Venous Collateral Circulation of the Extracranial Cerebrospinal Outflow Routes

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Abstract: A new nosologic vascular pattern that is defined by chronic cerebrospinal venous insufficiency (CCSVI) has been strongly associated with multiple sclerosis. The picture is characterized by significant obstacles of the main extracranial cerebrospinal veins, the jugular and the azygous system, and by the opening of substitute circles. The significance of collateral circle is still neglected. To the contrary, substitute circles are alternative pathways or vicarious venous shunts, which permit the drainage and prevent intracranial hypertension. In accordance with the pattern of obstruction, even the intracranial and the intrarachidian veins can also become substitute circles, they permit redirection of the deviated flow, piping the blood towards available venous segments outside the central nervous system. We review the complex gross and radiological anatomy of collateral circulation found activated by the means of EchoColor-Doppler and selective venography in the event of CCSVI, focusing particularly on the suboccipital cavernous sinus (SCS), the condylar venous system, the pterygoid plexus, the thyroid veins, and the emiazygous-lumbar venous anastomosis with the left renal vein.

Keywords: Cerebrospinal venous insufficiency (CCSVI), multiple sclerosis (MS), cerebral venous system, collateral circulation.

INTRODUCTION

A new nosologic vascular pattern recently identified, defined as chronic cerebrospinal venous insufficiency (CCSVI) is strongly associated with multiple sclerosis (MS) (Zamboni et al., 2009a).

CCSVI is characterized by multiple stenoses/obstruction affecting the principal extracranial outflow pathways of the cerebrospinal venous system, the internal jugular veins (IJVs) and azygous vein (AZY), distributed in four main patterns. CCSVI determines significant changes in cerebral venous hemodynamics, with a very high incidence of reflux in both intracranial and extracranial venous segments, and loss of the postural regulation of cerebral venous outflow (Zamboni et al., 2007, Zamboni et al., 2009a and 2009b; Franceschi, 2009).

Venous obstructions are compensated by substitute circles. Substitute circles are alternative pathways or vicarious venous shunts that allow for the piping of blood towards available venous segments outside the central nervous system (CNS).

In accordance with the pattern of obstruction, both the intracranial and the intrarachidian veins can also become substitute circles, they permit redirection of the deviated flow, preventing intracranial hypertension. However, over time, they become overloaded because they carry two different flows, their own draining flow and the shunted flow (Zamboni et al., 2009a; Franceschi, 2009; Zamboni et al., 2007).

There are no current reviews clearly indicating the collateral circles activated in case of stenosis of the main extracranial cerebral venous paths.

SCHEMATIC ANATOMIC ORGANIZATION OF THE VENOUS SYSTEM OF THE BRAIN

Cerebrovenous system (CVS) is a three-dimensional structure that is often asymmetric and considerably represents more variable pattern than the arterial anatomy (Schaller, 2004).

The CVS is mainly composed of dural sinuses and cerebral veins (Hassler, 1966; Meder et al., 1994; Muizelaar, 1989).

The venous outflow from cerebral hemispheres consists mainly of two different vascular systems (Andeweg, 1989):

- the superficial (cortical) system reaches dural sinuses by cortical veins and drains blood mainly from cortex and subcortical white matter (Meder et al., 1994; Aydin et al., 1997);
- the deep cerebral venous system (medullary or subependymal) (DCVs) is composed by subependymal veins, internal cerebral veins, basal vein and great cerebral vein of Galen and their tributaries, and drains the deep white and gray matter surrounding the lateral and third ventricles or blood from cortical regions (Meder et al., 1994; Ono et al., 1997).
Cortical System Draining Routes

The superficial middle cerebral vein runs along the Sylvian cistern and drains the anterior temporal lobe, parasympathetic cortex and anterior–inferior frontal lobes (Reisch et al., 2002). It subsequently empties into cavernous sinus, sphenoparietal sinus or pterygoid plexus (Schaller, 2004; Reisch et al., 2002).

It is formed by anastomosis of temporo-sylvian veins. These veins are connected with midline bridging veins on one side and juxta-basal temporal veins on the other, and enter predominantly the cavernous sinus, either directly or through the sphenoparietal sinus (Reisch et al., 2002). Many anatomical variations are possible: (1) in size: when very thin or even absent, neighboring veins become of greatest importance, (2) in termination: draining towards the pterygoid plexus or the superior petrosal sinus (Schaller, 2004; Huther et al., 1998; Reisch et al., 2002).

