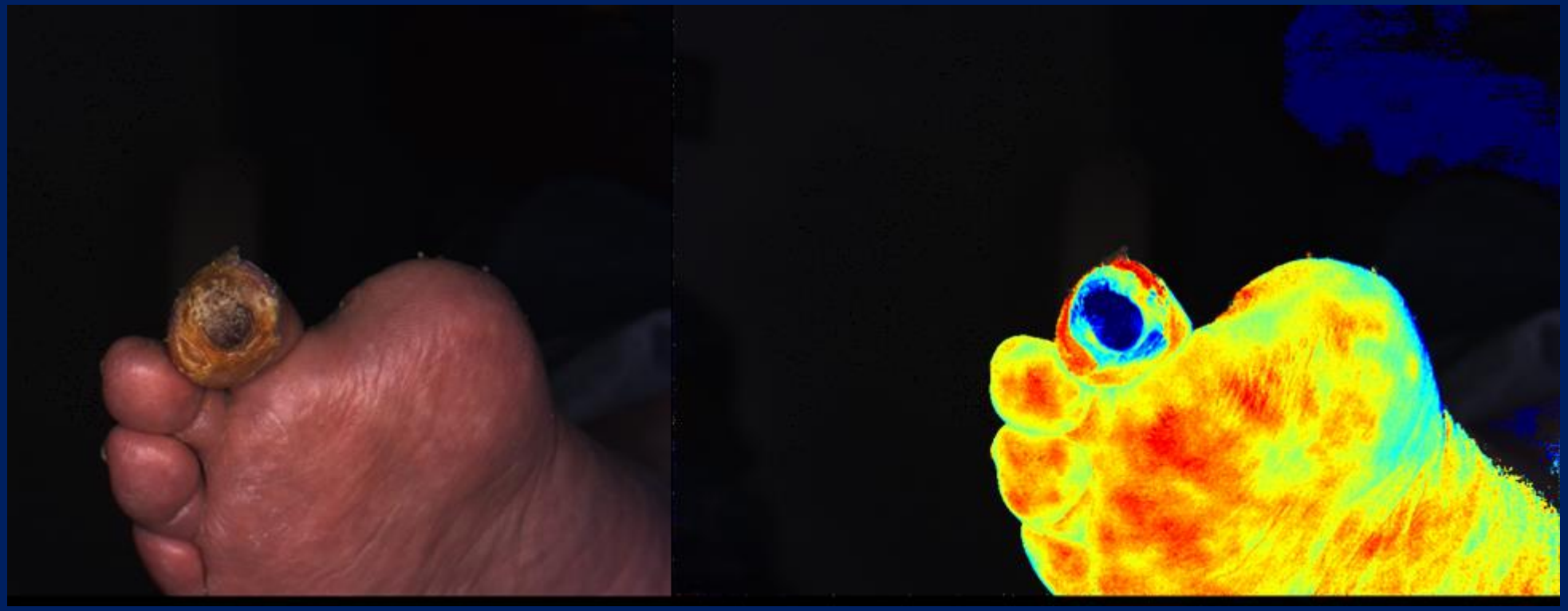
- 82 y/o diabetic male with known PAD status post right hallux amputation followed for an ulcer at the tip of right 2nd toe.
- Patient being considered for right 2nd toe amputation for a non healing wound and chronic osteomyelitis
- Vascular Evaluation – ABI 0.82, Biphasic wave forms DP and PT arteries. Toe pressures and toe wave forms not obtained

