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Response to: Commentary to "Bone conducted vibration is an effective stimulus for otolith testing in cochlear implant patients"

Thank you for bringing this up to the discussion in 'Commentary to "Bone conducted vibration is an effective stimulus for otolith testing in cochlear implant patients"' [1]. The intention of our paper was not to shift stimulus protocols but to point out that BCV is very useful to complement ACS in CI patients due to possible impairment of sound conduction. The occurrence of crossed cVEMP responses is indeed not mentioned in our paper and is certainly an important aspect to consider when interpreting cVEMP responses to BC stimuli in patients with suspected saccular impairment, e.g., following CI surgery [2].

We agree that the complexity of BC induced cVEMPs needs consideration. Since BC stimulation acts on both sides, responses from the contralateral side do exist. However, the inhibitory vestibulo-collic reflex from the saccule to the SCM is indeed unilateral, while the crossed (mainly utricular) reflex to the contralateral SCM is excitatory. This was shown by the animal work of Uchino (see [3], Fig. 7) and Rosengren and Colebatch 2018 (see [4], Fig. 3). However, the crossed responses in patients with unilateral vestibular loss (uVL) to stimulation of the affected side, i.e., the CI side in our study, appear at longer latencies and are small. Rosengren et al. reported that "lateral acceleration of the intact side in unilateral lesions (Fig. 8*A*) did not produce the reversal of polarity that might be expected for excitation of the lateral portion of the utricle (an initial negativity/excitation ipsilaterally and an early inhibition contralaterally). Instead, only a small c-p1/c-n2 response was seen in the SCM contralateral to the intact ear." [5]. Interaural head acceleration (i.e., medial acceleration of CI side and lateral acceleration of the contralateral side when placed on the CI side) was also used in our study with the B81 placed at the mastoid and not the forehead. Thus, the potential is unlikely to be mistakenly interpreted as cVEMP response. However, we strongly recommend that in clinical practice response curves are analyzed by experienced examiners only.

Some more considerations addressing the letter's arguments are the following:

1. We demonstrated in another study that with placement of the B81 on the forehead cVEMP response rates were very low even in healthy test subjects [6]. Only mastoid placement (interaural acceleration) lead to sufficient response rates.
2. If the contralaterally evoked p20 would have mistakenly been interpreted as cVEMP p13 from the CI side the latencies should be different between the CI and the contralateral side, i.e., longer for the CI side. However, the p13 n23 latencies of the CI side and the contralateral side reported in the study were comparable. The cVEMP latencies recorded in another study in healthy test subjects using the same setup can serve as a reference and were also comparable to the data reported here [6]. As there is currently no standard on the recording of VEMPs, each center is obliged to record their own reference values for amplitudes and latencies to ACS and BCV induced cVEMPs and oVEMPs. Variation is expected due to the use of different stimuli as well as stimulation and recording equipment and techniques.
3. Regarding the 0-1-0 AC stimulus used in the study, we agree that it results in significant frequency splatter (shown in Fig. 1). However, short rise times have been shown to be effective to elicit VEMPs while frequency specificity

is not a key requirement for VEMP stimuli [7, 8]. We showed that cVEMPs to ACS could be elicited in the patients of our study in the contralateral side using the described stimulus. Only the CI side showed poor response rates to this stimulus due to conductive impairment as we suspected. In healthy subjects, we did not find a difference between cVEMP response rates to ACS and BCV using the exact same stimuli (both 100%) [6]. However, it could be useful to implement cVEMP threshold measurements comparing a 0-1-0 versus 1-1-1 stimulus in future studies.

Therefore, we consider it unlikely that a crossed response from the healthy – contralateral – side was mistakenly interpreted as cVEMP from the CI side in our study. However, the knowledge of the existence of crossed responses when using BCV is essential when analyzing cVEMP results in patients with suspected saccular impairment. Thus, the comment adds valuable content to our discussion.

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