ORIGINAL ARTICLE doi: 10.2176/nmc.oa2013-0020

Neurol Med Chir (Tokyo) 54, 261–266, 2014 Online November 8, 2013

Determination of the Keyhole Position in a Lateral Suboccipital Retrosigmoid Approach

Yu TERANISHI,[1] Michihiro KOHNO,[1] Shigeo SORA,[1] and Hiroaki SATO[1]

[1]*Department of Neurosurgery and Stroke Center, Tokyo Metropolitan Police Hospital, Tokyo*

Abstract

Appropriate placement of the keyhole at the transverse and sigmoid sinus (T/S) junction is important for performance of safe and accurate lateral suboccipital craniotomy with minimum bone loss. Here, we report a method for predicting the position of the T/S junction and investigate the relationship between the T/S junction and asterion. The subjects were 88 patients treated surgically via a lateral suboccipital approach. These cases included 78 acoustic neuromas, 4 meningiomas, 1 trigeminal schwannoma, 1 epidermoid cyst, 2 trigeminal neuralgias, and 1 hemifacial spasm. To expose the T/S junction, we usually place the keyhole lateral to asterion by a half diameter of the burr hole. The distance of the T/S junction from asterion was investigated using three-dimensional computed tomography (3DCT) images. We investigated the differences between the actual and predicted positions of the T/S junction based on skull landmarks, and we compared our method with other literature methods. The mean distances were 5.7 mm caudal and 6.6 mm lateral. The difference between the actual and predicted positions was significantly smaller in our approach compared to other methods. Placing the keyhole lateral to a provisional burr hole just caudal to asterion and lateral by half the diameter of the burr hole was useful for exposure of the T/S junction. The best approach is to use preoperative 3DCT, but this may be limited by equipment problems, emergency cases, or allergy to contrast medium. Determination of the appropriate keyhole position with reference to skull landmarks is a universally useful method.

Key words: asterion, burr hole, junction of the transverse and sigmoid sinus, lateral suboccipital approach, skull landmarks

Introduction

The lateral suboccipital retrosigmoid approach is a standard approach for removing cerebellopontine angle tumors and for microvascular decompression. In this approach, it is important to expose the margin of the transverse and sigmoid sinus (T/S) safely and quickly. Adequate exposure of these margins by placing a keyhole on the junction of the T/S junction minimizes bone loss. It is considered ideal if half of the T/S junction can be seen in the keyhole and many methods have been described for preoperative identification of the positions of the transverse sinus, T/S junction, and the sigmoid sinus based on external skull bony landmarks.[1–5]

Historically, the asterion has been viewed as a landmark for the T/S junction.[4,6] However, the asterion is now seen as unreliable for this purpose because of difficulties with observation, palpation, and anatomical variety.[1,2,5,7–9] Tubbs et al. suggested that the mastoid process and the zygomatic arch were more reliable landmarks for prospective identification of the T/S junction.[5] Methods for distinguishing the T/S junction from other superficial structures, including the semispinalis capitis muscle, superior nuchal line, inion, and mastoid process, have also been described.[1–3,5]

There are many studies on the anatomical relationship between the T/S junction and the superficial bony structure using three-dimensional computed tomography (3DCT) volumetric image rendering technology.[10,11] Similarly, in this study, we investigated this relationship preoperatively using 3DCT images. We usually place the keyhole lateral to the asterion by a half diameter (6.5 mm) of the burr hole. This is because we predicted that this keyhole position is on the T/S junction. To evaluate the accuracy of our methods and other literature methods, we investigated

Received January 24, 2013; Accepted March 14, 2013

the difference between the actual and predicted positions of the T/S junction based on external skull bony landmarks, and we compare our results with those from other methods reported in the literature.

Materials and Methods

The subjects were 88 patients treated surgically via the lateral suboccipital retrosigmoid approach from March to November 2010 at Tokyo Metropolitan Police Hospital. This series included 78 acoustic neuromas, 4 meningiomas, 1 trigeminal schwannoma, 1 epidermoid cyst, 2 trigeminal neuralgias, and 1 hemifacial spasm. The distance between the T/S junction and the asterion was investigated using 3DCT images in which external skull bony landmarks and intracranial structures were visualized by opacity modulation using software designed for 3DCT images (Aquarius Netstation, version 1.5; TeraRecon, Inc., Tokyo).

