Microsurgical Anatomy of the Jugular Process as an Anatomical Landmark to Access the Jugular Foramen: A Cadaveric and Radiological Study

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BACKGROUND: The jugular process forms the posteroinferior surface of the jugular foramen and is an important structure for surgical approaches to the foramen. However, its morphological features have not been well described in modern texts.

OBJECTIVE: To elucidate the microsurgical anatomy of the jugular process and examine its morphological features.

METHODS: Five adult cadaveric specimens were dissected in a cadaveric study, and computed tomography data from 31 heads (62 sides) were examined using OsiriX (Pixmeo SARL, Bernex, Switzerland) to elucidate the morphological features of the jugular process.

RESULTS: The cadaveric study showed that it has a close relationship with the sigmoid sinus, jugular bulb, rectus capitis lateralis, lateral atlanto-occipital ligament, and lateral and posterior condylar veins. The radiographic study showed that 9/62 sigmoid sinuses protruded inferiorly into the jugular process and that in 5/62 sides, this process was pneumatized. At the entry of the jugular foramen, if the temporal bone has a bulb-type jugular bulb, and if surgery concerns the right side of the head, the superior surface of the jugular process is more likely to be steep.

CONCLUSION: The jugular process forms the posteroinferior border of the jugular foramen. Resection of the jugular process is a critical step for opening the jugular foramen from the posterior and lateral aspects. Understanding the morphological features of the jugular process, and preoperative and radiographical examination of this process thus help skull base surgeons to access the jugular foramen.

KEY WORDS: Jugular foramen, Jugular process, Skull base

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The jugular foramen is generally accessed laterally, medially, and posteriorly, and infrequently, anteriorly. One of the most well-known approaches to the jugular foramen was described by Ugo Fisch in 1979.[1] This approach permits superior, posterolateral, and anterolateral exposure of the jugular foramen. Following this report, many reports modified, extended, and improved this approach. Sanna et al[2] reported infratemporal fossa approach type A with a transcondylar–transtubercular extension to obtain posteroinferior and medial access to the jugular bulb.[2] For posterolateral exposure of the jugular foramen, Mazzoni and Sanna[3] proposed the petro-occipital transsigmoid (POTS) approach, and Tedeschi and Rhoton[4] presented the postauricular transtemporal approach. Almost all of these approaches include lateral or posterior access to the jugular foramen with resection of the jugular process.[5] A variety of other surgical approaches to the jugular foramen have also been described.[1,4-25] Despite numerous reports, only a few groups have mentioned the importance of the jugular process for accessing the jugular foramen.[5,23,24,26,27] The jugular process has not been the target of a surgical and anatomical study. This highlights the need for a detailed investigation of the microsurgical anatomy of this structure. To the best of our knowledge, this is the first to study morphological features of the jugular process.

METHODS

Cadaveric Dissection

Five formalin-perfused adult cadaveric heads were dissected. The arteries and veins were injected with a

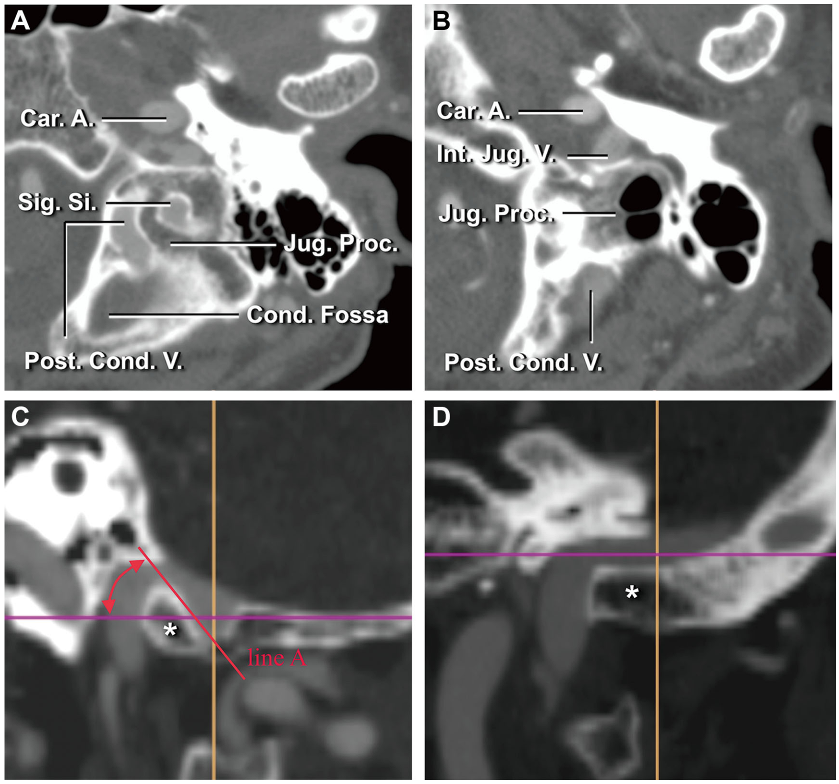


FIGURE 1. *Radiological examination.* **A**, *The sigmoid sinus protruding inferiorly into the jugular process.* **B**, *The jugular process is pneumatized.* **C**, *We measured the angle between the axial plane (purple line) and the line drawn through the bottom of the jugular foramen and sigmoid sinus (line A, red) on an arbitrary sagittal plane. This figure represents the angle as* $>45°$. *White asterisk indicates the jugular process.* **D**, *This figure represents that the angle between the axial plane and line A is* $\leq 45°$. *White asterisk indicates the jugular process. A., artery; Car., carotid; Cond., condylar; Int., internal; Jug., jugular; Post., posterior; Proc., process; Si., sinus; Sig., sigmoid; V., vein.*

