UNIVERSIDADE FEDERAL DE SANTA MARIA
CENTRO DE CIÊNCIAS RURAIS
PROGRAMA DE PÓS-GRADUAÇÃO EM MEDICINA VETERINÁRIA

Nadine Trinks Fischborn

EFEITOS DA OXIGENOTERAPIA HIPERBÁRICA EM PARÂMETROS HEMATOLÓGICOS, LACTATEMIA E HEMOGASOMETRIA DE GATAS SUBMETIDAS À OVARIOHISTERECTOMIA ELETIVA

Santa Maria, RS
2021

Nadine Trinks Fischborn

Efeitos da oxigenoterapia hiperbárica em parâmetros hematológicos, lactatemia e hemogasometria de gatas submetidas à ovariohisterectomia eletiva videoassistida

Dissertação apresentada ao Curso de Pós-Graduação em Medicina Veterinária, Área de Cirurgia e Clínica de Pequenos Animais, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para a obtenção do título de **Mestre em Medicina Veterinária**

Orientador: Prof. Dr. Maurício Veloso Brun

Santa Maria, RS

2021

Fischborn, Nadine
Efeitos da oxigenoterapia hiperbárica em parâmetros hematológicos, lactatemia e hemogasometria de gatas submetidas à ovariohisterectomia eletiva videoassistida / Nadine Fischborn.- 2021.
55 p.; 30 cm

Orientador: Maurício Veloso Brun
Dissertação (mestrado) - Universidade Federal de Santa Maria, Centro de Ciências Rurais, Programa de Pós Graduação em Medicina Veterinária, RS, 2021

1. Oxigenoterapia hiperbárica 2. Ovariohisterectomia 3. Felinos I. Veloso Brun, Maurício II. Título.

Sistema de geração automática de ficha catalográfica da UFSM. Dados fornecidos pelo autor(a). Sob supervisão da Direção da Divisão de Processos Técnicos da Biblioteca Central. Bibliotecária responsável Paula Schoenfeldt Patta CRB 10/1728.

Nadine Trinks Fischborn

EFEITOS DA OXIGENOTERAPIA HIPERBÁRICA EM PARÂMETROS HEMATOLÓGICOS, LACTATEMIA E HEMOGASOMETRIA DE GATAS SUBMETIDAS À OVARIOHISTERECTOMIA ELETIVA VIDEOASSISTIDA

.

Dissertação apresentada ao Curso de Pós-Graduação em Medicina Veterinária, Área de Cirurgia e Clínica de Pequenos Animais, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para a obtenção do título de **Mestre em Medicina Veterinária**

Aprovada em 11 de março de 2021:

_____

Maurício Veloso Brun, Dr. (UFSM)
(Presidente/Orientador)

_____

Daniel Curvello De Mendonça Müller, Dr. (UFSM)

_____

Carlos Afonso de Castro Beck, Dr. (UFRGS)

Santa Maria, RS
2021

AGRADECIMENTOS

À UFSM, por meio do PPGMV, ao CNPQ e CAPES, que viabilizaram o programa de pós-graduação.

Agradeço à minha família que me possibilitou chegar até aqui através do seu incentivo, paciência e amor.

Ao meu orientador Maurício Veloso Brun, que me acompanha desde a graduação e é modelo de profissional e professor, além de ser quem me abriu as portas para a área de cirurgia veterinária, dando um novo sentido à minha formação.

Meus animais de estimação, que incitaram o amor pela profissão, que me acompanham diariamente e são sempre fonte de inspiração para melhor servir a eles.

Meus amigos que estiveram presentes nos bons e maus momentos, impossível agradecer a todos nominalmente, porém estes sabem que sem seu apoio essa jornada não teria sido a mesma. Obrigada por trazerem conforto e por serem impulso quando eu precisei.

À Universidade Pública e as pessoas que conheci pertencentes a Universidade Federal de Santa Maria.

Aos professores que são inspiração e fonte de conhecimento, porto seguro das minhas dúvidas, e que nunca hesitaram em fornecer ajuda quando necessário. Um agradecimento especial aos professores Daniel e Saulo, que nunca fecharam suas portas e foram de extrema importância na minha formação pessoal e profissional.

Agradeço aos profissionais parceiros, fundamentais para viabilizar a execução do projeto, principalmente a equipe do LacVet e HUSM.

Aos estagiários, que possibilitaram a execução técnica dessa pesquisa, e foram muito mais do que se propuseram. Vocês são amigos que levarei para vida.

Aos residentes, técnicos, docentes, mestrandos, doutorandos que atuam no HVU/UFSM, especialmente os colegas do SOMIV. Não posso deixar de citar porém minha colega direta de pós-graduação Letícia, que trouxe luz aos meus dias e sem a qual essa pesquisa não seria possível, e à Marcella, que me acolheu quando eu era apenas uma estagiária e me levou a seguir esse caminho.

Agradeço também aos pacientes que ao longo destes 4 anos me ensinaram a ser mais humana.

Aos animais experimentais

Quando me sinto desalentado tudo o que tenho a fazer é contemplar meus gatos e assim ressurge-me a coragem. Eu estudo essas criaturas. Os gatos são meus mestres.

(Charles Bukowski)

RESUMO

EFEITOS DA OXIGENOTERAPIA HIPERBÁRICA EM PARÂMETROS HEMATOLÓGICOS, LACTATEMIA E HEMOGASOMETRIA DE GATAS SUBMETIDAS À OVARIOHISTERECTOMIA ELETIVA VIDEOASSISTIDA.

AUTOR: Nadine Trinks Fischborn

ORIENTADOR: Maurício Veloso Brun

A oxigenioterapia hiperbárica vem despontando como modalidade terapêutica no manejo de diversas afecções agudas e crônicas, tanto na medicina humana quanto veterinária. Sua aplicação leva à hiperoxigenação tecidual, imunomodulação e redução do estresse oxidativo em humanos. A ovariohisterectomia (OVH) eletiva consiste em um dos procedimentos cirúrgicos mais realizado na rotina da clínica de pequenos animais, e tem papel tanto no controle da concepção quanto na prevenção de diversas afecções. Existem diferentes técnicas para a execução da OVH minimamente invasiva, destacando-se entre elas a abordagem videoassistida. Não há na literatura registros das alterações fisiológicas em felinos submetidos à oxigenioterapia hiperbárica. Com esse estudo, objetivou-se avaliar as consequências do uso de oxigenioterapia em câmara hiperbárica em felinos submetidos à ovariohisterectomia videoassistida com dois portais no pré-operatório, além da sua influência sobre a gasometria sanguínea, lactatemia e contagem de células sanguíneas Para isso, 42 gatas foram separadas em três grupos para avaliação destes efeitos, sendo eles: Grupo Sham (GS), Grupo Hiperbárica (GH) e Grupo Hiperbárica Controle (GHC). Realizou-se avaliação hematológica, da lactatemia e gasometria venosa. Concluiu-se que não há influência significativa de pré-tratamento com HBOT sobre parâmetros como excesso de base em felinos hígidos. A HBOT pode levar ao aumento do lactato sérico em felinos e a queda do pH, sem necessariamente causar acidose metabólica. Há influência positiva da HBOT nos valores de pO_2 e pCO_2. Pode haver queda nos valores de hematócrito, hemácias e hemoglobina, sendo recomendado a realização de hemograma de controle antes da sessão. Pode ser esperada leucocitose com neutrofilia e linfopenia.

Palavras-chave: Oxigenioterapia hiperbárica, Videocirurgia, Perfusão, Hemograma, Gasometria venosa.

ABSTRACT

EFFECTS OF HYPERBARIC OXYGEN THERAPY ON HEMATOLOGICAL PARAMETERS, LACTATEMIA AND HEMOGASOMETRY OF CATS UNDERGOING VIDEO-ASSISTED OVARIOHYSTERECTOMY

AUTHOR: Nadine Trinks Fischborn

ADVISOR: Maurício Veloso Brun

Hyperbaric oxygen therapy has emerged as a therapeutic modality in the management of several acute and chronic conditions, both in human and veterinary medicine. Its application leads to tissue hyperoxygenation, immunomodulation and reduction of oxidative stress in humans. The elective ovariohysterectomy (OHE) is one of the most common surgical procedures performed in the small animal clinic, and has a role both in preventing mating and various conditions. There are different techniques for the execution of minimally invasive OHE, with emphasis on the video-assisted approach. There are no records in literature of physiological changes in cats undergoing hyperbaric oxygen therapy. This study aimed to evaluate the consequences of using oxygen therapy in a hyperbaric chamber in cats in the preoperative period of video-assisted ovariohysterectomy with two portals, in addition to assess its influence on blood gas analysis, lactatemia and blood cell count. Cats were separated into three groups to analyse these effects, namely: Sham Group (GS), Hyperbaric Group (GH) and Hyperbaric Control Group (GHC). Hematological, lactatemia and venous blood gas analysis was performed. It was concluded that there is no significant influence of pre-treatment with HBOT on parameters such as base excess in healthy cats. HBOT can lead to an increase in serum lactate in cats and a decrease in pH, without necessarily causing metabolic acidosis. There is a positive influence of HBOT in pO_2 and pCO_2 values. There may be a drop in the hematocrit, red blood cells and hemoglobin values, and it is recommended to carry out a control blood count before the session. Leukocytosis with neutrophilia and lymphopenia can be expected..

