Changes of Regional Cerebral Oxygen Saturation Using Near Infrared Spectroscopy during Neurosurgical Spine Operations in Prone Position

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Abstract

Near infrared spectroscopy (NIRS) used to maintain cerebral oxygenation during surgery prevents complications such as cognitive dysfunction, organ failure improving postoperative outcome.

The aim of the study was to determine whether prone position during neurosurgical spine surgery using NIRS devices intraoperatively impacts cerebral oxygen saturation.

Fifteen patients undergoing spinal surgery were included in the study. Regional cerebral oxygen saturation ($rScO_2$) was monitored intraoperatively using INVOS 4100. Postoperative complications and days spent in intensive care unit (ICU) were monitored.

Results showed medium $rScO_2$ lying supine left side (L) 72.39 %, right side (R) 72.49 %, in prone position L 74.73 %, R 74.01 %, returning on spine L 74.11 %, R 73.15 %. Seven out of fifteen patients showed a slight up to significant $rScO_2$ decrease when turned from supine to prone position. There was no incidence of postoperative complications, no patients were admitted to ICU.

Patients in prone position intraoperatively experience decrease in cerebral oxygen saturation. Regional cerebral oxygen saturation is a valuable intraoperative measurement in patients undergoing neurosurgical spine operations in prone position to manage perioperative period.

Keywords: regional cerebral oxygenation, prone position, spine surgery.

Introduction

Human brain is a very complex and fragile system. It receives about 15 % of cardiac output, consumes approximately 20 % of all oxygen having the highest metabolic rate of any organ system. Brain is highly vulnerable to desaturation. It consumes oxygen reserves in about 8–10 seconds. Cerebral hypoxia is a leading cause of adverse cerebral outcomes as well as the duration of hypoxia has a direct impact on brain survivability, activity and function. It has been proven that up to 53 % of CABG patients have such complications related to cerebral hypoxia as focal injury, stupor, coma, decrease of intellectual function, seizures, memory deficit, disorientation and death. Cerebral oxygenation cannot be detected by common monitoring devices or can only be detected after damage has already occurred.

Cerebral oximetry is a simple, non-invasive, continuous measurement which gives the ability to monitor regional cerebral oxygen saturation as well as to predict low cardiac output, being an early warning of problems developing in other organ systems. Monitoring standards set by the Association of Anaesthetists of Great Britain and Ireland are: electrocardiography (ECG), pulse oximetry, end tidal carbon dioxide and non-invasive blood pressure; yet, they give little indication of the adequacy of oxygen delivery (DO_2) to the patient during surgery (Bidd, 2013). Systemic arterial and (mixed/central) venous oxygenation can be measured routinely with widely established techniques like pulse oximetry, blood gas analysis, and venous finer oximetry (e.g., in pulmonary artery catheters). However, regional measurement of tissue oxygenation was not possible on a routine clinical basis until recently. Traditionally, tissue oxygenation has been measured by experimental tools that were either invasive (e.g., Clark-type needle electrodes) or dependent on toxic dyes (e.g., palladium phosphorescence), restricting their clinical use (Scheeren, 2012).

Normal values of cerebral oximetry are between 60 % and 80 % or has been kept 20–25 % below the baseline as preoperative readings may differ from patient to patient. Unlike pulse oximetry which is based on light loss due to pulsation of arterial blood, cerebral oximetry bases on light loss due to entire non-pulsative field consisting of approximately 30 % arterial and 70 % venous blood.

The first publications about cerebral oximetry were dated about 30 years ago, but it has gained its importance as an additional monitoring technique in operating rooms and intensive care units only recently. Mostly used in cardiac surgery and for severe head injury monitoring due to high risk for cerebral desaturation because of changes in cerebral blood perfusion and association with such postoperative complications like cognitive dysfunction, stroke, seizures and even death. Lately it has been extensively investigated in association with massive blood loss, surgery in the beach-chair position, surgery in prone position, by head and neck manipulations and one-lung ventilation (Hemmerling, 2008).

Neurosurgical spinal surgery includes one level, to multiple level surgery and patients vary from healthy, stable up to decompensated, hemodynamically unstable and sever trauma patients. Prone position used in spinal surgery leads to physiological changes affecting cerebral blood flow and cerebral oxygenation. The main cause is vena cava inferior and its branches compression causing blood deposition in epidural venous plexus favouring intraoperative blood loss, reducing blood return in the systematic circulation and affecting the cerebral blood flow.

