

Surface Landmarks Combined With Image-guided Sinus Location in the Retrosigmoid Approach and Their Clinical Feature Analysis

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Research

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Abstract

Background During craniotomy for the cerebellopontine angle (CPA) lesion by the typical retrosigmoid approach, the exact exposure of the margin of the venous sinuses complex remains an essential but risky step. This study aimed to reveal the exact position of asterion and sinuses by combining preoperative imaging with intraoperative landmarks. and analyse their clinical features.

Methods From February 2008 through November 2019, 94 patients who underwent removal of vestibular schwannoma (VS) through retrosigmoid craniotomies were enrolled in the series. We utilized preoperative images, including computed tomography (CT) and/or magnetic resonance imaging (MRI) combined with intraoperative anatomical landmarks, to determine the exact location of the sigmoid sinus and the transverse and sigmoid sinuses junction (TSSJ). MRI T1 sequences with gadolinium and/or the CT bone window were used to measure the distance relationship of the asterion to the sigmoid sinus.

Results In 94 cases of retrosigmoid craniotomies, we observed the asterion lay 12.71 millimeter on the posterior to the body surface projection of the TSSJ averagely. Intraoperative surface landmarks combined with preoperative image information identifying the distance from the asterion to sigmoid sinus at the transverse sinus level, enabled an appropriate initial burr-hole (the margin of the TSSJ). Just one case had a minor laceration of the sigmoid sinus when the bone flap was opened.

Conclusions By combining intraoperative anatomical landmarks with preoperative image information, the margin of the venous sinuses, especially the inferior margin of the transverse sinus in the retrosigmoid approach can be well and truly identified. The distance from the intersection of the asterion and occipitomastoid suture to the TSSJ is the shortest between the occipitomastoid suture and the sigmoid sinus.

Background

The retrosigmoid approach is one of the commonly used approach for CPA surgery [1]. Exposure of the sigmoid sinus and TSSJ remains a pivotal but advent neurosurgical procedure [2, 3]. This relationship that the asterion lies over the TSSJ is inaccurate, and individual variation exists in most of cases [4]. Before the exposure of the TSSJ, making the venous sinuses visualized is desirable for the precise localization of the burr hole over the TSSJ, avoiding hazardous step into the venous sinuses and extensive bone removal.

Asterion, an important surface landmark during posterolateral surgical approach for intracranial operation, is defined as the connection point of sutura parietomastoidea, sutura occipitomastoidea, and sutura lambdoidea. The projection of transverse sinus roughly overlapped with the asterion. Therefore, an imaginary beeline from the asterion to the TSSJ can be regarded as the body surface reflection of the posterior margin of the TSSJ. Based on such close anatomical relationship as described, we believe it is necessary to measure the distance from the asterion to the TSSJ, although the distance might be variable in different patients.

The use of preoperative image as a orientation method for craniotomies in the retrosigmoid approach is helpful for correctly drilling the burr hole. An exact intraoperative location of surface projection of TSSJ is appropriate for both avoiding inadvertent entry into the sinus, an unnecessarily large craniotomy and excessive bone removal. Therefore, in this prospective study, we reported 94 cases of retrosigmoid craniotomies. This image-guided anatomic study aimed to reveal the exact position relationship between the asterion and the TSSJ in every case by measuring their distance in the preoperative image system. Meanwhile, the relationship of the external landmarks with the TSSJ during surgery was also studied in order to confirm the accuracy of our preoperative image measurement.

Material And Methods

Preoperative image preparation and measurement

From February 2008 to November 2019, 94 patients who underwent removal of vestibular schwannoma (VS) through retrosigmoid craniotomies were enrolled in our series. Of these patients, 38 were male, while 56 were female. The mean age of male patients was 46.26 ± 14.60 years, while the mean age of female patients was 47.96 ± 11.84 years. There were all 188 sides in the 94 cases. The following structures were identified on each side: the lambdoid suture, parietomastoid suture, asterion, inion, occipitalmastoid suture, posterior zygoma root and mastoid process. For establishing individual procedure of exposure to sinuses, thin-slice, 1-mm-thick CT, and enhanced CT venography were performed and reconstructed by neuroimaging specialist. Once formed, three dimensional structure of sinuses could be manipulated and visualized in a three-dimension (3D) viewing window. Applying basic cutting and cropping tools on anatomic structures of interest, only ipsilateral 3D skull with lesion was kept. The three dimensional reconstructed transverse and sigmoid sinuses and its projection on the ipsilateral 3D skull, and the precise spatial position relation between asterion and sigmoid sinus, were represented in the visualization way (Fig. 1A). After identification of the key structures, the distance was measured: the asterion to the surface projection of the posterior edge of sulci for transverse and sigmoid sinuses on the outer surface. The distance between TSSJ and the occipitomastoid suture is reflected as the red line (Fig. 1B).

