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Review

Review on cochlear implant electrode array tip fold-over and scalar deviation

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ABSTRACT

Objective: Determine the occurrence rate of cochlear implant (CI) electrode tip fold-over and electrode scalar deviation as reported in patient cases with different commercial electrode types.
Data-sources: PubMed search for identifying peer-reviewed articles published till 2018 on CI electrode tip fold-over and scalar deviation. Key-words for searching were “Cochlear electrode tip fold-over”, “Cochlear electrode scalar position” and “Cochlear electrode scalar location”.
Articles-selection: Only if electrode related issues were investigated in patient cases. 38 articles met the inclusion-criteria.
Results: 13 articles on electrode tip fold-over issue covering 3177 implanted ears, out of which 50 ears were identified with electrode tip fold-over with an occurrence rate of 1.57%. Out of 50 ears, 43 were implanted with pre-curved electrodes and the remaining 7 with lateral-wall electrodes. One article reported on both tip fold-over and scalar deviation. 26 articles reported on the electrode scalar deviation covering an overall number of 2046 ears out of which, 458 were identified with electrode scalar deviation at a rate of 22.38%. After removing the studies that did not report on the number of electrodes per electrode type, it was 1324 ears implanted with pre-curved electrode and 507 ears with lateral-wall electrode. Out of 1324 pre-curved electrode implanted ears, 424 were reported with scalar deviation making an occurrence rate of 32%. Out of 507 lateral-wall electrode implanted ears, 43 were associated with scalar deviation at an occurrence rate of 6.7%.
Conclusion: This literature review revealing the fact of higher rate of electrode insertion trauma associated with pre-curved electrode type irrespective of CI brand is one step closer to obsolete it from the clinical practice in the interest of patient's cochlear health.

Contents

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1. Introduction

The preferred location for the surgical placement of Cochlear Implant (CI) electrode is the Scala Tympani (ST) (Aschendorff et al., 2007). While the Round Window (RW) approach of electrode insertion has been widely accepted as the standard of CI surgery (O'Connell et al., 2016) still cochleostomy approach is practiced by some group of surgeons (Badr et al., 2018). As per Eshraghi's scale of electrode insertion intra-cochlear trauma (Eshraghi et al., 2003), an electrode insertion into the cochlea would result in any of the following degree of trauma. Grade 0 corresponds to zero trauma or atraumatic insertion whereas, grade 1 corresponds to lifting of the basilar membrane (BM), grade 2 refers to rupture of BM or Spiral ligament (SL), grade 3 corresponds to the electrode dislocation from ST to Scala Vestibuli (SV) and grade 4 refers to the fracture of osseous spiral lamina (OSL) or modiolus wall. While every CI surgeon would aim for atraumatic electrode insertion, grade 2–4 is considered irreversible as the damage to the osseous spiral lamina or to the basilar membrane could mix-up the perilymph from ST with the endolymph of Scala Media (SM) (Bas et al., 2012). Electrode tip fold-over or rollover is another form of intra-cochlear complication which is a result of electrode tip getting stuck with any of the intra-cochlear structures which the surgeons may not feel and further pushing of the electrode makes the electrode tip to be folded over as shown in Fig. 1. While electrode tip fold-over can be corrected in the same surgery if identified by intra-operative images (McJunkin et al., 2018), it can also be corrected in a revision surgery (Sabban et al., 2018) if identified post-operatively if patients complain of vertigo, pitch confusion or tinnitus.

Visualizing the intra-cochlear electrode position in live patients can be done by the following methods of clinical-imaging (Aschendorff et al., 2007), Neural Response Threshold (NRT) (Mittmann et al., 2017) and Electro-Cochleography (ECochG) (Koka et al., 2018). While a plain film x-ray is enough to reveal the electrode tip fold-over/rollover issues (Dirr et al., 2013), clinical CT (computed Tomography) has been in use to detect electrode translocation. Grade 1 and 2 degree of trauma cannot be detected conclusively by the clinical CT due to the image artefact but grade 3 and 4 can be conclusively detected. There is enough number of publications since 2007 that reported on electrode tip fold-over (McJunkin et al., 2018; Sabban et al., 2018; Dirr et al., 2013; Timm et al.; Sipari et al., 2018; Gabrielpillai et al., 2018; Jia et al., 2018;