The superior sagittal sinus (SSS) starts at the foramen cecum, just anterior to the crista galli (Mehta et al., 2000). It courses along the gentle curvature of the inner table of the skull, within the leaves of the dura mater, to reach the confluence of sinuses: the torcular Herophili (Ayanzu et al., 2000). Along the way, the sinus receives the cortical bridging veins. After the subarachnoid course, they penetrated the SSS at different points in the dura mater depending on their rostrocaudal position (Fig. 1). Histologically the organization of the smooth muscle cells at the end of each cortical vein quite resembles a myoendothelial “sphincter”. Some authors hypothesize that such myoendothelial junction acts as smooth sphincter and that it plays a role in cerebral venous hemodynamics regulation (Vignes et al. 2007).

The SSS vascular caliber increases from anterior to posterior, because of the penetration of arachnoid villi inside its lumen (Ayanzu et al., 2000). The SSS is circulating in a more or less laminal way, accentuated by the existence of longitudinal septa, especially in midthird portion. Lateral sinuses drain the SSS, equally on both sides in only 20% of cases and asymmetrically in more than 50%, depending upon configuration of torcular Herophili (Schaller, 2004; Suzuki et al., 2001). In extreme, one lateral sinus may drain SSS in totality (most often on right side) and the other one the straight sinus; this accounts for 20% of the cases (Schaller, 2004; Suzuki et al., 2001). Atresia of the transverse sinus or even the agenesis on one side was observed in 17% of cases (Suzuki et al., 2001). So that the remaining sigmoid sinus drains the inferior cerebral veins (i.e., the Labbé system). The sigmoid sinus drains the posterior fossa (Reisch et al., 2002) receiving the superior and inferior petrosal sinuses (IPS) and sometimes veins coming from the lateral aspect of brainstem and medulla (Suzuki et al., 2001). Sigmoid sinus has frequent anastomosis with cutaneous venous network through mastoid emissary vein (Schaller, 2004; Suzuki et al., 2001). When the sigmoid segment of the lateral sinus is atretic, the transverse sinus with its affluent drains toward the opposite side (Schaller, 2004; Suzuki et al., 2001). The inferior sagittal sinus (ISS) follows a similar curve within the free margin of the falx cerebri (Wetzel et al., 1999). Often, its anterior portion is deficient and the sinus appears more linear than curvilinear. In contrast to its superior counterpart, the ISS empties into straight sinus, at or near its communicating vein with the vein of Galen (Schaller, 2004; Wetzel et al., 1999). The straight sinus, therefore, drains the deep venous system through the vein of Galen, as well as much of superficial venous system indirectly through the ISS and basal vein (Schaller, 2004; Suzuki et al., 2001). As all other sinuses, the straight sinus is situated within dural leaves, in this case, of tentorium cerebelli and falx cerebri (Schaller, 2004; Wetzel et al., 1999). Posteriorly, straight
sinus empties into torcular (Schaller, 2004; Wetzel et al., 1999). Another complex network of dural sinuses collects blood along the brain’s ventral surface (Ayanzu et al., 2000) including the cavernous, superior and inferior petrosal, and sphenoparietal sinuses. Cavernous sinus is a trabeculated dural venous packet along parasellar sphenoid bone (sphenoid sinus) (Schaller, 2004; Chanda, 2002). The sinus extends from superior orbital fissure to petrous apex. Its venous inflow includes orbital venous drainage (superior and middle ophthalmid veins), anterior middle cranial fossa drainage (superior and inferior middle cerebral veins) and sphenoorbital sinus. From cavernous sinus, blood drains posterolaterally along superior petrosal sinus to transverse sinus and inferior-laterally along IPS into jugular (Schaller, 2004; Andeweg, 1989) that originate 10–20 mm below the cortex and course centrally to the subependymal veins (Schaller, 2004; Hooshmand et al., 2001). Deep sinuses also interconnect by way of the basilar venous plexus along the dorsal clivus and the intercavernous sinus among the pituitary infundibulum. Occasionally, a prominent venous plexus connects the cavernous sinuses along the floor of the sella turcica.

