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Anatomical considerations of high jugular bulb in lateral skull base surgery

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Abstract
In order to study high jugular bulb management in lateral skull base surgery, an anatomical study was conducted on 30 temporal bones by examining the relationship between the internal auditory canal (IAC) and the jugular bulb. The following parameters were measured: 1) Height of the jugular bulb (H) . . . distance between the level of the jugular bulb dome and the line passing through the confluence of the sigmoid sinus with the jugular bulb (SS-JB), 2) Mastoid length (ML) . . . distance between the mastoid process and middle cranial fossa dura, 3) Distance between the most inferior part of the porus acousticus and jugular bulb dome (A), 4) Distance between the porus acousticus and SS-JB (B). The jugular bulb was defined as high when it occupied more than two thirds of (B). The incidence of a high jugular bulb was 23 per cent in this study. When the jugular bulb was high, the mean (H) and (A) were 9.4 ± 1.9 mm and 2.7 ± 0.5 mm, respectively. (H) was higher on the right side than on the left side. No statistically significant difference was found between small and large mastoids (*t*-test: $p>0.05$). It was concluded that when a high jugular bulb was encountered during lateral skull base surgery, the jugular bulb position allows a very small working area inferior to the IAC. In these cases, a 3 or 4 mm depression of the jugular bulb is necessary in order to expose the lower cranial nerves. This can be accomplished by lowering the jugular bulb with the technique already described.

Key words: Anatomy; Temporal bone

Introduction

A high jugular bulb is one of the main problems encountered in neurotological surgery through the temporal bone (Saleh *et al.*, 1994; Sanna *et al.*, 1995). The incidence of this anatomical finding has been reported to vary from six to 65 per cent according to the definition used. In some studies anatomical landmarks such as the inferior tympanic annulus, the round window, basal turn of the cochlea, and internal auditory canal (IAC) were used. (Overton and Ritter, 1973; Wadin and Willbrand, 1986; Kumar *et al.*, 1989; Turgut and Tos, 1992b; Rauch *et al.*, 1993; Shao *et al.*, 1993). The cause of this variability in the position of the jugular bulb is still debatable. Although pneumatization is claimed as a cause of high jugular bulb by some investigators (Graham, 1977; Wadin and Willbrand, 1986; Turgut and Tos, 1992b) there is no agreement on the relationship between the variability of the jugular bulb position and mastoid pneumatization in the literature. There are also some other researchers who advocate the idea that there is no relation between the position of the jugular bulb and pneumatization (Orr and Todd, 1988; Kumar *et al.*, 1989).

From a surgical point of view, whatever the reason for a high jugular bulb, the surgeon must be able to manage it when it is encountered during surgery, because it precludes a clear surgical view in some neurotological cases, such as translabyrinthine and retrolabyrinthine approaches to the skull base (Aristegui *et al.*, 1994; Saleh *et al.*, 1994). In these types of surgical approach to the cerebellopontine angle, in order to estimate the extent and limitations of surgical exposure, it is crucial to recognize the anatomical relationship between the IAC and the jugular bulb.

The present anatomical study was designed to examine the relationships between the IAC and the jugular bulb.

Material and methods

Thirty temporal bones preserved in formalin were dissected at the temporal bone laboratory of the Gruppo Otologico, Piacenza, Italy. There were 17 right and 13 left temporal bones. All temporal bones were from adults and were injected with coloured silicone prior to dissection (Landolfi *et al.*, 1995). After complete mastoidectomy, the distance between the middle cranial fossa dura and mastoid

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tip in the vertical plane, ie. mastoid length, was measured. The sigmoid sinus and the jugular bulb were skeletonized. Then, labyrinthectomy was performed. The dura of the IAC was identified. The nearest distance between the most inferior part of the porus acousticus and jugular bulb dome (A), and that between the confluence of the sigmoid sinus with the jugular bulb (SS-JB) and porus acousticus (B) were measured. The height of the jugular bulb (H) was described as the distance between the horizontal line passing tangentially through the jugular bulb dome, and the horizontal line passing through the SS-JB, in the vertical plane (Figure 1).