red or blue silicone rubber (Dow Corning, Midland, Michigan), Thinner 200 (Dow Corning), and an RTV catalyst (Dow Corning), and then dissected under 3 to 40× magnification. Bone dissection was done with a Midas Rex drill (Medtronic Inc, Dublin, Ireland).

Radiological Analysis

Thirty-one adult patients from the Department of Neurosurgery at Kyushu University Hospital who had undergone 3-dimensional (3D) computed tomography angiography (3D-CTA) to evaluate unruptured aneurysm and shown no mass-effect intracranial lesions were included in this study. This radiological study of the patients' Digital Imaging and Communications in Medicine (DICOM) data was approved by the Ethics Committee of Kyushu University Hospital (#27-311). The radiological analysis was performed by a trained neurosurgeon (S.M.) and a head and neck surgeon (N.K.). The study group included 8 men and 23 women, with a mean age of 63.5 ± 11.2 yr (range 40-85 yr).

CT images slices 1 mm thick were acquired on a Toshiba Aquilion 64 system (Toshiba Medical Systems, Otawara, Japan; $n = 20$) or a 320-slice Toshiba Aquilion One system (Toshiba Medical Systems; $n = 11$). Images were saved as DICOM files. DICOM data were reconstructed and analyzed using OsiriX imaging software (Version 5.9 64-bit; Pixmeo SARL, Bernex, Switzerland). All images were observed using 3D multiplanar reconstruction (MPR), and the axial planes were confirmed to be parallel to the orbitomeatal line. All images were carefully reviewed, and the morphological features, including the sigmoid sinus protruding into the jugular process (Figure 1A) and the pneumatized process (Figure 1B), were examined.

Before measurement, we assessed the dominance of the sigmoid sinuses, using the sinus diameter.[28] Images were viewed using 3D MPR oriented to the coronal and sagittal axes. The bottoms of the jugular bulb and sigmoid sinus were detected. OsiriX automatically reconstructed the oblique sagittal plane passing through these two points, which we used to draw a line (line A in Figure 1C) connecting them. We measured the acute angle between this line and the axial plane to estimate the difficulty of drilling the jugular process from the posterior or lateral direction. These angles were arbitrarily divided into 2 groups: $>45°$ (Figure 1C) or $\leq 45°$ (Figure 1D).

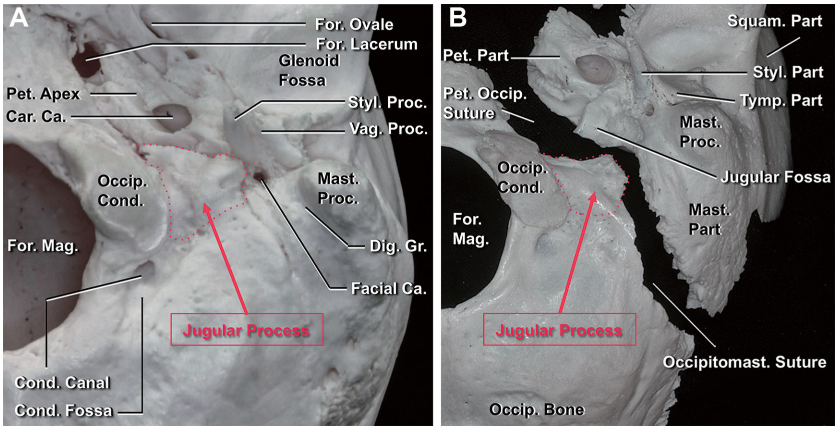


FIGURE 2. *Bone anatomy of the jugular process.* **A** *and* **B**, *The dotted red line shows the jugular process in a whole dry skull* **A** *and a disarticulated skull* **B**. *Ca., canal; Car., carotid; Cond., condyle or condylar; Dig., digastric; For., foramen; Gr., groove; Mast., mastoid; Occip., occipital; Occipitomast., occipitomastoid; Pet., petrous; Proc., process; Squam., squamous; Styl., styloid; Tymp., tympanic; Vag., vaginal.*

Statistics

The characteristics of jugular processes with an angle of >45° were compared with those with an angle of ≤45°, using a chi-squared test. Analyses were conducted in JMP Pro version 12 (SAS Institute, Cary, North Carolina). All tests were 2-tailed, and $P < .05$ was taken to indicate statistical significance. Data are presented as mean ± standard deviation (SD). Next, a logistic regression analysis was performed. Variables associated with a steeper jugular process with a P value of ≤.2 in the univariate analysis were included in stepwise binary logistic regression modeling. All odds ratios in the multivariate analysis reflect the probability of having a steeper jugular process, ie, the superior surface of a jugular process with an angle of >45°. Likelihood ratio tests were used to evaluate the significance of the variables.