Deep System Draining Routes

The subcortical and deep white matter are drained by DCVs (Schaller, 2004; Andeweg, 1989) that originate 10–20 mm below the cortex and course centrally to the subependymal veins that surround the ventricles (Friedman, 1997; Hooshmand et al., 1974). The subependymal veins drain from the deeper subcortical structures, such as internal and external capsule, the basal ganglia, and the dorsal part of the diencephalon, to the vein of Galen, which curves around the posterior surface of the splenium of the corpus callosum before terminating at the confluence of sinuses (Fig. 1) (Hooshmand et al., 1974). Except from the anatomical variations of the basal veins, the system of the DCVs remains relatively constant compared to the superficial cortical venous system (Schaller, 2004; Huther, et al., 1998; Reisch et al., 2002).

The DCVs can be subdivided into two different subgroups: i) the superficial branches drain 1–2 cm of white matter and course through the gray matter (Schaller, 2004; Okudera et al., 1988). They are connected to the cortical veins, ii) the deep branches begin within the white matter deeper than superficial medullar veins and course toward lateral ventricles, emptying into the subependymal veins of the walls of the lateral ventricle (Schaller, 2004; Friedman, 1997). A third group of DCVs defined as “transcerebral veins” completely transverses the hemisphere to reach subependymal veins (Schaller, 2004; Hassler, 1966; Huang et al., 1964). All these white matter veins run perpendicular to the long axis of the lateral ventricle, creating a fem-shaped appearance (Lee et al., 1996).

Three DCVs are commonly seen on the venous phase of a cerebral arteriogram (Capra, 1984; Mattei et al., 1991): (1) thalamostriate vein, (2) septal vein, and (3) internal cerebral vein. The thalamostriate veins join the septal veins from the internal cerebral veins (Schaller, 2004; Scott et al., 2003; Teksum et al., 2003). The point at which the anterior vein of the septum pellucidum joins the superior thalamostriate vein is called the venous angle and is usually located at the interventricular foramen (Scott et al., 2003). The internal cerebral veins are paired and run above the roof of the third ventricle (Schaller, 2004; Scott et al., 2003). These veins are joined by basal veins of Rosenthal forming the vein of Galen (Schaller, 2004; Scott et al., 2003) (Fig. 1). The basal vein of Rosenthal represents the confluence of veins draining basal and medial parts of frontal lobe, temporal lobe, basal ganglia, and insula (Schaller, 2004; Scott et al., 2003). Occasionally, basal vein of Rosenthal can drain aberrantly into a tentorial sinus or superior petrosal sinus (Schaller, 2004; Scott et al., 2003).

Extracranial Venous Drainage

The cerebral blood is finally collected into the dural sinuses and in turn redirected towards the main extracranial venous outflow routes: the IJVs and the vertebral venous system (Fig. 1). The anatomical pathways of jugular drainage are well established. The main jugular blood drainage pathway leads from the SSS and the transverse sinuses via the sigmoid sinuses into the IJVs, which meet the superior cava vein via the brachiocephalic vein.

Several ultrasound study of healthy volunteers demonstrated that the pattern of cerebral venous drainage changes, even under physiological conditions, depending on the body position (Valdueza et al., 2000; Doepp et al., 2004; Schreiber, et al., 2003; Menegatti and Zamboni, 2008).

In the prone position, the outflow through the IJVs is favored, this assumption was based on angiographic studies and cerebral blood flow analyses with nitrous oxide, labeled erythrocytes, and thermodilution techniques (Schreiber et al., 2003; Nylin et al., 1961; Huber, 1982; Shenkin et al., 1948; Wilson et al., 1972), which were all performed in a supine body position. Whereas passing to the upright position transfers most of the encephalic drainage to the VVs (Valdueza et al., 2000; Doepp et al., 2004; Menegatti and Zamboni, 2008).

Extracranial Draining Pathways of the Vertebral System

Vertebral venous system is a freely communicating, valveless system present throughout the entire spinal column and may be divided into an internal intraspinal part, the epidural veins, and an extraspinal paravertebral part.

