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Original Article

Preoperative Localization of the Carotid Bifurcation for Cervical Carotid Exposure Using the Mastoid-Hyoid Line

Abstract

Background and Importance: The location of the carotid bifurcation (CB) is highly variable, which makes precise exposure of the cervical carotid artery difficult, especially in transverse incisions. The method for preoperative localization of the CB is not well established. We used the distance from the mastoid-hyoid (M-H) line to the CB, measured preoperatively with computed tomography angiography, to localize the location of the transverse skin incision. We describe and evaluate the accuracy of a method for preoperative localization of the CB for cervical carotid exposure. **Methods:** The researchers retrospectively evaluated 16 patients with aneurysms arising from the internal carotid artery (ICA) who had received cervical carotid exposure using the localization method of incision and were retrospectively evaluated from February 2018 to November 2019. The method of measurement and localization of the skin incision are described, and two illustrative cases are demonstrated. **Results:** Saccular aneurysms of the ophthalmic (C2) segment and communicating (C1) segment of the ICA were found in 8 and 8 patients, respectively. Nine patients had left-sided exposure, and 7 patients had right-sided exposure. The mean distance from the M-H line to the CB was 2.1 cm (range 0.5–3.5 cm). The accuracy of this method was 93.8%. No paralysis of the depressor anguli oris or the depressor labii inferioris was found postoperatively. **Conclusion:** The distance from the M-H line to the CB can be used to estimate transverse skin incisions for cervical carotid exposure.

Keywords: *Carotid bifurcation, cervical carotid exposure, mastoid-hyoid line, preoperative localization*

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Introduction

Surgical exposure of the cervical carotid artery for proximal control may be necessary for paraclinoid internal carotid artery (ICA) aneurysms and some posterior communicating artery aneurysms, especially in cases of rupture and in large aneurysms.[1-4] For high-flow bypass and carotid endarterectomy (CEA), precise exposure of the carotid arteries is very important to access the external carotid and ICAs, respectively. Conventional incisions paralleling the medial border of the sternomastoid muscle may provide a wider corridor. However, the transverse incision (along the skin crease) allows a good cosmetic result, so the precise localization of the carotid bifurcation (CB) for transverse incisions is necessary.[1,5]

We defined a line from two palpable and fixed bony landmarks, the mastoid tip and lateral corner of the hyoid bone, called the mastoid-hyoid (M-H) line, to localize the CB. As an alternative to conventional angiography, we recently used computed tomographic angiography (CTA) for noninvasive imaging and the detection of intracranial aneurysms, which allowed good information about the relationship between bone and vascular structures. Preoperative CTA was analyzed by the simple measurement of the location of the CB using the distance from the M-H line to the CB. The preoperative CTA data were used to localize the CB and the transverse incision using the palpable landmarks. The details of the measurement and the accuracy of this method are described and evaluated.

Methods

Sixteen patients with aneurysms arising from the ICA were retrospectively evaluated between February 2018 and November 2019 following cervical carotid exposure

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using CB localization. The indications for cervical carotid exposure were unavailable space for proximal control of the intracranial ICA, a calcified C2 segment of the ICA, and the need for retrograde suction decompression. The method of measurement and localization of the skin incision are described, and two illustrative cases are demonstrated.

Methods of preoperative localization of the carotid bifurcation

Measurement of preoperative computed tomographic angiography

Using the sagittal view of the maximal intensity projection (MIP) image, the ipsilateral mastoid tip [Figure 1a] and ipsilateral side of the lateral corner of the ipsilateral hyoid bone (the junction between the body and greater horn of the hyoid bone) [Figure 1b] were identified and marked on the computer screen. The ipsilateral common carotid artery (CCA) and CB were confirmed on the same image [Figure 1c]. In this image, the M-H line was created, and the line of the CCA (C line) was made superiorly until it crossed the M-H line. The distance along the C line from the CB to the intersection point of the M-H line and C line was measured as A cm [Figure 1c and d].

Localization of the carotid bifurcation and skin incision on the patient's neck

The ipsilateral mastoid tip (just medial to the ear lobe) and lateral corner of the hyoid bone (superolateral to the laryngeal protuberance) were palpated. The M-H line was created. The C line was made by palpating the pulse of the CCA. The location of the transverse skin incision was A cm below the M-H line along the C line. For cosmetic reasons, the nearest skin crease was used for the incision because retraction had to be able to compensate for a few centimeters of deviation [Figure 1e].

