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STRUCTURES INVOLVED IN THE TRAJECTORY OF THE AUDITORY SYSTEM (PART II): SUPERIOR OLIVARY COMPLEX

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This bulletin describes structures involved in the trajectory of the auditory system which are essential in processing auditory information. Knowledge of the neuroanatomy and neurophysiology of the Central Auditory Nervous System (CANS) is important in providing appropriate patient care, and here we look at the Superior Olivary Complex (SOC). It supplements previous bulletins on structures of the auditory system, and to gain a full understanding we recommend that the reader consult them.

The SOC can be subdivided into the ipsilateral and contralateral SOC, although both these structures receive information from both ears. Olivocochlear neurons are modulated by activity originating from the cochleas on both sides as well as from higher levels of the auditory pathway. Thus, the SOC controls the flow of auditory information coming from the periphery towards the central nervous system, and acts on pathways originating from both inner and outer hair cells. Thus, SOC fibers encompass both the ascending and descending pathways as well as the ipsilateral and contralateral pathways, and pass on information to the central auditory nervous system for processing.

The function of the SOC is to transform monaural information into binaural information, and aspects of this are mentioned below. Decomposing a sound source into discrete components depends on accurately identifying auditory information and this in turn depends on recognising subtle intra-aural differences. These processes rely on the effective functioning of the superior olive complex.

THEREFORE, THE SOC ENABLES BINAURAL REPRESENTATION, WHICH PLAYS A VITAL ROLE IN THE PROCESSING OF AUDITORY INFORMATION. TIME, FREQUENCY, AND INTENSITY DATA ARE ANALYSED BY BOTH EARS AND THE RESULT IS THEN PROCESSED BY THE BRAIN.

Among the skills that the SOC is responsible for are:

- **Sound intensity detection;**
- **Sound frequency detection;**
- **Detection of the time of sound emission;**
- **Sound source detection;**
- **Sound localisation;**
- **Binaural information.**

