JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, January 2010, Vol. 55, No. 1
doi: 10.1111/j.1556-4029.2009.01212.x
Available online at: interscience.wiley.com

TECHNICAL NOTE

ANTHROPOLOGY

Norman Wendell Todd,[1] *M.D., M.P.H.; Matthias Graw,*[2] *M.D.; and Maria Dietzel,*[2] *Dipl.Biol.*

"Lateral Angle" of the Internal Auditory Canal: Non-Association with Temporal Bone Pneumatization

ABSTRACT: The "lateral angle," the angle with which the posterior wall of the internal auditory canal meets the posterior fossa plate, is arguably wider in females (>45°) than males (<45°). Not previously addressed, however, are repeatability of angle determination, and whether the extent of temporal bone pneumatization is a confounder. Forty-one adult human cranial specimens (82 clinically normal temporal bones) were studied; no sex information was available for this United States sample. Two casts were created from each ear; each cast was independently categorized twice. No association of lateral angle with mastoid size was found. Repeatability was good. Although bilateral symmetry was suggested (phi = 0.60, $p = 0.05$), two crania had oppositely categorized right-left angles. We observed a new finding: narrowed but clinically normal canals in 10% of crania. The lateral angle is a good candidate to be a morphological method in determination of sex.

KEYWORDS: forensic science, temporal bone, pars petrosa ossis temporalis, skull base, internal auditory canal, fragmented skeletal remains, sex determination

The petrous parts of the temporal bones, which predominate the cranial base, have extreme mechanical strength and are usually preserved. Because of these features, and the continuing need for a quick easy morphological method of sex determination, petrous contributions to sex determination have been sought (1–3). In 80% of cases, Graw (1) could distinguish sex by using two or three single measurements of the cranial base. Even if only the supraorbital margin is assessed, 70% of specimens can be sex-identified (4). Petrous-only discriminators, with a hit rate of about 70%, include distances between the right and left internal auditory pori (especially as determined by the index of distance between pori divided by biauricular width) (4), and the "lateral angle"—the angle with which the posterior wall of the internal auditory canal meets the posterior fossa plate. A lateral angle's cast is shown in Fig. 1. Internal auditory canals of males are comparatively lateral and dorsal (1).

Although no explanation is established for why lateral angles are wider for females than males, 45° being the demarcation, evolutionary theory may offer a suggestion. The forward positioned foramen magnum of *Homo sapiens* may have dragged the petrous apices forward. The foramen magnum is generally more forward in females than males. A female's more open "lateral angle" may be attributable to the comparatively anchored posterior-lateral aspects of the temporal bone, so the "lateral angle" is pulled wider in females.

With the prior referenced studies as a foundation, the present study addressed four goals:

- To address the hypothesis that size of "lateral angles" correlate with the extent of temporal bone pneumatization, a highly variable feature of human temporal bones, that is generally bilaterally symmetrical, and unrelated to sex (5).
- To address the hypothesis that determination of lateral angle is highly repeatable.
- To address the hypothesis that the measurements of "lateral angles" have tight bilateral symmetry.
- To study a sample other than of Germanic ancestry.

[1]Department of Otolaryngology, Emory University, 1365A Clifton Road, Atlanta, GA 30322, USA.
[2]Institut für Rechtsmedizin, Ludwig-Maximilians-Universität, Nußbaumstr. 26., 80336 Munich, Germany.

Received 31 Mar. 2008; and in revised form 9 Dec. 2008; accepted 14 Dec. 2008.

Materials and Methods

Specimens

Forty-one adult skulls (82 temporal bones) were provided by the Anatomy Department. Institutional Review Board approval was not applicable to these postmortem specimens. All were from humans who antemortem had bequeathed their bodies to science. Not available was information about age, sex, and group affiliation, and ethnicity. Although none had died of ear disease, unambiguous ear historical data were not available.

This collection of specimens was chosen for convenience: readily available; of different group affiliation and ethnic origin than specimens of other reports of "lateral angles"; and mastoid sizes had already been determined. Unfortunate for this study, only remaining were the cranial bases' middle and anterior portions: no supraorbital margin, or tissue posterior to the foramen magnum.

