



## Muscle Insertion Line as a Simple Landmark To Identify the Transverse Sinus When Neuronavigation Is Unavailable

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■ **OBJECTIVE:** Skull opening in occipital and suboccipital regions might be associated with risk of damage to the transverse venous sinus and the confluence of sinuses. We analyze the value of magnetic resonance (MR) imaging in localizing the venous sinuses in relation to the superior muscle insertion line (MIL) on the occipital bone.

■ **METHODS:** We retrospectively analyzed head MR images of 100 consecutive patients imaged for any reason from 1 January 2013. All MR images were interpreted by a radiologist (R.K.). The superior MIL was identified at the midline and on both midpupillar lines, which represent the most frequent sites of skin incision and craniotomy (median and lateral suboccipital craniotomy, respectively).

■ **RESULTS:** Patients comprised 56 women (56%) and 44 men (44%). Their mean age was 54 (range 18–84) years. The muscles of the posterior skull were readily visible and clearly identified in both T1 and T2 images of all patients. Identification of the insertion zone and its relation to the venous structures was most readily made in the sagittal plane.

■ **CONCLUSION:** We found that the upper muscle insertion line on occipital bone corresponds to the underlying venous sinus and can be used as a reliable anatomic landmark. We identified it in 100% of preoperative MR images of heads with an intact occiput.

### INTRODUCTION

One of the most important steps in posterior cranium opening is localizing the dural venous sinuses. Intraoperative damage of the transverse sinus and confluence of sinuses may result in profuse bleeding and later thrombosis,

venous outflow disturbances, and increased intracranial pressure. When operating in a sitting position, inadvertent sinus opening causes air embolism. Modern frameless neuronavigation systems are useful in localizing venous sinuses before craniotomy, but they are not yet widely available due to high price. Furthermore, when surgery is performed in a sitting or prone position, some difficulties with neuronavigation may occur. Many studies have been conducted regarding the role of external skull bony landmarks in localization of posterior venous sinuses. Our study is the first to analyze a simple and effective way to localize the venous sinuses in relation to the superior muscle insertion line (MIL) on occipital bone. In this region, a surgical view after skin incision includes (from cephalad to caudal) the occipital bone surface, MIL, and muscles covered by the superficial layer of cervical fascia. Thus identifying the MIL is easy, and the neurosurgeon can confidently navigate further according to a corresponding finding on preoperative magnetic resonance imaging (MRI). The goal of this study was to show that MIL may be clearly identified in the preoperative MRI sagittal view and thus could be used as an anatomic landmark after skin incision in every particular case.

### METHODS

The study was carried out at the Neurosurgical Department of Helsinki University Central Hospital. We retrospectively analyzed head magnetic resonance images of 100 consecutive patients imaged for any reason. Cases included in the study comprised patients older than 18 years with no previous surgery in the posterior skull or neck region and with either a T1 or T2 sagittal view MRI (Signa 1.5T, GE Medical Systems, Wauwatosa, Wisconsin, USA) available. All magnetic resonance images were analyzed by a radiologist (R.K.). The superior muscle insertion line (MIL) was identified at the midline and on both midpupillar lines, which represent the most frequent sites of skin incision and craniotomy (median and lateral suboccipital craniotomy, respectively). To identify the relationships with underlying venous sinuses, we drew on MRI sagittal images an imaginary line through the MIL

### Key words

- Posterior craniotomy
- Muscle insertion
- Venous sinuses

### Abbreviations and Acronyms

- MIL:** Muscle insertion line
- MRI:** Magnetic resonance imaging
- SNL:** Superior nuchal line