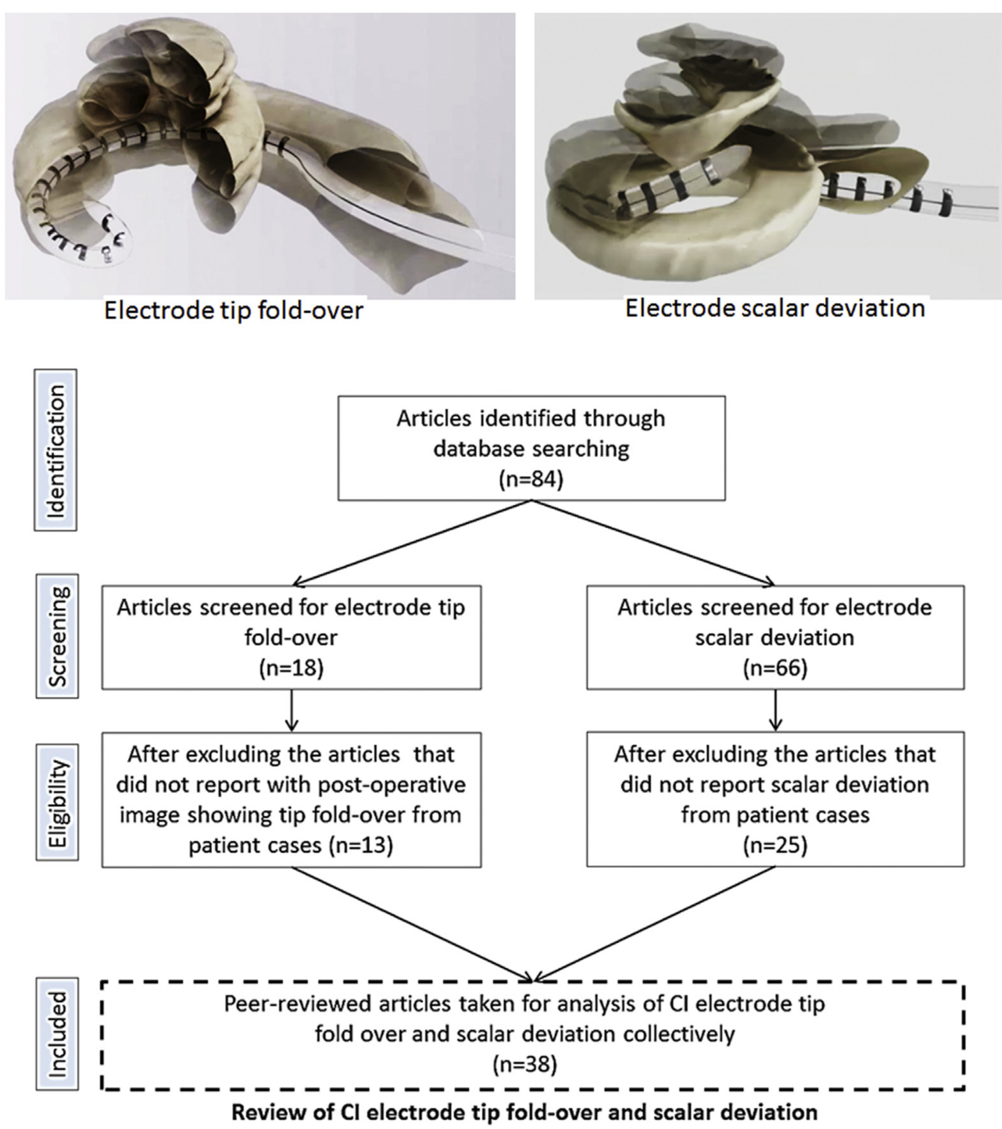

Fig. 1. Literature review process.

