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ORIGINAL ARTICLE

Transcranial Doppler study in patients with cluster headache

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KEYWORDS

Transcranial Doppler;
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Abstract *Background:* Hemodynamic changes occur in the cerebral blood flow during cluster headache.
Objective: The aim of the present work was to study the middle cerebral artery blood flow velocities and vasoreactivity in cluster headache patients as baseline values and after administration of 100% oxygen during the cluster period.
Materials and methods: Three groups were studied. The 1st consisted of 12 patients with cluster headache, the 2nd consisted of 12 patients with unilateral migraine, and the 3rd one was healthy controls. The three groups had baseline velocity measurement of the MCA bilaterally by transcranial Doppler at standard conditions and after inhalation of 100% O_2. Then breath-holding was allowed to calculate the breath holding index.
Results: The breath holding index following administration of oxygen (BHI-O_2) was higher in the cluster group compared to the migraine group and the difference was statistically significant ($t = 2.811$ when $P = 0.010$). There was a statistically significant inverse correlation between the severity of the cluster attacks and the breath holding index ($r = 0.750$ when $P = 0.005$).
Conclusion: Cerebral vessels are more reactive to stimuli after O_2 inhalation in patients with cluster headache. Cerebrovascular reactivity may be one of the future predictors of good response to O_2 therapy in patients with cluster headache.

1. Introduction

Hemodynamic changes in cluster headache (CH) have received less attention compared with the entity of signs/symptoms of the disease. Administration of oxygen during the CH attack has been demonstrated to reduce/interrupt the pain in 70% of the patients.[1,2] Few studies have focused on cerebral blood flow (CBF) during the different phases of CH (active/remission), and the effect of oxygen therapy on it.

Recently, transcranial Doppler (TCD) monitoring of cerebral blood velocity (CBV) at the middle cerebral artery

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(MCA) level has been found to be a very useful method to investigate the intracerebral vascular changes, which may have a role in CH pathogenesis.[3,4]

2. Aim of the work

The aim of the present work was to measure middle cerebral artery blood flow velocities and vasoreactivity in cluster headache patients during the cluster period and following administration of 100% oxygen.

3. Patients

This study was conducted on 24 patients presented to the neurology department at El-Hadara University Hospital with cluster and migraine headaches and 12 healthy controls as follows:

- **Study group**: 12 patients complaining of cluster headache during the cluster period.

  Control groups:

  Patient control group: 12 patients complaining of unilateral migraine without aura.

  Healthy control group: 12-age matched-healthy volunteers.

  Diagnostic criteria of cluster headache and migraine according to the International Headache Society (IHS) were applied for inclusion of the patients[3,4]:

  Exclusion criteria:
- Patients with prior history of stroke.
- Patients on vasoactive drugs.
- Patients recently received acetazolamide.
- Patients with hematocrit <33 or $>47\%$.
- Patients with mean arterial blood pressure >150 or <50 mmHg.

Both patient groups had not received abortive or prophylactic medications for at least 24 h prior to the examination.

4. Methods

4.1. All patients were subjected to the following:

1. Questionnaire for analysis of headache[5] and headache pain severity scale.[6]
2. Thorough medical and neurological examination.
3. Laboratory investigations when needed.
4. Neuroimaging (CT brain or MRI brain) when needed.
5. Transcranial Doppler examination: recording was performed in a quiet comfortable place. A 2-MHz pulsed Doppler ultrasound system (Multidop P, DWL Elektronische System GmbH, Sipplingen, Germany) was used to measure the following parameters:
   A. Peak systolic velocity (PSV)
   B. Mean velocity (MV)
   C. End diastolic velocity (EDV)
   D. The breath holding index (BHI) was calculated as percent increase in MCA mean blood velocity recorded by breath holding divided by seconds of breath holding. $([Vbh - Vr/Vr] \times 100/S)$ where Vbh is MCA mean blood velocity at the end of breath holding, Vr is MCA mean blood velocity at rest and S is the time in seconds of breath holding.[7]

The transcranial Doppler studies were done twice for each person; one as a baseline and the other after 5 min of 100% O2 inhalation at a flow rate of 10 liters per minute.

4.2. Statistics

Student's t test, one way ANOVA, Pearson correlation test and Chi Square test were done using SPSS package version 13.

5. Results

5.1. Demographic data

- The cluster group consisted of 12 patients; all were males (100%).
- The migraine group consisted of 12 patients; eight were females (66.67%).
- The control group consisted of 12 healthy volunteers; there were seven males (58.33%).

5.2. Comparing flow velocity changes after O_2 administration

On comparing the cluster group to the migraine group after oxygen inhalation; MCA mean flow velocity in the cluster headache group was lower (44.58 ± 8.83 SD cm/s) compared to the migraine group (53.67 ± 6.01 SD cm/s), and this difference was statistically significant (Table 1).