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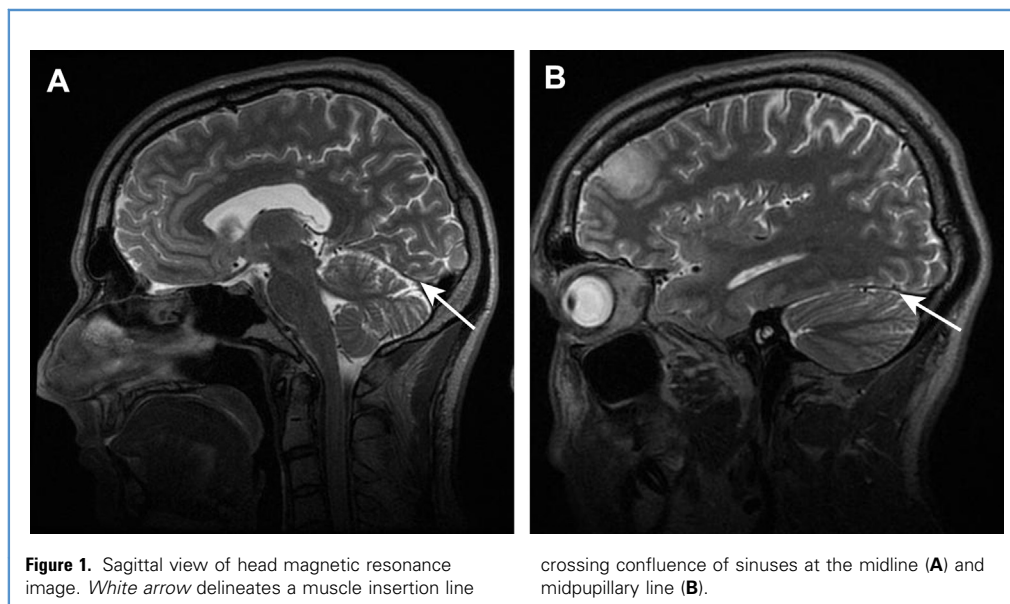
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perpendicular to the bone surface and measured the distance from this line to the upper and lower margins of the sinuses (Figure 1). This MIL passed the sinus in different manners: 1) under the lower margin of the sinus, 2) above the upper margin of the sinus, and 3) crossing the sinus.

Statistical analysis included univariate test (Pearson's  $\chi^2$  test) and used SPSS software for Windows, version 19.0 (SPSS, Inc., Chicago, Illinois, USA). The level of significance was set at  $P < 0.05$ .

## RESULTS

Patients comprised 56 women (56%) and 44 men (44%). Their mean age was 54 (range 18–84) years. MIL could be reliably identified on MRI in all patients. The muscles of the posterior skull were readily visible and clearly identified in both T1 and T2 images. Identification of the insertion zone and its relation to the venous structures was most conveniently made in the sagittal plane. For identification purposes, the use of contrast is unnecessary. The confluence of sinuses was visible in all patients, whereas the transverse sinus was unidentifiable on the left in 4 patients (4%) and on the right in 1 patient (1%). The MIL crossed the sinus in the midline most frequently, in 78 of 100 patients (78%), whereas on the right paramedian this was the case in 48 of 99 patients (48%) and on the left paramedian in 60 of 96 patients (63%). The MIL passed below the lower sinus margin in the midline in 14 cases (14%), on the right paramedian in 44 cases (44%), and on the left paramedian in 18 cases (19%) (Figure 2). Passing of the MIL above the upper margin of the sinus was uncommon, occurring in the midline in 8 cases (8%), on the right paramedian in 7 cases (7%), and on the left paramedian in 18 cases (19%) (Figure 3).

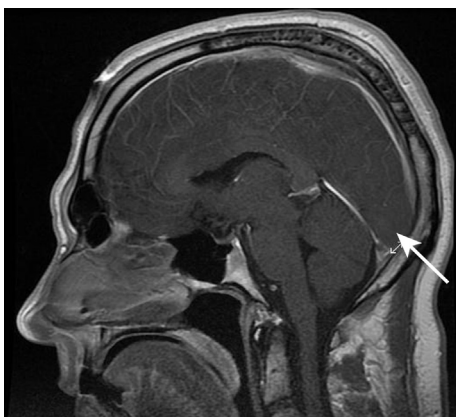
Neither sex nor age showed any correlation with the MIL relationship with venous sinuses. There were inverse correlations between midline and paramedian MIL locations; when it passed

below the sinus in the midline, it did not pass above the sinus on either the right ( $P = 0.004$ ) or left paramedian site ( $P = 0.037$ ). When the MIL passed above the sinus in the midline, it did not pass below the sinus on either the right or left paramedian.

## DISCUSSION

The muscle insertion line on occipital bone appears to be a simple and reliable anatomic landmark. It allows individualized localization of the posterior venous sinuses, which is crucial when performing a posterior craniotomy without neuronavigation. In the past, neurosurgeons have had to rely solely on anatomic data provided by cadaver measurements; however, these may vary significantly and cannot always be extrapolated to living persons.