Pre-operative Assessments for Healing Potential

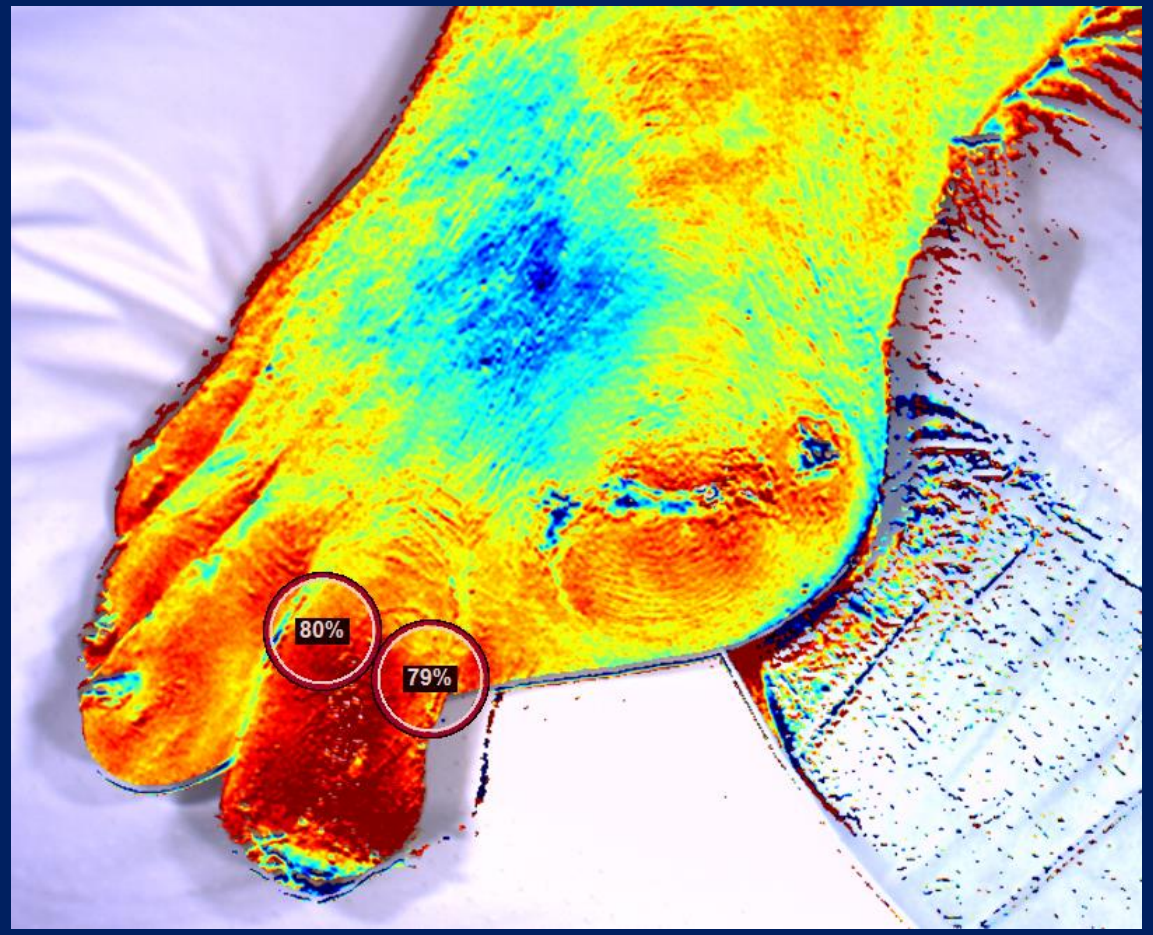


Chronic osteomyelitis second toe verified by MRI

Pre-operative Assessments for Healing Potential



Pre-operative Assessments for Healing Potential



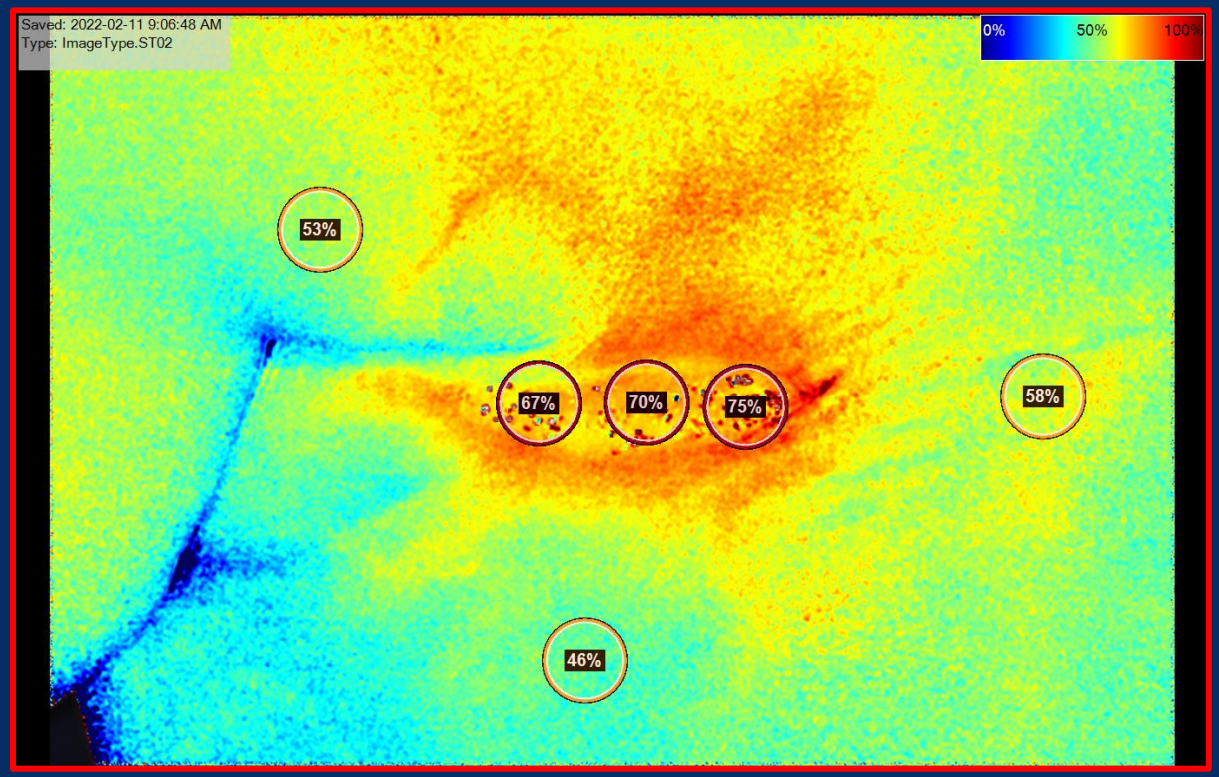