RESULTS

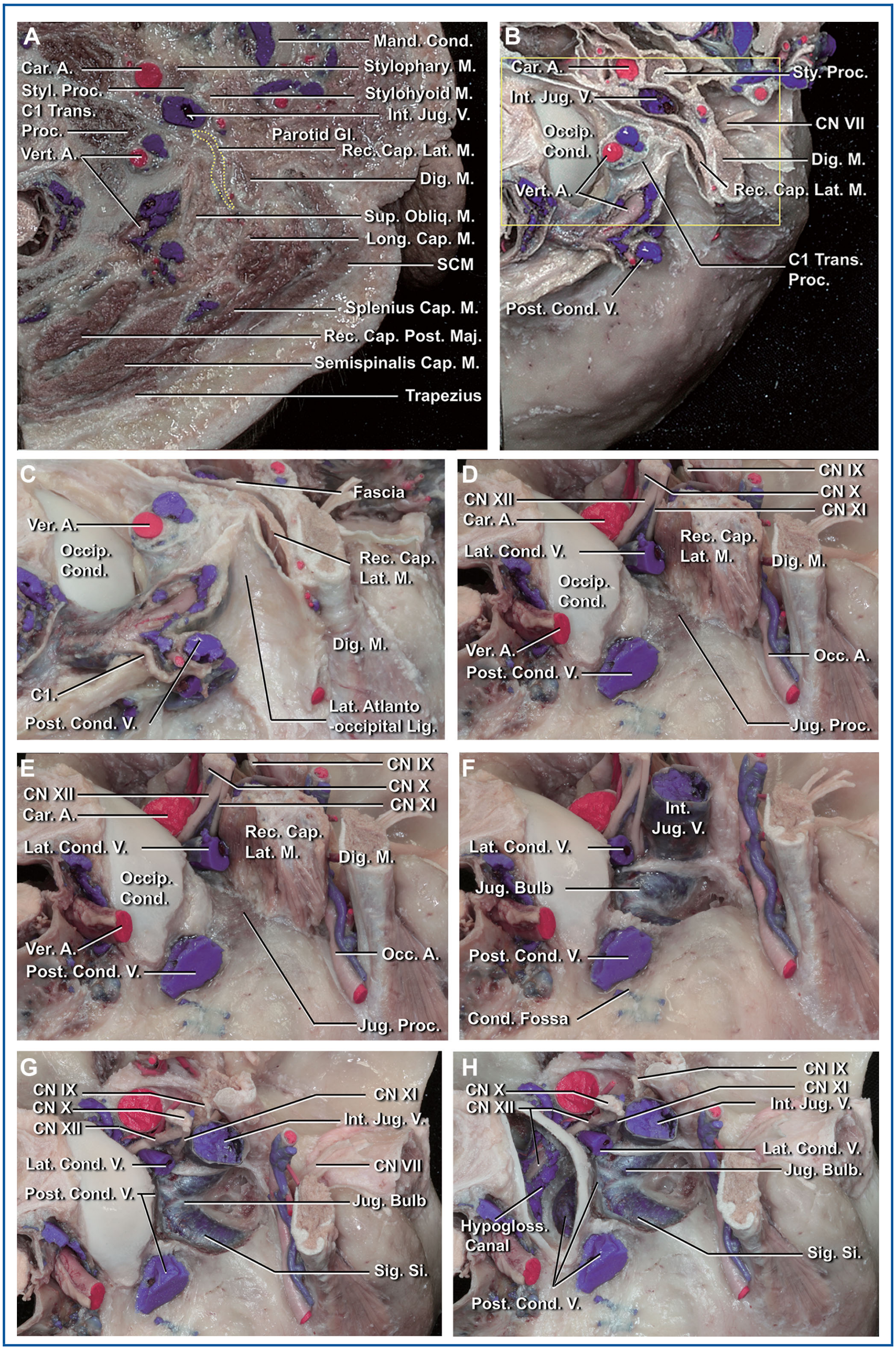
Anatomy From the Inferior Direction

The jugular process, which is a part of the occipital bone, is located between the mastoid process of the temporal bone and the condyle of the occipital bone (Figure 2). The jugular process forms the posterior margin of the jugular foramen and extends laterally from the posterior half of the occipital condyle. The occipitomastoid suture passes between the lateral edge of the jugular process and the medial edge of the digastric groove, the orifice of the facial canal, and the styloid process (Figure 2).

