

THE MANY SONOGRAPHIC FACES OF THE CHRONIC CEREBROSPINAL VENOUS INSUFFICIENCY: HOW TO PERFORM DOPPLER EXAMINATION IN A MULTIPLE SCLEROSIS PATIENT.

Multiple sclerosis patients nearly always are found abnormal venous outflow obstacles in extracranial veins draining the central nervous system. These venous outflow blockages are described as chronic cerebrospinal venous insufficiency (CCSVI) and finding of CCSVI parameters in the sonographic examination is highly pathognomonic for multiple sclerosis.

Venous obstacles compromising blood outflow from the brain and spinal cord can be very diverse. A whole constellation of venous pathologies can be found, including: occlusion, stenosis, narrowing, septum and inverted valves. Nowadays it is thought that these venous obstacles are primarily congenital, although a presence of post-traumatic or post-thrombotic lesions is also possible.

However, irrespective of the actual origin of these venous occlusions and stenoses, to look properly for these venous pathologies by means of Doppler ultrasound it is necessary to understand hemodynamic principles ruling the venous outflow from the brain and spinal cord. Both the brain and spinal cord are enclosed in osseous chambers (skull in case of the brain and spinal canal in case of the spinal cord). Therefore, vessels directly draining the brain and spinal cord are: first, non-collapsible that means that they contain approximately the same volume of the blood, irrespective of velocity and direction of the flow; second, they cannot shrink or dilate consequently to pressure or outflow resistance changes, as varicose veins do. Moreover, cerebral veins and sinuses as well as spinal veins and venous plexuses lack valves, and flow characteristics in these vessels depends nearly exclusively on the level of flow resistance in the extracranial and extraspinal veins. However, despite valveless nature of these veins, because of their localization inside the rigid osseous chambers, a reflux similar to that that accompanying varicose veins cannot occur. Of course, refluxes in the veins draining the central nervous system can be found, but they are rather manifestations of vicarious shunts (flow bypassing an obstacle) and they differ significantly from those found in varicose veins.

At the moment, details of venous hemodynamics in the territory of brain and spinal cord are not completely elucidated. Yet, basic principles of the physiologic venous return from the brain are as follows:

- a) in the supine position venous return from the brain is maintained mostly through internal jugular veins (Fig.1),

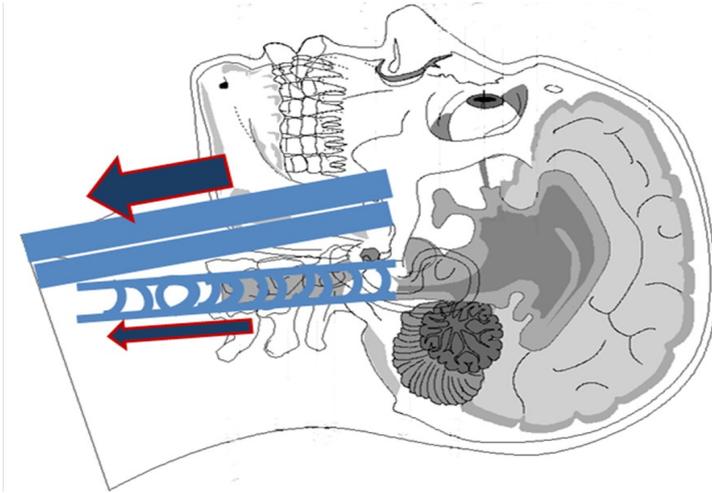


Fig.1

- b) on the contrary, in the upright position blood outflows mainly through spinal epidural plexus and vertebral veins (Fig.2).