Point of care near infrared spectroscopy documents adequate oxygenation to heal a toe amputation avoiding the need for more invasive techniques to assess perfusion

Second toe amputation performed with no complications

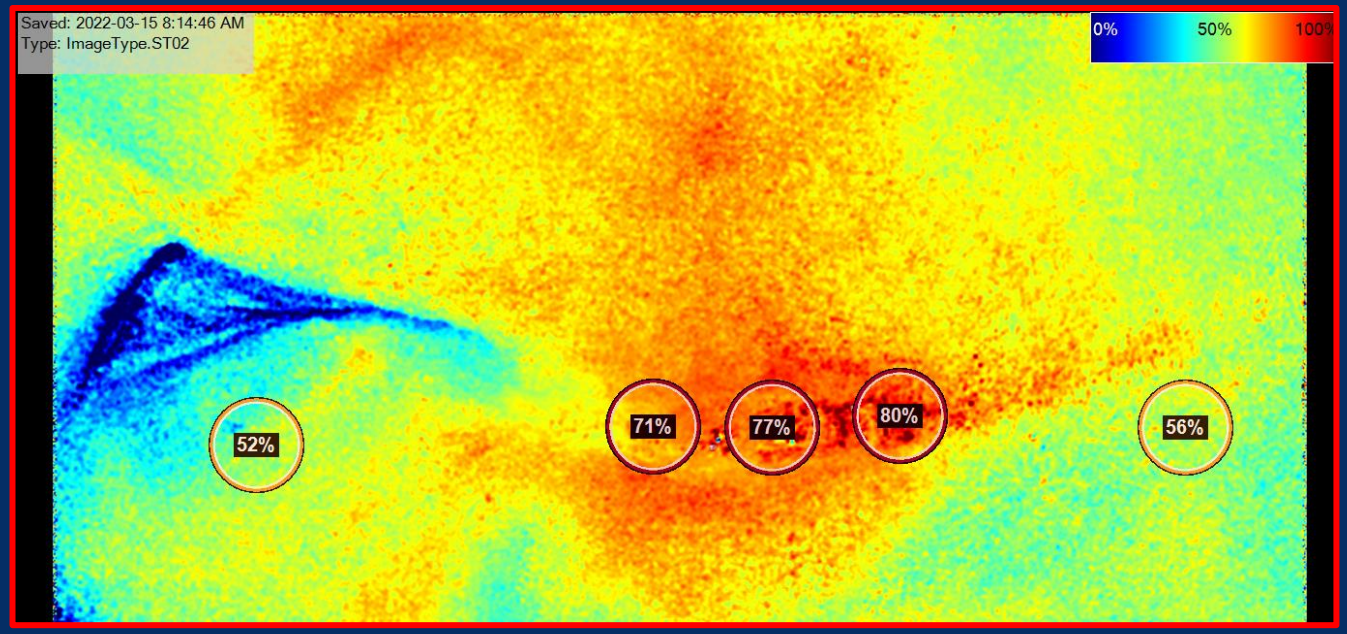
TOT Treatment of Non-Healing Irradiated Mastectomy Site Monitored with NIRS