There are various definitions of the T/S junction and only a few reports have given a clear definition. Therefore, we defined a single point on the 3DCT image as the T/S junction. A transverse line (*line A*) was drawn as a tangent rostrally to the curve of the transverse sinus and a sigmoid line (*line B*) was drawn as a tangent laterally to the curve of the sigmoid sinus. The point of intersection between the medial edge of the sinus and the bisector of the angle between *lines A* and *B* was defined as the T/S junction (Fig. 1).

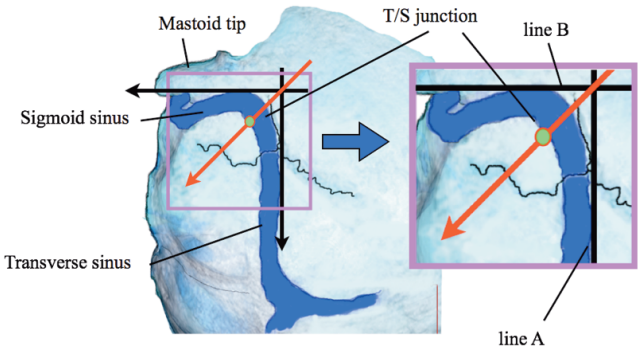

Fig. 1 Definition of the transverse and sigmoid sinus (T/S) junction used in this study. The illustration shows the intracranial transverse-sigmoid sinus junction and extracranial landmarks. This illustration was drawn using volumetric imaging of three-dimensional computed tomography images in a patient with left acoustic neurinoma. The transverse line (*line A*) is a tangent rostrally to the curve of the transverse sinus, and the sigmoid line (*line B*) is a tangent laterally to the curve of the sigmoid sinus. The T/S junction is defined as the point of intersection between the medial edge of the sinus and the bisector of the angle between lines A and B.

We usually place the keyhole lateral to a provisional burr hole, which is just caudal to the asterion by half the diameter of the burr hole, because we predicted that this prospective keyhole position is on the T/S junction (Fig. 2). That is, the prospective keyhole is determined to be both lateral and caudal to the asterion by half the diameter (6.5 mm) of the burr hole (Fig. 2). In addition, more recently we have modified the conventional keyhole position based on preoperative 3DCT images.

We investigated the difference between the actual T/S junction based on 3DCT and the center of the prospective keyhole established based on external skull bony landmarks, and compared the results of our method with those reported in the literature[1,8] (Table 1, Figs. 3, 4). Statistical analysis was performed by Student *t* test (SPSS for Windows,

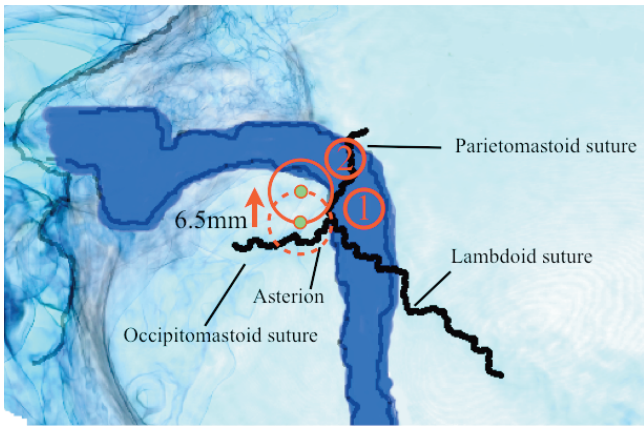

Fig. 2 Illustration of the design of craniotomy using a lateral suboccipital retrosigmoid approach, as performed in our department. A burr hole (the provisional burr hole) is initially located as a tangent caudally to the asterion (①: *red dotted circle*). This burr hole is then moved laterally by a half diameter (6.5 mm) of the burr hole to determine the keyhole position (the prospective burr hole) (②: *circle*).

Table 1 Predicted keyhole position from external skull bony landmarks

References	Position
Lang and Samii (1991)[2]	Average 30 mm behind the suprameatal spine on the FHP
Ribas et al. (2005)[4]	1 cm anterior to the asterion across the parietomastoid suture
Our cases	6.5 mm inferior, 6.5 mm lateral to the asterion

FHP: Frankfurter horizontal plane.