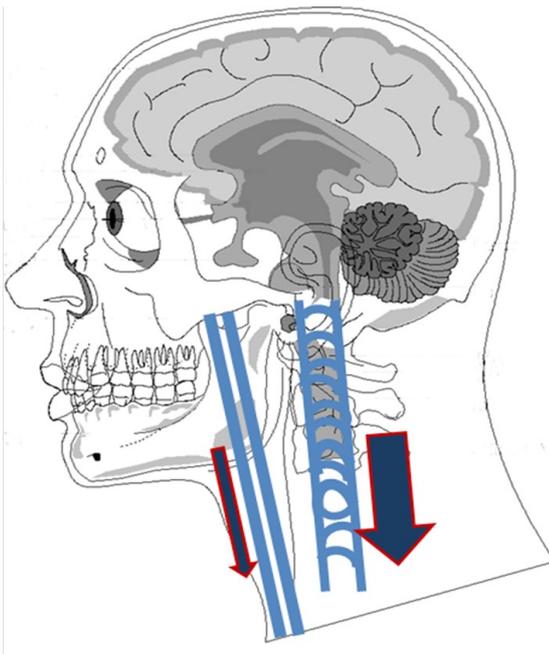


Fig.2

But why does blood outflow via different pathways, depending on position of the body? Cross-section area of the both internal jugular veins is comparable to that of spinal epidural plexus and vertebral veins, and therefore these two routes can be regarded as alternative ones. Yet, it should be noticed that internal jugular veins are collapsible, while spinal epidural plexus and, to a lesser extent vertebral veins, thanks to their anatomical localization are rather non-collapsible.

In the supine position, when the both pathways are theoretically patent, blood outflows mainly through the internal jugular veins, because these vessels are much wider in comparison with vertebral pathway, which consists of a network of tiny veins and venous plexuses, and therefore vascular resistance (that depends not only on a total cross-section area, but also on cross-sections of particular vessels) in the jugular pathway is lower. Consequently, in the supine position blood outflows mainly through internal jugular veins.

On the contrary, in the upright position, due to gravitational effects, internal jugular veins collapse. Secondary to their decreased diameter they generate higher resistance if compared to the vertebral pathway. Therefore, in the upright position, blood outflows from the brain mainly through spinal epidural plexus and vertebral veins.

Understanding the principles of the above-described patterns of physiological venous return, it is easier to understand why different localizations of venous obstacles result in very diverse sonographic findings. Moreover, it is possible to deduct from sonographic findings where a lesion should be found, even if it is not directly visible.

Thus, we will try to discuss abnormal parameters of venous flow from the perspective of hemodynamics of venous return from the brain and upper spinal cord.

1. Stenosis or occlusion of the internal jugular vein.

Internal jugular veins, as well as vertebral veins, should be assessed using high-frequency (7.5-10 MHz) linear probe, similarly to the examination of carotid arteries. The probe should apply minimal pressure to the skin, in order to prevent compression of a vein.

Venous obstacles can directly visualized. But a presence of such a lesion can also be diagnosed indirectly. It should be remembered that internal jugular veins can be occluded by very different pathologic structures. These could be: narrowing of the vein (usually narrowed portion of the vein exhibits stiffness of its wall), a membranaceous or netlike septum (such structures are usually found in the lower portion of the vein), inverted valve (also usually localized at the junction with brachiocephalic vein).

Since an obstacle in the internal jugular vein is the source of additional vascular resistance, flow pattern in a case of an obstruction changes. The search for occlusions of the internal jugular veins should be primarily performed in the supine position, since in this hemodynamic situation jugular veins are physiologically dilated and it is easier to find a lesion. However, the veins should be also assessed in the upright or sitting position to look closer at hemodynamics.

a) lower portion of internal jugular vein.

In the case of unilateral stricture localized in the lower portion of the internal jugular vein, flow in the vein can be decreased (Fig.3) if compared with contralateral vessel.

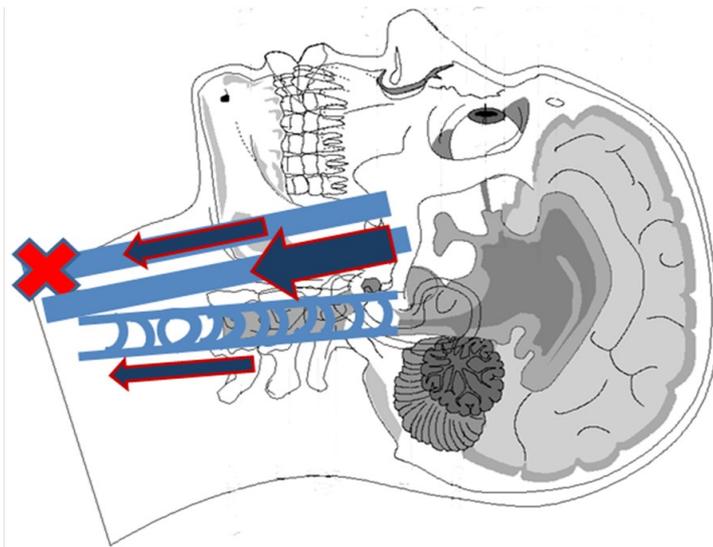


Fig.3

The vein above the stricture can be dilated or even may develop venous aneurysm (Fig.4).

