Taylor & Francis
Taylor & Francis Group

Renal Failure

ISSN: 0886-022X (Print) 1525-6049 (Online) Journal homepage: informahealthcare.com/journals/irnf20

Cerebral oximetry values in dialyzed surgical patients: a comparison between hemodialysis and peritoneal dialysis

Georgios Papadopoulos, Evangelia Dounousi, Athanasios Papathanasiou, Georgios Papathanakos & Petros Tzimas

To cite this article: Georgios Papadopoulos, Evangelia Dounousi, Athanasios Papathanasiou, Georgios Papathanakos & Petros Tzimas (2013) Cerebral oximetry values in dialyzed surgical patients: a comparison between hemodialysis and peritoneal dialysis, Renal Failure, 35:6, 855-859, DOI: 10.3109/0886022X.2013.794675

To link to this article: https://doi.org/10.3109/0886022X.2013.794675

Published online: 28 May 2013.

RENAL FAILURE

http://informahealthcare.com/rnf
ISSN: 0886-022X (print), 1525-6049 (electronic)

Ren Fail, 2013; 35(6): 855–859
 DOI: 10.3109/0886022X.2013.794675

informa healthcare

CLINICAL STUDY

Cerebral oximetry values in dialyzed surgical patients: a comparison between hemodialysis and peritoneal dialysis

Georgios Papadopoulos[1], Evangelia Dounousi[2], Athanasios Papathanasiou[3], Georgios Papathanakos[1], and Petros Tzimas[1]

[1]Department of Anesthesia and Postoperative Intensive Care, University Hospital of Ioannina, Ioannina, Greece, [2]Department of Nephrology, University Hospital of Ioannina, Ioannina, Greece, and [3]Intensive Care Unit, University Hospital of Ioannina, Ioannina, Greece

Abstract

Background: Cerebral tissue regional oxygen saturation (rSO_2) through near-infrared spectroscopy (NIRS) is a method for non-invasive monitoring of cerebral tissue oxygenation. However, nowadays there is limited information on the level of cerebral tissue oxygenation in dialyzed end-stage renal disease (ESRD) surgical patients. The aim of this observational study was to evaluate the baseline cerebral rSO_2 values, to compare values between hemodialysis (HD) and peritoneal dialysis (PD) patients and identify risk factors that could predict cerebral tissue oxygenation in these patients. *Patients/Methods*: Thirty-two ESRD patients ($\geq$18 years old), scheduled to undergo elective minor or major surgery, were enrolled. Patients were allocated in two groups according to dialysis modality. Twenty-three patients were treated with HD and nine were treated with PD. Demographic and clinical characteristics, comorbidities and arterial hemoglobin oxygen saturation (SpO_2) of the study population were recorded. *Results*: Patients who were treated with HD had significant lower baseline rSO_2 values compared with PD patients [median, 50% (28–63) vs. 63% (45–69), $p = 0.002$]. Hierarchical linear regression model analysis showed that preoperative Hb and SpO_2 were positive predictive variables ($B = 0.353$, $p = 0.01$ and $B = 0.375$, $p = 0.009$, respectively) for rSO_2. Moreover, dialysis modality was independent predictor for baseline rSO_2. The modality of dialysis remained an independent predictor for rSO_2 after controlling for the other significant variables ($B = 0.291$, $p = 0.032$) and PD was associated with higher baseline values of rSO_2. *Conclusion*: In conclusion, ESRD surgical patients undergoing PD treatment appear to have significantly higher baseline cerebral tissue saturation values compared with HD.

