

# **Surgical Techniques of Cochlear Implantation**

**Essay**

*Submitted for Partial Fulfillment of Masters Degree  
In Otorhinolaryngology*

**By**

**Ahmed Abd El MoneimTeama**

*M.B.B.Ch*

*Faculty of Medicine- Ain Shams University*

**Under Supervision of**

**Prof. Dr. Ossama Ahmed Abd El Hamid**

*Professor of Otorhinolaryngology*

*Faculty of Medicine- Ain Shams University*

**Prof. Dr.TalaatAli El Samny**

*Professor of Otorhinolaryngology*

*Faculty of Medicine- Ain Shams University*

**Dr. Amr Nabil Rabie**

*Assistant Professor of Otorhinolaryngology*

*Faculty of Medicine- Ain Shams University*

**Faculty of Medicine**

**Ain Shams University**

**2014**

# **Acknowledgment**

*I am thankful to **ALLAH** for granting me the will and power to finish this work*

*I would like to express my deepest gratitude and cardinal appreciation to **Prof Dr. Ossama Abdel Hamid**, Professor of Otorhinolaryngology, Faculty of Medicine, Ain shams University, for his great encouragement, sharing of his thoughts, experience, sound advice and precious guidance in the production of this work. Working under his supervision was indeed a great honour.*

*Also I wish to express my deep thanks to **Prof Dr. Talaat El Samny**, Professor of Otorhinolaryngology, Faculty of Medicine, Ain Shams University, for his continuous support, kind cooperation and valuable advice, which have been of great help in the final outcome of this work.*

*My sincere gratitude to **Dr. Amr Nabil Rabie**, AssistantProfessor of Otorhinolaryngology, Faculty of Medicine, Ain Shams University, for his generous assistance, great help, valuable advice, and sacrifice of much of his precious time to make this work possible.*

*Finally, I would like to express my deepest thankfulness to **my parents**, for their great help and support throughout my medical career.*

**Ahmed Abd El MoneimTeama**

# Contents

List of Tables.....	I
List of Figures.....	II
List of Abbreviations.....	VI
<b>Introduction</b> .....	<b>1</b>
<b>Aim of the Work</b> .....	<b>4</b>
<b>Review of Literature</b> .....	
- Chapter (1): Surgical anatomy.....	<b>5</b>
- Chapter (2): Radiological assessment.....	<b>36</b>
- Chapter (3): Cochlear implant devices.....	<b>75</b>
- Chapter (4): Candidate selection .....	<b>89</b>
- Chapter (5): Surgical techniques .....	<b>111</b>
- Chapter (6): Cochlear implant rehabilitation.....	<b>158</b>
- Chapter (7): Explantation and reimplantation .....	<b>170</b>
<b>Summary</b> .....	<b>186</b>
<b>References</b> .....	<b>191</b>
<b>Arabic Summary</b> .....	<b>—</b>

## List of Tables

<b>Table</b>	<b>Title</b>	<b>Page</b>
<b>1</b>	Reference points for the apical, middle, and basal turns of the cochlea	12
<b>2</b>	Preoperative high resolution computed tomography examination for cochlear implantation	45
<b>3</b>	Key points for preoperative imaging studies for cochlear implantation	54
<b>4</b>	Comparison of devices according to companies	82
<b>5</b>	The cochlear implant pathway	110
<b>6</b>	Collection of complications data according to technique 1	153
<b>7</b>	Collection of complications data according to technique 2	154
<b>8</b>	Reasons for explantation	172
<b>9</b>	Failure rates among manufacturers	173
<b>10</b>	Indications for revision surgery	173
<b>11</b>	Revision surgeries in the literature	177

## List of Figures

<b>Figure</b>	<b>Title</b>	<b>Page</b>
<b>1</b>	Temporal bone	6
<b>2</b>	The Facial Nerve	8
<b>3</b>	Posterior tympanotomy in a left ear, showing the anatomical relations	8
<b>4</b>	The medial wall of the tympanic cavity	10
<b>5</b>	Endoscopic view of the posterior medial wall of the tympanic cavity	10
<b>6</b>	Diagram of the cochlea and the oval and round windows	11
<b>7</b>	Inner ear structures	14
<b>8</b>	The Membranous Labyrinth	15
<b>9</b>	Cochlear cross-section	16
<b>10</b>	The cochlea and vestibule, viewed from above	17
<b>11</b>	Section of cochlea in the basal turn	17
<b>12</b>	Segmental anatomy of the basal turn of the cochlea	18
<b>13</b>	Lateral view of the cochlea and the medial wall of the tympanic cavity	20
<b>14</b>	Illustration of the turn of the bony spiral lamina in the basal turn of cochlea	22
<b>15</b>	Scanning electron micrograph of a section of the organ of Corti	25
<b>16</b>	Antero-lateral view of the cochlea	26
<b>17</b>	Illustrations of the cochlea in the plane perpendicular to the axis of the modiolus	28