Keywords: Hyperbaric oxygen therapy, video surgery, perfusion, blood count, venous blood gas analysis.

LISTA DE TABELAS

MANUSCRITO

LISTA DE ILUSTRAÇÕES

MANUSCRITO

LISTA DE ABREVIATURAS

ATA: Atmosferas absolutas

BE: Excesso de base

CO_2: Dióxido de carbono

F3: Ferormônio facial felino

GH: Grupo hiperbárica

GHC: Grupo hiperbárica controle

GS: Grupo sham

HBOT: Oxigenoterapia hiperbárica

IM: Intramuscular

IV: Intravenoso

O_2: Oxigênio

OHE: Ovariohisterectomia

pCO_2: Pressão parcial de dióxido de carbono

pH: Potencial hidrogeniônico

pO_2: Pressão parcial de oxigênio

PSI: Libra-força por polegada quadrada

q12h: A cada 12h

SC: Subcutâneo

T0: Tempo 0

T1: Tempo 1

T3: Tempo 3

T5: Tempo 5

SUMÁRIO

APRESENTAÇÃO

Esta dissertação está estruturada em seções dispostas da seguinte forma: Introdução; Objetivos; Desenvolvimento (Referencial Teórico, Manuscrito Científico); Conclusão e Referências.

Os itens Material e Métodos, Resultados, Discussão e Referências encontram inseridos no manuscrito na seção “Produção Científica” e representam a íntegra desse estudo.

A “Lista de Referências” se refere ao referencial utilizado nos itens anteriores ao manuscrito, e o item “Referências” refere-se às referências utilizadas no manuscrito.

1. INTRODUÇÃO

A oxigenioterapia hiperbárica (HBOT) consiste em um método antigo de tratamento (EDWARDS, 2010). Embora os primeiros registros do uso de terapia hiperbárica em humanos datem de 1662, somente em 1887 foram relatados os primeiros resultados da aplicação da técnica na medicina veterinária, os quais demonstraram a capacidade de redução do status febril de coelhos em sepse induzida após sessões em câmara hiperbárica (BEAN, 1945).

Com mais câmaras sendo disponibilizadas e mais pesquisas demonstrando o benefício do seu uso, a HBOT tem se destacado cada vez mais como opção terapêutica, tanto na medicina humana quanto veterinária. Além disso, consiste em uma técnica com diversas aplicações, como em situações emergenciais tais como intoxicação por monóxido de carbono, síndrome compartimental, acidentes ofídicos e lesões nervosas centrais. Ademais, pode também ser empregada em afecções de evolução crônica, como nos casos de lesões com cicatrização retardada, queimaduras e flapes ou enxertos cutâneos (EDWARDS, 2010).

A ovariohisterectomia (OVH) é amplamente utilizada tanto para esterilização eletiva quanto para tratamento de doenças do trato reprodutivo ou auxílio na estabilização de doenças sistêmicas, sendo o procedimento cirúrgico mais realizado na década passada casuística veterinária de pequenos animais (FERREIRA et al., 2011; HEDLUND, 2008). Além disso, pode diminuir o risco de desenvolvimento de neoplasias mamárias e piometra (DAVIDSON et al., 2004).

Muitas variações da técnica cirúrgica de OVH têm sido descritas, desde a abordagem convencional via celiotomia mediana, até as abordagens

minimamente invasivas laparoscópicas (DALMOLIN, 2016) ou videocirúrgicas, nas suas diferentes modalidades. Os acessos minimamente invasivos vêm ganhando popularidade por apresentarem diversas vantagens quando comparada as cirurgias convencionais. Entre essas vantagens, podemos citar menor estímulo álgico pós-operatórios devido ao menor dano tecidual somático, reduzido período de hospitalização pós-operatória, menor risco de deiscência e hemorragia, redução na formação de aderências e melhores resultados estéticos (DUQUE e MORENO, 2015; FERREIRA et al., 2011; MALM et al., 2004).

Os procedimentos envolvendo o uso de HBOT em felinos são realizados a partir de informações obtidas em outras espécies, não havendo ainda pesquisas com foco na espécie em questão. Desta forma, não há informação disponível para a avaliação da interferência da HBOT nos padrões fisiológicos em felinos. Explorar a variação de parâmetros basais em felinos saudáveis submetidos à HBOT precedendo procedimento eletivo permite que a técnica ganhe respaldo científico visando a aplicabilidade na terapêutica de animais doentes através da extrapolação destes dados para situações patológicas.

2. OBJETIVOS

2.1. OBJETIVO GERAL

Avaliar as consequências do uso da oxigenoterapia hiperbárica pré-operatória sobre a contagem de células sanguíneas, gasometria e lactatemia em gatas submetidas à ovariohisterectomia videoassitida com dois portais.

2.2. OBJETIVOS ESPECÍFICOS

a. Identificar se há alterações em marcadores de perfusão periférica (como lactatemia) nos animais que passarem por tratamento com oxigenoterapia hiperbárica pré-cirúrgica;

b. Determinar se o pré-tratamento em oxigenioterapia hiperbárica promove alteração de gasometria sanguínea nas gatas avaliadas;

c. Identificar possíveis alterações hematológicas significativas decorrentes do pré-tratamento com oxigenoterapia hiperbárica.

3. REFERENCIAL TEÓRICO

A oxigenioterapia hiperbárica consiste na administração de oxigênio a 100% a uma pressão acima de 1 atmosfera absoluta (ATA) em uma câmara (EDWARDS, 2010). Sob essas condições a pressão parcial de oxigênio aumenta de 100 mmHg (ar ambiente com pressão de 1 ATA) para 1400 mmHg à 2 ATA com oxigênio à 100%, levando à uma hiperoxia transitória (GAUTIER et al., 2020).

Oxigênio é necessário para prover energia e possibilitar a respiração celular, portanto um aporte deficitário de oxigênio leva à morte das células. Um animal doente possui menor capacidade de transporte de O_2 ao passo que aumenta a necessidade tecidual deste gás, levando ao colapso do sistema e gerando estresse oxidativo (YANAGISAWA et al., 2011).

Segundo Jain (2004), os princípios da HBOT são baseados em como gases de diferentes solubilidades se comportam nos tecidos e fluidos corporais sob diferentes pressões e volumes, fenômeno este determinado pelas leis do comportamento gasoso descritas por Henry, Fick e Boyle. A lei de Henry descreve como a pressão do gás afeta sua concentração no interior dos tecidos, enquanto a de Fick refere-se à taxa de difusão de um gás através destes tecidos. Já a lei de Boyle diz respeito ao comportamento dos gases sob pressão.

Há diversos mecanismos propostos para justificar os benefícios fisiológicos da HBOT (GEMMA, DARREN e MATTHEW, 2018). Os efeitos primários da HBOT consistem em aumentar a oxigenação tecidual e redução de bolhas gasosas em vasos e tecidos (lei de Boyle). Os efeitos fisiológicos secundários são resultados do estresse oxidativo à curto prazo e incluem

resposta antioxidante compensatória, modulação da resposta imune e inflamatória, aumento da atividade antibacteriana, angiogênese, estímulo de fatores de crescimento, vasoconstrição e redução de edema vasogênico (BAI et al., 2014). Seus possíveis efeitos adversos incluem pneumotórax, barotrauma, toxicidade pulmonar e convulsões (HEYBOER, SHARMA e SANTIAGO, 2017).

A função respiratória, especificamente a capacidade de oxigenação e ventilação pode ser avaliada através de hemogasometria. Embora a oximetria de pulso possa ser usada na detecção de hipóxia, a gasometria, especialmente a aferição da pO_2, segue sendo o padrão ouro. A obtenção dos resultados de hemogasometria é crucial para pacientes com afecções agudas tais como sepse, trauma, insuficiência respiratória ou falência de órgãos, assim como na monitoração de quadros crônicos (GONZALEZ e WADDELL, 2016).