Keywords

Cerebral oximetry values, end-stage renal disease, hemodialysis, peritoneal dialysis

History

Received 28 January 2013
Revised 27 March 2013
Accepted 29 March 2013
Published online 28 May 2013

Introduction

Cerebral oximetry is a user-friendly and non-invasive monitor that reflects the balance between cerebral oxygen supply and consumption in large parts of the brain tissue. The cerebral oxygen supply depends on cerebral blood flow and oxygen content of blood.[1] It has been shown that decreased regional cerebral oxygen saturation (rSO_2) during surgery is associated with unjustified neurologic effects such as cognitive dysfunction, stroke and coma and moreover with a complicated postoperative course associated with higher morbidity rates.[2,3] It is generally known that cerebral rSO_2 is influenced by age, carbon dioxide partial pressure, arterial hemoglobin oxygen saturation, cerebral blood flow and changes in cerebral metabolic rate, cardiac index, hemoglobin concentration and blood volume.[4–10]

However, limited information is currently available in the literature on the level of cerebral tissue oxygenation in end-stage renal disease (ESRD) surgical patients receiving dialysis. Although the two dialysis modalities, hemodialysis (HD) and peritoneal dialysis (PD), exhibit similar patient's survival, important differences do exist with regard to technique and physiology. It has been shown that HD treatment itself contributes to transient hypotension, arterial hypoxemia, low cerebral perfusion, and finally cerebral atrophy.[11]

We conducted this observational study to evaluate the baseline cerebral rSO_2 values in dialyzed ESRD surgical patients, to compare values between HD and PD patients and identify risk factors that could predict cerebral tissue saturation in this population.

Patients and methods

This observational study was conducted at our tertiary care University Hospital between January and December 2011. Thirty-two ESRD dialyzed patients older than 18 years scheduled to undergo elective minor or major surgery were enrolled. Exclusion criteria were refusal to participate or inability to provide informed consent, emergency or urgent operation and trauma, major cardiovascular event during the

Address correspondence to Evangelia Dounousi, MD, Lecturer in Nephrology, Department of Nephrology, University Hospital of Ioannina, 45332 Ioannina, Greece. Tel: +302651099653; Fax: +302651099890; E-mail: evangeldou@gmail.com

Table 1. Demographic, clinical characteristics, comorbidities and baseline rSO_2 values in the two groups.

Variables	Group A $n=23$	Group B $n=9$	p Value
Age, median (range)	76 (21–85)	61 (51–80)	NS
Gender (male/female)	16/7	7/2	NS
Diabetes mellitus, *n*	12	4	NS
Hypertension, *n*	13	7	NS
History CVD, *n*	11	5	NS
Duration of RRT (months), median (range)	8.5 (3–168)	10.5 (2–64)	NS
Preoperative Hb, (mg/dl), median, (range)	10 (7–12)	11 (9–12)	0.04
SpO_2 (%), median, (min–max)	96 (88–99)	99 (93–99)	NS
MAP (mmHg), median (min–max)	98 (66–135)	96 (73–120)	NS
Baseline rSO_2 L (%) median (min–max)	50 (28–63)	63 (45–69)	0.002
Baseline rSO_2 L < 50 (%), *n*	11 (48%)	1 (11%)	0.05

Note: Values are expressed as median (range) or number (proportion) as appropriate.

last 3 months and time on dialysis less than 2 months. Patients were allocated in two groups according to dialysis modality (HD or PD). Twenty-three patients [aged 76 (21–85) years] were treated with HD through an arteriovenous fistula or a graft (Group A) and nine [aged 61 (51–80) years] were treated with PD (Group B). Demographic and clinical characteristics, including age, gender, time on dialysis, mean arterial pressure (MAP), preoperative hemoglobin (preop Hb) and arterial hemoglobin oxygen saturation (SpO_2) were recorded. Comorbidities namely, arterial hypertension (HT) and diabetes mellitus (DM) along with history of cardiovascular disease (CVD) (coronary heart disease, cerebrovascular disease and peripheral vascular disease) were recorder as well.

Standard monitoring equipment, heart rate (HR), electrocardiography (Lead II), non-invasive arterial blood pressure, pulse oximetry was used during surgery. Baseline cerebral oximetry values were recorded upon arriving to the operating room, using the INVOS® (In Vivo Optical Spectroscopy) 5100C monitoring device (Somanetics®, Troy, MI), with sensors placed bilaterally on the patient forehead in accordance with manufacturer instructions. However, as the left hemisphere is considered to be the dominant hemisphere in the vast majority of the general population, we chose to use the left rSO_2 baseline values as the dependent variable in the analysis. Baseline rSO_2 values from the left hemisphere were recorded 3 min after the sensors were applied in all patients. Supplemental oxygen administration (40% by Venturi mask) started after recording of baseline rSO_2 was completed.

