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SCIENTIFIC ARTICLE

Monitorization of the effects of spinal anaesthesia on cerebral oxygen saturation in elder patients using near-infrared spectroscopy

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KEYWORDS

Cerebral oxygen saturation;
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Abstract

Objective: Central blockage provided by spinal anaesthesia enables realization of many surgical procedures, whereas hemodynamic and respiratory changes influence systemic oxygen delivery leading to the potential development of series of problems such as cerebral ischemia, myocardial infarction and acute renal failure. This study was intended to detect potentially adverse effects of hemodynamic and respiratory changes on systemic oxygen delivery using cerebral oxymetric methods in patients who underwent spinal anaesthesia.

Methods: Twenty-five ASA I–II Group patients aged 65–80 years scheduled for unilateral inguinal hernia repair under spinal anaesthesia were included in the study. Following standard monitorization baseline cerebral oxygen levels were measured using cerebral oximetric methods. Standardized Mini Mental Test (SMMT) was applied before and after the operation so as to determine the level of cognitive functioning of the cases. Using a standard technique and equal amounts of a local anaesthetic drug (15 mg bupivacaine 5%) intrathecal blockade was performed. Mean blood pressure (MBP), maximum heart rate (MHR), peripheral oxygen saturation (SpO₂) and cerebral oxygen levels (rSO₂) were preoperatively monitored for 60 min. Pre- and postoperative haemoglobin levels were measured. The variations in data obtained and their correlations with the cerebral oxygen levels were investigated.

Results: Significant changes in pre- and postoperative measurements of haemoglobin levels and SMMT scores and intraoperative SpO₂ levels were not observed. However, significant variations were observed in intraoperative MBP, MHR and rSO₂ levels. Besides, a correlation between variations in rSO₂, MBP and MHR was determined.

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PALAVRAS-CHAVE

Saturação de oxigênio cerebral;
Raquianestesia;
Espectroscopia de luz próxima ao infravermelho (NIRS)

Conclusion: Evaluation of the data obtained in the study demonstrated that post-spinal decline in blood pressure and also heart rate decreases systemic oxygen delivery and adversely affects cerebral oxygen levels. However, this downward change did not result in deterioration of cognitive functioning.

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Monitoramento dos efeitos da raquianestesia sobre a saturação de oxigênio cerebral em pacientes idosos com o uso de espectroscopia de luz próxima ao infravermelho

Resumo

Justificativa e Objetivo: o bloqueio central proporcionado pela raquianestesia possibilita a realização de muitos procedimentos cirúrgicos, enquanto as alterações hemodinâmicas e respiratórias influenciam a oferta de oxigênio sistêmico, levando ao desenvolvimento em potencial de uma série de problemas, como isquemia cerebral, infarto do miocárdio e insuficiência renal aguda. O objetivo deste estudo foi detectar potenciais efeitos adversos das alterações hemodinâmicas e respiratórias sobre a oferta de oxigênio sistêmico, usando métodos oximétricos cerebrais em pacientes submetidos à raquianestesia.

Métodos: vinte e cinco pacientes, 65–80 anos de idade, estado físico ASA I–II, programados para correção de hérnia inguinal unilateral sob raquianestesia foram incluídos no estudo. De acordo com o monitoramento padrão, os níveis de oxigênio cerebral foram medidos no início do estudo usando métodos oximétricos cerebrais. O Mini Teste Padronizado do Estado Mental (Standardized Mini Mental Test – SMMT) foi aplicado antes e depois da operação para determinar o nível de funcionamento cognitivo dos casos. Usando uma técnica padrão e quantidades iguais de um fármaco anestésico local (15 mg de bupivacaína a 5%), o bloqueio intratecal foi realizado. Pressão arterial média (PAM), frequência cardíaca máxima (FCM), saturação periférica de oxigênio (SpO₂) e níveis cerebrais de oxigênio (rSO₂) foram monitorados no pré-operatório por 60 min. Os níveis pré- e pós-operatórios de hemoglobina foram medidos. As variações nos dados obtidos e suas correlações com os níveis cerebrais de oxigênio foram investigadas.