Garaycochea et al., 2017; Aschendorff et al., 2017; Zuniga et al., 2017; Fischer et al., 2015; Cosetti et al., 2012; Grolman et al., 2009) and electrode scalar deviation (McJunkin et al., 2018; Mittmann et al., 2017; Koka et al., 2018; Dirr et al., 2013; Sipari et al., 2018; Jia et al., 2018; Aschendorff et al., 2017; Shaul et al., 2018; Ketterer et al., 2017; An et al., 2017; O'Connell et al., 2017a; O'Connell et al., 2017b; Lathuillière et al., 2017; O'Connell et al., 2016a; O'Connell et al., 2016b; Wanna et al., 2015; Nordfalk et al., 2016; Mittmann et al., 2015a; Mittmann et al., 2015b; Mittmann et al., 2015c; Boyer et al., 2015; Wanna et al., 2014; Nordfalk et al., 2014; Aschendorff et al., 2011; Wanna et al., 2011; Lane et al., 2007) detected with x-ray, clinical CT, NRT and ECochG methods. All the commercially available CI electrodes vary in its size, shape and the method of insertion, the operating surgeon should be well informed about all these variation before the surgery. Reviews on the CI electrode design are given in detail by Briggs et al. (2011), Boyle et al. (Boyle, 2016) and Dhanasingh et al. (Dhanasingh and Jolly, 2017) covering various commercially available CI electrodes.

In this review study, Slim-Modiolar (SM), Contour Advance (CA), Contour (C), Mid-Scala (MS) and Helix (H) were all grouped under pre-curved electrode type. The remaining electrodes from all the CI brands were grouped under the straight lateral wall (LW) type for example Slim-Straight (SS), 1J, Standard (Std), Medium (M), Compressed (S) and FLEX electrodes (FLEX SOFT, $FLEX^{28}$, $FLEX^{24}$) as (F). To the best of authors ability and responsibility, every published literature that reported mainly on electrode tip fold-over and electrode scalar deviation in patient cases were identified without any bias hoping that this could be of any minor assistance to the operating surgeons to know more about the incidence rate of tip fold-over and scalar deviation and its negative effects (Sabban et al., 2018; Shaul et al., 2018; Ketterer et al., 2017). As for the CI companies, this could already be a final alarm for them to come-up with newer electrode design that results in zero tip fold-overs and scalar deviations, which will highly benefit the patients at the end.

2. Materials and methods

A thorough search on PubMed (https://www.ncbi.nlm.nih.gov/pubmed/) was performed using the key words “Cochlear electrode tip fold over”, “Cochlear electrode tip roll over”, “Cochlear electrode scalar position” and “Cochlear electrode scalar location”. Articles published only in English language were taken for the review. Break down analysis corresponds to finding the incidence rate of tip fold-over and scalar deviation within the pre-curved and straight electrode type.

2.1. Inclusion criteria

Inclusion criteria for this study were as follows with studies that reported on (1) electrode tip fold-over and (2) electrode scalar deviation (grade 3 trauma) detected using post-operative imaging or intra-operative electrophysiological assessment only in patient cases and not from cadaveric temporal bone studies.

2.2. Exclusion criteria

Articles reported on electrode tip fold-over and scalar deviation in cadaveric temporal bones and the duplicate articles that came in the list when using different key words were excluded.

3. Results

84 peer reviewed publications reported on electrode tip fold-over and scalar deviation from patient cases were identified using the search method given in Fig. 1. Fig. 1 also pictorially represents how an electrode tip fold-over and scalar deviation would look like inside the cochlea. After removing the inappropriate articles that did not have to do anything with electrode tip fold-over or electrode scalar deviation, duplicate articles and reports from cadaveric temporal bones a total of 38 articles were found eligible for the review analysis.

