

**COMMON FEMORAL ARTERY DOPPLER FINDINGS PRE AND POST
HYPERBARIC OXYGEN THERAPY FOR LEG ULCERATION**Cristiane Antequiera Maran^a<https://orcid.org/0000-0003-2487-9462>Sergio Xavier Salles-Cunha^b<http://orcid.org/0000-0002-1996-8615>**Abstract**

Hyperbaric Oxygen Therapy (HBOT) assumes that high pressure hyperoxygenation causes faster tissue recovery and wound healing. Lower extremity flow rates are affected by leg ulcers that change vasodilation, microcirculation resistance, and local tissue demands; how blood hyper oxygenation influences these factors is still unclear. Peripheral arterial occlusive disease (PAOD) has been mostly associated with HBOT results in the femoral artery than in other arteries. Common femoral artery (CFA) peak systolic velocities (PSV), measured pre and post HBOT, were analyzed to research HBOT hemodynamics. Sixteen patients with leg ulcers who were 65 ± 11 (SD) (38-87) years-old, had HBOT of 90 minutes at 2.6 ATA. Bilateral CFA Doppler velocity waveforms were recorded immediately pre and post HBOT. Ulcerated vs non-ulcerated peak systolic velocity (PSV) data were compared using paired t-test. CFA PSV were significantly equal in the ulcerated and non-ulcerated extremities before HBOT: 114 ± 35 (SD) cm/s vs 116 ± 41 cm/s ($p = 0.87$ by paired t-test). CFA PSV in the ulcerated extremity increased to 122 ± 35 cm/s after HBOT but were statistically insignificant ($p = .19$ by one-tailed paired t-test). On the other hand, CFA PSV decreased to 103 ± 28 cm/s ($p = .049$ by one-tailed paired t-test) in the non-ulcerated extremity and were significantly lower after HBOT, with 103 ± 28 cm/s vs 122 ± 35 cm/s for the ulcerated limb ($p = .02$ by paired t-test). Blood velocity responses post HBOT showed differences between ulcerated vs non-ulcerated

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extremities. The non-ulcerated extremity apparently responded to oxygenation more than the ulcerated extremity. Such observation suggests further research on hemodynamic reactions caused by HBOT.

Keywords: Ulceration. Hyperbaric oxygen therapy. Arterial Doppler.

ACHADOS DE DOPPLER DA ARTÉRIA FEMORAL COMUM ANTES E DEPOIS DA OXIGENOTERAPIA HIPERBÁRICA PARA ÚLCERA DE PERNA

Resumo

A oxigenoterapia hiperbárica (HbOT) assume que a oxigenação de alta pressão resulta em mais celeridade na recuperação do tecido e na cicatrização de feridas. As taxas de fluxo nas extremidades inferiores são afetadas por úlceras nas pernas que alteram a vasodilatação, a resistência da microcirculação e as demandas locais de tecido; esses fatores podem ser influenciados pela hiperoxigenação sanguínea de maneiras ainda não claramente compreendidas. A doença arterial oclusiva periférica femoral (DAOP) tem sido associada a melhores resultados de HBOT quando comparada a outras artérias. As velocidades sistólicas de pico (PSV) da artéria femoral comum (CFA) medidas antes e depois da HBOT foram analisadas como parte de um projeto de pesquisa da hemodinâmica da HBOT. Dezesesseis pacientes com úlceras de perna, com idade 65 ± 11 (DP), 38-87 anos, realizaram HBOT com duração de 90 minutos a 2,6 ATA. As formas de onda de velocidade do Doppler CFA bilateral foram registradas imediatamente antes e depois da HBOT. Os dados de PSV ulcerado vs. não ulcerado foram comparados usando o teste t pareado. Pre HBOT CFA PSV não foi significativamente diferente nas extremidades ulceradas e não ulceradas: 114 ± 35 (DP) cm/s vs 116 ± 41 cm/s ($p = 0,87$ pelo teste t pareado). O PSV pós HbOT CFA na extremidade ulcerada aumentou para 122 ± 35 cm/s, mas não atingiu significância estatística ($p = 0,19$ pelo teste t pareado unicaudal). Em contraste, CFA PSV na extremidade não ulcerada diminuiu para 103 ± 28 cm/s ($p = 0,049$ pelo teste t pareado unicaudal). O pós-HbOT CFA PSV foi significativamente menor no membro não ulcerado, 103 ± 28 cm/s vs 122 ± 35 cm/s para o membro ulcerado ($p = 0,02$ pelo teste t pareado). As respostas da velocidade do sangue após HbOT mostraram diferenças entre as extremidades ulceradas e não ulceradas. Aparentemente, a extremidade não ulcerada respondeu mais significativamente à oxigenação do que a extremidade ulcerada. Tal observação sugere pesquisas adicionais sobre as reações hemodinâmicas decorrentes da HbOT.

