Hyperbaric Oxygen Therapy in Combination with Fluorescence Imaging: Patient Selection and Monitoring

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Disclosures

- **Dr. Andersen:** Speaker – Acelity, Novadaq Technologies Inc., Organogenesis
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- This continuing education activity includes medication brand names for participant clarity purposes only. No product promotion or recommendations should be inferred.

Learning Objectives

After completing this activity, participants should be able to

- Assess the science on use of fluorescence imaging in assessing tissue perfusion in diabetic foot ulcers and non-healing wounds
- Evaluate the use of fluorescence angiography in identifying patients who would benefit from hyperbaric oxygen therapy (HBOT)
- Employ methods to monitor perfusion of wounds undergoing HBOT
- Review clinical cases of wounds that underwent hyperbaric oxygen treatment, fluorescence imaging solutions and application of an acellular dermal matrix
The Role of Fluorescence Imaging in Advanced Wound Care

Charles Andersen, MD, FACS, FAPWCA

Measurement of Tissue Perfusion

- Critical to every component of advanced wound care
- Fluorescent angiography helps answer key questions
  - Is there a need for revascularization, and is revascularization adequate?
  - Is there adequate perfusion to heal a wound?
  - Is debridement adequate?
  - Is the wound responding to advanced wound care, including HBO?

HBO = hyperbaric oxygen.
Measurement of Tissue Perfusion

- Clinical judgment
- ABIs, toe pressures, toe waveforms
- Forefoot pulse volume recording
- Duplex scan
- Transcutaneous oximetry
- Skin perfusion pressure

ABI = ankle-brachial index.

Measurement of Tissue Perfusion

- Current methods utilized to evaluate tissue perfusion are often limited by medial calcinosis, scarring, wounds, prior amputations, and infection
- Current methods can be technically challenging, costly, and time consuming, and don’t measure global perfusion of the foot
- Fluorescent angiography offers an additional option to measure tissue perfusion
- Fluorescent angiography is becoming a critical component of advanced wound care

Fluorescent Angiography

Visualize and quantitate microcirculation: See what the eye can’t see

Definition

- **Fluorescent angiography** is a diagnostic technique that uses fluorescent dye ICG injected IV to allow the sequential visualization of blood flow

ICG = indocyanine green.
ICG

- Strong record of safe clinical use
- Excreted hepatically – not contraindicated in patients with compromised renal function
- 3-5 – minute half-life
- Only contraindication – should be used with caution in patients who have a history of sensitivity to iodine


Fluorescent Angiography

- 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, saved, and printed for medical reference

Vascular Interventions

- Fluorescence angiography can help answer critical questions
  - Is revascularization required?
  - Did revascularization provide adequate tissue perfusion (involved angiosome)?
  - If a procedure is planned following revascularization, when is maximal perfusion established (timing of a podiatric procedure)?


Case 1

Assess the Need for Revascularization and the Results of Revascularization
History

- 72-year-old male with severe ischemic rest pain in the left foot and an ulcer between the 4th and 5th toes and an ulcer at the base of the 5th toe
- 8/19/14 – arteriogram with placement of 8x61 self-expanding iliac stent
- **Fluorescent angiography** studies obtained prior to the intervention and in subsequent days

8/18/2014 – Rest Pain with Dependent Rubor and Pallor on Elevation

- Dependent Rubor
- Pallor on Elevation
Pre-Treatment and Immediate Post-Treatment:
101% Improvement in Ingress Rate

Immediate Post-Treatment Compared to 1 Day Post-Treatment
Perfusion Continued to Improve with a 35% Improvement in Ingress

FOV = field of view.
Role of Fluorescent Angiography in Vascular Surgery

- Assesses the need for revascularization
  - Assess regional perfusion of the foot
- Assesses adequacy of perfusion following revascularization (involved angiosome)
- Assesses time of maximum perfusion (aids in timing of a secondary procedure)


Assessing Perfusion to Determine Amputation Level
Case 2

Hallux Amputation for Gangrene Osteomyelitis, Cellulitis, and Abscess

History

- 79-year-old male with diabetes and multiple comorbidities admitted with gangrene, osteomyelitis, and cellulitis of the right great toe and dorsal foot
- 2-3 – week history of pain and swelling
- Poor historian – not sure of trauma
- History of deep vein thrombosis with chronic venous insufficiency, peripheral arterial disease, and atrial fibrillation
History

- Positive blood cultures for MRSA
- Started on broad-spectrum IV antibiotics with resolution of cellulitis on dorsum of foot
- Vascular assessment
- Fluorescent angiography
- February 2015 – Right hallux amputation

MRSA = methicillin-resistant staphylococcus aureus.

