JOURNAL OF DATA-DRIVEN ENGINEERING SYSTEMS

Automated Segmentation and Measurement of Cochlear Nerve for Predicting Cochlear Implant Outcome in Sensorineural Hearing Loss

Zeynep Bulut[1*], Emel Altan[2] Aysel Emine[3]

[1] Electrical Engineering and Computer Science Department, Izmir Institute of Technology, Turkey, Izmir
[2] Engineering and Applied Informatics Department, Izmir Institute of Technology, Turkey, Izmir
[3] Electrical Engineering and Computer Science Department, Izmir Institute of Technology, Turkey, Izmir

(Received: 12th November 2021; Accepted: 10th February 2022; Published on-line: 18h February 2022)

Abstract

Sensorineural hearing loss is a condition characterized by damage to the inner ear or nerve pathways connecting it to the brain, resulting in hearing impairment. Cochlear implants have been developed as a solution for children with bilateral or unilateral sensorineural hearing loss. However, the success of cochlear implant surgery relies on the presence and functionality of the cochlear nerve. Therefore, accurate segmentation and measurement of the cochlear nerve are crucial for surgeons to predict the outcome of the cochlear implant procedure. In this study, we propose a modified region growing segmentation algorithm that accurately segments the cochlear nerve region. The segmentation accuracy is assessed using various parameters, including Jaccard, Dice, False Positive Dice, and False Negative Dice. Additionally, the segmented region is measured using long diameter, short diameter, and cross-sectional area. Statistical analyses, such as intra/inter-observer correlation and limits of agreement, are conducted on the cross-sectional area of the cochlear nerve to assess the reproducibility of the automated measurement. This automated segmentation and measurement approach holds promise for predicting the outcome of cochlear implantation in individuals with sensorineural hearing loss.

Keywords: Sensorineural hearing loss, cochlear implants, cochlear nerve, segmentation algorithm, measurement, outcome prediction

I. Introduction

Sensorineural hearing loss (SNHL) is a hearing impairment caused by damage to the inner ear or the auditory nerve pathway. Early diagnosis and treatment of SNHL are crucial for children's development. Cochlear implants (CIs) have proven effective for pediatric patients with congenital SNHL. To predict the success of CI surgery, measuring the size of the cochlear nerve (CN) plays a significant role. Additionally, CN size measurements are valuable for diagnosing CN disorders [1-2]. Previous studies have emphasized the importance of normal CN size. Magnetic resonance (MR) images have been used to assess CN size differences between patients with normal hearing and those with post-lingual deafness [3]. However, conflicting findings regarding CN size in acquired SNHL have been reported. Absence or reduced CN size has been associated with SNHL, and assessing CN integrity is critical for managing the condition. In the context of CI surgery, the absence or underdevelopment of the CN poses challenges, while a near-normal CN size is associated with better implant outcomes. Therefore, accurate CN size measurement is essential for deciding on CI surgery in patients with congenital or acquired SNHL [4].

Traditionally, experienced radiologists manually analyze MR images of the inner ear to measure CN size. However, manual measurements are time-consuming, monotonous, and prone to errors. Computer-assisted algorithms offer a faster and more reliable alternative, aiding radiologists in diagnosis and subsequent decision-making [5]. Developing an automatic algorithm for CN segmentation and measurement using computer analysis of 3D-constructive interference steady state (CISS) images is crucial. Segmentation and measurement of the CN in MR images present significant challenges. Precise CN segmentation is essential for accurate measurements. An proposed automated segmentation and measurement approach

segment the CN and its edges. In this study, we propose a region-growing method for CN segmentation within the ROI. This method is simple, computationally efficient, and capable of segmenting regions with similar properties based on initial seed points and a threshold. Previous studies have explored region-growing segmentation methods, such as seeded region growing (SRG), boundary segmentation, and local seeded region growing (LSRG). However, these methods have limitations such as over-generation of seed points, experimental threshold selection, or time-consuming threshold testing. To overcome these drawbacks, we introduce a CN segmentation approach based on kernel density estimation (KDE) that considers only the maximum intensity pixel in the ROI. Adaptive seed points and threshold selection are employed to ensure accurate CN segmentation and quantification.

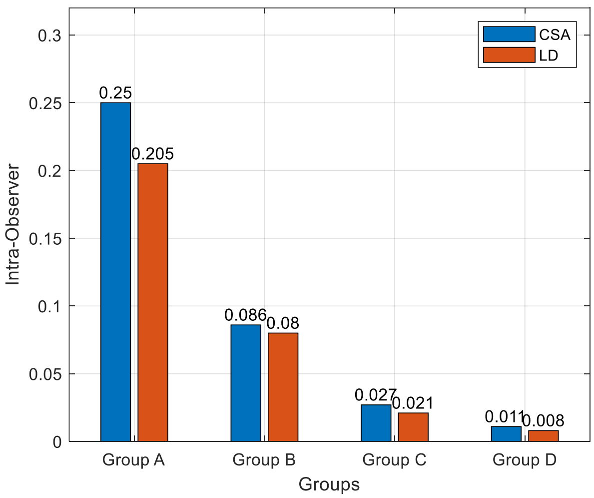

Fig. 9. Measurement accuracy- Intra-Observation groups

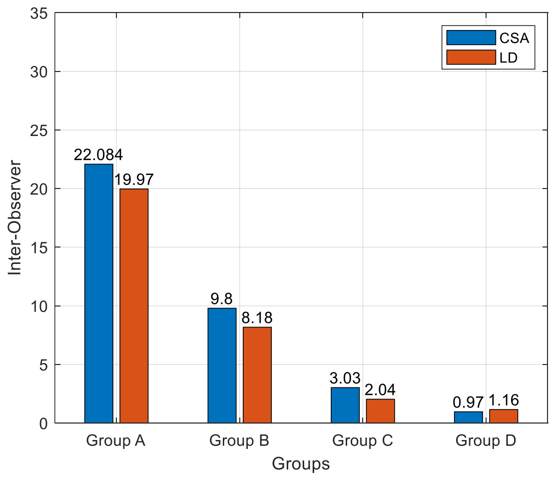

Fig. 10. Measurement accuracy- Inter-Observation groups

References

[1] Adunka OF, Roush PA, Teagle HF, Brown CJ, Zdanski CJ, Jewells V, Buchman CA. Internal auditory canal morphology in children with cochlear nerve deficiency. Otology & Neurotology. 2006 Sep 1;27(6):793-801.