The Ethical committee approved this study and an informed consent was obtained by the patient.

Statistical analysis

Data were expressed as median (range) or absolute number and percentage, as appropriate. Kolmogorov–Smirnov test was performed to evaluate the normality of each parameter. Comparisons between two groups of continuous variables were performed by the Mann–Whitney *U*-test, while Fisher's exact test was used for categorical variables. Multiple linear hierarchical stepwise regression analysis was performed to investigate any association between baseline rSO_2 values from the left cerebral hemisphere, and statistical significant variables as derived from the univariate regression analysis, and analyze the contribution of these variables to the observed baseline rSO_2 variability. Comparisons were considered statistically significant when $p<0.05$. All analyses were carried out with SPSS® 17.0 statistical package for Windows® (SPSS Inc, Chicago, IL).

Table 2. Univariate regression analysis.

	Unstandardized coefficients		Standardized coefficients	
Parameter	B	Std. error	Beta	Significance
Age	−0.128	0.129	−0.178	0.330
Preoperative Hb	4.169	1.041	0.590	0.000
MAP	0.066	0.103	0.116	0.526
SpO_2	1.829	0.396	0.645	0.000
CVD	−3.999	4.426	−0.175	0.382
Diabetes mellitus	−3.653	4.717	−0.159	0.447
Hypertension	−1.800	5.721	−0.065	0.756
Duration of RRT	−1.27	0.058	−0.461	0.065
Dialysis modality	−13.266	3.559	−0.563	0.001

Note: Dependent variable: baseline rSO_2.

Results

Demographic characteristics, comorbidities and clinical data, including baseline rSO_2 values from the left cerebral hemisphere (baseline rSO_2 L) are presented in Table 1. Hemodialysis patients were experienced significant lower levels of Hb compared with patients on PD. No statistical significant differences were observed in age, MAP, SpO_2, duration of renal replacement therapy (RRT) and prevalence of HT, DM and history of CVD between the two study groups (Table 1).

Patients who were treated with HD had significant lower rSO_2 values compared with PD patients [median, 50 (28–63) vs. 63 (45–69), $p=0.002$, for group A and group B patients, respectively]. Furthermore, 11 (out of 23) versus 1 (out of nine) patients in group A and B, respectively, experienced levels of rSO_2 lower than 50% (Table 1).

The results from univariate regression analysis are shown in Table 2. Age, MAP and duration of RRT as well as co-morbidities were not statistically significant predictors for cerebral tissue saturation as derived from univariate analysis (Table 2). Hierarchical linear regression model analysis (Table 3) was then performed taking into account the statistical significant variables as derived from an univariate analysis. The analysis demonstrated that preop Hb and SpO_2

Table 3. Multivariate hierarchical stepwise regression analysis with baseline rSO_2 as dependent variable: standardized and unstandardized coefficients.

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. error	Beta	*t*	Significance
1	(Constant)	11.743	10.277		1.143	0.262
	Hb Preop	4.146	1.029	0.593	4.031	0.000
2	(Constant)	−103.171	34.843		−2.961	0.006
	Hb Preop	2.704	0.980	0.386	2.759	0.010
	SpO_2	1.355	0.397	0.478	3.409	0.002
3	(Constant)	−60.860	35.475		−1.716	0.098
	Hb Preop	2.472	0.988	0.353	2.502	0.019
	SpO_2	1.064	0.380	0.375	2.799	0.009
	Dialysis modality	−6.860	3.032	−0.291	−2.262	0.032

Note: Dependent variable: baseline rSO_2.

Table 4. Hierarchical stepwise regression, with baseline rSO_2 as dependent variable.

