

Objective

To develop an algorithm, based on the voltage matrix, for detecting regular cochlear implant (CI) electrode position during the implantation procedure, tip fold-over or basal kinking for lateral-wall electrodes. The availability of an algorithm would be valuable in clinical routine, as incorrect positioning of the electrode array can potentially be recognized intraoperatively. [1, 2, 3]

Methods and Materials

In this retrospective study the imaging and the voltage matrix (see Fig. 1) of 525 implantations was analyzed. The voltage matrix was obtained intraoperatively using the clinical software MAESTRO (MEDEL, Innsbruck, Austria) resulting in a 12x12 voltagematrix matrix, when the voltage is measured for each stimulation electrode on all contacts. The imaging was obtained postoperatively using Digital Volume Tomography. Beside a regular position (in 99% of the cases) three tip fold over and four basal kinkings were found, revealing typical patterns in the voltagematrix, respectively (see Fig. 1-2). The voltage distribution of the matrix was analyzed by using a quadratic measure, the normalized squared sum of the cross-diagonals, as shown in Figure 1c. All elements of the voltage matrix were normalized to the largest observed voltage. Then, for each cross-diagonal, the squared normalized voltages were summed and divided by the number of summed elements. The middle of the array is represented by the main cross-diagonal (solid red line in Figure 1b). The cross-diagonals separate into an even (red lines) and an odd (blue lines) group, due to respective different distances of its elements to the stimulated channel. If no peak was detected the case was assigned to a regular position, if a peak was detected the cases was assigned to a tip fold over if the peak was in the apical region (diagonal offset < 0) and to a basal kinking, if the peak was located in the basal region (diagonal offset > 0).

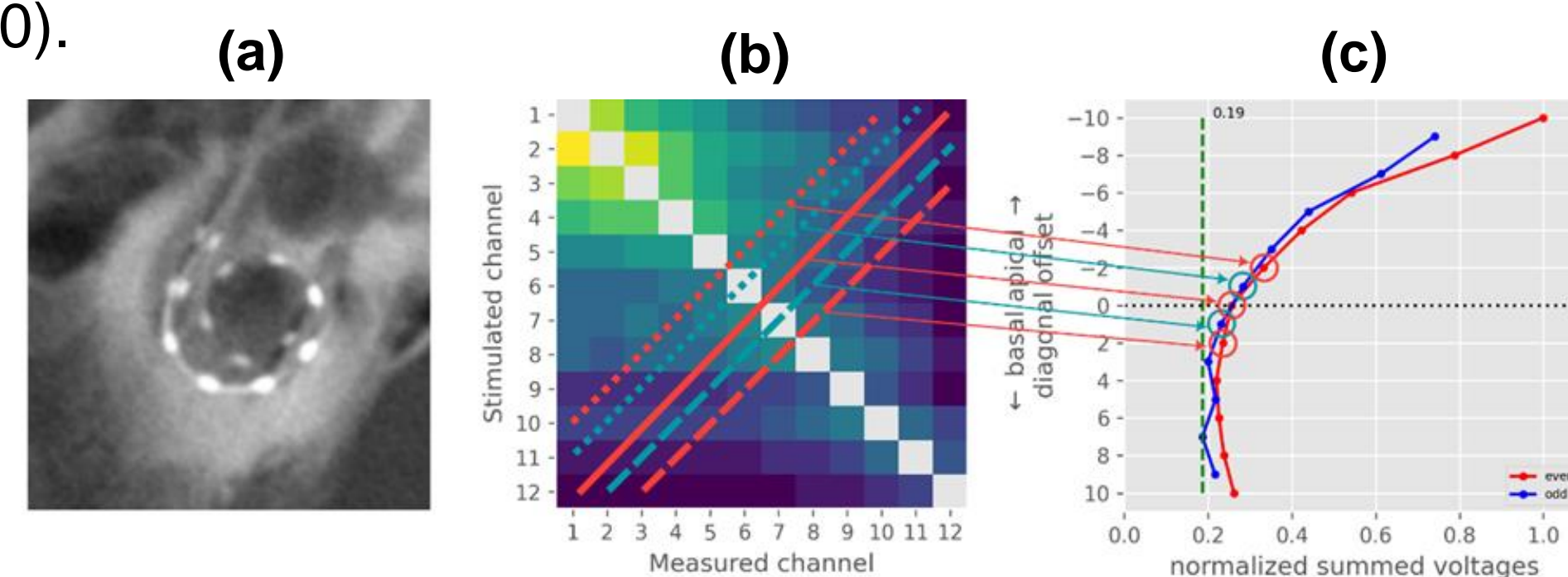


Fig. 1: Example of a case with regular electrode position
(a) Digital Volume Tomography (DVT)
(b) Color coded voltage matrix with a schematic draw of the cross-diagonals
(c) Plot of normalized squared sums of even and odd cross-diagonals

Conclusion

The color coded voltagematrix reveals a typical patterns for regular electrode position, for tip fold over and for basal kinkings, respectively. This allows to judge electrode position intraoperatively. Furthermore, the algorithm was found to be an effective screening tool for detecting correct positioning, tip fold-over or basal kinking since it detected all misplacements with at least three electrodes involved correctly.

