Quantitative Assessment of the Age-related Change of Inferior Alveolar Neurovascular Bundle Using Diffusion Weighted Magnetic Resonance Imaging

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Abstract

Many studies have reported assessment to apparent diffusion coefficient (ADC) values of the nerves system such as normal gray and white matter, hyperacute stroke. However, there were few studies, that ADC values of the normal inferior alveolar neurovascular bundle by age using diffusion-weighted magnetic resonance imaging (DWI). The purpose of this study was to investigate age-related change of the mean of ADC values of the normal inferior alveolar neurovascular bundle. This was prospective cohort study. We analyzed the ADC map of 187 patients without disease affecting the nerve and artery performed between October 2017 and March 2019. This study investigated to mean of ADC values of inferior alveolar neurovascular bundle by age on ADC map. We calculate Spearman's correlation coefficients using age groups as explanatory variables and ADC values as criterion variable. $P < 0.05$ was considered to indicate significance. The mean ADC values were $1.07 \pm 0.12 \times 10^{-3} \text{mm}^2/\text{s}$, $1.15 \pm 0.13 \times 10^{-3} \text{mm}^2/\text{s}$, $1.24 \pm 0.12 \times 10^{-3} \text{mm}^2/\text{s}$, $1.28 \pm 0.10 \times 10^{-3} \text{mm}^2/\text{s}$, $1.33 \pm 0.12 \times 10^{-3} \text{mm}^2/\text{s}$, $1.39 \pm 0.13 \times 10^{-3} \text{mm}^2/\text{s}$ and $1.47 \pm 0.13 \times 10^{-3} \text{mm}^2/\text{s}$. Each data's corresponding to the 20–29 old years group, 30–39 old years group, 40–49 old years group, 50–59 old years group, 60–69 old years, 70–79 old years group, 80–82 old years group, respectively. ($P < 0.001$). In conclusion, our result suggested that ADC values of the normal inferior alveolar neurovascular bundle was correlate with aging.

Keywords :

inferior alveolar neurovascular bundle, aging, MRI, DWI, ADC

Introduction

Diffusion-weighted imaging (DWI) of the nervous system has been shown to be useful in clinical status and diagnosis. In brain, DWI is used such as to assessment of gray matter and white matter and diagnosis of hyperacute stroke, tumors (1–5). In hyper acute stroke, restricted diffusion resulting in low signal intensity on apparent diffusion coefficient (ADC) map. A possible explanation for these results is that restricted water diffusibility caused by ischemia. Hyperacute stroke is depicted at DWI before infarction is depicted at convention-

al Magnetic resonance imaging (MRI) or Computed tomography (CT). Also, in maxillofacial area, there is studies have reported that to evaluation of the normal inferior alveolar neurovascular bundle using Diffusion-tensor imaging (DTI) that applied DWI (6). Furthermore, there have been many reports on MRI assessment of the inferior alveolar neurovascular nerve that were based on conventional MR images such as T1- and T2-weighted images (7, 8). However, little is known about the influence of aging on inferior alveolar neurovascular bundle in the normal adult using DWI.

In general, structural, functional and biochemical changes have been reported in peripheral nerves by aging. Due to aging, cellular and histological changes can begin to impair nerve function and can lead to fibrotic de-

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generation. Decreased numbers or densities of myelinated fibers have been reported as human peripheral nerves aging, with loss of nerve fibers(9–11). The slowing of axonal transport with aging can fail to maintain the cytoskeletal framework, resulting in axonal size reduction and eventual degeneration. Loss of unmyelinated fibers has been observed in the peripheral nerves of elderly humans (12). Thus, understanding the Age- related mean ADC of alveolar neurovascular bundle in normal patients might help in objectively assessing neurovascular bundle affected by the disease.

The purpose of this study was to investigate age-related change of the mean of ADC values of the normal inferior alveolar neurovascular bundle using DWI.

Materials and Methods

We designed and implemented a prospective cohort study, which was approved by our university ethics committee(EC19-011). The study subjects(369 sites; 39 men, 148 women; 20-82 years of age; mean age, 51.96 years) was composed of all patients excluding, severe artifact, trauma, surgery, diabetes, hyperlipidemia, atherosclerosis and history of neuropathy, who had undergone MRI between October 2017 and March 2019.

MRI was performed with a 1.5-T superconductive MR unit(Intera Achieva® 1.5 T Nova; Philips Medical Systems, Best, Netherlands)and a five-channel phased array coil in the outpatient radiology department at our institution. Diffusion-weighted imaging conditions were set as follows: TR/TE = 5100/70 msec, 6.0 mm section thickness, 256×256 matrix, 250×250 mm FOV, intersection gap 1.4 mm, imaging time 3 min 29 s, and $b = 0, 1000$ s/mm². ADC map was made on MRI console. STIR images were obtained using a spin echo sequence with the following parameters: TR/TE/TI = 2500/60/180 msec, respectively. Other study conditions were set as follows: 6.0 mm section thickness, 320×256 matrix, 230×195.5 mm FOV, and 1 acquisition.

