Prediction of Intradialytic Hypotension Based on Oxygen Saturation Variations

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Abstract

Hemodialysis sessions are often complicated by the occurrence of intradialytic hypotension (IDH), mainly due to the decrease of central blood volume. Blood oxygen content may play a role in hypotension onset and can reflect changes in cardiac output and tissue perfusion. Currently, there is an increasing interest in intradialytic monitoring, through the development of biofeedback based technologies aimed to IDH prevention. Blood Oxygen saturation (SO_2) is a patient parameter easy to monitor during hemodialysis thanks to optical noninvasive sensors placed on blood line. The aim of this study was to analyze SO_2 variations in relationship with IDH in ten hypotension prone patients with central venous vascular access. A higher decrease of SO_2 was found in sessions complicated by hypotension, in comparison with stable sessions ($p<0.001$). The existence of predictive information in SO_2 variations in relationship with IDH was evidenced through ROC analysis (AUC=0.631, $CI_{95\%}$ 0.564-0.690).

Our results suggest that SO_2 decrease can characterize sessions complicated with hypotension and monitoring SO_2 could be useful in clinical practice to prevent IDH occurrence.

1. Introduction

Hemodialysis (HD) is a well-established treatment of end stage renal disease (ESRD) patients, able to improve the living conditions of patients, but it is also associated with critical side effects. Intradialytic hypotension (IDH) is the most important and frequent short-term complication of HD, and affects twenty to fifty percent of patients with a 20% incidence of all treatment [1,2]. IDH is the critical consequence of multifactorial causes, but mainly it is due to the decrease of central blood volume resulting from the insufficient refilling of fluid from the interstitial to the vascular compartment. Furthermore, IDH presents a series of symptoms, as dizziness, weakness, nausea, cramps etc. that complicate dialysis sessions with the risk of limiting effectiveness of treatment and determining nursing interventions.

The evolution of dialysis therapy is increasingly direct towards the development of technologies answering to the specific needs of each patient during dialysis sessions with the possibility of IDH prediction and/or prevention. In this context biofeedback system seems able to adapt dialytic therapy to patients status starting from on-line monitoring of patient parameters, such as relative blood volume [3].

Blood Oxygen saturation (SO_2) is a patient parameter that can be continuously and non invasively monitored during dialysis through optical sensors placed on blood lines. A relationship between SO_2 variations and hemodynamic instability is documented in literature [4-6] and it is based on the assumption that blood Oxygen content variations can reflect changes in cardiac output and tissue perfusion in agreement with Fick's principle.

The aim of the study was to analyze SO_2 variations in relationship with hypotension occurrence in dialysis patients with central vascular access.

2. Methods

2.1. Patients

Ten ESRD patients in renal replacement therapy with thrice-weekly standard bicarbonate haemodialysis afferent to different Italian dialysis centres were selected. Patients were eligible if aged between 18 and 85 years old

and after provided informed consent, were monitored along three months without changes of the usual prescription.

Only subjects with central vascular access were selected, and included in the study if hypotension prone, meaning that they were affected by acute intradialytic hypotensive episodes in at least 20% of the last month sessions before the study started.

IDH was defined according the following criteria [7]: 1) if predialysis systolic arterial pressure (SAP) is greater than 100 mmHg, then any episode with SAP less than 90 mmHg, even without complaints; 2) if predialysis SAP is less than 100 mmHg, then any SAP reduction by at least 10% associated with complaints; 3) any SAP reduction of 25% or more of the predialysis value with the typical symptoms requiring specific intervention.

2.2. Hemodialysis equipment and data measurements

All patients were treated with the dialysis monitor Formula Therapy (Bellco srl, Italy) equipped with the optical sensor Hemox (Datamed srl, Italy) placed on the arterial blood line. SO_2 was acquired during the treatment with a frequency of 1 sample per 5 seconds (fc = 0.2 Hz) by means of Hemox.

Systolic and diastolic arterial blood pressures were measured in pre-dialysis phase and every 30 minutes during the treatment by an automatic oscillometric sphygmomanometer (SPHYGMO, Bellco srl, Italy).

The occurrence of typical low blood pressure symptoms (muscular cramps, headache, dizziness, vomiting, nausea, sweating) and time of appearance were also recorded, as well as every fluid infusion (saline, plasma expanders, sodium).

All data downloaded by the monitors were stored and analyzed in a personal computer (HP Pavilion dv6000) equipped with Matlab 7.8 and NCSS 2007.