- 62 y/o female
- 9/20/2021 – Right modified radical mastectomy and left simple mastectomy
- 11/22/2021 – 12/23/2021 Radiation therapy right breast
- Chronic wound present for 38 days with failure to progress
- TOT therapy monitored by NIRS to measure tissue oxygenation

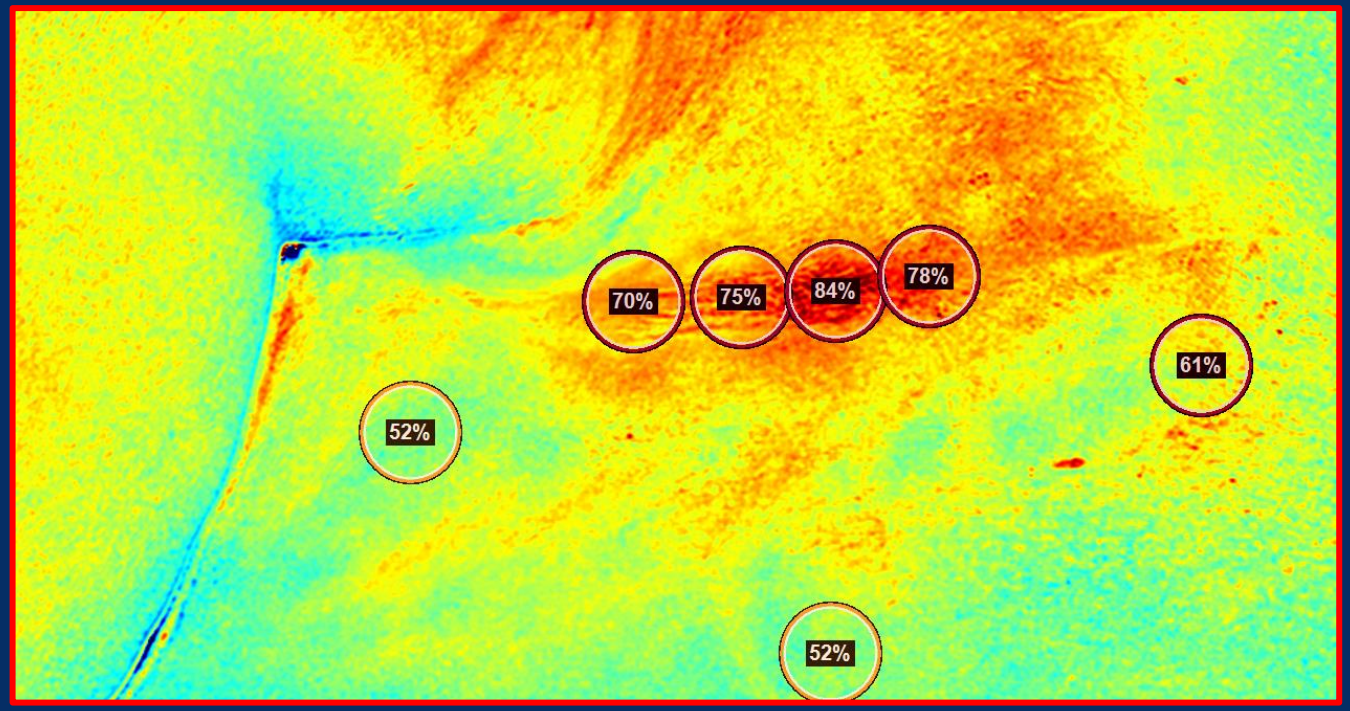
EO2 Treatment of Non-Healing Irradiated Mastectomy Site: Pre-treatment



