

Development of the Geniculate Ganglion in Human Fetuses

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ABSTRACT

AIM: To present the quantitative development of the geniculate ganglion (GG) in foetal cadavers.

MATERIAL and METHODS: This study focused on 60 temporal bones of 30 (15 female and 15 male) fetuses aged 18–30 weeks of gestation (mean age, 22.83 ± 3.49 weeks) to measure the length, width and area of the GG.

RESULTS: According to gestational weeks and months, the ganglion length (1.21 ± 0.41 mm), width (1.03 ± 0.28 mm) and area (1.24 ± 0.61 mm²) did not change. In terms of sexes or sides, ganglion dimensions were not significantly different. Positive correlation was found between the length and width (p=0.033, r=0.276), between the length and area (p<0.001, r=0.762) and between the width and area (p<0.001, r=0.622). Linear functions were calculated for the ganglion area (y=0.355 + 0.039 × weeks), length (y=0.636 + 0.025 × weeks) and width (y=0.634 + 0.017 × weeks).

CONCLUSION: The ganglion size did not change in foetal cadavers aged 18–30 weeks of gestation. This finding may be important for anatomists and embryologists in performing morphometric studies and understanding the development of the GG and for neuro-otologists and neurosurgeons in achieving greater success in skull base surgeries.

KEYWORDS: Dissection, Facial Nerve, Foetuses, Geniculate Ganglion

INTRODUCTION

The geniculate ganglion (GG; also called the perigeniculate area or first genu) is divided into the anterior portion (which hosts cell bodies of taste fibres of the chorda tympani and greater superficial petrosal nerve and preganglionic secretory fibres for the pterygopalatine ganglion) and the posterior portion (which consists of the facial nerve motor fibres) (9,13). The morphology of the ganglion (its diameter and dehiscence) attracts attention of researchers for some reasons: firstly, as a reference point to attain the internal auditory canal through the middle cranial fossa approach (11) and, secondly, as a risk area for

iatrogenic facial nerve injury during treatment of associated pathological entities such as tumours or arachnoid cysts via the middle cranial fossa, translabyrinthine or transmastoid approach (8,11,14,16,17,19). In this context, some authors have proposed further anatomical investigations on the GG in different populations (e.g. foetal, paediatric or adult subjects such as patients or cadavers) to comprehend alterations in the GG anatomy throughout life (3).

The complex procedure of the ossification of the ganglion fossa starts at the early weeks of gestation (13). In the 15th week, the epitympanum ensures the continuity of the tympanic cavity with the middle cranial fossa. At the top of

the anterior epitympanum, the ganglion extends to the dura mater along with its vessels. In the 20th week, osseous plates begin to appear within the temporal bone periosteum (its squamous and petrous portions) throughout the floor of the middle cranial fossa, and in the later weeks, these plates approach each other. At around in the 35th week, a bony layer formed under the inferior surface of the ganglion (i.e. the floor of its fossa) by the fusion of the medial and lateral osseous plates separates the epitympanum from the GG. However, the superior surface of the ganglion is still directly connected to the dura mater. As the dehiscence in this area is mostly present at birth, the ossification process of the roof of the ganglion fossa proceeds until childhood. Nevertheless, facial hiatus, a type of dehiscence, does not ossify at all during life. In the same foetus, the ossification pattern in the right differs from that in the left (10). We thought that an expanded algebraic examination focusing on foetal subjects might help researchers find asymmetry in the GG size. In this regard, this foetal cadaveric study aimed to show changes in ganglion development.

■ MATERIAL and METHODS

Selection of Study Population

This foetal examination was carried out in the laboratory of Anatomy Department of Medical Faculty of University, after ethical confirmation was obtained from the Clinical Research

Ethics Committee of the University (dated 19.02.2020, no. 020/133). This study included 60 temporal bones of 30 (15 female and 15 male) formalin-fixed (10%) fetuses (mean age, 22.83 ± 3.49 weeks; range 18–30 weeks) (Table I). Beger et al. compared different cadaver-embalming methods including formalin fixation and explained that this technique did not result in significant reduction of plasticity in tissue content; therefore, its effect on the tissue was underestimated during our examination (4). On account of scarce data (e.g. cause of death) related to the study population, exclusion criteria were determined as follows: a) fetuses with any visible malformations (polydactyly, meningomyelocele, CHARGE syndrome, cleft palate and/or lip, syndactyly, etc.), b) fetuses with a dissected skull base (especially the temporal bone) and c) fetuses of unknown age and sex (5,6,20).