Palavras-chave: Ulceração. Oxigenoterapia hiperbárica. Doppler arterial.

Resumen

La terapia de oxígeno hiperbárico (HbOT) asume que la hiperoxigenación a alta presión da como resultado una recuperación más rápida de los tejidos y una cicatrización de heridas. Las tasas de flujo de las extremidades inferiores se ven afectadas por úlceras en las piernas que alteran la vasodilatación, la resistencia de la microcirculación y las demandas de los tejidos locales; estos factores pueden verse influenciados por la hiperoxigenación de la sangre, de formas que aún no se han entendido con claridad. La enfermedad oclusiva arterial periférica femoral (PAOD) se ha relacionado con los mejores resultados de HbOT que otras arterias. Las velocidades sistólicas máximas (PSV) de la arteria femoral común (CFA) medidas antes y después de la HbOT se analizaron como parte de un proyecto para investigar la hemodinámica de la HbOT. Dieciséis pacientes con úlceras en pierna, 65 ± 11 (DE) (38-87) años, 12 hombres, 11 diabéticos, tenían HbOT de 90 minutos a 2,6 ATA. Se registraron formas de onda de velocidad de CFA Doppler bilaterales inmediatamente antes y después de la HbOT. Se compararon los datos de la velocidad sistólica máxima (PSV) ulcerada frente a la no ulcerada mediante la prueba t pareada. Pre HbOT CFA PSV no fue significativamente diferente en las extremidades ulceradas y no ulceradas: 114 ± 35 (DE) cm/s vs 116 ± 41 cm/s ($p = 0,87$ por prueba t pareada). Post HbOT CFA PSV en la extremidad ulcerada aumentó a 122 ± 35 cm/s pero no alcanzó significación estadística ($p = .19$ por prueba t unilateral pareada). En contraste, CFA PSV en la extremidad no ulcerada disminuyó a 103 ± 28 cm/s ($p = .049$ por prueba t unilateral pareada). El PSV después de la HbOT CFA fue significativamente menor en la extremidad no ulcerada, 103 ± 28 cm/s frente a 122 ± 35 cm/s para la extremidad ulcerada ($p = 0,02$ según la prueba t pareada). Las respuestas de velocidad sanguínea post HbOT mostraron diferencias entre las extremidades ulceradas y no ulceradas. Aparentemente, la extremidad no ulcerada respondió más significativamente a la oxigenación que la extremidad ulcerada. Tal observación sugiere una mayor investigación sobre las reacciones hemodinámicas debidas a la HbOT.

Palabras clave: Ulceración. Oxigenoterapia hiperbárica. Doppler arterial.

INTRODUCTION

Research on blood flow regarding ulcer healing, particularly diabetes-related ulcer of the foot and leg, is on demand. Hyperbaric Oxygen Therapy (HBOT) is a treatment modality

that has shown effective healing results but has many controversies¹⁻⁶. Essentially, HBOT helps patients with concomitant ischemia heal from diabetic leg ulcers¹. How HBOT is affected, however, is still unclear. Modern trials are currently studying effects of HBOT⁷.