Silicone Casts of the Lateral Angles

Microsonic's Mega-Sil™ vinyl polysiloxan A-B impression material, common in the United States for making earmold impressions, was used. Such silicone impression is "flexible," "yet has total memory," and "will never sag or collapse and cannot generally be damaged by handling or shipping." (6) The

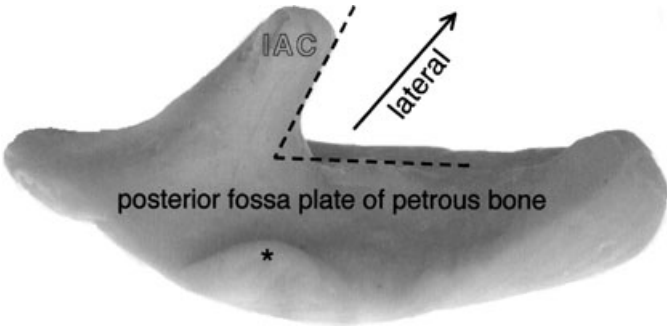

FIG. 1—*Image of a cast, right ear, as viewed from above. IAC = internal auditory canal. The "*" indicates where some silicone impression material extended superiorly into the grove for the superior petrosal sinus. The dashed line approximates the "lateral angle."*

syringe method was used (by NWT) to insert and position the impression material.

Lateral Angle Determination

The angle at which the posterior-lateral wall of the internal auditory meatus meets the adjacent posterior face of the petrous bone, the "lateral angle," was optically measured using a 45° setsquare. The challenge was to determine whether each lateral angle was smaller or larger than 45°—"a simple morphological method for sex determination" (2). Each cast was categorized on a five-grade scale:

>>5° = definitely more than 45°
>45° = probably more than 45°
0 = could not determine, or cast incomplete
<45° = probably less than 45°
>>45° = definitely less than 45°

Temporal Bone Pneumatization

Law lateral plain mastoid radiographs were used to describe the extent of pneumatization, i.e., how much the temporal bone, in sites adjacent to the middle ear cavity and mastoid antrum, had air cells. A high degree of pneumatization correlates with healthy middle ears during childhood; conversely, small pneumatization correlates with otitis media.

The outline of pneumatization of each radiographic image was traced onto paper, on two separate independent occasions. The antrum region was included. Areas were measured by planimetry (7). The average of two mastoid area measurements was used.

Statistics

The measure of each parameter ("lateral angle" and mastoid size) of each specimen was carried out independently. Two separate silicone impressions were made of each "lateral angle." Each cast, labeled with a random number so as to ensure independence of assessments, was categorized separately two times (by MD) for lateral angle, unaware of data of that ear's other silicone cast, the antimere's cast, and extent of pneumatization. Thus, eight independent determinations for every individual of this collective were made, i.e., four determinations for the left and four for the right temporal bone. The first step was to compare two independent designations of the same cast. Only consistently categorized "lateral angles" were included in the second step: compare the categorizations of the two casts of each ear. In the third step, consistently categorized

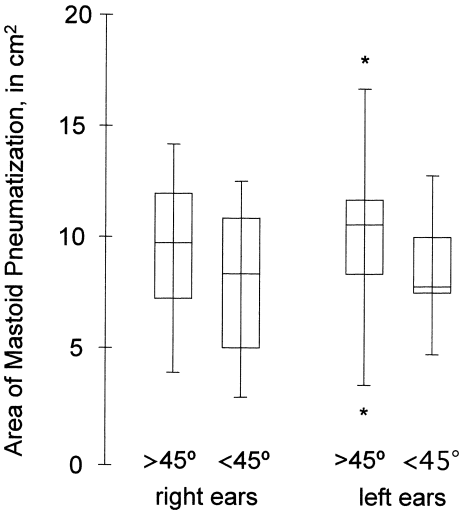

FIG. 2—*Non-association of mastoid pneumatization with the "lateral angle," Pneumatization is that of the ipsilateral mastoid. Only included are lateral angles consistently categorized (on each of the two independent casts of each angle). For left ears, the number of angles categorized as >45° was 21; as <45°, 5 (these numbers are apparent in Table 1). For right ears, the number of angles categorized as >45° was 23; as <45°, 4 (these numbers are apparent in Table 2).*

lateral angles (i.e., >>45° and >>45°, or >>45° and >45°, or >45° and >45°; <<45° and <<45°, or <<45° and <45°, or <45° and <45°) were used: expressing bilateral symmetry, and in searching for association with mastoid size.

Agreement of categorizations of the two casts of each lateral angle was expressed by Cohen's linearly weighted kappa statistic.