In cases where the planned skin incision was <2 cm close to the angle of the mandible, the skin incision was moved 2 cm below the angle of the mandible to avoid the marginal mandibular branch of the facial nerve.

Accuracy of the method

The accuracy of the method was assessed by the intraoperative location of the CB and center of the operative field. A straight line from the both sides of the skin incision was defined as the center of the operative field. A distance between the CB and the center of the operative field of <1 cm were considered to be accurate.

Postoperative paralysis of the depressor anguli oris and the depressor labii inferioris

During the postoperative period, inversion or flattening of the ipsilateral lip and an asymmetrical smile with elevation of the lower lip due to injury of the marginal mandibular branch of the facial nerve were assessed.

Results

Eight aneurysms of the ophthalmic (C2) segment of the ICA and eight aneurysms of the communicating (C1)

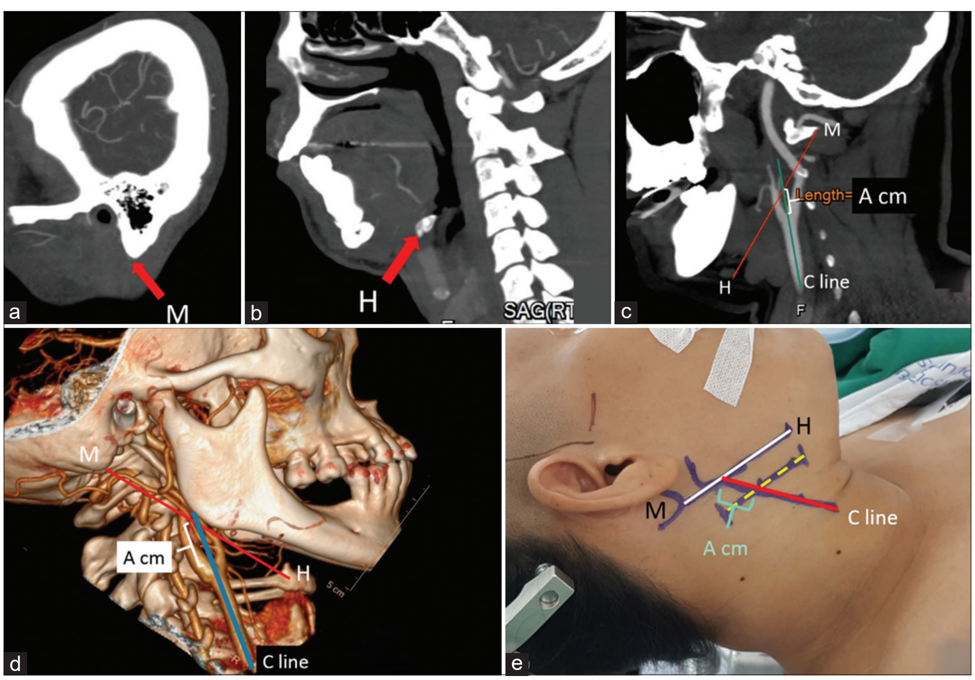

Figure 1: (a and b) The mastoid tip (m) and lateral corner of the hyoid bone (h) (c and d) The straight line (red line) was created from M to H (M-H line). Another line along the center of the CCA was created as the C line (green line). The distance from the crossing point (red and green line) and the CB was measured as A cm. (e) The mastoid tip, lateral corner of the hyoid bone and CCA were identified by palpation, and the M-H line and C line were created. The location of the CB was located on the C line below the crossing point of the M-H line and C line A cm. The skin incision (dashed line) was localized. M-H – Mastoid-hyoid; CB – Carotid bifurcation; CCA – Common carotid artery

segment of the ICA were found. There were nine cases of left-sided exposure and 7 of right-sided exposure. The mean distance from the M-H line to the CB was 2.1 cm (0.5-3.5 cm). The skin incision was moved to 2 cm below the angle of the mandible in six cases (37.5%). The accuracy of this method was 93.8%. In one case, CB was not found in the center of the operative field because of the missed localization of the hyoid bone. No paralysis of the depressor anguli oris or the depressor labii inferioris was detected postoperatively [Table 1].

