The Anterior Condylar Arteriovenous Fistula from the Viewpoint of the Osseous Venous Anatomy

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The anterior condylar arteriovenous fistula (AC-AVF) is a relatively rare AVF that affects the vasculatures adjacent to the hypoglossal canal. We aimed to discuss the etiology and definition of the AC-AVF from the viewpoint of the osseous venous anatomy. Our recent study, which used modern imaging technology (CT digital subtraction venography and cone beam CT reconstructed from 3D rotational angiography), elucidated the intraosseous venous anatomy in this region and the precise fistulous locations of AC-AVFs. Those findings suggest that the AC-AVF is a group of “osseous” AVF that involves the anterior condylar vein and jugular tubercle venous complex (JTVC), and the osseous veins connected to them. The AC-AVF develops in osseous veins adjacent to the hypoglossal canal, and it is one of the most common subtypes of osseous AVFs. The angioarchitectures and etiology of AC-AVFs discussed herein are essential to understand this clinical entity.

Keywords ▶ anterior condylar arteriovenous fistula, osseous vein, jugular tubercle venous complex, osseous arteriovenous fistula, hypoglossal canal

Introduction

The anterior condylar arteriovenous fistula (AC-AVF) has been reported to be a relatively rare subtype of dural arteriovenous fistulas (DAVFs) that affect the vasculatures adjacent to the hypoglossal canal. It was first reported by Barnwell et al. as a DAVF involving the inferior petrosal sinus in 1990. In a subsequent report in 1997, McDougall et al. described it as a DAVF of the marginal sinus. In 1999, the association of the anterior condylar vein with the AC-AVF was first described by Ernst et al. Since then, AVFs in this region have been usually referred to as anterior condylar (vein or canal) DAVFs or hypoglossal canal DAVFs. Involvement of the other adjacent structures in this region with DAVFs has been also described; Miyachi et al. reported DAVFs involving the anterior condylar confluence (ACC) and referred to them as ACC-DAVFs. Other authors also reported DAVFs located within the bone adjacent to the hypoglossal canal. These multiple locations have been assumed as fistulous locations, and accordingly, a comprehensive analysis of the shunt location is necessary to understand the pathophysiology of AC-AVFs and to facilitate effective and safe treatment. Recently, we reported that the AC-AVF is a group of fistula that develops in emissary and osseous veins adjacent to the hypoglossal canal. On the basis of our recent findings, we discuss herein the etiology and definition of the AC-AVF from the viewpoint of the osseous venous anatomy.

Venous Anatomy Adjacent to the Hypoglossal Canal

The venous component is the center of the lesion in so-called “DAVFs”; it is formed on the wall of the venous dural sinuses, and obliteration of the fistulous outlet on the venous side can cure DAVFs. Accordingly, to understand the pathophysiology of DAVFs and to perform effective and safe treatment, anatomical knowledge of the venous structures...
that is affected by DAVFs is fundamentally important. Although the association of osseous venous structures with AC-AVF has been reported frequently,3,8,9,11,13–17,19) the osseous venous structures adjacent to the hypoglossal canal were studied rarely20–23) before we recently investigated them using CT digital subtraction venography.18)

The bone surrounding the hypoglossal canal contains many venous structures (Figs. 1 and 2). In particular, the intrasosseous venous network is frequently observed within the jugular tubercle, superiorly to the hypoglossal canal. We named the venous structure within the jugular tubercle the jugular tubercle venous complex (JTVC), which was found in 46% of jugular tubercles.18) It was always continuous with the anterior condylar vein, and most JTVCs had another connection with the surrounding venous structures through intrasosseous or transosseous channels: the
The Anterior Condylar Arteriovenous Fistula

The venous channels in this region are valveless; they enable blood to move freely within them and provide connections with the internal jugular system and vertebral venous system through the surrounding venous structures. It is possible that these osseous venous structures along with the surrounding venous structures can be considered to consist of the venous network, which enables blood to change its flow direction smoothly during postural changes.

The physiological role of these intraosseous venous channels has not been fully elucidated. One of their roles may be drainage of the osseous structures. However, they sometimes may serve a role other than simple osseous drainage. Some authors assumed that the venous channels in this region provide a connection between the internal jugular system and vertebral venous system, and function as a venous reservoir to stabilize the intracranial pressure and venous pressure during postural changes.

