



Fluid management in the neurointensive care patient using transcranial doppler ultrasound: Preliminary study

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ABSTRACT

Background: Fluid management in the neurointensive care patient is aimed at maintaining an adequate cerebral blood flow. Recent data suggests that an adequate fluid administration may have an important role on outcome.

Materials and methods: in this preliminary study we evaluated the use of mean flow velocity normalization as a parameter to guide fluid therapy in neurointensive care patients. We recruited all patients after craniotomy surgery between September 2016 and August 2017 not septic, without cardiac pathologies or pregnancy, with ages of 42 ± 21 standard deviation (SD) and compared pulse pressure variation (PPV) and middle cerebral artery mean velocity (MCA-MV) using transcranial doppler ultrasound (TDU) to guide fluid therapy. The goal was normalization by age of MCA-MV values using fluid therapy with crystalloids, and the main outcome was mortality rate.

Results: 50 patients were recruited with no significant differences in APACHE-II score and all patients had PPV > 15% and low MCA-VM at admission. Hospitalization ($55,1 \pm 13,8$ SD Vs $51,3 \pm 15,1$ SD) and mechanical ventilation ($6,6 \pm 7,8$ SD vs. $5,4 \pm 10,7$ SD) days had no significant difference as outcome with $P = 0,949$ and $0,654$ respectively, control patients after PPV normalization who didn't achieve the MCA-MV goal had fatal outcome and according to that mortality was significantly high in the control group with 36% compared with 8% in TDU group with $P = 0,017$, MCA-MV in control patients with fatal outcome and was significantly lower than those who survived ($P < 0,01$).

Conclusions: MCA-MV normalization by age may be an objective tool to guide fluid therapy in neurointensive care patients, however, a larger outcome study is recommended to confirm this hypothesis.

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1. Introduction

Transcranial Doppler Ultrasound (TDU) was introduced in clinical practice since 1982 [1] to measure cerebral blood flow velocity. It is widely used in neurointensive care and useful in adults and pediatrics to assess critical conditions like vasospasm in subarachnoid hemorrhage, traumatic brain injury, acute ischemic stroke and even brain stem death [2].

Several expert consensus recommend its use in Intracranial Pressure monitoring, Cerebral perfusion pressure [3] and a recent study performed by Hung Z in 2016 suggested the use of TDU to guide fluid therapy in patients with vasospasm associated with subarachnoid hemorrhage with good results [4]. Muñoz-Sánchez M et al. studied in 2004 the hemodynamic variables like middle

cerebral artery (MCA) mean velocity (MV) and pulsatility index (PI) to diagnose hemodynamic situations in the brain and found that MV modifications were associated with brain volume status when compared with age adjusted MCA-MV normal values [5]. In base of all described before we performed a preliminary study with the hypothesis of TDU MCA-MV which may guide fluid therapy in patients after brain surgery.

2. Materials and methods

In order to observe the utility of the Transcranial Doppler Ultrasound (TDU) as a tool to fluid management in the neurointensive care patient in this preliminary study we gained approval from the Venezuelan Central University ethical committee in August 2016. We recruited all patients admitted to the Intensive Care Unit (ICU) at Caracas University Hospital in Caracas-Venezuela between September 2016 and August 2017 after craniotomy intervention, in mechanical ventilation support, using as exclusion criteria for

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septic patients, acute respiratory distress syndrome, chronic heart failure history, vasopressors use, infections, pregnancy or immunologic diseases. After obtaining all patients written informed consent approvals we divided the patients using a simple randomization method into two groups using computer generated random numbers. In both, invasive pulse pressure variation and TDU was performed each hour by a single trained operator with a Phillips Sparq ultrasound manufactured in Eindhoven-Netherlands and 3–5 MHz sectorial probe.

In the Control group, fluid goals were managed using pulse pressure variation (PPV) in order to obtain PPV between 11 and 14% and using intravenous 100 ml/h Ringer Lactate with PPV > 15%. The other group was the Experimental group where the fluid management goal had mean velocity (MV) of the middle cerebral artery (MCA) measured using TDU. Normal MV was obtained from the Ringelstein E et al. [6] studies by age and standard deviation and hemodynamic status using the adapted Muñoz-Sanchez M et al. chart [5]. We used the Ringer Lactate 100 ml/h in those with MV standard deviation which was lower than normal values in order to return to normal velocities.