The regions of interest(ROI)was manually placed on the ADC map on which the inferior alveolar neurovascular bundle in the mandibular foramen without affected by bone marrow. The cortical bone and around tissue were excluded(Fig. 1). ADC values of inferior alveolar nerve was measured and recorded by two oral radiology specialists(K. I., 10 years of experience; H. M., 9 years of experience). Intraclass Correlation Coefficient(ICC)results

Fig. 1. The regions of interest(ROI)was manually drawn on the apparent diffusion coefficient(ADC)map on which the inferior alveolar neurovascular bundle. The cortical bone and around tissue were excluded.

were interpreted as follows: values between 0- 0.2 as indicating slight agreement, 0.21- 0.39 as minimal, 0.40- 0.59 as weak, 0.60- 0.79 as moderate, and 0.80- 0.90 as strong, and above 0.90 as perfect agreement. The sex group were then compared using the Mann-Whitney U-test. Spearman's correlation coefficients were calculated using ADC value of the nerve as the criterion variable and age as explanatory variables. These analyses were performed with a statistical package(SPSS version 21.0®, IBM Japan Inc., Tokyo, Japan). $P < 0.05$ was considered to indicate significance.

Ethics approval and consent to participate

The study had the approval of Nihon University ethics committee(EC19-011).

Results

Table 1 shows the ADC value of the inferior alveolar neurovascular bundle in each sex group. The ADC value of inferior alveolar neurovascular bundle in men was $1.27 \pm 0.14 \times 10^{-3}$ mm²/s. The ADC value in women was $1.27 \pm 0.16 \times 10^{-3}$ mm²/s. There was not different between each sex groups($P > 0.05$) (Table 1).

The mean ADC values($\times 10^{-3}$ mm²/s)of the inferior alveolar neurovascular bundle were 1.07 ± 0.12 (20–29 years; mean age 24.84 years, $n = 50$), 1.15 ± 0.13 (30–39 years; mean age 34.83 years, $n = 35$), 1.27 ± 0.12 (40–49

Table 1. Mean ADC values of the inferior alveolar neurovascular bundle.

	Mean ADC value of men (n=77) ($\times 10^{-3} \text{ mm}^2/\text{s} \pm \text{SD}$)	Mean ADC value of women (n=292) ($\times 10^{-3} \text{ mm}^2/\text{s} \pm \text{SD}$)
Number of inferior alveolar neurovascular bundle (n=369)	1.27 $\pm$ 0.14	1.27 $\pm$ 0.16

ADC= Apparent Diffusion Coefficient
SD= Standard Deviation
n=369

Table 2. ADC values of inferior alveolar neurovascular bundle in different age group.

Age groups (yrs.)	Mean age ($\pm \text{SD}$)	ADC value of neurovascular bundle (Bilateral side) ($\pm \text{SD} \times 10^{-3} \text{ mm}^2/\text{s}$)	ADC value of neurovascular bundle (Right side) ($\pm \text{SD} \times 10^{-3} \text{ mm}^2/\text{s}$)	ADC value of neurovascular bundle (Left side) ($\pm \text{SD} \times 10^{-3} \text{ mm}^2/\text{s}$)
20~29	24.84	1.07 $\pm$ 0.12 (n=50)	1.07 $\pm$ 0.13 (n=25)	1.08 $\pm$ 0.13 (n=25)
30~39	34.83	1.15 $\pm$ 0.13 (n=35)	1.19 $\pm$ 0.14 (n=17)	1.11 $\pm$ 0.11 (n=18)
40~49	45.21	1.27 $\pm$ 0.12 (n=74)	1.27 $\pm$ 0.12 (n=38)	1.27 $\pm$ 0.13 (n=36)
50~59	54.26	1.28 $\pm$ 0.10 (n=78)	1.29 $\pm$ 0.09 (n=39)	1.27 $\pm$ 0.1 (n=39)
60~69	65.25	1.33 $\pm$ 0.12 (n=80)	1.33 $\pm$ 0.12 (n=40)	1.34 $\pm$ 0.11 (n=40)
70~79	73.96	1.39 $\pm$ 0.13 (n=44)	1.38 $\pm$ 0.15 (n=23)	1.39 $\pm$ 0.11 (n=21)
80~82	81.25	1.47 $\pm$ 0.13 (n=8)	1.51 $\pm$ 0.19 (n=4)	1.43 $\pm$ 0.1 (n=4)
r		0.562**	0.561**	0.661**

ADC= Apparent Diffusion Coefficient

SD= Standard Deviation

n=369

**: $P < 0.001$

years; mean age 45.21 years, n = 74), 1.28 $\pm$ 0.10 (50–59 years; mean age 54.26 years, n = 78), 1.33 $\pm$ 0.12 (60–69 years; mean age 65.25 years, n = 80), 1.39 $\pm$ 0.13 (70–79 years; mean age 73.96 years, n = 44), 1.47 $\pm$ 0.13 (80–82 years; mean age 81.25 years, n = 8), respectively (r = 0.562, $P < 0.001$) (Table 2, Figs. 2, 3). The ADC values of the inferior alveolar neurovascular bundle showed a significant positive correlation with age.