A total of 13 peer-reviewed publications report on electrode tip fold-over in patient cases was identified from the data base. All these articles either applied post-operative computed tomography (CT)/plain film x-ray or intra-operative fluoroscopy in the identification of electrode tip fold-over.Table 1 summarizes these 13 studies with different electrode types from all 3 major CI brands. Altogether, 3177 implanted ears were taken for analysis and out of which 50 ears were identified with electrode tip fold-over making an overall occurrence rate of 1.57% irrespective of CI brand and electrode type. Out of these 50 implanted ears, 43 ears were implanted with pre-curved electrode type and 7 ears with LW electrode type irrespective of the CI brand. Gabrielpillai et al. (2018), Zuniga et al. (2017), Dirr et al. (2013), did not provide number of cases per electrode type that made it difficult to perform the electrode type break-down analysis. With these 3 studies neglected, the total number of pre-curved electrode and lateral wall electrode implanted ears accounted to 553 and 387 respectively. Out of these numbers, 26 and 3 ears were reported with tip fold-over making an incidence rate of 4.7% and 0.80% respectively with the pre-curved and lateral wall electrode types.

Electrode scalar deviation is another important and the most traumatic event that could happen inside the cochlea during electrode placement. A total of 26 peer-reviewed publications were found reporting on intra-cochlear electrode array scalar deviation in patient cases with the current commercially available electrode types (McJunkin et al., 2018; Mittmann et al., 2017; Koka et al., 2018; Dirr et al., 2013; Sipari et al., 2018; Jia et al., 2018; Aschendorff et al., 2017; Fischer et al., 2015; Shaul et al., 2018; Ketterer et al., 2017; An et al., 2017; O'Connell et al., 2017a; O'Connell et al., 2017b; Lathuillière et al., 2017; O'Connell et al., 2016a; O'Connell et al., 2016b; Wanna et al., 2015; Nordfalk et al., 2016; Mittmann et al., 2015a; Mittmann et al., 2015b; Mittmann et al., 2015c; Boyer et al., 2015; Wanna et al., 2014; Nordfalk et al., 2014; Aschendorff et al., 2011; Wanna et al., 2011; Lane et al., 2007) and were summarized in Table 2.

A total of 2046 implanted ears reported from 26 peer-reviewed published articles were taken for analysis. Out of 2046 implanted ears, a total of 458 ears were reported with electrode scalar deviation making an overall incidence rate of 22.38% irrespective of CI electrode types and brands. Dirr et al. (2013) did not provide electrode type specific number and with the exclusion of that data a total of 1831 implanted ears were available for further analysis. Out of 1831 implanted ears, pre-curved electrode including the Mid-Scala electrode were implanted in 1324 ears and the remaining 507 ears were implanted with lateral wall electrode type irrespective of the CI brand. Bringing C, CA, H and MS all under pre-curved electrode type ($392 + 32$), a total of 424 implanted ears had scalar deviation making an incidence rate of 32% with this electrode type. The lateral wall electrode implanted ears showed scalar deviation rate of only 6.7% (34/507).

Lee et al. (2011) in 2011 reported on electrode scalar deviation identified by the histopathologic method from patients who were implanted with the older generation of electrodes when they were alive and these electrodes are currently not available in the market as given in Table 3. Lateral wall electrodes irrespective of CI brands are given in Table 3 were involved in the scalar deviation.

Table 1
Summarizing the 13 studies on tip fold-over.

Study	No. of cases taken for analysis/method	No. of electrode per type/brand			No. of cases reported tip fold-over
		A	B	C	
Timm et al (2018)	275 (CT)	–	–	275 (F28, F24, F20, F16)	0
Sipari et al. (2018)	23 (CT)	–	MS (23)	–	2
Gabrielpillai et al. (2018)	1722 (CT)	**No info on brand segments**			7 (CA), 6 (SM), 2(SS)
Jia et al. (2018)	65 (Intra-op CT) (Contains 3 electrodes from Oticon)	CA (12), SM (1), SS (31)	1J (2), MS (3)	F28 (13)	1 (SM)
Sabban et al. (2018)	2 (x-ray & CT)	–	MS	–	2
McJunkin et al. (2018)	117 (intra-op x-ray)	SM	–	–	9
Garaycochea et al. (2017)	1 (Intra-op fluoroscopy)	SM	–	–	1 (100%)
Aschendorff et al. (2017)	45 (intra-op x-ray/fluoroscopy)	SM	–	–	2 cases. 1st case corrected in the same surgery. 2nd case underwent revision surgery
Zuniga et al. (2017)	303 (CT)	CA, SS **No info on brand segments**	MS, 1J	–	3(CA), 1(MS), 1 (SS) and 1(1J)
Fischer et al., 2015	63 (CT)	–	–	F24,F28, Std	1
Dirr et al. (2013)	215 (Post-op x-ray)	CA, SS **No info on brand segments**	–	Std, M, S, FL, F28	2 (F)
Cosetti et al. (2012)	277 (Intra-op x-ray)	CA	–	–	5
Grolman et al. (2009)	72 (Intra-op rotational x-ray)	CA	–	–	4
Total	**3180**				**50 (43 pre-curved electrode + 7 lateral wall electrode)**
Total, after excluding 3 studies that did not specify number per electrode type	**940**	**Pre-curved (553) Lateral wall (387)**			**Pre-curved (26) Lateral wall (3)**