A gasometria sanguínea pode ser realizada através de amostras de sangue arterial ou venoso. Nos felinos o pH venoso é consideravelmente inferior ao pH arterial, enquanto a pCO2 venosa é mais alta que a arterial, levando ao aumento na concentração de bicarbonato, porém sem alterações significativas no excesso de base (TAMURA et al., 2015).

Amostras de sangue venoso são mais simples de coletar, geram menor desconforto ao paciente e podem ser coletadas de forma repetida com menor possibilidade de trombose em consequência da punção (RIESER, 2013). Em pacientes felinos, é recomendada sempre que possível a coleta venosa, especialmente em animais não anestesiados, devido ao estresse gerado pela punção e pelo risco de acidentes tromboembólicos com punções sequenciais. Parâmetros aferidos através da hemogasometria incluem o pH, pO_2, pCO_2,

diversos eletrólitos e metabólitos como bicarbonato, ácido carbônico, lactato, glicose, entre outros.

O pH é definido como sendo o logaritmo negativo da concentração de íons de hidrogênio (H+) e é aferido para determinar o grau de acidez ou alcalinidade de uma solução. Acidose respiratória é caracterizada pela queda no pH e aumento da pCO_2, frequentemente em conjunção com um aumento de bicarbonato e excesso de base (BE) compensatórios. Costuma ser o resultado de insuficiência respiratória e hipoventilação. Alcalose respiratória é caracterizada por um aumento no pH e decréscimo na pCO_2, associado à consequente queda no bicarbonato e BE. Costuma ser o resultado de hiperoxia e hiperventilação (GONZALEZ e WADDELL, 2016).

A pressão parcial ou tensão de gás é se caracteriza pela pressão exercida por um gás em uma mistura de gases ou em um líquido. Essa pressão parcial é refletida através da proporção da concentração do gás em relação à pressão total da mistura. A pressão parcial de um gás é calculada através da multiplicação da porção de gás na amostra pela pressão total. O controle central da ventilação altera a pCO_2 sanguinea. Devido à combinação de gás carbônico e água levar à produção de ácido carbônico, ao diminuir a ventilação e aumentar a pCO_2 o pH sanguíneo diminui. Ao aumentar a capacidade ventilatória e diminuir a pCO_2 o pH sanguíneo pode ser aumentado (DIBARTOLA, 2012).

O lactato consiste em um subproduto do metabolismo anaeróbico, e é um biomarcador útil ao diagnóstico e prognóstico de choque em medicina humana e veterinária, por refletir um desequilíbrio na quantidade de oxigênio demandada pelo tecido e a quantidade recebida por este. É um parâmetro seguro para avaliação de perfusão tecidual em gatos pois sofre pouca influência dos métodos

de coleta (REDAVID, 2012), embora uma manipulação cuidadosa do paciente na obtenção de amostras para análise seja imprescindível para evitar hiperlactatemia por estresse (RAND et al., 2002).

O hemograma consiste em um exame diagnóstico para pacientes com alguma afecção clinicopatológica, bem como parte da inspeção de rotina de indivíduos saudáveis. Um estudo realizado por Sinan et al (2016) demonstrou uma queda significativa do hematócrito e contagem de hemácias após algumas sessões de HBOT em pacientes com diversas afecções. Contudo, Gunes e Aktas (2017) realizaram um estudo em que pacientes humanos foram submetidos à mais de 60 sessões de HBOT, e não houve alteração significativa nos valores de hemácias, hemoglobina e hematócrito em nenhum dos grupos avaliados.

Leucocitose consiste no aumento da contagem total de leucócitos e é considerada um achado comum em exames laboratoriais. Em geral é relacionada a condições relativamente benignas, como presença de infecção ou processos inflamatórios (CHABOT-RICHARDS e GEORGE, 2014). A contagem periférica de células brancas pode dobrar dentro de poucas horas após certos estímulos devido ao grande reservatório intramedular e *pools* intravasculares de neutrófilos marginalizados. Fatores capazes de gerar leucocitose aguda incluem procedimentos cirúrgicos, exercício, trauma e estressores psicológicos. Estresse físico ou emocional pode levar ao aumento da contagem leucocitária total, combinada ao aumento da fração de neutrófilos e diminuição da fração linfocitária (RILEY e RUPERT, 2015).

4. PRODUÇÃO CIENTÍFICA

Os resultados inseridos nesta dissertação apresentam-se sob a forma de manuscrito científico, o qual se encontra aqui estruturado. Os itens Material e Métodos, Resultados e Discussão, Conclusão e Referências, encontram-se no próprio artigo (Item 4).

4.1. MANUSCRITO

Effects of hyperbaric oxygen therapy on hematological parameters, lactatemia and blood gas analysis of cats undergoing elective video-assisted ovariohysterectomy

Nadine Trinks Fischborn, Letícia Reginato Martins, Bernardo Nascimento Antunes, Pâmela Caye, Jean Carlos Gasparotto, Vinícius da Silva Cadiñanos, Thiago Rodrigues da Cunha, Ana Paula Backes Lisboa, Maurício Veloso Brun

Status: Artigo submetido para a revista Journal of Feline Medicine and Surgery JFMS-21-0041

Effects of hyperbaric oxygen therapy on hematological parameters, lactatemia and blood gas analysis of cats undergoing elective video-assisted ovariohysterectomy

Nadine T Fischborn[1], Letícia R Martins[1], Bernardo N Antunes[1], Pâmela Caye[1], Jean C Gasparotto[1], Vinícius S Cadiñanos[2], Thiago R Cunha[2], Ana Paula B Lisboa[2], Maurício V Brun[3]

[1] Graduate Program in Veterinary Surgery and Clinics, Federal University of Santa Maria, RS, Brazil

[2] Veterinary Medicine College, Federal University of Santa Maria, RS, Brazil

[3] CNPq-Brazil researcher (305876/2018-0), Department of Small Animal Clinics, Federal University of Santa Maria, RS, Brazil

Correspondig author:

Nadine Trinks Fischborn

Federal University of Santa Maria, Santa Maria, Avenida Roraima, 1000, 97105-900, Santa Maria, Rio Grande do Sul, Brasil.

E-mail: nadinefischborn@gmail.com

ORCID: https://orcid.org/0000-0002-0170-1664

Key words: Hyperbaric oxygen therapy, Perfusion, Blood count, Blood gas analysis.

Abstract

Objectives: To evaluate the influence of hyperbaric oxygen therapy (HBOT) - at a 2 ATA pressure for 45 minutes - in the blood count, lactatemia and venous blood gas analysis of healthy cats undergoing video-assisted ovariohysterectomy.

Methods: 42 healthy queens were randomly divided into three groups: GH (animals received HBOT at a pressure of 2 ATA for 45 minutes and were subsequently submitted to OHE), GHC (animals received HBOT at a pressure of 2 ATA for 45 minutes) and GS (animals submitted to OHE). Blood samples for hematological analysis were collected at times T0 (before any procedure) and T5 (72h after extubation) and blood samples for venous blood gas analysis and lactatemia were collected at times T1 (after pre-medication) and T3 (after extubation).

Results: There were no significant changes to base excess. The values of hematocrit ($p = 0.018$), hemoglobin ($p = 0.01$) and red blood cells ($p = 0.0018$) decreased between T0 and T5 in GH. Total leukocytes ($p = 0.0062$) and neutrophils ($p = 0.0055$) increased between T0 and T5 in GH. Lymphocytes decreased in Time 5 in GHC in relation to T5 of GS ($p = 0.027$). The lactate values

were higher at T1 (p = 0.021) and T3 (p = 0.025) in GHC compared to GS, and higher at T3 in GHC compared to T3 in GH (0.035).The pH was lower in T3 than in T1 in GH (p = 0.03), lower in T3 in GH compared to T3 in GHC (p = 0.0017) and lower in T3 in SHAM compared to T3 in GHC (p = 0.0097). The pO_2 was higher in T1 (p = 0.014) and T3 (p = 0.0026) in GH than it was in GHC. It was also higher in T1 (p = 0.0013) and T3 (p = 0.0026) in the SHAM group compared to GHC. For pCO_2, T1 (p = 0.02) and T3 (p = 0.008) in GH were greater than that of GHC, and T1 (p = 0.05) and T3 (p = 0.059) in GS were greater than that of GHC. There was an increase between T1 and T3 in GH (p = 0.04).