There was moderate agreement in ADC value of inferior alveolar neurovascular bundle (ICC=0.77).

Discussion

The specific aim of the study was to investigate ADC values of a baseline for future detection of diseases involving the inferior alveolar neurovascular bundle. We hypothesized that ADC values in inferior alveolar neurovascular bundle were associated with aging. In this study, we implemented a retrospective study including a wide range of age to investigate the relationship between ADC values of the inferior alveolar neurovascular bundle and patient aging. The present study found that significant correlations between ADC value of the inferior alveolar

Fig. 2. 32-year-old woman.
A, B: Axial STIR MR images and diffusion weighted images shows inferior alveolar neurovascular bundle (arrowheads and regions of interest (ROI)).

Fig. 3. 77-year-old woman.
A, B: Axial STIR MR images and diffusion weighted images shows inferior alveolar neurovascular bundle (arrowhead and regions of interest (ROI)).

neurovascular bundle and aging.

The inferior alveolar neurovascular bundle is aggregation of a branch of the mandibular nerve and arteriovenous. After branching from the mandibular nerve, the inferior alveolar nerve travels behind the lateral pterygoid muscle, and it enters the mandibular foramen(13). This nerve runs in a canal within the mandible and supply sensation to the lower teeth. In clinical, this nerve injury

is a well-known complication of third molar surgery, the nerve can also be injured after osteotomies, implant placement or fracture. The inferior alveolar nerve injury is caused to impairment of sensation in the lower lip(13). In the past, it has been reported that such as assessment of the relationship between mandibular third molars and inferior alveolar nerve using CT and the early evaluation of inferior alveolar nerve neurological complications after

mandibular third molar extraction using MRI(8, 14). In addition, in acute osteomyelitis, elevated intramedullary pressure also leads to direct compression of neurovascular bundles, accelerating thrombosis and ischemia, and is known to cause inferior alveolar nerve dysfunction known as Vincent's symptoms(15).

Generally, the nerve fibers have been to cause fibrotic degeneration by aging. In previous study reported that significant decrease in the proportion of myelinated fibers was found in the elderly subjects(9, 10). In addition, it has been reported that a definite trend towards a general decrease in size of the inferior alveolar artery with increase in age(11). Therefore, understanding the mean ADC of alveolar neurovascular bundle in normal patients might help in objectively assessing neurovascular bundle affected by the disease. We hypothesized that the structural changes of normal inferior alveolar bundle by aging is associated with ADC value.

Kotaki et al reported that the mean of ADC values of the inferior alveolar nerve in adults(Age range, 20-36 years) were $0.98 \pm 0.24 \times 10^{-3} \text{ mm}^2/\text{s}$, $0.97 \pm 0.28 \times 10^{-3} \text{ mm}^2/\text{s}$, $0.86 \pm 0.40 \times 10^{-3} \text{ mm}^2/\text{s}$, corresponding to the mandibular foramen of the right, second molar of the right, mental foramen of the right(6). Similarly, the mean of ADC values of the inferior alveolar nerve in adults were $1.02 \pm 0.24 \times 10^{-3} \text{ mm}^2/\text{s}$, $0.96 \pm 0.32 \times 10^{-3} \text{ mm}^2/\text{s}$, $0.84 \pm 0.36 \times 10^{-3} \text{ mm}^2/\text{s}$, corresponding to the mandibular foramen of the left, second molar of the left, mental foramen of the left(6). In addition, they report that there were no significant differences between the right and left sides, the anteroposterior positions in these data. In this study, we showed the ADC value of the inferior alveolar neurovascular bundle at the mandibular foramen was almost the same as the report by kotaki et al(6). Furthermore, found that ADC values of the inferior alveolar neurovascular bundle were statistics positive correlation between ADC value and age. A possible explanation of this result is that loss of nerve fibers and decrease in size of the artery with aging causes an increased interstitial, furthermore fluid into the interstitial. The enhancing the diffusive capability of water molecules due to increase interstitial and fluid was considered to have increased the ADC in inferior alveolar neurovascular bundle. A limitation of our study was not possible to measure the ADC values in patients with severe image distortions resulting from susceptibility artifacts. Therefore, future studies

should employ high-resolution imaging techniques, including non-echo planner-DWI sequences, which are less vulnerable to susceptibility artifacts.

In conclusion, our results suggest that ADC value of the inferior alveolar neurovascular bundle is associated with aging. This suggests that, evaluating the inferior alveolar neurovascular bundle on non-invasive MRI might contribute to the accurate diagnosis of neurovascular bundle affected by the disease.

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Conflict of Interest

There are no conflicts of interest to declare.

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