Morphometric Parameters and Measurement Technique

The senior otologist (DUT) of the study team dissected the structures to expose the ganglion under a surgical microscope (Carl Zeiss f170, Carl Zeiss Meditec AG, Germany). Afterwards, the ganglion was photographed with a millimetre scale in the same position/distance using the microscope camera (Nikon d3300 digital camera, Nikon, Tokyo, Japan). The length, width and area of the ganglion were measured according to methods presented in previous studies (10,12) (Figure 1A, B). For this purpose, images of the ganglion were transferred to a digital image analysis software (Rasband WS, Image J, US National Institutes of Health, Bethesda, MD, USA, <https://image.j.nih>).

Table I: Demographic (Age, Sex, Number of Fetuses) and Morphometric Data (Measurements of the Parameters)

Gestational Age		Foot Length (mm)	Gender, n			Parameters		
Months	Weeks		Male	Female	Number of sides	Length (mm)	Width (mm)	Area (mm ²)
V	18	25.23 ± 0.21	2	1	6	0.95 ± 0.30	0.94 ± 0.30	0.87 ± 0.58
	19	27.48 ± 0.68	1	2	6	1.24 ± 0.40	0.94 ± 0.25	1.30 ± 0.51
	20	30.11 ± 0.94	1	2	6	1.33 ± 0.38	0.79 ± 0.06	1.14 ± 0.29
VI	21	32.86 ± 0.49	1	2	6	1.14 ± 0.24	1.12 ± 0.11	1.03 ± 0.50
	22	34.96 ± 0.86	3	1	8	1.17 ± 0.46	1.15 ± 0.40	1.32 ± 0.61
	23	38.51 ± 1.40	0	3	6	1.06 ± 0.23	1.08 ± 0.43	1.21 ± 0.68
	24	41.44 ± 0.84	1	1	4	1.36 ± 0.42	0.97 ± 0.24	1.26 ± 0.24
VII	25	42.12 ± 0.32	1	0	2	1.50 ± 0.40	0.85 ± 0.09	1.31 ± 0.29
	26	45.78 ± 3.07	2	1	6	1.25 ± 0.61	1.13 ± 0.33	1.57 ± 1.16
	27	49.81 ± 0.73	1	0	2	0.82 ± 0.06	0.96 ± 0.07	0.78 ± 0.10
	28	51.90 ± 0.33	0	1	2	1.33 ± 0.48	1.00 ± 0.32	1.33 ± 0.77
VIII	29	53.05 ± 0.44	2	0	4	1.40 ± 0.57	1.23 ± 0.15	1.65 ± 0.76
	30	54.44 ± 1.98	0	1	2	1.71 ± 0.45	1.06 ± 0.14	1.33 ± 0.09
All	22.83 ± 3.49	37.47 ± 8.84	15	15	60	1.21 ± 0.41	1.03 ± 0.28	1.24 ± 0.61
p						0.509	0.511	0.814

gov/ij/, 1997–2018). Measurements were performed once by two independent investigators (OB and PT). Foot lengths were measured with a digital calliper (0.01-mm precision, Mahr, 16 ER, Göttingen, Germany) for prediction of gestational age (weeks or months).