CA: Contour Advance; SM: Slim-Modiolar; MS: Mid-Scala; SS: Slim Straight; Std: Standard; M: Medium; S: Compressed; FL: FLEX SOFT, F28: FLEX^{28}; F24: FLEX^{24}; F20: FLEX^{20}; F16: FLEX^{16}.

4. Discussion

Atraumatic (Grade 0) intra-cochlear electrode placement ensures better audiological performance irrespective of electrode type following the CI surgery (O'Connell et al., 2016; Shaul et al., 2018; Ketterer et al., 2017; O'Connell et al., 2017a; O'Connell et al., 2016a; Wanna et al., 2015; Wanna et al., 2011; Holden et al., 2013) especially in patients with low frequency residual hearing. With electrode types varying in its design and insertion methods among the CI brands (Dhanasingh and Jolly, 2017), it is a challenging task for the operating surgeon in consistently and atraumatically handle the electrode in every patient in which the cochlear anatomy is also varying which results in considerable rates of intra-cochlear trauma.

Tables 1 and 2 summarizes the 38 peer reviewed publications that collectively reported on electrode tip fold-over and scalar deviation issues respectively with the electrode types from all 3 major CI manufacturers in patient cases. Fig. 2 simply shows incidence rate of both tip fold-over and scalar deviation by pre-curved and lateral wall electrodes separately. While the rate of tip fold-over with pre-curved and lateral wall electrode type accounts to 4.7% and 0.8% of implanted ears respectively, rate of scalar deviation with these two electrode types accounts to 32% and 6.7% respectively. Both tip fold and scalar deviation is approximately 5 times higher with the pre-curved electrodes in comparison to the lateral wall electrodes.

Understanding how electrode tip fold-over happens is essential. With pre-curved electrode type, pre-mature pulling of the stylet rod out of the electrode could be thought as one of the several other reasons whereas with lateral wall electrode type, the tip geometry alone can be blamed. Fig. 3 shows the tip geometry of all the electrodes taken here for the analysis. Considering the rough/porous surface of the modiolus wall inside the cochlea, the chances for pointed/conical tip to get stuck is highly there and this could explain how the tip fold-over could happen inside the cochlea for both electrode types. Though there are colored markers available along the pre-curved electrode array length indicating the insertion depths to which the pre-curved electrodes should be inserted with the stylet in place, variations in the cochlear size and shape jeopardizes the benefits of colored markers. If tip fold-over can be identified intra-operatively then there are higher chances to correct it in the same surgery, if not the tip fold-over could create pitch confusions, vertigo and tinnitus as reported by Sabban et al., in 2018 (Sabban et al., 2018). Trakimas et al., in 2018 (Trakimas et al., 2018) reported new bone and fibrous tissue formation right at the place where the intra-cochlear electrode bending, kinking and tip fold-over happened as seen from the CI implanted patients who died and donated their bodies for research.