Model	*R*	R^2	Adjusted R^2	Std. error of estimate	R^2 change	*F* change	Sig. *F*. change
1	0.593[a]	0.351	0.330	8.819	0.351	16.246	0.000
2	0.733[b]	0.537	0.505	7.579	0.186	11.624	0.002
3	0.801[c]	0.642	0.589	6.905	0.068	5.118	0.032

Notes: [a]Predictors: (Constant). Hb Preop.
[b]Predictors: (Constant). Hb Preop, SpO_2.
[c]Predictors: (Constant). Hb Preop, SpO_2, Dialysis modality.

were positive predictive variables ($B = 0.353$, $p = 0.019$ and $B = 0.375$, $p = 0.009$, respectively) for rSO_2. Moreover, dialysis modality was an independent predictor for baseline rSO_2 left (L) and remained independent predictor for rSO_2 after controlling for the other significant variables (B=0.291, $p = 0.032$), while PD (group B) was associated with higher baseline values of rSO_2 (Table 3).

Preoperative Hb is responsible for 33% of the observed baseline rSO_2 variability (adjusted R^2 =0.330, $p < 0.0001$), while preop Hb and SpO_2 combined account for 50.5% of rSO_2 variability (adjusted $R^2 = 0.505$, $p = 0.002$).

Moreover, all independent variables combined (preop Hb, SpO_2 and dialysis modality) account for 58.9% of the observed variability (adjusted $R^2 = 0.589$, $p = 0.032$) (Table 4).

Discussion

The results of this observational study showed that, in patients with ESRD on RRT undergoing elective minor or major surgery, preop Hb, SpO_2 and dialysis modality were predictors for the baseline rSO_2. Moreover, we found that PD, compared with HD, was associated with higher baseline levels of rSO_2 independently of patients' levels of preop Hb and SpO_2.

Given the shortage of data coming from ESRD dialyzed surgical patients, we have compared our findings with the results from other investigators who studied rSO_2 in normal subjects and in cardiac surgical/neurosurgical patients. In line with our results, they have demonstrated that Hb and arterial Hb oxygen saturation could predict cerebral tissue saturation.[6,9] A negative correlation between rSO_2 and age, and a positive correlation with Hb were observed by Kishi et al.[7] Similarly, Yoshitani et al. reported a positive correlation of rSO_2 with Hb concentration and mean arterial pressure.[9] On the other hand, Han et al.[12] found that acute normovolemic hemodilution in patients undergoing orthopedic surgery does not influence rSO_2 values in the absence of hypotension, whilst Green[5] reported a positive correlation of rSO_2 with Hb but a negative correlation with blood loss.

In our ESRD population, although the majority of our patients had a preop Hb level within the proposed range according to the KDIGO guidelines for anemia in chronic kidney disease,[13] it continued to affect significantly the baseline rSO_2 values. In one of the few studies with ESRD population by Stefanidis et al., investigators found that during HD treatment, the percentual changes of mean blood flow velocity in the middle cerebral artery were interrelated among other parameters to the percentual changes of the hematocrit, of the arterial oxygen saturation and of the arterial blood oxygen content.[14] In an another study in HD clinical stable patients, Hirakata et al. aimed at estimating an optimal hematocrit (Ht) for the maximum oxygen delivery to the brain by using both the actual values of cerebral blood flow (positron emission tomography) and the calculated arterial oxygen content (CaO_2).[15] They showed that the oxygen delivery reached a maximum level of only 3.7 ml O_2/100 g/min at Ht of 35.3% in the cerebral hemisphere. They did not object to achieve higher levels of Ht, as normalization of Ht is known to cause a trend of higher mortality rates in HD patients with history of ischemic heart disease.[16] Considering all the above, a low preop Hb level might negatively affect the rSO_2 of dialyzed ESRD patients during elective surgery, which could further result in a complicated postoperative course.