Pre-Op
Pre-Op

Abscess surrounding the flexor hallucis longus

Tendon is concerning for infective tenosynovitis

Moderate osteoarthritis of the right foot

MRI = magnetic resonance imaging.
Pre-Op Vascular Assessment

• ABIs – noncompressible vessels with ABIs greater than 1.5
• Biphasic waveforms at right ankle
• Right toe pressure not obtainable

Management Questions

• Does the patient need a CTA or arteriogram?
• If these studies are performed, does he need vascular intervention? Will vascular disease be seen?
• Based on the arterial studies, should a BKA be performed?

CTA = computed tomography arteriography; BKA = below-knee amputation.
Pre-Op Fluorescence Angiography

Management Outcomes

- No CTA or arteriogram
- No BKA
- Limited amputation under regional anesthesia
- Intraoperative modification based on fluorescent angiography
Intra-Op Fluorescence Angiography

Flap revision following intra-op fluorescence angiography

Amputation
Amputation following excision of ischemic distal flap

Flap closure
Fluorescence Angiography Following Closure

Post-Op

2 days post-op

5 days post-op
The use of fluorescent angiography in limb salvage
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**INTRODUCTION**

The current rate of amputation in the United States is higher than ever, with lesser invasive options. Despite advances in endovascular techniques and limb salvage, the risk of further amputation is still elevated. The authors describe their experience using fluorescent angiography coupled with Acellular Dermal Matrix (ADM) for limb salvage.

**METHODS**

A case series with a use of fluorescent angiography for planning, preoperative, and postoperative phases of the patient's care. Fluorescent angiography is a non-invasive technique that allows for visualization of vascular anatomy and its function without the need for contrast injection. ADM is a biocompatible, acellular dermal matrix used for tissue regeneration.

**DISCUSSION**

The combination of fluorescent angiography and ADM offers a minimally invasive approach for limb salvage. The authors report positive outcomes in their cases, highlighting the potential of this technique in reducing the risk of further amputation.

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**CASE 1**

A patient with non-healing ulceration of the foot. Fluorescent angiography revealed adequate perfusion, and ADM was administered with successful wound closure.

**CASE 2**

A patient with a toe amputation. Fluorescent angiography was used to plan the salvage procedure, and ADM was used to promote healing.

**CASE 3**

A patient with a hallux amputation. Fluorescent angiography was used to determine the extent of bone involvement, and ADM was used to facilitate healing and prevent further amputation.

**DISCUSSION**

Fluorescent angiography and ADM provide a minimally invasive approach for limb salvage. The combination of these techniques can help in reducing the risk of further amputation, and further studies are needed to validate their efficacy in a larger patient population.

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**Debridement and Assessment of Acellular Dermal Matrix**

**Case 3**

Debridement and assessment of Acellular Dermal Matrix (ADM) were performed with positive outcomes. ADM was used to promote healing and prevent further amputation.

**DISCUSSION**

The use of ADM in conjunction with fluorescent angiography offers a minimally invasive approach for limb salvage. Further studies are needed to validate its efficacy in a larger patient population.
History

- 12/9/14: 81-year-old admitted with congestive heart failure and recurrent venous ulcer with cellulitis
- History of recurrent venous ulcers treated with perforator ligation and compression
- 12/11/14: debridement in wound care clinic followed by fluorescent angiography with additional debridement

Pre-Debridement
Fluorescent-Assisted Debridement

Post-Debridement
Baseline Fluorescent Study

- Baseline fluorescent study documenting good arterial inflow but low egress rate, consistent with venous disease
- Inflammatory response around the wound

1 Week Post-Debridement
Application of DermaMatrix

1 Week Post-Application
2 Weeks Post-Application

Increased Perfusion in Wound

[Images of graphs and wound images]
Preoperative Perfusion Study at Level of Planned Amputation

Monitoring Response to Advanced Wound Care Treatment

- Negative pressure wound therapy
- Provant® Therapy System
- Biologic tissues
- HBO
- ArtAssist
Conclusions – Fluorescent Angiography

- Faster and more accurate evaluation of tissue perfusion than any other available technology
- Assess the need for and the results of revascularization
- Facilitate more aggressive treatment in more challenging patients
- Aid to debridement and use of advanced wound care products, including HBO

THANK YOU!