Reasons for electrode scalar deviation can be the following. The stiffness of the electrode can be substantially blamed for such an electrode insertion trauma. Again the colored markers in the array indicating the insertion depth to which the pre-curved electrode with the metal stylet rod or polymer sheath should be inserted inside the cochlea, the cochlear size and shape variation could mislead and as a result, pre-curved electrode made straight with the metal stylet inside the array could have already pierced through the spiral ligament at the end of the straight portion of the basal turn. Also if there is a disorientation with stimulating channels slightly facing the basilar membrane at the beginning of the electrode insertion and as stylet rod/polymer rod is pulled out to make the pre-curved electrode to hug the modiolus wall after reaching the prescribed insertion depth, the stiff electrode with the conical/pointed tip of the electrode can break the osseous spiral lamina or the organ of corti and enter the SV. These are beyond what a surgeon can control during the surgical procedure. Shaul et al., in 2018 (Shaul et al., 2018), Ketterer et al., in 2017 (Ketterer et al., 2017), O'Connell et al., in 2016 (O'Connell et al., 2016a; O'Connell et al., 2016b), Wanna et al., in 2011 (Wanna et al., 2011) and Holden et al., in 2013 (Holden et al., 2013) reported on drop in audiological performance among the CI patients with electrode scalar deviation

Table 2
26 studies reported on electrode scalar deviation.

Study	No. of cases taken for analysis	Analyzing method	No. of electrode from type/brand			No. of cases reported with scalar deviation		
			A	B	C	MH	MS	LW
Shaul et al. (2018)	110	Imaging	CA (92), SM (18)	–	–	18 (19.5%)	–	–
Sipari et al. (2018)	23	Imaging	–	MS (23)	–	–	5 (22%)	–
Koka et al. (2018)	32	Imaging/ EcochG	–	MS (32)	–	–	7 (22%)	–
Jia et al. (2018)	65	Imaging	CA (12), SM(1), SS (31)	1J (2), MS (3)	F28 (16),	1 (8%)	1 (20%)	–
McJunkin et al. (2018)	23	Imaging	SM (23)	–	–	6 (**26%**)	–	–
Ketterer et al., 2017	368	Imaging	CA (368)	–	–	118 (**32%**)	–	–
An et al., 2017	26	Imaging	SS (5)	–	F28 (21)	–	–	1 (**4.7%**) F28, 1(**20%**) SS
Aschendorff et al. (2017)	45	Imaging	SM (45)	–	–	0 (**0%**)	–	–
O'Connell et al., 2017a	48	Imaging	–	–	F24, F28, Std (48)	–	–	0 (**0%**)
O'Connell et al., 2017b	18	EcochG	–	MS (18)	–	–	6(**33%**)	–
Mittmann et al. (2017)	50	NRT	SS (50)	–	–	–	–	2 (**4%**) SS
Lathuillière et al., 2017	24	Imaging	CA (24),	–	–	3 (13%)	–	–
O'Connell et al., 2016a	56	Imaging	CA (36), SS (20)	–	–	19 (**52%**)	–	2 (**10%**) SS
O'Connell et al., 2016b	220	Imaging	CA (115), SS (19),	1J(21), MS (14)	F28 (28), Std (17), F24 (4) & M (2)	59 (**51%**)	8(**57%**)	4 (**4.4%**) F
Wanna et al. (2015) (Wanna et al., 2015)	45	Imaging	CA (15) SS, 1J & F collectively (27)	MS (3)		4 (**26%**)	1(**33%**)	2 (**7%**)- 1J &SS
Nordfalk et al. (2016) (Nordfalk et al., 2016)	39	Imaging	–	–	F28 (18), FL (17), F24 (4)	–	–	0 (**0%**) F
Mittmann et al., 2015a	23	NRT	CA (23)	–	–	6 (**26%**)	–	–
Mittmann et al., 2015b	85	NRT	CA (85)	–	–	16 (**18%**)	–	–
Boyer et al. (2015)	61	Imaging	CA (31),	–	FL, F28, F24, Std (30)	8 (**25%**)	–	0 (0%) FLEX, 1 (**3%**) Std.
Fischer et al., 2015	63	Imaging	–	–	F28 (40), F24 (2), FL (7), Std (14)	–	–	5 (**12.5%**) F28
Wanna et al. (2014)	116	Imaging	CA, MS (69)		(47) LW from all 3 CI brands	29 (**42%**) with MH	–	5 (**10.6%**) All LW
Dirr et al. (2013)	215	imaging	107		108	–	–	1(0.92%) F
Nordfalk et al. (2014)	13	Imaging	CA (7)	1J (3)	Std (2), F24 (1)	3 (**43%**) with CA,	–	1 (**50%**) Std, 1 (**33%**) 1J
Aschendorff et al. (2011)	223	Imaging	C (21), CA (202)	–	–	19 (**90%**) C, 70 (**35%**) CA.	–	–
Wanna et al. (2011)	32	Imaging	20	10	2	7 (**35%**)	4(**40%**)	0 (**0%**) F
Lane et al. (2007)	23	Imaging	C/CA (13) LW electrodes from brand A & B (9)	H (1)	–	6 (**46%**) C	–	7 (**78%**) LW
Total	**2046**		**1415**	**272**	**359**	**392**	**32**	**34**
Total, after excluding Dirr et al that did not specify number per electrode type	**1831**		**Pre-curved (1324) Lateral wall (507)**			**Pre-curved (424) Lateral wall (34)**		

