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Accuracy of Regional Cerebral Oxygen Saturation in Predicting Postoperative Cognitive Dysfunction After Total Hip Arthroplasty: Regional Cerebral Oxygen Saturation Predicts POCD

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ABSTRACT

To estimate the accuracy of regional cerebral oxygen saturation (rSO_2) in predicting postoperative cognitive dysfunction (POCD) for patients undergoing total hip arthroplasty, 46 patients aged more than 50 years old were enrolled. We measured the patients' cognitive function by using a battery of six neuropsychological tests before surgery and then 7 days after surgery again. rSO_2 was continuously monitored by near-infrared spectroscopy during surgery. POCD was present in 9 (19.6%) patients 1 week after surgery. Logistic regression analysis showed that increasing age [OR = 1.224, P = 0.035] and maximum percentage drop in rSO_2 ($rSO_{2\%max}$) [OR = 1.618, P = 0.011] were significant risk factors for POCD. The area under the receiver operating characteristic curve of $rSO_{2\%max}$ was 0.833 [95% confidence interval (CI) 0.615–1.051] at cutoff value of 11%. The specificity and sensitivity of $rSO_{2\%max} > 11\%$ in predicting POCD were 77.8% and 86.5%, respectively. $rSO_{2\%max}$ more than 11% was a potential predictor for POCD.

Postoperative cognitive dysfunction (POCD), as distinct from postoperative delirium, is a permanent decline of cognitive status after surgery [1]. A proportion of these patients, especially elderly people, present hypomnesia, slow reaction or incapacity for dealing with daily routine lasting for months or years [2]. POCD can prominently interfere with patients' quality of life, prolong length of stay, and increase hospital expenses and mortality [3,4]. Cardiopulmonary bypass (CPB) has long been recognized as a trigger for POCD [5]. However, it has lately been demonstrated that POCD seems to be a widespread phenomenon not only in cardiac surgery but also in non-cardiac surgery. It has been indicated by Rodriguez et al. that 41% of patients that underwent total knee arthroplasty displayed cognitive deterioration at 7 days postoperatively [6]. Neurocognitive decline might affect the outcome of artificial joint replacement.

The potential mechanisms of POCD remain abstruse so far. Multiple factors appear to be involved, such as anaesthetic, postoperative pain, hypoperfusion, thrombosis or fat embolism, inflammatory responses, environmental factors and so on [7]. Reviewing the recent reports, cerebral desaturation may be associated with POCD [8]. Nevertheless, there is still no valid clinical indicator to predict POCD besides advancing age. Indications for total hip arthroplasty (THA) in elderly patients have been increasing, therefore we designed the research to verify the assumption that monitoring regional cerebral oxygen saturation (rSO_2) can predict POCD for patients undergoing THA.

Methods

Materials

After being given permission by the clinical research ethics committee of our institution (Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China), written informed consent was attained from 50 patients aged more than 50 years who underwent an elective total hip arthroplasty from July 1, 2009 to January 31, 2010. We abided by the following exclusion criteria: preoperative Mini-Mental State Examination (MMSE) score less than 24; a current or past history of psychiatric disorder or central nervous system diseases; a history of cardiovascular surgery or craniotomy; drug or alcohol dependence; hepatic failure; renal failure; inability to read or speak Chinese; and serious hearing or vision impairment.

Reduplicative neuropsychological testing has been suggested to give rise to a learning effect [4,9]. In order to eliminate the practice effect, we looked for 10 healthy volunteers as control subjects who were matched to the patients in terms of age, gender distribution and education level.

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2012.06.041.

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Management

After each patient entered the operation room, electrocardiograph (ECG) monitor, noninvasive blood pressure device and pulse oximetry were routinely attached to monitor. Three electrodes connected with Narcotrend® monitor (Narcotrend®-Compact, MT MonitorTechnik GmbH und Co. KG, Germany) and a sensor of rSO_2 connected with near-infrared spectroscopy (INVOS 5100B, Somanetics, Troy, MI, USA) were placed on the skin of the forehead region to separately record values of Narcotrend and rSO_2 at 30-s intervals throughout surgery. After 5 min for balance, Narcotrend and rSO_2 readings were regarded as the baseline value. Anesthesia induction was administrated with 2–3 μg/kg fentanyl, 1.5–2 mg/kg propofol and 0.1 mg/kg vecuronium i.v. Anesthesia maintenance was conducted with sevoflurane inbreathed continuously, in combination with intermittent infusion of vecuronium and fentanyl, to keep Narcotrend index between D_1 and E_1 and stable hemodynamics. All anesthesia-related data including dose of anesthetic agents, fluids input quantity, blood loss, the duration of operation and anesthesia, and recovery time were recorded routinely.

Neuropsychological Assessment

Neuropsychological tests were administered before surgery and 7 days after operation. The battery primarily focused on memory, learning, attention, executive functions and cognitive flexibility, and encompassed the following tests: Mini-mental state examination, Digit span test, Digit symbol substitution test (DSST), Trail making test (part A), Verbal fluency test, and Word recognition memory tests. The same physician carried out the evaluation of cognitive function among patients and controls. Learning effects were defined as mean variation of each test from baseline among control subjects. Refer to the International Study of Postoperative Cognitive Dysfunction (ISPOCD1 and ISPOCD2) [10,11], a Z score for each individual test was calculated via comparing baseline scores with test results 1 week after surgery, subtracting the average learning effect from these changes, and dividing by the standard deviation of control group. POCD was defined as Z scores on at least two tests of 1.96 or greater.