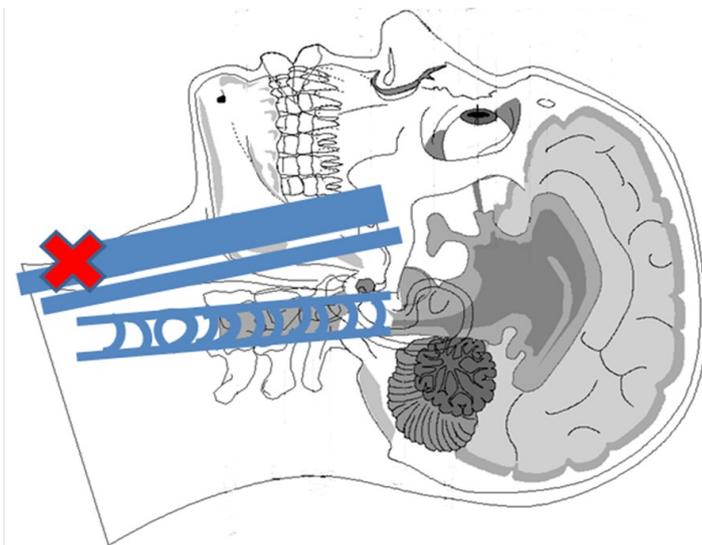


Fig.4

If a structure pretending to be a septum or pathologic valve is recognized, it should be checked it with Doppler - whether it is the real structure, or an artifact. In the case of actual

obstruction Doppler spectra obtained from the vein above and below the septum differ significantly, while in the case of artifact Doppler spectra are much alike (Fig.5).

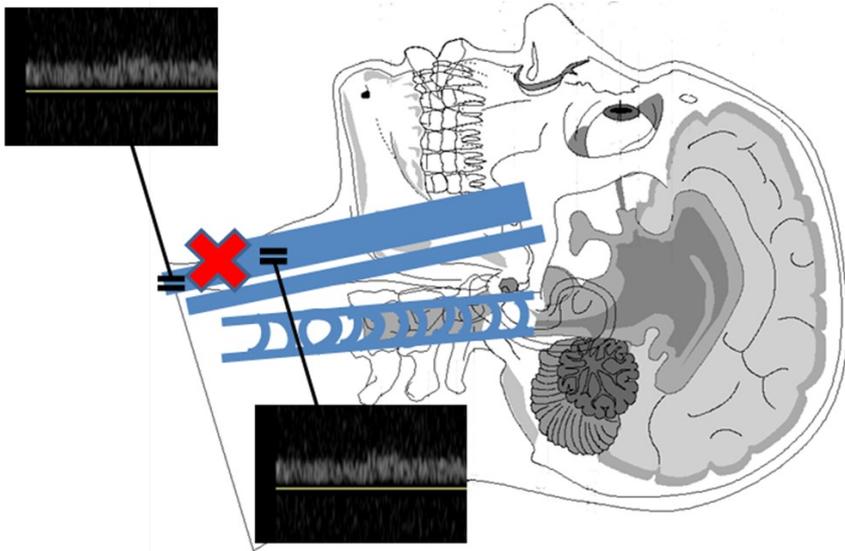


Fig.5

Bilateral occlusions in lower portions of the internal jugular veins usually result in abnormally high outflow through vertebral pathway in the supine position (Fig.6).

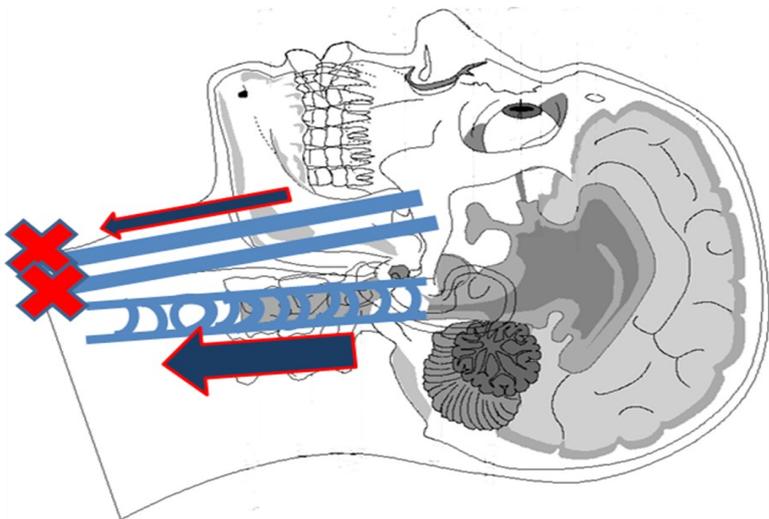


Fig.6

b) middle portion of internal jugular vein.