First, we used cadavers amputated at the level of C1 to examine the detailed anatomy of the jugular process and surrounding structures from the inferior direction. The rectus capitis lateralis is the only muscle that attaches to the jugular process (Figures 3A-3C). This muscle is located just anterior to the lateral atlanto-occipital ligament (Figure 3C),[29] and is shown with a dotted yellow line in Figure 3A. Removing the muscles attaching to the occipital bone, skin, parotid gland, and fat tissue, except for the styloid apparatus, digastric muscle, and rectus capitis lateralis, clearly exposes the structures around the jugular process (Figure 3B). The rectus capitis lateralis is inserted into the inferior surface of the jugular process along the anterolateral edge of this process (Figures 3C-3D). The lateral condylar vein runs between the rectus capitis lateralis and the occipital condyle (Figure 3D). Detaching the rectus capitis lateralis exposes the posterior surface of the internal jugular vein just below the orifice of the jugular foramen (Figures 3D and 3E). Removing the jugular process exposes the inferior and posterior surfaces of the jugular bulb (Figures 3E and 3F). Drilling the occipital condyle and leaving the surrounding cortical bone reveal the relationship between the jugular bulb and its associated structures. The posterior condylar vein passes into the condylar canal and empties into the jugular bulb from the posteromedial direction. The lateral condylar vein passes into the anterior confluent, into which the venous plexus in the hypoglossal canal empties (Figures 3G and 3H). The hypoglossal canal passes superior to the occipital condyle.

Anatomy From the Lateral Direction

Next, we examined the jugular process from the lateral aspect. Removal of the sternocleidomastoid muscle exposes the digastric and splenius capitis muscles (Figure 4A). The digastric muscle laterally covers the rectus capitis lateralis and the jugular process. Removal of the fat pad exposes the transverse process of C1 and the attachment of the rectus capitis lateralis to this process. Dividing the digastric muscle and translocating the parotid gland anteriorly reveals the relationship between the facial nerve, digastric muscle, rectus capitis lateralis, and internal jugular vein (Figure 4B). The digastric muscle attaches to the digastric groove, which is located just medial to the mastoid tip and posterior to the facial nerve. Thus, removal of the mastoid tip and digastric muscle


A
Mand. Cond.
Car. A.
Stylophary. M.
Styl. Proc.
Stylohyoid M.
C1 Trans. Proc.
Int. Jug. V.
Parotid Gl.
Vert. A.
Rec. Cap. Lat. M.
Dig. M.
Sup. Obliq. M.
Long. Cap. M.
SCM
Splenius Cap. M.
Rec. Cap. Post. Maj.
Semispinalis Cap. M.
Trapezius
B
Car. A.
Sty. Proc.
Int. Jug. V.
CN VII
Occip. Cond.
Dig. M.
Vert. A.
Rec. Cap. Lat. M.
C1 Trans. Proc.
Post. Cond. V.
C
Fascia
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D
CN IX
CN X
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CN XI
Car. A.
Rec. Cap. Lat. M.
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Dig. M.
Occip. Cond.
Ver. A.
Occ. A.
Post. Cond. V.
Jug. Proc.
E
CN IX
CN X
CN XII
CN XI
Car. A.
Rec. Cap. Lat. M.
Lat. Cond. V.
Dig. M.
Occip. Cond.
Ver. A.
Occ. A.
Post. Cond. V.
Jug. Proc.
F
Int. Jug. V.
Lat. Cond. V.
Jug. Bulb
Post. Cond. V.
Cond. Fossa
G
CN IX
CN XI
CN X
Int. Jug. V.
CN XII
Lat. Cond. V.
CN VII
Post. Cond. V.
Jug. Bulb
Sig. Si.
H
CN IX
CN X
CN XI
CN XII
Int. Jug. V.
Lat. Cond. V.
Jug. Bulb.
Hypogloss. Canal
Sig. Si.
Post. Cond. V.

FIGURE 3. *Step-by-step dissection from the inferior view.* **A**, *Inferior view of the dissected cadaver.* **B**, *View after the removal of skin, a group of occipital muscles, fat tissue, and the parotid gland, leaving the fascia and neurovascular structures.* **C**, *Enlarged view of the area outlined with a yellow line in* **B**. **D**, *Removal of the lateral atlanto-occipital ligament exposes the rectus capitis lateralis.* **E**, *Removal of the rectus capitis lateralis can expose the whole inferior surface of the jugular process.* **F**, *Oblique view after drilling of the jugular process.* **G**, *Inferior view after drilling of the jugular process.* **H**, *Inferior view after the removal of the occipital condyle, leaving the cortical lateral surface of the condyle. A., artery; Cap., capitis; Car., carotid; Cond., condyle or condylar; CN, cranial nerve; Dig., digastric; Gl., gland; Hypogloss., hypoglossus; Int., internal; Jug., jugular; Lat., lateralis; Lig., ligament; Long., longissimus; M., muscle; Maj., major; Mand., mandibular; Occip., occipital; Obliq., oblique; Post., posterior; Proc., process; Rec., rectus; SCM, sternocleidomastoid; Si., sinus; Sig., sigmoid; Styl., styloid; Stlyohyo., stylohyoid; Stylophary., stylopharyngeal; Sup., superior; Trans., transverse; V., vein; Vert., vertebral.*