Interestingly, we did not find age and MAP to predict cerebral tissue saturation in our ESRD patients as showed by other investigators in non-uremic patients.[7,9]

Consistent with our results regarding the significant correlation between the percentage reduction rSO_2 and SpO_2, Germon et al. reached the same conclusion in healthy adults during hypoxia.[17]

In our specific population of dialyzed patients, the baseline cerebral oximetry measurements on the left hemisphere were significantly lower in HD compared with PD patients. The median level of rSO_2 in the HD group was 50% and almost half of rSO_2 values were less than 50%. As have been proposed from several studies in different studied populations, a critical threshold of rSO_2 value lower than 50% has been associated with specific adverse events, such as postoperative cognitive dysfunction,[3,18] a higher rate of stroke or coma,[19] increased postoperative morbidity from other nonneurological causes,[20] and a prolonged stay in the high-dependency unit or the hospital.[2] Although, we did not assess surgical complications and survival rates in the studied population, our results could probably support findings of another study which compared perioperative outcomes between HD and PD patients undergoing cardiothoracic surgery. They showed that HD patients had higher incidence of any postoperative complications than PD patients.[21]

Prohovnik et al. showed low oxygen saturation in stable HD patients.[11] The mean level of rSO_2 measured before, during and after a dialysis session was $41\% \pm 13\%$ compared with $70\% \pm 2\%$ in their healthy control group. Transient hypotension, arterial hypoxemia and fluctuations in electrolytes during HD result in cerebral atrophy and possibly induce brain damage. The acute intravascular volume loss and fluid shifts that occur during dialysis induce cerebral edema and decreased intracerebral blood pressure, blood velocity and cerebral perfusion.[22] Furthermore, the endothelial dysfunction because of the chronic inflammatory process and the oxidative stress exacerbate the pre-existent arteriosclerosis in patients with moderate or severe chronic kidney disease and in patients on HD. The above abnormalities are related to each other and potentially contribute to the lower cerebral saturation as well.[23–25] On the other hand, ESRD patients undergoing PD exhibit more normal perfusion.[11] This is in line with our finding and could justify the significant higher cerebral oximetry measurements in the PD group.

We recognize that our study exhibits some limitations. The sample size of our study is relatively small and therefore does not allow for definitive conclusions. The absence of a healthy control group to compare ESRD dialyzed patients is another limitation.

In conclusion, PD patients appear to have significant higher baseline cerebral tissue saturation values compared with HD population. The monitoring of cerebral oxygenation is a very useful tool in the course of some types of surgery. However, more studies are needed, potentially out of the operative room, in this group of patients, to whom dialysis modality, duration of dialysis and optimal control of renal anemia may play an important role in cerebral perfusion and in cerebral oxygenation.