Statistical Analysis

The average value of two measurements (OB and PT) was used to perform statistical assessment. Intraclass correlation coefficients (ICC) were utilised to evaluate the reliability between measurements of two researchers. Through one-way analysis of variance and post-hoc Bonferroni test, alterations in the length, width and area of the ganglion according to gestational age (weeks and months) were analysed. Student's t-test was employed to compare male and female values (independent sample t-test) and right and left values (dependent sample t-test). Pearson correlation coefficient test was used to show correlations between the ganglion length, width and area. Regression equations of these parameters were calculated with the simple linear regression test. Normality of quantitative values was evaluated with Shapiro-Wilk test. Variance homogeneity of the data was checked with Levene test. The $p < 0.05$ was the significant level.

RESULTS

Demographic features of the foetal subjects (weeks and months of gestation, number of the temporal bones, foot measurements, sex information) are shown in Table I. The ICC scores for parameters were calculated from 0.970 to 0.990 ($p < 0.001$), which displayed that the inter-observer reproducibility was excellent. The findings were as follows:

- The ganglion size did not change according to the gestational age in weeks (Table I) and months (Table II).
- In terms of sexes or sides, the ganglion dimension was not significantly different (Table III).
- Weak positive correlation was found between the length and width ($p = 0.033$, $r = 0.276$), while strong positive correlations were observed between the length and area ($p < 0.001$, $r = 0.762$) and between the width and area ($p < 0.001$, $r = 0.622$).
- Linear functions were calculated for the ganglion area as $y = 0.355 + 0.039 \times \text{weeks}$, for the length as $y = 0.636 + 0.025 \times \text{weeks}$ and for the width as $y = 0.634 + 0.017 \times \text{weeks}$ (Figure 2A-C).

Table II: Morphometric Data of the Parameters According to the Gestational Months

Parameters	V th Month (n=18)	VI th Month (n=24)	VII th Month (n=12)	VIII th Month (n=6)	p
Length (mm)	1.17 ± 0.38	1.17 ± 0.35	1.23 ± 0.50	1.50 ± 0.51	0.329
Width (mm)	0.89 ± 0.23	1.09 ± 0.32	1.03 ± 0.27	1.17 ± 0.16	0.067
Area (mm ²)	1.10 ± 0.49	1.21 ± 0.54	1.35 ± 0.87	1.54 ± 0.61	0.423

Table III: Male-Female and Right-Left Comparisons

	Males (n=30)	Females (n=30)	p	Right (n=30)	Left (n=30)	p
Length (mm)	1.17 ± 0.43	1.26 ± 0.39	0.371	1.19 ± 0.44	1.24 ± 0.38	0.676
Width (mm)	1.04 ± 0.26	1.02 ± 0.31	0.823	1.00 ± 0.29	1.06 ± 0.28	0.398
Area (mm ²)	1.21 ± 0.52	1.27 ± 0.70	0.718	1.12 ± 0.52	1.35 ± 0.68	0.142

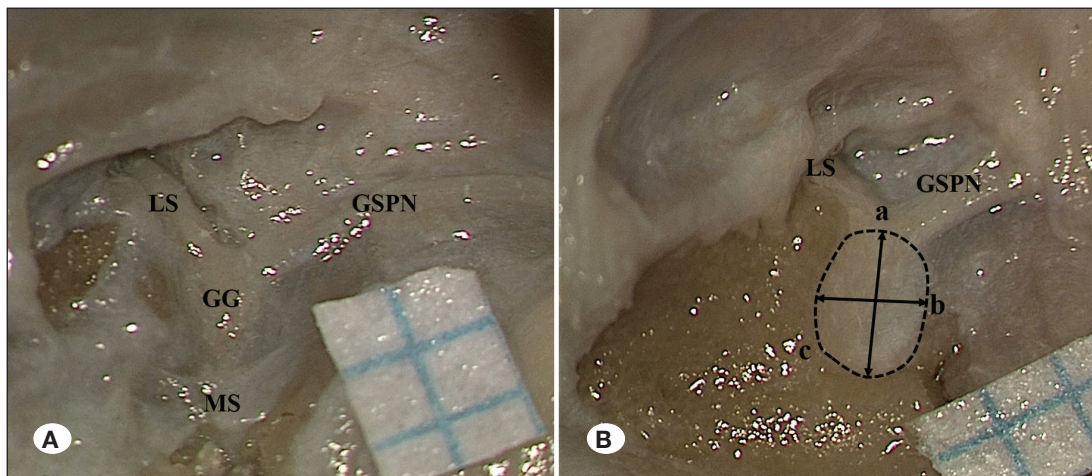


Figure 1: Geniculate ganglion (GG) and its parameters (a: length, b: width and c: area). LS, labyrinthine segment of the facial nerve; MS, meatal segment of the facial nerve; GSPN, greater superficial petrosal nerve.