Resultados: não observamos alterações significativas nas mensurações de hemoglobina, escores do SMMT e níveis de SpO₂ nos períodos pré- e pós-operatório. No entanto, variações significativas foram observadas nos níveis de PAM, FCM e rSO₂ no período intraoperatório. Além disso, a correlação entre as variações de rSO₂, PAM e FCM foi determinada.

Conclusão: a avaliação dos dados obtidos no estudo demonstrou que a queda da pressão arterial pós-raquianestesia e também da frequência cardíaca diminui a oferta de oxigênio sistêmico e afeta negativamente os níveis cerebrais de oxigênio. Contudo, essa alteração não resultou em deterioração da função cognitiva.

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Introduction

Though main objective of spinal anaesthesia is to provide sensory and motor blockade, sympathetic denervation is regarded as a side effect inducing the development of systemic alterations.¹ Spinal anaesthesia-related hypotension is the most frequently encountered complication. Systemic vascular resistance decrease, as a result of decreased arterial pressure and heart rate decrease secondary to sympathetic blockade resulting in decline in cardiac output. Systemic delivery of oxygen decreases in proportion with a decrease in cardiac output leading to an onset of many problems such as development of cerebral ischemia, myocardial infarction, acute renal failure and cardiac arrest because of tissue hypoxia.^{1,2}

Elder population increases globally at an extremely higher rate in parallel with improvements in the quality of life. Elder and very old people are considered to be ≥ 65 and ≥ 80 years of age, respectively.³ When compared with

general anaesthesia, application of spinal anaesthesia offers elder people some advantages during and after the operation as preservation of cognitive functioning, lesser amount of intraoperative bleeding, decreased risk of thromboembolism and provision of effective analgesia. However, it has also some disadvantages as hypotension, bradycardia and delayed ambulation.^{4–10}

Even if decreased cardiac output caused by spinal anaesthesia does not impair hemodynamic processes and systemic delivery of oxygen at an extreme rate or induce clinical symptoms, it especially exerts a certain impact on cerebral blood flow. Even though markedly depressing effects of hypotension on cerebral circulation of particularly elder patients has been noted in various studies, this subject is still debatable.^{11,12}

The main objectives of neuromonitorization are to maintain and preserve neurological functions and provide optimal conditions for their improvement. To that end non-invasive near-infrared spectroscopy (NIRS)-based cerebral oximeter

is a monitor used for the measurement of regional cerebral oxygen saturation (rSO_2). This monitor does not require pulse rate and blood flow measurements. It mainly demonstrates the balance between cerebral oxygen deliver and demand for oxygen, in addition to rSO_2 in target organs.¹³

Systemic delivery of oxygen (DO_2) is used to determine the amount of oxygen required by tissues. Cardiac stroke volume is in direct proportion with heart rate, haemoglobin level and arterial blood oxygen content. In cases where one or more than one of these parameters decrease quantitatively, systemic delivery of oxygen is also reduced leading to tissue hypoxia. In practice, each of the more easily measured parameters such as blood pressure, heart rate, peripheral oxygen saturation and haemoglobin levels is a predictor of systemic oxygen delivery. Cerebral oxygenation is also affected by levels of haemoglobin, MBP, MHR and SpO_2 .^{14,15} In this study, these parameters have been monitored in patients over 65 years of age who had undergone spinal anaesthesia.

In this study, our aim was to investigate the impact of the changes developed secondary to the application of spinal anaesthesia on cerebral oxygenation in elder people according to a standard protocol.

Materials and methods

After approval of the institutional ethics committee, a total of 25 cases aged 65–80 years in ASA I–II (American Society of Anaesthesiologists) risk groups who were scheduled for unilateral hernia repair to be performed by the department of general surgery under preferred mode of anaesthesia (i.e. spinal anaesthesia) were included in the study. Patients with mental and/or neurological diseases, congestive heart failure, anemia, hematologic disorders were not included in the study. Spinal anaesthesia administered cases whose levels of sensory blockade are inadequate for the realization of the operation or above T10 as detected by a pin-prick test were excluded from the study.