1) At the craniocervical level, anterior sources of intraspinal system arise from basal plexus and IPS (Schaller, 2004; Chaynes, 2003). A posterior communicating venous drainage exists with occipital sinus, which may be relevant in cases of lateral sinus hypoplasia (Schaller 2004). The system communicates with deep thoracic and lumbar veins, intercostal veins, AZY, and hemiazygous veins, as well as with the inferior vena cava. Particularly, the collateral circle between the AZY and the inferior vena cava, via the left renal vein is particularly relevant in course of CCSVI. The AZY in the MS group was obstructed in 86% of cases. Most cases involved membranous obstruction of the junction with the superior vena cava, twisting, or, less frequently, septum and atresia (Zamboni et al., 2009a). In such cases, descending venography documented a reflux flow along the AZY system, which re-enters into the caval system through the hemiazygous-lumbar anastomosis with the left renal vein (Fig. 2). In type B pattern of CCSVI, characterized by significant stenoses of both IJV's
combined with proximal strictures of the proximal AZY, such a collateral circle becomes the main extracranial pathways for draining the CNS (Zamboni et al., 2009a). Obstruction of the superior vena cava cranially from the AZY vein is tolerated well, but obstruction involving connection of termination of AZY vein to heart leaves collateral flow only towards inferior vena cava, which results in insufficient cranial venous outflow (Hoffmann et al., 2002).

2) The extraspinal system receives blood anteriorly from cavernous sinus via pterygoid plexus (Schaller, 2004). A dorsal part is connected to suboccipital venous plexus, which receives blood through mastoid and condylar emissaries (Schaller, 2004; Brew, 2004). Although the jugular veins were previously thought to be the predominant draining pathway (Cowan et al., 1983), anatomical recent study-findings have demonstrated that this role is confined to the supine position; redirection of venous flow to the vertebral veins occurs in upright-position (Schaller et al., 2004; Schreiber et al., 2003; Hoffmann et al., 2002). The vertebral veins (VVs) are part of the vertebral system, which have been shown to serve as venous collaterals in cases of jugular flow obstruction (Schreiber et al., 2003). The VVs represent the main longitudinal part of the external vertebral venous system. VVs and the deep cervical veins, which are located within the muscle layers of the nape, receive inflow from the marginal and sigmoid sinuses via condylar veins and emissaries and from the venous plexus surrounding the foramen magnum (Schreiber et al., 2003). In addition, there are several frequently segmental connections between the internal and external parts of the vertebral venous system. VVs, deep cervical veins, and the external jugular vein finally join the brachiocephalic vein.

Anastomoses of Intra- and Extracranial Veins

Batson (Schaller et al., 2004; Batson, 1967) described vessel-connections between intra and extracranial veins at cranial base as a single large venous plexus, and this appears to be the most practical view: (1) The suboccipital venous plexus represents the cranial beginning of the posterior external vertebral plexus between the dorsal muscles, it is connected to the sigmoid sinuses via mastoid and condylar emissaries (Fig. 3) (Pedley et al., 1998). (2) The posterior internal vertebral plexus receives blood from occipital sinus and, thus, from confluens sinus (Pedley et al., 1998). The latter is often plexiform and asymmetrical, and when one lateral sinus is narrow or absent, occipital sinus is larger than usual, and in neonates the occipital sinus is very large (Batson, 1967; Pedley et al., 1998). (3) The anterior internal vertebral plexus is a continuation of basal plexus, which lies on clivus and connects IPS and both cavernous sinuses (Pedley et al., 1998). (4) The anterior external vertebral plexus is a continuation of large pterygoid plexus, which receives blood from cavernous sinuses (Fig. 4) (Batson, 1967; Pedley et al., 1998).

The pharyngeal venous plexuses may play a role in the anterior region that should not be ignored. The plexus communicates with the intracranial venous sinus through the pterygoid venous plexus, and draining into the internal jugular vein, and/or into the laryngeal and tracheal venous plexus (Fig. 4).
Besides these affluent pathways, the outflow channels of vertebral plexuses can also be summarized (Schaller, 2004; Batson, 1967): (1) in the thoracolumbar area, outflow from vertebral plexuses takes place via the lumbo-hemiazygous system, which also forms a collateral channel between inferior and superior vena cava. Valves in the AZY system are superior rudimentary and nonfunctioning. (2) In vertebral plexuses of cervical area, longitudinal collecting channels besides internal jugular vein on either side are deep cervical vein posteriorly between muscles, vertebral vein (through the transverse process of the cervical vertebrae) and, subcutaneously, external jugular vein (Batson, 1967). These veins join subclavian and internal jugular veins in forming brachiocephalic vein (Batson, 1967).