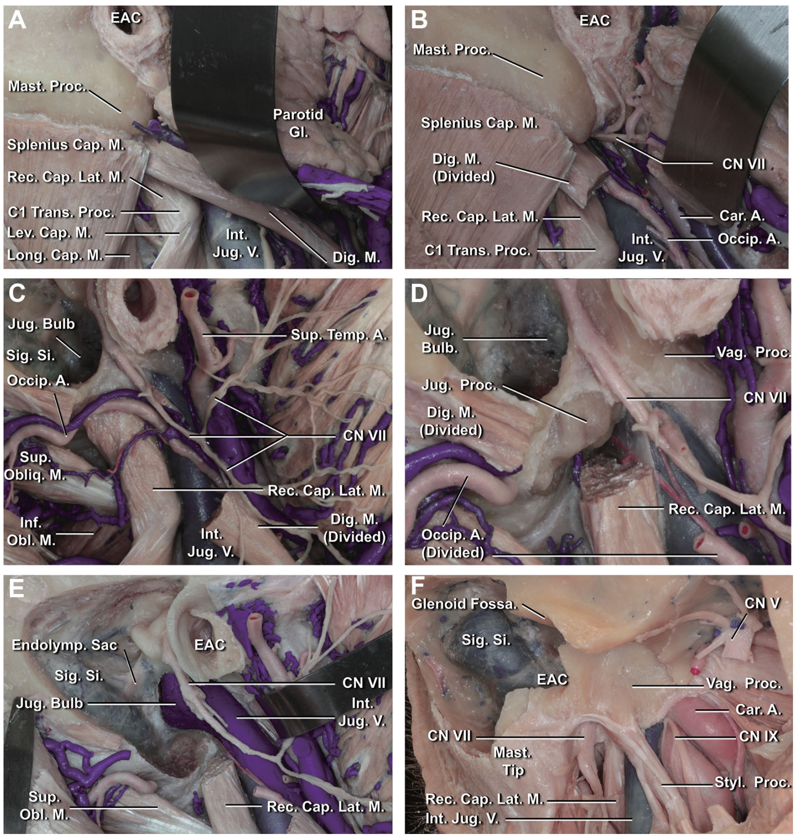

FIGURE 4. *Step-by-step dissection from the lateral view.* **A**, *Lateral view after the removal of fat tissue.* **B**, *Dividing the digastric muscle and retracting the parotid gland anteriorly reveals the structures in the retromandibular space.* **C**, *The mastoidectomy was completed, and the parotid gland, mastoid tip, sternocleidomastoid muscle, and longissimus capitis muscle were removed. The superolateral surface of the jugular bulb was exposed.* **D**, *The insertion of the rectus capitis lateralis was removed to expose the inferior surface of the jugular process.* **E**, *The removal of the jugular process and rectus capitis lateralis exposed the inferoposterior surface of the jugular bulb.* **F**, *The relationship between the rectus capitis lateralis, the internal jugular vein, and vaginal process of the tympanic bone was exposed. A., artery; Car., carotid; Cap., capitis; CN, cranial nerve; Dig., digastric; EAC, external auditory canal; Endolymp., endolymphatic; Gl., gland; Inf., inferior; Int., internal; Jug., jugular; Lat., lateralis; Lev., levator; Long., longissimus; M., muscle; Mast., mastoid; Obliq., Oblique; Occip., occipital; Proc., process; Rec., rectus; Si., sinus; Sig., sigmoid; Styl., styloid; Sup., superior; Temp., temporal; Trans., transverse; V., vein; Vag., vaginal.*

exposes the insertion of the rectus capitis lateralis into the inferior surface of the jugular process. The occipital artery runs between the rectus capitis lateralis and the digastric muscles (Figures 4C and 4D). Even from the lateral direction, if surgeons remove the jugular process, the jugular bulb can be exposed all the way to its inferoposterior surface (Figure 4E). Just below the jugular foramen, the internal jugular vein is descending just posterior to the vaginal process of the tympanic part of the temporal bone and just anterior to the jugular process (Figures 4D and 4F).

Anatomy From the Posterior Direction

From the posterior aspect, reflecting the suboccipital muscles, which attach to the occipital bone, expose the condylar fossa, posterior condylar vein and rectus capitis lateralis (Figures 5A-5C). Removal of the jugular process can clearly expose the posteroinferior surface of the jugular bulb (Figures 5D and 5E). Removal of the posterior half of the occipital condyle provides access not to the jugular bulb but to the hypoglossal canal and posterior condylar canal (Figure 5D). Additional removal of the jugular process can open the jugular foramen (Figure 5E). To prove that removal of the jugular process is a main step to access the jugular foramen, we drill the jugular process leaving the occipital condyle. We then verified that it is enough to open the jugular foramen (Figures 5F and 5G). However, to gain a wide surgical field for the removal of the pathogen, drilling the lateral part of the occipital condyle should be considered. The rectus capitis lateralis attaches to the anterolateral edge of the transverse process of C1 and covers the posterior wall of the internal jugular vein just below the jugular foramen. Removal of the rectus capitis lateralis thus exposes the posterior surface of the internal jugular vein (Figures 5E and 5G).

Radiographic Study

We found bulb-like structures on the sigmoid sinus protruding into the jugular process inferiorly in 9 of the 62 sides (14.5%), and the jugular process was pneumatized in 5 of the 62 sides (8.1%; Figures 1A and 1B). In our cadaveric dissections, we found that the difficulty of drilling the jugular process varied. Thus, we examined the angle between line A and the axial plane (Figure 1C). This angle was $>45^\circ$ in 29 of the 62 sides (46.8%). A chi-squared test revealed that the sides with an angle $>45^\circ$ were significantly more likely to have a sigmoid sinus that protruded into the jugular process, a bulb-type jugular bulb, and a jugular bulb that reached the external auditory canal (EAC; $P < .01$, $= .04$, and $< .01$, respectively; Table 1). Next, a logistic regression analysis was performed. Variables that were associated with a steep angle of the superior surface of the jugular process with a P-value $\leq .2$ in the univariate analysis were included in stepwise binary logistic regression modeling. This multivariate analysis showed that an angle of $>45^\circ$ between line A and the axial plane was significantly associated with the right side of the jugular process and a bulb-type jugular bulb (Asterisks in Table 2).

