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Insonation angle impact on micro-Doppler evaluation in cerebrovascular surgery: technical note

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Abstract

Introduction: The insonation angle consideration is important in the Doppler-sonographic evaluation of blood flow velocities and volume, however, the concept is rarely applied to the intraoperatively used micro-Doppler.

This technical note aims to emphasize the possibility and necessity of insonation angle correction and preservation for the blood flow assessment in cerebrovascular surgery.

Methods: Bi-directional surgical Doppler with a 20MHz flexible bayonet 1.2mm diameter probe was used for the intraoperative blood flow assessment, with the variable insonation angle on the straight parts of the arteries, and the results were recorded to demonstrate the importance.

Results: The measurements performed confirmed that the blood flow features, including the direction, velocity, and especially the volume, are highly susceptible to the insonation angle variations. Although there were significant alterations, positioning the probe at an angle of ~60 degrees resulted in the variable but less altering measurements.

Conclusion: Positioning the probe at ~60 degrees is desirable; however, it appears that it is even more important to maintain the same insonation angle and probe position when assessing the vessels repeatedly for blood flow alterations that might occur in the course of cerebrovascular surgery.

Keywords: micro-Doppler; insonation angle; cerebrovascular surgery

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Introduction

Intraoperative micro-Doppler blood flow evaluation is one of the most useful tools in cerebrovascular surgery[1], allowing to recognize inadvertent vessel narrowing, or incomplete aneurysm occlusion[2,3], bypass effects and patency[4], and perform stepwise AVM elimination[5]. In order to obtain relevant measurement results, at least the basics of micro-Doppler use should be mastered.

The insonation angle consideration is indispensable in evaluation of normal values, physiological variations, as well as in the evaluation of pathological findings of blood flow velocities in Doppler examination[6,7]. Inappropriate Doppler-sonographic measurement may lead to the false satisfactory results, due to the insonation angle differences between examinations, leading to the oversight of the blood flow disturbance, or deeming the altered blood flow appropriate[8].

Transcranial color-coded duplex sonography (TCCD) introduced simultaneous visualization of the vessels in color, together with Doppler measurement of blood flow velocities and made the correction of the insonation angle possible, resulting in more realistic values of flow velocities for intracranial arteries. After several papers emphasized the importance of the insonation angle[6,8,9], the function to adjust insonation angle was added to almost every ultrasound system.

On the other hand, not much attention was drawn to the concept in the intraoperative use of micro-Doppler. With a clear view of the vessels to be examined it was rarely considered in the literature, while the devices used do not allow for the adjustment of the insonation angle by software means[10]. In the recent study, neuronavigation was used to perform the insonation at an appropriate insonation angle[11].

This technical note aims to emphasize the possibility and necessity of insonation angle correction during the intraoperative cerebral blood vessel assessment, without any additional burden.

Methods

Micro-Doppler sonography is routinely used in our department for all cerebrovascular cases undergoing surgery for aneurysm, arteriovenous malformation or dural arteriovenous fistula, as well as those receiving a bypass surgery for any underlying pathology[5,12].

Bi-directional surgical Doppler DVM 4300 with a 20MHz flexible bayonet 1.2mm diameter probe (Hadeco, Kawasaki, Japan) was used for the intraoperative blood flow assessment, while watery fluid environment was provided by the probe and vessels irrigation flushing.

Since the probe placement at the position for the measurement of maximum (real) velocity is usually impossible (0 degrees in relation to the blood flow direction), in clinical settings, it is usually recommended to strive towards ~60 degrees angle of insonation[13].

For the purpose of this technical note, the blood flow was evaluated with the variable insonation angle varying from 30 to 150 degrees to the blood flow direction, on the straight parts of the arteries and the results were recorded to demonstrate the importance, while the velocity of ~0, notable at 90 degrees was used to emphasize this feature[14]. ***(Figure 1)***.