THE CONCEPT OF VICARIOUS VENOUS SHUNT IN COURSE OF CCSVI

Venous function is a central mechanism of regulation of cell and tissue biology, although there is a lack of study on its influence in the central nervous system (CNS). It has been recently illustrated a vascular picture that has not previously been described, correctly defined as chronic cerebrospinal venous insufficiency (CCSVI), strongly associated with MS (Zamboni et al., 2009a,b; Zamboni et al., 2007; Franceschi, 2009). The picture is characterized by significant obstacles of the main extracranial cerebrospinal veins, the jugular and AZY system, and by the opening of substitute circles. When the venous flow is deviated into collaterals to bypass an obstacle, there exists what is called a vicarious shunt (Franceschi, 1996). This type of shunt is desirable because it bypasses blocked veins and, thereby, reduces resistance to drainage. It flows permanently under the effects of distal cardiac residual pressure and proximal thoracoabdominal aspiration. However, the expected time of venous outflow is longer, as confirmed by the mean transit time measured in MS patients by the means of MR perfusional study, even in normal-appearing white matter (Law et al., 2004).

The significance of the shunt depends on the overload of the volume of blood that is deviated, the starting-point and end-point of the deviation (Franceschi, 1996). Shunts may be directed outward, but in the case of CCSVI, a retrograde flow has been demonstrated in the majority of cases, meaning reflux in the CNS.

The main deep cerebral veins, the transversal sinus, the IJVs and the VVs and the AZY were deeply investigated with Eco Color-Doppler and selective venography in the event of CCSVI (Zamboni et al., 2007; Zamboni et al., 2009a,b). These investigations showed the activation of collateral pathways described in this review, underlying the importance of such venous vicarious pathways when the principal extracranial outflow routes are obstructed. We extensively review in the further paragraph the main vicarious shunt activated in course of CCSVI, because such pathways permit to avoid intracranial hypertension in such cases.

Suboccipital Cavernous Sinus (SCS) and Condylar Vein

The SCS is a structure surrounding the internal carotid artery, it anatomically resembled the vertebral venous plexus surrounding the horizontal portion of the vertebral artery at the skull base.

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Fig. (3). The condylar venous system vicarious shunt. Left: Schematic exemplificative obstruction of the IJVI in course of CCSVI associated to MS. The 3 condylar veins, connected respectively with the thyroid veins and with the VVs, become a preferential substitute circle. Right: RX selective venography of a severe stenosis of the IJVI (arrow). The condylar veins (COND.V.) pipe blood toward the thyroid veins (THYR.V.), and the brachio cephalic trunk (BCT) and the superior vena cava (SVC).
Arnautovic et al. (Arnautovic et al., 1997; Takahashi et al., 2005) revealed the SCS to be connected with the following venous structures: anterior condylar vein (ACV), posterior condylar vein (PCV), lateral condylar vein (LCV), anterior internal vertebral venous plexus (AVVP), and vertebral artery venous plexus (VAVP) surrounding the vertical portion of the vertebral artery, and internal vertebral venous plexus. The SCS is an important outflow tract of the vertebral venous system that would play an important role in venous obstructive disease. The SCS sinus connects indirectly the internal vertebral venous plexus to the dural venous sinuses of the skull base (Fig. 3).

The ACV and PCV were defined as follows according to international anatomic nomenclature: ACV, venous plexus of the hypoglossal canal that drains through the hypoglossal canal (anterior condylar canal); PCV, condylar emissary vein that drains through the posterior condylar canal as described by San Millan Ruiz et al. (San Millan Ruiz et al., 2002; Takahashi et al., 2005). The ACV, PCV, and LCV are connected with both the jugular bulb and SCS. In an MR imaging study, Caruso et al. (Caruso et al., 1998; Takahashi et al., 2005) reported that the ACV connected with the SCS through the marginal sinus. Moreover, San Millan Ruiz et al. (San Millan Ruiz et al., 2002; Takahashi et al., 2005) described the marginal sinus as connecting anteriorly with the ACV, sometimes forming a bridge between the ACV and suboccipital vein. Although the portion of the ACV described herein may represent part of the marginal sinus, the presence of the marginal sinus could not be confirmed, as no circular filling occurred around the foramen magnum on bilateral anterior condylar venography.

The ACV and LCV communicate with each other at the external orifice of the hypoglossal duct. This meeting point was termed the “anterior condylar confluent” (Fig. 3) (San Millan Ruiz et al., 2002; Takahashi et al., 2005).