5.3. Comparing BHI after O_2 administration

On comparing the breath holding index following oxygen inhalation; (BHI-O_2) was significantly higher in the cluster group than in either the migraine group, (mean 0.91 ± 0.19

Table 1 Comparison between the mean velocities of the three groups before and after oxygen inhalation.

Mean velocity of MCA on the symptomatic side	Cluster headache	Migraine	Healthy control	F (p)
Baseline	72.08 ± 10.41	73.42 ± 5.16	70.75 ± 6.55	0.319 (0.729)
	$t = 0.332$ (when $p = 0.743$)			
After O_2 inhalation	44.58 ± 8.83	53.67 ± 6.01	62.61 ± 5.84	23.94 (0.001)*
	T 2701 = (when $p = (0.001)$)*			

* Statistically significant.

Table 2 Comparison between the breath-holding indexes of the three groups before and after oxygen inhalation.

BHI	Cluster headache	Migraine	Healthy control	F (p)
Baseline	0.86 ± 0.13 t = 0.332 (when p = 0.743)	0.79 ± 0.13	0.75 ± 6.55	0.453 (0.640)
After O_2 inhalation	0.91 ± 0.19 t = 2.811 (when p = 0.010)*	0.68 ± 0.20	0.62 ± 0.09	10.47 (0.001)*

* Statistically significant.

SD), or the controls (mean 0.68 ± 0.20 SD), respectively (Table 2).

5.4. Correlation between pain severity and either mean baseline velocity or BHI

There was a statistically significant inverse correlation between the severity of the cluster attacks and the breath-holding index (r = 0.750 when P = 0.005). The baseline mean flow velocity of the MCA was increased significantly in correlation with the severity in the cluster patients, so the more severe the cluster attacks were, the higher mean flow velocity encountered in the MCA (r = 0.954 when P = 0.043).

6. Discussion

In recent years, TCD has been applied to studies of the pathophysiology of migraine,[8,9] cluster headache, [3,4] tension-type headache,[10] and experimental headache.[11,12] It provides a simple method of determination of cerebrovascular reactivity, which reflects the capacity of the cerebral vessels to react to changes of arterial CO_2 partial pressure with dilatation and constriction, thus showing their autoregulatory capacity.[13,14]

The dynamics of cerebral blood flow before and during the pain phase of CH have been investigated by noninvasive neuroimaging studies. Transcranial Doppler ultrasonography (TCD) and magnetic resonance arteriography (MRA) have shown an initial phase of vasodilatation with concomitant decrease of blood flow velocities in intracranial arteries during the headache phase, both in spontaneous and nitroglycerin-induced CH.[15–18]

It is unclear whether these vascular changes are causally related to the head pain of CH or whether they merely represent a phenomenon associated with a primary neural discharge.[19]

Studies investigating the diagnostic value of ultrasonic features in cluster headache have not provided encouraging results because of their low sensitivity. However, preliminary results suggest that the study of cerebrovascular reactivity may enhance the diagnostic yield of TCD and provide information on the pathophysiology of cluster headache.[20]

Most of the studies were in accordance with the findings of the present study, they have shown an increase in the cerebrovascular reactivity in the symptomatic side, compared to the non-symptomatic side[15] which goes with the vascular theory of the cluster headache.[21]

On comparing the breath holding index following administration of oxygen (BHI-O_2) it was higher in the cluster headache group which showed a statistical significance.

Most of the studies addressing cerebrovascular reactivity using TCD were studying the migraine headache, they showed variability, some studies found a normal cerebrovascular response to CO_2 in migraineurs,[22] others reported reduced reactivity,[23,24] however, most of the investigators agree that increased cerebrovascular reactivity is a feature of migraine.[25]

One study was conducted on cluster headache patients by Shen JM et al.,[26] there was a significant difference in intracranial artery vasomotor reactivity (VMR) between patients and controls in response to hypocapnia, also the difference of VMR between the bout and remission on the symptomatic side showed a statistical significance. But, they found that this difference disappeared 30 min after the headache phase. This study used voluntary hyperventilation rather than the breath-holding technique. They insonated the anterior cerebral artery. However, to the best of our knowledge, no study compared between the vasomotor reactivity before and after O_2 administration.

Also, to the best of our knowledge, there was no study found correlating the severity of the attack with the vasoreactivity considering the cluster headache patients.[27]

7. Conclusion

The cluster patients showed significantly lower mean flow velocity compared to the migraine group after oxygen inhalation following breath holding. The breath holding index following oxygen inhalation is significantly higher in the cluster patients compared to the migraine patients.

There was a statistically significant inverse correlation between the severity of the cluster attacks and the breath holding index.

8. Recommendations

More studies should be conducted to give a more clear explanation to the pathophysiology of the cluster headache.

More studies should be conducted to correlate the cerebral vasoreactivity after oxygen inhalation and the abortive effect of oxytherapy to the cluster attack.

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