Sample Translation

Medicine

- See below for the original Chinese manuscript.
- **A native-speaker of English who has studied this field** proofreads the translated English.
- The quality of the translated manuscript is suitable for publication in an international journal.

Introduction

The human cochlear is a small, spiral shaped structure with approximately two and half turns [1]. Typically, artificial cochlear implant insertion involves electrode placement in the inner ear which exert force upon the inner wall of the Scala Tympani, in both the basal turn and apex turn regions. The insertion force during an electrode placement is composed of forward pressure from insertion, accompanying frictional forces, electrode recoil forces and adhesion forces between the electrode and the inner cochlea [2]. The main factors influencing force during electrode implantation are surgical technique and electrode design [2]. Variations in these factors, in addition to natural variations in cochlear spiral length in the patient population, result in a range of possible electrode insertion forces. In practice, however, the applied force during electrode insertion, is most heavily dependent on surgical technique and expertise, with a high risk of damage to the cochlea [3]. In recent years, numerous protocols have been developed regarding electrode insertion force and contour path, in order to optimize electrode insertion and minimize damage to cochlea [4-8].

Prior research has applied 3D finite element and helicon-spiral models to model and simulate human cochlear geometry, using mathematical models to describe the various parts of cochlea in detail [9-11]. Histological sectioning has been used to measure cochlear curvature, while liquid volume measurements were used to assess cochlear volume [12-13]. The cochlear spiral has also been measured, using orthogonal projection with computed tomography (CT) to reconstruct images of histological sections [14]. However, all the above experimental methods used in vitro samples alone; none included in vivo data.

The advancement of medical imaging techniques has led to the use of the non-invasive modalities of CT and MRI [15-19]. The development of 3D reconstruction technology has allowed 2D images to be rendered into 3D volume images [20-22]. These techniques have resulted in significant advances in inner-ear imaging. The inherent nature of computed tomography provides good in vivo delineation of bony anatomy in general, and the bony labyrinth in particular. [23]. However, upon implantation, the electrode must pass the basal membrane of the membranous labyrinth, a soft tissue structure [24, 25]. Therefore, MRI is arguably the optimum imaging modality with which to visualize and measure inner ear anatomy, including any deformities. Thus, many researchers have opted to use MRI for inner ear imaging. The modality has been used to aid surgeons in their clinical evaluation of the inner ear [26]. Another study used MRI imaging to identify inner ear deformities in patients with sensorineural hearing loss (SNHL), and investigate the deformities' role in hearing loss. Geometrical measurements of inner ear deformities have also been performed [27]. Therefore, MRI is an appropriate, reproducible technology in the field of inner ear research.

This study utilized MRI to non-invasively image the human inner ear in vivo. Image processing was used to obtain a 3D volume image of the inner ear, and the cochlear spiral in particular. This was used to measure the length and curvature of each of the basal turn, middle turn and apex turn segments. These measurements provide an individual's geometry for pre-artificial cochlear implant assessment. The measurements can be used to plan the electrode insertion method and route, thus minimizing potential damage by reducing the frictional, electrode recoil and adhesion forces during implantation.

人類耳蝸是一個約為兩圈半的極微小螺旋型狀[1]，一般傳統之電極植入方式容易對耳蝸中之鼓室階的轉彎處造成壓力及磨擦，不論是在基底部區域(basal turn area)或是頂端部區域(apex turn area)。而電極植入時所產生的力包含：向前推進所產生之磨擦力(frictional force)、電極回彈之回復力(relaxation force)以及附著在耳蝸內之附著力(adhesion forces)[2]，而影響植入力道之主要因素

為：手術者之行為與電極之設計[2]。然而，在進行人工電子耳手術時，由於手術醫師的不同以及每位患者耳蝸螺旋長度之差異，再加上電極的不同，致使於植入電極時所產生之力道也有差異，因此，在植入電極時，其施力的掌握必須完全依靠醫師們的經驗而定，造成耳蝸有受傷的風險[3]。近年來，有許多針對植入電極時所產生的力道以及路徑的評估被提出[4-8]，皆期望能夠找出適合的電極植入方式，用以避免對耳蝸造成傷害。

在早期的研究中，有學者提出以 3D finite element 以及 helico-spiral model 對人耳蝸幾何外型進行模組化分析[9-11]，透過數學模型的方式，將耳蝸各部加以描述。而近年來，在耳蝸曲率的量測上，有以組織學切片方式[12]進行量測，並以排水試驗法進行體積之量測[13]。更進一步地，有利用 CT 影像及組織學切片透過正交投影(orthogonal projection)之方式進行影像之重建，並對其耳蝸螺旋進行量測[14]，然而，其皆採用體外試驗(in-vitro)的方式進行，而非以活體實驗進行。

隨著醫學影像技術的成熟，開始，以電腦斷層掃瞄(Computer Tomography，CT)技術以及核磁共振造影(Magnetic Resonance Imaging，MRI)技術為基礎，導入以非侵入式方式進行[15-19]。而近年來，更加入了三維重建技術，將其造影所得之二維影像經由重建之後，建構出立體三維模型[20-22]，這對於內耳成像方面確實是一大突破。CT scan 可以明顯的觀察活體骨組織，由於內耳位於顳骨當中，故可透過 CT 影像觀察骨性迷路[23]，而得知內耳外型。然而，電極之植入必須是附著在膜性迷路(membranous labyrinth)中的基底膜上[24, 25]，因此，在影像系統的選擇上，便需選擇適用於軟組織成像之 MRI 系統，藉此取得內耳影像。而且許多研究者均採用 MRI 系統作為內耳成像之工具。例如：以 MRI 對患者進行內耳成像，取得其膜性迷路與耳蝸神經之影像，方便醫師作為臨床評估之用[26]，或是以感音性聽力損失(sensorineural hearing loss，SNHL)之患者為對象，進行內耳成像，討論內耳畸形與聽力損失的相關性，並對內耳畸型進行幾何外型量測[27]，由此可知

MRI 應用於內耳方面研究之可信度。

因此，本研究將透過 MRI 取得活人體內耳影像，經由醫學影像處理軟體，以非侵入式之方式，建立內耳之三維模型，並針對耳蝸部，以幾何重建法(geometric construction)獲得耳蝸螺旋線，用以量測 basal turn area、middle turn area、apex turn area 等各分段之曲率，進而提供人工電子耳術前評估之參考，而能針對各個患者規劃出較理想之電極植入方式及路徑，用以降低磨擦力(frictional force)、電極回彈之回復力(relaxation force)以及附著在耳蝸內之附著力(adhesion forces)。