Intraoperative exposure of key structures

During craniotomy procedure, a linear skin incision approximately paralleled with venous sinuses was designed, with a rough 7-centimeter length. To make these bone sutures and the asterion clear and easily discriminated, saline gauze was usually used in the operative field after getting rid of the soft tissue in bone sutures. The umbriferous position of the TSSJ can be highlighted on the base of preoperative image-guided individualized anatomical localization information and intraoperative skull surface landmarks. Then the asterion and the body surface projection of the posterior edge of the TSSJ were ascertained as a landmark for identifying the burr hole point. The shortest distance between the asterion and the digastric point (projective TSSJ) was calculated in millimeters. The burr hole was placed medially and inferiorly at the projection spot of TSSJ to avoid undesired sinus exposure (Fig. 1C). After elevating

the bone flap, the real position of the medial and the inferior margin of the TSSJ, the sigmoid sinus and transverse sinus could be limpidly recognized (Fig. 1D).

Statistical analysis

Continuous variables were shown as mean \pm standard deviation (SD). Categorical variables were shown as counts and percentages. We applied the independent-samples T test to compare the differences of the distance relationship between the genders and the sides. The scatter plot and the Pearson product-moment correlation coefficient were utilized to explore the linear correlation between distance and age. A two-tailed $P < 0.05$ was considered statistically significant. All data were analyzed with IBM® SPSS® Statistics Version 20.

Results

Of all 94 patients diagnosed as VS preoperatively, 38 were male, while 56 were female. The mean age of male patients was 46.26 ± 14.60 years, while the average age of female patients was 47.96 ± 11.84 years, which is of no statistical significance ($P = 0.536$), assisting in excluding the influence of age on the distance between the TSSJ and the asterion (occipitomastoid suture) when the comparison is between genders. The result of plot data in our study is shown in Fig. 2. In male patients, the distance from the TSSJ to the asterion was 12.55 ± 5.26 mm, while in female patients, the distance was 12.82 ± 4.68 mm. The difference in the distance between male and female is not statistically significant ($P = 0.794$), which illustrates that the distance between TSSJ and occipitomastoid suture may not be associated with genders (Fig. 3).

Preoperative image data from 94 patients were studied. The study of bilateral side yielded 188 sides. Distance measurement from the asterion to the posterior edge of the TSSJ on the preoperative CT or MRI was performed in the image system, and relations of the surface landmarks with the TSSJ was studied according to the image measurement during surgery. The distance from the asterion to the TSSJ was variable in different patients. The projection of transverse sinus roughly overlapped with the asterion. The beeline from the asterion to the surface reflection of the posterior margin of the TSSJ, was measured on preoperative image. Among patients, 44 cases were found with the tumor on the left side while 50 cases on the right side. Surprisingly, we found a significant difference between the left side and right side for the distance from the TSSJ to the asterion ($P = 0.006$) (Fig. 4). For left side, TSSJ was anterior to occipitomastoid suture at a distance of 11.24 ± 5.14 mm. For right side, TSSJ was anterior to the asterion at a distance of 14.00 ± 4.32 mm. In our series, the location of TSSJ was all anterior to the asterion, and the distance was 12.71 ± 4.90 mm (Fig. 5). The real margin of TSSJ was clearly perceptible after drilling the digastric point in each case. Uncontrolled sinus bleeding was encountered in no patient. The case displayed in Fig. 1D show a desired doublication between reckoned burr-hole and the actual. Skull base repeated CT after early surgery demonstrated that the burr hole was exactly on the margin of TSSJ and narrow bone defect only existed along the sigmoid sinus (Fig. 1D). In this manner, the anatomical reconstruction are easily available. Patients failed to touch appreciable bone defect in the operative area.

A scatter plot was used to evaluate whether there was a linear correlation between the distance and age, and the correlation coefficient was -0.003 , which strongly indicated that the distance between TSSJ and occipitomastoid suture is not associated with age (Fig. 2). In all 94 cases, preoperative images identifying the distance from the asterion to sigmoid sinus at the transverse sinus level, enabled the intraoperative location of the TSSJ, with an accuracy flaw below 2 millimeter (mm). Just one case had a laceration of the sigmoid sinus during the craniotomy.

Discussion

The retrosigmoid craniotomy is widely adopted to gain access to the CPA area. However, only depending on superficial anatomic landmarks usually has difficulty in determining the accurate location of venous sinuses, which leads to unsafe and/or complicated surgical access [5–7]. In such procedure, the exact localization of venous sinuses, particularly the transverse and sigmoid sinuses junction (TSSJ) is imperative to decrease the risk of the venous sinus injury, and available through osteal landmarks combined with the preoperative image-guided sinuses localization method. In our clinical practice, the method using preoperative image information with intraoperative skull anatomical landmarks had been confirmed to be accurate and practical for identifying the TSSJ and establishing the relationship between the location of the asterion and the TSSJ in retrosigmoid craniotomy.