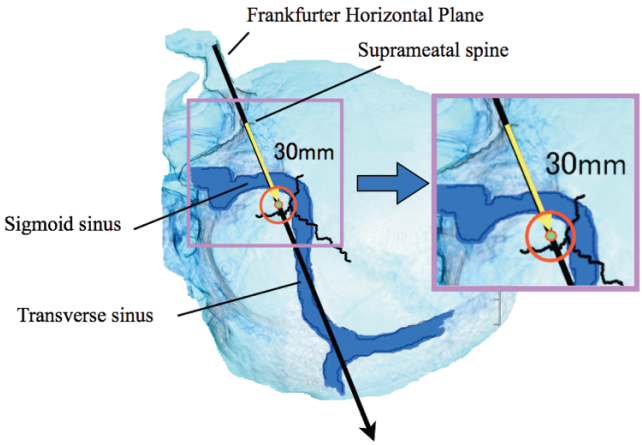

Fig. 3 Schema illustrating the intracranial transverse sinus, sigmoid sinus and extracranial landmarks in a patient with left acoustic neurinoma. The Frankfurter horizontal plane (FHP) is defined by the lowest point of the inferior orbital rim and the most superior point of the external acoustic meatus. Lang and Samii described this junction as lying 30 mm posterior to the suprameatal spine on the FHP.[2)]

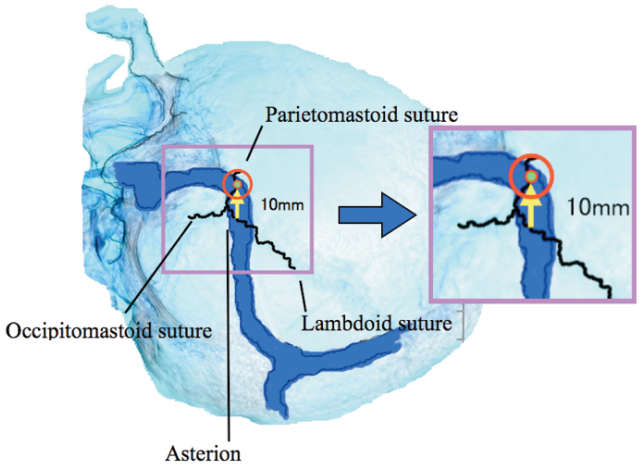

Fig. 4 Schema illustrating the intracranial transverse sinus, sigmoid sinus, and extracranial landmarks in a patient with left acoustic neurinoma. Ribas et al. proposed that the transverse and sigmoid sinus junction is 1 cm anterior to the asterion across the parietomastoid suture.[4)]

version 15; SPSS, Inc., Chicago, Illinois, USA) with significance set at $P < 0.05$.

Results

The mean distances from the T/S junction to the asterion were 5.7 mm [range –2.8 to +14.8 mm; standard deviation (SD) 3.3 mm] caudal and 6.6 mm (–5.0 to +14.9 mm; SD 3.7 mm) lateral. These distances were 4.4 mm (–1.5 to +11.5 mm; SD 3.5 mm) caudal and 6.7 mm (–5.0 to +14.9 mm; SD 3.7 mm) lateral on the left side; and 6.6 mm (–2.8 to +14.8 mm; SD 3.4 mm) caudal and 6.7 mm (–1.7 to +11.3 mm; SD 2.5 mm) lateral on the right side (Table 2A).

Table 2A The distance between the asterion and the T/S junction

Reference	Caudal	Lateral
Left	4.4 ± 3.5	6.7 ± 3.7
Right	6.6 ± 3.4	6.7 ± 2.5
Total	5.7 ± 3.3	6.6 ± 3.7

Values are means (mm) ± standard deviation. T/S: transverse and sigmoid sinus.

Regarding the relationship between the asterion and the transverse sinus, the position of the asterion was over that of the transverse sinus in 70% of cases on the right side and in 71.1% on the left. The asterion was caudal to the transverse sinus in 20% of cases on the right and in 18.4% on the left. The asterion was located rostral to the transverse sinus in 10% of cases on the right and in 10.5% on the left (Table 2B).