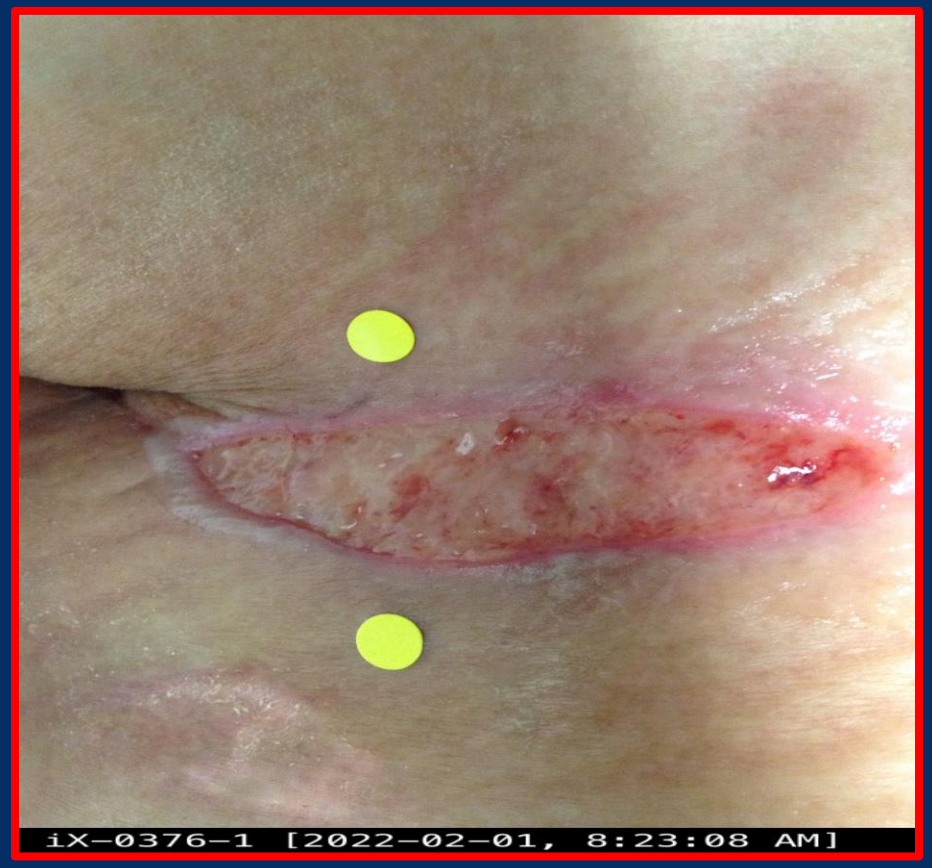
EO2 Treatment of Non-Healing Irradiated Mastectomy Site: 32 days



EO2 Treatment of Non-Healing Irradiated Mastectomy Site: 38 days (Wound Healed)



EO2 Treatment of non-healing irradiated Mastectomy Site: 38 days (Wound Healed)