In the supine position, venous blood from the brain empties into the internal jugular vein; however, in the upright position, during Valsalva maneuvers, or in patients with compromised internal jugular veins, the vertebral venous plexus has been considered as the main drainage route from the brain.

Fig. 3 Venous drainage route and postural changes. (A) Supine position. (B) Upright position. According to past literature, the internal jugular veins drain from the brain when one is in the supine position (A); however, the vertebral venous plexus is considered as the main drainage route when one is in the upright position and during Valsalva maneuvers, or in patients with compromised internal jugular veins. The venous structures in this region have multiple connections with each other and may function as a venous reservoir. Orange lines, intraosseous veins. ACC: anterior condylar confluence; ACV: anterior condylar vein; CDV: clival diploic vein; IPCV: inferior petroclival vein; IPS: inferior petrosal sinus; JTVC: jugular tubercle venous complex; LCV: lateral condylar vein; MS: marginal sinus

Angioarchitecture of the Anterior Condylar AVF

The fistulous pouch of AC-AVF can form at any osseous vein adjacent to the hypoglossal canal, including the anterior
intraosseous veins other than the anterior condylar vein and JTVC; specifically, these fistulous pouches were located in the jugular process (22.2%) or condyle (11.1%) and drained through osseous veins to the jugular vein (22.2%) or lateral condylar vein (11.1%).

Based on our investigation, the AC-AVF seemed to be considered as a group of fistulas adjacent to the lateral parts (exoccipital) of the occipital bone, which includes the hypoglossal canal, jugular tubercle, occipital condyle, and the jugular process. Although the involvement of the osseous structures has been frequently reported previously, the anterior condylar vein has been traditionally considered as a location of a fistulous pouch in AC-AVF. Without modern CT digital subtraction venography or cone beam CT, it is difficult to recognize these intraosseous venous structures and to distinguish between the two fistulous locations: the anterior condylar vein and JTVC. Accordingly, in the literature, some fistulous pouches in the JTVC might have been incorrectly identified as those of the anterior condylar vein.

Understanding the angioarchitecture of AC-AVFs discussed herein is important in determining the treatment strategy. Transvenous embolization within the anterior condylar vein has been usually considered as a primary therapeutic option for AC-AVFs. A fistula of the JTVC is usually drained through one short osseous channel into the anterior condylar vein, and obliteration of the downstream anterior condylar vein may cure it. However, the use of selective embolization within the JTVC, when possible, instead of packing the anterior condylar vein can reduce the risk of post-therapeutic hypoglossal nerve palsy, which is one of the major complications after treatment.

Anterior Condylar “Osseous” AVFs

The DAVF has been generally recognized as an AVF formed within the dura mater that connects dural arteries and dural venous channels. The AC-AVF has been considered as a subtype of DAVFs and is an AVF that affects osseous venous channels, including the anterior condylar vein, JTVC, and intraosseous veins adjacent to the hypoglossal canal, which raises the following question: Can the lesion be a “dural” AVF?

According to past literature, the hypoglossal canal accompanies the dural sleeve (the inner meningeal layer of the dura mater) and penetrates the dura mater at the dural pole within the hypoglossal canal. It has been suggested...
The Anterior Condylar Arteriovenous Fistula

mostly within the dura mater, in our opinion, the AVF can also form in the osseous veins because of the following reasons. Embryologically, the dura mater is still undeveloped in the early fetal stage, and vasculatures adjacent to the brain are covered with only sparse mesenchymal tissue, that is, the meninx primitive. At this stage, the future osseous veins and dural veins cannot be distinguished. In the following stages, the meninx primitiva differentiates into several layers: the bone develops from the outermost dense skeletogenous layer, and the dural mater is formed from the inner layer. Accordingly, venous channels within the osseous layer and dural layer have the same embryological background. We assume that the osseous veins may also have physiological arteriovenous shunts embryologically and that AVFs can develop by a mechanism

that fistulas develop in this dural sleeve. Involvement of the periosteum (the outer layer of the dura mater) in the formation of DAVFs may be assumed. The outer layer of the dura mater covers the whole surface of the cranium and foramina, where the nerves pass through, which serves as a better explanation for the formation of DAVFs within the hypoglossal canal. However, these hypotheses are insufficient to explain intraosseous AC-AVF.