<b>Figure</b>	<b>Title</b>	<b>Page</b>
<b>18</b>	Cochlear vasculature	32
<b>19-22</b>	Cochlear microdissection	33-35
<b>23</b>	CT the cochlea and the transmastoidal route of surgery	38
<b>24</b>	Patient positioning for examination of the temporal bone	39
<b>25</b>	MRI inner ear	40
<b>26</b>	FSE-MRI of a normal inner ear	41
<b>27</b>	MRI delineation of the cochlear nerve	44
<b>28</b>	MRI size and aspect of a normal cochlear tube	44
<b>29</b>	HRCT sections cochlea	46
<b>30</b>	Axial CT scan through the round window and cochlear basal turn	47
<b>31</b>	MRI scans of the internal auditory canal	48
<b>32</b>	CT cuts of the middle and inner Ear, axial	49-50
<b>33</b>	CT cuts of the middle and inner Ear, Coronal	50-51
<b>34</b>	MRI cuts of the inner Ear & IAC T2 Coronal	52-53
<b>35-45</b>	Radiology for inner ear congenital anomalies	57-63
<b>46-52</b>	Radiology for inner ear inflammatory conditions	63-66
<b>53</b>	Intra-operative CBCT scan	67
<b>54-55</b>	Stenver's view, normally positioned implant	68
<b>56-59</b>	Stenver's view, abnormally positioned implant	69-70
<b>60</b>	Illustration of the application of fMRI to examine candidates for CI	73

<b>Figure</b>	<b>Title</b>	<b>Page</b>
<b>61</b>	fMRI resulting from the stimulation of two different electrodes	74
<b>62</b>	Early history of cochlear implants	77
<b>63</b>	Position of the internal and external portions of CI device	79
<b>64</b>	Cochlear implant device models	81
<b>65</b>	Nuroton implant	88
<b>66</b>	Processor Template	112
<b>67</b>	Implant template	112
<b>68</b>	Bone recess template	113
<b>69</b>	Electrode Claw	113
<b>70</b>	Incision planning	114
<b>71</b>	The evolution of the cochlear implantation incision	116
<b>72</b>	The well	117
<b>73</b>	Posterior Tympanotomy	118
<b>74</b>	Cochleostomy	119
<b>75</b>	Electrode insertion	120
<b>76</b>	Accessibility of the RWM in the RW-intentioned approach	121
<b>77</b>	Visualization of the anterior facial recess hole	128
<b>78</b>	EMA RW cochleostomy	128
<b>79</b>	Electrode inside the groove in EMA	129
<b>80</b>	Drawing of a section of the temporal bone through the facial recess for EMA	129

<b>Figure</b>	<b>Title</b>	<b>Page</b>
<b>81-84</b>	Suprameatal approach	132- 133
<b>85-86</b>	Minimal access incision technique	136- 137
<b>87</b>	Labyrinthotomy into common cavity	140
<b>88-89</b>	Endoscopic CI	142
<b>90</b>	Percentage of major and minor complications by approach	145
<b>91</b>	Complications for SMA and MPTA groups	153
<b>92</b>	Cumulative CI revision rates	183



## List of Abbreviations

<b>Abb.</b>	<b>Meaning</b>
<b>3D</b>	3 dimensions
<b>ABI</b>	Auditory brain stem implant
<b>ABR</b>	Auditory Brainstem Response
<b>ACE</b>	Advanced combination encoder
<b>ADRO</b>	Adaptive Dynamic Range Optimization
<b>AICA</b>	Anterior inferior cerebellar artery
<b>ART</b>	Auditory nerve Response Telemetry
<b>ASSR</b>	Auditory Steady State Response
<b>BOLD</b>	Blood oxygenation level dependent
<b>BOR</b>	brachio-oto-renal síndrome
<b>BSL</b>	Bony spiral lamina
<b>BTE</b>	Behind the ear
<b>CAT</b>	Combined approach technique
<b>CBCT</b>	Cone beam Computed tomography
<b>CDC</b>	Center for Disease Control
<b>CI</b>	Cochlear implant
<b>CIS</b>	Continuous interleaved sampling
<b>CMV</b>	Cytomegalovirus
<b>CSF</b>	Cerebrospinal fluid
<b>CT</b>	Computed tomography
<b>EABR</b>	Electrical auditory brainstem response
<b>EAC</b>	External auditory canal
<b>ECAP</b>	Evoked compound action potentials
<b>ECG</b>	Electrocardiography
<b>EEG</b>	Electroencephalography
<b>EEG</b>	Electroencephalography
<b>EMA</b>	Endomeatal approach
<b>ERG</b>	Electroretinography
<b>fMRI</b>	Functional magnetic resonance imaging
<b>FSE-MRI</b>	Fast Spin Echo magnetic resonance imaging
<b>HL</b>	Hearing level