Conclusions and relevance: HBOT can lead to an increase in serum lactate in cats and a decrease in pH, without necessarily causing metabolic acidosis. There is a positive influence of HBOT in pO_2 and pCO_2 values. There may be a drop in the hematocrit, red blood cells and hemoglobin values, and it is recommended to carry out a control blood count before the session. Leukocytosis with neutrophilia and lymphopenia can be expected.

Introduction

Hyperbaric oxygen therapy (HBOT) consists of the administration of 100% oxygen at a pressure above 1 absolute atmosphere (ATA) in a chamber[1]. Oxygen is necessary to provide energy and enable cellular respiration, so a deficient supply of oxygen leads to the death of cells.

In a diseased animal there is a decrease of O_2 transporting capacity while increasing the tissue's need for this gas, leading to the collapse of the gas homeostatic system[2]. There are several mechanisms proposed to justify the physiological benefits of HBOT, such as plasma oxygen availability, tissue hyperoxygenation, barometric effect, immunomodulation and reduction of oxidative stress[3].

Ovariohysterectomy (OHE) is widely used both for elective sterilization and in the treatment of diseases of the reproductive tract or aid in the stabilization of systemic diseases[4,5]. In addition, it can decrease the risks of patients mammary malignancies and pyometra[6]. Minimally invasive approaches have been gaining popularity as they present several advantages when compared to conventional surgeries.[7].

No information is available to assess HBOT interference in feline physiological patterns. In addition, the present study is the first to explore baseline

parameters in healthy cats undergoing HBOT preceding an elective procedure, relevant data due to the future possibility of using this therapeutic option in sick animals prior to surgery.

This study aims to identify possible changes in hematological and peripheral perfusion markers in animals undergoing treatment with pre-surgical HBOT, in addition to determining whether the pretreatment in hyperbaric oxygen therapy promotes alteration of blood gas analysis in the cats undergoing OHE.

Materials and methods

The study was approved by the Ethics Committee on the Use of Animals at the Federal University of Santa Maria (nº 513426082). An informed consent form was signed by all patient owners involved in the project.

Forty-two queens weighing between 1.5 and 5 kg, aged 8 months old to 5 years old and of undefined breed, considered healthy from clinical and laboratory examination were selected to participate in this study. Inclusion criteria included tolerance to manipulation, evidenced by the absence of aggression at the time of thoracic limb trichotomy and venipuncture for blood collection.

The cats went through an adaptation period of three days in order to get used to the place and the team. In this environment, a synthetic analogue of the feline facial pheromone (F3) was spread 24 hours before the hospitalization. The animals remained in individual boxes with paper boxes, pillows and blankets, water and food containers and a litter box. They were given water and food *ad libitum.*

On the fourth day the animals were fasted for 8 hours and then randomly assingned to three groups with 14 patients each: GH (hyperbaric group: animals pretreated with HBOT at a pressure of 2 ATA for 45 minutes and undergoing elective video-assisted OHE), GHC (hyperbaric control group: animals treated with HBOT at a pressure of 2 ATA for 45 minutes) and GS (sham group: animals undergoing elective video-assisted OHE).

For blood gas analysis, lactatemia and blood count, blood samples were collected from patients at different times. Blood samples of 0.5 ml were collected for complete blood count at the following times:

Time 0 (T0) = prior to any procedures;

Time 5 (T5) = 72h after the end of the surgical procedure. For those patients who did not undergo a surgical procedure, T5 collections occurred 72 hours after pre-medication reversal.

0.6ml blood samples were collected from the jugular vein with a syringe prepared with sodium heparin for blood gas analysis. The parameters evaluated in the gas analysis involved pH, partial pressure of oxygen (pO_2), partial pressure of carbon dioxide (pCO_2) and base excess (BE). Blood lactatemia was measured with a drop of blood. These parameters were evaluated at two different times:

Time 1 (T1) = Immediately before the start of surgery, in anesthetic stabilization. For patients not undergoing surgery, T1 was collected 25 minutes after the application of anesthetic pre-medication.

Time 3 (T3) = At the time of extubation. For patients not undergoing surgery, T3 was collected 30 minutes after pre-medication reversal .

Gasometry was assessed using a blood gas analyzer (Cobas B221 Roche OMNI S), and lactatemia using a portable lactate analyzer (Accutrend® Plus - Roche).

Patients in the GH and GHC groups underwent hyperbaric oxygen therapy (HBOT) under a pressure of 2 ATA (equivalent to 15 PSI) for 45 minutes prior to the application of pre-anesthetic medication. The chamber was pressurized to 15 PSI over a period of 15 minutes, remaining under treatment pressure for 45 minutes and then depressurized for another 15 minutes. Throughout the session

oxygen concentration, carbon dioxide concentration and chamber pressure parameters were recorded every 5 minutes.

All animals went through the same anesthetic protocol, being pre-medicated with dexmedetomidine hydrochloride (20 µg / kg,IM). After 25 minutes, trichotomy and venous access of the cephalic vein were performed.

For those patients who did not undergo surgical procedure (GHC group) T1 blood samples were collected 25 minutes after the premedication. Then, reversion with atipemazole was performed and after 30 minutes samples were obtained for T3. For groups undergoing surgery, T1 samples were collected immediately before starting the surgery.

General anesthesia was induced with propofol (5 ± 1.3 mg/kg, IV) and maintained with isoflurane carried in oxygen. After anesthetic stabilization patients received atipamezole (10 µg/kg, IM).

The video-assisted OHE was performed by a team of proficient surgeons. The pneumoperitoneum pressure adopted was 6 mmHg and it lasted for 30 minutes. Analgesia was obtained with continuous infusion of remifentanil hydrochloride (10 µg/kg/h, IV). Lactated Ringer's solution was administered throughout the procedure (3 ml/kg/h, IV). During the trans-anesthetic period, heart rate, respiratory rate, electrocardiogram, central temperature, perfusion index, rectal temperature and partial O_2 saturation were continuously monitored.

After the patients' extubation, blood samples were collected for the measurement of venous blood gases and lactatemia for T3. After the end of the surgery, the animals received dipyrone (25 mg / kg, SC, q12h for three days). T5 samples were collected 72 hours after extubation. Immediately after T5 sample collections, patients in the GHC group underwent conventional OHE, and then afterwards all patients were discharged.

For statistical analysis of the data regarding blood count, blood gas analysis and lactatemia a two-way analysis of variance test was performed, with repeated measurement, followed by Duncan's Multiple Range test

Results

46 cats were selected for this study, and four were excluded. The first was excluded due to the need to change the anesthetic protocol due to severe hypotension and the others due to the impossibility of management due to the aggressive behavior displayed during the hospitalization period. The remaining 42 cats were randomly distributed among the GH, GHC and SHAM groups in order to compose a total of 14 patients per group. These had an average age of 21.8 months and weighed an average of 3.05 kg (Table 1).

There were no complications regarding surgical and anesthetic procedures. There were no adverse effects related to HBOT. The values of the

114 blood count variables are described in Tables 2 and 3, while the findings of
115 venous blood gas and lactate are listed in Table 4. The values of bicarbonate
116 were not assessed by this research due to a systemic fault in the blood gas
117 analyzer.

Table 1. Demographic data

	GH	GS	GHC
Age (months)	27,7	20,69	17,7
Weight (kg)	3,3	3,05	2,81

GH = hyperbaric group; GS = Sham group; GHC = hyperbaric control group

118 There was no difference between the comparisons of base excess
119 between the groups and evaluated times. The blood count values, despite
120 oscillating, remained within the reference ranges according to Cornell University
121 (2008).

122 There was a significant difference ($p < 0.05$) in the values of hematocrit,
123 hemoglobin, erythrocytes, total leukocytes and neutrophils between the initial and
124 final times of the GHC group. The values of hematocrit ($p = 0.018$), hemoglobin
125 ($p = 0.01$) and erythrocytes ($p = 0.0018$) showed a substantial drop between Time
126 0 and Time 5 in GH (Figure 1), whereas the values of total leukocytes ($p = 0.0062$)
127 and neutrophils ($p = 0.0055$) increased between times 0 and 5 in this same group.

The lymphocyte count was reduced in Time 5 in GHC in relation to T5 in the SHAM group (p = 0.027), as shown in Figure 2.