Usually, there is no problem with visualization of a stenosis in the middle portion of the internal jugular vein. Overall flow in the stenosed vein can be diminished, yet in the area of stricture the flow can be accelerated (similarly to the case of a stenosis in the carotid artery). Flow through vertebral veins in the supine position can be increased (Fig.7).

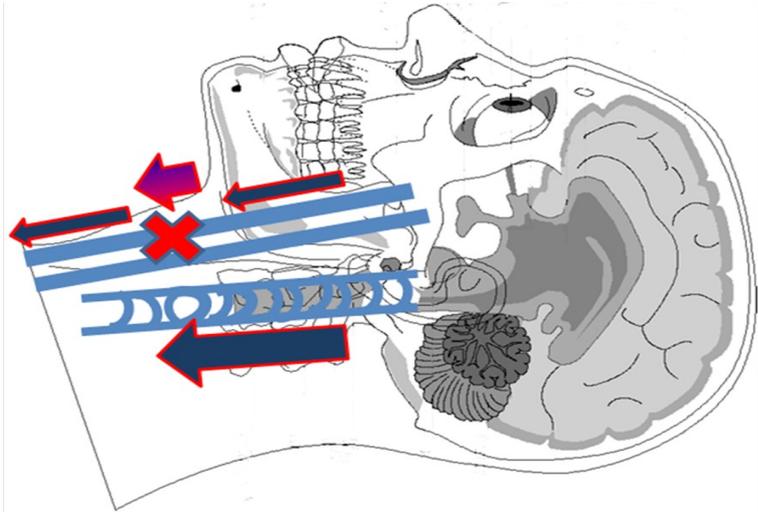


Fig.7

c) upper portion of internal jugular vein.

Lesions, which are localized at the base of skull, could be hardly visualized with ultrasound. However, in a case of bilateral stenoses, flow through vertebral veins in the supine position can be abnormally high (Fig.8).

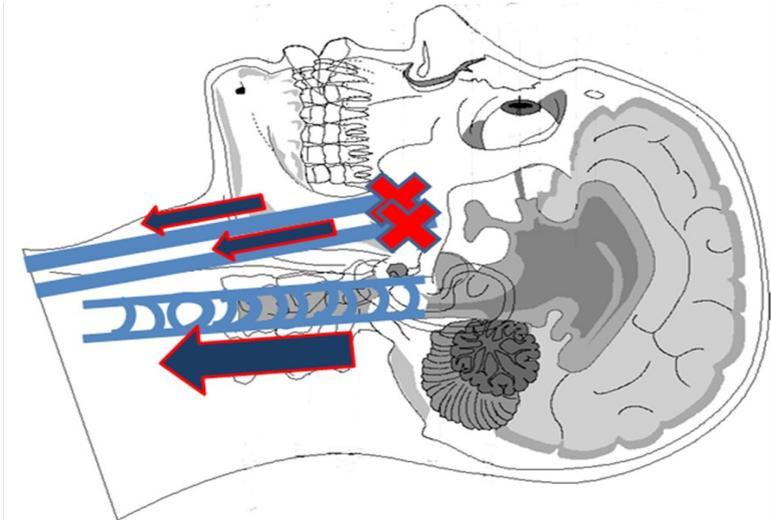


Fig.8

Asymmetric flow can be detected in the case of high stenosis of one internal jugular vein (Fig.9).