DISCUSSION

Resection of the jugular process is the one of the most critical procedures for accessing and opening the jugular foramen. Surgeons should become familiar with this process and its surrounding area including the ligaments, venous networks, and bony structures.

Understanding the ligaments related to the jugular process is important for safe and accurate dissections to avoid injury of the surrounding structures. The rectus capitis lateralis is considered one of the most important landmarks for accessing the jugular foramen.[5,27] Our study found that a thick ligament is positioned posterior to this muscle. Tubbs et al[29] revealed that the lateral atlanto-occipital ligament originates from the anterolateral aspect of the transverse process of the atlas and is inserted into the jugular process. It was clearly different from the anterior atlanto-occipital membrane.[29] Furthermore, in our study, we found a fascia that posteriorly covered the internal jugular vein and formed the posterior wall of the carotid sheath, the rectus capitis lateralis posterior to this fascia, and the thick ligament that posteriorly covered the rectus capitis lateralis, which we have identified as the lateral atlanto-occipital ligament. This improved understanding of the order in which the layers attach to the jugular process indicates that it may be helpful to access the jugular foramen from the posterior direction. The occipitomastoid suture passes between the lateral edge of the jugular process and the medial edges of the digastric groove and styloid process, to terminate at the jugular foramen. The fascia identified between the digastric muscle and rectus capitis lateralis is firmly attached to this suture. The facial nerve courses just lateral to this fascia, so care should be taken to not extend the bone drilling laterally or over the suture, as well as to avoid unintentionally breaking this fascia.

Posterior and lateral approaches to the jugular foramen, including the transjugular, juxtacondylar, infralabyrinthine, and POTS approaches, include an important step involving drilling out the jugular process to open the jugular foramen.[5] The process is surrounded by an abundant venous network. Thus, it is important to understand the relationship between the jugular process and the surrounding venous structures, especially 2 condylar emissary veins. The lateral condylar vein is given off from the anterior condylar confluence coursing along the lateral surface of the occipital condyle, which is just inferomedial to the jugular process and drains into the vertebral venous plexus.[30] The posterior condylar vein courses into the posterior condylar canal and connects the suboccipital venous plexus with the sigmoid sinus or jugular bulb.[31] Generally, drilling the occipital bone lateral to the posterior condylar vein allow surgeons to access the jugular foramen without damaging the lateral rim of the foramen magnum. The lateral and posterior condylar veins occasionally communicate with each other through a bony channel.[30,32] Thus, preoperative examination of the relationship between the venous plexus and the jugular process is necessary to avoid unnecessary bleeding during surgery.[32-35]