All bones were classified into two groups related to their mastoid lengths. The bones with a mastoid length above 35 mm were defined as large mastoids, while the bones with a mastoid length of 35 mm or below were defined as small mastoids. In each group, the mean values for (H) and (A), were calculated.

After identification of IAC dura, the position of the jugular bulb was assessed subjectively as either high or low, according to the degree of difficulty in bone removal between the IAC and the jugular bulb. It was noticed that in bones with a high jugular bulb, the jugular bulb occupied approximately more than two thirds of (B). Therefore, it was decided to exploit this criteria in the definition of HJB in this study. Then, in each bone, the percentage of the area occupied by the jugular bulb between the IAC and SS-JB, was calculated by dividing (H) by (B). When the jugular bulb occupied more than two thirds, ie. more than 67 per cent, of (B), it was considered as 'high' (Group 1). However, it was defined as 'low' (Group 2) when the jugular bulb occupied less than two thirds of (B). In each group, the mean values of (A) and (H), were calculated.

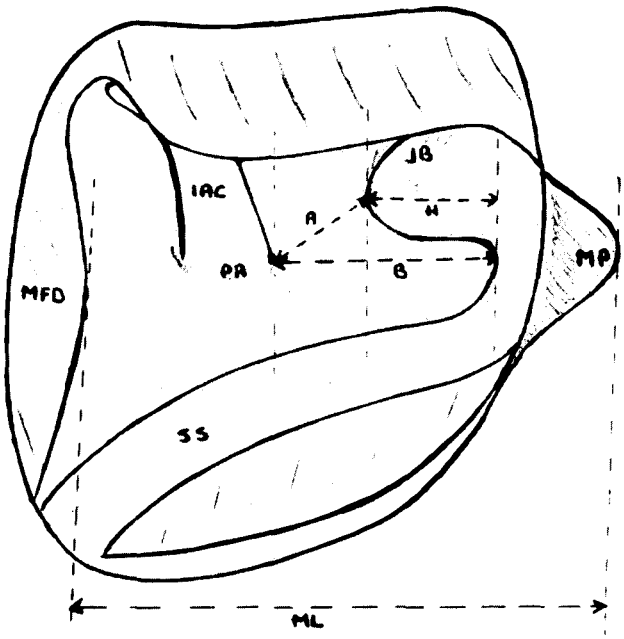

FIG. 1

Schematic presentation of measurement points (Right ear). JB– Jugular bulb, IAC– Internal auditory canal, SS– Sigmoid sinus, MFD– Middle fossa dura, PA– Porus acousticus, MP– Mastoid process, A– distance of JB dome to PA, B– distance of PA to the confluence of SS with JB, H– Height of the JB, ML– Mastoid length.

TABLE I
MEASUREMENTS OF H (+) AND A (&) RELATED TO ML (&&)

	ML≤35 mm (n = 17)	ML>35 mm (n = 13)
H	5.2 ± 3.8 (0–12)*	6 ± 2.9 (0–10)
A	6.6 ± 3.5 (2–14)	8.5 ± 3.7 (3–13)

Measurements are expressed in mm.
\+ H . . . Jugular bulb height.
& A . . . Distance between the most inferior part of the porus acousticus and jugular bulb dome.
&& ML . . . Mastoid length.
*indicates the range.

The *t*-test was used in the statistical analysis of the results.

Results

The mean value for (H) was 5.5 ± 3.4 mm (0–12 mm). The (H) mean was 6.7 ± 2.9 mm (3–12 mm) on the right-sided bones, while it was 4 ± 3.5 mm (0–9 mm) on the left-sided bones. The statistical analysis revealed the significant difference between two groups ($p<0.05$).

The mean value for (A) was 7.5 ± 3.7 mm (2–14 mm), and the mastoid length mean was 36 ± 5.7 mm (27–48 mm). There was no statistically significant difference between each of the two measurements ($p>0.05$).