Results

Repeatability of measurements was good (see Tables 1 and 2). For the right ears' lateral angles, weighted kappa was 0.52 (95% confidence interval 0.29–0.74); for left, 0.65 (0.46–0.83). For both the right and left mastoid areas, $r = 0.91$ (95% CI 0.84–0.96);

TABLE 1—*Comparison of the lateral angle categorizations made for each cast.*

		Interpretation of the ear's first determination					
Left ears		>>45°	>45°	n.d.	<45°	<<45°	Total
Interpretation	>>45°	11/7*	7/8†				18/15
of that ear's	>45°	3/3	2/6	1/2‡	0/2		6/13
second	n.d.		1/1	9/6			10/7
determination	<45°		1/1		2/1		3/2
	>>45°				1/0	3/4	4/4
	Total	14/10	11/16	10/8	3/3	3/4	41/41
Right ears	>>45°	14/13	4/8*		1/0		19/21
Interpretation	>45°	3/3	4/3†	1/5‡			8/11
of that ear's	n.d.		1/1	6/2			7/3
second	<45°		0/1	0/1	3/1	1/0	4/3
determination	<<45°				1/0	2/3	3/3
	Total	17/16	9/13	7/8	5/1	3/3	41/41

n.d., no diagnosis; i.e., cast incomplete, or lateral angle equaled 45°, or cast had an atypical shape.

*The first number represents the initial categorization, the second number for the "second call" of that cast.

†Shaded cells designate casts that were consistently assigned in the two determinations.

‡Non-shaded cells designate casts that generated different results in the two determinations.

TABLE 2—*Comparison of the first and second casts built of each temporal bone.*

		Interpretation of the ear's first cast			
Left ears		>>45°/>45°	n.d.	<<45°/<45°	Total
Interpretation of that ear's second cast	>>45°/>45°	20*	3†		23
	n.d.	1	5		6
	<<45°/<45°			5	5
	Total	21	8	5	34
Right ears					
Interpretation of that ear's second cast	>>45°/>45°	22*	3†	1	26
	n.d.		1		1
	<<45°/<45°			4	4
	Total	22	4	5	31

n.d., no diagnosis; i.e., cast incomplete, or lateral angle equaled 45°, or cast had an atypical shape.

*Shaded cells designate casts that were consistently assigned in the two interpretations.

†Non-shaded cells designate casts that generated different results in the two interpretations.

otherwise stated, for right ears, 76% agreed within 2.0 cm^2 or better, 83% for left. A wide range of mastoid sizes and lateral angles was apparent for both the right and left sides of the 41 crania, as shown in Fig. 2.

Bilateral symmetry was suggested for the consistently categorized lateral angles (see Table 3). Phi = 0.60, $p = 0.05$. Note that two of the 18 crania with consistently categorized lateral angles had right-left oppositely categorized angles. For mastoid areas, bilateral symmetry was apparent: $r = 0.64$ (95% CI 0.42–0.80).

No relationship of temporal bone pneumatization with lateral angle categorization was apparent, as shown in Fig. 2. The two crania with oppositely categorized angles had mastoid areas in the 25th–75th percentile range for both the right and left sides.

A surprise finding was that seven of the 82 casts exhibited, as interpreted in the ears' first cast, had flat or narrow internal acoustic meatuses. The seven were from just four of the crania, so bilateral symmetry was suggested. A review of photographs of the cranial specimens revealed those meatuses, and a few additional meatuses, to have comparatively superior-inferior flattening of the meatuses. No specimen exhibited clinical pathology.

Discussion

Limitations of this study included the lack of information about the age, sex, group affiliation, and otologic history of the specimens. Erroneous or inaccurate pneumatization and lateral angle determinations, and postmortem changes in the specimens, are unlikely. That only 18 of 41 crania had casts bilaterally consistently categorized is attributable mostly to the "could not determine, or cast incomplete" category. Flat/narrow meatuses, a new finding in the casts of this population, account for some of the "could not determine, or cast incomplete" designations. Two of the 18 bilaterally consistently categorized crania had cross sex designation, i.e., one side male but antimere female.

TABLE 3—*Bilateral symmetry of lateral angles.*

		Right ears' casts		
Lateral angles				
Left ears' casts	*	>45° on each†	<45° on each‡	Total
	>45° on each†	14	1	15
	<45° on each‡	1	2	3
	Total	15	3	18§

*Phi = 0.60, $p = 0.05$.

