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Research Article

Changes in Oxygen-Energy Metabolism Before General Anesthesia and Surgery Under the Influence of the Stange Test: Double-Blind, Randomized Clinical Trial

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Abstract

Introduction: Patients with oxygen-energy dysfunction detected by a Barbell breakdown prior to surgery are at high risk of perioperative critical incidents and complications.

Material and Methods: A prospective randomized double-blind study of 44 patients with lumbosacral radiculopathies of discogenic nature (36 men, 8 women), ASA ≤ II point, was performed. Patients with pain syndrome ≥ III points on the YOUR scale, ASA ≥ III points were excluded. Everyone was prescribed a discectomy under general anesthesia. The patients were divided into two groups with the appointment of energy support during the upcoming general anesthesia (EPA) and surgery [18 patients - 3 women] and without EPA (18 - 5). Before the operation, a test of Stange was performed. Recorded minute volume of respiration (l/min), oxygen content on inspiration (%), at the end of exhalation (%), partial pressure of carbon dioxide on inspiration (mmHg), at the end of exhalation (mmHg) oxygen consumption (ml), elimination of CO_2 (ml), respiratory coefficient, energy requirements.

Results: Energy demand in both groups increased (Me from 2524 IR 2058 - 3385 and to Me 4630 IR 3631 - 6938, p = 0.013; Me from 1771 IR 1549 - 2004 and to Me 2543 IR 2223 - 2749, p = 0.012). Before and after the test, energy consumption was higher in the EPA group (Me 2524 IR 2058 - 3385 and Me 1771 IR 1549 - 2004, p = 0.009) and (Me 4630 IR 3631 - 6938 and Me 2543 IR 2223 - 2749, p = 0.001).

Summary: Indirect calorimetry should be used to determine energy requirements prior to surgery. Performing the Stange test before the start of general anesthesia and surgery caused an increase in oxygen consumption and energy requirements in all patients. Conducting the Stange test prior to the start of general anesthesia and surgery reveals oxygen-energy dysfunction in the form of hypoergosis.

Keywords: Oxygen-Energy Metabolism; Stange Test

Abbreviations

CNS: Central Nervous System; REE: Idle Power Consumption; EPA: Energy Support During General Anesthesia and Surgery

Key Message

The basis for the occurrence of perioperative complications is hidden in the oxygen-energy dysfunction. To assess the state of oxygen and energy exchange before the start of General anesthesia and surgery, a Rod sample was used.

Introduction

High preoperative psychoemotional stress [8,21], the initial violations of the morphofunctional state of life support systems (CNS, cardiorespiratory, hemostasiological), surgical intervention cause energy imbalance [12]. The reference method for determining energy expenditure at rest (REE) in clinical nutrition practice is indirect calorimetry, whic has certain limitations, requires significant financial costs and is not widely used [10]. Patients with marked oxygen-energetic disorders before surgery are prone to perioperative critical incidents and complications [6].

In the present research, we tested the hypothesis that the Stange test would reveal a latent dysfunction of oxygen-energetic metabolism before anesthesia and surgery, underlying perioperative critical incidents and complications.

In this regard, an appropriate goal of the work is defined.

In order to achieve this goal, the following research objectives were formulated:

- Compare methods for determining energy requirements (indirect calorimetry or Harris-Benedict equation) before anesthesia and surgery.
- To determine changes in the state of oxygen and energy metabolism before general anesthesia and surgery under the influence of the Stange test.
- To detect latent disturbances of oxygen-energy metabolism in different groups of neurosurgical patients before general anesthesia and surgery using the Stange test.

Material and Methods

A prospective randomized, double-blinded (surgeon and patient) clinical trial was carry out in May 2007 at the neurosurgical department of the Department of Surgery Clinic of the S.M. Kirov Military Medical Academy.

The clinical trial included 44 patients (36 men, 8 women) with lumbosacral radiculopathies of discogenic nature, with radicular pain syndrome less than III points on the VAS scale, ASA ≤ II points. We excluded patients with severe radicular pain ≥III points on the VAS scale, ASA ≥III points.