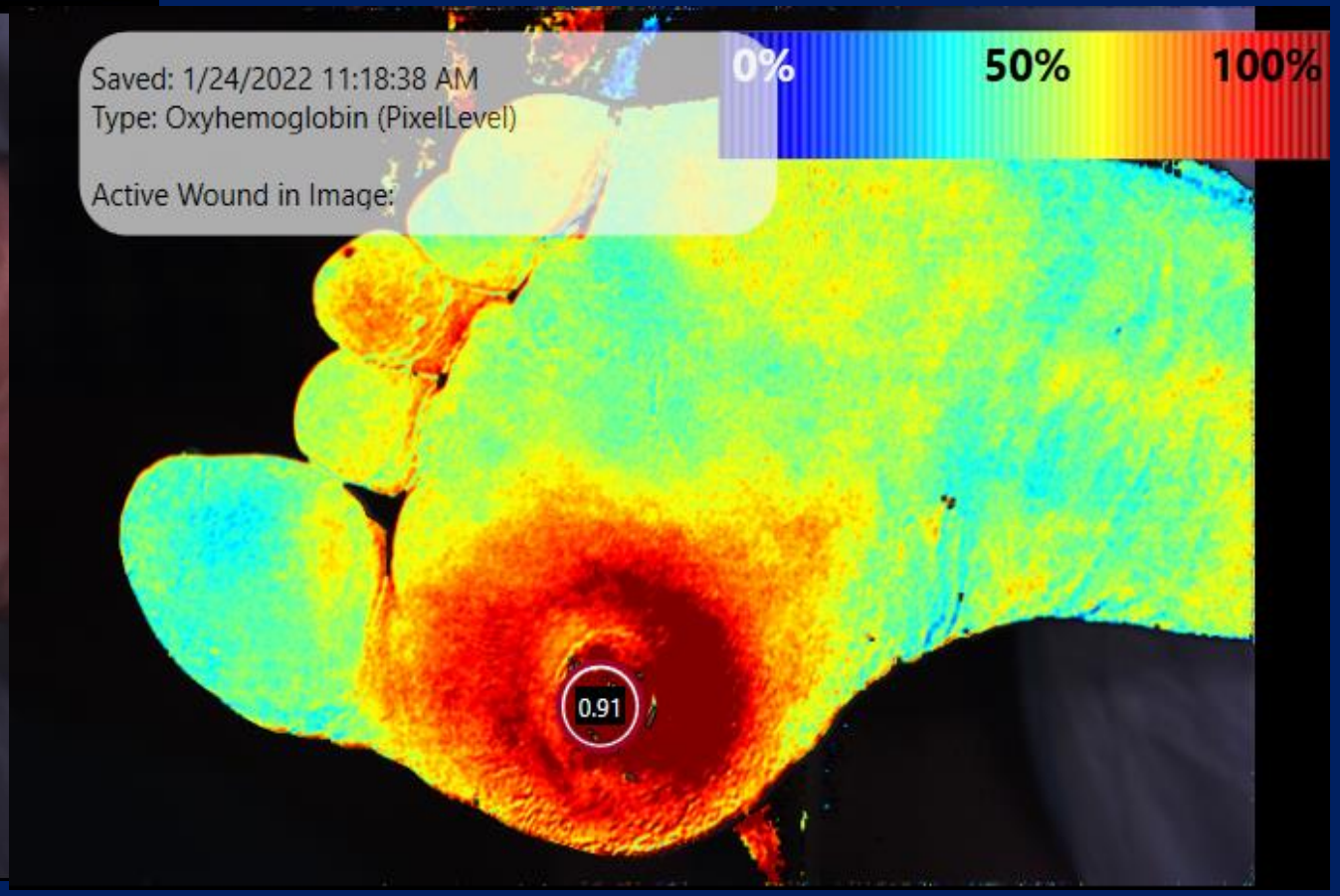
Redefining healing - Thesis

- Healing is an inflammatory process. Inflammation is associated with increased oxygenation
- As healing progresses the inflammation and oxygenation decreases
- Observation – when a wound is epithelialized, there is still associated inflammation. We redefined healing as normalization of oxygenation