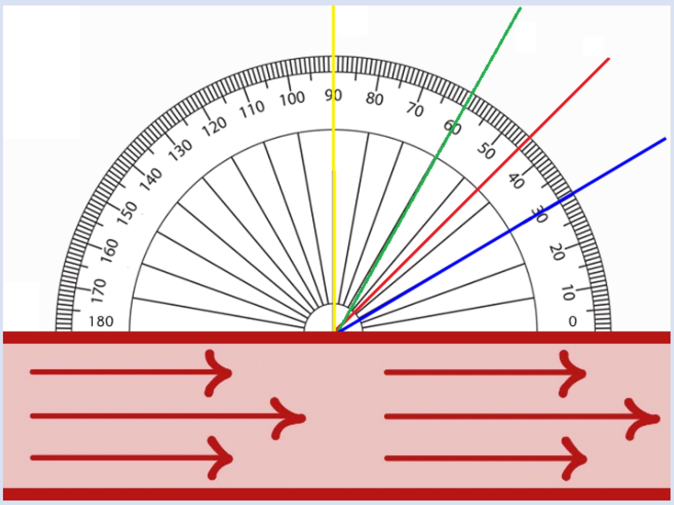

Figure 1. Various positionings of the micro-Doppler probe to the blood flow within the vessel

Results

The measurements performed confirmed that the blood flow features, including the direction velocity, and especially the volume is highly susceptible to the insonation angle variations.

The velocity direction varied when the probe was aligned at an angle towards the flow, and when aligned opposite to the expected flow direction (<90 and >90 degrees respectively).

Minimal blood flow velocity values (+5 to –5 cm/s) were measured when the probe was placed at ~90 degrees to the vessel flow, while the velocities of up to 50cm/s were measured when the probe was placed at 45-60 degrees. These differences appear even more accentuated when considering the volumes with variations ranging from 10 to more than 200 ml/s with these same insonation angle placements (***Figure 2***).

Although there were significant alterations, in consistency with the previous study[14], positioning the probe at an angle anywhere between 45-60 degrees resulted in the variable but less altering measurements.

Discussion

Digital subtractional angiography is a gold standard in the blood flow evaluation in cerebrovascular surgery, however, it is ergonomically and economically disadvantaged, and time-consuming. Indocyanine green (ICG) videoangiography appears as a rightfull successor, but ICG-videoangiography is not able to replace micro-Doppler, as it cannot determine the velocity characteristics of the blood flow. Moreover, micro-Doppler sonography remains frequently used mainly due to the ease of use, repeatability, and time efficiency[15].

The velocity, measured by Doppler ultrasound systems, is physically dependent on the cosine function of the angle between the blood flow and the direction of the ultrasound emitted by the probe. The cosine of a 90-degree angle is zero, therefore, measuring velocities at an angle close to 90 degrees gives falsely low values of blood flow velocities[16].

With the introduction of Duplex sonography, which implies the simultaneous application of imaging (2D or B-mode) simultaneously with Doppler, and especially after the introduction of color Doppler (Triplex), the possibility of correcting the insonation angle based on the imaging of the blood vessel and the direction of the Doppler beam was obtained. With the feature introduction, awareness was raised, and nowadays, angle of insonation implementation is considered a common practice in transcranial Doppler-sonography[17].

Although intraoperative use allows for the direct visual control of the angle of insonation, there are a few features, which usually limit the micro-Doppler probe manipulation, namely the constrained operative field (limited by the size of craniotomy, extent of Sylvian fissure dissection, brain edema) and the microscope use, with altered visualization planes, leading to the inaccuracies when considering a certain angle is achieved[18] (***Figure 2***).