Table 2. Comparison of erythrogram variables between collection times

	GH		GS		GHC	
Parameter	Time 0	Time 5	Time 0	Time 5	Time 0	Time 5
Ht	40,7±0,31	35,31±0,33*	38,2±0,47	34,9±0,49	35,67±0,62#	32,16±0,59
Hg	13,53±0,10	11,77±0,11*	12,7±0,15	11,93±0,14	11,80±0,17#	10,80±0,18
Hm	8,84±0,08	7,44±0,08*	8,49±0,12	7,77±0,10	7,59±0,11	6,94±0,12

*Different from the 1st time (p <0.05); # Different from the GH group in the same period of time (p <0.05); GH = hyperbaric group; GS = Sham group; GHC = hyperbaric control group; Time 0 = before HBOT for groups GH and GHC and before OHE for GS; Time 5 = 72h post-extubation; Ht = hematocrit; Hg = Hemoglobin; Hm = red blood cells

Table 3. Comparison of white blood cell variables between collection times

	GH		GS		GHC	
	Time 0	Time 5	Time 0	Time 5	Time 0	Time 5
Leu	11235±1089	16017±1615*	12908±1473	16052±1646	18292±2593	16033±1958
Neu	7520±822	11501±1505*	8234±1059	9295±1107	13.466±2247	11731±1527
Lym	2928±439	3060±4163	3368±446	4527±585	2950±412	2617±393+

*Different from the 1st time (p <0.05); + Different from the GH group in the same period of time (p <0.05); + Different from the SHAM group in the same time period of time. GH = hyperbaric group; GS = Sham group; GHC = hyperbaric control group; Time 0 = before HBOT for groups GH and GHC and before OHE for GS; Time 5 = 72h post-extubation; Leu = Leukocytes; Neu = Neutrophils; Lym = Lymphocytes

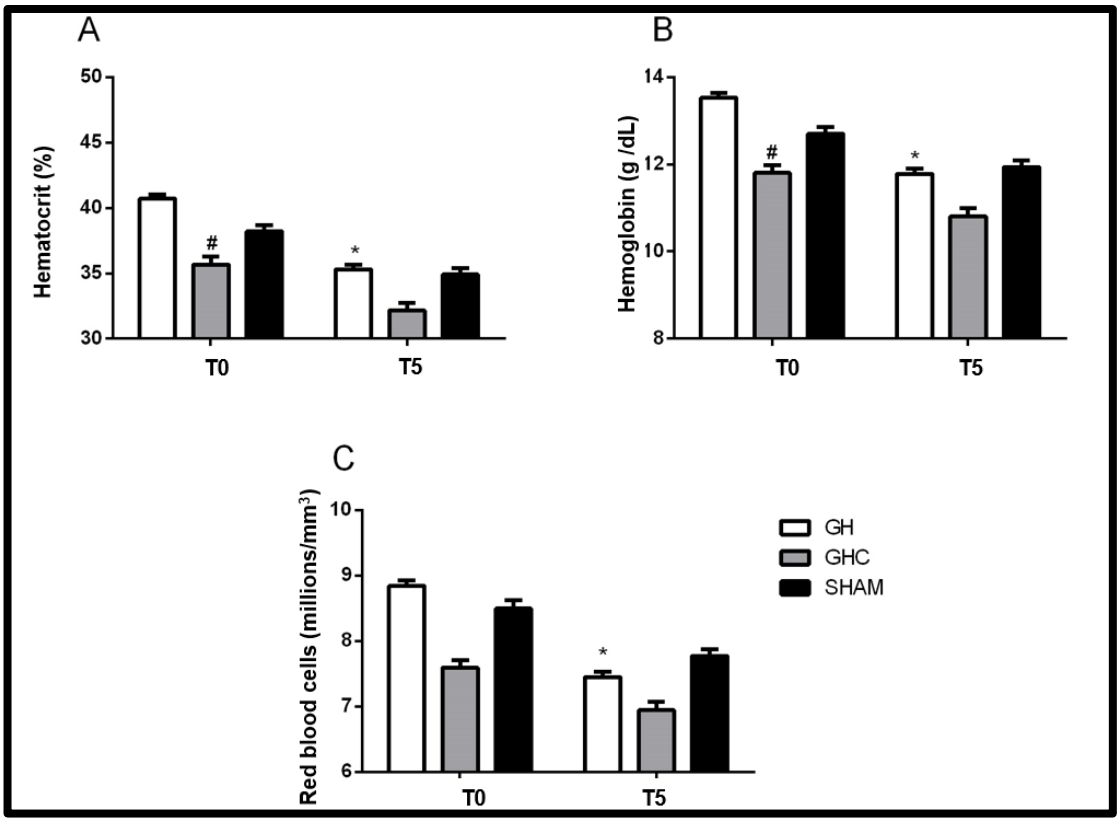

Figure 1. Mean values of Hematocrit (A), Hemoglobin (B) and Red Blood Cells (C) in groups GH, GHC and SHAM at times T0 and T5. * Different from the 1st time ($p < 0.05$); # Different from the GH group in the same period of time ($p < 0.05$); + Different from the SHAM group in the same time period. GH = hyperbaric group; SHAM = Sham group; GHC = hyperbaric control group; Time 0 = before HBOT for groups GH and GHC and before OHE for GS; Time 5 = 72h post-extubation

The lactate values (Figure 3) were higher at T1 ($p = 0.021$) and T3 ($p = 0.025$) in GHC when compared to the SHAM group. In addition, they were higher in T3 in GHC when compared to T3 in GH (0.035). The pH showed a significant reduction from T1 to T3 in GH ($p = 0.03$), in addition to being lower in T3 in GH

134 when compared to T3 in GHC (p = 0.0017) and lower in T3 in SHAM when
135 compared to T3 in GHC (p = 0.0097).

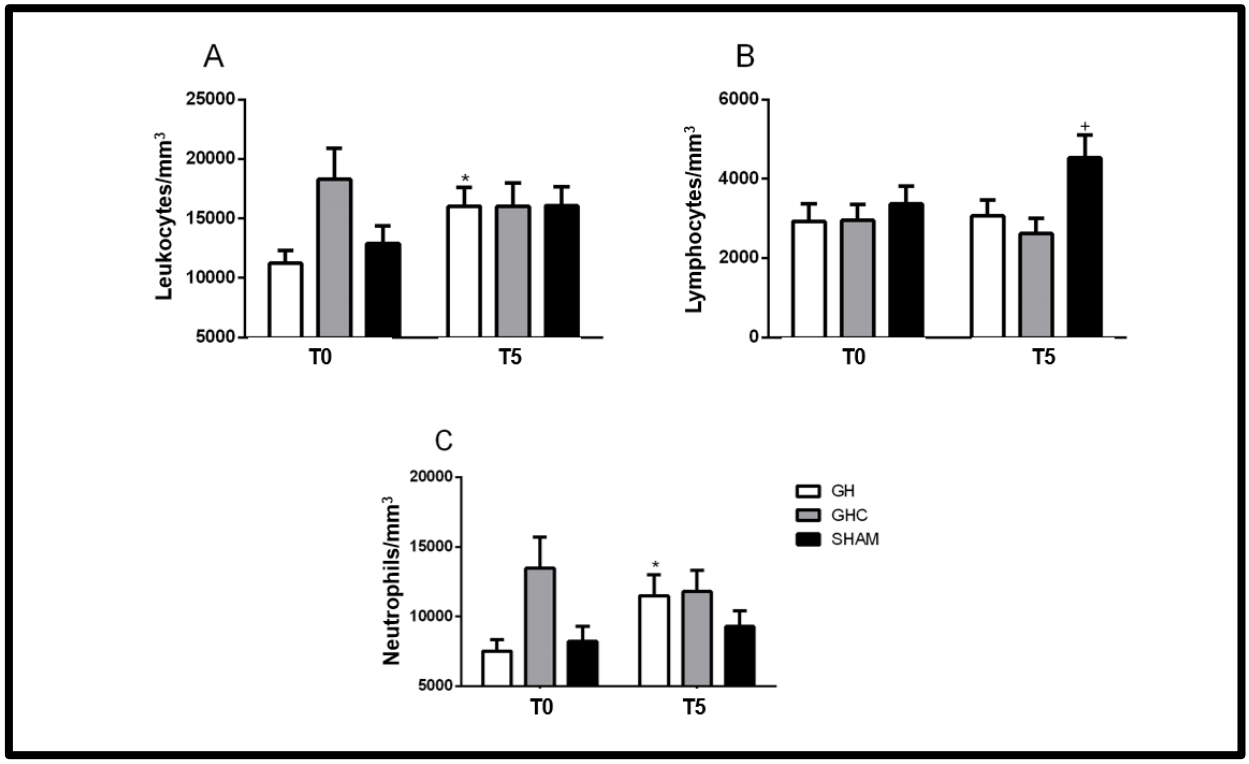

Figure 2. Average values of Leukocytes (A), Lymphocytes (B) and Neutrophils (C) in the GH, GHC and SHAM groups at times T0 and T5. GH = hyperbaric group; SHAM = Sham group; GHC = hyperbaric control group; Time 0 = before HBOT for groups GH and GHC and before OVH for GS; Time 5 = 72h post-extubation

136 The pCO_2 values were higher at times T1 (p = 0.014) and T3 (p = 0.0026)
137 for GH than for GHC for the same times. The values were also higher in T1 (p =
138 0.0013) and T3 (p = 0.0026) in the SHAM group in comparison to GHC. The pCO_2

followed these results, so that the values of T1 (p = 0.02) and T3 (p = 0.008) in GH were higher than those in GHC and T1 (p = 0.05) and T3 (p = 0.059) in SHAM were greater than that in GHC. In addition, it showed a significant increase between T1 and T3 in GH (p = 0.04).