NRT: neural response telemetry, EcochG: electrocochleography.

in comparison to CI patients with electrode completely residing in ST.

Study by Lee et al. (2011) included 38 cadaveric cochlear samples from patients who were previously implanted with CI was not included in the analysis of scalar deviation as it had the older generation of electrodes which are currently not available in the market anymore. They reported scalar deviation with 17 cases which were all implanted with the lateral wall electrode type of the older generation. Moreover, the patients who were implanted with these older generations of electrodes were reported with preoperative complications like labyrinthitis ossificans, otosclerosis, temporal bone fracture and soft tissue obstruction which could well be responsible for the electrode scalar deviation.

While straight lateral wall electrode type is expected to be placed along the lateral wall of cochlea, chances of touching the basilar membrane is highly there and this will be classified as Grade 1 trauma per Eshraghi's scale. Though this is interesting and important information to know, how this can be visualized from

Table 3
One study reporting on electrode scalar deviation from older generation of electrodes which are currently not available in the market.

Study	No. of cases taken for analysis	Analyzing method	No. of electrode from type/brand				No. of cases reported with scalar deviation		
			A	B	C	D	MH	MS	LW
Lee et al. (2011)	38	Histology	Nucleus 22 (16) (LW), 24R (1) (MH), 24 M (4) (double array LW), 24 RST (1) (LW)	Clarion (1) (LW)	MED-EL 40+ (1) (LW)	Ineraid (10) (LW)	0	–	Nucleus 22 (8) Clarion (1) Ineraid (4) 40+ (1)

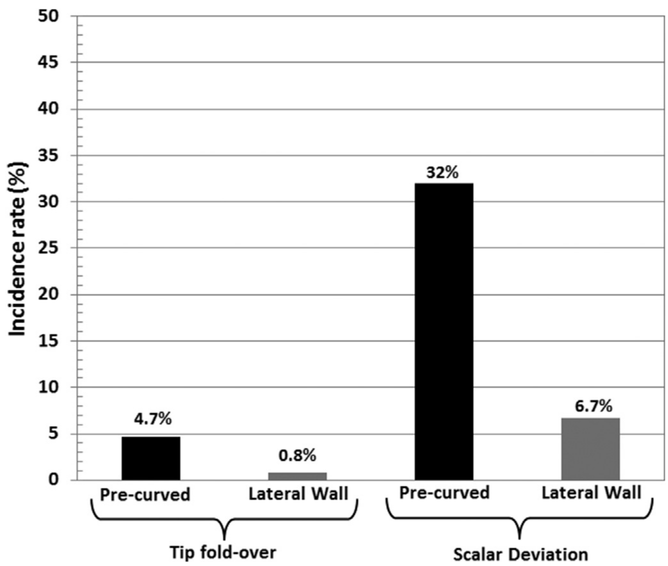

Fig. 2. Histogram chart showing the % of electrode related issues with two general types of CI electrodes.

