Evaluation of Closed Head Injury Patients Using Transcranial Doppler Monitoring

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Introduction

Continuous recording of basal cerebral artery velocities using transcranial Doppler may provide a more practical alternative to CBF methods for the assessment of cerebrovascular responses in patients with head injury and other neurological conditions requiring ICP management. A method is described where continuous recordings of blood flow velocity (BFV), arterial blood pressure (ABP), intracranial pressure (ICP), and end tidal CO_2 (Et CO_2) are obtained by portable equipment which can easily be taken to the ICU. This unit can then be used to test blood flow response to CO_2 changes, autoregulation, response to barbiturates and response to mannitol therapy. By obtaining information on the effectiveness of these responses in head injury patients, it may be feasible to use this information to guide therapy.

Clinical Material and Methods

The feasibility of TCD monitoring was evaluated in 22 patients with a diagnosis of closed head injury Age range was 16–69 with a mean of 36. Average Glasgow coma score (GCS) was 6. These patients had continuous ABP, ICP, and Et CO_2 monitoring and were artificially ventilated during their initial hospital course.

Middle cerebral velocity (MCV) signals were located through a transtemporal window, using probes fixed with an elastic headband during the recording sessions. Analog signals from the 4 different modalities were then stored digitally by computer and a custom software program was used to analyze the results.

Reactivity to CO_2 was tested by inducing step changes in arterial CO_2 concentration by temporarily disconnecting the patient from the ventilator and hand ventilating, for at least 2 minutes. The values from stable recording periods from before and after the manipulation were then averaged, and the percentage response (blood flow velocity change per mm CO_2 change) was calculated.

Autoregulation was tested according to the method of Aaslid et al. by inflating leg cuffs around both thighs to a suprasystolic blood pressure for a period of 2 minutes and then rapidly deflating them, inducing a systemic blood pressure drop. The relative change in CBF (evaluated by the change in mean MCA velocity) was observed following the sudden blood pressure decrease and recovery. Relative changes in velocity in comparison to relative ABP changes were examined relative to their control values immediately following the BP drop. The rate of regulation (RoR), was defined as the change in calculated cerebrovascular resistance/the change in time, divided by the change in ABP. In a previous study of a group of healthy volunteers at normocapnia, the normal value for RoR was found to be 20 ± 3 [1].

Response to mannitol was tested by giving 4 mg/kg of 20% mannitol intravenously over 5 minutes. Continuous recording of all parameters was then performed for at least 20 minutes following the end of the infusion. Change in blood flow velocity was then calculated as the maximum percentage change that occurred following the infusion. This usually occurred 10 minutes after the mannitol was given.

Response to barbiturate was assessed by rapidly infusing a loading dose (5 mg/kg) of thiopentone according to the method of Cold et al., and observing the response in blood flow velocity, ABP, and ICP. Relative blood flow change was determined from the percent change in blood flow velocity following the infusion.

Results

CO_2 Testing

Middle cerebral artery velocity response to CO_2 was tested in 20 patients. The results obtained showed reactivities between 0 and 4.63% change/mmHg. The results of CO_2 reactivity within 48 hours of admission for both hemispheres were combined and compared to Glasgow outcome score at 1 month in 15 patients. CO_2 reactivity was higher in patients who made a good recovery or had a moderate disability (2.25%/mm CO_2 ± 0.87) than those who died, were severely disabled, or were in a persistant vegetative state (1.51%/mm CO_2 ± 0.25), but the difference was not statistically significant ($0.1 > p > 0.05$).

Autoregulation

The rate of regulation, which was calculated from the change in cerebrovascular resistance induced by sudden transient decreases in blood pressure, varied from 0 to 29.4 in the 118 studies performed. The results indicated that in this group of patients the autoregulation response was not either absent or present but could be impaired to varying degrees. In selected patients there were marked differences between the hemispheres. There was no correlation of RoR to admission GCS or outcome at 1 month.

Mannitol Response

Following mannitol infusion most patients had an increase in middle cerebral artery velocity. The greatest increase occurred ten minutes following the end of the infusion. The degree of increase in MCV was greatest in those patients with the most impaired autoregulation and least in patients with intact autoregulation but the number of patients with completely intact autoregulation was small. Regression analysis showed an inverse correlation between RoR and MCV increase following mannitol infusion ($r = -0.59$).

Barbiturate Response

Following barbiturate administration the typical response which was seen was a transient drop in blood pressure followed by a return to pre-infusion or near pre-infusion values in some patients, and a more persistant blood pressure drop in others. Patients judged to have a favorable response to barbiturates had a decreased blood flow velocity and a decreased ICP, without a significant drop, or in some cases an improvement, in perfusion pressure. Patients who were judged to have an unfavorable response had either a minimal change in blood flow velocity and ICP or a significant drop in cerebral perfusion pressure.

Discussion

Recording of blood flow velocities in the basal cerebral arteries does not give an absolute value for CBF; however, the velocity change is directly proportional to the changes in blood flow provided the diameter of the conducting artery remains constant [1, 2]. This has been demonstrated by Lindegaard et al. [7] in humans by observing spontaneous blood flow changes during carotid endarterectomy while simultaneously recording MCV using Doppler ultrasound and carotid blood flow using an electromagnetic flowmeter. These results indicate that under these circumstances basal artery diameter must not vary to any significant degree because the majority of the velocity changes are directly reflecting changes in flow. To gain an index of the effectiveness of autoregulation or CO_2 responsiveness in patients, knowledge of the absolute blood flow is not necessary [3, 4, 5, 8]. More valuable is a continuous measure of relative changes in blood flow under changing conditions of ICP, ABP, or CO_2. Recent experimental evidence has supported the validity of the TCD method for determining autoregulation [2, 6]. More research is needed to determine the relationship between CBF and MCA velocity in response to different medications.

References

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