Real-Time Ultrasound Doppler Enhances Precision in Image-Guided Approaches to the Cerebellopontine Angle

Davit Baghdasaryan[1,2], Marcel Albrecht[1], Mihr Shahnazaryan[1], Steffen Rosahl[1]

OBJECTIVE: **To evaluate efficacy and reliability of intraoperative Doppler sonography in localizing the transverse and sigmoid sinuses during lateral suboccipital craniotomy.**

METHODS: **A 16-Mhz intraoperative micro-Doppler ultrasound (16Mhz, Multi-Dop pro, Compumedics, Singen, Germany) was applied to detect the medial border of the sigmoid sinus and the inferior border of the transverse sinus in 25 patients. Micro-Doppler measurements were compared with magnetic resonance- and computed tomography-based image guidance (Kolibri, Brainlab, Munich, Germany). Visual detectability of the sinuses with the operating microscope was also documented.**

RESULTS: **Inadvertent incision of the transverse or sigmoid sinuses did not occur in any patient when the 2 localizing methods have been used in combination. The mean mismatch of image-guided system and micro-Doppler was 2.64 mm (range, 0–6 mm; standard deviation, 1.55 mm). With the microscope the transverse sinus was invisible in 7 patients, the sigmoid sinus was visually undetectable in 1 case. The micro-Doppler indicated blood flow outside the visible borders of the sinuses in 5 patients.**

CONCLUSIONS: **A combination of image-guidance and micro-Doppler enhances the accuracy in localizing the margins of the transverse and sigmoid sinuses using the retrosigmoid approach, thus preventing inadvertent injury. The method could potentially be applied during other craniotomies involving the exposure of a venous sinus.**

INTRODUCTION

The retrosigmoid or lateral suboccipital craniotomy is a standard procedure to approach lesions in the cerebellopontine angle. The superior and medial borders of the craniotomy are the transverse and sigmoid sinuses, respectively. In the semisitting position, injury to these anatomic structures bears a risk of venous air embolism and potentially lethal outcome. The asterion (i.e., the junction of the lambdoid, temporooccipital, and occipitomastoid bone sutures) is not a safe outer landmark to determine the transition of the transverse to the sigmoid sinus inside the skull, as this junction may vary by as much as 10 mm in location (**Figure 1A**).[1,2]

The venous sinuses can be flat and covered by thick dural layers rendering them invisible with the microscope. We have previously seen that with the assistance of image guidance systems during retrosigmoid craniotomy, the rate of venous sinus injury and venous air embolism decreased to 8% and 4%, respectively, compared with 15% and 19% without neuronavigation.[3] The margins of error of current image guidance systems used in daily routine do not allow for further improvement. Doppler sonography has been used as an online tool in vascular neurosurgery primarily to detect and measure blood flow in arterial vessels.

The purpose of this study was to evaluate the feasibility and reliability of intraoperative micro-Doppler guidance to locate the transverse and sigmoid sinuses during retrosigmoid approaches.

PATIENTS AND METHODS

A total of 25 patients undergoing surgery for lesions in the cerebellopontine angle were selected for the study. An image guidance system (Kolibri, Brainlab, Munich, Germany) and an intraoperative Doppler ultrasound system equipped with a 1-mm diameter 16 Mhz sonography probe (Multi-Dop pro,

Key words
- Craniotomy
- Image guidance
- Micro-Doppler
- Retrosigmoid approach

From the [1]Department of Neurosurgery, HELIOS Klinikum Erfurt, Erfurt, Germany; and [2]Department of Neurosurgery, Yerevan State Medical University, Yerevan, Armenia

To whom correspondence should be addressed: Davit Baghdasaryan, M.D. [E-mail: d.baghd86@gmail.com]

Citation: World Neurosurg. (2017) 107:482-487.
http://dx.doi.org/10.1016/j.wneu.2017.08.003