A burr hole medial to the TSSJ can reveal the margin of the TSSJ with the least risk. However, no recognized initial burr-hole has been recommended until now [8]. How to gain the right orientation before drilling the key hole for retrosigmoid craniotomy has been widely explored by most neurosurgeons [9–11]. Classically, the neurosurgeons intend to determine the surface projection of TSSJ by the asterion to place the initial burr hole. However, more and more literatures reported the asterion has been considered as a unreliable landmark [12–14]. In order to precisely expose the inferior edge of the transverse (superiorly) and the posterior margin of the sigmoid sinuses (inferiorly), an optimal initial burr-hole is in proximity to the margin of the TSSJ, allowing their exposure without their damage.

In the present study, we observed the asterion lie directly over the inferior margin of the transverse sinus in 97.87% of cases, so the distance from the intersection of the asterion and occipitomastoid suture to the TSSJ is the shortest between the occipitomastoid suture and the sigmoid sinus. The posterior border of the mastoid process can be used as a parameter to identify the posterior margin of the sigmoid sinus [15]. The illumination of mastoid air cells correlates well with the sigmoid sinus in the retrosigmoid approach [16]. In clinical practice, we found these methods do not reflect the exact position of the sigmoid sinus, and mastoid air cells vary largely in different patients.

In retrosigmoid craniotomy, neurosurgeons commonly rely on surface landmarks and their experience to evaluate the position of venous sinuses and estimate an appropriately initial burr-hole, which is not accurate because of variability in different patients. In the previous study, many neurosurgeons have established their own methods to locate the sigmoid sinus. The author measured the x and y coordinates of the anterosuperior point of transverse-sigmoid sinus junction and the squamosal-parietomastoid

suture junction to define a rectangular coordinate system [11]. However, the measurement is based on skull samples instead of patients alive, where there might be some measurement bias. The sample size was also too small to generalize this method in clinical application. The author locates the TSSJ based on 3D-CT in retrosigmoid craniotomy, but not all hospitals are equipped with 3D-CT images, and its accuracy is not high [17]. In our present study, we introduce a simplified procedure based on MRI and CT to localize the TSSJ in retrosigmoid craniotomy, and the location of the sigmoid sinus. 94 patients who underwent retrosigmoid craniotomy were analyzed. On the internal view of the skull in MRI, we measured the distance between TSSJ and the intersection of the asterion and occipitomastoid suture of every patient. Such distance is reflected as a red line labeled on the outer surface of cranium indicated in Fig. 1B. This simple method could help in localizing the sigmoid sinus and TSSJ and avoiding the risk of sinus injury and reducing the bone defect. The method does not need to establish any coordinate system, so it is convenient but sufficiently precise for practical application at surgical planning.

We have illustrated that the distance between the TSSJ and the occipitomastoid suture is not associated with age or gender, which pushes our work into a more universal level and makes it easier to apply to most patients. Due to anatomic heterogeneity in different cases, it is not reliable to traditionally depend on the asterion for the margin of TSSJ. For clinical practice, individual anatomic information from preoperative imaging data is necessary for different patients. CT scan, especially bone window, is superior to MRI to study bone features, but the T1WI MRI sequence was clearer in indicating the transverse and sigmoid sinuses, which was helpful for determining the distance from the intersection of the asterion and occipitomastoid suture to the TSSJ [11, 15]. In our series, the distance data from the asterion to the margin of TSSJ on the base of CT scan images combined with MRI images can be obtained preoperatively. According to these information and intraoperative osseous anatomical landmarks, the location of the burr hole could be determined on the cranium surface and its location corresponds to the projection of the margin of TSSJ.

Because surface landmark in the literature for identifying the transverse TSSJ junction is unreliable, we have attempted to refine this location method with the largest sample size to date. These data can assist neurosurgeons in localizing the preoperative projection and intraoperative location of the TSSJ when the surface landmark is not accurate. We studied relations of the external landmarks with the venous sinuses, of which the anatomic position was variable. Knowing the location of the venous sinuses avoids inadvertent entry into the venous sinuses and limitation of the size of the bony opening.

Interestingly, we found a significant difference between left sides and right sides for the distance from occipitomastoid suture to TSSJ ($P = 0.006$) in our series. The distance on the right side is longer than that on the left side at a distance of 2.76 mm on average. This might be due to the different sizes of the transverse sinuses in between the left sides or the right sides. Hwang RS et al. found that the right and left TS were constantly different in size, and the right TS was more often larger than the left TS [18]. This may guide neurosurgeons to pay attention to such a difference during craniotomy since the tumor is on different sides. Ribas et al. performed measurements on 50 sinuses from 25 dried skulls [17]. He found that TSSJ occurred approximately 1 cm in front of the asterion, which is in accordance with our result.