The patients were brought into the preoperative preparation room and their baseline blood pressures (MAP), maximum heart rates (MHR), peripheral (SpO_2) and cerebral oxygen saturation (Somanetics Invos Oxymeter 5100C: Somanetics Comp., 1653 East Maple Road, Troy, MI, USA) values were monitored and recorded. A venous access route was opened using an 18–20 G peripheral vein cannula and RL solution was given intravenously at a rate of 10 mL.kg^{-1} . Then the patients were taken into the operating room and values of MAP, MHR, rSO_2 and SpO_2 were recorded. While the patients in the erect sitting position, the skin of the entry site was disinfected and covered with a sterile drape in compliance with an antiseptic technique. With a 22–25 Quincke needle, L3–L4 intervertebral space was entered and the needle was advanced into subarachnoid space and intratechal blockade was realized using a standard technique and equal amounts of a local anaesthetic drug (15 mg, 0.5% bupivacaine) for all patients. After spinal anaesthesia, the patients were placed in an appropriate supine position. Sensory block levels of the cases were determined using pin-prick tests performed within postspinal 10 min (3, 5 and 10 min) and evaluated based on responsive dermatomes. Pre- and

postoperative haemoglobin levels were determined. Any medication effective on cognitive findings was not administered during the perioperative period. Standardized Mini Mental Test (SMMT) was applied on patients so as to evaluate cognitive functioning before and within 6 h after the operation. The scores obtained were recorded. Achievement of adequate sensory blockade was awaited for 30 min after induction of spinal anaesthesia (at the start of the operation, $VAS < 20\text{ mm}$), then surgical intervention was started after approval of the anaesthesiologist. After spinal tap, hemodynamic parameters were followed up at 5-min intervals for 60 min. Administration of ephedrine was planned in cases where actual blood pressure measurements were 30% lower than the baseline values or decline in systolic or diastolic blood pressures below 90 mm Hg and 40 mm Hg, respectively, while atropin sulphate injections were considered in patients with maximum heart rates below 40 bpm. The data retrieved were evaluated statistically and correlations between significantly altered variables and variations in cerebral oxygenation were evaluated.

Statistical analysis

For the statistical analysis of study findings, NCSS (Number Cruncher Statistical System) 2007&PASS 2008 Statistical Software (Utah, USA) program was used. As an outcome of Power analysis, in evaluations based on the average of the left rSO_2 measurements, when we assume a difference of 12 and standard deviation of 10, in the defined groups with a statistical power of 0.90, β : 0.10 and α : 0.10, the sampling size was determined as 23 patients for each group. In order to determine the correlation between rSO_2 and MBP measurements, measurement time points were taken as covariants and generalized linear regression analyses were performed. For the evaluation of study data descriptive statistical methods (means \pm standard deviation) and for the analysis of correlations between parameters in the comparison of quantitative data Spearman's rho correlation coefficients were used. Significance was evaluated at a $p < 0.05$ level.

Results

The study was performed on 19 (76%) male and 6 (24%) female patients. Ages of the patients ranged between 65 and 77 years with a mean age of 69.80 ± 4.38 years.

Statistically significant variations were observed among MBP measurements performed at baseline and at 5, 10, 15, 20, 30, 40, 50 and 60 min ($p = 0.0001$) (Table 1). In order to determine the correlation between measurements of rSO_2 and MBP, measurement time points were assumed as covariants and generalized linear regression analyses were performed. A significant correlation was observed between rSO_2 and MBP values and among measurement time points ($p = 0.006$ and $p = 0.001$, respectively). Adjusted R^2 value which ascertained the level of correlation was estimated as 0.269 (Table 2).

