Original investigations

Observations on the Tullio phenomenon

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Summary. Vestibular responses (vertigo, nystagmus-like eye movements) to acoustic stimuli are known as the “Tullio phenomenon”. Detailed electro-oculographic analysis of this reaction, as observed in a 30-year-old patient, revealed the following: a maximum amplitude of eye movement (mainly vertical) was achieved by sine wave bursts of high intensity, a frequency of 500 to 1000 Hz and a duration of 100 ms. The ocular deviation was composed of a fast initial component, followed by a slower resetting movement that was often divided into two parts of different velocities. At longer stimulus durations (more than 100 ms) the electro-oculogram showed a fractionation of the eye deviation, terminating in an “off-response”. Various positions of the patient’s head influenced the direction of the eye motion. The possibility that the Tullio phenomenon may be due to an abnormal excitation of the statolith organs is discussed.

Key words: Eye movement – Nystagmus – Vertigo

The fact that acoustic stimuli can produce an effect on the vestibular organ [8, 25] was first reported at the beginning of this century and later carefully studied in pigeons by Tullio [32]. Following the fistulization of the bony labyrinth, Tullio was able to provoke, by means of loud sounds, movements of the head and eyes, the plane of which corresponded to that of the fistulated semicircular canal. Tullio assumed that the excitability of the cristae ampullares had been increased by the operative procedure. On the other hand, Huizinga’s [14, 16] interpretation, which is now widely accepted [3, 10, 20], is that the sound waves which are extinguished by interference under normal conditions can only produce an excitation of the cristae ampullares [9] as a consequence of the unphysiological fenestration of the labyrinth.

Following the first presentation by Benjamins in 1938 [2], the Tullio phenomenon has been reported as a symptom of human pathology in several publications, mainly in the otolaryngological literature (for synopsis, see [7, 27]). As this phenomenon should also be known to neurologists, especially with regard to the differential diagnosis of vertigo, we report the clinical and detailed electrophysiological analysis of a patient who showed the Tullio phenomenon.

Case report

One year prior to his first admission to hospital, whilst listening to loud music via headphones a 30-year-old man suddenly experienced that his surroundings “tilted to the left” to the rhythm of the bass. This sensation, accompanied by an intense feeling of vertigo, was triggered off mainly by different noises of high intensity and predominantly lower frequencies, but sometimes even when he uttered certain vowels (“a”), heard a dialing tone (only in the left ear), swallowed or experienced pressure on the left external auditory canal.

The case history was uneventful, apart from the fact that he had a left temporal blow (from a stone) at the age of 8 years.

Neurological examination, audiometry and electronystagmography (caloric and rotatory testing) revealed no abnormalities. However, the stapedius reflex could not be elicited on the left by stimulation of either the homolateral or contralateral ear. Moreover, the fistula test clearly produced positive results in the left ear. CT scan of the middle ear showed the stapes to be of normal shape on both sides.

Analysis of the Tullio phenomenon

Sine wave bursts of variable duration, frequency, intensity and repetition rate were applied monaurally. Eye movements were recorded by means of two vertically mounted pairs of electrodes (Fig. 1) and two horizontally arranged electrodes placed on the lateral side of each eye. A four-channel Medelec-MS-6 system was used; the bandpass of the amplifiers was set at 0.016–32 Hz.

Clinical observations

Appropriate stimulation of the left ear (see below) provoked a rapid conjugate oblique deviation of both eyes upwards and to the right, without a clearly visible rotatory component; subsequently the eyes rolled back to their initial position at a lower speed. Elimination of fixation using Frenzel’s glasses did not change the deviation. No compensatory head movement was observed.

Electro-oculographic analysis

The shapes of the recorded eye movements were found to be congruent in both eyes (Fig. 1A); however, they varied...
Fig. 1. A EOG recording of vertical eye movements (channels 1 and 2) evoked by a sine wave burst (channel 3) applied to the left ear. Eyes open; the Tullio response (TR) is clearly separated from the spontaneous blink reflex (BR). B Two different types of eye deviation. Calibration in A and B: 12° and 100 ms

Fig. 2. Vertical eye movements. To assess the stimulus-response interval, four traces (HF filter set at 100 Hz) are superimposed. A sine wave burst of 20 ms duration (bottom) is used (Fig. 1B) rather randomly without any discernible relationship to changes in a certain stimulus parameter. The vertical component (up to 20°) was constantly pronounced when compared with the horizontal one (up to 4°; see Fig. 6). Fixation did not change the electro-oculogram.

The amplitudes displayed a remarkable variation even under constant stimulus conditions and at low repetition rates (0.1/s). With regard to this instability, the mean value of ten single recordings was taken as the basis for further assessments. The latency time between the start of the stimulus and the beginning of the eye deviation was approximately 20 ms (Fig. 2).

Using different stimulus durations (at 500 Hz and 120 dB SL) we found that the mean amplitude of the vertical eye deviation reached a maximum at 100 ms. Beginning with a duration of 200 ms a progressive fractionation of the stimulus response was seen (Fig. 3). The initial main component was followed by various numbers of smaller ones, which gradually disappeared during repeated stimulation; consistently, however, an "off-response" was recorded.

The influence of frequency and intensity of the sine waves was examined using tone bursts consisting of 50 sine waves of 64 to 4000 Hz and intensities of 90 to 120 dB SL. The results are given in Fig. 4.

Under optimal stimulus conditions (500 Hz, 100 ms duration, 120 dB SL intensity) the stimulus repetition rate was increased step-by-step from 0.1 to 10/s. The mean amplitude decreased from 11° (0.1/s) to 8° (0.5/s), 7° (1/s), 3° (5/s) and 1° (10/s). Within a single series, each consisting of 20 stimuli, the amplitudes nevertheless remained stable (Fig. 5). Applying the acoustic stimuli (with the patient's head in different posi-