Anatomical landmarks complemented with preoperative images offer a simple and reliable method in the identification of the TSSJ position for retrosigmoid craniotomy. This method significantly promotes speed and safety in the retrosigmoid approach and decreases venous sinus injuries, which displayed the reliability of our study in the location of TSSJ in all cases of our series.

Some authors described a high incidence of venous injury simply based on image-guided retrosigmoid craniotomy [2, 3]. This is not case in our series and the sigmoid sinus burst did not occur. In the present study, the umbriferous position of TSSJ onto the external surface of the cranium, indirectly located by the preoperative image with intraoperative landmarks, can confirm the burr hole place during surgery. Every patient has a distinctive location relationship between the asterion (occipitomastoid suture) and the TSSJ. Morphometric data from CT and MRI scans makes precise localization of venues structure possible in individual patient.

Although neuronavigation can achieve an accurate orientation of the target area, it brought on additional damage to patients because of installing Mayfield clamps and added preoperative and intraoperative procedures [16]. Briefly speaking, neuronavigation is invasive, time-consuming and produces more costs.

One of the limitations of our study is that we just measured the distance from TSSJ to the occipitomastoid suture in the asterion plane. It is reported that in some cases, the TSSJ was below the asterion plane, which is uncommon. Another limitation was that most of our patients were adults, which limits our study applied to other patients. However, the method combining preoperative image data and intraoperative anatomical landmarks discards complicated coordinate systems and provides a simple method for neurosurgeons to locate the TSSJ practically and precisely.

Conclusions

By combining intraoperative anatomical landmarks with preoperative image information, we observed the asterion lies 12.71 mm on average posterior to the TSSJ, and directly over the inferior margin of the transverse sinus in most cases, so the distance from the intersection of the asterion and occipitomastoid suture to the TSSJ is the shortest between the occipitomastoid suture and the sigmoid sinus. Surface landmarks combined with image-guided sinus is an easy, fast and safe procedure for the localization of the transverse-sigmoid sinus complex in the retrosigmoid approach, which closely matches the individual anatomy of the patient and reduces the risk at injury to the hidden venous sinuses, preventing a wide craniotomy and extensive bone removal.

Abbreviations

TS: transverse sinus; SS: sigmoid sinus; CPA: cerebellopontine angle; TSSJ: transverse and sigmoid sinuses junction; VS: vestibular schwannomas; CT: computer tomography, MRI: magnetic resonance imaging; mm: millimeter

Declarations

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Availability of data and materials

The data during and/or analysed during the current study are available from the corresponding author.

Authors' contributions

All authors contributed equally to the paper. Ji Zhang, Chao Ke and Zhaoyang Liu drafted the manuscript. Xiaoyu Guo, Yi Zhou, Haibin Liu and Yonggao Mou performed data collection. Ji Zhang supervised the data collection and revised this article. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

This study was approved by the Ethic Committee of Sun Yat-sen University Cancer Center, and written informed consent was obtained from every participant.