Illustrative cases

Illustrative case 1

A 24-year-old male [case no. 2 in Table 1 and Figure 2] suffered from severe headache. Diffuse subarachnoid hemorrhage and a 6-mm left ICA-posterior communicating artery aneurysm with posterolateral projection were detected by CTA. The proximal neck of the aneurysm was close to the anterior clinoid process. The distance between the ipsilateral M-H line and left CB was measured as 3.4 cm on the lateral MIP image [Figure 2a and b]. With a supine position and a 40° head rotation to the right side, the left mastoid tip and left lateral corner of the hyoid bone were palpated, and then, the M-H line was created. The column of the left CCA pulse was palpated, and then, the C line was made and extended superiorly until it crossed the M-H line. The skin incision along the skin crease was located 3.4 cm below the crossing point [Figure 2c]. After the exposure of the cervical carotid artery, the CB was located 0.8 cm above the center of the operative field [Figure 2d].

Illustrative case 2

A 45-year-old female [case No. 8 in Table 1] suffered from acute altered consciousness. Diffuse subarachnoid hemorrhage and a 6-mm right ICA-superior hypophyseal artery aneurysm with inferomedial projection were detected

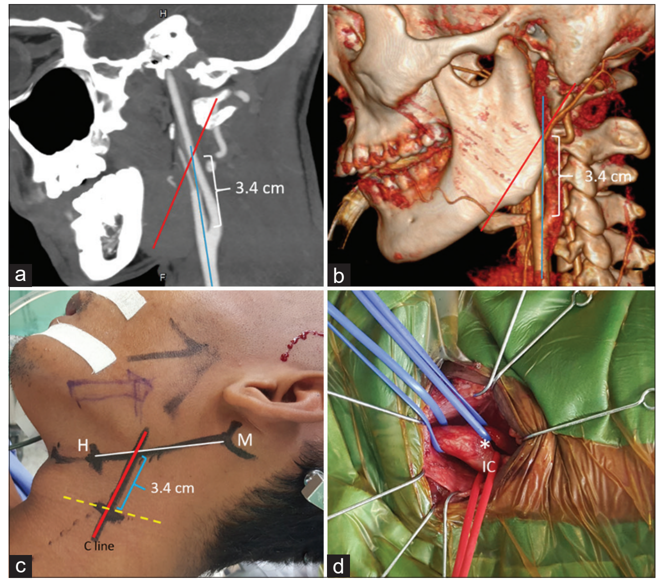

Figure 2: Illustrative case 1 [case no. 2 in Table 1] (a) Sagittal view of the MIP image demonstrates the M-H line (red line), C line (blue line) and location of the CB from the M-H line (3.4 cm below the M-H line). (b) The method of measurement was demonstrated on three-dimensional computed tomographic angiography. (c) On the patient's neck, the M-H line (white line) and C line (red line) were identified by palpation. The skin incision (dashed line) was located 3.4 cm from the M-H line. (d) The CB (asterisk) was located 0.8 cm above the center of the operative field. M-H – Mastoid-hyoid; CB – Carotid bifurcation

Table 1: Characteristics of the patients who underwent cervical carotid exposure and accuracy of the method

Aneurysm location	Side of exposure	Distance between M-H line and CB on preoperative CTA (cm)	The exact skin incision was changed to 2 cm below AOM	Accuracy of intraoperative finding	Postoperative paralysis of DAO and DLI
IC-PC	Left	4	−	+	−
IC-PC	Left	3.4	−	+	−
IC-SHA	Left	0.5	+	+	−
IC-PC	Right	0.9	+	+	−
IC-PC	Left	1.3	+	+	−
IC-SHA	Right	1.9	−	+	−
IC-OphA	Left	2.1	−	+	−
IC-SHA	Right	1.7	+	+	−
IC-SHA	Left	3.5	−	+	−
IC-SHA	Left	2.8	−	+	−
IC-PC	Left	2.7	−	+	−
IC-OphA	Right	2.3	−	+	−
IC-PC	Right	1.1	+	+	−
IC-PC	Right	2	−	−	−
IC-AchA	Left	0.9	+	+	−
Dorsal C2 segment	Right	3.2	−	+	−

+ – Yes; − – No; AchA – Anterior choroidal artery; AOM – Angle of mandible; DAO – Depressor anguli oris; DLI – Depressor labii inferiores; IC – Internal carotid artery; OphA – Ophthalmic artery; PC – Posterior communicating artery; SHA – Superior hypophyseal artery; CB – Carotid bifurcation; CTA – Computed tomographic angiography; M-H – Mastoid-hyoid