**HRCT**      High resolution Computed tomography

<b>Abb.</b>	<b>Meaning</b>
<b>IAC</b>	Internal auditory canal
<b>IAM</b>	Internal auditory meatus
<b>IHC</b>	Inner hair cells
<b>IP</b>	Incomplete partition
<b>ITMAIS</b>	Infant Toddler Meaningful Auditory Integration Scale
<b>LNT</b>	Lexical Neighbor test
<b>LO</b>	Labyrinthitis ossificans
<b>LOC</b>	Lateral olivocochlear bundle
<b>MCF</b>	Middle cranial fossa
<b>Med-El</b>	Medical Electronic Corporation
<b>MEG</b>	Magnetoencephalography
<b>MOC</b>	Medial olivocochlear bundle
<b>MPEAK</b>	Multipeak
<b>MPTA</b>	Mastoidectomy-posterior tympanotomy approach
<b>MRI</b>	Magnetic resonance imaging
<b>MSCT</b>	Multislice computed tomography
<b>NICU</b>	neonatal intensive care unit
<b>NMNPT</b>	Non-mastoidectomy non-posterior tympanotomy technique
<b>NRI</b>	Neural Response Imaging
<b>NRT</b>	Neural Response Telemetry
<b>OHC</b>	Outer hair cells
<b>PET</b>	Positron emission tomography
<b>PP</b>	Postis posterior
<b>RWN</b>	Round window niche
<b>SBC</b>	Standard bony promontory cochleostomy
<b>SD</b>	Standard deviation
<b>SMA</b>	Suprameatal approach
<b>SNHL</b>	Sensory neural hearing loss
<b>SPEAK</b>	Spectral peak
<b>VSS</b>	Vessel Sealing System

## Introduction

Cochlear implantation has proved to be an excellent therapy for patients with severe to profound sensorineural hearing loss. It restores the ability to hear sound and to understand speech to various degrees (**Marel et al., 2011**). With today's technology and the demonstrated success of cochlear implantation, candidacy criteria have greatly widened (**Chen et al., 2009**).

In cochlear implant surgery, there are three principal approaches: the classic approach, uses the facial recess, the suprameatal approach, does not require mastoidectomy and uses the creation of a tunnel over the facial nerve to enter the middle ear, and the endomeatal approach which is based on the completion of a groove in the posterior wall of external auditory canal (**Zernotti et al., 2012**).

The classical approach uses the facial recess for passage of electrodes from the mastoidectomy into the middle ear. This technique requires a simple mastoidectomy and a posterior tympanotomy. Access to the middle ear is narrow at this point and requires precision and experience, since the presence of the facial nerve requires certain risks to be assumed. Critics of the technique emphasise this point, arguing that this access can be

bypassed, thus avoiding the proximity of the facial nerve and its possible complications (**Zernotti et al., 2012**).

Alternative techniques to classic mastoidectomy and posterior tympanotomy for cochlear implantation have already been described but their main drawbacks result in either: the risk of an electrode extrusion through the skin as the groove is drilled into the auditory canal or the risk of a facial nerve injury as the tunnel is drilled blindly into the posterior canal wall (**Guevara et al., 2010**).

With a common cavity malformation, the transmastoid labyrinthotomy approach to the common cavity is an effective and simple technique for placing the electrode array (**Zarandy, 2008**). Percutaneous cochlear implant surgery consists of a single drill path from the lateral mastoid to the cochlea via the facial recess cortex. Within all fields of surgery, there has been a push toward minimizing the invasiveness of procedures image-guided surgical systems (IGS) (**Labadie et al., 2008**).

The combined approach technique (CAT) is a variation of the classical technique, it combines a transcanal approach to cochleostomy with a reduced posterior tympanotomy for insertion of electrodes, a safe alternative approach in cochlear implant surgery, with no related major complications and fewer cases of electrode migration when compared with the classical

posterior tympanotomy approach. These findings encourage the use of the transcanal route to cochleostomy as an alternative approach option (**Lavinsky et al., 2012**).

Despite the fact that the transmastoid facial recess approach continues to be the gold standard and most commonly utilized worldwide for cochlear implant (CI) surgery, other techniques have been developed and described in the literature. While many of them are employed when anatomical constraints require nontraditional approaches such as a small mastoid cavity, make the facial recess approach more difficult, others are used depending on the preference, comfort level, and specific training of the surgeon. While these alternative techniques are important additions to any otologist, it is paramount that CI surgery remain safe and effective while minimizing complications (**Zeitler et al., 2010**).

## **Aim of the Work**

To review the literature regarding the different surgical techniques of cochlear implantation, highlighting the advantages and disadvantages of each technique.

## Surgical Anatomy

Knowledge about the anatomy and physiology of the auditory system is a prerequisite for understanding not only the normal function of the auditory system, but also for understanding the fact that changes in function may result from surgical manipulations (**Moller, 2011**).

### **Mastoid air cell system**

A portion of the mastoid process is pneumatized to form numerous mastoid air cells of inconstant size and number. Although anterosuperiorly they are large, irregular, and air containing, the inferior-most cells are often rather small and may even contain marrow. The tympanic antrum is the large irregular air cavity lined by mucous membrane beginning at the aditus and extending posteriorly (Fig. 1) (**Nayak, 2001**). With cochlear implant surgery it is necessary to remove the cells from part of the mastoid bone to provide space for the receiver-stimulator and lead wire assembly. Air cells must also be removed to expose the posterior wall of the middle ear for access to the round window and basal turn of the cochlea for the insertion of the electrode array through a posterior tympanotomy (**Clark, 2003**).