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Figures

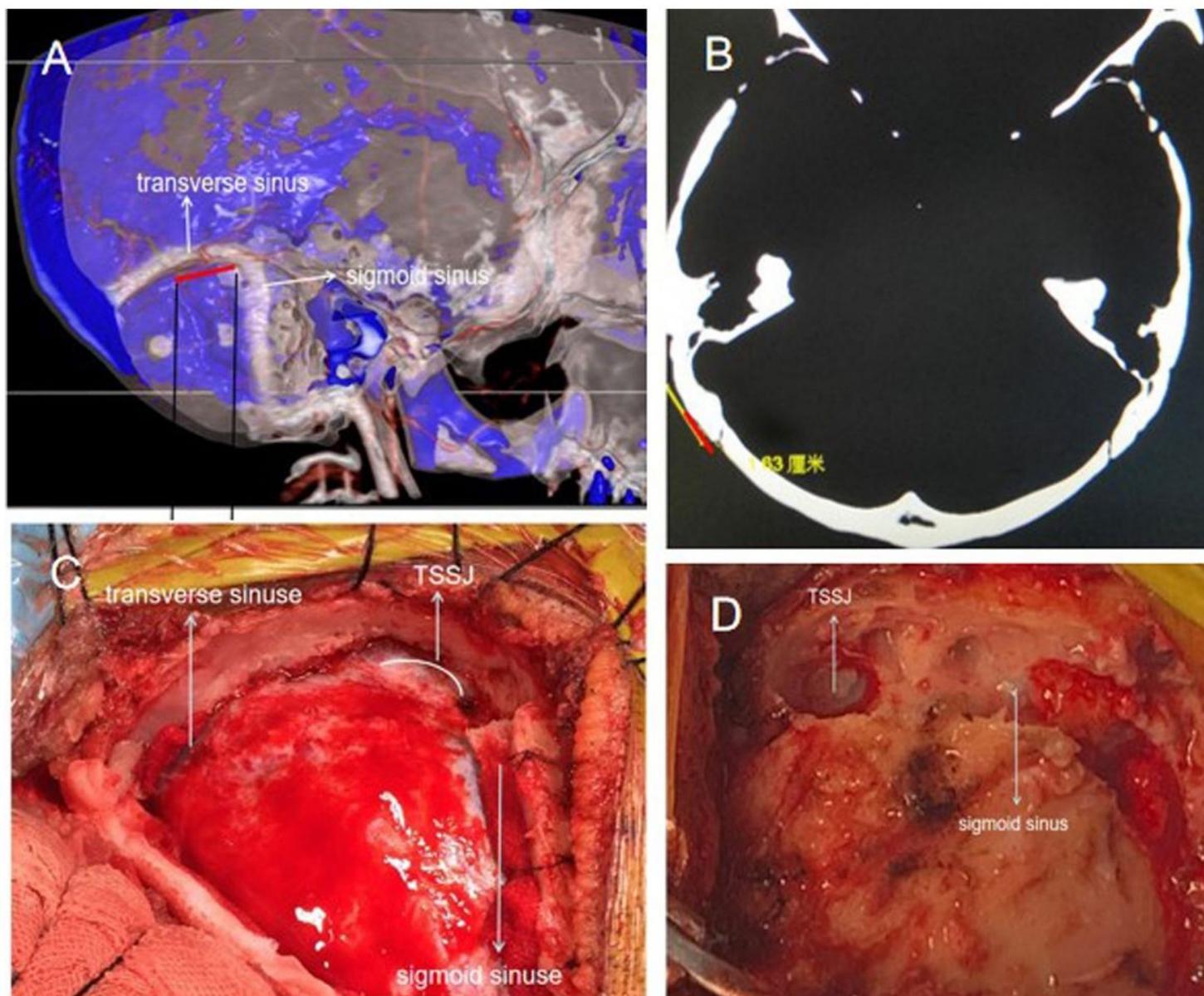


Figure 1

Three-dimensional reconstructed transverse and sigmoid sinuses and its projection on the skull (right). The red line is defined as the distance from the asterion to the body surface projection of posteriorinferior edge of sulci for transverse and sigmoid sinuses on the inner surface (A). The red line stands for the shortest distance from the occipitalmastoid suture to the posterior margin of sigmoid sinus groove on the bone window of craniocerebral CT (B). Intraoperative photo shows that the burr-hole exactly exposes the margin of TSSJ and the sigmoid sinus (C). Intraoperative photo shows that the exposed margin of TSSJ, sigmoid sinus and transverse sinus (D).