A brief review of literature regarding HBOT raised the following topics: HBOT increases skin oxygenation despite vasoconstriction⁸; increased oxygenation decreases muscular blood flow during exercise⁹; blood flow could decrease during hyperoxygenation for various causes other than vasoconstriction¹⁰. Cardiac Doppler helped assess the improvement of myocardial diastolic function post HBOT¹¹. Doppler waveforms and color or power Doppler imaging showed how HBOT affected the bladder of a patient treated for post-radiation cystitis¹². Oxygenation alone could reduce cerebral blood flow, unlike atmospheric pressure¹³. Calf blood flow decreased during oxygenation; this is a significant finding for this investigation¹⁴.

Besides age and gender, several comorbidities could be limiting factors for HBOT: diabetes duration and type, retinopathy, nephropathy, neuropathy, coronary artery disease, stroke, hypertension, smoking, hemoglobin, sedimentation rate, C-reactive protein, and peripheral arterial occlusive disease (PAOD)¹⁵. HBOT is more negatively affected by femoral PAOD than by infrapopliteal PAOD¹⁵. This evidence made us focus on common femoral artery Doppler velocity measurements.

Transcutaneous oxygen tension measurement values were established¹⁶. Dermal vascular responses were assessed by laser-Doppler¹⁷⁻¹⁸. Besides transcranial Doppler (TCD) ultrasound, venous bubbles were also detected by ultrasound with echocardiographic techniques¹⁹. Doppler velocity measurements may be associated with diabetic ischemia evaluation, but actual description of HBOT effects are practically inexistent²⁰⁻²⁷.

In short, HBOT was expected to reduce blood flow, whereas ulceration would increase it. According to our hypothesis, peak systolic velocity (PSV) measurements could perceive changes in blood flow. Therefore, this quality assurance project focused on Doppler velocity measurements of the common femoral artery pre and post-HBOT.

METHODS

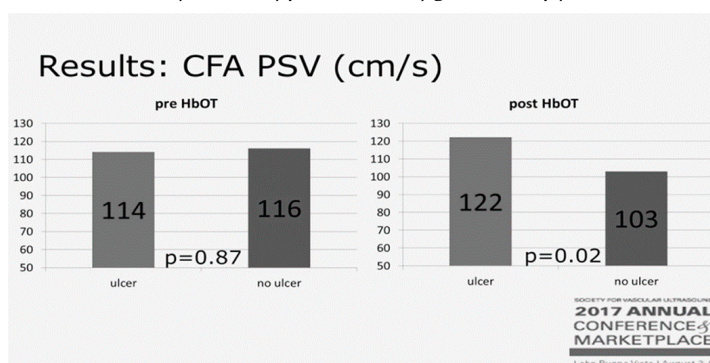
Sixteen patients with leg ulcers, 65 ± 11 (SD) (38-87) years-old, had HBOT of 90 minutes at 2.6 ATA. Nine ulcers were on the right lower extremity and seven were on the left extremity. Bilateral common femoral artery (CFA) Doppler velocity waveforms were recorded immediately pre and post-HBOT with a 10-5 MHz linear transducer connected to a Sonosite S series instrument (Sonosite Inc., Bothell WA). Subjects were rested and in supine position.

Analysis included descriptive and comparative statistics available at Excel. Pre-HBOT data of ulcerated and non-ulcerated extremities were compared by two-tailed paired t-test. Pre and post-HBOT data of ulcerated and non-ulcerated extremities were compared by one-tailed paired t-test based on PSV decrease expectancy. Post-HBOT data of ulcerated and non-ulcerated extremities were compared by two-tailed paired t-test.

RESULTS

Common femoral artery (CFA) peak systolic velocities (PSV) of the lower extremity with ulcers averaged 114 ± 35 (SD) cm/s, similar to the 116 ± 41 cm/s ($p = 0.87$) of the contralateral, non-ulcerated extremity (**Figure 1**).