Magnetic resonance images were used to assess Modic changes (MCh) [19] in studies of the lumbar spine. All patients were found to have intervertebral disc herniations with radicular syndrome, which was the reason for prescribing surgical intervention in the form of discectomy. Patients with Modic changes type I were selected.

The patient's metabolic expenditure during surgery is 60-70 kcal/hour or 1-1.17 kcal/min [7]. D. Satoh, N. Toda, I. Yamamoto (2018) performed energy and plastic support intraoperatively with energy and plastic substrates in large volumes (glucose solution 3-4.5 g/h and amino acids 1.2-1.8 g/h). In our trial energy support was planned to start simultaneously with general anesthesia to compensate patient's metabolic losses during anesthesia and surgery [7] with glucose solution 10% at a rate of 140-160 ml/h [60-70 kcal/h (1-1.17 kcal/min)].

Patients were divided into two groups by the envelope method, based on the assignment of energy support during the upcoming general anesthesia (EPA) and surgery [18 patients - 3 women] and without EPA (18 - 5). The predominance of men in the groups was explained by a higher incidence of discogenic lumbosacral radiculopathies.

Pharmacological premedication included a narcotic analgesic – morphine solution (0.15 mg/kg) and an M-cholinolytic - atropine solution (0.1 mg/kg), which were injected intramuscularly 30 minutes before the anesthesia and surgery.

Before general combined anesthesia with mechanical ventilation and surgery under the control of oxygen-energetic exchange, all patients underwent Stange test according to the method proposed by V.F. Kirichuk., *et al*. (2017) in sitting position. The patient took a deep, but not maximal inhalation and held his breath as long as possible, squeezing his nose with his fingers. The duration of the breathing break was counted with a stopwatch. At the moment of exhalation, the stopwatch was stopped. In healthy but untrained persons, the time of breath holding ranged from 40-60 seconds in men and 30-40 seconds in women. In athletes this time increased to 60-120 sec in men and to 40-95 sec in women.

Before and after the test using the face mask of multigas analyzer anesthesiabreathing apparatus "KION" was recorded minute respiratory volume (MRV in l/min), oxygen content at inspiration (F_iO_2 in %) and at the end of exhalation (F_eO_2 in %), partial pressure of carbon dioxide at inspiration (P_iCO_2 in mm Hg) and at the end of exhalation ($P_{et}CO_2$ in mm Hg). Oxygen consumption (*VO_2 in ml), CO_2 elimination (*VCO_2 in ml), and respiratory quotient (RQ = *VCO_2/*VO_2) were calculated. Basic metabolism was obtained (metabolic rate estimation) using the Harris-Benedict equation [9]. Changes in energy requirements were studied (energy expenditure was measured by indirect calorimetry). Calculation formula: 3.941*VO_2 + 1.106*VCO_2 - 2.17* urinary nitrogen excretion (g/day) [kcal/day (EF in kcal/day)]. Final calculation formula: energy (kcal/day) = 3.941*VO_2+1.106 VCO_2-39 (average). The primary point chosen is the changes in oxygen-energy metabolism under the influence of the Stange test. The secondary point is represented by patients with decreased oxygen-energy metabolism under the influence of the Stange test, which indicates the risk of perioperative complications.

Nonparametric method was used for statistical analysis of the obtained parameters. Descriptive statistics - we determined median and interquartile range. Comparative statistics - we studied shifts within groups by Friedman method. We analyzed changes in the indices in the groups before and after the Stange test before anesthesia using Wilcoxon signed-rank test for paired comparisons. Differences between the groups were examined using Mann-Whitney test.

The clinical trial was performed with the permission of the Independent Ethics Committee (IEC) The trial was performed with the permission of the local ethics committee of Saratov State Medical University named after V.I. Razumovsky.

All patients received informed voluntary consent to perform the Stange test.

Results

Table 1 presents anthropometric parameters, pain syndrome according to the VAS scale (ten-point scale), and anesthetic-operative risk according to the ASA in the groups of patients examined.