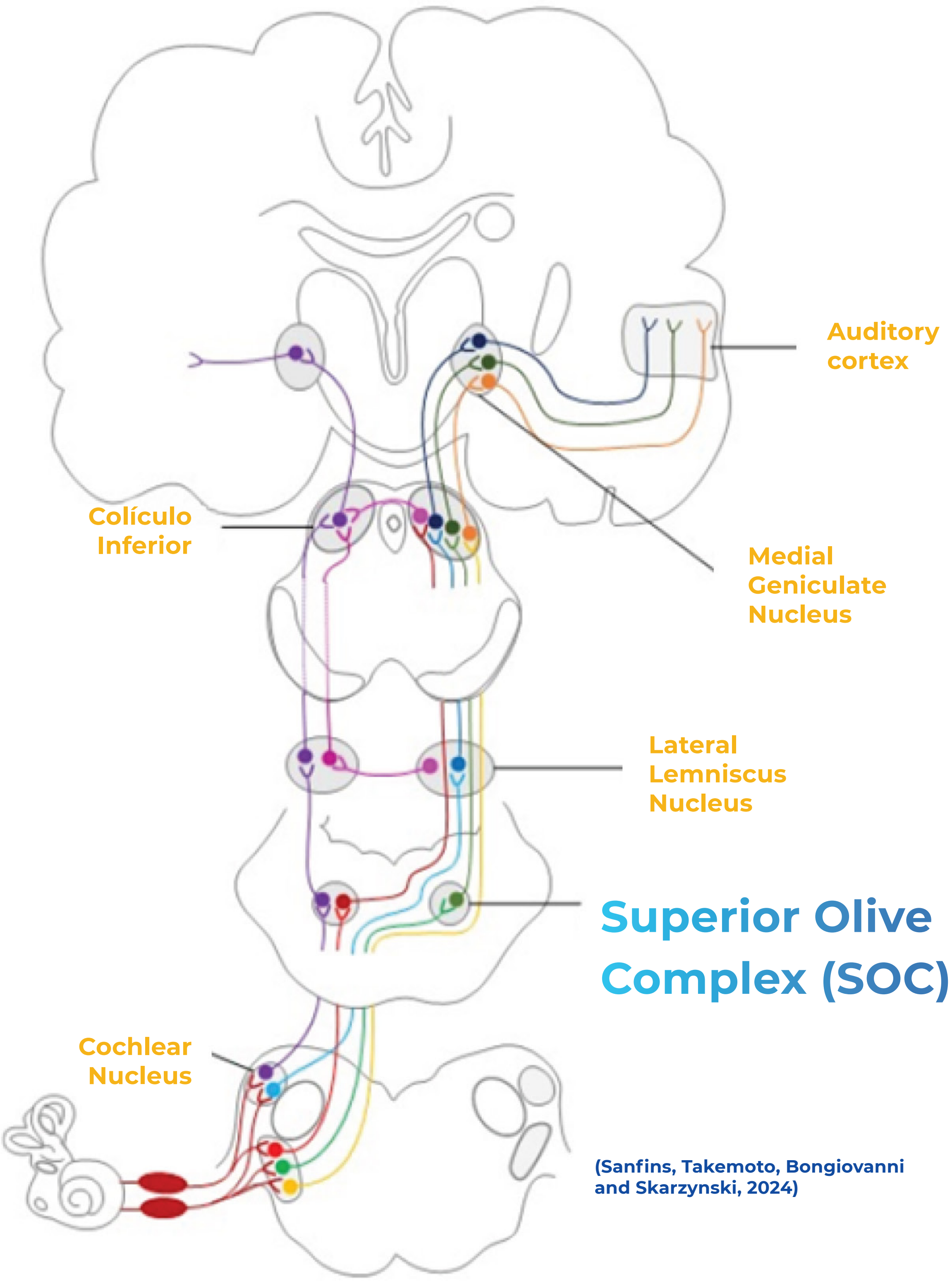

Figure 1: *Diagram of where the SOC lies within the auditory trajectory*

There is another important role for this structure. Rasmussen (1942) described a bundle of fibers that originated from the SOC and projected to the cochlea, named the olivocochlear bundle (OCB). Guinan and collaborators described two main OCB pathways: the crossed pathway and the uncrossed pathway. The uncrossed pathway originates in the lateral superior olivary complex (LSOC) and consists of unmyelinated fibers that mostly terminate on the afferent fibers of the inner hair cells. In contrast, the crossed pathway originates in the medial superior olivary complex (MSOC) and consists of myelinated fibers that end directly on fibers of the outer hair cells.

It is believed that the role of the crossed and non-crossed pathways is to allow the efferent system to have an inhibitory effect. Research has shown that the LSOC contains neurons that are classified as excitatory–inhibitory, since they receive excitatory information from the ipsilateral cochlear nucleus and inhibitory information from the contralateral cochlear nucleus. Thus, the efferent auditory system tends to inhibit the ability of outer hair cells to amplify the movement of the basilar membrane. At the same time, the SOC, due to its ability to localise a sound source and activate the inhibitory system, improves speech understanding under noisy conditions.

There is a theory that activity of the SOC correlates with psychiatric conditions. The idea is that excessive excitation, or even difficulty in inhibiting auditory information, might be present in these pathologies. Perhaps hallucinations could arise from a change in the control of sensory inputs, and this might involve the SOC. However, the topic is controversial, as illustrated by Fisman (1975). He evaluated 9 patients with proven auditory hallucinations, and 4 of them had atrophy of the SOC. Similarly, among 5 patients with schizophrenia, atrophy of the SOC was found in 2 of them.

Atrophy of the SOC can result from different conditions, such as traumatic brain injury (TBI). It is understood that the SOC is susceptible to pathogenesis and/or trauma. In this way, sound localisation can become impaired in patients after injury to regions to which the COS is inserted, that is, in the brainstem. Research shows that, after a TBI, patients may experience difficulties in processing auditory information due to increases in the neuronal conduction time involving the structures that capture this signal. The more severe the injury, the greater the delay in auditory processing.

TBIs can occur in any age group.

Atrophy and/or injury to the SOC can be even more harmful in children, since they are still in the process of development and learning how to deal with auditory information. These children may present impairments in the areas of attention, memory, or learning, as well as psychiatric pathologies. In this way, there appear to be correlations between TBI, damage to the SOC, psychiatric pathologies, and difficulties in processing auditory information.