**Figure 3.** Muscle insertion line (white) located above the venous sinus.

In accord with earlier cadaveric studies, we found that the relationship between MIL and the margins of the transverse sinus can vary.<sup>1</sup> We observed the MIL to cross the sinus (confluence) in the midline more frequently than the left or right paramedian sites (78% vs. 60% and 48%). Furthermore, passing of the MIL above the upper margin of the sinuses on the left was more than twice as frequent as on the right or on the midline (18% vs. 7% and 8%). When crossing the sinus, the median distance from the MIL to the upper and lower margins of sinuses varied from 3–5 mm. In the midline, MIL was commonly located at the level of the sinus, indicating that the burr hole(s) should be

placed at least 5 mm caudal or cranial to it depending on the intradural approach. At the paramedian site, the MIL level is more variable, but still more frequently located at the level of or below the transverse sinus.

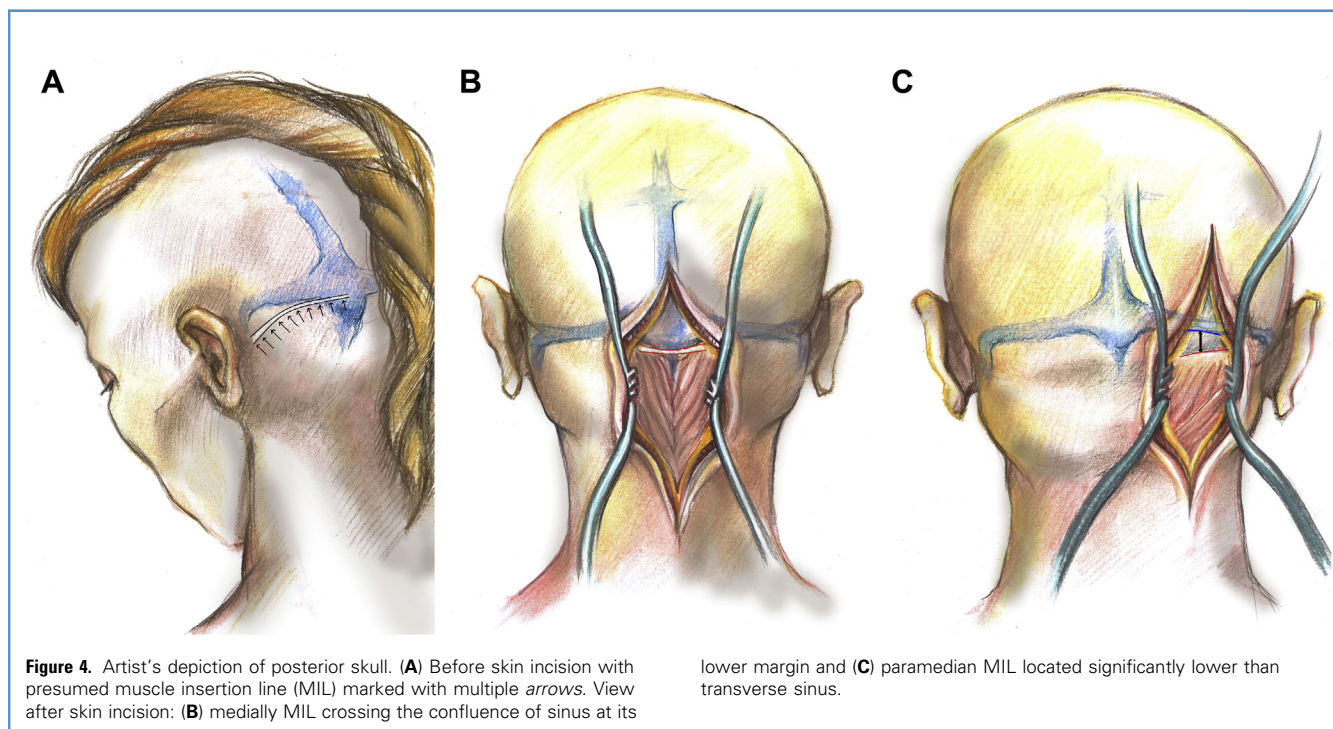
We were able to identify statistically significant correlation in MIL location at different sites of the occiput; when it passed below the sinus at the midline, it did not pass above the sinus on either the right or on the left paramedian site, and vice versa. This might be useful in large craniotomies in the occipital region when extended exposure of sinuses is planned.

