A case study demonstrating the assessment of wound bed hypoxia as a cause of wound chronicity

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INTRODUCTION

Proper wound healing depends on a number of factors, most of which have been extensively researched and customarily evaluated for proper management of wounds, e.g. host nutrition, infection, medication usage, etc. The wound healing paradigm provides a useful approach to the management of wounds, including assessment of the TISSUE, INFECTION (present or not), MOISTURE balance and the EDGE of the wound; referred to as the "T-I-M-E" principles. One factor that is rarely assessed properly is the adequacy of oxygen supply to the wound bed area. Most of the steps in the wound healing process are dependent on oxygen, which would explain why a hypoxic wound bed would lead to non-healing of a wound. Despite this central role played by oxygen, it is most commonly only assessed indirectly and frequently ignores microvascular insufficiency even in the presence of an adequate macrovascular supply.

Case History:

A 74 year old female presented with a non-healing abdominal wound after an inguinal block dissection complicated by surgical site infection. Co-morbidities included insulin-dependent diabetes, hypertension, morbid obesity and melanoma. She underwent numerous debridements in the following 2 months without any success of wound healing or closure. She also completed in-hospital antibiotic treatment for confirmed MRSA wound sepsis and received optimal conventional wound care as well as VAC therapy. She suffered very low emotional moral, had a poor appetite and became immobile during the long period of hospitalization.

Despite all factors influencing wound healing being addressed adequately, the wound failed to heal. The patient was referred for Transcutaneous Oximetry Measurements (TCOM) and possible Hyperbaric Oxygen Theraphy (HBOT) as a last resort. Even though the macrovascular supply was adequate, hypoxia of the wound bed was indicated to be the cause of the non-healing nature of the wound.

20 April 2010 - Before 3rd debridement

24 May 2010 - Before TCOM & HBOT

Wound healing comprises of the following:

- Vasoconstriction post trauma with activation of coagulation and complement cascade
- Clot formation through platelet adhesion and aggregation
- Histamine and 5HT mediated inflammatory response → influx of neutrophils, macrophages and lymphocytes
- Macrophages produce growth factors → migration of fibroblasts and epithelial cells
- Fibroblast proliferation
- Collagen synthesis & deposition
- Angiogenesis
- Epithelialization
- Remodelling through collagen cross linking and scar maturation

Factors influencing wound healing[1]:

- Systemic factors:
  - Age and sex
  - Nutrition
  - Vitamin/ trace element deficiencies e.g. vitamin C, vitamin A, zinc
  - Drugs e.g. steroids, chemotherapeutic agents, immunosuppressants
  - Systemic disease e.g. diabetes, malignancy
  - Hypoxia
- Local Factors
  - Blood supply
  - Infection
  - Foreign bodies
  - Surgical technique

Risk factors associated with surgical site infection (SSI)[1]

Patient characteristics (x)

- Advanced age x
- Poor nutritional status x
- Diabetes x
- Smoking
- Obesity x
- Colonization with microorganisms x
- Coexisting remote body site infection x
- Altered immune response x
- Preoperative hospitalization x

References:

1. Krasner DL, Rodeheaver GT, Sibbald RG. Chronic wound care 4th Edition - Chapters 25, 41, 43, 53
2. Fife CE, Smart DR, Sheffield PJ, et al. Transcutaneous oximetry in clinical practice: Consensus statements from an expert panel based on evidence. UHM 2009;36(1):43-53
3. Piantadosi CA. Physiology of hyperbaric hyperoxia. Respir Care Clin N Am. 1999;5(1):7-19

