Collateral cerebral venous outflow by scalp veins in patients with parasagittal meningiomas

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Abstract

Background: Invasion of the superior sagittal sinus (SSS) by parasagittal meningiomas (PSM) causes formation of collateral pathways of venous outflow (including scalp veins) from the cranial cavity. However, their importance, considering this function, is still under question. The purpose of this study was to determine the importance of scalp veins in collateral cerebral venous outflow in patients with PSM.

Methods: Eight patients with PSM (52-73 year-old) with invasion of the SSS and 4 healthy volunteers were examined, in supine position, with bilateral transcranial Doppler monitoring (MultiDop X, DWL) of blood flow velocity (BFV) in both middle cerebral arteries (MCA), and with blood pressure (BP) monitoring using photoplethysmography (Ohmeda, Finapres 2300). In patients circular compression of scalp veins with pneumatic cuff around glabella and inion during 3 minutes was performed, while in volunteers a simultaneous transient complete compression of both internal jugular veins controlled by ultrasound in B-mode (Vivid E, GE) was performed.

Results: Significant changes of BFV, pulsatility index (PI) and BP were not detected during the whole period of compression of scalp veins. These data indicate a low importance of scalp veins in collateral venous outflow from the cranial cavity. Simultaneous compression of both internal jugular veins in all 4 volunteers caused BFV decrease by 9±4% (p<0.05) and PI increase by 18±12% (p<0.05) associated presumably with intracranial hypertension and impairment of venous outflow from the cranial cavity.

Conclusions: Temporary circular compression of scalp veins in patients with invasion of the SSS does not cause impairment of venous outflow from the cranial cavity, which presumably indicates their low importance.

Keywords: Scalp veins, Cerebral venous outflow, Parasagittal meningiomas, Collateral venous pathways.
Introduction

Parasagittal meningiomas (PSM) are intracranial tumors that arise from the superior sagittal sinus (SSS). 70% of PSM grow inside the lumen of the SSS. Partial and complete invasion of the SSS is present in 40% and 30% of patients with PSM respectively [1, 2]. Gradual occlusion of the SSS by PSM invasion causes formation of collateral pathways of venous outflow from the cranial cavity. Surgery is the main treatment option for PSM. However damage to these collateral venous pathways during surgical approach for PSM removal may lead to serious neurologic complications and even death due to cerebral edema and venous infarction. Their preoperative evaluation and intraoperative rational preservation is a standard in surgery of PSM. All neurosurgeons agree that scalp veins may take part in collateral venous outflow in patients with PSM [1–4]. This fact has been demonstrated angiographically nearly four decades ago [5]. However their importance considering this function is still under question. Possible importance of scalp veins concerning the whole cerebral venous system can influence surgical strategy and surgical outcome in patients with PSM.

The purpose of this study was to determine the importance of scalp veins in patients with PSM in collateral venous outflow from the cranial cavity.

Methods

Eight patients with PSM (age range 52-73 years, mean age 62±8 years) with invasion of the SSS (complete invasion in four cases) and four healthy volunteers (30-40 years old) were studied by parallel bilateral transcranial Doppler monitoring (MultiDop X, DWL) of blood flow velocity (BFV) in both middle cerebral arteries (MCA) and blood pressure (BP) monitoring by photoplethysmography (Ohmeda Finapres 2300), in supine position. In patients circular compression of scalp veins with pneumatic cuff around glabella and inion (head-cuff) during 3 minutes was used. To be sure that scalp veins were actually compressed we detected BFV in proximal parts of superficial temporal artery and vein by an 8 MHz probe (Figures 1–3).

In volunteers we used simultaneous transient (during 30 s) complete compression of both internal jugular veins (with carotid arteries intact) controlled by ultrasound in B-mode (Vivid E, GE) in supine position (Figure 4). We used volunteers in order to detect hemodynamic changes when venous outflow from the cranial cavity is reliably compromised.

Results

In our patients BFV, pulsatility index (PI) in MCA and BP did not change significantly (p>0.5) before and during all period of scalp compression. Group-averaged hemodynamic parameters before and during compression of scalp veins were 45±13 and 46±10 cm/s for BFV, 0.88±0.15 and 0.86±0.16 for PI, 101±31 and 100±25 mmHg for BP respectively. These data indicate a low importance of scalp veins in collateral venous outflow from the cranial cavity.

An example of the head-cuff test in one of our patients is presented on the Figure 5.

Simultaneous compression of both internal jugular veins in volunteers caused statistically significant (p<0.05) decrease of BFV and increase of PI and BP. These changes reversed to initial state after compression was finished. In all 4 volunteers in both left and right MCA PI increased by 7–36% (18±12%) while BFV decreased by 3–14% (9±4%). Group-averaged BFV, PI and BP before, during and after simultaneous compression of both internal jugular veins in our volunteers were the following: 76±18, 69±17 and 75±17 cm/s for BFV, 0.76±0.08, 0.89±0.06 and 0.77±0.11 for PI, 91±18, 99±20 and 90±19 mm Hg for BP respectively. We associate these changes with intracranial hyperten-
sion caused by impairment of venous outflow from the cranial cavity.