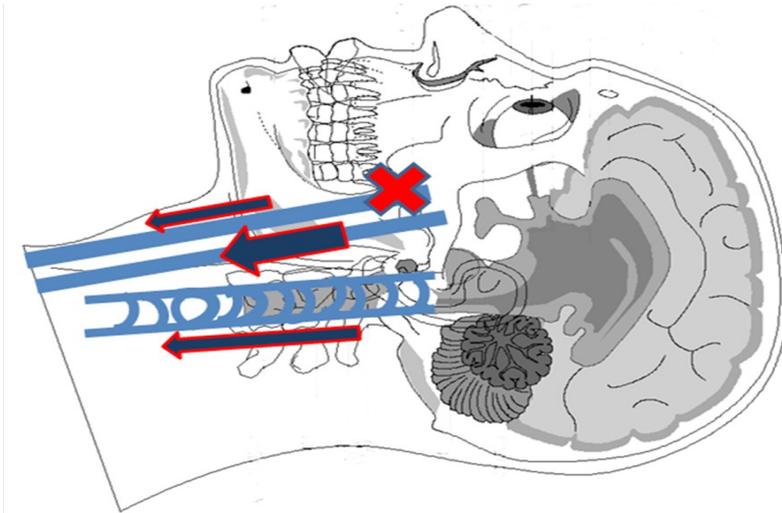


Fig.9

2. Reflux in the internal jugular or vertebral veins.

In multiple sclerosis patients reflux, i.e. pathologic, inverted direction of flow actually represents vicarious shunt: reversed direction of flow bypassing an obstacle. Usually refluxes are detected distally from strictures.

a) Stenosis in the internal jugular veins (Fig.10).

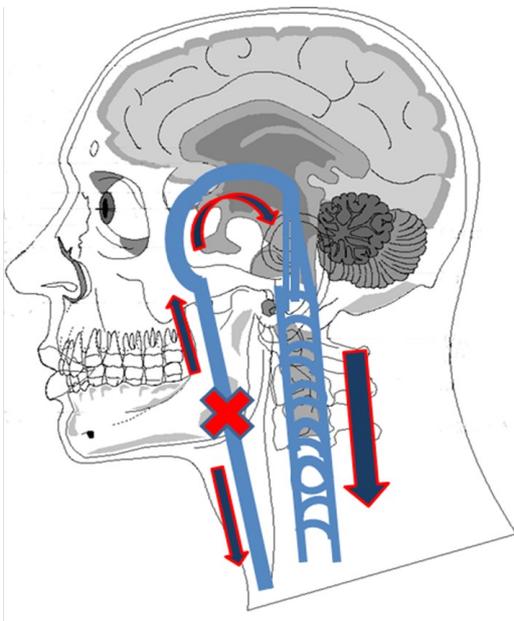


Fig.10

b) Stenosis in the azygous vein (Fig.11).

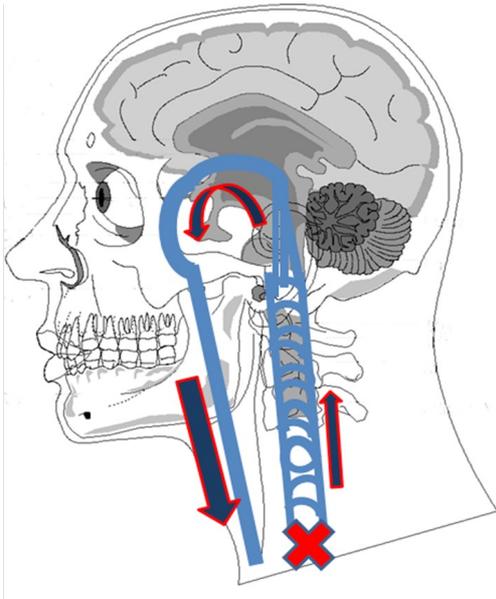


Fig.11

3. No detectable flow in the internal jugular or vertebral veins

In some cases pressure gradient secondary to venous obstacles is not sufficient to produce inverted flow (reflux), but due to nearly balanced pressures flow in the affected segment of vein stops. In the internal jugular veins such a situation can take place in the case of occlusion of this vein (Fig.12). In vertebral veins no visible flow can be a sign of occluded azygous vein (Fig.13).