Results

In 98.67 % of the cases a regular electrode position was found by means of imaging. Seven incorrect electrode positions, three tip fold (0.57%) and four basal kinking (0.76%) were found by means of imaging. Due to isolated contacts (assumable air bubbles) or a dry reference contact at the stimulator housing during voltage measurements 10% of the cases were excluded for further analyzing. For detecting correct positioning by means of the algorithm, a sensitivity of 100%, a specificity of 83.3% and a positive predictive value (PPV) of 99.8% were found. For detecting tip fold-over a sensitivity of 100%, a specificity of 100% and a PPV of 100% were found. For detecting basal kinking, three out of four cases were detected by means of the algorithm. In the case, the algorithm did fail, only one electrode was involved in the kinking. This resulted in a sensitivity of 66%, a specificity of 100% and a PPV of 100%.

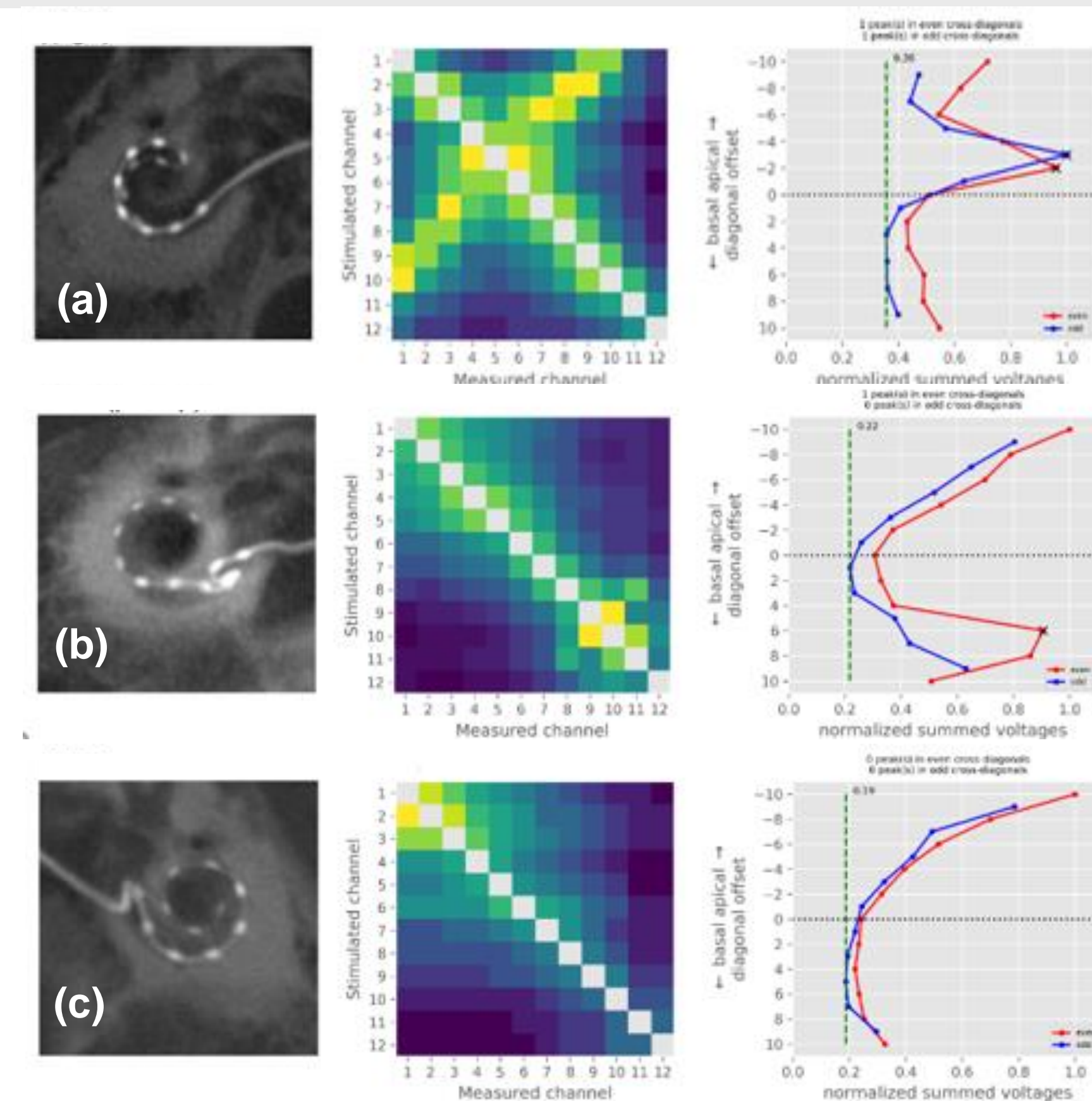


Fig 2: Imaging, voltagematrix and summed squared cross diagonals for a tip fold over (a), a basal kinking (b) that were detected correctly by the algorithm and another basal kinking (c) that was not detected correctly.

References

- [1] Hans S, Arweiler-Harbeck D, Kaster F et al (2021) Transimpedance Matrix Measurements Reliably Detect Electrode Tip Fold-over in Cochlear Implantation. *Otol Neurotol* 42:e1494–e1502. <https://doi.org/10.1097/MAO.0000000000003334>
- [2] Hoppe U, Brademann G, Stöver T et al (2022) Evaluation of a Transimpedance Matrix Algorithm to Detect Anomalous Cochlear Implant Electrode Position. *Audiol Neurootol* 27:347–355. <https://doi.org/10.1159/000523784>
- [3] Müller A, Kropp MH, Mir-Salim P et al (2021) Intraoperatives Tip-Foldover-Screening mittels Spread of Excitation Messungen. *Z Med Phys* 31:276–288. <https://doi.org/10.1016/j.zemedi.2020.07.002>