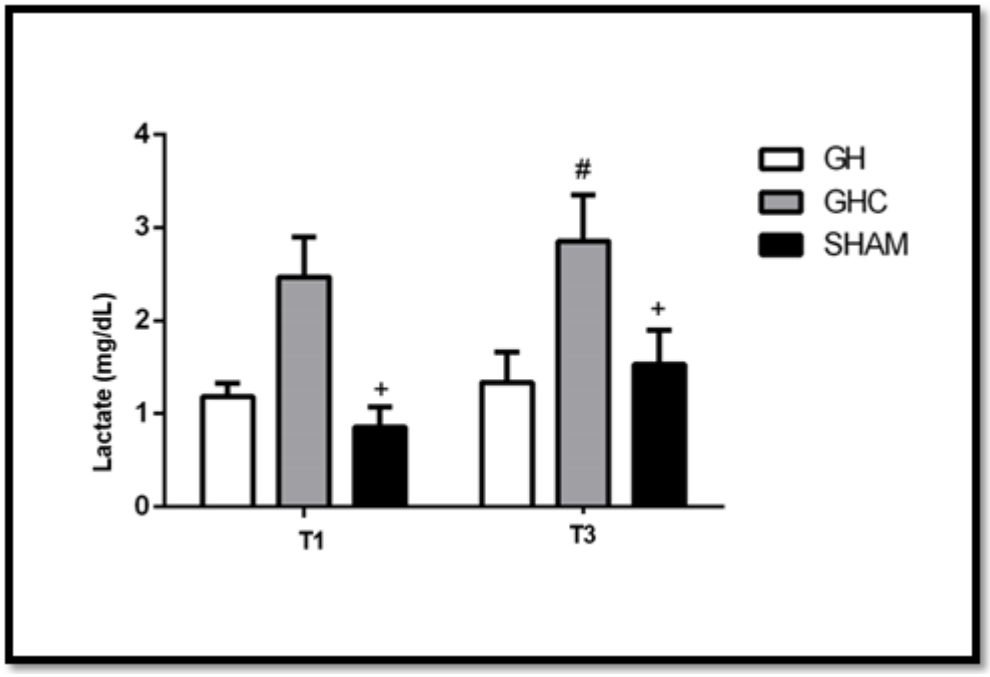

Figure 3. Average lactate values in groups GH, GHC and SHAM at times T1 and T3. * Different from the 1st time (p <0.05); + Different from the SHAM group in the same time period (p <0.05) GH = hyperbaric group; SHAM = Sham group; GHC = hyperbaric control group; Time 1 = after MPA; Time 3 = after extubation

Table 4. Comparison of lactate and venous blood gas variables between collection times

	GH		GS		GHC	
Parameter	Time 1	Time 3	Time 1	Time 3	Time 1	Time 3
Lactate	1,18±0,14	1,33±0,32	0,85±0,21	1,53±0,36	2,46±0,42^{+}	2,85±0,49$^{\#+}$
pH	7,22±0,01	7,16±0,01*	7,22±0,01	7,18±0,02	7,25±0,01	7,25±0,01$^{\#+}$
CO_2	47,95±1,25	53,38±3,2*	47,47±2,07	50,83±2,00	40,59±1,63$^{\#+}$	44,16±1,07$^{\#+}$
pO_2	64,94±5,61	67,87±5,22	70,62±8,78	62,48±4,09	42,63±1,77$^{\#+}$	38,92±1,26$^{\#+}$
Base	-5,73±0,47	-6,53±0,45	-6,15±0,45	-6,65±0,69	-6,30±0,68	-5,41±0,44

* Different from the 1st time ($p < 0.05$); + Different from the GS group in the same time period ($p < 0.05$)

GH = hyperbaric group; SHAM = Sham group; GHC = hyperbaric control group; Time 1 = after pre-medication; Time 3 = after extubation

Discussion

The present study brought relevant data to help understand the physiological effects of HBOT on peripheral perfusion markers, blood gas analysis and blood count in cats. The tolerability of patients to pretreatment was high, with no signs of adverse effects to the therapy over the time and pressure applied. The safety of hyperbaric oxygen therapy for dogs and cats has been previously tested in other studies[2,3], that also did not observe any damages resulting from the therapy.

There was no interference of the presence or absence of HBOT in the values of base excess between the groups and times evaluated, suggesting that there are no benefits or harms in the therapy when considering this variable. Gautier et al[8] evaluated the effects of HBOT in bitches submitted to OHE and it did not induce any detectable response.

Blood gas analysis can be performed using arterial or venous blood samples. They can be used to assess metabolic or electrolyte disorders, in addition to providing information on the patient's ventilatory status[9]. In cats, venous pH is considerably lower than arterial pH, whereas venous pCO_2 is higher than arterial pCO_2, leading to an increase in bicarbonate concentration, but without significant changes in base excess[10].

Venous blood samples are easier to collect, cause less discomfort to the patient and can be collected repeatedly with less possibility of thrombosis resulting from the puncture[11]. In feline patients, venous sampling is recommended whenever possible, especially in non-anesthetized animals, due to the stress caused by arterial puncture and the risk of thromboembolic accidents with sequential punctures. Due to the need for repeated collections and given the cat friendly character of the project, it was decided to use venous blood samples for the measurement of blood gases.

Bachmann et al[12] stresses in their studies the need to relate clinical findings to blood gas analysis results because the results referring to pO_2, pCO_2, base excess and pH may suffer interference when not collected in syringes suitable for gas analysis. Tamura et al[10] reports significant differences between the results of central and peripheral venous blood gas analysis, although Bachmann[12] shows that peripheral collection can be reliable when considering the patient's general condition and perfusion, in addition to generating less discomfort.

The results obtained in the present study demonstrate values of pO_2 in the GH group (pre-treatment combined with the surgical procedure) higher than those in the GHC group (presence of pre-treatment in a hyperbaric chamber without interference from the surgical procedure) both in Time 1 of collection (after pre-medication) and in Time 3 (after extubation). In addition, it shows GHC values significantly lower than thosein the SHAM group for both times.

The groups submitted to the surgical procedure were maintained during the entire anesthetic period under 100% oxygen vaporization, which could have a positive impact on the result of the measurement of pO_2 in these groups, more than the presence or absence of HBOT prior to collection. The pO_2 of the GH and SHAM groups remained above the reference range established by Bachmann et

189 al[12] (33,9–56,3 mmHg), whereas the values in the GHC group remained within
190 this range.

191 The pCO_2 varied between groups hence following the variation in pO_2, in
192 which both the collection times in the GH and SHAM groups obtained higher
193 values of partial pressure of carbon dioxide than those in the GHC group. The
194 variation in the pCO_2 values between the groups followed the pH variation, so
195 that in the groups and times when the pCO_2 was higher, the pH was lower, going
196 according to what was described by Gonzalez et al[9]. However, the presence of
197 hypercapnia in this case was not accompanied by respiratory acidosis, as there
198 was no change in lactate levels and base excess when considering physiological
199 reference intervals.

200 Venous blood gas analysis, however, can be an unreliable method for
201 assessing oxygenation, which reduces the reliability of these results[13]. The other
202 variables analyzed from peripheral venous samples may be affected by changes
203 in circulation and metabolism, and these factors must be taken into account when
204 interpreting the results.[13].

205 Lactate is a by-product of anaerobic metabolism, and is a useful biomarker
206 for the diagnosis and prognosis of shock in human and veterinary medicine, as it
207 reflects an imbalance in the amount of oxygen demanded by the tissue and the

amount received by it. It is a safe parameter for assessing tissue perfusion in cats, as corroborated by Redavid[14], who demonstrated that there was no correlation between collection stress and the presence of hyperlactatemia in healthy cats.