Aim

The aim of the study was to determine whether prone position during neurosurgical spine surgery using NIRS devices intraoperatively impacts cerebral oxygen saturation.

Material and Methods

Fifteen patients scheduled for spinal neurosurgery were included in the study. Inclusion criteria: age > 18 years, spinal surgery performed in prone position (transpedicular fixation (TPF), microdiscectomy (MDE), removal of spinal tumours); exclusion criteria: spinal surgery not performed in prone position. Cerebral oxygen saturation ($rScO_2$) was continuously monitored using INVOS 4100 (COVIDIEN, USA) near infrared spectroscopy oximeter intraoperatively. Non-invasive blood pressure (NIBP), heart rate (HR), end tidal carbon dioxide tension ($EtCO_2$), and peripheral oxygen saturation (SpO_2) were also monitored. All the data was fixed every five minutes. We observed cognitive dysfunction, the rate of postoperative complications – stroke, organ dysfunction, wound infection, days spent in ICU.

All patients received standard anaesthesia. Induction with fentanyl 0.1–0.2 mg, propofol 1–2 mg/kg, miorelaxation with cisatracurium 0.2 mg/kg. For maintenance, there was used fentanyl 0.03–0.06 µg/kg/min, cisatracurium 0.06–0.1 mg/kg/h. During maintenance of anaesthesia sevoflurane was used to achieve MAC 0.7–1.0. Mechanical lung ventilation with inspired oxygen concentration FiO_2 0.5. Two INVOS Cerebral/Somatic Oximetry Adult cerebral oximetry sensors were placed on a patient's forehead before induction of anaesthesia. After operation all the patients were extubated in operating room.

Statistical analysis was performed using the IBM SPSS Statistics.

The study was performed with the approval of Rīga Stradiņš University ethics committee (Nr. 61/28.01.2016).

Results

Fifteen patients (men – 9, woman – 6, mean age – 60 years) were enrolled in the study. Results showed the average regional cerebral oxygen saturation during operation for the left side (L) 79.9 %, the right side (R) 79.52 %. Lying supine before intubation L 72.39 %, R 72.49 %, in prone position L 74.73 %, R 74.01 %, returning back to spinal position L 74.11 %, R 73.15 %. Significant changes in the calculated average $rScO_2$ values between supine and prone position were not observed (Table 1). Despite the calculated average $rScO_2$ values, seven out of fifteen patients showed a slight up to significant decrease in $rScO_2$ when turned from supine to prone position (Table 2). The minimum $rScO_2$ value observed during the whole surgery was 55 % (Table 3). One patient's $rScO_2$ values decreased by 32 % from baseline values when turned to prone position (from 85.5 % supine to 58.5 % in prone position). One patient with stroke in anamnesis showed initial values lying supine 21 % lower than average (57.5 % compared to average $rScO_2$ lying supine 72 %). No cognitive dysfunction, no incidence of stroke or organ dysfunction was observed, no patients were admitted to ICU.

Table 1. Patient details

Patient, No	Age/Sex	Surgery	Blood loss, ml	Mean $rScO_2$, %					
				Supine 1		Prone position		Supine 2	
				Right side	Left side	Right side	Left side	Right side	Left side
1	62/M	TPF	200	72	71	69	65	69	72
2	52/M	TPF	200	85	85	80	80	89	89
3	60/M	TPF	150	57	58	70	71	69	70
4	48/M	TPF	150	72	78	91	94	85	87
5	27/M	MDE	100	86	87	92	92	86	85
6	59/M	TPF	300	61	61	75	78	64	66
7	72/M	MDE	150	69	69	77	80	69	69
8	78/M	MDE	150	69	69	64	64	74	74
9	72/F	MDE	150	74	74	69	68	64	65
10	82/F	TPF	500	70	70	73	73	70	70
11	74/M	TPF	2000	85	86	56	61	71	70
12	49/F	MDE	150	59	55	59	58	60	65
13	54/F	TPF	700	62	62	85	84	74	76
14	37/F	MDE	150	89	89	83	83	83	83
15	84/F	Th1 meningioma	150	75	68	61	63	66	66
Average $rScO_2$ (%)				72	72	74	74	73	74

M – male; F – female; TPF – transpedicular fixation; MDE – microdiscectomy.
Supine 1 – position on spine before prone position at the beginning of surgery.
Supine 2 – position on spine after prone position at the end of surgery.