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***

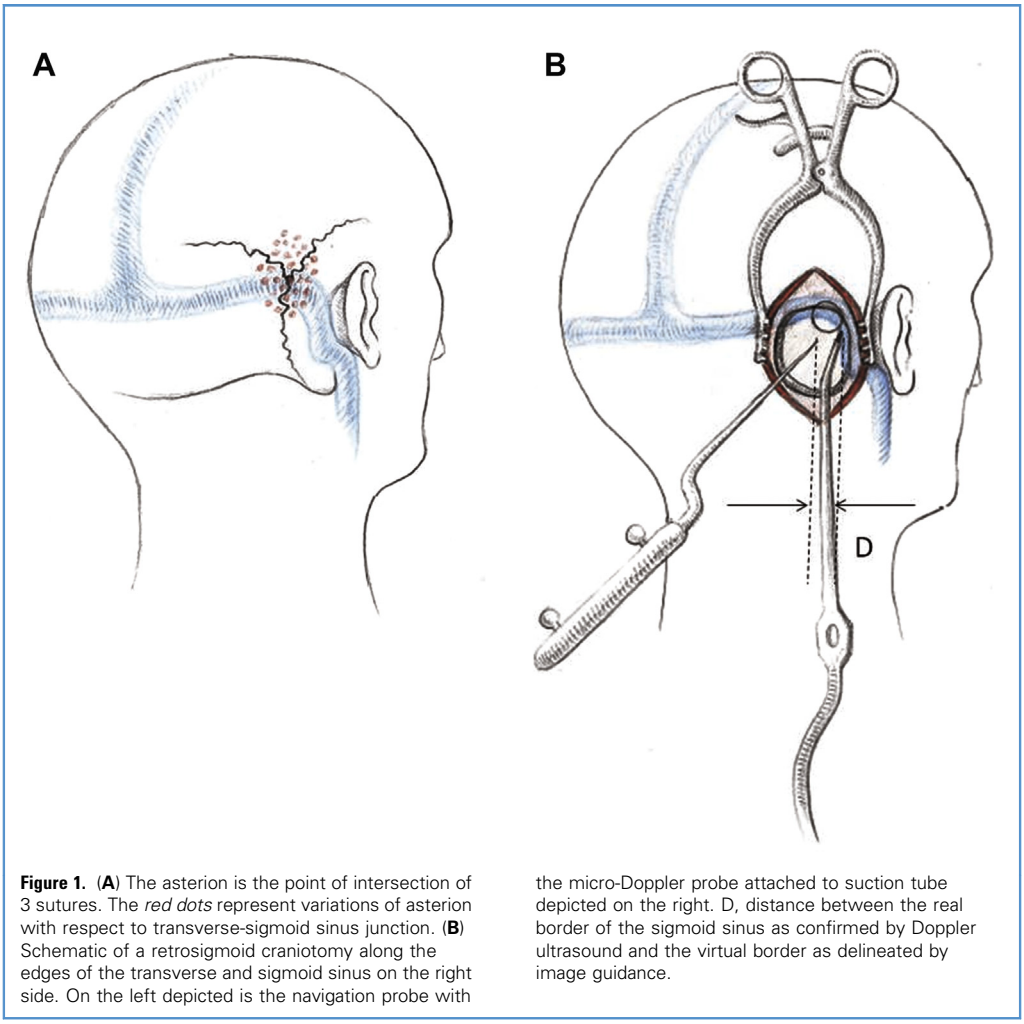

Figure 1. (**A**) The asterion is the point of intersection of 3 sutures. The *red dots* represent variations of asterion with respect to transverse-sigmoid sinus junction. (**B**) Schematic of a retrosigmoid craniotomy along the edges of the transverse and sigmoid sinus on the right side. On the left depicted is the navigation probe with the micro-Doppler probe attached to suction tube depicted on the right. D, distance between the real border of the sigmoid sinus as confirmed by Doppler ultrasound and the virtual border as delineated by image guidance.

Compumedics, Singen, Germany) were used to locate the transverse-sigmoid venous complex. The micro-Doppler probe was attached to a neuronavigation pointer in search for the venous sinuses after craniotomy with an insonation angle of 30–60 degrees (Figure 2C, D). The depth of optimal ultrasound penetration was set at 2 mm, resulting in a spatial accuracy of 1 mm when the mean thickness of the dura mater was subtracted.

Ultrasound was applied after the first burr and after completion of the craniotomy before incision of the dura (Figure 2C, D). The ultrasound-guided search for the sinuses started from the upper and medial margin of the burr hole. Upon completion of the craniotomy, the micro-Doppler was used once more to delineate the borders of both sinuses before the dura incision was made along these borders with a distance of about 2 mm. If venous pressure was below zero in cases with the patient in a semisitting position, jugular compression was applied to increase the Doppler signal.

Image guidance was used to locate the appropriate position of the first burr hole and was further employed throughout the procedure (Figure 2A–D).

Intraoperative signals were evaluated according to flow velocities as well as their visual and acoustic characteristics. The signals were distinguished as regular, irregular, or absent.

The mean and maximum errors of the image guidance system were calculated from the measured distance between the location of the sinuses, as indicated by the image guidance system, and the real location, as indicated by the Doppler probe after completion of the craniotomy (Figures 1 and 2). The appearance of the sinuses with the operating microscope was recorded. Finally, the time required to prepare and apply image guidance and ultrasound Doppler was measured.

RESULTS

The exact location of the transverse sinus was invisible in 7 patients, whereas the sigmoid sinus was visually undetectable in 1 case.

Inadvertent incision of the transverse or sigmoid sinus did not occur in any patient when the 2 localizing methods had been used in combination.

In most patients sinus venous signals had a typical low pitched sound ("blowing breeze"). The difference between maximal systolic and diastolic velocities in the sigmoid sinus did not exceed 5 cm/s. Higher pitch sounds on the sinuses also did occur and in 1 patient a cerebellar artery, just inferior to the transverse sinus, mimicked a typical blood flow signal in the sinus. This artifact