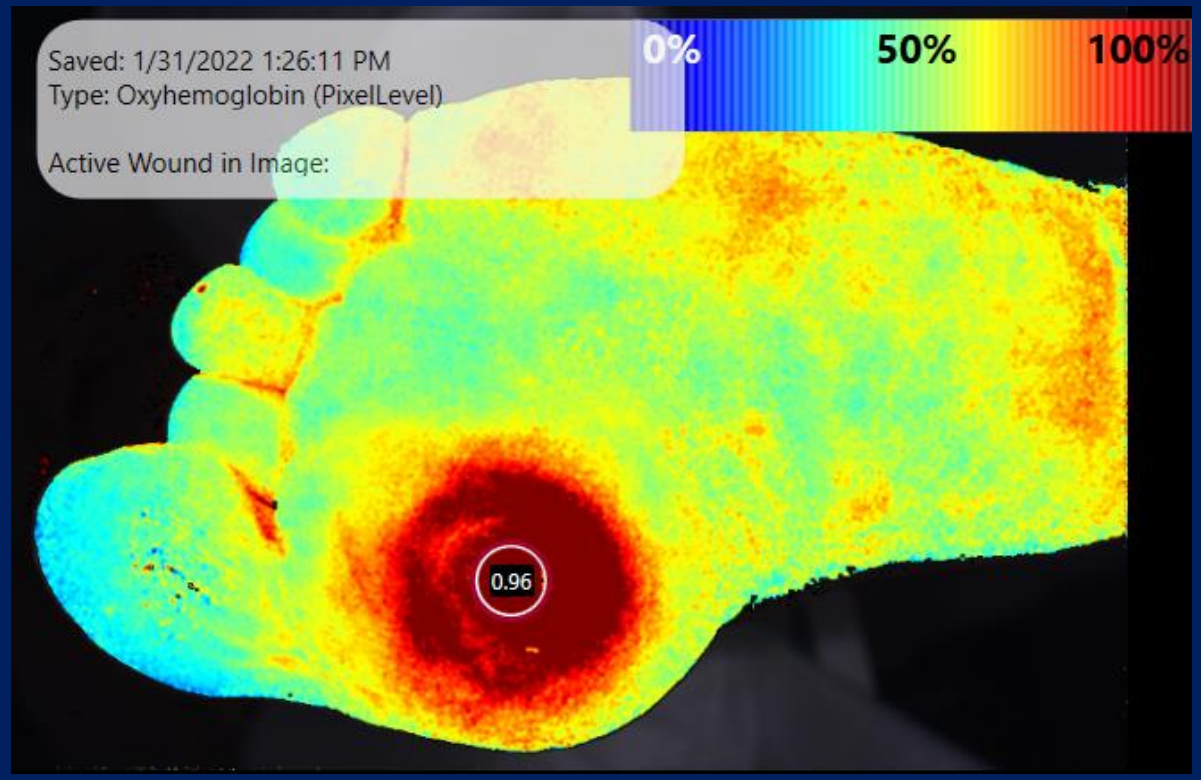
Case Study

- 63 y/o diabetic male with severe equinus and recurrent forefoot ulceration over 1st metatarsal head
- Ulceration treated with serial TCCs and healing monitored with NIRS