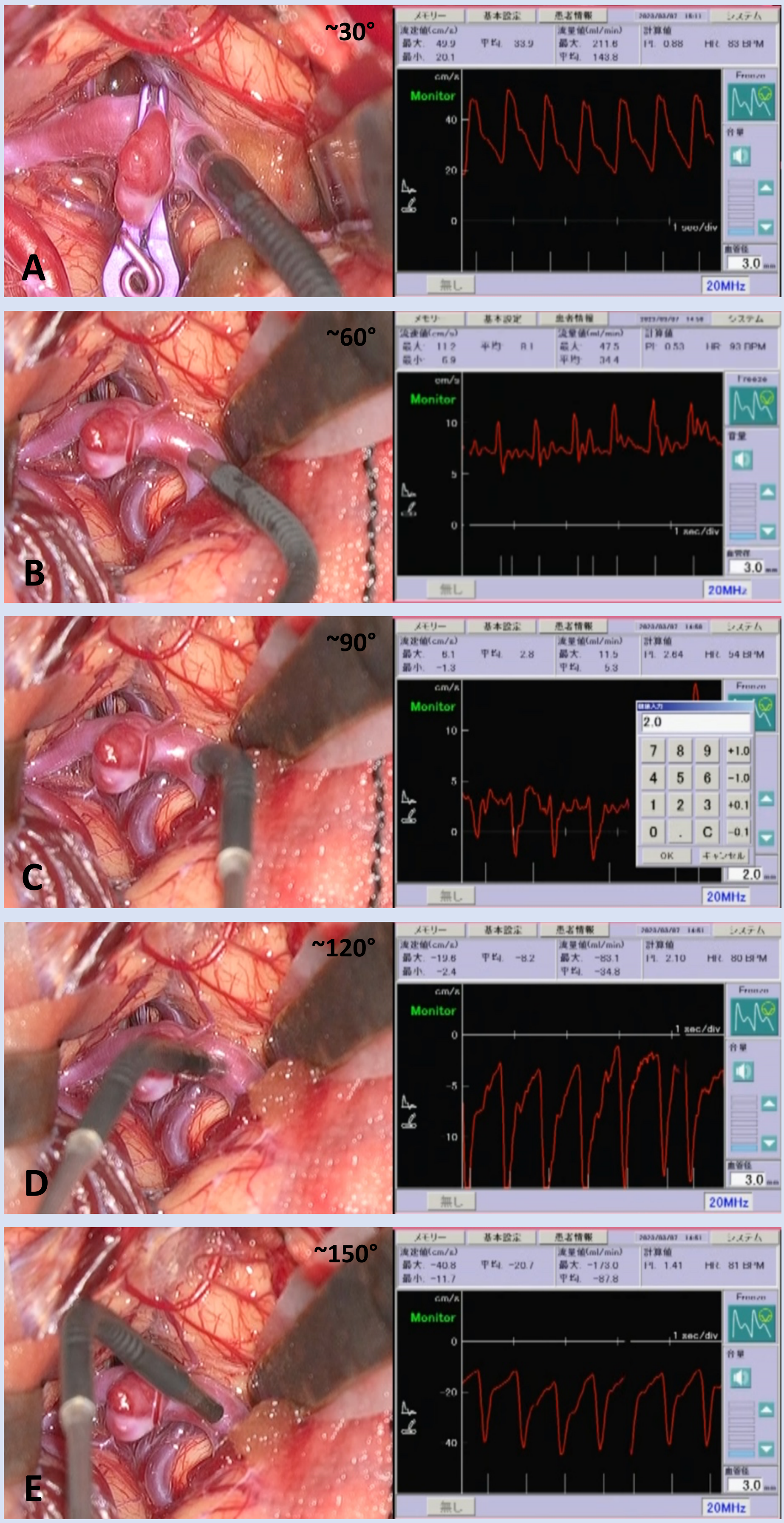

Figure 2. Various angles of insonation used for the same artery assessment showing significant variability of blood flow velocities and volumes, at the: A. ~30; B. ~60; C. ~90; D. 120; and E. 150; degrees insonation angles. Note the inaccuracy in angle perception.

To overcome these the limitations related to the operative field, as the features should not be corrected purely to accommodate micro-Doppler probe, achieving the desired angle may turn out to be impossible, it is important to maintain a same (or similar, at least) angle in the two measurements. In our experience, it is usually useful to lean the probe against the brain parenchyma, dura, or bony surface while keeping the same spot on the vessel when replacing the probe. The accuracy of replacement could be further improved with dye markings on the vessel wall.

As it was previously reported, the variations of the blood flow velocity and volume vary significantly between 0-90 degrees, however, for the same inaccuracies of 10 degrees, the differences are less pronounced when the desired angle is about 60 degrees, when compared to 80 or 30[14]. Another possibility is use of the negative (mirror) flow measurement, when the probe is placed >90 degrees, to achieve better positioning and more favorable angle by the utilization of the wider space on the contralateral side.

Finally, to overcome the microscope related inaccuracy, it is always possible to position the probe under naked-eye, however, this manipulation might be dangerous, and it could get complicated in those without 20/20 vision, when using microscope diopter adjustment feature for vision correction. Nevertheless, when used in an exoscopic environment, the chances of an error diminish.

Conclusion

Based on the previous recommendations and our experience it is usually most appropriate to position the probe at ~60 degrees, however, it appears that it is even more important to maintain the same insonation angle and probe position when assessing the vessels repeatedly to capture the valid blood flow alterations that might occur in the course of cerebrovascular surgery.

Disclosures

Conflict of Interest: All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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