Heschl's Gyrus: Anatomic description and methods of identification in MRI

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Introduction

The primary auditory cortex is thought to be located in a characteristic gyrus on the superior surface of the temporal lobe known as Heschl's gyrus. The area posterior to that gyrus is termed "planum temporale" and is thought to be related to the cortical representation of language. Both structures are separated by Heschl's sulcus. Since it was shown that functional hemispheric asymmetries are also reflected in differences in the size of the planum, which is larger on the left hemisphere where language is represented, interest so far mainly concentrated on the morphometric characteristics and asymmetries of the planum temporale. Consequently, the attention attributed to Heschl's gyrus was mainly related to the fact that it was considered the anterior border of the planum temporale. With the advent of functional magnetic resonance imaging (fMRI), Heschl's gyrus generated increased interest when locating auditory functions. We therefore analyzed the shape of Heschl's gyrus using MRI and anatomic dissection, and we looked for landmarks that could assist in locating it in the different MRI planes.

Material and Methods

1) *Subjects and specimens*: We included 50 subjects in our study: 41 healthy volunteers (24 men, 17 women; age range: 21-39 y, mean age: 26.7 y), 7 patients with multiple sclerosis (MS) and 2 patients with a temporal cavernoma; 41 were right-handed and 5 left-handed. We examined 18 hemispheres of 9 brain specimens.
2) *MRI*: Imaging was performed on a 1.5 T Magnetom Vision. The brains of all volunteers, 9 out of 10 patients and all specimens were examined using a magnetization prepared rapid angle gradient echo (MPRAGE) sequence (TR/TE = 12/4.4 msec, TA = 13.38 min, AC = 1, FOV = 250*250, matrix = 256*256). In 6 of the MS patients, imaging was performed after the administration of Gd-DTPA.
3) *Anatomic dissection*:The arachnoid membrane covering the surface of 9 brain specimens was removed to allow exposure of the convexity surface of the sylvian fissure and the adjacent sulci and gyri. The sylvian fissure was opened until the cortex of the insula became visible.
4) *Image analysis*: Images were reconstructed in three planes with a slice thickness of 1 mm without gap. Heschl's gyrus was assessed in all three planes with respect to shape, location and number of gyri.

Results

1) *Anatomic configuration of Heschl's gyrus*. Number: In the 100 hemispheres of subjects examined, one single Heschl's gyrus was identified in 66 hemispheres, two in 33 and three gyri were identified in one hemisphere. No statistically significant differences were found between right and left or between dominant and non-dominant hemispheres. MRI and anatomic analysis of the number of Heschl's gyri correlated in 18 of 18 hemispheres of specimens. Shape: In the **sagittal** plane, the shape of Heschl's gyrus depended on the presence of a sulcus. In its absence, Heschl's gyrus had the shape of a simple omega. The presence of a shallow sulcus changed the configuration of the gyrus to the shape of a heart. In the **coronal** plane, Heschl's gyrus always had the form of a supratemporal Ω-shaped protrusion. On anterior slices, this Ω "moved" laterally, became gradually less prominent, and disappeared towards the convexity of the brain. In the **transverse** plane, Heschl's gyrus had an antero-lateral direction, that varied from very lateral, almost perpendicular on the median axes, to a much more anterior or frontal course.
2) *Landmarks for the identification of Heschl's gyrus*. In all 3 planes we identified landmarks characterizing the slice in which Heschl's gyrus could be recognized best. a) Sagittal plane: In all hemispheres examined (n=120) Heschl's gyrus was identified on the supratemporal surface by its own characteristic shape (Ω- or heart-shaped). b) Coronal plane: In all hemispheres examined (n=120) Heschl's gyrus was identified in the slice that displayes the tent-like configuration of the crura of the fornices shortly posterior to where they joined togetherto form the body of the fornix. In the same slice, the eighth cranial nerves could be recognized in all hemispheres of subjects (n=100); a comparable evaluation of the specimens was not possible due to spatial distortion of the axes of the brain stem. c) Transverse plane: In 98 of 100 hemispheres of subjects and in 12 hemispheres of specimens Heschl's gyrus was identified when the section crossed the adhaesio interthalamica. After the administration of Gd-DTPA (n= 12 hemispheres), the internal cerebral veins were a second landmark. Spatial distortion made an adequate evaluation of four hemispheres of specimens difficult.

Discussion

1) *Anatomic configuration.* A general problem when dealing with the anatomic configuration of Heschl's gyrus is to determine the number of Heschl's gyri present. It has been shown that even when only one single Heschl's gyrus existed, a lateral impression could mimick a bifurcated appearance. When this impression increases in depth it is termed sulcus intermedius. Ultimately, the differentiation between a split Heschl's gyrus and two distinct Heschl's gyri might remain arbitrary. In 2/3 of the hemispheres we examined one Heschl's gyrus was detected, in 1/3 two or more gyri were identified without any significant difference between the left and the right hemispheres or between the dominant and the non-dominant hemispheres. Pfeifer remarked in his study, that most often the left hemisphere was characterized by one single Heschl's gyrus and the presence of a posteriorly located planum temporale, whereas the right hemisphere was characterized by the presence of two Heschl's gyri and the absence of a planum temporale. Pfeifer's norm had, although contested, an important impact on subsequent studies. It was often used as a rule to determine the anterior border of the planum temporale. Our results show that the application of Pfeifer's norm, which would create a bias in favour of a larger left planum temporale, is not justified.
2) *Landmarks for the identification of Heschl's gyrus in MRI.* The landmarks we described using MPRAGE should serve as guidelines to accurately locate lesions in the superior temporal region. Moreover, when evaluating this area scientifically, it is obvious that great care must be taken to define the corresponding anatomic structures precisely and, if possible, according to a more generally accepted system. This may especially be the case 1) when acoustic and language activity is localized using fMRI, 2) when looking for morphometric particularities of the planum temporale under special clinical conditions such as handedness, developmental neuropsychologic disorders or schizophrenia.