Spiral Ganglion

Anatomy and Ultrastructure

Essay

Submitted for partial Fulfillment of Master Degree in

Otorhinolaryngology

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(2009)

Acknowledgements

I would like to express my utmost gratitude to ENT department of faculty of medicine (Ain Shams university) and to my professors; prof. dr. Abdel Rehiem Sarwat, prof. dr. Yasser El Beltagy and assistant prof. Ossama Hassan for the efforts they exerted for me.

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List of abbreviations

Ad.BDNF	Brain-derived neurotrophic factor - secreting adenoviruses.
AICA	Anterior inferior cerebellar artery.
AMPA	Alpha-3-hydroxy-5-methyl-4-isoxazole propionic acid.
AP	Action potential.
BDNF	Brain-derived neurotrophic factor.
BDNF-SCs	Schwann cells that were genetically modified to express EGFP-tagged BDNF.
bFGF	Basic fibroblast growth factor.
BMP4	Bone morphogenetic protein 4.
Ca	Calcium.
Cl	Chloride.
CMV	Cytomegalovirus.
CNS	Central nervous system.
CNTF	Ciliary-derived neurotrophic factor.
DA	Dopamine.
DCC	Deleted in colon cancer –receptor for netrin-1.
eABRs	Electrically evoked brainstem responses.
EGF	Epidermal growth factor.
EGFP	Enhanced green fluorescent protein (fluorescent marker).
EGFP-SCs	Schwann cells that were genetically modified to express EGFP.
EPSP	Excitatory postsynaptic potential.
ES	Electrical stimulation.
GABA	Gamma-aminobutyric acid.
GCs	Growth cones.
GDNF	Glial cell-derived neurotrophic factor.
ger	Great epithelial ridge.
GFP	Green fluorescent protein.
Glu	Glutamate.
gRb1	Ginsenoside Rb1.
5-HT	Serotonin.
IC	Inferior colliculus.
ICES	Intracochlear electrical stimulation.
IHCs	Inner hair cells.
IPSP	Inhibitory postsynaptic potential.
IR	Immunoreactivity.
K	Potassium.
LIF	Leukemia inhibitory factor.
LSO	Lateral superior olive.

n.	Number.
Na	Sodium.
NFs	Nerve fibers.
NO	nitric oxide.
Ntf3	Neurotrophin 3.
Ntf3-SCs	Schwann cells that were genetically modified for EGFP-tagged Ntf3.
OCB	Olivocochlear bundle.
OHCs	Outer hair cells.
OSL	Osseous spiral lamina.
P0 to P60	Postnatal (days).
pNestin-GFP	Nestin promoter green fluorescent protein.
RC	Rosenthal's canal.
ROS	Reactive oxygen species.
S.c	Sub-cuteneous.
SCs	Schwann cells.
SEM	Scanning electron microscopy.
SG	Spiral ganglion.
SGCs	Spiral ganglion cells.
SGNs	Spiral ganglion neurons.
SNHL	Sensorineural hearing loss.
TLVM	Time lapse video microscopy.
VR/ NP	Vesicle-rich and neurofilament-poor.
VP/NR	Vesicle-poor and neurofilament-rich.

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Introduction

The mammalian spiral ganglion consists mainly of the bipolar cell bodies of primary afferent auditory neurons. The cell bodies are enclosed in Rosenthal's canal (spiral canal) in the attached margin of the osseous spiral lamina, which spirals around the modiolus of the cochlea. The central processes of the spiral ganglion neurons pass through the internal auditory meatus forming the auditory nerve, and the peripheral processes project to the organ of corti where they connect with the hair cells **(Glueckert et al., 2005b; Cartee et al., 2006)**.

Spiral ganglion neurons are the primary afferent neurons that transmit auditory information from the organ of corti to the cochlear nuclei. The number of neurons in the normal human spiral ganglion is important for evaluating changes associated with aging or pathological conditions. There have been a few studies on the number of spiral ganglion neurons, but the results are conflicting **(Ishiyama et al., 2001; Whitlon et al., 2007)**.

Degeneration of the spiral ganglion cell may occur as a primary or a secondary event according to hair cell loss **(Varga et al., 2003; Kujawa and Liberman, 2006).**

Cochlear implantation is a well established method of rehabilitating severe to profound deafness **(Geers et al., 2002)**. One possible common link between the preoperative factors and the outcome of the cochlear implant procedure is the survival of eighth nerve structures, especially the spiral ganglion neurons **(Rejali et al., 2007)**, which are directly stimulated by the cochlear implant electrode. So, the spiral ganglion neurons (SGNs) are the target neurons for cochlear implants and its degeneration renders the success of cochlear implantation.

A regeneration of inner ear neurons induced by growth factors **(Wise et al., 2005; Richardson et al., 2007)**, stem cell **(Corrales. et al., 2006; Martinez – Monedero et al., 2007)**, growth cones **(Anderson et al., 2006)** and chronic electrical stimulation **(Coco et al., 2007)** is a challenging future.