An example of a study on a volunteer is presented on the Figure 6.

Discussion

PSM are the most common type of intracranial meningiomas. Rational preservation of direct and collateral venous pathways is a well-known key to good outcome in surgery of PSM. The collateral venous pathways include cortical anastomotic veins, cortical veins with end-to-end anastomoses, anastomoses of superficial with deep cerebral veins, meningeal veins, inferior sagittal sinus, diploic (including emissary) veins and scalp veins. It has been confirmed by S. Waga and H. Handa in 1976 on angiographic images in patients with PSM that scalp veins may take part in collateral venous outflow from the cranial cavity [5]. In their study scalp veins were detected as collateral venous pathways in 3 out of 13 patients with PSM with invaded SSS.

However some venous pathways, scalp veins included, are inevitably damaged, firstly during surgical approach to PSM, then during tumor removal trying to accomplish it more totally. Exclusion of several venous pathways during one-stage operation significantly increases the risk of severe complications.

Therefore some neurosurgeons believe that in some cases it is reasonable to divide operation into 2 (or even more stages) with a one–two week interval to gain time for cerebral venous system to find other ways of venous outflow [3, 4].

Scalp veins should be considered important in venous outflow from the cranial cavity if their compromise (dissection or compression) causes cerebral hemodynamic changes indicating worsening of cerebral venous outflow. Increase in intracranial pressure (ICP) is one example of these cerebral hemodynamic changes and we used it as criterion in our study. Transcranial Doppler monitoring is a well-known method of noninvasive evaluation of changes in ICP [6]. The ICP–PI relationship is dependent upon many factors, mostly pCO$_2$ and cerebral autoregulation, however quantitative evaluation of ICP by PI has been shown to be possible in some cases [7–9]. During our head-cuff test in patients with PSM we consider pCO$_2$ and cerebral autoregulation constant, therefore the ICP–PI relationship is expected to be strong. There are a lot of studies showing rise in PI after ICP increases as well as studies showing that ICP increases after blood flow in both internal jugular veins is abruptly compromised. Since we could not find a study in the literature that links rise in PI with blood flow compromise in both internal jugular veins we conducted our study with volunteers, which significantly (p<0.05) showed this relationship. The main idea to use volunteers in our study is to show that abrupt simultaneous compromise of venous outflow from the cranial cavity causes abrupt and statistically significant changes in cerebral hemodynamic parameters, namely decrease of BFV and increase of PI and BP. These changes reversed after compression was finished. It should be mentioned that since venous outflow from the cranial cavity is accomplished through vertebral venous plexus as well, changes of cerebral hemodynamic parameters in our volunteers could be absent.

Figure 2. Changes of BFV spectra in superficial temporal artery before (a), in the middle (b) and on the peak (c) of scalp compression. BFV = Blood flow velocity

Figure 3. Simultaneous monitoring of BFV in superficial temporal artery (red line) and superficial temporal vein (blue line) before, during and after scalp compression. Arrows indicate start and finish of compression. Spectra of BFV in superficial temporal artery and vein before compression are presented on the right. BFV = Blood flow velocity
Tests of the importance of invaded SSS and bridging veins are performed in surgery of PSM, in order to evaluate the risk of venous sacrifice, when trying a more total resection (usually clipping tests) [10, 11]. For example, L. Sekhar, a prominent American neurosurgeon, uses as a standard a clipping test before PSM resection together with the fragment of the SSS (en bloc resection) [10]. The test comprises measurement of intrasinus pressure in the proximal part of the SSS before and after applying a clip on the invaded part of the SSS. Increase in intrasinus pressure after applying a clip means that the fragment of the SSS with partial or seemingly complete invasion is functionally important and should be preserved.
A test for importance of scalp veins has actually been developed specifically at our Institute 20 years ago and is used presently. It is based on evaluation of electroencephalogram before and during head-cuff test with circular compression of scalp vessels [12]. Significant changes of bioelectrical activity during scalp compression indicate importance of scalp veins, which in turn indicates that the system of venous outflow from the cranial cavity is “saturated” or has low plasticity and the risk of one-stage operation is high. Of course, changes in bioelectrical activity are secondary to hemodynamic changes and reliability of using them is questionable. Actually all 8 patients in our study had positive result in head-cuff test using electroencephalogram.

**Conclusion**

Circular compression of scalp veins in patients with PSM with invasion inside the SSS did not cause impairment of venous outflow from the cranial cavity in our study. This fact indicates low importance of scalp veins in collateral venous outflow from the cranial cavity in our patients, although they could act as collateral venous pathways.

However, in case of complete “saturation” of intracranial pathways of venous outflow it seems possible that scalp veins become important. In neither of our patients this was the case. Hence, further research is needed.

**Abbreviations**

BFV: Blood flow velocity; BP: Blood pressure; ICP: Intracranial pressure; MCA: Middle cerebral artery; PI: Pulsatility index; PSM: Parasagittal meningiomas; SSS: Superior sagittal sinus

**Competing interests**

The authors declare no conflict of interest.

**References**

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