Impairments in the SOC can cause changes in how sound is processed. The SOC can be considered the key structure for locating a sound stimulus, and so damage to this structure has a cascade effect. Damage makes it difficult, for example, to distinguish which direction a sound source is coming from; in picking out one sound among competing sounds; and in discriminating speech sounds among background noise.

Behavioral and electrophysiological tests can assess the performance of the SOC. We suggest reading an earlier issue of this bulletin on new perspectives in hearing assessment (and see the references listed in Sanfins, Skarzynski and Hall, 2024).

In the bulletin can be found tables on the diagnostic value of behavioral and electrophysiological procedures that can help in the diagnosis of different pathologies.

Regarding electrophysiological assessments, there is the Brainstem Auditory Evoked Potential (BAEP), which analyses electrical responses resulting from sound stimuli, some of which reflect activity in regions of the brainstem where the SOC is located. When one considers the structures involved in generating the BAEP responses, and their correlations with the wave peaks, it turns out that the SOC is related to the generation of wave IV (see figure 2).

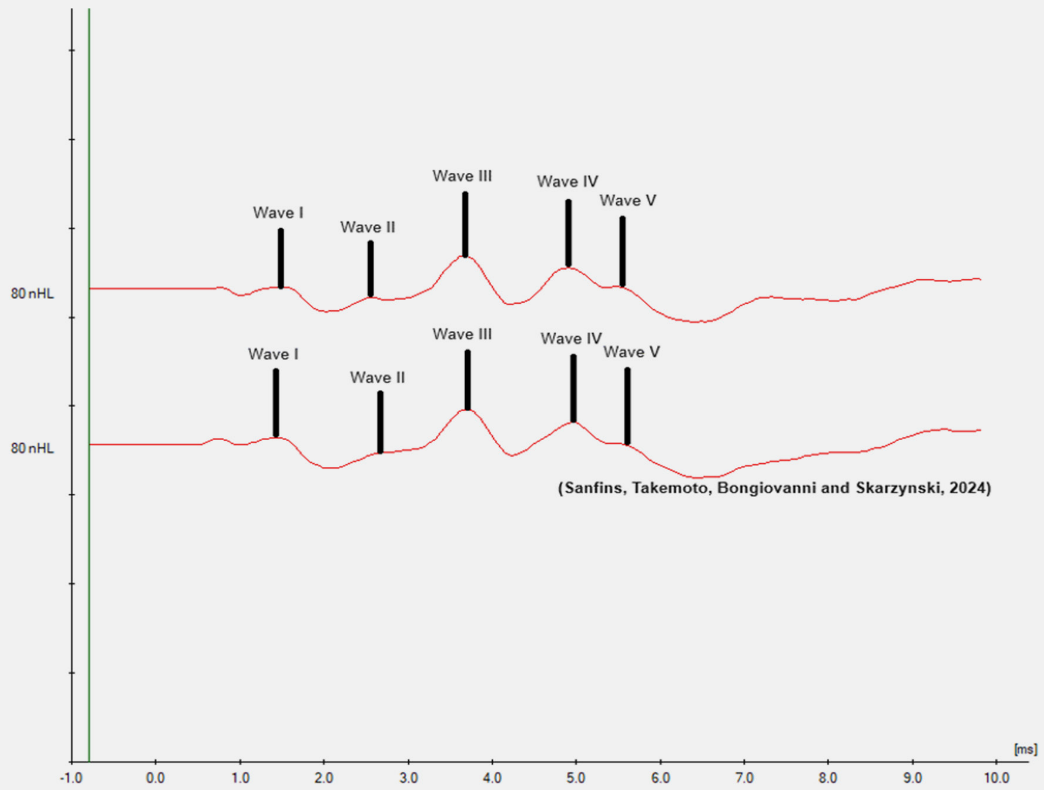

Figure 2: *Example of a click-ABR showing waves IV and V.*

There are some authors who consider that the SOC generates both waves IV and wave V of the click-BAEP, explaining why abnormalities in waves IV and V have been seen in patients with vascular changes and/or demyelinating diseases. In many click-ABR responses, waves IV and V appear as a complex that encompasses both waves, as shown in figure 3.