Statistical Analysis

According to the definition of POCD, patients were split into two groups: POCD group and non-POCD group. For data analysis, mean rSO_2 ($\overline{rSO_2}$), minimum rSO_2 (rSO_{2min}) and maximum percentage drop in rSO_2 ($rSO_{2\%max}$) were collected. Statistical analysis was conducted by using SPSS version 13.0(SPSS Inc, Chicago, Illinois). Continuous variables were expressed as mean ± SD and processed with Student's t-test. Categorical variables were expressed as numbers (percentage) and processed with chi-square test. Numerical data were represented as 95% confidence intervals (95% CIs) or median, and analyzed with Wilcoxon signed-rank tests. Receiver operating characteristic (ROC) analysis was performed to assess the accuracy of each parameter (*i.e.*, rSO_{2min}, $\overline{rSO_2}$, $rSO_{2\%max}$) in discriminating POCD from non-POCD patients. Determining independent risk factors for POCD mainly used multivariate logistic regression. Statistically significance was defined as $P < 0.05$.

Table 1
Characteristics of the Patients and Control Subjects.

Characteristic	Patients (n = 46)	Controls (n = 10)
Age (years)	64.8 ± 9.6	65.7 ± 6.4
Sex (%)		
Male	26	30
Female	74	70
Educational level (%)		
Less than high school	22	20
High school	52	50
More than high school	26	30
Preoperative MMSE scores	28.7 ± 1.9	29.0 ± 1.2

Data are presented as mean ± SD, or percentage of all patients.
MMSE = Mini-Mental State Examination.

Table 2
Demographic and Intraoperative Data Between the Two Groups.

	non-POCD(n = 37)	POCD(n = 9)	*P* value
Age(years)	64 ± 9	72 ± 7	0.026
Gender (%)			
Male	27	22	0.828
Female	73	77	
Height (cm)	161 ± 7	160 ± 8	0.831
Weight (kg)	61.3 ± 10.4	61.3 ± 10.1	0.913
BMI	23.5 ± 3.4	24.0 ± 3.6	0.605
ASA physical status (%)			
II	43	44	0.892
III	57	56	
Preoperative complication (%)			
Hypertension	54	22	0.144
Diabetes	11	11	0.945
Smoking history (%)	16	11	0.828
Surgical History (%)	46	55	0.663
Duration of anesthesia (min)	153 ± 47	155 ± 39	0.807
Duration of surgery (min)	104 ± 46	109 ± 40	0.624
Recovery time(min)	40 ± 11	40 ± 17	0.807
Fluid replacement (ml)	2942(2719–3165)	3250(2613–3887)	0.461
Blood loss (ml)	685(506–864)	806(233–1378)	0.703
Fentanyl (mg)	0.39 ± 0.07	0.40 ± 0.03	0.789
Vecuronium (mg)	10.5 ± 2.3	10.1 ± 2.1	0.957

Data are presented as mean ± SD, or median (5th–95th percentile), or percentage of all patients.
POCD = postoperative cognitive dysfunction; BMI = Body Mass Index; ASA = American Society of Anesthesiologists.

Results

50 patients were screened for the study; four patients were excluded because they failed to complete neuropsychological tests one week after surgery. Actually, 46 patients in total were enrolled. Table 1 compares the characteristic of patients with controls. As is shown, there were no differences among age, gender distribution, educational attainment, and preoperative MMSE scores between them.

On the 7th day after surgery, 19.6% (n = 9) of patients showed cognitive decline. Table 2 illustrates the comparison of demographic and factors related to operation between POCD group (n = 9) and non-POCD group (n = 37). Our data exhibited the correlation between POCD and advancing age ($P < 0.05$).

Table 3
Neuropsychological Test Results for the Patients at Baseline and 7 Days after Surgery.

	Baseline		7 days after surgery	
	non-POCD (n = 37)	POCD (n = 9)	non-POCD (n = 37)	POCD (n = 9)
MMSE	29.0 ± 1.2	29.6 ± 0.5	28.4 ± 1.7**	27.1 ± 1.1*,**
Digit span test				
Correct order	8.2 ± 1.3	8.6 ± 0.7	8.3 ± 1.1	7.8 ± 1.0**
Reverse order	4.3 ± 1.1	4.6 ± 1.1	4.1 ± 1.0	3.9 ± 0.6
Symbol digit test	32.7 ± 12.2	31.0 ± 12.1	31.8 ± 13.7	25.3 ± 12.6**
Trail making test A (s)	17.6 ± 13.8	19.4 ± 11.0	18.7 ± 13.9	20.5 ± 17.1
Verbal fluency test	16.7 ± 3.5	13.8 ± 2.7	17.1 ± 3.4	12.6 ± 4.6*
Word Recognition memory tests	1.2 ± 1.4	1.3 ± 1.4	1.5 ± 1.2	1.9 ± 1.4

Data are presented as mean ± SD.
POCD = postoperative cognitive dysfunction; MMSE = Mini-Mental State Examination.
* $P < 0.05$ in comparison with non-POCD group.
** $P < 0.05$ in comparison with baseline in either group.