Groups		Parametrs				
	Age (years)	Sex (m\w)	Growth (sm)	Body weight (kg)	VAS (points)	ASA
General group	47 (37-63)	36/8	173 (167-178)	81 (73-95)	2 - 6	I-II
Group 1 (EPA)	46 (43-61)	18/3	170 (167-176)	65 (62-104)	3 – 6	I-II
Group 2 (without EPA)	47 (36-63)	18/5	174 (168-178)	82 (77-95)	2 - 5	I-II

Table 1: Demographic and clinical data.

The anthropometric parameters of the patients did not differ between the groups. All examined patients had a similar pain syndrome according to the VAS scale and anesthesia-operative risk according to the ASA.

Table 2 shows the shifts of the studied parameters of oxygen-energetic metabolism in the groups of patients under the influence of the Stange test.

Of the nine parameters studied, only P_iCO_2 (torr) and F_iO_2 (%) did not change significantly under the influence of the Stange test.

MRV in the EPA group increased ($p = 0.012$). After the Stange test, MRV was more in the EPA group ($p = 0.002$). F_eO_2 decreased in both groups (in the EPA patient group, $p = 0.012$; in the non-EPA patient group, $p = 0.013$). Oxygen consumption increased in both groups ($p = 0.013$ and $p = 0.012$, respectively). Before and after the Stange test, oxygen consumption was more in the EPA group (p =

Indicators	Before the Stange test		After the Stange test	
	Groups		Groups	
	EPA	Non EPA	EPA	Non EPA
MRV (l/min)	5,70 (5,33 - 8,90)	5,50 (4,45 - 5,75)	10,70^{*,y} (8,10 - 13,35)	5,90 (5,55 - 6,90)
F_iO_2 (%)	24,50 (24,00 - 29,00)	21,00 (20,50 - 21,00)	24,50 (24,00 - 29,00)	21,00 (21,00 - 24,50)
F_eO_2 (%)	19,00 (16,50 - 24,50)	16,50 (16,00 - 17,50)	16,50* (14,00 - 22,50)	15,00* (13,50 - 19,00)
VO_2 (ml)	538^{y} (410 - 720)	347 (296 – 394)	994^{*,y} (777 - 1531)	509* (460 – 576)
$P_{et}CO_2$ (torr)	34,50 (31,00 - 39,00)	36,00 (31,50 - 39,50)	44,00* (39,50 - 44,50)	42,00 (40,00 - 44,00)
P_iCO_2 (torr)	0,50 (0 – 1)	0 (0 - 1,0)	1 (1 - 2,5)	2 (1 - 4)
VCO_2 (ml)	438 (381 - 524)	375 (337 - 427)	685* (602 - 824)	446 (421 - 515)
RQ	0,79^{Y} (0,72 - 1,02)	1,08 (1,00 - 1,18)	0,67^{*,Y} (0,54 - 0,78)	0,84* (0,78 - 0,94)
Energy consumption (kcal/day)	2524^{Y} (2058 – 3385)	1771 (1549 – 2004)	4630^{*,Y} (3631 - 6938)	2543* (2223 – 2749)

Table 2: Gas exchange parameters and energy consumption in groups with and without EPA.

Note. MRV - * - p = 0.012; y - p = 0.002; F_eO_2 - * - p = 0.012, * - p = 0.013; VO_2 - * - p = 0.013 and * - p = 0.012; y - p = 0.017 and p = 0.001; $P_{et}CO_2$ * - p = 0.012; VCO_2 * - p = 0.002; RQ - * - p = 0.012 and * - p = 0.013; Y - p = 0.036 and Y - p = 0.01; Energy consumption - * - p = 0.013 and * - p = 0.012; Y - p = 0.009 and Y - p = 0.001.

0.017 and p = 0.001). $PetCO_2$ increased only in the EPA-designated patient group (p = 0.012). After the Stange test, carbon dioxide elimination increased in the EPA group (p = 0.002). The respiratory quotient decreased in both groups after testing (p = 0.012 and p = 0.013). Before and after the Stange test, the respiratory quotient was lower in the EPA group (p = 0.036 and p = 0.01).