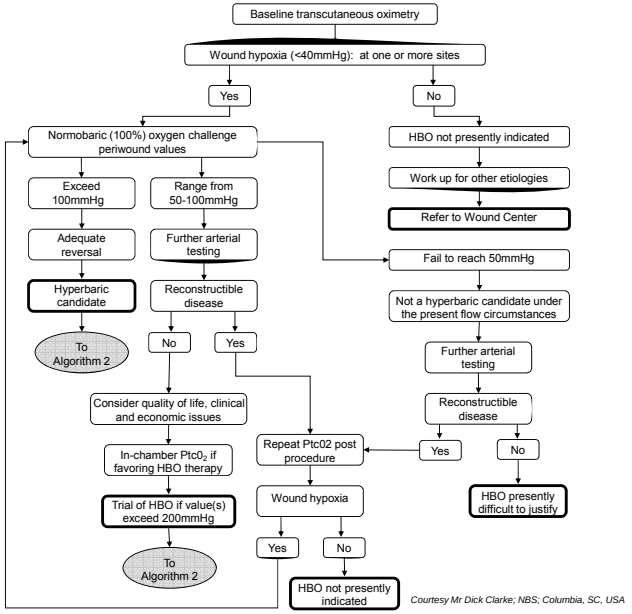
TCOM Report of Patient	Reference 2nd ICS (L)	Below wound	Above wound
Air (15min)	51mmHg	12mmHg	32mmHg
Oxygen (1min)	68mmHg	37mmHg	62mmHg
(2min)	87mmHg	65mmHg	92mmHg
(3min)	101mmHg	72mmHg	110mmHg
(4min)	110mmHg	76mmHg	117mmHg
(5min)	115mmHg	89mmHg	119mmHg
(10min)	141mmHg	104mmHg	111mmHg

25 May 2010 - TCOM testing; VAC in situ

Transcutaneous oximetry ($TcpO_2$) is a non-invasive test that directly measures the oxygen level of tissue beneath the skin. Because oxygen is carried to tissues by blood flow in the arteries, $TcpO_2$ is an indirect measure of blood flow. This test is often used to evaluate advanced peripheral arterial disease, a condition in which blood flow to an extremity (usually the leg) is greatly reduced. Results of this test help physicians determine how severely tissues are deprived of blood flow. The test is especially useful in predicting wound healing or amputation healing.

$TcpO_2$ measurements on room air ($21\%O_2$) <45mmHg indicate tissue hypoxia in diabetic patients. Normal lower extremity $TcpO_2$ values exceed 50mmHg. As indicated in the evidence-based review article by Fife et al[2] wounds with TCOM readings below 20mmHg is associated with failure to heal and a $TcpO_2$ 20-40mmHg is associated with delayed healing and a high risk for infection. The response of this patient to an oxygen challenge (100% medical oxygen at 1ATA administered via a non-rebreather mask), as described in the same article, demonstrates that she will benefit from Hyperbaric Oxygen Therapy to improve wound bed oxygenation and address the underlying hypoxia.

The Normobaric Transcutaneous Algorithm below demonstrates the usefulness of TCOM in the assessment of wound oxygenation status and evaluation for Hyperbaric Oxygen Therapy .



Courtesy Mr Dick Clarke; NBS; Columbia, SC, USA

Hyperbaric Oxygen (HBO):

HBOT utilizes oxygen as a medicine. Patients breath 100% oxygen in a specially designed pressure vessel (hyperbaric chamber) at a pressure of up to 2 bar (3 atmospheres). Treatment duration is 90 minutes and given once or twice daily, for 10 to 30 treatments, depending on the indication.

The direct supra-physiological increase in plasma oxygen fraction available for cellular metabolism as well as other indirect effects like cell messaging through the induction of nitric oxide formation and gene transcription (e.g. the expression of growth factor receptors), has the following effects:

- Hyperoxygenation directly reverses tissue hypoxia
- Improved leukocyte oxidative killing
- Enhanced collagen deposition & cross-linking
- Increased fibroblast repair function with resulting epithelialization and reduced tissue fibrosis
- Angiogenesis/ micro-neovascularization
- Reduces edema through hyperoxic vasoconstriction
- Potentiation of antibiotics through oxygen-dependent transport across the bacterial cell wall
- Suppression of bacterial toxin production

12 June 2010 - After 14 HBOT sessions

14 July 2010 -22 days post 20 HBOT

Conclusion /Recommendations:

Oxygen plays a vital role in the healing of wounds and the adequacy of wound oxygenation should specifically be assessed in wounds with delayed healing. The process of evaluating oxygen tensions in wounds is described and a flow-diagram is included in the presentation as a guideline for the assessment of peri-wound oxygenation.