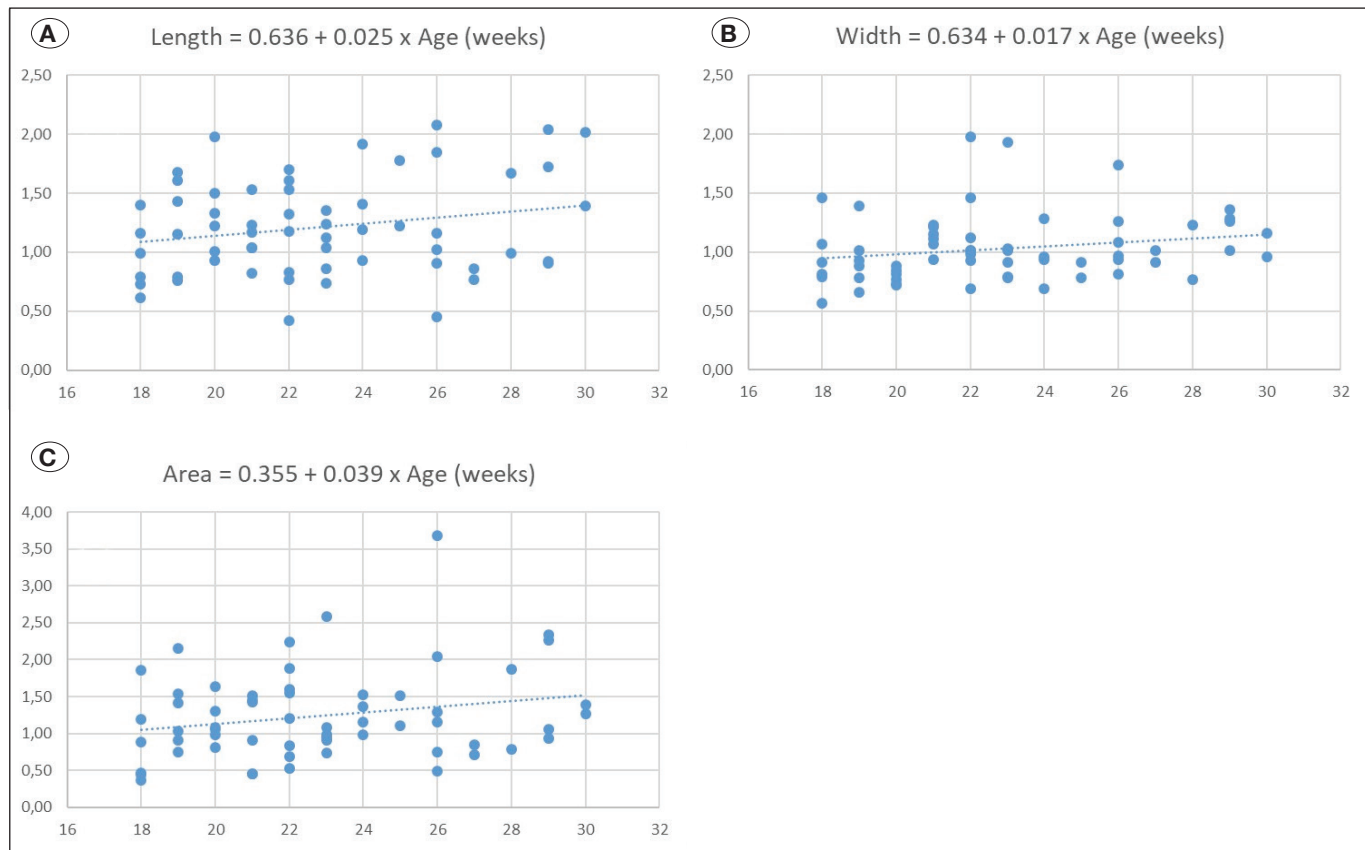


Figure 2: Linear regression line of the geniculate ganglion length (A), width (B) and area (C).