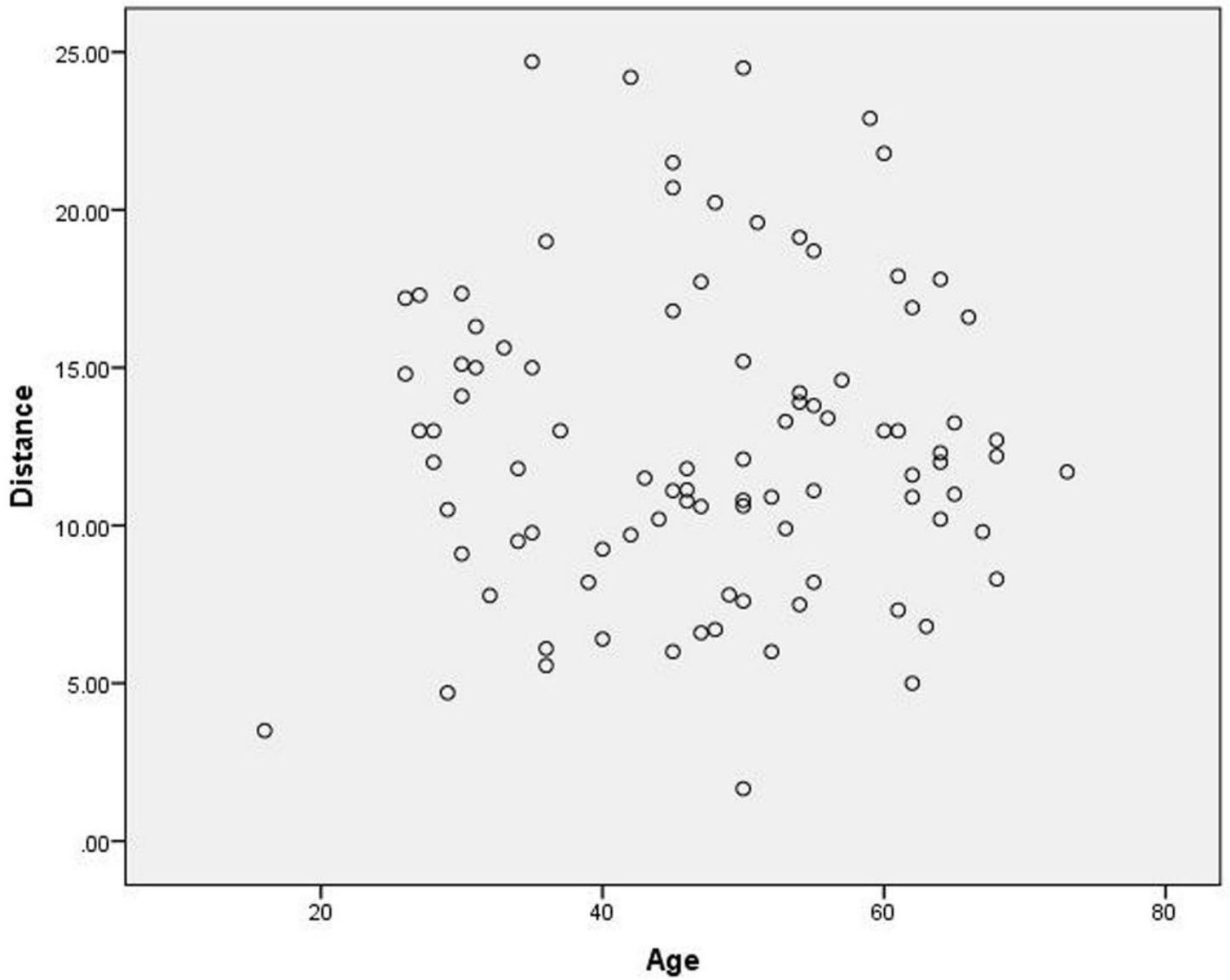


Figure 2

Scatter plot shows age in relation to the distance between TSSJ and the asterion on 3D CT bone images. The vertical axis is a line connecting the asterion and margin of TSSJ and the lateral axis is age.