1/24/2022 Open Wound



1/31/2022 Halfway Closed



4/11/2022 Epithelialized

4/25/2022 Deep Dermal Healed

Normalization of inflammation 14 days following epithelization

Re-defining Wound Healing

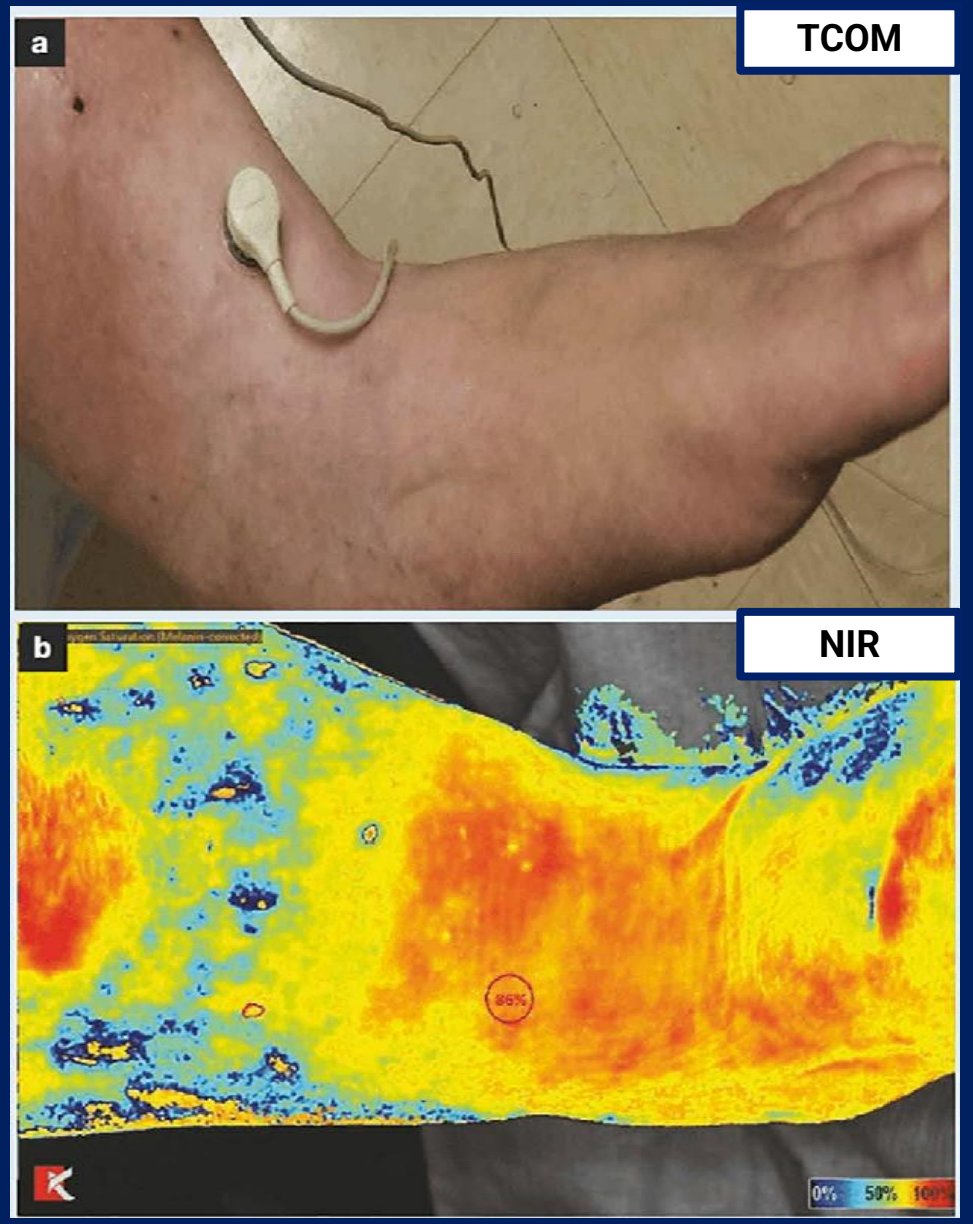
- Complete epithelization is not a good indicator of the ability to transition patients back to protective shoe gear use and activities.
- Experienced wound care providers currently empirically maximize off-loading measures for several days to weeks after complete epithelialization has occurred to reduce the potential for early wound recurrence. Objective evidence of how long to continue maximum off-loading has been lacking
- NIRS provides visualization and an objective measure of deep dermal microvascular oxygenation and relative perfusion.

Deep dermal healing still happening

NIRS Provides an objective measure of deep dermal healing

Validation of NIRS

- N = 10; 4F 6M
- Age: 56 (35-83)
- Comparison of transcutaneous oxygen measurement (TCOM) vs. near infrared spectroscopy (NIRS) in hard to heal wounds
- NIRS saturation values were converted to partial pressure of oxygen via standard Severinghaus oxygen dissociation curve.
- Bland-Altman analysis was used to assess the level of agreement between TCOM and NIRS.
- Pearson correlation was used to test correlation between TCOM and NIRS.



Serena TE, Yaskov R, Serena L, Mayhugh T, Harrell K. Comparing near infrared spectroscopy and transcutaneous oxygen measurement in hard-to-heal wounds: a pilot study. J Wound Care; WUWHS Suppl. 2020; 29(6): S4-S10.