†Consistently categorized lateral angles of Table 2: i.e., >>45° and >>45°, or >>45° and >45°, or >45° and >45°.

‡Consistently categorized lateral angles of Table 2: i.e., <<45° and <<45°, or <<45° and <45°, or <45° and <45°.

§Data for 23 crania are not depicted, because there was no diagnosis possible for one side of three crania, both sides of one cranium, and 19 crania had casts that generated different results in the two designations for at least one ear.

The repeatability (144 of 164 casts, i.e., 87.8%) of consistently categorized casts is relatively high. Likewise relatively high was the agreement between the two casts that were made of one "lateral angle": 87.7%. Thus, a differentiation by the "lateral angle," with a definition at 45°, can be categorized quite consistently.

That 16 of the 18 (88.9%) of these crania showed a bilaterally symmetric lateral angle designation is similar to that found in another separate series of specimens (8). Remarkable about the material of the present report is that 14 of 16 crania (87.5%) categorized consistently by this method have lateral angles >45°, i.e., linked with female. An explanation of this phenomenon could be that actually more females than males are represented in this collective, or some casts categorized as females are in fact males. Note that boys, between 0 and 12 years, mostly have a lateral angle wider than 45° (8). Another explanation could be that there are other populations, for example blacks, in this collective. The lack of information about age, sex, and group affiliation for the specimens studied, precludes such accounting. Nevertheless, for these specimens, there is congruence of lateral angles with another petrous-only correlate of sex: the distance between the right and left internal auditory pori (1). For the two crania with arguably male lateral angles, the distances were 65.25 and 61.0 mm; for the 14 with arguably female angles, range 47.75–63.5 mm, median 56.0 mm; $p < 0.09$ (Wilcoxon rank sum test). The distances are consistent with those reported by Graw (1).

The hypothesis that "lateral angle" designation correlates with the extent of temporal bone pneumatization was not supported by these data. Thus, all four goals of the study were attained: no relation of lateral angle with pnematization; repeatability of lateral angle determination was very high; bilateral symmetry was found; and another population was studied.

The surprise finding that about 10% of the crania had bilateral superior-inferior flattened or narrowed internal auditory canals confounded this study by the casts being indeterminant or incomplete. The explanation for this surprise finding, unlikely attributable to cast technique, may be related to features of a particular population—perhaps blacks, who are unlikely to have been included in prior "lateral canal" studies.

In conclusion, the "lateral angle," the angle with which the posterior wall of the internal auditory canal meets the posterior fossa plate, is repeatable, has bilateral symmetry, and is not confounded by the extent of temporal bone pneumatization. As the petrous bone is mechanically strong and usually preserved, the lateral angle is a good candidate to be a morphological method in determination of sex.

References

1. Graw M. Metric sex determination of the skull base. Homo 1999;50:101–6.
2. Graw M, Schulz M, Wahl J. A simple morphological method for gender determination at the petrous portion of the os temporalis. Forensic Sci Int 2003;136(Suppl. 1):165–6.
3. Graw M, Wahl J, Ahlbrecht M. Course of the meatus acusticus internus as criterion for sex differentiation. Forensic Sci Int 2005; 147:113–7.

4. Graw M, Czarnetzki A, Haffner HT. The form of the supraorbital margin as a criterion in identification of sex from the skull: investigations based on modern human skulls. Am J Phys Anthropol 1999;108:91–6.
5. Diamant M. Otitis and pneumatisation of the mastoid bone. Acta Otolaryngolog Suppl 1940(Suppl. XLI):1–149.
6. Microsonic, Inc. Custom earmold manual, 8th edn. Ambridge, PA: Microsonic, Inc., 2006;13, http://www.earmolds.com
7. Todd NW, Pitts RB, Braun IF, Heindel H. Mastoid size determined with lateral radiographs and computerized tomography. Acta Otolaryngol 1987;103:226–31.
8. Dietzel M. Ein interspezifischer Vergleich des Verlaufs des Meatus acusticus internus der Hominidae – Mit einem Schwerpunkt auf die morphognostische und morphometrische Geschlechtsdiagnose von juvenilen Partes petrosae ossis temporalis des Homo sapiens [diplomarbeit]. München: Fakultät f Biologie, Ludwig-Maximilians-Universität, 2007.

Additional information and reprint requests:
N. Wendell Todd, M.D., M.P.H.
Department of Otolaryngology
Emory University
1365A Clifton Road
Atlanta
GA 30322
E-mail: ntodd@emory.edu