Before the Stange test using indirect calorimetry the level of energy requirements was higher (by 59%) than that calculated using the Harris-Benedict equation (p = 0.001). Calculated energy requirements increased in both groups after the Stange test (p = 0.013; p = 0.012). Before and after the test, the energy requirement was more in the assigned EPA group (p = 0.009 and p = 0.001).

Discussion

Determination of energy requirements using the Harris-Benedict equation is not suitable for patients under psycho-emotional stress [8], according to C.D. Smallwood, N.M. Mehta (2017) of little use in pediatrics, in cancer patients [13] and surgical patients [15]. They are supported by J. M. Miles (2006), as. REE in hospitalized patients (postoperative (28%), those with trauma or sepsis (26%), cancer (18%), lung disease (9%), cardiovascular disease (2%), and other conditions (9%), and those without said pathology (6%), excluding those with burns, brain injury, and fever, 2%) averages approximately 113% of BEE calculated using the Harris-Benedict equation. More recently, A. S. Pinto., *et al*. (2016), comparing three alternative methods (indirect calorimetry, electrical bioimpedance measurement, Harris-Benedict equation, and Mifflin- St. Jeor Equation), found that the HarrisBenedict equation is the most reliable for estimating basal energy expenditure measurements in liver transplant recipients.

According to the data from our clinical trial, the patient's energy metabolism as a result of the Harris-Benedict equation before general anesthesia and surgery cannot be lower than the basal metabolism (1440 kcal/day) and be 1197 (1081-1273) kcal/day.

In all examined patients, the Stange test prior to anesthesia and surgery resulted in a marked increase in oxygen consumption and carbon dioxide elimination, indicating increased metabolism. Substrate supply of energy metabolism changed under the influence of the Stange test. According to RQ data before the Stange test, carbohydrate and fat utilization predominated in the group of patients with presumptive EPA, and lipogenesis predominated after the test. In the group of patients without EPA, predominant fat utilization was observed before the test, and carbohydrate and fat utilization prevailed after the test.

Important is the different state of energy metabolism of patients before general anesthesia and surgery discovered by the trial. According to H. S. Ribeiro., *et al*. (2020) increased preoperative total energy expenditure and age were prognostic factors of postoperative complications. Patients of the group without EPA entered anesthesia and surgery in hypoergic state [3], which implied high risk of perioperative complications [6].

The predominance of male patients (78%) is a limitation of our study. The present research article did not examine the relationship of the information obtained from the study with identical parameters in the intraoperative period with regard to the risk of critical incidents and complications.

The obtained data will force anesthesiologists to assess in a new way the state of patients before general anesthesia and surgery. It will become reasonable to determine the risk of perioperative critical incidents and complications from the position of detection of hidden disorders of oxygen and energy metabolism.

The study should be continued to investigate changes in oxygen-energetic metabolism during the intraoperative period.

Conclusion

We evaluated the effect of the Stange test on oxygen-energy metabolism in neurosurgical patients before general anesthesia and surgery. The use of the HarrisBenedict equation to determine energy requirements is not suitable for neurosurgical patients before general anesthesia and surgery. The Stange test causes an increase in metabolism, a change in the substrate supply of energy metabolism. Performing the Stange test reveals latent preoperative oxygen-energetic dysfunction in neurosurgical patients in the form of hypoergosis.

Findings

- Direct calorimetry should be used to determine energy requirements before surgery;
- Using of the Stange test before general anesthesia and surgery caused an increase in oxygen consumption and energy requirements in all patients;
- Using of the Stange test before general anesthesia and surgery can reveal oxygen-energy dysfunction in the form of hypoergosis.

Authorship Contribution Statement

Prigorodov M.V. created the concept and research plan, received analyzed and interpreted the data. Levshankov A.I. organized a study, critically reviewed the article to create intellectual content. Together (Prigorodov M.V., Levshankov A.I.) determined the final version of the article and submitted for approval in the journal "AS Medical Sciences Journal". ORCID - 0000-0002-0318-6635.

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Conflict of Interest

The authors confirms that this article content has no conflict of interest.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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