The mean values for (H) and (A) related to mastoid length are demonstrated in Table I. The difference between mastoid length and each of two measurements was insignificant ($p>0.05$).

Table II exhibits the mean values for (H) and (A) in cases with and without a high jugular bulb. A statistically significant difference was found between the two groups ($p<0.001$).

According to the definition used in the present study, the incidence of high jugular bulb was seven out of 30 bones (23 per cent). However, in some bones, the sigmoid sinus did not bend upwards to the hypotympanum (Figure 2). In these bones the jugular bulb was flat, and (H) was determined as 0 mm. A flat jugular bulb was observed in five bones (16 per cent). In four out of these five bones, the mastoid length was 35 mm or less.

Discussion

HJB often complicates surgery in neurotological procedures such as the translabyrinthine and retrolabyrinthine approach by impeding the surgical view

TABLE II
MEASUREMENTS OF H AND A RELATED TO EXISTENCE OF HIGH JUGULAR BULB (HJB)

	Group 1 (n = 7)	Group 2 (n = 23)
H	9.4 ± 1.9 (7–12)*	4.3 ± 2.8 (0–9)
A	2.7 ± 0.5 (2–3)	8.9 ± 2.9 (3–14)

Measurements are expressed in mm.
Group 1 . . . cases with HJB.
Group 2 . . . cases without HJB.
*indicates the range.

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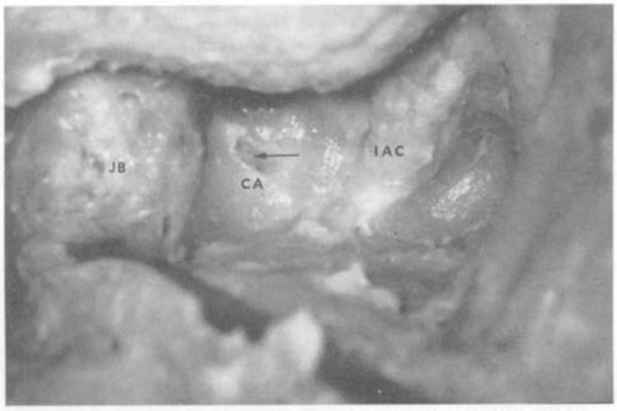

FIG. 2

Translabyrinthine surgical exposure in a left temporal bone with flat jugular bulb. An available area between the jugular bulb (JB) and internal auditory canal (IAC) is sufficient to see the cochlear aqueduct (CA), which indicates the 9th cranial nerve (Black arrow) as seen in the Figure.

(Aristegui *et al.*, 1994; Saleh *et al.*, 1994). In the literature, there have been studies of the anatomical relationships of HJB in relation to skull base surgery (Roland *et al.*, 1988; Koval *et al.*, 1993; Rauch *et al.*, 1993). The main interest of these studies was on the distance between the IAC and jugular bulb (A), which can be described as the working area inferior to the IAC in the translabyrinthine approach. We found this distance to be 7.5 ± 3.7 mm (range, 2–14 mm). Nevertheless, Roland *et al.* (1988) report the same distance as 4.1 ± 1.8 mm with a range of 7.5 to −0.5 mm, while Koval *et al.* report it as 6.3 mm (range, 3.5–9.5 mm) (Koval *et al.*, 1993). In addition, Orr and Todd measured the distance between the jugular bulb roof and the plane of the lateral semicircular canal as 8.8 mm (range, 2–15 mm) (Orr and Todd, 1988). But, in these studies, the relationship between the high jugular bulb and this distance (A) was not examined. In the present study, (A) was 2.7 ± 0.5 mm when the jugular bulb was high. In these bones, (H) was 9.4 ± 1.9 mm. Height is important since adequate space for drilling of the bone inferior to the IAC and medial to the bulb can only be obtained by pressing upon the jugular bulb. This measure, in turn, allows for visualization of the cochlear aqueduct, which is the lower limit of the translabyrinthine approach, and allows control of the area around the lower cranial nerves (Figure 2) (House, 1994; Sanna *et al.*, 1995).