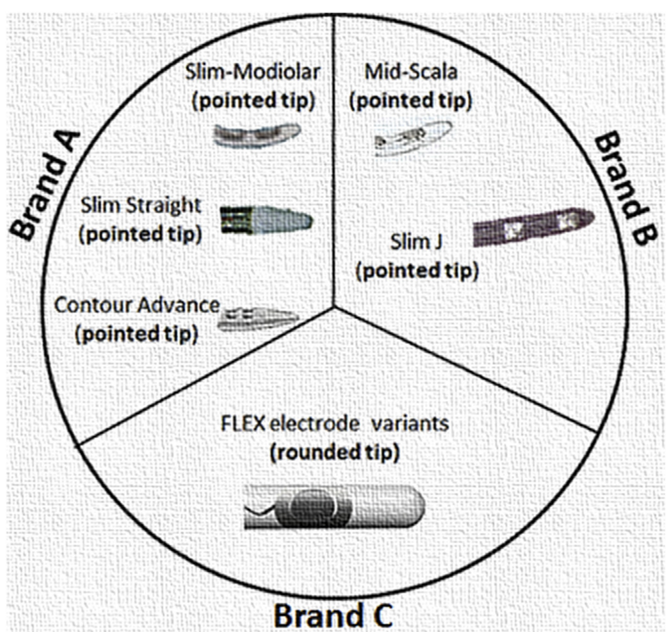

Fig. 3. Electrode tip geometry from all three major CI brands.

the clinical CT images of patients which are highly inconclusive is a question, whereas Grade 3 trauma of scalar translocation can be easily recognized from the clinical CT images. If closer proximity of the stimulating contacts to modiolus wall is considered a big advantage of pre-curved electrode, how often does a pre-curved electrode type places the stimulating contacts closer to modiolus wall is again a big question and this was raised by Wang et al. (2017). In their study they pointed out clearly that "*Our results show that perimodiolar EAs, more often than not, do not sit adjacent to the modiolus where they are likely most effective*". If pre-curved electrode do not provide the stimulating contacts a closer proximity to modiolus wall and in addition, it involves in scalar deviation at a rate which is higher than straight lateral wall electrode, it poses the question to the operating surgeon why not select lateral wall electrode type in all cases in which there are no anatomical complications. Pre-curved electrodes may be of good choice for example cases with otosclerosis in which the stimulating contacts placed relatively closer to modiolus wall proved beneficial (Battmer et al., 2008). Not to forget the issue of electrode array migration out of the cochlea associated with lateral wall electrode irrespective of CI brand as reported by Dietz et al., in 2015 (Dietz et al., 2016) and van der Marel et al., in 2012 (van der Marel et al., 2012).Techniques like fixation clip (Cohen and Kuzma, 1995; Müller et al., 1998) can be thought to minimize or eliminate the electrode array migration issue. Recently, intra-operative electrocochleography method has been used as a research tool in finding the scalar deviation as reported by Koka et al. (2018), hoping that it could reliably inform the operating surgeon before the scalar deviation happens. Scalar deviation is mainly detected using the post-operative CT imaging and this method has been validated using histology section as reported by Iso Mutajärvi et al., in 2017 (Iso-Mustajärvi et al., 2017). Therefore the reliability of the scalar deviation detection method should not pose serious question on how representative the data used in this review.

5. Conclusion

Electrode tip fold-over and electrode scalar deviation are gaining importance among clinicians as more and more reports are coming out demonstrating relatively lower CI outcomes with electrode insertion trauma especially scalar deviation. With the data analyzed from the peer-reviewed publications in this review, it is evident that pre-curved electrode type encounters intra-cochlear trauma relatively at a higher rate compared with lateral wall electrode type. While CI brings some hearing benefit in all patients with or without any electrode related intra-cochlear trauma and irrespective of electrode type, the hearing benefit increases with the electrode completely positioned in the ST and this needs to be taken into a serious consideration in the interest of the patients while selecting the electrode type.

Declaration

Both the authors are employees of MED-EL Austria, at the time of writing this manuscript. Authors declare that this review was done to the best of their ability and responsibility avoiding any bias and considering all the critical comments by the reviewers.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.joto.2019.01.002.

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