DISCUSSION

This study revealed that the ganglion size including its length, width and area did not change in fetuses aged 18–30 weeks of gestation.

Ramsay Hunt syndrome (15), geniculate neuralgia (9), Bell's palsy (7), tumours such as meningiomas (8), conductive hearing loss (1) and arachnoid cyst (19) may be listed as pathological entities associated with the ganglion. Changes in the normal anatomy of the GG may be used as a sign in the diagnosis of some of these pathologies (1,18). For instance, Ames et al. found enlargement at the GG fossa owing to the ganglion venous malformation during the evaluation of computed tomography images of a 9-year-old boy with conductive hearing loss (1). In their patient (36 patients aged 12–65 years with traumatic facial paralysis)–control (107 subjects aged 4–83 years) study, Mu et al. explained that the ganglion dimension of the patients (1.9 ± 0.3 and 2.2 ± 0.4 mm for the transverse and vertical diameter, respectively) was greater than that of controls (1.3 ± 0.3 and 1.4 ± 0.3 mm for the transverse and vertical diameters, respectively) (18). In this scope, Beger et al. proposed further algebraic investigations of ganglion dimensions to determine its abnormalities observed during the diagnosis of conditions such as vascular malformations or traumatic facial paralysis (3). Therefore, the regression formulas calculated for the ganglion area, length and width may help guess the dimension of the GG.

The mean values of the ganglion length (mean range, 1.76–2.35 mm), width (mean range, 1.29–1.86 mm) and area (mean age, 3.87–4.38 mm²) were presented in previous adult studies (7,10,12) (Table IV). Moreover, Beger et al. measured the length, width and area in paediatric subjects as follows: 2.09 ± 0.37 mm, 1.58 ± 0.29 mm and 3.45 ± 0.89 mm², respectively (3). Our mean data related to the ganglion length (mean, 1.21 ± 0.41 mm; range, 0.42–2.08 mm), width (mean, 1.03 ± 0.28 mm; range, 0.57–1.98 mm) and area (mean, 1.24 ± 0.61 mm²; range, 0.36–3.68 mm²) was smaller than the average values obtained from adults (7,10,12) and children (3). However, Dobozi examined histological samples of 24 paediatric and adult subjects aged 11–82 years and measured the ganglion length and width as 1.09 mm and 0.76 mm, respectively (9). In another histological examination conducted on fetuses aged 15–40 weeks of gestation, Ge and Spector reported an average length of 0.97 mm (range, 0.33–1.20 mm) and average width of 0.32 mm (range, 0.12–0.56 mm) (10). The finding that the length and width data in these two studies (9,10) were smaller than our measurements and those of previous studies might have been caused by the reduction of plasticity in the ganglion content due to histological chemicals used. We observed that the ganglion dimension did not vary according to gestational age (18–30 weeks in utero). This observation was compatible with the interpretation of Ge and Spector, who declared that the ganglion growth was completed before 15 weeks of gestation (10). Nevertheless,

Table IV: The Morphometric Data of GG Including Its Length, Width and Area (mean \pm SD, min-max) in the Previous Studies