With respect to the difference in position between the keyhole and the T/S junction, the mean distances from the keyhole to the T/S junction were –0.8 mm (–9.3 to +8.3 mm; SD 3.3 mm) caudal and 0.1 mm (–11.5 to +8.4 mm; SD 2.8 mm) lateral. These distances from the keyhole to the T/S junction were –2.1 mm (–8.0 to +5.0 mm; SD 3.3 mm) caudal and 0.2 mm (–11.7 to +8.4 mm; SD 3.7 mm) lateral on the left side; and 0.1 mm (–9.3 to +8.3 mm; SD 3.5 mm) caudal and 0.2 mm (–8.2 to +4.8 mm; SD 2.8 mm) lateral on the right side.

Discussion

I. Anatomical study

There have been several anatomical studies on the relationship between the asterion and the T/S junction.[1,8,9)] Day et al. found that the asterion was positioned over the transverse sinus in 61% of cases on the right and in 66.6% on the left; and that the asterion was located caudal to the transverse sinus in 32% on the right and 25% on the left, and rostral to the transverse sinus in 7% on the right and 9% on the left.[1)] Sripairojkul and Adultrakoon reported respective rates of 74.4%, 58.1%, 23.3%, 32.6%, 2.3%, and 9.3% for these data.[8)] Ucerler and Govsa found the asterion positioned over the transverse

Table 2B Relationship between the T/S junction and the asterion (left, right)

References	On the T/S junction		Caudal to the T/S junction		Rostral to the T/S junction	
	Left	Right	Left	Right	Left	Right
Day et al. (1996)[1]	66%	61%	25%	32%	9%	7%
Sripairojkul and Adultrakoon (2000)[8]	58.1%	74.4%	32.6%	23.3%	9.3%	2.3%
Our cases	71.1%	70%	18.4%	20%	10.5%	10%

T/S: transverse and sigmoid sinus.

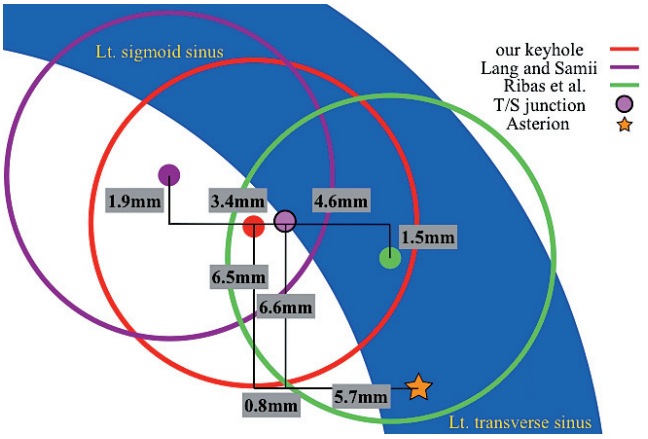

Fig. 5 Illustration of the results is shown in Table 3. Keyholes are shown in our cases (*red circle*), and in the models of Lang and Samii[2] (*purple circle*) and of Ribas et al.[4] (*green circle*). The asterion is illustrated as an orange star and the transverse and sigmoid sinus (T/S) junction as a pink dot. The distance between each keyhole position and T/S junction was shorter using the method described in the current study, as shown in Table 3.

sinus in 87% of cases, and caudal and rostral to the transverse sinus in 11% and 2%, respectively.[9] In our subjects, the asterion was positioned over the transverse sinus in 70% of cases on the right and 71.1% on the left, over the posterior fossa dura in 20% on the right and 18.4% on the left, and rostral to the transverse sinus in 10% on the right and 10.5% on the left. These results are similar to those found in the earlier studies.

There have been few studies on the distance between the predicted keyhole position and the actual T/S junction.[1] We usually position the keyhole lateral to the provisional burr hole, which is just caudal to the asterion by a half diameter of the burr hole. That is, the keyhole is both lateral and caudal to the asterion by a half diameter (6.5 mm) of the burr hole (Fig. 2). The current study showed that this prospective position for the keyhole is close to the actual T/S junction (Fig. 5).

