CO₂ Reactivity and Autoregulation in Severe Head Injury: Bedside Assessment by Relative Changes in Arteriojugular Differences of Oxygen

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Introduction

It has been demonstrated both clinically and in experimental models that autoregulation and CO₂ reactivity can be impaired independently of each other in many brain insults, the so-called dissociated vasoparalysis [1]. The theoretical combination of preserved CO₂ reactivity and impaired or absent autoregulation can have many clinical implications in the overall daily management of brain-injured patients. To optimize their treatment, a bedside assessment of autoregulation and CO₂ reactivity is desirable. In spite of some unresolved and controversial methodological problems, monitoring hemodynamic parameters through a reverse catheter with its tip in the jugular bulb is an easy way of monitoring brain metabolism and cerebral blood flow (CBF) coupling and in some cases of estimating CBF [2–4]. When the cerebral metabolic rate of oxygen (CMRO₂) is constant, changes in arteriojugular differences of oxygen (AVDO₂) reflect changes in CBF [5]. In this situation, relative changes in AVDO₂ can be viewed as inverse changes in CBF and used as an evaluation method of CO₂ reactivity and autoregulation. Our aims in this chapter are to use relative changes in AVDO₂ after manipulations of mean arterial blood pressure and arterial pCO₂ to assess CO₂ reactivity and autoregulation in severe head injury patients.

Patients and Methods

In 48 consecutive severe head injury patients (postresuscitation, prehospital or admission Glasgow Coma Score (GCS) ≤8) with a mean age of 30 ± 18.4 years and a diffuse brain injury, cerebrovascular response to changes in
pCO₂ was tested within the first 24 h after injury. Diffuse brain injury was considered in all the patients with no midline shift above 3 mm and no measured focal lesions above 25 ml. In 28 of these patients, autoregulation was also assessed. Immediately after admission a radial artery was canaled in each patient and a 14G catheter inserted percutaneously in the internal jugular bulb (IJ) using the technique described by Goetting and Preston [6]. The catheter was placed, whenever possible, in the right jugular bulb. X-Ray verification of the catheter position was obtained in all patients before obtaining jugular blood samples. Those cases with inappropriate situation of the reverse IJ catheter were excluded. Arterial and jugular blood samples were obtained at the same time, at least twice during the first 24 h after injury. AVDO₂ were calculated by the following equation: 

\[ \text{AVD}O_2 = 1.34 \times \text{Hb(SaO}_2 - \text{SjO}_2) \]

**CO₂ Reactivity Studies**

To test CO₂ reactivity, and as a first step, arterial and jugular blood samples were extracted to establish baseline values for pCO₂ (pCO₂B), arterial pO₂, oxyhemoglobin saturation in the jugular bulb (SjO₂B), arterial oxyhemoglobin saturation (SaO₂), hemoglobin content (Hb), and basal arteriojugular differences of oxygen (AVDO₂B). Basal intracranial pressure (ICP_B) and mean arterial blood pressure (MABP) were also determined. These values were used as a reference for the following manipulations of arterial pCO₂. As a second step, manipulations in the ventilator settings were made to change the arterial pCO₂B. The goals in changing ventilator parameters were to increase or decrease arterial pCO₂ toward the “normoventilation range.” To simplify these tests, and to avoid unnecessary ventilator manipulations, in those patients with a basal pCO₂ below 40 mmHg the ventilator settings were manipulated to increase the arterial pCO₂, while in those with pCO₂ above or equal to 40 mmHg the manipulations were directed to reduce arterial pCO₂. The mean absolute change in arterial pCO₂ in the entire group was 4.4 ± 2.3 mmHg (mean ± SD). After 10–15 min of the ventilator manipulations, AVDO₂ and all parameters were recalculated. Assuming a constant CMR₀₂ during the test, changes in AVDO₂ reflect inverse changes in CBF. A relative CBF value (1/AVDO₂) was calculated from baseline AVDO₂ and was expressed as 100% [7]. Changes in 1/AVDO₂ after pCO₂ manipulation give a good estimate of changes in global CBF [7]. Two different indexes were calculated: (1) specific or absolute CO₂ reactivity (CO₂R_ABS) and (2) percentage reactivity (CO₂R%) [8]. Absolute reactivity refers to the absolute change of AVDO₂ per mmHg change in the arterial pCO₂ and was calculated as the change in AVDO₂ divided by the measured change in pCO₂: \( \Delta \text{AVDO}_2/\Delta \text{pCO}_2 \) [8]. The results were expressed as µmol/mmHg pCO₂. Percentage reactivity was calculated as the percent increase or decrease of estimated CBF (1/AVDO₂) per mmHg change in pCO₂. This index was calculated according to the following equation: 

\[ ((1/\text{AVDO}_2^H - 1/\text{AVDO}_2^B)/1/\text{AVDO}_2^B) \times 100, \]