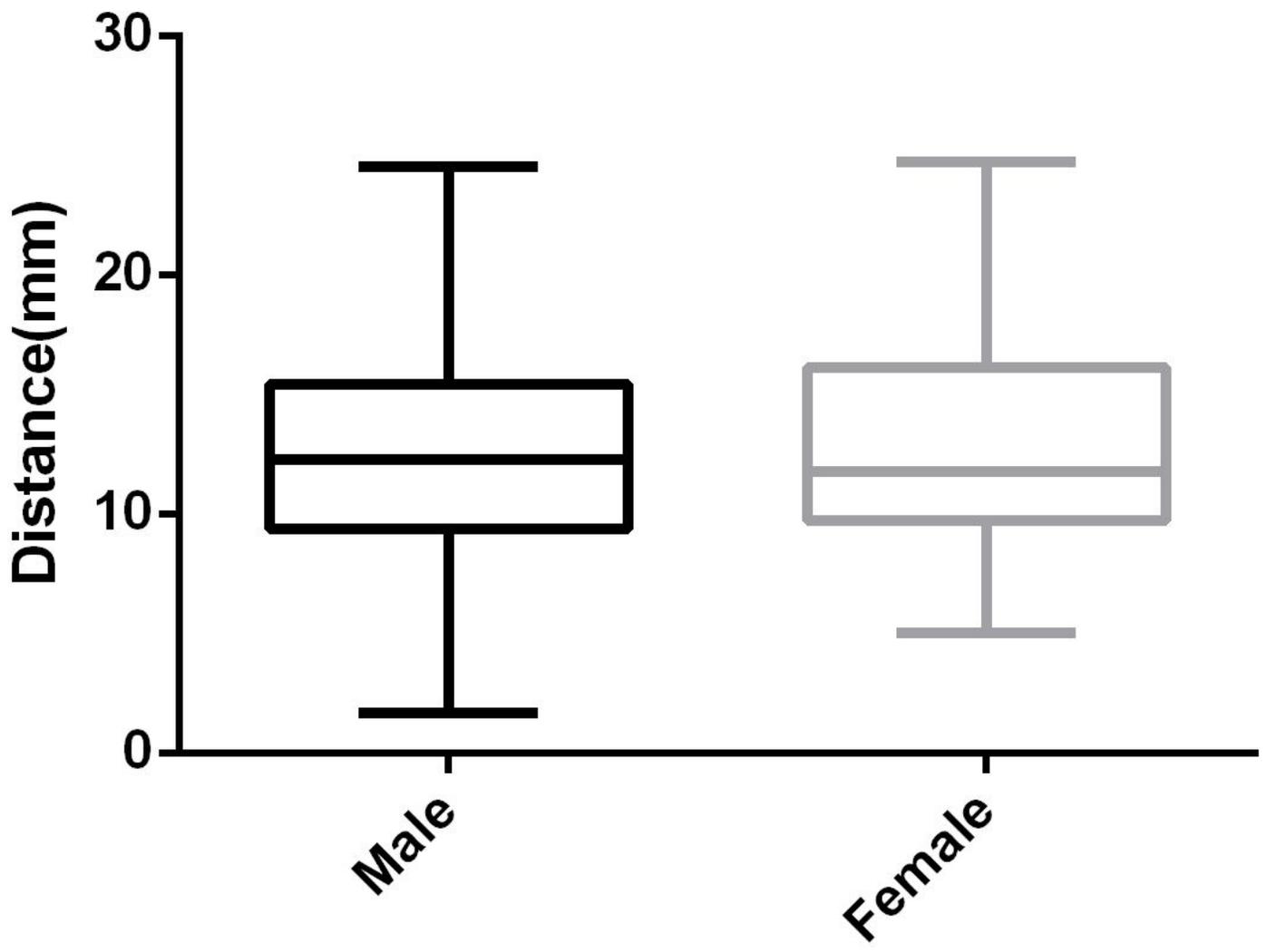


Figure 3

The box diagram illustrates that the distance between TSSJ and occipitomastoid suture does not statistically difference between male and female.