[2] Freeman SR, Sennaroglu L. Management of cochlear nerve hypoplasia and aplasia. Advances in Hearing Rehabilitation. 2018;81:81-92.

[3] Huang BY, Zdanski C, Castillo M. Pediatric sensorineural hearing loss, part 1: practical aspects for neuroradiologists. American journal of neuroradiology. 2012 Feb 1;33(2):211-7.

[4] Teagle HF, Roush PA, Woodard JS, Hatch DR, Zdanski CJ, Buss E, Buchman CA. Cochlear implantation in children with auditory neuropathy spectrum disorder. Ear and hearing. 2010 Jun 1;31(3):325-35.

[5] Joshi VM, Navlekar SK, Kishore GR, Reddy KJ, Kumar EV. CT and MR imaging of the inner ear and brain in children with congenital sensorineural hearing loss. Radiographics. 2012 May;32(3):683-98.

[6] Izadi S, Jabari K, Izadi M, Hamedani BK, Ghaffari A. Identification and Diagnosis of Dynamic and Static Misalignment in Induction Motor Using Unscented Kalman Filter. In2021 13th Iranian Conference on Electrical Engineering and Computer Science (ICEESC) 2021.

[7] Clemmens CS, Guidi J, Caroff A, Cohn SJ, Brant JA, Laury AM, Bilaniuk LT, Germiller JA. Unilateral cochlear nerve deficiency in children. Otolaryngology--Head and Neck Surgery. 2013 Aug;149(2):318-25.

[8] Amini M, Hassani Mehraban A, Pashmdarfard M, Cheraghifard M. Reliability and validity of the Children Participation Assessment Scale in Activities Outside of School–Parent version for children with physical disabilities. Australian Occupational Therapy Journal. 2019 Aug;66(4):482-9.

[9] Buchman CA, Teagle HF, Roush PA, Park LR, Hatch D, Woodard J, Zdanski C, Adunka OF. Cochlear implantation in children with labyrinthine anomalies and cochlear nerve deficiency: implications for auditory brainstem implantation. The Laryngoscope. 2011 Sep;121(9):1979-88.

[10] Cullen RD, Fayad JN, Luxford WM, Buchman CA. Revision cochlear implant surgery in children. Otology & Neurotology. 2008 Feb 1;29(2):214-20.

[11] Miyasaka M, Nosaka S, Morimoto N, Taiji H, Masaki H. CT and MR imaging for pediatric cochlear implantation: emphasis on the relationship between the cochlear nerve canal and the cochlear nerve. Pediatric radiology. 2010 Sep;40:1509-16.

[12] He S, Shahsavarani BS, McFayden TC, Wang H, Gill KE, Xu L, Chao X, Luo J, Wang R, He N. Responsiveness of the electrically stimulated cochlear nerve in children with cochlear nerve deficiency. Ear and hearing. 2018 Mar;39(2):238.

[13] Cheraghifard M, Shafaroodi N, Khalafbeigi M, Yazdani F, Alvandi F. Psychometric properties of the Persian version of Volitional Questionnaire in Patients with Severe Mental Illnesses. Journal of Rehabilitation Sciences & Research. 2019 Jun 1;6(2):86-90.

[14] Young NM, Kim FM, Ryan ME, Tournis E, Yaras S. Pediatric cochlear implantation of children with eighth nerve deficiency. International journal of pediatric otorhinolaryngology. 2012 Oct 1;76(10):1442-8.

[15] Adunka OF, Jewells V, Buchman CA. Value of computed tomography in the evaluation of children with cochlear nerve deficiency. Otology & Neurotology. 2007 Aug 1;28(5):597-604.

[16] K. Jabari, M. Izadi, S. Izadi, B. Khadem Hamedani, and A. Ghaffari, "Predictive and Data-Driven Control of Traffic Lights in Urban Road Networks using Linear and Time-Varying Model," in 2022 14th Iranian Conference on Electrical Engineering and Computer Science (ICEESC), 2022.

[17] Tahir E, Bajin MD, Atay G, Mocan BÖ, Sennaroğlu L. Bony cochlear nerve canal and internal auditory canal measures predict cochlear nerve status. The Journal of Laryngology & Otology. 2017 Aug;131(8):676-83.

[18] Roche JP, Huang BY, Castillo M, Bassim MK, Adunka OF, Buchman CA. Imaging characteristics of children with auditory neuropathy spectrum disorder. Otology & neurotology: official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology. 2010 Jul;31(5):780.

[19] Valero J, Blaser S, Papsin BC, James AL, Gordon KA. Electrophysiologic and behavioral outcomes of cochlear implantation in children with auditory nerve hypoplasia. Ear and hearing. 2012 Jan 1;33(1):3-18.

[20] Najari, A., Shabani, F. and Hosseynzadeh, M., 2021. INTEGRATED INTELLIGENT CONTROL SYSTEM DESIGN TO IMPROVE VEHICLE ROTATIONAL STABILITY USING ACTIVE DIFFERENTIAL. Acta Technica Corviniensis-Bulletin of Engineering, 14(1), pp.79-82.