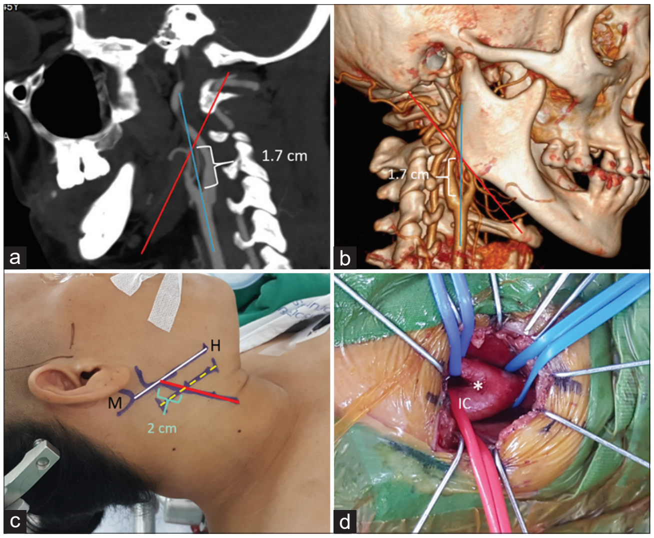

Figure 3: Illustrative case 2 [case no. 8 in Table 1] (a) The MIP image shows the M-H line (red line), C line (blue line) and location of the CB from the M-H line (1.7 cm below the M-H line). (b) The method of measurement was shown on three-dimensional computed tomographic angiography. (c) On the patient's neck, the M-H line (white line) and C line (red line) were marked. The planned incision was located 1.7 cm below the M-H line, but the exact incision (dashed line) was located 2 cm below the mandible to avoid the marginal mandibular branch of the facial nerve. (d) The CB (asterisk) was located 0.3 cm above the center of the operative field. M-H – Mastoid-hyoid; CB – Carotid bifurcation

by CTA. The distance between the ipsilateral M-H line and CB was measured as 1.7 cm on the lateral MIP image [Figure 3a and b]. With a supine position and 40° head rotation to the left side, the right mastoid tip and right lateral corner of the hyoid bone were palpated, and then, the M-H line was created. The column of the right CCA pulse was palpated, and then, the C line was made and extended superiorly until it crossed the M-H line. The skin incision should be located at a point 1.7 cm below the crossing point. However, this point was <2 cm from the angle of the mandible; therefore, the exact skin incision was 2 cm below the angle of the mandible [Figure 3c]. After the exposure of the cervical carotid artery, the CB was located 0.3 cm above the center of the operative field [Figure 3d].

Discussion

Indications for cervical carotid exposure

Exposure of the cervical ICA is necessary for high-flow bypass, retrograde suction decompression, and CEA. For paraclinoid ICA aneurysms, especially in ruptured cases, proximal control through the cervical ICA makes the operation safe. The precise location of the skin incision allows adequate exposure of the CB, external carotid, and ICA, especially when using transverse incisions. Compared to longitudinal incisions, transverse skin incisions allow for minimally invasive exposure and a better cosmetic result, but the disadvantage is the limited exposure; retraction of the skin edge may provide a few centimeters of deviation to compensate for this.[1]

Landmark and location of the carotid bifurcation

Conventionally, several locations of the CB have been reported, such as a point between the C3 and C5 vertebrae,[6] the levels of the C3 and C4 vertebrae,[7-10] the superior edge of the thyroid cartilage, the level of the body or the greater horn of the hyoid bone,[11] 2-finger widths inferior to the genus of the mandible,[7,10] 6–10 mm above the upper border of the thyroid cartilage, the level of the isthmus of the thyroid cartilage, the level of the greater horn of the hyoid bone, and two-fifths of the distance from the mastoid process to the sternal extremity of the clavicle and closer to the mastoid process.[12]

Many studies have shown high variation in the location of the CB.[11,13-15] Carotid artery bifurcation as low as T4 and as high as C1 has occasionally been reported. Suggestions for the most accurate landmark have not yet been provided.[15]

Because of the great variation in the location of the CB, localization of the CB should be individually identified using the preoperative vascular imaging. CTA as a noninvasive imaging technique has been more recently used for the detection of cerebral aneurysms and for the preoperative planning of CEA.[1,16-18]

Palpable bony landmarks for the carotid bifurcation

Three-dimensional CTA reconstruction using bony landmarks provides a useful image for the preoperative workup of patients considered for CEA. Traditional spinal landmarks may be identified easily on imaging,[6-10] but are difficult when accurately localizing the cervical spine level by palpation without fluoroscopy. Palpable bony landmarks have been used until recently. Measuring the distance of the CB from the mastoid process has been used for predicting difficult neck dissection for CEA. A distance from the mastoid process of 5 cm may alert the surgeon to potential difficulties.[19] The external acoustic canal may be used as an external landmark for the mid-portion of the C2 segment of the ICA. The C2 segment-cervical CB distance may be used to accurately estimate the vertical distance from the EAC to the bifurcation.[1]