Lang *et al.* report the distance between the IAC and the external opening of the cochlear aqueduct as 6.45 mm (Lang, 1985). From this perspective, the previously mentioned results reveal that in cases with a high jugular bulb, in addition to the distance between IAC and the jugular bulb, 3 or 4 mm of exposure must be obtained to see the cochlear aqueduct. This exposure can be accomplished by pressing the jugular bulb, using oxidized cellulose and bone wax, thus protecting it from inadvertent injury during drilling (Saleh *et al.*, 1994).

The definition of high jugular bulb in this study maybe questioned, although there is no consensus of opinion as to a definition in the literature. Several anatomical landmarks such as the inferior tympanic annulus, the round window, basal turn of the cochlea, and IAC, have been proposed (Overton and Ritter, 1973; Wadin and Willbrand, 1986; Kumar *et al.*, 1989; Rauch *et al.*, 1993; Shao *et al.*, 1993). Nevertheless, from a surgical standpoint, after labyrinthectomy by the translabyrinthine approach, the best available landmark for the jugular bulb position during surgical exposure, is the IAC. Rauch *et al.* defined the jugular bulb as high when the distance between the IAC and jugular bulb is less than 2 mm (Rauch *et al.* 1993). But, since this definition as well as other previously mentioned definitions does not provide any information on (H), which is outstanding in the management, we did not find it useful. On the contrary, both parameters, ie. (H) and (A), are taken into consideration in our definition. Using this, we found the incidence of a high jugular bulb as 23 per cent. Moreover, in some bones, the dome of the jugular bulb was not important (Figure 2). These flat jugular bulbs were found in 16 per cent of bones. This is consistent with the results of Saleh *et al.* who found flat jugular bulbs in 20 per cent of bones (Saleh *et al.*, 1995). Nevertheless, in four out five bones with flat jugular bulbs, the mastoid length was 35 mm or less. This finding was in contrast to the conventional idea which claims that the jugular bulb is high in small, constricted bones (Graham, 1977; Kennedy *et al.*, 1986; Wadin and Wilbrand, 1986; Turgut and Tos, 1992b; Nager, 1993).

The finding that the jugular bulb is higher on the right side must be kept in mind while dealing with this type of surgery. In fact, this finding supports previous observations of some researchers indicating that a large sigmoid sinus and jugular veins are found on the right side in 75 per cent (Graham, 1977; Kennedy *et al.*, 1986; Ichijo *et al.*, 1993; Nager, 1993). Embryogenesis might have some role in this asymmetry and Ayeni *et al.* have credited Muller and O'Rahilly with reporting the existence of this in embryos at eight weeks (Ayeni *et al.*, 1995).

Although (H) was higher on the right side, it did not correlate with mastoid length. In addition, there was no relationship between mastoid length and (A). The mastoid length is known to be shorter in poorly pneumatized bones (Turgut and Tos, 1992a; Nager, 1993; Tos, 1995). Turgut and Tos found that the length of the mastoid process was significantly shorter in specimens with small pneumatization (Turgut and Tos, 1992a). The absence of correlation of (H) with the mastoid length in the present study, can be interpreted as the absence of correlation between the height of the jugular bulb and pneumatization. This is in accordance with the reports of Kumar *et al.* and Orr and Todd, which indicate that there is no relationship between the jugular bulb configuration and mastoid pneumatization (Orr and Todd, 1988; Kumar *et al.*, 1989). Our results indicate that the high jugular bulb is not found only in small mastoids. Consequently, the surgeon must be prepared to encounter it in every case.

In summary, when there is a HJB, little working area is available at the inferior part of the IAC during surgery of the skull base through temporal bone. It can be enhanced by lowering the jugular bulb. Measurement of jugular bulb height in cases of HJB, permits this procedure. Higher jugular bulbs are more frequently found on the right side and the height of the jugular bulb is not correlated with mastoid length. These facts must be taken into consideration in cases with large mastoids in pre-operative evaluation.

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