We also measured the distances from the keyhole predicted by other methods and the T/S junction. Lang and Samii described the keyhole as lying approximately 30 mm from the Frankfurt horizontal plane (defined by the lowest point of the inferior orbital rim and the most superior point of the external acoustic meatus[2] (Fig. 3, Table 1), whereas Ribas et al. defined the keyhole to be 1 cm anterior to the asterion across the parietomastoid suture[4] (Fig. 4, Table 1). In these methods, they measured the distance between bony landmarks and the margin of the T/S, but these reports did not give the definition of the T/S junction. Using the Lang and Samii definition, the mean distances from the keyhole to the T/S junction were –3.4 mm (–17.2 to +13.8 mm; SD 3.3 mm) caudal and 1.9 mm (–12.5 to +11.8 mm; SD 3.5mm) lateral. Using the definition of Ribas et al.,[4] these distance were –4.6 mm (–5.7 to +12.9 mm; SD 3.7 mm) caudal and 1.5 mm (–13.0 to +14.4 mm; SD: 7.9 mm) lateral (Table 3, Fig. 5).

II. Where is the best keyhole position in a lateral suboccipital approach?

In this approach, it is important to expose the margin of the T/S safely and quickly. There are many ways to expose the margin of the T/S. We considered ideal if half of the T/S junction can be seen in the keyhole. We usually place the keyhole lateral to a provisional burr hole, which is just caudal to the asterion by half the diameter of the burr hole, because we think that half of the T/S junction can be seen in this prospective keyhole (Fig. 2). That is, the prospective keyhole is determined to be both lateral and caudal to the asterion by half the diameter (6.5 mm) of the burr hole (Fig. 5).

However, there is possibility that the T/S junction injured by placing the keyhole on the T/S junction. To avoid the sinus injury, some institutions expose the margin of the T/S by drilling. Sinus

Table 3 The distances from predicted keyhole position to the T/S junction

References		Caudal	Lateral
Lang and Samii (1991)[2]	Average 30 mm behind the suprameatal spine on the FHP	−3.4 ± 6.5	1.9 ± 3.5*
Ribas et al. (2005)[4]	1 cm anterior to the asterion across the parietomastoid suture	4.6 ± 3.7	−1.5 ± 7.9*
Our cases	6.5 mm inferior, 6.5 mm lateral to the asterion	−0.8 ± 3.3	0.1 ± 2.8

Values are means (mm) ± standard deviation (SD). *$p < 0.05$. FHP: Frankfurter horizontal plane.

injury will cause blood loss, air embolism, and sinus occlusion. Therefore, we need to recognize the risk of sinus injury, and to know the way to deal with sinus injury. Even if the way to expose the margin of the sinus is anything, it is important to predict where the T/S junction is from skull bony landmarks.

The asterion was originally thought to be a superficial landmark for the T/S junction, but this assumption is now considered to be unreliable. A number of methods have been proposed for prospective identification of the T/S junction from external skull bony landmarks other than the asterion,[1–3,5] including the mastoid groove, zygomatic arch, mastoid line, and the zygomatic line. However, we believe that these landmarks are also unreliable. It is difficult to approximate the mastoid groove and the mastoid line as straight lines, since these features are curved and tend to meander. It is also difficult to identify the zygomatic arch and zygomatic line before craniotomy because they are located outside the operative field in lateral suboccipital craniotomy. Therefore, these features are subjective landmarks and the error in using them to predict the actual T/S junction is likely to be greater than that in our method.

For comparison with our results, we chose two studies[2,4] in which the keyhole was predicted from external skull bony landmarks. Lang and Samii described the T/S junction as lying approximately 30 mm from the Frankfurt horizontal plane[2] and Ribas et al. defined the T/S junction to be 1 cm anterior to the asterion across the parietomastoid suture.[4] All the predicted keyhole positions using these methods were somewhat close to the actual T/S junction. In particular, the difference from the T/S junction for the comparator methods was lower in the axial plane, but larger in the sagittal plane. The reason for this difference is the quality of the external skull bony landmarks. The suprameatal spine can be clearly recognized on 3DCT images, but the Frankfurt horizontal plane tends to be shifted in the vertical direction when drawn on 3DCT images. Similarly, the asterion can be recognized clearly as a point, but it is difficult to approximate the parietomastoid suture as a straight line, since this feature tends to meander.

Regarding the relationship between the asterion and transverse sinus, the asterion was rostral to the transverse sinus in 10% of our cases, and was rostral to the transverse sinus by more than the diameter of a burr hole (13 mm) in 1%. That is, our keyhole would be completely rostral to the transverse sinus in 1% of cases. To obtain greater accuracy, we now modify our prospective keyhole position based on preoperative 3DCT images. These images provide the best approach to establishing the keyhole position with reference to the asterion in a lateral suboccipital approach, but 3DCT images may not always be available due to equipment problems, emergency cases, or allergy to contrast medium. Therefore, placement of a keyhole based on external skull bony landmarks is still a useful method.