We observed ventilation days, ICU hospitalization days and survival to compare both procedures, all data was analyzed using GraphPad PRISM 6.0 for Windows and results presented in tables and graphics using mean and standard deviation (SD) and percentage, for quantitative comparison between groups. Students T test was calculated, and for qualitative variants Chi square normal distribution was calculated, accepting a significant variability of $p < 0,05$.

3. Results

A total of 50 patients were recruited between September 2016 and August 2017. 25 patients were in each group with mean age 42 ± 21 of SD, 24 females and 26 males with a mean APACHE II score of $6,0 \pm 5,5$ SD with no significant difference between groups ($P = 0,093$). All patients had PPV > 15% or MCA-MV below normal value at admission requiring fluid therapy, PPV at admission was $21,4\% \pm 5,0$ SD ($P = 0,78$ between groups) and middle cerebral artery mean velocity (MCA-MV) of $34,9 \text{ cm/s} \pm 9,6$ SD ($P = 0,59$) (Table 1).

All patients achieved PPV between 11 and 14% and we observed a significant increase of MCA-MV after fluid therapy ($P < 0,0001$) (Fig. 1). The control group required a mean of $400 \text{ ml} \pm 108$ SD and TDU group $452 \text{ ml} \pm 87,1$ SD with not a significant difference between them $p = 0,067$. However in control group, 36% of patients after PPV goal achieved did not achieve a normal MCA-MV with those patients having a fatal outcome. Comparing MCA-MV in patients with fatal outcome in the control group and with those who survived we found a significant difference with $P < 0,0001$ where

MCA-MV of those with fatal outcome were $22,6 \text{ cm/s} \pm 3,4$ SD and those who survived $54,2 \text{ cm/s} \pm 14,2$ SD (Fig. 2). We also found that the amount of fluid given to those patients who did not survive was significantly lower than those who survived even after achieving a PPV goal of $P = 0,013$ ($435,3 \text{ ml} \pm 111,5$ SD Vs $325 \text{ ml} \pm 46,2$ SD).

After comparing mechanical ventilation days, we found no significant difference between the groups. In the control group, mechanical ventilation days mean was $6,6 \pm 7,8$ SD and TDU had $5,4 \pm 10,7$ SD with a $p = 0,654$. Hospitalization days did not have any significant difference and in the control group the mean was $7,9 \pm 8,3$ SD and TDU group $7,7 \text{ days} \pm 13,3$ SD with a $p = 0,949$. Mortality was significantly higher in the control group, with a 36% mortality compared with 8% of the TDU group, Chi² $P = 0,017$ (Table 1). No fluid overload in side effects was observed in any patient.

4. Discussion

The present study found that MCA-MV increases after crystalloids volume infusion as reported by Muñoz-Sanchez et al in 2004 [5] meaning that TDU could be a useful tool to evaluate cerebral hemodynamic changes. Actual methods recommended by literature in brain-injured patients to guide fluid therapy are central venous pressure, pulmonary wedge pressure or cardiac index measure [7] but all of them are invasive and expensive; the earliest consensus recommends the use of less invasive and dynamic parameters like pulse pressure variation (PPV), stroke volume variation or transesophageal doppler to improve volume status [8] and reduce brain insults.

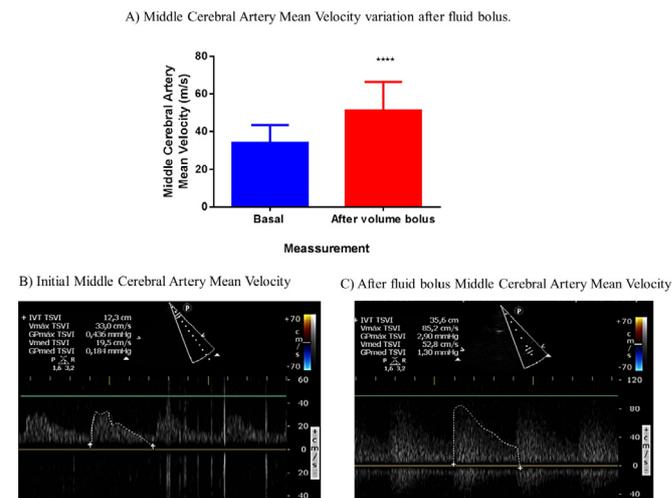


Fig. 1. Middle cerebral artery Mean Velocity variation after volume bolus administration.