2.3. Data analysis

Dialysis sessions were classified according to the presence or absence of hypotensive event (Hypo or NoHypo, respectively).

To analyze temporal variation of SO_2, mean values for 30-min interval were calculated. A delta value of Oxygen saturation (ΔSO_2) was calculated as difference between the SO_2 mean value in the last 30 minutes before the end of treatment (in NoHypo sessions), or before a hypotensive episode (in Hypo sessions) and SO_2 mean value in the first 30 minutes.

According to Cordtz et al [4], a preliminary investigation of SO_2 variation predictive power in relationship with IDH occurrence, was done considering the ΔSO_2 corresponding to the first 150 minutes (the average time at which IDH occurs [8]). Then, a more rigorous analysis was carried out setting a 30-min length temporal window, 1 minute shifting, from the beginning of the session to the hypotensive episode in Hypo sessions or until 30 minutes before the end of session in NoHypo sessions.

2.4. Statistics

Values are expressed as mean ± standard deviation (SD) or standard error (SE).

Intergroup comparison were made using the unpaired t test, while a paired t test was performed for in intragroup comparisons. ROC curves analysis was run to identify a threshold leading to a good compromise between sensitivity and specificity. Statistical analysis was performed with NCSS 2007 and Matlab Statistic Toolbox.

3. Results

The sessions analyzed were 365: 124 sessions were classified as Hypo due to the presence of a hypotensive event and 241 were classified as NoHypo. In Figure 1 are shown systolic and diastolic blood pressure (top panels) and SO_2 signal (bottom panels) of exemplificative sessions with and without hypotension (left and right panels, respectively).

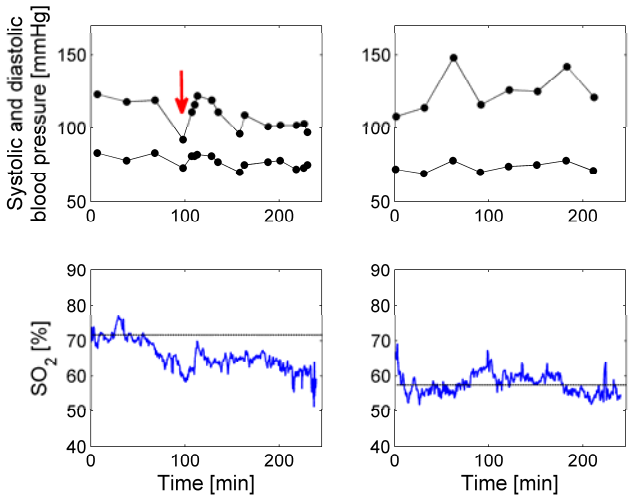

Figure 1. Blood pressure and SO_2 signal during exemplificative Hypo and NoHypo session. The red arrow indicates the time of hypotension occurrence. In SO_2 panels the dashed line is the mean value of SO_2 in the first 30 minutes.

Table 1 summarize treatment characteristics of Hypo and NoHypo sessions: only postdialysis systolic and

diastolic blood pressure were found significantly different ($p<0.001$).

Table 1. Values obtained during sessions with or without hypotensive event, Hypo or NoHypo, respectively.

Treatment characteristics	Hypo	NoHypo	p
Systolic BP (mmHg)			
Predialysis	126 ± 40	127 ± 27	ns
Postdialysis	110 ± 29	132 ± 29	0.001
Diastolic BP (mmHg)			
Predialysis	68 ± 18	70 ± 14	ns
Postdialysis	61 ± 17	73 ± 14	0.001
Duration (min)	217 ± 24	222 ± 24	ns
SO_2, first 30 min (%)	60 ± 10	60 ±11	ns

Values are mean ± SD
BP = blood pressure; ns = nonsignificant; SO_2 = Oxygen saturation

In Table 2 are reported delta blood pressure values measured at the end of treatment (NoHypo sessions) or before a hypotensive event (Hypo sessions) and ΔSO_2 from the last 30 minutes of treatment or before the hypotensive event. The different distribution of ΔSO_2 in Hypo and NoHypo sessions is shown in Figure 2.