When variations in MHR were evaluated, significant changes were observed among MHR measurements performed at baseline, at 5, 10, 15, 20, 25, 30, 40, 50 and 60 min ($p = 0.0001$) (Table 1). Significant correlations were observed

Table 1 Levels of MBP, MHR, SpO₂, right and left rSO₂, SMMT and Hb.

	Base	5 min	10 min	15 min	20 min	25 min	
MBP	114.88 ± 16.10	106.64 ± 13.38	100.16 ± 14.23	97.32 ± 14.61	92.52 ± 13.66	89.88 ± 13.38	
MHR	78.20 ± 11.32	75.92 ± 11.06	74.80 ± 10.69	73.92 ± 10.22	74.04 ± 9.57	72.56 ± 9.82	
SpO ₂	98.53 ± 1.04	98.52 ± 1.15	98.36 ± 0.99	98.24 ± 1.05	98.36 ± 1.18	98.52 ± 0.96	
Right rSO ₂	65.04 ± 6.75	64.08 ± 6.23	62.84 ± 6.28	61.64 ± 6.08	60.56 ± 5.81	58.88 ± 5.41	
Left rSO ₂	64.96 ± 5.74	63.84 ± 5.85	62.44 ± 5.73	61.36 ± 5.68	59.80 ± 5.42	57.84 ± 5.34	
Before operation							
SMMT						18.44 ± 2.53	
Hb						12.56 ± 1.78	
	30 min	40 min	50 min	60 min	<i>p</i>		
MBP	88.60 ± 13.20	86.40 ± 12.90	84.88 ± 11.13	83.80 ± 11.71	0.0001		
MHR	72.08 ± 9.15	72.20 ± 9.35	72.40 ± 9.21	72.04 ± 8.76	0.0001		
SpO ₂	98.32 ± 1.03	98.44 ± 1.04	98.40 ± 1.08	98.32 ± 0.94	0.598		
Right rSO ₂	57.68 ± 5.03	56.96 ± 5.00	56.32 ± 4.96	55.76 ± 5.01	0.0001		
Left rSO ₂	56.88 ± 5.34	56.40 ± 5.08	55.64 ± 5.30	54.88 ± 5.24	0.0001		
After operation							
SMMT						18.48 ± 2.55	0.664
Hb						11.80 ± 1.56	0.132

Table 2 Measurement time points were assumed as covariants in the determination of the correlation between rSO₂ and MBP and MHR and generalized linear regression analysis was performed. A statistically significant correlation was observed between levels of rSO₂, MBP and MHR and also among measurement time points. Adjusted *R*² values ascertaining the level of correlation were also calculated.

rSO ₂	Collection of squares	Degrees of permissiveness	Mean squares	<i>F</i>	<i>p</i>
MBP	240.429	1	240.429	7.740	0.006
MHR	225.330	1	225.330	7.246	0.007
<i>Measurement times</i>					
MBP	2853.631	9	317.070	10.207	0.001
MHR	5023.388	9	558.154	17.950	0.001
<i>Residue</i>					
MBP	15190.591	489	31.065		
MHR	15205.690	489	31.095		
				rSO ₂ /MBP	rSO ₂ /MHR
<i>R</i> ²				0.291	0.287
Adjusted <i>R</i> ²				0.269	0.268

between rSO₂ and MHR values and among measurement time points ($p=0.007$, and $p=0.001$, respectively). Adjusted *R*² value which determined the level of the correlation was found to be 0.268 (Table 2).

A significant change was observed among right rSO₂ measurements obtained at baseline, 5, 10, 15, 20, 25, 30, 40, 50 and 60 min ($p=0.0001$) (Table 1). When compared with pre-spinal baseline values, a steady decline was noted in right rSO₂ measurements. Besides, significant variations were observed among left rSO₂ measurements performed at baseline, 5, 10, 15, 20, 25, 30, 40, 50 and 60 min ($p=0.0001$) (Table 1). A steady decline was also seen in left rSO₂ measurements relative to pre-spinal baseline values

($p=0.0001$) (Table 1). A significant change was not observed among SPO₂ measurements ($p=0.598$), pre- and postoperative SMMT scores ($p=0.664$) and haemoglobin levels ($p=0.794$) (Table 1).