Declaration of interest

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

References

1. Yao FS, Tseng CC, Ho CY, Levin SK, Illner P. Cerebral oxygen desaturation is associated with early postoperative neuropsychological dysfunction in patients undergoing cardiac surgery. *J Cardiothorac Vasc Anesth.* 2004;18:552–558.
2. Heringlake M, Garbers C, Kabler JH, et al. Preoperative cerebral oxygen saturation and clinical outcomes in cardiac surgery. *Anesthesiology.* 2011;114:58–69.
3. Murkin JM, Arango M. Near-infrared spectroscopy as an index of brain and tissue oxygenation. *Br J Anaesth.* 2009;103 (Suppl 1): i3–i13.
4. Goldman S, Sutter F, Ferdinand F, Trace C. Optimizing intraoperative cerebral oxygen delivery using noninvasive cerebral oximetry decreases the incidence of stroke for cardiac surgical patients. *Heart Surg Forum.* 2004;7:E376–E381.
5. Green DW. A retrospective study of changes in cerebral oxygenation using a cerebral oximeter in older patients undergoing prolonged major abdominal surgery. *Eur J Anaesthesiol.* 2007;24: 230–234.
6. Kim MB, Ward DS, Cartwright CR, Kolano J, Chlebowski S, Henson LC. Estimation of jugular venous O2 saturation from cerebral oximetry or arterial O2 saturation during isocapnic hypoxia. *J Clin Monit Comput.* 2000;16:191–199.
7. Kishi K, Kawaguchi M, Yoshitani K, Nagahata T, Furuya H. Influence of patient variables and sensor location on regional cerebral oxygen saturation measured by INVOS 4100 near-infrared spectrophotometers. *J Neurosurg Anesthesiol.* 2003;15: 302–306.
8. Moritz S, Rochon J, Volkel S, et al. Determinants of cerebral oximetry in patients undergoing off-pump coronary artery bypass grafting: an observational study. *Eur J Anaesthesiol.* 2010;27: 542–549.
9. Yoshitani K, Kawaguchi M, Miura N, et al. Effects of hemoglobin concentration, skull thickness, and the area of the cerebrospinal fluid layer on near-infrared spectroscopy measurements. *Anesthesiology.* 2007;106:458–462.
10. Papadopoulos G, Karanikolas M, Liarmakopoulou A, Berris A. Baseline cerebral oximetry values in elderly patients with hip fractures: a prospective observational study. *Injury.* 2011;42: 1328–1332.
11. Prohovnik I, Post J, Uribarri J, Lee H, Sandu O, Langhoff E. Cerebrovascular effects of hemodialysis in chronic kidney disease. *J Cereb Blood Flow Metab.* 2007;27:1861–1869.
12. Han SH, Bahk JH, Kim JH, et al. The effect of esmolol-induced controlled hypotension in combination with acute normovolemic hemodilution on cerebral oxygenation. *Acta Anaesthesiol Scand.* 2006;50:863–868.
13. KDIGO. Clinical Practice Guideline for Anemia in Chronic Kidney Disease Chapter 3: Use of ESAs and other agents to treat anemia in CKD. *Kidney Int.* 2012;2(4):299–310.
14. Stefanidis I, Bach R, Mertens PR, et al. Influence of hemodialysis on the mean blood flow velocity in the middle cerebral artery. *Clin Nephrol.* 2005;2(64):129–137.
15. Hirakata H, Kanai H, Fukuda K, et al. Optimal hematocrit for the maximum oxygen delivery to the brain with recombinant human erythropoietin in hemodialysis patients. *Clin Nephrol.* 2000; 53(5):354–361.
16. Besarab A, Bolton K, Browne JK, et al. The effects of normal as compared with low hematocrit values in patients with cardiac disease who are receiving hemodialysis and epoetin. *N Eng J Med.* 1998;339(9):584–590.
17. Germon TJ, Kane NM, Manara AR, Nelson RJ. Near-infrared spectroscopy in adults: effects of extracranial ischemia and intracranial hypoxia on estimation of cerebral oxygenation. *Br J Anaesth.* 1994;73:503–506.
18. Slater JP, Guarino T, Stack J, et al. Cerebral oxygen desaturation predicts cognitive decline and longer hospital stay after cardiac surgery. *Ann Thorac Surg.* 2009;87:36–44; discussion 44–45.
19. Olsson C, Thelin S. Regional cerebral saturation monitoring with near-infrared spectroscopy during selective antegrade cerebral perfusion: diagnostic performance and relationship to postoperative stroke. *J Thorac Cardiovasc Surg.* 2006;131: 371–379.

20. Murkin JM, Adams SJ, Novick RJ, et al. Monitoring brain oxygen saturation during coronary bypass surgery: a randomized, prospective study. *Anesth Analg.* 2007;104:51–58.
21. Kumar AV, Ananthakrishnan S, Rasgon AS, Yan E, Burchette R, Dewar K. Comparing cardiac surgery in peritoneal dialysis and hemodialysis patients: perioperative outcomes and two-year survival. *Perit Dial Int.* 2012;32(2):137–141.
22. Murray AM, Tupper DE, Knopman DS, et al. Cognitive impairment in hemodialysis patients is common. *Neurology.* 2006;67:216–223.
23. Annuk M, Lind L, Linde T, Fellstrom B. Impaired endothelium-dependent vasodilatation in renal failure in humans. *Nephrol Dial Transplant.* 2001;16:302–306.
24. Oberg BP, McMenamin E, Lucas FL, et al. Increased prevalence of oxidant stress and inflammation in patients with moderate to severe chronic kidney disease. *Kidney Int.* 2004;65:1009–1016.
25. Yilmaz MI, Saglam M, Caglar K, et al. The determinants of endothelial dysfunction in CKD: oxidative stress and asymmetric dimethylarginine. *Am J Kidney Dis.* 2006;47:42–50.