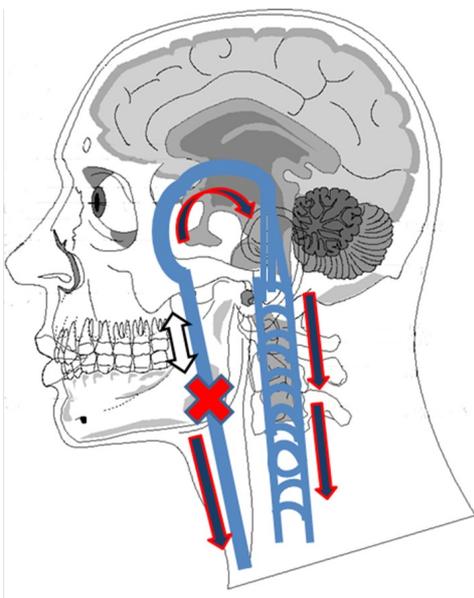


Fig.12

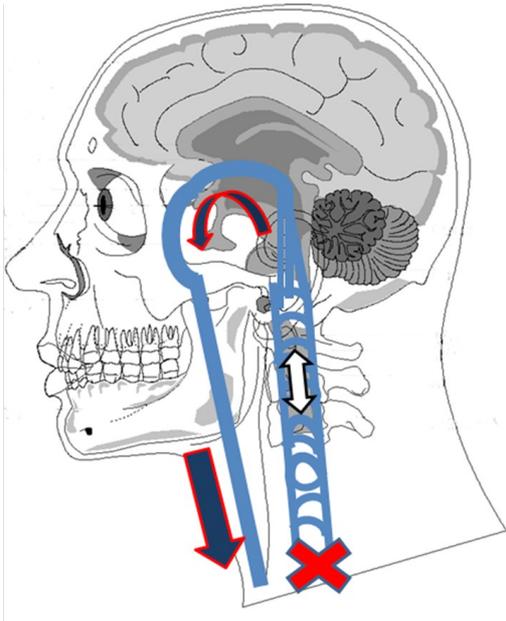


Fig.13

4. No position-dependent change in diameter of the internal jugular vein.

In physiologic conditions internal jugular veins are dilated in the supine position, while in the upright position they collapse (Fig.14). This is due to gravitational effects.

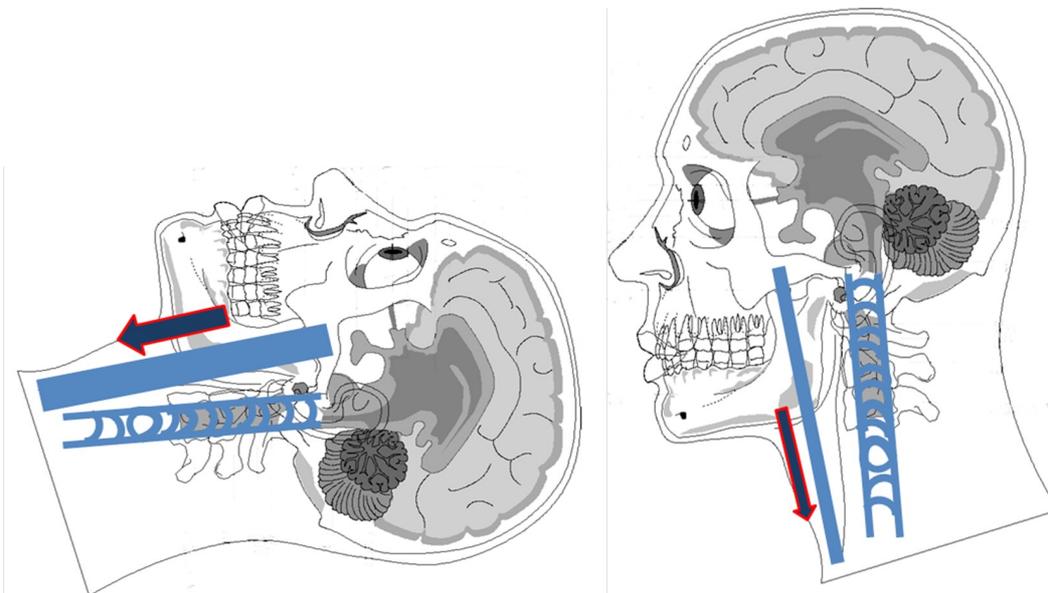


Fig.14

But in a case of venous obstacle in some patients these veins do not collapse in the upright position. Sometimes they even dilate in comparison with the diameter obtained in the supine

position. This can result from a stiff venous wall in the are of stenosis (Fig.15) or be due to the presence of inverted valve or another obstacle in the lower part of the vein (Fig.16). Besides, internal jugular veins do not collapse in a case of total obstruction of the vertebral pathway (Fig.11).