Lactate values have a large reference range for cats. A study by Tynan[15] refers to values of 0.67-5.44 mmol/l, while Bachmann's[12] work brings a range of 0.61–5.86 mmol/l. It is suggested that this variation is due to several factors such as stress, collection method, sample management and studied population[14]. In our study, only healthy cats were admitted, and the lactate values for all patients were within the known reference ranges, despite their oscillation between groups. As for the collection method, samples from the jugular and lateral saphenous vein show equivalent results for lactatemia levels[14].

The lactate values varied inversely proportional to pO_2 values, corroborating data from other studies[9,10,12]. The average of the values in both collection times for the GHC group was higher than that of the SHAM group. In addition, the T3 values in the GHC group were higher than those in the GH group. There was no significant change in base excess values, which is in line with the findings by Kohen et al[16], which states that hyperlactatemia may be present in patients without metabolic changes in the acid-base state.

There are several mechanisms that can lead to the development of hyperlactatemia. The most common is through anaerobic metabolism, leading to concomitant metabolic acidosis. Another cause involves the occurrence of respiratory alkalosis and subsequent compensatory hyperlactatemia in order to achieve metabolic homeostasis[16].

Due to the high intake and oxygen consumption and the consequent decrease in carbon dioxide in the chamber during the hyperbaric oxygen therapy session, this may be a cause related to the increase in lactate in the HBOT control group, since this may be a compensatory response[9] to the assumed respiratory alkalosis. This hypothesis is based on the fact that there is an increase in lactate levels concomitantly with the moments of pCO_2 decrease and pH increase in the groups.

There are other mechanisms of hyperlactatemia not associated with the patient's acid-base status. Among these are cellular energy metabolism stimulated by catecholamines or pro-inflammatory cytokines[17]. Gautier et al[8] demonstrated that there is no interference of HBOT in the systemic inflammatory response in bitches, however there is no data on its effect in cats, and its influence on these variables cannot be ruled out.

In our study, the pH showed a significant drop from the initial to the final collection time in the GH group, inversely proportional to the increase in pCO_2 in the same interval. The drop in pH in cats may be related to the stress generated by the collection, the hypoperfusion generated by vasoconstriction due to anesthetic drugs and other behavioral and metabolic factors[14,17]. The values for T3 in the GHC group are higher than those in the SHAM and GH group for this same interval, suggesting that the effect of hyperoxygenation in the chamber without the influence of surgical stress has influenced this increase.

The blood count consists of a diagnostic exam for patients with some clinicopathological condition, as well as part of the routine inspection of healthy individuals[18]. The effects of HBOT on feline hematological patterns have not yet been reported. In our study, the values of hematocrit ($p = 0.018$), hemoglobin ($p = 0.01$) and red blood cells ($p = 0.0018$) showed a substantial drop between Time 0 and Time 5 of collections in GH, in which the patients were submitted to pretreatment in a hyperbaric chamber followed by a video-assisted surgical procedure.

A study carried out in humans by Sinan et al[19] demonstrated a significant decrease in hematocrit and red blood cell count after 20 sessions of HBOT in patients with various conditions. These findings are in line with a study that

demonstrated similar results after 21 days[20]. Such results can be considered expected in view of the effects of hyperoxygenation on the erythropoiesis process due to the reduction in erythropoietin production by a negative feedback process[21].

This hypothesis could justify the decrease in hematological values in the GH group, in association with the effect of the surgical procedure. Teixeira et al[22] showed that a group of cats submitted to OHE did not present significant changes in hematocrit at 2, 3, 5, and 10 days after the operation, which would demonstrate that the surgical procedure would not have any influence on these parameters.

Nonetheless, Gunes e Aktas[18] conducted a study in which human patients underwent more than 60 sessions of HBOT, and there was no significant change in the values of red blood cells, hemoglobin and hematocrit in any of the groups evaluated. It was then suggested that HBOT has no relevant role in altering hematological patterns. Gautier et al[8] in a study with bitches submitted to HBOT and elective ovariohysterectomy stated that there was no influence of hyperbaric therapy on the hemolysis patterns of the studied population.

The total leukocyte count showed a significant increase from T0 to T5 in GH, as well as the neutrophil count. Lymphocytes, on the other hand, had a lower value in GHC T5 than when compared to T5 in the SHAM group. HBOT increases

283 neutrophil activation through increasing its oxidative capacity by creating reactive
284 oxygen species[23], what added to the physiological challenge created by the
285 surgical procedure could lead to greater expression of these cells in the GH
286 group. Furthermore, oxygen therapy leads to apoptosis of peripheral
287 lymphocytes, contributing to the decrease in cell count[24].

288 The experience of undergoing HBOT can be a stress trigger for cats. This
289 can lead to an increase in serum cortisol levels, which leads to the redistribution
290 of blood lymphocytes to the interstitium and increases the number of circulating
291 neutrophils[25], a fact that may be related to the increase in neutrophils in the GH
292 group and the decrease in lymphocytes in the GHC group when compared to the
293 SHAM group. The tests also showed the constant presence of hypersegmented
294 neutrophils, which corroborates this theory.

295 Our results are based on a single HBOT session in a sample of 42 cats.
296 As this is a population originating from the hospital routine, the perfect
297 standardization of the research subjects is not possible. For these reasons,
298 further investigation is warranted.

299 For the first time, the influence of HBOT on the blood count, lactatemia
300 and venous blood gas analysis of healthy cats is reported, following a scientific

method, however more studies are needed in order to complement the reported data and evaluate its real applicability in the clinical routine.

Conclusions

The data obtained through this study demonstrate that there is no significant influence of pre-treatment with HBOT on parameters such as base excess in healthy cats. An increase in serum lactate levels and a reduction in pH values can be expected after hyperbaric therapy,. However, lactate levels remained within the reference values, which corroborates the safety of the procedure.

Hyperbaric therapy can contribute to an increase in pO_2 and pCO_2, making it important to assess the patient's ventilatory capacity prior to therapy. Findings of leukocytosis due to neutrophilia and lymphopenia can be expected after the session. In addition, it is possible that there is a significant reduction in the values of hematocrit, hemoglobin and red blood cell count.

Acknowledgements

Special regards to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

Conflict of interest

The authors declare that there are no potential conflicts of interest regarding the research, authorship and publication of this article.

Funding

This study was funded by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). The hyperbaric chamber used in this study (HVM-H1) comes from the *Hiperbaric Veterinary Medicine* (HVM^{TM}), via an interinstitutional agreement with UFSM.

References

1. EDWARDS ML. **Hyperbaric oxygen therapy. Part 1: history and principles**. *J Vet Emerg Crit Care* 2010; 20:284-297.

2. Yanagisawa H et al. **Hyperbaric Air Therapy in Dogs for Clinical Veterinary Medicine: A Basic Study**. *J Vet Med Sci* 2011; 73:1351–1354.

3. Birnie GL, Fry DR and Best MP. **Safety and Tolerability of Hyperbaric Oxygen Therapy in Cats and Dogs**. *J Am Anim Hosp Assoc* 2018; 54:188–194.

4. Ferreira MP, et al. **Ovário-salpingo-histerectomia videolaparoscópica em gatos domésticos: técnica com dois portais**. *Acta Sci Vet* 2011; 39:1-5.

5. Hedlund CS. **Cirurgias do sistema reprodutivo e genital**. In: FOSSUM, T. W. Cirurgia de pequenos animais. Rio de Janeiro, RJ: Elsevier, 2008, pp.702-774.

6. Davidson EB, Moll HD and Payton ME. **Comparison of laparoscopic ovariohysterectomy and ovariohysterectomy in dogs**. *Vet Surg* 2004; 33:62-69.

7. Dalmolin F, et al. **Biomarcadores inflamatórios e de estresse oxidativo em cadelas submetidas à ovário-histerectomia videoassistida ou convencional**. *Arq Bras Med Vet Zootec* 2016; 68:687-694.

8. Gautier A, Graff EC, et al. **Effects of Ovariohysterectomy and Hyperbaric Oxygen Therapy on Systemic Inflammation and Oxidation in Dogs**. *Front Vet Sci* 2020; 6:506.

9. Gonzalez AL, Waddell LS. **Blood gas analyzers***. Topics in Compan An Med* 2016; 05:1-36.

10. Tamura J, Itami T, et al. **Central venous blood gas and acid-base status in conscious dogs and cats.** *J Vet Med Sci* 2015; 77:865–869.

11. Rieser TM. **Arterial and Venous Blood Gas Analyses**. *Topics in Compan An Med* 2013; 28:86-90.

12. Bachmann K, Kutter A, et al. **Determination of reference intervals and comparison of venous blood gas parameters using standard and non-standard collection methods in 24 cats**. *J Feline Med Surg* 2016; 1–10.