Table 1
Sample information.

	All	Control	TDU	P
Sample (n)	50	25	25	—
Female (n/%)	24 (48)	11 (45,8)	13 (54,2)	—
Male (n/%)	26 (52)	13 (50)	13 (50)	—
Age (mean \pm SD)	41,9 \pm 20,9	37,3 \pm 20,1	46,6 \pm 21,1	0,011
APACHE II Score (mean \pm SD)	6,0 \pm 5,5	4,7 \pm 5,0	7,4 \pm 5,8	0,093
Initial Pulse Pressure Variation % (mean \pm SD)	21,4 \pm 5,0	21,6 \pm 5,2	21,2 \pm 4,8	0,781
Final Pulse Pressure Variation % (mean \pm SD)	12,7 \pm 0,9	12,7 \pm 0,8	12,8 \pm 1,0	0,886
Initial Mean Velocity cm/s (mean \pm SD)	34,9 \pm 9,6	35,6 \pm 10,2	34,2 \pm 9,1	0,591
Final Mean Velocity cm/s (mean \pm SD)	53,2 \pm 14,4	55,1 \pm 13,8	51,3 \pm 15,1	0,353
Hospitalization days (mean \pm SD)	6,0 \pm 9,3	7,9 \pm 8,3	7,7 \pm 13,3	0,949
Mechanical Ventilation Days (mean \pm SD)	7,8 \pm 11,0	6,6 \pm 7,8	5,4 \pm 10,7	0,654
Survival (n/%)	39 (61)	16 (64)	23 (92)	0,017

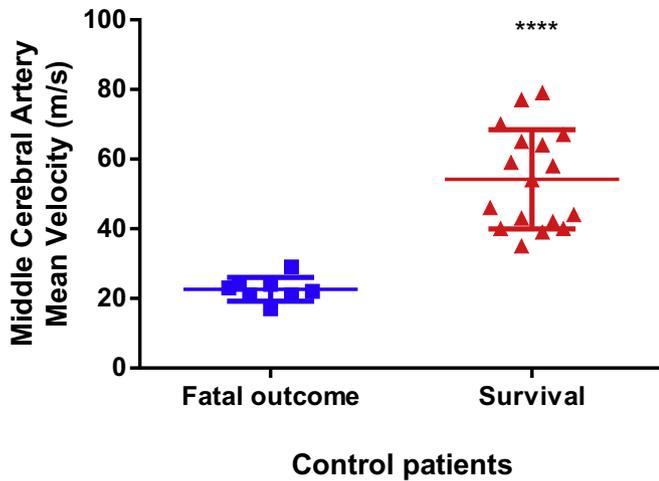


Fig. 2. Middle cerebral artery mean velocity after fluid therapy in control patients.

The latest publications recommend the use of multimodal fluid monitoring to reach normovolemia and avoid the complications of hypovolemia and hypervolemia that can increase the risk of mortality and hospitalization days in the neurointensive care patient [10]. There is only one study reporting the use of TDU to guide fluids in neurointensive care patients in 2 clinical cases [4] with good results, however it did not report mechanical ventilation days or compared the mortality outcome.

The use of MCA-MV may be influenced by many factors such as the ultrasound method. Observer training is important; there are also hemodynamic factors like vasospasm, vasculitis, stenosis or hypocapnia that can modify arterial velocities [9]. This is the first study in neurointensive care patients using MCA-MV as a hemodynamic endpoint to guide fluid therapy, however, as a preliminary study, the sample size was small and the need for more prospective large trials are required.

As observed in our results, using TDU MCA-MV normalized by age to guide fluid therapy it can reduce mortality in neurointensive care patients compared with PPV alone but without statistical differences in ICU hospitalization or mechanical ventilation days. We can conclude that MCA-MV normalization by age can be an objective tool to guide fluid therapy in neurointensive care patients improving blood flow and reducing mortality, however more studies with a larger population are necessary to confirm the hypothesis of this preliminary study.

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