Blaisdell *et al*. used a line drawn from the tip of the mastoid process to the angle of the mandible (M-M line) as the upper limit of the accessible ICA.[20] The position of M-M lines is variable in neutral and extensional cervical postures due to the large variability of the movement of the angle of the mandible between these postures.[21]

Kubota *et al*. used a line drawn from the C1 transverse process to the lateral corner of the hyoid bone (C1-H line) as an indicator of the upper limit of the operating field for CEA.[21,22]

M-H line and limitations

In our practice, we routinely used a transverse skin incision for cervical carotid exposure. We considered that the

C1-H line of Kubota may also be used as the landmark for localization of the CB for cervical carotid exposure. The lateral corner of the hyoid bone is a superficial bony structure and is easily palpated, but the transverse process of C1 is deep and difficult to palpate. The mastoid tip, which is located close to the transverse process of C1, can be palpated more easily and is relatively fixed while moving the neck. Therefore, we used the mastoid tip instead of the transverse process of C1 to create a similar vector called the M-H line. The M-H line was easy to see on CT and to palpate on the neck of a patient. In obese patients, the hyoid bone may be palpated with difficulty due to the thickness of the skin. We sometimes used the laryngeal protuberance (thyroid notch) to guide the location of the lateral corner of the hyoid bone, which is usually located superolaterally to the thyroid notch. In case which the thyroid notch was not prominent and difficult to palpate, we used the highest bony structure palpated beneath the mandible as the hyoid bone. Because the ICA has a highly tortuous configuration[19] and because the CCA is easier to palpate than the ICA, we used the column of the CCA as the reference line (C line) to locate the CB.

Because the C1-H line is an indicator of the upper limit of the operating field for CEA[21,22] and the close relationship of the transverse process of C1 and the mastoid tip, the M-H line can be used as the upper limit of the operating field for CEA and the upper limit of the accessible CB. When the CB line is higher than the M-H line, a longitudinal skin incision and extensive exposure may be needed.

The accuracy of our method was 93.8%. One inaccurate result may have been caused by an error in the positioning of the hyoid bone or mastoid tip in a patient with a fatty neck. The bias in our study may be due to the compensation of skin retraction, especially with a skin hook.

The disadvantage of this method is the subjective ability to palpate the mastoid tip, hyoid bone, and cervical carotid pulse, which creates the errors in locating the M-H line and localizing the CB.

Accuracy of the landmarks

Mirjalili *et al*. reported that the hyoid bone can descend by 6–7 mm when moving from the supine to the sitting position and can move somewhat cranially and caudally with extension and flexion of the neck.[9] However, other studies reported that there is no association between the head position and the displacement of the hyoid bone.[23,24] Riley *et al*. reported that the hyoid bone moves in an anterior–superior direction during swallowing.[25]

To our best knowledge, there is no studies regarding the displacement of carotid artery and mastoid tip after changing the neck position and the displacement of the hyoid bone and carotid artery after intubation and giving muscle relaxants but some displacements of these structures may occur due to many of the above factors. The relatively movable landmarks (hyoid bone, mastoid tip, and carotid artery) may lead to the errors in determining the M-H line when the surgical position is set and affect the accuracy of the method.

Preservation of the marginal mandibular branch

The marginal mandibular branch of the facial nerve, which innervates the depressor anguli oris and the depressor labii inferioris, has not been found to pass >2 cm below the mandible.[26] If the distance of the submandibular incision is <2 cm from the angle of the mandible, there is a high risk of damaging the marginal mandibular branch of the facial nerve.[27]

In cases where the location of skin incisions that used the distance from the M-H line was less than 2 cm from the angle of the mandible (37.5% in our study), the skin incision was moved to 2 cm below the angle of the mandible to avoid the marginal mandibular branch of the facial nerve. This may be another cause of error in our study. Because a deviation within 1 cm from the center of the operative field was defined as accurate, the accuracy rate in our study was quite high (93.8%). In our study, paralysis of the depressor anguli oris or the depressor labii inferioris was not detected after the surgery.

Conclusion

The distance from the M-H line to the CB can be used to estimate transverse skin incisions for cervical carotid exposure.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the legal guardian has given his consent for images and other clinical information to be reported in the journal. The guardian understands that names and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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