In a study of microsurgical anatomy, Katsuta et al. (Katsuta et al., 1997; Takahashi et al., 2005) described a venous confluence at the lower end of the IPS that drained into the medial aspect of the jugular bulb, naming this the “petrosal confluence”. They found the IPS connected with the anteromedial portion of the jugular bulb, while the ACV communicated with the postero-medial portion of the jugular bulb. The “petrosal confluence” and “anterior condylar confluent” may, thus, represent the same structure, or be located in the very near vicinity.

The PCV was defined to international anatomic nomenclature condylar emissary vein that drains through the posterior condylar canal. The PCV connected with the postero-medial aspect of the jugular bulb and supero-posterior aspect of the SCS.

The cranial connections of the anterior internal vertebral venous plexus with the anterior condylar vein could offer a cranial escape route for thoracic and abdominal venous return when thoracic pressure and abdominal pressure are increased concomitantly. One could even consider venous blood from the anterior internal vertebral venous plexus draining into the superior ophthalmic vein and cavernous sinus through the basilar plexus and IPS and, thus, terminally into the pterygoid plexus and facial veins (Fig. 4). Parkinson recently described the extradural neural axis compartment (Parkinson, 2000; San Millan Ruiz et al., 2002). The extradural neural axis compartment contains a continuum of veins that extends from the ophthalmic to the coccygeal veins and offers numerous longitudinal and transverse venous anastomoses. In the cranio-cervical region, the basilar plexus, inferior petrosal sinuses, and anterior condylar veins represent the venous elements of this extradural neural axis compartment.

The cranial connections of the anterior internal vertebral venous plexus with the anterior condylar vein could offer a cranial escape route for thoracic and abdominal venous return when thoracic pressure and abdominal pressure are increased concomitantly.
The numerous anastomoses of the ACC make it a crossroad between the cavernous sinus, dural venous sinuses of the posterior fossa, and posterior cervical outflow tracks. All the major tributaries of the ACC and outflow pathways of the cerebral venous system were shown on the phlebographic images.

Pterygoid Plexus
This venous plexus lies around and partly within the lateral pterygoid muscle. Its tributaries correspond to the branches of three parts of the maxillary artery although the area drained is somewhat smaller than that supplied by artery. Blood from the periphery of the latter area drains via other routes, such as the facial veins. The pterygoid plexus also communicates with the facial vein through the deep facial vein, with the cavernous sinus by means of one or more emissary veins passing through the foramen ovale (or the emissary sphenoidal foramen if present) and with the inferior ophthalmic vein through the inferior orbital fissure. It drains through the short but wide maxillary vein, which runs between the neck of the mandible and the sphenomandibular ligament to unit with the superficial temporal vein and form the retromandibular vein. The plexus may be difficult to find in the cadaver where it is empty of blood but in the living subject it is frequently a prominent structure.

Cervical Anastomosis: The Thyroid Veins
The superior, middle, and inferior thyroid veins all drain their respective lobes. The superior and middle thyroid veins drain into the IJVs, whereas the inferior thyroid vein drains into the brachiocephalic trunk. Such a collateral circle has been seen constantly activated when chronic obstruction of the IJVs occurred (Zamboni et al., 2009a). It permits to bypass stenoses of the distal IJVs segment collecting the blood towards the brachiocephalic trunk (Fig. 5).

CONCLUSIONS AND REMARKS
The blood leaves the brain through a very complex anatomical apparatus, with really high variability. The present review provides a simplified description of the functional organization of the extra and intracranial main pathways, as well as of the main extra-intracranial and/or extracranial collateral circulation. The knowledge of the main collateral pathways is really relevant in a number of clinical situations, including also the recent description of CCSVI associated to MS. In the latter, substitute circle permits to drain blood sufficiently to avoid intracranial hypertension.

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ABBREVIATIONS
ACC = Anterior condylar confluent
ACV = Condylar vein
AVVP = Anterior internal vertebral venous plexus
AZY = Azygous vein
CCSVI = Chronic cerebrospinal venous insufficiency
CNS = Central nervous system
CVS = Cerebrovenous system
IJVs = Internal jugular veins

Fig. (5). The thyroideal veins vicarius shunt. Left: Exemplificative obstruction of the IJVI bypassed by the thyroid veins. Right: RX selective venography showing a 95% stenosis of the IJVI in corse of CCSVI associated to MS, with corresponding vicarious shunt of the thyroid veins (THYR. V.) toward the superior vena cava (SVC).
REFERENCES