Nowadays, the neurosurgeon deals with magnetic resonance images, which are more informative than cadaver measurements, showing unique anatomic features of living individuals. Careful analysis of the MRI anatomy in each case allows a tailored surgical plan to be created for every patient.

Modern microsurgery is based on principles of minimal invasiveness, including short skin incisions, smaller craniotomies, and cautious manipulations of brain tissue, saving the normal anatomy.<sup>2,3</sup> In view of these principles, a meticulous preoperative planning based on each individual's anatomic features is a cornerstone of the neurosurgical procedure.

### Surgical Anatomy

Skull opening in occipital and suboccipital regions might be associated with a risk of damage to the transverse venous sinus and the confluence of sinuses. This risk is higher in elderly patients, who typically have a very thin dura that is closely attached to the bone. Traditionally, the location of underlying transverse venous sinuses has been estimated on the basis of skeletotopic landmarks, including the asterion, inion, superior nuchal line (SNL), the line drawn from the squamosal-parietomastoid suture



**Figure 4.** Artist's depiction of posterior skull. (A) Before skin incision with presumed muscle insertion line (MIL) marked with multiple *arrows*. View after skin incision: (B) medially MIL crossing the confluence of sinus at its

lower margin and (C) paramedian MIL located significantly lower than transverse sinus.

junction to theinion, and the line drawn from the zygoma root to theinion.<sup>1,4-7</sup> Some authors recommend preoperative computed tomography (CT) or CT angiography to gain a better view of bony anatomy.<sup>7</sup> However, the drawbacks of skeletotopic orientation include 1) significant variations in location and appearance of bony prominences and sutures, 2) unreliable or misleading findings when palpating the occiput of obese or brawny patients, and 3) a limited view of neighboring bone surface structures after the short skin incision made in accordance with the principles of minimal invasiveness of modern neurosurgery. Despite a fairly clear view on preoperative CT images, occipital bone sutures might be unidentifiable on the surface of the skull during the actual surgery. Even in cadaver heads, the asterion could be identified in no more than 60% of cases.<sup>4</sup> The SNL is close to the underlying transverse sinuses, but nevertheless the anatomic relationship is variable and intraoperative spotting of the SNL is difficult and unreliable.<sup>1,8,9</sup> After skin incision and application of wound dilators, some shift of the scalp is typical, especially in obese patients, which may also hinder the surgeon's interpretation of visible bony sutures, prominences, and grooves. In inexperienced hands, this might cause problems in further steps of craniotomy, including disorientation in the craniocaudal direction with inappropriate placement of burr hole(s).

We evaluated the role of MIL—a simple anatomic landmark—in navigating in the occipital region and avoiding sinus damage during craniotomy (Figure 4, A–C). The role of the superior MIL as a useful intraoperative landmark has been emphasized in a report by Tubbs et al.<sup>10</sup> However, their study was performed on cadavers with a sample size of only 15 heads. Moreover, the authors focused on only the medial part of the transverse sinus and the musculus semispinalis capitus, whereas some parts of the musculus trapezius and the musculus splenius capitus were removed bilaterally.

In our study, we focused on the relationship between MIL and the internal venous sinuses based only on MRI view because in the vast majority of cases, preoperative diagnostics of intracranial pathology is performed with this modality. In analysis of 100 consecutive head MRI studies of adult patients with an intact occipital region, we were able to identify MIL in every case, evaluating its relationship with the underlying venous sinuses when present.

### Practical Use

With the advent of frameless neuronavigation, the planning of craniotomy has become simpler and more reliable. Utilization of neuronavigators with the patient in supine position is usually helpful, but in prone or sitting positions it may be associated with mismatching and failures in navigating. Furthermore, the exceptionally high price of these systems limits their routine use in hospitals worldwide. Thus meticulous preoperative planning based on magnetic resonance images remains a critical component of a successful surgery. At our department, every step of the operation is planned according to our paradigm of surgery to be simple and fast and to preserve normal anatomy.<sup>2,3</sup> We believe that use of MIL to localize the transverse sinuses can significantly facilitate the posterior approach.

### CONCLUSIONS

Appropriate craniotomy site based on preoperative planning is crucial for successful surgery. Upper MIL on the occipital bone corresponds to the underlying venous sinus and can be used as a reliable anatomic landmark. In our study, it was identified in 100% of preoperative magnetic resonance images of heads with an intact occiput. Further studies on use of MIL as an intraoperative landmark are justified.

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