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## Handedness and the Bilateral Asymmetry of the Jugular Foramen

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**ABSTRACT:** This paper examines the proposed association of bilateral asymmetry of the jugular foramen as an indicator of handedness observable from cranial morphology. The jugular foramina of 54 subjects were observed for size asymmetry during routine autopsy procedures. Hand preference data were collected on each subject from family members. Of the 54 subjects, 47 were documented as being right-handed and 7 as being left-handed. These values approximate the average percentage of right-handed versus left-handed individuals from larger populations. Jugular foramen asymmetry was qualitatively identified for 36 subjects (66.7%) and was judged equivocal for the other 18 (33.3%). Of the 36 subjects exhibiting asymmetry, 28 (77.7%) showed positive correlation between the asymmetry direction and handedness. This moderate level of congruence, coupled with the result that 4 of the 7 left-handers exhibited dominant right-side foramina, casts doubt on the reliable use of jugular foramen asymmetry for estimating handedness.

**KEYWORDS:** physical anthropology, musculoskeletal system, handedness, human identification, skeletal asymmetry

Forensic anthropologists continue to seek new techniques and methodologies to aid in identification of human skeletal remains. In addition, old methods are reevaluated and revised to ensure accuracy as larger, documented, and more representative samples become available. Handedness or hand preference is one identification feature suggested from skeletal remains. Traditionally, hand preference has been estimated from the observable size or morphological asymmetry, or both, of arm long bone lengths, muscle attachment areas of the arm bones, beveling of the dorsal margin of the scapulae, and jugular foramen size on the base of the skull [1-3]. In a paper by Glassman and Bass [1], the association between jugular foramen asymmetry and asymmetry in the lengths of the humeri, radii, and ulnae was examined in light of their consistency in predicting handedness. That paper concluded that, because no strong association was found between the asymmetry parameters, one or both of the parameters were poor predictors of hand preference. However, because the sample was limited to individuals whose hand preference was not documented, it could not be ascertained which, if either, of the two parameters was most appropriate for estimating handedness.

The present study extends the evaluation of predicting handedness from jugular foramen asymmetry by testing the association on a documented sample.

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## Background

Although definitions may vary, handedness refers to the preference for using one hand more often than the other for completing daily activities such as writing and eating. Estimates of hand preference in modern populations generally range between 90 and 97% for right-handedness [3,4]. Estimating handedness from skeletal remains has been based on the theory that the differential use of one hand over the other will result in increased growth in the length and in the development of muscle attachment areas of the arm bones on the side demonstrating greater use. In addition, increased use of one arm over the other is thought to increase stress in the shoulder joint, resulting in observable degenerative reformation of the glenoid cavity. Although these theories appear reasonable given our present knowledge of bone growth and development, doubts have been raised over the past 50 years that preferential use of one hand over the other could be held directly responsible for the common frequencies of arm long bone asymmetry in length and thickness in adults [5–8]. Nevertheless, the use of long bone asymmetry in identification remains commonplace.

The technique and the theoretical basis for using jugular foramen asymmetry as an indicator of handedness are more obscure. As indicated in a previous paper [1], the technique can be traced back to Dr. Charles E. Snow, who related the asymmetry to demands of blood supply and flow. To rationalize undertaking the present study, a more specific hypothesis was generated to account for an association between handedness and jugular foramen asymmetry. The authors of the present paper hypothesized that the increased use of one arm over the other would lead to a greater developed musculature, which, in turn, would cause back pressure of the venous system up into the jugular vein on that side. Ultimately, this would generate remodeling of the foramen, increasing its size to greater than that of its homolog. Notice that this hypothesis is not based on differential blood drainage of the limbs, as the internal jugular vein has no functional relationship with this condition. Also, the hypothesis is not subject to criticism that increased hemispheric blood flow on the dominant side needs to be consistent with the contralateral control of the left side of the body by the right hemisphere of the brain and vice versa. This control would have necessitated the prediction that left-arm dominance is the common pattern, as larger right-side jugular foramina are most often observed.

## Materials and Methods

Jugular foramen asymmetry was scored for 54 subjects during routine autopsies performed at the Bexar County Medical Examiners Office, San Antonio, Texas. The sample was composed of 40 males and 14 females. Racially, 47 of the subjects were white and 7 were black. Their ages ranged from 15 to 86 years.