Discussion

Various studies have demonstrated that decline in blood oxygen levels results in inadequate delivery of oxygen into cerebral structures. Decreased cerebral oxygen delivery might be linked to the decreases in the oxygen content of the inspired air, cardiac output or haemoglobin levels. In

the elder population, acceptable level of haemoglobin for cerebral perfusion was indicated as 7 g/dL.^{16–18} In this study, any patient with severe bleeding episodes which would adversely affect haemoglobin levels and respiratory problems which would unfavorably affect arterial blood oxygen content were not encountered.

Hypotension which occurs in patients operated under spinal anesthesia is the most frequently (33%) encountered complication of the spinal anaesthesia. Hypotension is related to the loss of systemic vascular resistance because of sympathetic blockade. Venular dilation enhances venous capacity leading to stagnation of blood in veins and reduced cardiac output.^{1,2} Hypotension might be severe enough to affect blood circulation in various organ systems.¹⁹ In line with this finding, various studies have been performed on the impact of spinal anaesthesia on cerebral oxygenation. Some of these studies have demonstrated that spinal anaesthesia effects cerebral oxygenation unfavourably which is more prominent in the elder patients.^{11,12,20} In this study, significant changes were observed in rSO₂, MBP and MHR measurements performed at postspinal 5, 10, 15, 20, 25, 30, 40, 50, and 60 min when compared with the baseline values. ($p=0.0001$). A correlation was noted between decreases in cerebral oxygenation, MBP and MHR values. These data revealed that decrease in cerebral oxygen levels are associated with inability to compensate hypotensive attacks which occur as a result of degeneration of cerebral vessels and deranged autoregulatory mechanisms and also decreased cardiac output because of deceleration of heart rate in the elderly.

Respiratory functions in spinal anaesthesia are not adversely affected provided that spinal blockade involves dermatomes innervated by T7–T10 spinal nerves. Pulmonary functions are not affected and respiratory rate per minute, end-tidal CO₂, PaO₂, PaCO₂ values do not change in spinal blockade up to T4 level thanks to compensatory mechanisms exerted by diaphragm which is innervated by *N. phrenicus*.¹⁷ In this study, the level of spinal blockade did not exceed T8 level in patients who had undergone spinal anaesthesia, accordingly significant respiratory changes which would otherwise adversely affect SpO₂ and cerebral oxygen delivery were not observed ($p=0.598$).

Cognitive dysfunction can be defined as loss of memory and intellectual talents. Most frequently, hypotension and hypothermia increase the risk of postoperative cognitive dysfunction. Standardized mini mental test is a screening test which quantitatively evaluates cognitive functions. It is preferred in various studies thanks to its established validity, reliability, brevity, and easy applicability during pre- and postoperative periods.²¹ The severity of deterioration in cognitive functions in patients who received spinal anaesthesia is dependent on the degree and duration of hypoxia and hypotension.²² Though any alteration in respiratory functions was not observed in our study and the levels of hemodynamic parameters decreased without any significant difference between pre- and postspinal cognitive functions as assessed by SMMT scores ($p > 0.05$). Decreases in blood pressure and heart rates observed in patients included in our study did not adversely affect cognitive functions.

In conclusion, hemodynamic changes occurring during intratechal anaesthesia in elderly patients affect cerebral

oxygenation adversely. This effect is directly correlated to the development of hypotension and decrease in heart rate. Although in this study hemodynamic changes developing during spinal anaesthesia did not lead to a clinically symptomatic state, literature data have emphasized their potential risk in the elder patients. Owing to evolving innovative imaging techniques, it is possible to determine disordered cerebral oxygen balance. Among them, NIRS is a reliable and easily applicable method. This study has demonstrated that this imaging modality is helpful in the management of anaesthesia in the elderly and it can be routinely used in risky patients thanks to its easy applicability.

Conflicts of interest

The authors declare no conflicts of interest.

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