Aim of Work

The aim of this essay is to review the literature concerning the anatomy, ultrastructure of spiral ganglion and its role in cochlear implantation. Recent advances about the role of stem cell, growth factor, growth cones and electrical stimulation on regeneration of inner ear and spiral ganglion will be discussed.

Chapter 1

Embryology and anatomy of the cochlea and spiral ganglion

Embryology of the cochlea

The first rudiment of the internal ear appears shortly after that of the eye, in the form of a patch of thickened ectoderm, the **auditory plate,** over the region of the hind-brain. The auditory plate becomes depressed and converted into the **auditory pit** (fig.1.1). The mouth of the pit is then closed, and thus a shut sac, the **auditory vesicle.** Each vesicle divides into a ventral component that gives rise to the saccule and cochlear duct and a dorsal component that forms the utricle, semicircular canals, and endolymphatic duct. These epithelial structures are known as the membranous labyrinth **(Wareing et al., 2006)**.

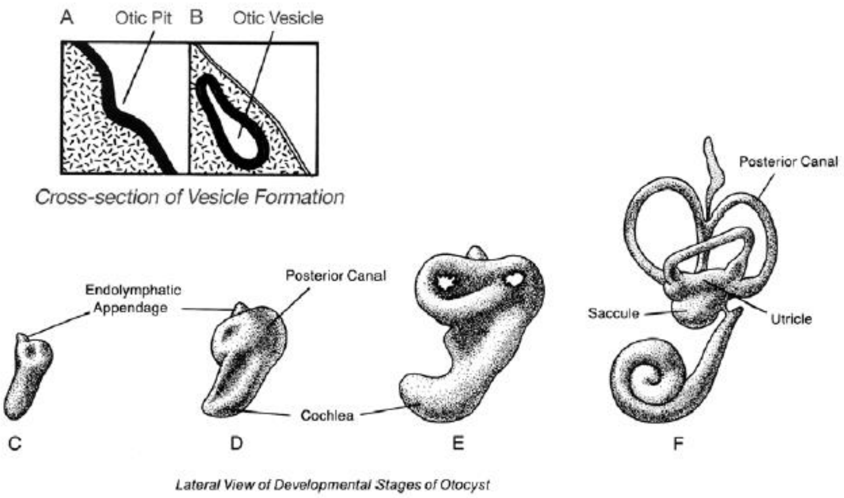

Figure 1.1. The evolution of the endolymphatic (otic) labyrinth. A = 22 days, B = 4 weeks, C = 41. Weeks, D = 51. Weeks, E = 6 weeks, and F = 8+ weeks **(Gulya and Schuknecht 1995)**.

In the **sixth week** of development, the cochlear duct forms from a tubular outgrowth of the saccule and penetrates surrounding mesenchyme to complete 2.5 turns (Fig.1.2). By **8th weeks**, the mesenchyme surrounding the cochlear duct differentiates into cartilage, and in the **10th week**, this cartilaginous shell undergoes vacuolization to create the scala vestibuli and scala tympani, both perilymph spaces **(Kenna and Hirose, 2003)**.

The epithelial cells of the cochlear duct differentiate into an inner ridge (eventual spiral limbus) and outer ridge (eventual organ of corti). The cells in these two ridges secrete a gelatinous substance that becomes the tectorial membrane **(Rodriguez et al., 2007)**.

The modiolus which carrying the cochlear nerve and osseous spiral lamina of the cochlea is not preformed in cartilage but are ossified directly. Bone deposition occurs within the modiolus between **20 and 21 weeks** between the basal and second turns of the cochlea, and by **25th week**, ossification is nearly complete **(Gulya, 2002)**.

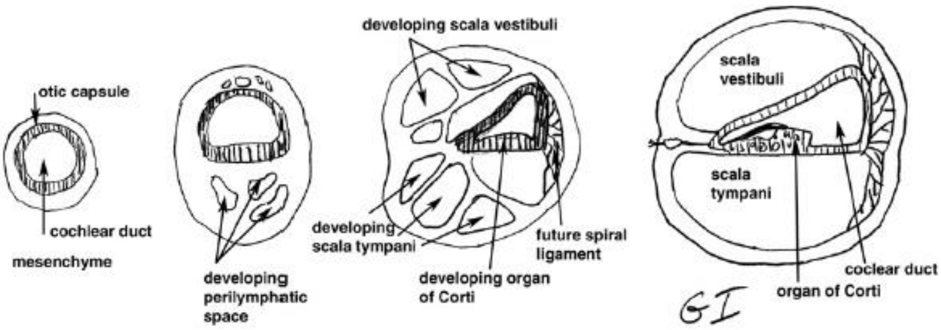

Figure 1.2. Cochlear development **(Isaacson, 2003)**.

<u>Embryology of spiral ganglion</u>

The rudiment of the acoustic nerve appears about the end of the third week as a group of ganglion cells closely applied to the cephalic edge of the auditory vesicle. Whether these cells are derived from the ectoderm