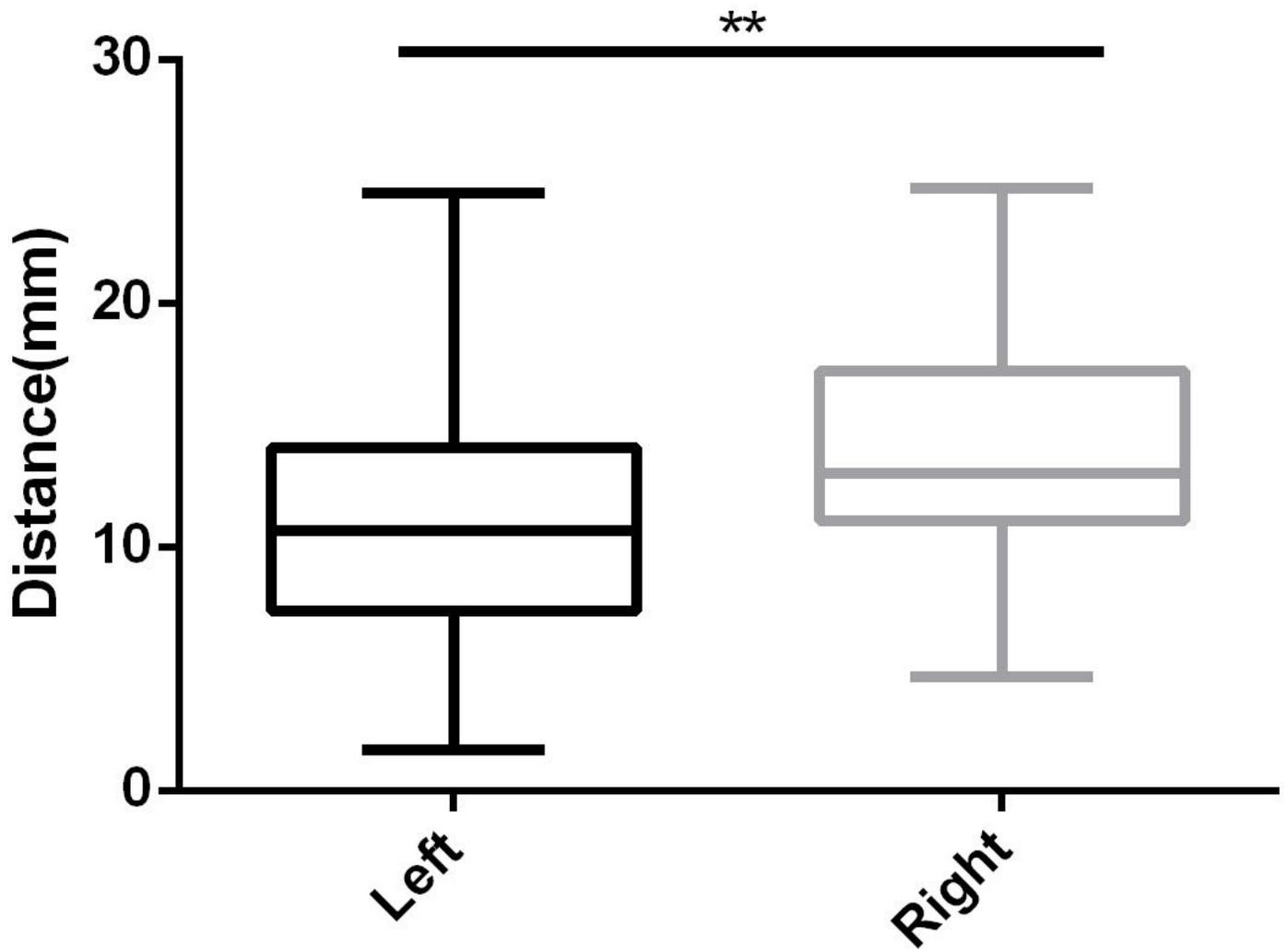


Figure 4

The box diagram illustrates that a significant difference exists between left side and right side in the distance from TSSJ to the occipitomastoid suture.

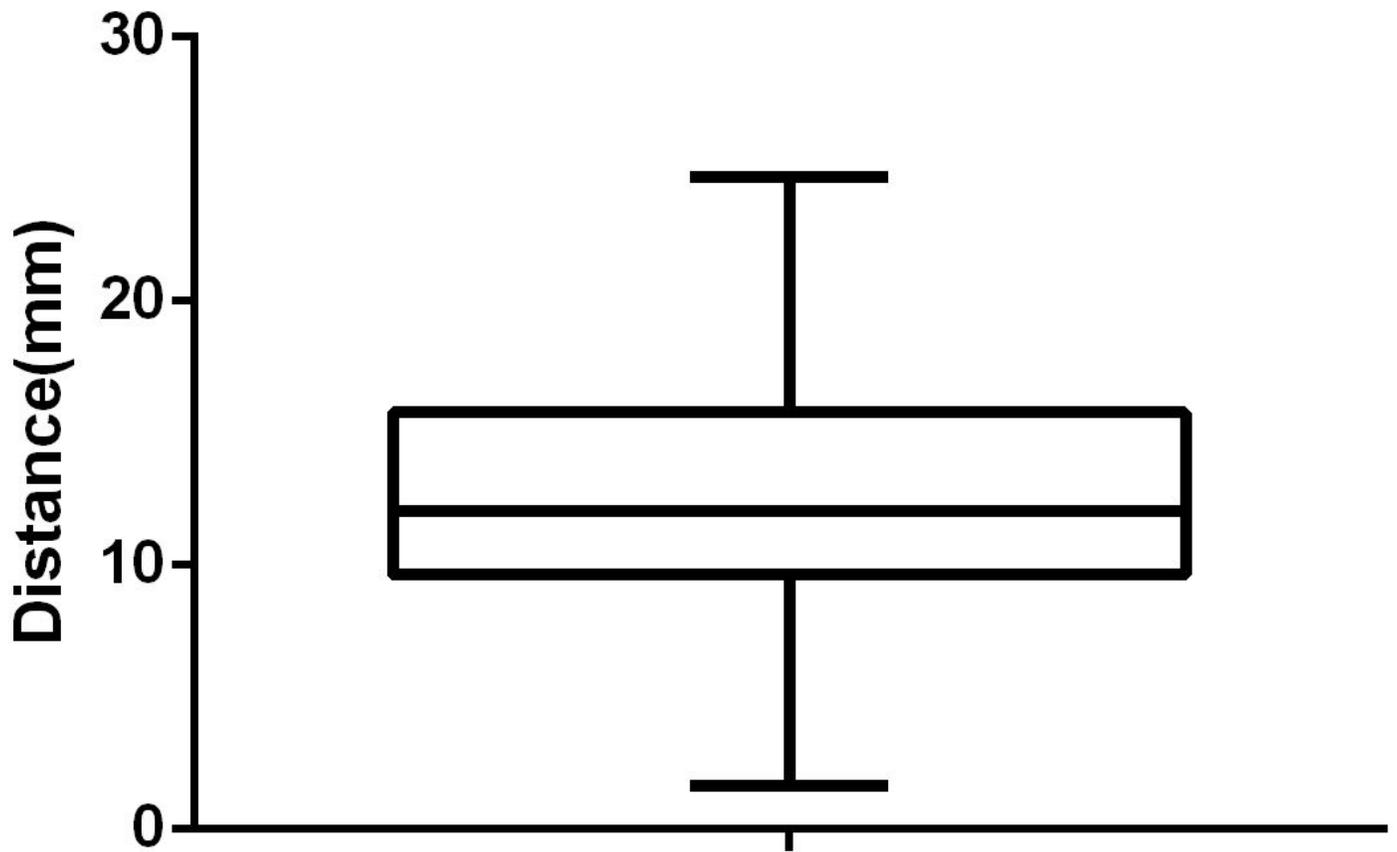


Figure 5

The box diagram displays the distance between TSSJ and occipitomastoid suture in our series.