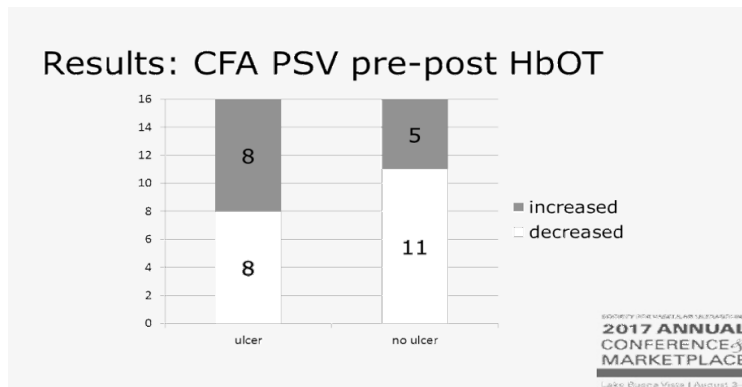
Figure 1. Peak systolic velocities (PSV) measured at the common femoral artery (CFA) before and immediately after hyperbaric oxygen therapy. Salvador, Bahia – 2019



CFA PSV in the ulcerated extremity increased from 114 ± 35 (SD) cm/s to 122 ± 35 cm/s after hyperbaric oxygen therapy, but was statistically insignificant ($p = .19$ by one-tailed paired t-test). PSV increased in half of the ulcerated extremities ($n = 8/16$) and decreased in the other half (**Figure 2**).

On the other hand, CFA PSV decreased in 11 of 16 non-ulcerated extremities. It decreased from 116 ± 41 cm/s to 103 ± 28 cm/s ($p = .049$ by one-tailed paired t-test) and was significantly lower after hyperbaric oxygen therapy, with 103 ± 28 cm/s vs 122 ± 35 cm/s ($p = .02$ by paired t-test).

Figure 2. Number of extremities with increased or decreased common femoral artery (CFA) peak systolic velocities (PSV) after hyperbaric oxygen therapy. Salvador, Bahia – 2019



DISCUSSION

Hyperoxygenation can decrease blood flow if oxygen is the main substance affecting the flow's distribution to muscles and other tissues of the lower extremity. The CFA PSV decreased about 10% in the non-ulcerated lower extremity, but was statistically significant. Five of the sixteen non-ulcerated extremities, however, may not be completely normal, since their flow or velocity did not drop as expected.

Expected HBOT vasoconstriction was noticed in half of the lower extremities with a leg ulcer (8/16). Ulcer-related vasodilation and HBOT-related vasoconstriction competed with corresponding ulcerated extremities. Complex factors may slightly influence blood flow, particularly in affected, ischemic extremities. Patients should therefore be analyzed individually to explain conditions of vasodilation, vasoconstriction, and ulcer healing.

Hyperbaric chambers were designed to treat decompression sickness. Atmospheric pressure is around 760 mmHg and pressure increases by 760 mmHg as the divers go ten meters deeper in the ocean. The return to normal atmosphere must be controlled and the hyperbaric chamber can help re-accommodate to earth. Depth pressure changes disrupt blood gases; therefore, oxygen has been used to clean the blood and the surrounding systems within the human body.

HBOT is primarily used if ulcers did not heal properly with traditional treatment. Certain patients could possibly heal faster with HBOT, but questions about best patient selection and ulcer re-occurrence, for example, are still unanswered.

This study's quality assurance research was based on discovery. Patients who entered the study so far are too few to analyze contributing factors to the patient's individual signs and symptoms. Doppler velocity measurement values will most likely focus on individual changes and treatment observations. Such longitudinal follow up could show contradictory responses between extremities until complete healing.

CONCLUSION

Common femoral artery peak systematic velocities had different responses to HBOT in extremities with and without leg ulcer. PSV were significantly lower in the non-ulcerated extremity in most subjects. Response in the ulcerated extremity was equally divided between PSV increase or decrease. CFA PSV could indicate if HBOT vasoconstriction can outweigh ulcer-related vasodilation individually.

PARTICIPATION

1. Project design, analysis and interpretation of data: Cristiane Antequiera Maran and Sergio Xavier Salles-Cunha.

2. Writing of the article and critical review of its intellectual content: Cristiane Antequiera Maran and Sergio Xavier Salles-Cunha.

3. Review and/or approval of the final version to be published: Cristiane Antequiera Maran and Sergio xavier Salles-Cunha.

4. Responsible for all aspects of the study, ensuring accuracy and integrity in any of its sections: Cristiane Antequiera Maran and Sergio Xavier Salles-Cunha.

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Received: 10.29.2021. Accepted: 12.6.2021.