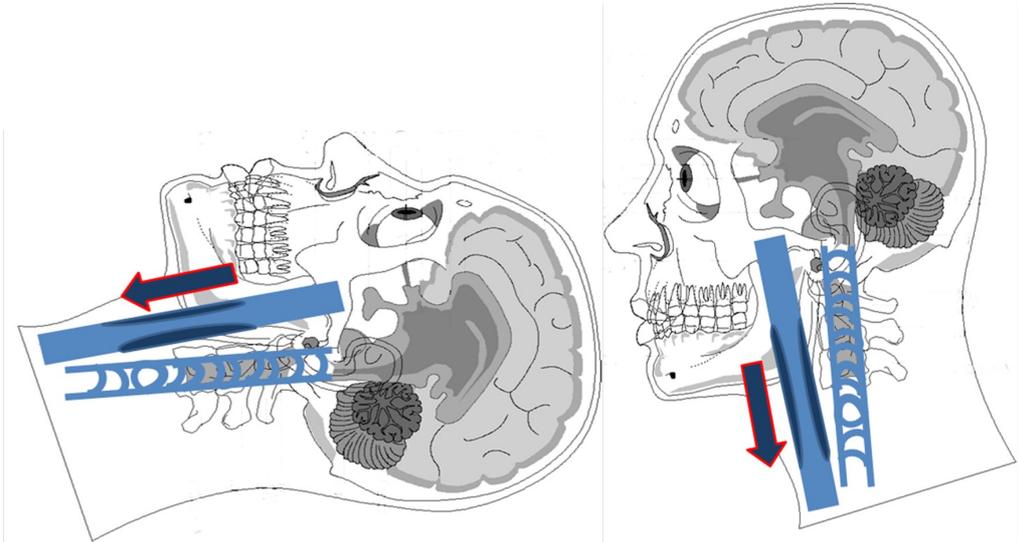


Fig.15

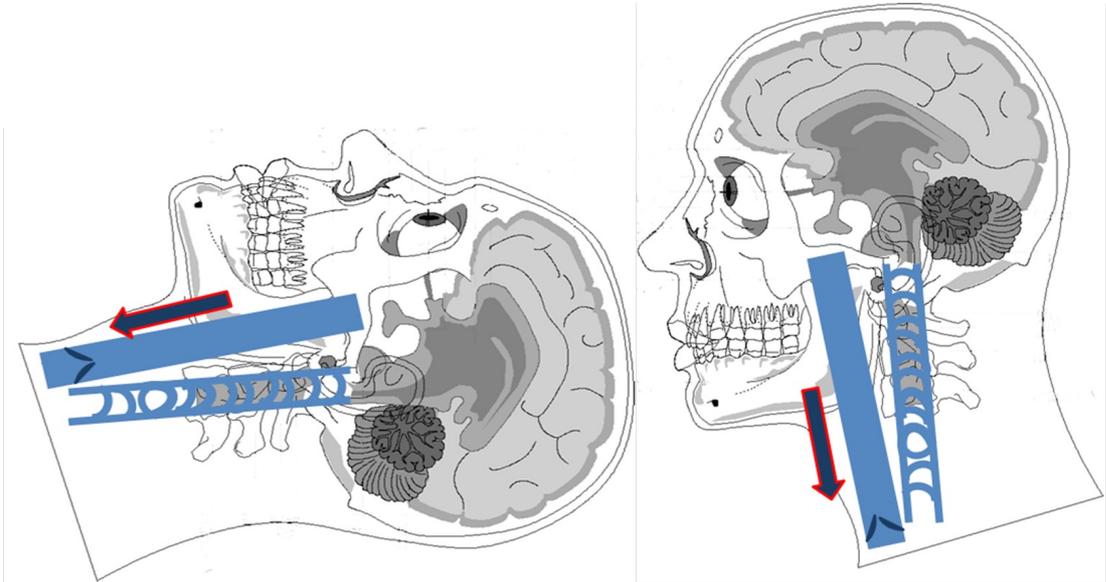


Fig.16

5. Reflux in the deep cerebral veins

In a case of obstructed internal jugular or azygous vein, the venous flow must bypass an obstacle. In many patients this secondary route is maintained through intracranial veins (fig. 10 and 11). In such hemodynamic situation venous outflow from deep structures of the brain is profoundly compromised. This part of brain is drained by the great vein of Galen and its tributaries (dark-blue vessel on Fig.17). In the hemodynamic situation when the main cerebral veins do not serve purpose of draining the blood, but rather of bypassing it, the flow in the great vein of Galen can be refluxing (red arrow on Fig.17) or even the flow towards cortical veins can develop (red arrowheads on Fig.17).