Studies	Years	Region	Samples	Age	Methods	n	Area (mm ²)	Length (mm)	Width (mm)
Celik et al. (7)	2017	Turkey	P without BP	40.3 \pm 21.3 y	CT scans*	34	-	-	1.61 \pm 0.25 (1.31-2.35)
Dobozi (9)	1975	Switzerland	Cadavers	11-82 y	Histologic**	24	-	1.09	0.76
Ge and Spector (10)	1981	USA	Fetuses	15-40 gw	Histologic**	40	-	0.97 (0.33-1.2)	0.32 (0.12-0.56)
Mu et al. (18)	2012	China	Cadavers	Adult	Dissection**	10	-	1.76 (1.2-2.25)	1.29 (0.9-1.95)
Hamzaoglu et al. (12)	2020	Turkey	P without TFP	4-83 y	CT scans*	107	-	1.4 \pm 0.3	1.3 \pm 0.3
Beger et al. (3)	2020	Turkey	Cadavers	45-92 y	CT scans*	20	4.38 \pm 1.27	2.35 \pm 0.31	1.86 \pm 0.38
			P with CI	1-18 y	Dissection**	20	3.87 \pm 1.23	2.21 \pm 0.36	1.82 \pm 0.40
			Fetuses	18-30 gw	CT scans*	82	3.45 \pm 0.89	2.09 \pm 0.37	1.58 \pm 0.29
				\leq 2 y		36	3.35 \pm 0.66 (2.14-4.88)	2.07 \pm 0.34 (1.55-2.91)	1.55 \pm 0.25 (0.83-2.17)
				3-9 y		24	3.23 \pm 1.02 (1.15-4.99)	1.99 \pm 0.43 (1.09-2.55)	1.46 \pm 0.28 (1.04-2.03)
				>9 y		22	3.85 \pm 1.01 (2.35-5.65)	2.22 \pm 0.33 (1.50-2.90)	1.74 \pm 0.29 (1.15-2.22)
This study	2021	Turkey	Fetuses	18-30 gw	Dissection**	60	1.24 \pm 0.61 (0.36-3.68)	1.21 \pm 0.41 (0.42-2.08)	1.03 \pm 0.28 (0.57-1.98)

P: Patients, **TFP:** Traumatic facial paralysis, **BP:** Bell palsy, **gw:** Gestational weeks, **y:** years, **N:** Number of temporal bones, **CI:** Cochlear implantation, *****: The measurements belonging to the ganglion fossa, ****:** The measurements belonging to the ganglion.

Ge and Spector also studied 10 cadaveric adult temporal bones and measured the ganglion length and width as 1.76 mm and 1.29 mm, respectively (10). In our opinion, the distinct difference between foetal and adult measurements in the study of Ge and Spector (10) shows that the ganglion size increases during childhood. Beger et al. performed computed tomography of the temporal bones of children aged 1–18 years and found that the ganglion fossa area and width were increasing after birth, but the length remained (3). Hamzaoglu et al. compared the ganglion dimensions obtained from computed tomography (GG fossa measurements) and dissection (GG measurements) and reported no significant difference between the two measurements (12). In the light of these studies (3,10,12), we think that the ganglion enlarges with age in harmony with its fossa after birth.

Beger et al. stated that the data presented in previous morphometric studies were quite different (3). Possible reasons were as follows: a) individual determinants (temporal bone pneumatization, jugular bulb position, mastoid apex development, etc.), b) study methodology (dissection, radiologic or histologic measurements) and c) demographic information (age, region, etc.) (2,3,20). For example, the length and width of the ganglion fossa on computed tomography in Chinese were smaller than those in Turkish (3,12,18). In addition, these two parameters in the foetal histological study of Ge and Spector (10) were smaller than those in our dissection work, probably due to methodological differences.

CONCLUSION

Our findings show that the ganglion is dimensionally shaped in the early stages of foetal life. This finding may be important for anatomists and embryologists in performing morphometric studies and in understanding the development of the GG and for neuro-otologists and neurosurgeons in achieving greater success in skull base surgeries.

AUTHORSHIP CONTRIBUTION

Study conception and design: OD, OB, PT, AD, DUT

Data collection: OD, OB, PT, DUT

Analysis and interpretation of results: OD, ABO, YV, DUT

Draft manuscript preparation: OD, OB, AD, DUT

Critical revision of the article: OD, AD, YV, DUT

Other (study supervision, fundings, materials, etc...): OD, AD, ABO, DUT

All authors (OD, OB, PT, AD, ABO, YV, DUT) reviewed the results and approved the final version of the manuscript.

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