To document jugular foramen asymmetry, the subjects were placed facedown on the table, the cranium was cut, and the dura was stripped from the foramen magnum across the clivus. The table of the petrous portion was cut and all tissue was cleaned away. Figures 1a, 1b, and 1c illustrate the procedure for exposing the jugular foramina. The interior surface of the skull was viewed to assess the asymmetry, which was scored according to subjective criteria. Asymmetry was scored as dominant right, dominant left, or equivocal. For a subject to be scored as asymmetric, side bias had to be clearly demonstrated.

Documentation of handedness for each subject was obtained by contacting and requesting relevant information from family members. Most of the respondents based their opinions on which hand the subject used for writing and, in some cases, for eating. Although it is possible that the hand one uses to write with is not necessarily the hand used most often in daily or occupational activities, we have assumed this to be the case



FIG. 1a—*Procedure used to expose the jugular foramen: the dura stripped from the cranial surface.*

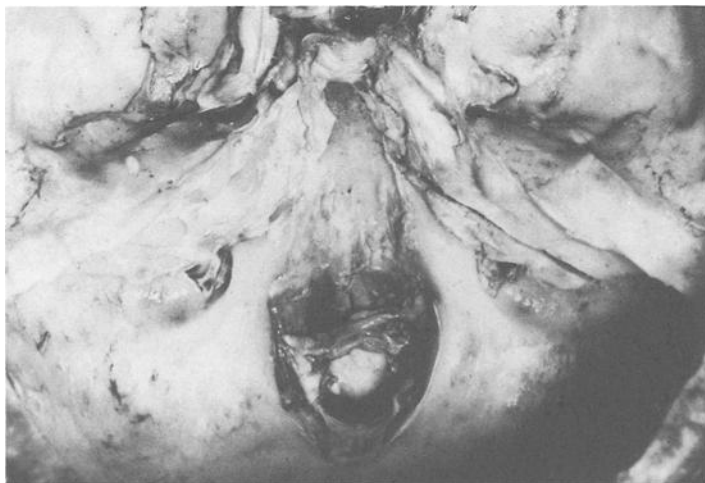


FIG. 1b—*The petrous portion cut away from the specimen in Fig. 1a.*



FIG. 1c—The remaining tissue cleared away from the specimen in Fig. 1b for clear viewing and scoring of the foramen dominance.

for purposes of this study. In order for handedness to be beneficially used as an identification parameter, it must be consistent with the most common or general perception.

Asymmetry scores for all individuals were tabulated as histograms describing the relative frequencies of side dominance. Histograms describing the frequency of right-handedness versus left-handedness in the individuals were also tabulated. Prior to testing our main hypothesis concerning the association of handedness with jugular foramen asymmetry, differences in the frequencies of handedness and asymmetry related to gender and race were tested. The results showed no significant difference, and the entire sample was pooled for further analyses. The pooled data were subjected to chi-square analysis for association, and an alpha level of 0.05 was selected as the criterion for significance.

### Results

The histograms of observed frequencies for handedness are presented in Fig. 2. Of the 54 subjects, 47 (87%) were documented as being right-handed and 7 (13%) as being left-handed. This ratio does not vary substantially from estimates for larger populations. The breakdown of jugular foramen asymmetry into percentages of right-side dominance, left-side dominance, and equivocality is presented in Fig. 3. An asymmetric condition was judged present in 36 subjects (66.7%), with the other 18 subjects (33.3%) scored equivocal. Of the 36 subjects exhibiting asymmetry, 30 (83.3%) exhibited larger right-side foramina, whereas 6 (16.7%) exhibited larger foramina on the left side. At this step, it would appear that some association may exist between handedness and jugular foramen asymmetry because of the similarity in the frequency percentages of both parameters.