Table 2. Medium $rScO_2$ (%) in supine and prone position

Patient, No	Medium $rScO_2$, %		$rScO_2$ decrease, %
	Supine position	Prone position	
1	71.75	67.44	4.31
2	85.00	80.83	4.17
3	69.00	64.71	4.29
4	74.00	69.13	4.88
5	85.50	58.93	26.57
6	89.50	83.00	6.50
7	72.00	62.58	9.42

Table 3. Descriptive $rScO_2$ (%) values for each patient during surgery

Patient, No	Mean $rScO_2$ value, %	Std. Deviation	95 % Confidence Interval for mean		Minimum $rScO_2$ value, %	Maximum $rScO_2$ value, %
			Lower bound	Upper bound		
1	69.75	2.72	66.90	72.60	65.00	72.00
2	85.05	3.80	81.07	89.04	80.80	89.33
3	65.98	6.62	59.03	72.94	57.00	71.40
4	84.81	8.28	76.11	93.50	72.00	94.00
5	88.40	3.08	85.17	91.63	85.80	92.38
6	67.32	6.97	60.01	74.64	61.00	78.47
7	72.42	5.03	67.13	77.70	69.00	80.50
8	69.24	4.16	64.87	73.60	64.71	74.00
9	69.43	3.99	65.23	73.62	64.50	74.00
10	71.65	1.45	70.13	73.18	70.67	73.69
11	71.65	12.01	59.04	84.25	56.67	86.00
12	59.37	3.26	55.94	62.79	55.00	65.00
13	74.32	10.11	63.71	84.93	62.50	85.07
14	85.17	3.36	81.64	88.69	83.00	89.50
15	67.03	4.75	62.04	72.01	61.58	75.25
Total	73.44	9.94	71.36	75.52	55.00	94.00

Discussion

Non-invasive cerebral oxygenation monitoring has lately gained its importance and topicality in different medical fields. Being non-invasive, it offers a possibility to use it intraoperatively as an extra monitoring device and enhances patient safety and improves surgical outcome by reducing postoperative complication rate.

According to literature, no significant changes in $rScO_2$ were observed during prone position intraoperatively which also correlates with our first 15 patients' data (Fuchs, 2000). Deiner et al. in their study showed that mild cerebral desaturation episodes were 2.3 times more frequent for elderly patients (> 68 years of age) undergoing surgery in prone position vs. supine (Deiner, 2014). In our study patients' mean age was 60 years and our average values did not show $rScO_2$ decrease when patients were turned from supine to prone position although 7 out of 15 patients $rScO_2$ medium values decreased while being in prone position.

There are studies performed regarding the monitoring of brain saturation and the interventions to restore its proper values to improve treatment outcomes, particularly in regard to the incidence of neurological complications and postoperative cognitive dysfunction as well as the intraoperative reduction of brain saturation which correlates with prolonged treatment in ICUs and increased mortality (Biedrzycka, 2016). In our study we did not observe any postoperative complications such as stroke, organ dysfunction or cognitive dysfunction after surgery which also correlates with the fact that no significant intraoperative $rScO_2$ decrease was observed.

A systematic review was undertaken to determine whether spinal surgery in prone position impacts cerebral oxygenation. Relevant publications were found using PubMed database. Search strategy included MeSH terms: (Spectroscopy) OR (Monitoring/Intraoperative) OR (Spine) OR (Prone position), in total 309 articles were found (published between 2000 and 2014). Only 3 articles met all the criteria ((Spectroscopy) and (Monitoring/Intraoperative) and (Spine) and (Prone position)) showing that cerebral oxygen saturation monitoring during neurosurgical spine surgery in prone position is still an open field for further investigations.

Conclusion

Although our first experience revealed that the average intraoperative cerebral oxygen saturation changes during neurosurgical spine operations in prone position from baseline values is not significant, 7 out of 15 patients showed a mild to moderate decrease in cerebral oxygen saturation.

Regional cerebral oxygen saturation is a valuable intraoperative measurement in patients undergoing neurosurgical spine operations in prone position to manage perioperative period.

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