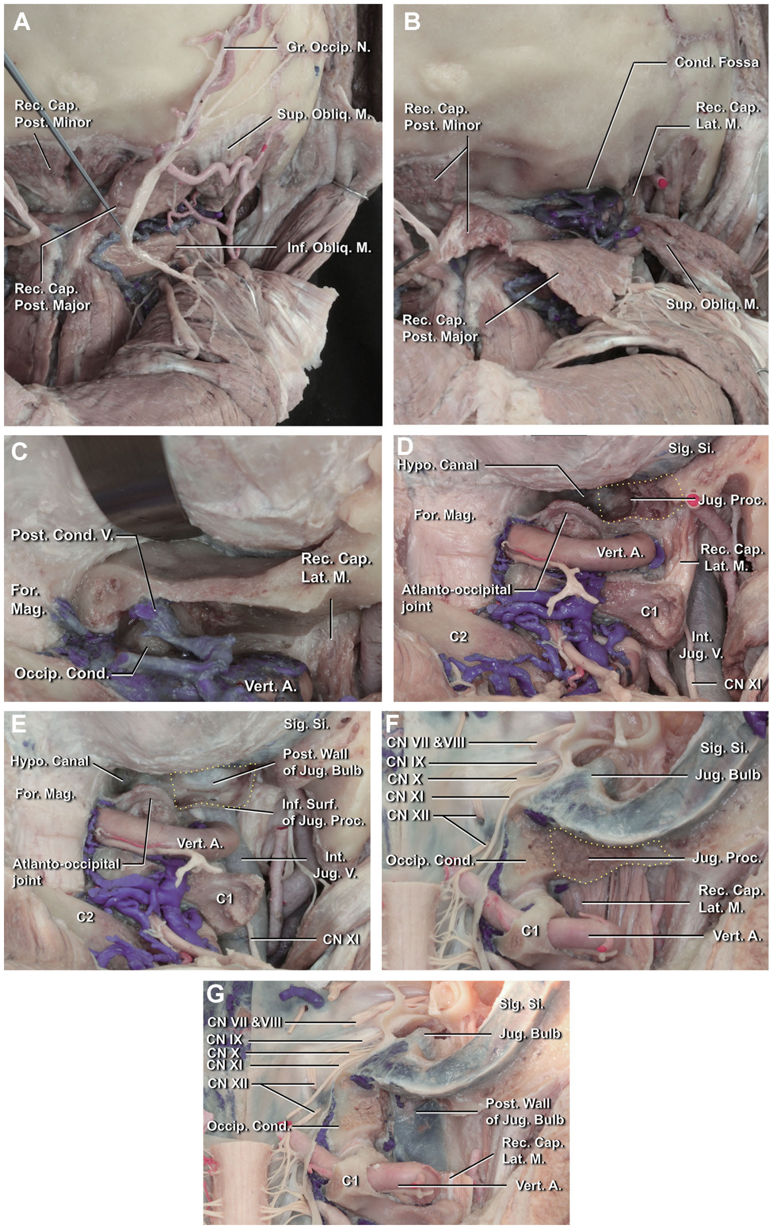

FIGURE 5. *Step-by-step dissection from the posterior. The jugular process is indicated by the dotted yellow line (panels* **A**, **C**, *and* **D***).* **A**, *Muscles in the posterior neck were exposed.* **B**, *Reflecting the muscles exposes the foramen magnum, condylar fossa and rectus capitis lateralis.* **C**, *Relationship between the occipital condyle, posterior condylar vein and rectus capitis lateralis inserting the inferior surface of the jugular process is shown.* **D**, *Removal of the occipital condyle exposes the hypoglossal canal, not the jugular foramen.* **E**, *Removal of the jugular process, leaving the inferior surface of the jugular process, exposes the inferoposterior surface of the jugular bulb.* **F**, *The view of the jugular process from the posterior before drilling the jugular process.* **G**, *Removal of the jugular process leaving the occipital dondyle exposes the inferoposterior surface of the jugular bulb. A., artery; Cap., capitis; Cond., condyle; CN, cranial nerve; For., foramen; Gr., greater; Hypo., hypoglossal; Inf., inferior; Int., internal; Jug., jugular; Lat., lateralis; M., muscle; Mag., magnum; N., nerve; Obliq., oblique; Occip., occipital; Post., posterior; Proc., process; Rec., rectus; Si., sinus; Sig., sigmoid; Surf., surface; Sup., superior; V., Vein; Vert., vertebral.*

TABLE 1. Chi-Square Test on the Angle of Superior Surface of the Jugular Process

	Angle between line A and axial plane				
	≤45° (n = 33)		>45° (n = 29)		
Characteristic	No. of sides (n)	%	No. of sides (n)	%	*P*
Side					
R	13	39.4%	18	62.1%	.07
L	20	60.6%	11	37.9%	
Bulb-type jugular bulb	10	30.3%	23	79.3%	< .01
Protrusion into jugular process	2	6.1%	7	24.1%	.04
Dominancy of sigmoid sinus	13	39.4%	15	51.7%	.33
Jugular bulb reaching IAM	6	18.2%	8	27.6%	.38
Jugular bulb reaching EAC	18	54.5%	28	96.6%	< .01
Pneumatized jugular process	3	9.1%	2	6.9%	.75

TABLE 2. Logistic Regression Analysis on Variables Affects the Steep Angle of the Superior Surface of the Jugular Process

Variable	Odds ratio	95% Confidence interval	*P*
Side (right vs left)	4.39	1.19-20.05	.026*
Bulb-type jugular bulb	5.25	1.25-26.42	.023*
Protrusion into jugular process	3.78	0.61-37.26	.162
Jugular bulb reaching EAC	6.98	0.84-152.06	.073

In our radiological study, we found that the inferior edge of the sigmoid sinus occasionally forms bulb-like structures that protrude into the jugular process (observed in 9 of the 62 sides). Furthermore, although in some cases the jugular bulb slopes into the internal jugular vein without forming bulb-like structures (Figure 1D), we observed bulb-type jugular bulbs in 33 of 62 sides in our radiological examination. Thus, both slope- and bulb-type versions of both the sigmoid sinus and jugular bulb exist. Interestingly, our radiological study also revealed that the jugular process can be pneumatized (5 of 62 sides), despite the fact that the jugular process is lineated by the occipitomastoid suture.

When drilling the jugular process, if the sigmoid sinus is of a bulb type, care should be taken to avoid damaging the bulb-type structure protruding into the jugular process. If the jugular process is pneumatized, care should be taken to avoid cerebrospinal fluid leakage and infection through air cells in the mastoid sinus after drilling. The superior surface of the jugular process on the right side and jugular processes with bulb-type jugular bulbs are likely to have a steep angle (>45°) between line A and the axial plane. Ichijo et al[36,37] examined the height and size of the jugular bulb using high-resolution CT and concluded that the right sigmoid sinus is likely to be larger, and the right jugular bulb to be higher. Given these facts, the surgical procedure utilized on the right side requires greater attention. However, veins and jugular processes vary greatly among individuals, as shown in this study. Thus, to prevent surgical complications, it is most important to obtain a thin-sliced CT image and to examine the patient's precise morphological features of these structures preoperatively. The morphological features, which include the size of the jugular process and its relationship to the lateral and posterior condylar veins should be furthered examined in future research.