The idea that waves IV and V are generated by the SOC is supported by studies of brainstem lesions. Despite extensive lesions, the IV-V complex can remain intact, whereas in cases of vascular and demyelinating lesions, changes in the IV-V complex are observed.

In addition to injuries and psychiatric histories, there are many other conditions and pathologies that seem to be associated with this remarkable structure, such as auditory neuropathy spectrum disorder (ANSD). ANSD is a neurodevelopmental condition in which there appears to be associated auditory dysfunction. Auditory dysfunctions vary in each case, but there is a general problem related to the

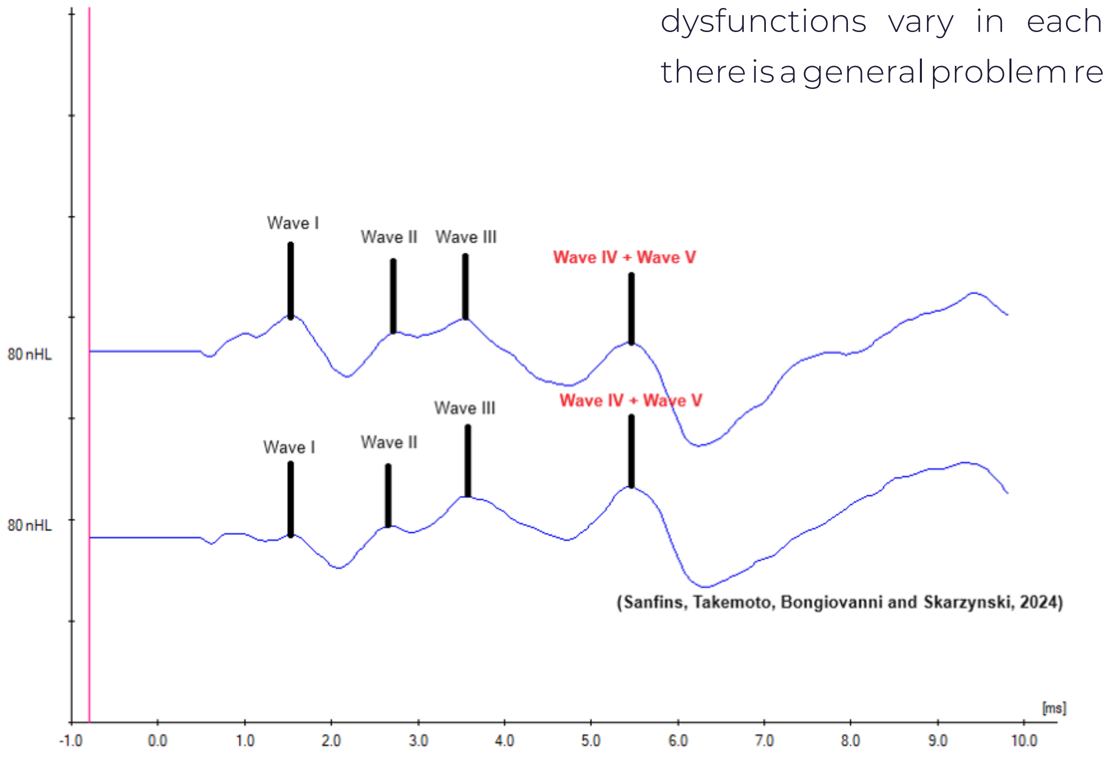

Figure 3: *Example of a click-ABR where there is a single IV-V complex (i.e., wave IV and wave V are combined).*

difficulty in filtering background noise, and this may indicate a compromised brainstem region involving the SOC. Individuals with ANSD have a reduction in the number of neurons in the SOC. Concomitantly with this reduction, the remaining neurons appear to have an anatomical change with a decrease in size and abnormal contours.

With the development of new technologies that allow for a more precise and accurate analysis of the structures involved in the auditory trajectory, it will be possible to understand the function of the SOC more precisely. Due to the positioning of the SOC in the lower area of the auditory system (as illustrated in figure 1), this knowledge is very relevant, since changes in this part of the system can have consequences throughout the afferent and efferent pathways.

We invite you to follow us on this journey of auditory structures in our next newsletter.

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