13. Tregor R, Pirouz S, Kamangar N, et al. **Agreement between central venous and arterial blood gas measurements in the intensive care unit**. *Clin J Am Soc Nephrol* 2010; 5:390.

14. Redavid L, Sharp CR, Mitchell M, et al. **Plasma lactate measurements in healthy cats***. J Vet Emerg Crit Care* 2012; 22: 580–587.

15. Tynan B, Kerl ME, Jackson ML, et al. **Plasma lactate concentrations and comparison of two point-of-care lactate analyzers to a laboratory analyzer in a population of healthy cats**. *J Vet Emerg Crit Care* 2015; 25: 521–527.

16. Kohen C, Hopper K, et al. **Retrospective evaluation of the prognostic utility of plasma lactate concentration, base deficit, pH, and anion gap in canine and feline emergency patients**. *J Vet Emerg Crit Care* 2017; 1–8

17. Levy B. **Lactic acidosis and hyperlactatemia**. In: Vincent J-L, ed. Intensive Care Medicine. New York: Springer; 2006, pp. 88–98.

18. Gunes AE, Aktas S. **Effect of hyperbaric oxygen therapy on complete blood count**. *Undersea Hyperb Med* 2017; 4:357-364.

19. Sinan M, Ertan NZ et al. **Acute and long-term effects of hyperbaric oxygen therapy on hemorheological parameters in patients with various disorders**. *Clin Hemorheol Microcirc* 2016; 62:79–88.

20. Thorsen E, Haave H, et al. **Exposure to hyperoxia in diving and hyperbaric medicine effects on blood cell counts and serum ferritin.** *Undersea Hyperb Med* 2001; 28:57–62.

21. Hofso D, Ulvik RJ, et al. **Changes in erythropoietin and haemoglobin concentrations in response to saturation diving**. *Eur J Appl Physiol* 2005; 85:191–196.

22. Teixeira LG, Martins LR, et al. **Evaluation of postoperative pain and toxicological aspects of the use of dipyrone and tramadol in cats**. *J Feline Med Surg* 2020; 22:467-475.

23. Braswell C, Crowe DT. **Hyperbaric Oxygen Therapy**. Compendium: *Continuing Education for Veterinarians* 2012; 1-6.

24. Bai X, Song Z, et al. **The apoptosis of peripheral blood lymphocytes promoted by hyperbaric oxygen treatment contributes to attenuate the severity of early stage acute pancreatitis in rats**. *Apoptosis* 2014; 19:58-75.

25. Hampton A, Ford A, et al. **Effects of music on behavior and physiological stress response of domestic cats in a veterinary clinic.** *J Feline Med Surg* 2020; 22:122-128

5. CONCLUSÃO

Os dados obtidos através da realização dessa dissertação demonstram que:

- Pode-se esperar aumento dos níveis séricos de lactato e redução dos valores de pH após a terapia hiperbárica;

- A terapia hiperbárica pode contribuir com o aumento da pO_2 bem como da pCO_2, sendo importante a avaliação da capacidade ventilatória do paciente previamente à terapia;

- Achados de leucocitose por neutrofilia e linfopenia podem ser esperados em pacientes após a sessão;

- É possível que haja redução significativa nos valores de hematócrito, hemoglobina e contagem de hemácias. Isso demonstra a importância da realização de hemograma de controle anterior à terapia hiperbárica.

LISTA DE REFERÊNCIAS

BAI, X.; SONG, Z.; ZHOU, Y. et al. The apoptosis of peripheral blood lymphocytes promoted by hyperbaric oxygen treatment contributes to attenuate the severity of early stage acute pancreatitis in rats. **Apoptosis**. 2014.

BEAN, J. W. Effects of oxygen at increased pressure. **Physiol Ver**. v. 25, p.1–147, 1945.

CHABOT-RICHARDS, D. S.; GEORGE, T. I. Leukocytosis. **Int J Lab Hematol**. v. 36, p. 279–288, 2014.

DALMOLIN, F. et al. Biomarcadores inflamatórios e de estresse oxidativo em cadelas submetidas à ovário-histerectomia videoassistida ou convencional. **Arquivo Brasileiro Medicina Veterinária e Zootecnia,** v. 68, p. 687-694, 2016.

DAVIDSON, E. B.; MOLL, H. D.; PAYTON, M. E. Comparison of laparoscopic ovariohysterectomy and ovariohysterectomy in dogs. **Veterinary Surgery,** v. 33, n. 1, p. 62-69, 2004.

DIBARTOLA, S. P. **Metabolic acid-base disorders**. In DiBartola SP, editor: Fluid, electrolyte, and acid-base disorders in small animal practice, ed 4. St Louis: Saunders. p. 253-286, 2012.

DUQUE, C. T. N.; MORENO, J. C. D. Anestesia e analgesia para videolaparoscopia. In: BRUN, M. V. **Videocirurgia em pequenos animais**. 1° ed. Rio de Janeiro:Editora Roca, 2015. Cap. 2, p. 7- 20

EDWARDS, M. L. Hyperbaric oxygen therapy. Part 1: history and principles. **Journal of Veterinary Emergency and Critical Care**. v. 20, p.284-297, 2010.

FERREIRA, M. P. et al. Ovário-salpingo-histerectomia videolaparoscópica em gatos domésticos: técnica com dois portais. **Acta Scientiae Veterinariae**, v. 39, n. 4, p. 1-5, 2011.

GAUTIER, A.; GRAFF, E. C. et al. Effects of Ovariohysterectomy and Hyperbaric Oxygen Therapy on Systemic Inflammation and Oxidation in Dogs. **Front Vet Sci**, v. 6, n. 506, 2020.

GEMMA, L. B.; DARREN, R. F.; MATTHEW, P. B. Safety and Tolerability of Hyperbaric Oxygen Therapy in Cats and Dogs. **JAm Anim Hosp Assoc**. v. 54, p. 188–194, 2018.

GONZALEZ, A. L.; WADDELL, L. S. Blood gas analyzers. **Topics in Compan An Med**. v. 05, p. 1-36, 2016.

GUNES, A. E., AKTAS, S. Effect of hyperbaric oxygen therapy on complete blood count. **Undersea Hyperb Med**. v. 4, p. 357-364, 2017.

HEDLUND, C. S. Cirurgias do sistema reprodutivo e genital. In: FOSSUM, T. W. **Cirurgia de pequenos animais**. 3° ed. Rio de Janeiro: Editora Elsevier, 2008. Cap. 26, p.702-774.

HEYBOER, M.; SHARMA, D.; SANTIAGO, W. Hyperbaric oxygen therapy: side effects defined and quantified. **Adv Wound Care**. v.6, p. 210–224, 2017.

JAIN K. K. The History of Hyperbaric Medicine. Textbook ofHyperbaric Medicine.**Hogrefe and Huber Publishers**. v. 4, p. 3–8, 2004

MALM, C. et al. Ovário-histerectomia: estudo experimental comparativo entre as abordagens laparoscópica e aberta na espécie canina-. Estresse pela análise do cortisol plasmático. **Arquivo Brasileiro Medicina Veterinária e Zootecnia,** v. 57, p. 584-590, 2005.

RAND, J. S.; KINNAIRD, E.; BAGLIONI, A. et al. Acute stress hyperglycemia in cats is associated with struggling and increased concentrations of lactate and norepinephrine. **J Vet Intern Med**. v. 16, p. 123–132, 2002.

REDAVID, L.; SHARP, C. R.; MITCHELL, M. et al. Plasma lactate measurements in healthy cats. **J Vet Emerg Crit Care**. v. 22, p. 580–587, 2012.

RIESER, T. M. Arterial and Venous Blood Gas Analyses. **Topics in Compan An Med** v. 28, p. 86-90, 2013.

RYLEY, L. K.; RUPERT, J. Evaluation of Patients with Leukocytosis. **Am Fam Physician**. v. 92, p. 1004-1011, 2015.

SINAN, M.; ERTAN, N. Z. et al. Acute and long-term effects of hyperbaric oxygen therapy on hemorheological parameters in patients with various disorders. **Clin Hemorheol Microcirc**. v. 62, p. 79-88, 2016.

TAMURA, J.; ITAMI, T. et al. Central venous blood gas and acid-base status in conscious dogs and cats. **J Vet Med Sci**. v. 77, p. 865-869, 2015.

YANAGISAWA, H. et al.Hyperbaric Air Therapy in Dogs for Clinical Veterinary Medicine: A Basic Study. **J. Vet. Med. Sci**. v. 73, p. 1351–1354, 2011.