Mt. Rainier at Sunrise

Dr. Charles Andersen – cande98752@aol.com
Indocyanine Green Fluorescent Angiography for the Wound and Hyperbaric Physician

Thomas E. Serena, MD, FACS

Introduction
Monitoring Perfusion
Angiogenesis Dependent on Oxygen Gradient

- In irradiated tissue: oxygen gradient 10-20 mm Hg
- Under hyperbaric conditions: increases to 230 mm Hg


SDF-1a = stromal cell-derived factor 1α; VEGF = vascular endothelial growth factor; EPCs = endothelial progenitor cells; NOS = nitric oxide synthase; eNOS = endothelial nitric oxide synthase; HBO = hyperbaric oxygen.

VEGF Expression During the Course of Healing


Patient Compliance

• 86 patients scanned a total of 378 times over 7 months
• Scans were performed both before and after treatment
  – HBOT
  – Ambient pressure oxygen breathing
  – Debridement

IWCHM = Institute for Wound Healing and Hyperbaric Medicine.

• Use of FVA scanning allowed clinicians to:
  – Define wound types
  – Demonstrate the impact of HBOT
  – Document when HBOT had restored CUSH
  – Illustrate the benefits of HBOT in patients failing TCOM

CUSH = capacity for unaided secondary healing; TCOM = transcutaneous oxygen measurement.
FVA for Guiding Clinical Decisions

- Introduced in outpatient wound/HBOT clinic
- In first 3 months, 68 patients received a total of 345 FVA studies
- In initial review, useful clinical decisions were made in >80% of patients using FVA results


FVA and HBOT Assessment

Standard ICG Imaging prior to HBOT

Post-HBOT Imaging demonstrates lower pixel density

FVA Future Applications

- Analysis of wound pathophysiology
- Precise measurement of HBOT effects, allowing for more tailored therapy
- Device registry
- Clinical trials


Fluorescence Vascular Angiography in the Selection and Management of HBOT Patients

Stephen D. Guthrie, MD, PhD
If This Presentation on FVA Has Succeeded, You Will Answer “YES” to These Questions:

- Are you convinced that indocyanine green fluorescence angiography visualizes the actual microcirculation of the wound and peri-wound tissue?
- Do the FVA examples shown illustrate the differences between normal tissue, ischemic tissue, and wounded tissue?
- Is it clear that FVA imaging illustrates how a therapeutic intervention is reflected?

FVA = fluorescence vascular angiography.

If You Answered “YES” to Those Questions:

- Quantification of the FVA images will reinforce your intuitive impression of the level of perfusion
- Quantification of the FVA images will allow you to grade the severity of the wound
- Quantification of the FVA images will allow you to grade the effectiveness of your treatment

Roger P. Contour Map

Non-healing L2 amputation site before and after tibial bypass

221 vs 533

FVA Is a Reality

For FVA to be accepted and to be effective requires:

• Demonstration that patient will respond to HBOT

• Demonstration that HBOT is moving the FVA metric towards the “normal” profile

• Demonstration that HBOT has restored the wound to the state of CUSH

• Assessment of recidivism risk
Subjective assessment and quantitative analysis of FVA data can reflect the effects of a series of hyperbaric oxygen treatments.
Quantitative Analysis of FVA Data Can Assess HBOT Candidacy in “Failed” tCOM Patients
Donald P. Contour Map

@ 17 seconds

@ 40 seconds

Donald P. Transcutaneous Oximetry
tCOM in single digits and no $O_2$ response
Angelo A. Contour Map

FVA before HBO₂Rx

FVA following HBO₂Rx

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