Results of ROC analysis are shown in Figure 3. Dashed grey curve was obtained considering ΔSO_2 during the first 150 minutes: the AUC was 0.720 ($CI_{95\%}$ 0.657-0.773). Setting a threshold value, e.g. equal to -4.77, Sensitivity reached 60% ($CI_{95\%}$ 0.508-0.682) and Specificity was 75% ($CI_{95\%}$ 0.691-0.802). Solid blue curve was obtained through ΔSO_2 computed by a 30-min-length shifting window: AUC was 0.631 ($CI_{95\%}$ 0.564-0.690); choosing a threshold value equal to -7.80 Sensitivity was 62% ($CI_{95\%}$ 0.537-0.709) and Specificity was 60% ($CI_{95\%}$ 0.535-0.659).

4. Discussion and conclusions

In our study, we have found that sessions complicated with hypotensive episode are characterized by a higher decrease of SO_2 with respect to hemodynamically stable sessions. This result is in agreement with what demonstrated by Cordtz et al [4]. In fact they found that hypotension prone patients exhibited a SO_2 decrease during dialysis session, while this decline was not observed in hypotension resistant patients. The most interesting and innovative aspect of our study, is that patients selected were all affected by acute intradialytic hypotensive episodes in at least 20% of sessions. Even in NoHypo sessions we found a negative mean ΔSO_2 but with an absolute value significantly minor than ΔSO_2 of Hypo sessions ($p<0.001$).

Based on these results, distinguishing Hypo e NoHypo sessions could be realistic and more relevant than

Table 2. Mean values measured at the end of treatment or before a hypotensive event.

	Hypo	NoHypo	p
ΔBP_{sys} (mmHg)	-46.7 ± 2.8‡	5.8 ± 1.6	0.001
ΔBP_{dias} (mmHg)	-15.5 ± 1.4‡	3.0 ± 0.9	0.001
ΔSO_2 (%)	-7.5 ± 0.6‡	-3.6 ± 0.4	0.001

Values are mean ± SE
‡ Value significantly different ($p<0.001$) from the predialysis BP value and SO_2 in the first 30 minutes
ΔBP = changes in systolic and diastolic blood pressure; ns = nonsignificant; ΔSO_2 = changes of Oxygen saturation

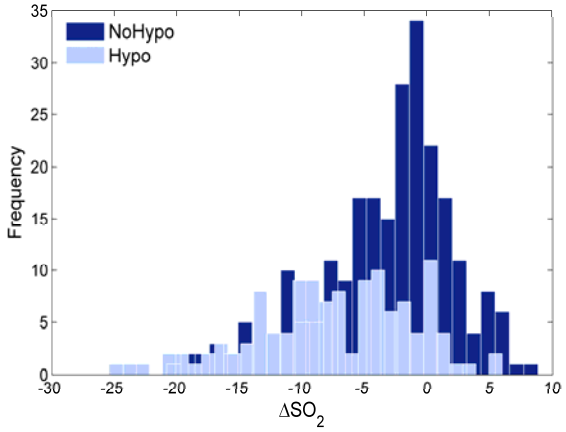

Figure 2. ΔSO_2 distribution in Hypo and NoHypo sessions.

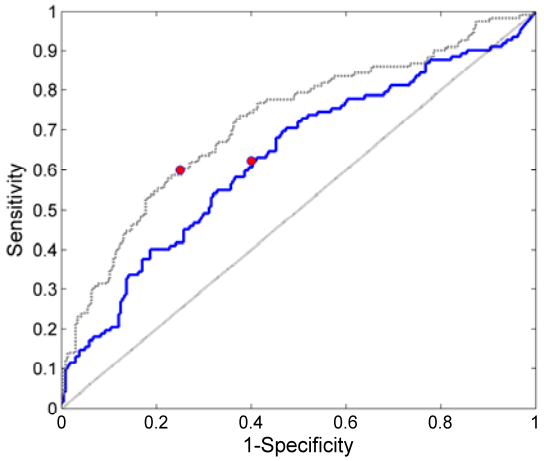

Figure 3. ROC curves obtained considering ΔSO_2 during the first 150 minutes (dashed grey curve) and ΔSO_2 computed in temporal window of 30-min length, 1 minute shifting, from the beginning of the session to the hypotensive episode in Hypo sessions or until 30 minutes before the end of session in NoHypo sessions (solid blue curve). Red circles indicate exemplificative threshold values.

recognizing HP and HR patients as shown by the ROC analysis.

In conclusion, our study suggests that SO_2 decrease can reflect hemodynamic instability and characterize sessions complicated by hypotension. Monitoring SO_2 variations could be useful in clinical practice in order to prevent IDH occurrence. Larger studies are needed to evaluate and plan the possible use of SO_2 also in combination with other parameter to potentiate the effectiveness of intradialytic monitoring.

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