Regarding the etiology of intracranial DAVFs, most of them have been considered as an acquired lesion, resulting from secondary growth of pre-existing physiological arterial venous shunts induced by multiple inflammatory and angiogenetic factors including but not limited to trauma, surgery, and sinus thrombosis. Although previous literature has limited the etiological discussion to mostly within the dura mater, in our opinion, the AVF can also form in the osseous veins because of the following reasons. Embryologically, the dura mater is still undeveloped in the early fetal stage, and vasculatures adjacent to the brain are covered with only sparse mesenchymal tissue, that is, the meninx primitive. At this stage, the future osseous veins and dural veins cannot be distinguished. In the following stages, the meninx primitiva differentiates into several layers: the bone develops from the outermost dense skeletogenous layer, and the dural mater is formed from the inner layer. Accordingly, venous channels within the osseous layer and dural layer have the same embryological background. We assume that the osseous veins may also have physiological arteriovenous shunts embryologically and that AVFs can develop by a mechanism
similar to that of intracranial DA VFs. The dura mater does not seem to be a prerequisite for the formation of AVFs. The fistula itself develops on the epithelial wall of the venous channel, and the dura mater or bone surrounding the shunts may provide the environment for its growth. In a broad sense, we assume that so-called “DAVFs” can be considered as AVFs developed within the osseous and/or dural structures. Osseous AVFs and true DAVFs can be distinguished from the viewpoint of the tissue where the AVFs developed. From the etiological viewpoint, these two AVFs are considered as the same clinical entity, so-called “DAVFs”.

We assume that AVFs mostly develop in the dura mater because it is comprised of vascular-rich tissues and possibly susceptible to infection and/or inflammation, which triggers thrombosis and the angiogenesis of vasculatures within it, inducing the formation of an AVF.

Osseous AVFs, except for AC-AVF, have been reported in other locations: the posterior condylar vein,44–46) the diploic vein in the parietal bone,47) within the sphenoidal bone,48–50) the petrous bone,14,51) and occipital bone.14,52) Authors of previous studies assumed that these osseous lesions are acquired lesions and that thrombosis in the osseous vein induced by paranasal sinus inflammation or the skull base infective process trigger the formation of the osseous AVF,48) which is consistent with our theory.

The AC-AVF may be one of the largest subtypes of osseous AVFs. The reasons why AC-AVF are formed in these specific osseous veins (the anterior condylar vein and the JTVC) adjacent to the hypoglossal canal may be explained by the fact that this region is one of the most vascular-rich regions within the cranial bone, and that osseous veins in this region have multiple channels and function as a venous reservoir, which means that blood flow within it is physiologically prone to being turbulent or stagnant and thrombosed. Indeed, although the JTVC or the anterior condylar vein can have multiple connections with the surrounding venous system via osseous veins, the fistulas formed in the JTVC or the anterior condylar vein usually drain through the anterior condylar vein or one osseous drainage vein, and lose the other multiple connections.18) Thrombosis within the JTVC or its connections might cause the development of AVFs in this region (Fig. 5).

Several authors reported fistulas located in the ACC.12,53,54) Fistulas in these extracranial locations may be explained as follows. In our previous study, we found that the osseous veins were sometimes connected to the ACC.18) If AVFs develop in these osseous veins and the shunt flow is exclusively drained through the osseous veins continuously to the ACC, these fistulas may be recognized as AVFs in the ACC (Fig. 5C and 5D). Another explanation is that although these venous structures are extracranial, they still face the occipital bone. As aforementioned, the dura mater or bone provides the environment, and fistulas may develop in any veins adjacent to these structures; therefore, fistulas in these venous structures may be considered as the same clinical entity.

**Conclusion**

The AC-AVF develops in osseous veins adjacent to the hypoglossal canal, and it is one of the most common subtypes of the osseous AVF. The angioarchitectures and etiology of AC-AVFs discussed herein are essential to understand this clinical entity.

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**Disclosure Statement**

All authors have declared no conflicts of interest.

**References**