Limitations

This study has the following minor limitations. First, we used the data of 3D-CTA, which was performed to evaluate unruptured aneurysms. Thusly, it may lead to a patient selection bias. In addition, radiological analysis was performed only by a trained neurosurgeon and a head and neck surgeon, not by a radiologist. However, these factors do not seem to spoil our conclusion.

CONCLUSION

The jugular process is one of the most important landmarks for accessing the jugular foramen (Figure 6). A profound understanding of the relationship between the jugular process and its related structures, as well as the morphological features of this process, is needed for successful completion of the challenging approach to the jugular foramen.

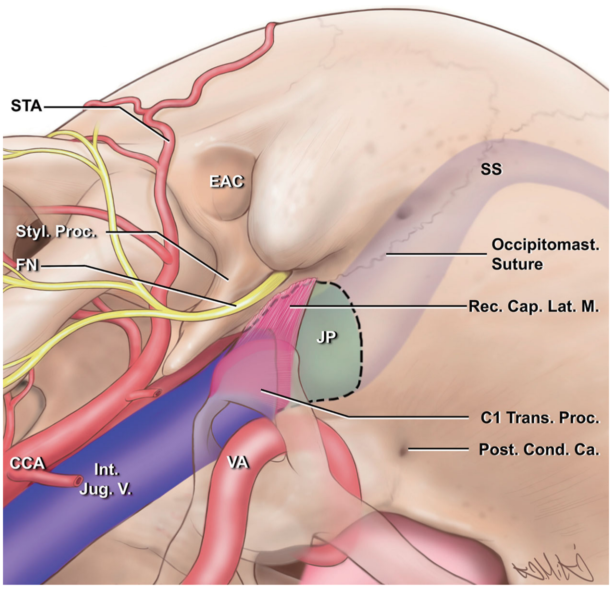

FIGURE 6. *Overview of the jugular process. Green area surrounded by black interrupted line indicates the jugular process, which forms the posterior edge of the jugular foramen and where the rectus capitis lateralis attached covering the posterior aspect of the internal jugular vein. Ca., canal; Cap., capitis; CCA, common carotid artery; Cond., condylar; EAC, external auditory canal; Int., internal; JP, jugular process; Jug., jugular; Lat., lateralis; M., muscle; Occipitomast., occipitomastoid; Post., posterior; Rec., rectus; STA, superficial temporal artery; SS, sigmoid sinus; Styl., styloid; Trans., transverse; V., vein; VA, vertebral artery.*

Disclosures

In this study, cadaveric dissections were performed by first and second authors in the late Dr Albert L. Rhoton, Jr's laboratory at the University of Florida and the use of these pictures are permitted by The Rhoton Collection®. This work was supported by the University of Florida Foundation. The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

The authors of this paper provide a beautifully illustrated depiction of the anatomy involving the jugular process and jugular foramen region. They present its usefulness as a landmark when addressing pathology in this region. The anatomical dissections are excellent and detailed and will serve as a nice reference when reviewing the anatomy of this region when planning a surgical approach.

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The authors present a well-illustrated study of the jugular process. Herein they describe morphologic features of this bony landmark in both cadaveric specimens and using radiographic imaging. In particular they measure the angle of the superior surface of this bony protuberance on CT and correlate acute angles with more difficulty drilling in their cadaveric specimens. The provided illustrations clearly demonstrate the anatomy as it would be seen in a step-wise approach to the jugular process.

The illustrations and descriptions in this text provide a useful addition to the growing body of literature on jugular foramen morphology and will provide a valuable reference for surgeons approaching this region. Clinicians will likely find the emphasis on preoperative assessment of the jugular process with thin cut CT imaging to be beneficial in preparing for their case in terms of pneumatization of the jugular process or protrusion of the sigmoid sinus into the jugular process. A detailed understanding of this anatomy is key to successful surgery in this area and to minimizing the likelihood of complications.

Angela M. Richardson
Ricardo J. Komotar
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The authors present a complete anatomical research about the jugular processes and related ligaments. A cadaveric dissection study included 5 specimens to demonstrate the relationship of the jugular processes to surrounding anatomical structures, and a radiological study included computed tomography data from 31 heads (62 sides) to exam the morphological features of this process. Their images are organized in step-by-step panels that help the understanding of the complex anatomy of this region, and the results show the likelihood of having the jugular process pneumatized or the sigmoid sinus protruding inside this region. Also, the authors related the difficulty of drilling the jugular process to its position in relation to the axial plane, an angle that can be measured preoperatively in computed tomography.

Deep anatomical knowledge is always paramount for surgeons, leading to safer and more precise surgeries. This small part of the occipital bone forms the posteroinferior border of the jugular foramen, and its resections is crucial for opening this foramen. We congratulate the authors for better clarifying in detail the anatomy of this region.

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The authors summarize in exquisite detail the microsurgical anatomy of the jugular process as an anatomical landmark to access the jugular foramen. This anatomical study with detailed cadaveric dissections and corresponding CT images is very well done, and provides a useful overview for the surgeon addressing lesions in this complex area of anatomy.

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