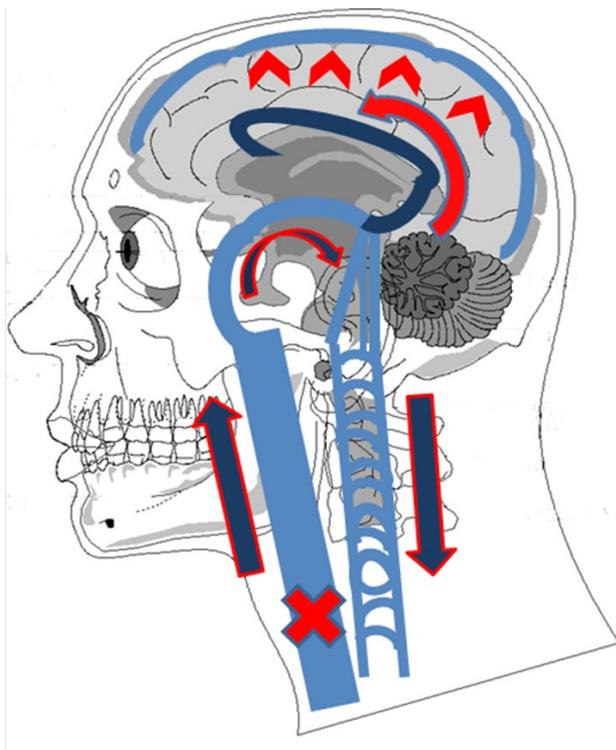


Fig.17

Superficial cerebral veins, because of their low-velocity flow characteristics, cannot be imaged with conventional ultrasound methods. Deep cerebral veins (great vein of Galen, veins of Rosenthal and internal cerebral veins), however, can be visualized with color Doppler technique through trans-temporal acoustic window. For the assessment of intracranial veins 2.5 MHz convex transducer should be used. Low-flow sensitive color program with a low wall filter setting has to be used and the pulse repetition frequency (PRF) needs to be reduced. The color gain should be increased just below the artifact threshold.

Normal venous Doppler signals in the deep cerebral veins, unlike peripheral veins, display a low pulsatility with a constant monodirectional flow (Fig.18), which may be similar to signal

from an artery, but the amplitude of pulsatility is much lower . This monodirectional flow can be increased and decreased by breathing, but activation of the flow only during a particular breathing phase (Fig.19), bidirectional flow, or a high-velocity monodirectional flow towards subcortical white matter should be recognized as pathological.

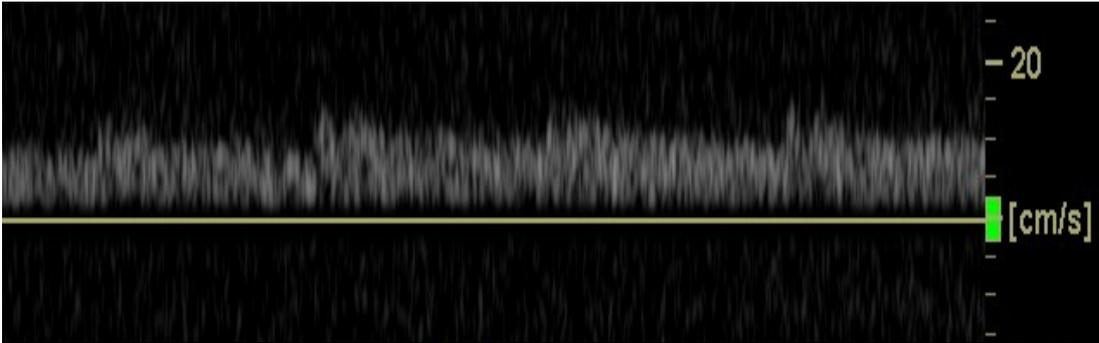


Fig.18

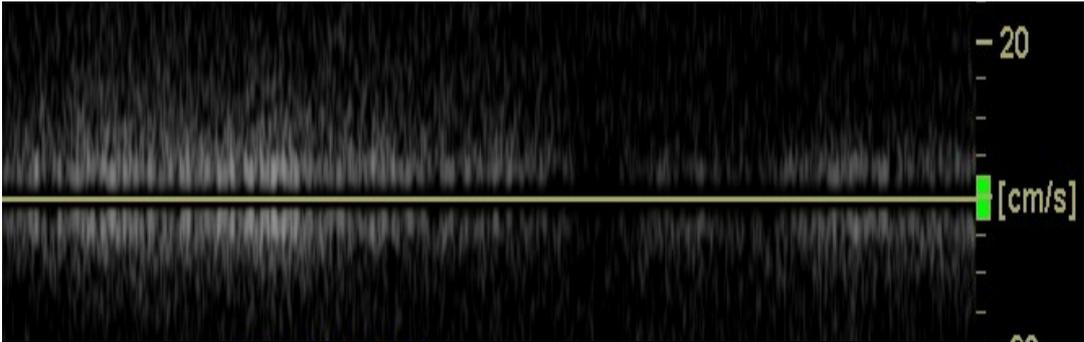


Fig.19