As mentioned above, skull bony landmarks including the zygomatic arch, zygomatic line, tympanomastoid suture, spine of Henle, and external auditory meatus are located outside the operative field in the lateral suboccipital approach, and other landmarks cannot be identified during craniotomy. The suture line meanders inside the operative field and the difference from the actual T/S junction may be large in referring to the ridge of the mastoid process and superior nuchal line, since these are difficult to approximate as a straight line. In contrast, the asterion is a single point inside the operative field in the lateral suboccipital approach and can be observed just before craniotomy. Therefore, we utilize the asterion as an external skull bony landmark for prospective location of the T/S junction. This method is simple and was found to be more effective than the previous methods, based on the smaller difference between the predicted and actual positions of the T/S junction compared with the other methods.

Conclusion

We investigated the relationship between the positions of the T/S junction and asterion using 3DCT images. Placing the keyhole lateral to a provisional burr hole, which was just caudal to the asterion by a half diameter of the burr hole, was useful for exposure of the T/S junction. Ideally, 3DCT images should be taken in all cases, but this may not be possible due to equipment problems, emergency cases, or allergy to contrast medium. Thus, determination of the appropriate placement of a keyhole with reference to external skull bony landmarks is a useful methodology that is applicable to all cases.

Conflicts of Interest Disclosure

The authors have no conflict of interest or any financial disclosures to make. All authors who are members of the Japan Neurosurgical Society (JNS) have registered online self-reported COI Disclosures Statement Forms through the website for JNS members.

References

1) Day JD, Kellogg JX, Tschabitscher M, Fukushima T: Surface and superficial surgical anatomy of the posterolateral cranial base: significance for surgical planning and approach. *Neurosurgery* 38: 1079–1083; discussion 1083–1084, 1996
2) Lang J Jr, Samii A: Retrosigmoidal approach to the posterior cranial fossa. An anatomical study. *Acta Neurochir (Wien)* 111: 147–153, 1991
3) Day JD, Tschabitscher M: Anatomic position of the asterion. *Neurosurgery* 42: 198-199, 1998
4) Ribas GC, Rhoton AL Jr, Cruz OR, Peace D: Suboccipital burr holes and craniectomies. *Neurosurg Focus* 19: E1, 2005
5) Tubbs RS, Loukas M, Shoja MM, Bellew MP, Cohen-Gadol AA: Surface landmarks for the junction between the transverse and sigmoid sinuses: application of the "strategic" burr hole for suboccipital craniotomy. *Neurosurgery* 65(6 Suppl): 37–41; discussion 41, 2009
6) Rhoton AL Jr: The cerebellopontine angle and posterior fossa cranial nerves by the retrosigmoid approach. *Neurosurgery* 47(3 Suppl): S93–S129, 2000
7) Avci E, Kocaogullar Y, Fossett D, Caputy A: Lateral posterior fossa venous sinus relationships to surface landmarks. *Surg Neurol* 59: 392–397; discussion 397, 2003
8) Sripairojkul B, Adultrakoon A: Anatomical position of the asterion and its underlying structure. *J Med Assoc Thai* 83: 1112–1115, 2000
9) Ucerler H, Govsa F: Asterion as a surgical landmark for lateral cranial base approaches. *J Craniomaxillofac Surg* 34: 415–420, 2006
10) Gharabaghi A, Rosahl SK, Feigl GC, Safavi-Abbasi S, Mirzayan JM, Heckl S, Shahidi R, Tatagiba M, Samii M: Image-guided lateral suboccipital approach: part 2—impact on complication rates and operation times. *Neurosurgery* 62(3 Suppl 1): 24–29; discussion 29, 2008
11) Oishi M, Fukuda M, Saito A, Hiraishi T, Fuji Y: [Presurgical evaluaton for lateral suboccipital craniotomy using contrast-enhanced CT volumetric imaging]. *No Shinkei Geka* 37: 459–465, 2009 (Japanese)

Address reprint requests to: Yu Teranishi, MD, Department of Neurosurgery and Stroke Center, Tokyo Metropolitan Police Hospital, 4-22-1, Nakano, Nakano-ku, Tokyo 164-8512, Japan.
e-mail: eugeneterra@me.com