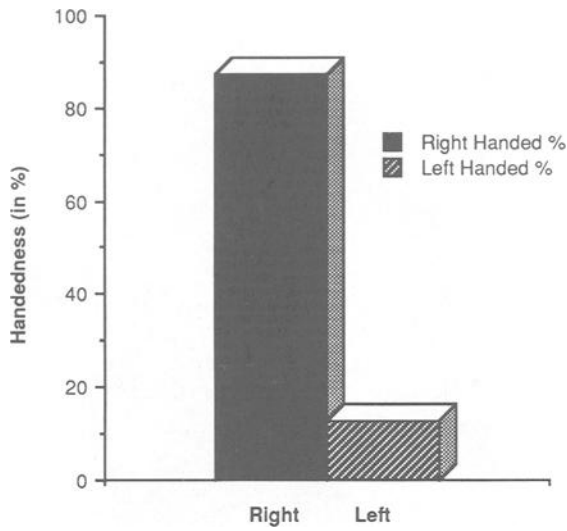


FIG. 2—Frequency histogram for handedness.

Table 1 presents cross tabulations of the observed frequencies for jugular foramen asymmetry and handedness. The table reveals an inconsistent pattern in the association between the two variables. Of the 30 subjects exhibiting dominant right-side foramina, 26 were right-handed and 4 were left-handed. However, of the 6 subjects exhibiting larger left-side foramina, only 2 were left-handed. An interpretation of non-association was supported by the chi-square analysis results (Table 2).

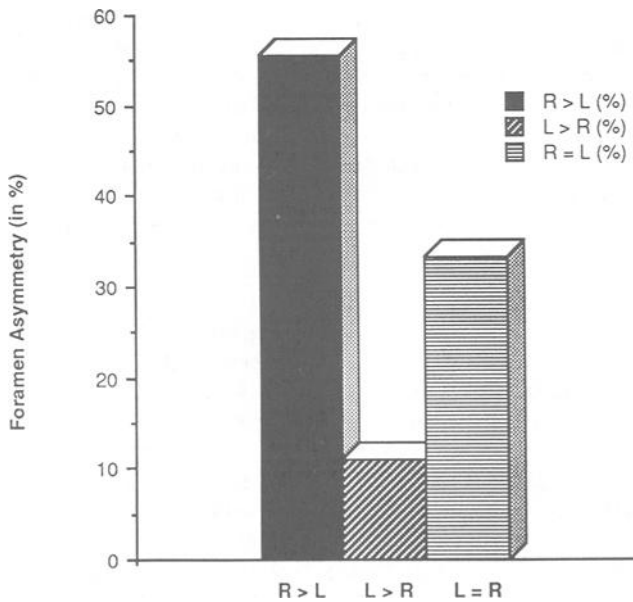


FIG. 3—Frequency histogram for jugular foramen asymmetry.

TABLE 1—Cross tabulations of the observed frequencies for the dominant side of the jugular foramen and handedness.

| Handedness | Jugular Foramen |      |      |
|------------|-----------------|------|------|
|            | Right           | Same | Left |
| Right      | 26              | 17   | 4    |
| Left       | 4               | 1    | 2    |

TABLE 2—Chi-square statistics and Cramer's V coefficient for association between the asymmetry of the jugular foramen size and handedness.

| Test                           | Degrees of Freedom | $\chi^2$ | P     | Cramer's V Coefficient |
|--------------------------------|--------------------|----------|-------|------------------------|
| Jugular foramen and handedness | 2                  | 3.086    | 0.214 | 0.239                  |

To eliminate the possibility of the results being biased by the inclusion of the relatively large group of individuals demonstrating no asymmetry in jugular foramen size, the data were reevaluated by chi-square analysis using a two-by-two design. Therefore, only those subjects who exhibited an asymmetric condition were included. The results, again, indicated no significant association.

### Discussion

The results suggest that no significant association exists between a size difference in the right and left jugular foramina and the handedness of an individual. The foramen asymmetry technique undoubtedly arose from observations made on archeological populations. Comparisons of crania within and between populations consistently yield a frequency of larger right-side foramina in the majority of subjects. Because this frequency coincides with the frequency of right-hand dominance in modern populations, the hypothetical association between handedness and foramen asymmetry could have been drawn.

Acceptance of the null hypothesis in the present study compels us to suggest that forensic anthropologists and others refrain from using jugular foramen asymmetry as a sole determinate of handedness from the skeleton. Given that the population is approximately 90% right-handed, one would do better to guess right-handedness on any given case, including, as this study indicates, those that demonstrate left-side dominance of the jugular foramen as well.

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