Virtual Navigator study: Subset of preliminary data about cerebral venous circulation

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\textbf{KEYWORDS}
Virtual Navigator; Fusion imaging; Cerebral veins; Transcranial; TCCS; Transverse sinus

\textbf{Summary}
\textit{Introduction:} Neuroradiological techniques are known for their high spatial resolution in imaging of intracranial structures, in comparison with neurosonological techniques (TCCS), known for their high temporal resolution. An ideal study of intracranial circulation should combine the high temporal resolution of ultrasound with the high spatial resolution of Magnetic Resonance (MR) Imaging. This imaging fusion system is actually used for the ultrasound liver examination and it is known as Virtual Navigator. Therefore we implemented this system for the examination of the intracranial venous hemodynamics.

\textit{Patients and methods:} Fifteen consecutive subjects (7 men and 8 women, mean age 51.5 ± 8.64 years) were chosen among patients who underwent standard TCCS examinations at our lab and had age >18 years, a suitable temporal acoustic window and a recently performed intracranial MR venography. The axial scanning approach was used from the temporal window and the standard TCCS examination was compared with the Virtual Navigator examination, for the insonation rate of the basal vein of Rosenthal (BVR), Galen vein (GV), Straight sinus (SRS) and Transverse sinus (TS).

\textit{Results and discussion:} The insonation rates of the venous structures are only slightly improved for BVR (from 90% to 96.67%) but are substantially increased for SRS and TS (for this last one from 63.33% to 86.67%) with a statistically significant difference ($p < 0.05$).

\textit{Conclusions:} The Virtual Navigator protocol can help to insonate the intracranial venous system.

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\textit{Abbreviations:} BVR, Basal vein of rosenthal; CT, Computed tomography; GV, Galen vein; MRI, Magnetic Resonance Imaging; SRS, Straight sinus; TCCS, Transcranial color-coded sonography; TS, Transverse sinus.

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Introduction

Ultrasound techniques have an high dynamicity and therefore a good temporal resolution. Instead neuroradiological techniques have an high anatomic definition and therefore a good spatial resolution. The possibility of combining the ultrasound examination with a reference modality and to fuse this data set with the ultrasound scan could improve the understanding of the current scan situation in real time. This combination of two diagnostic modalities may result is a faster and more reliable procedure. The Virtual Navigator allows the real-time visualization of the ultrasound scan next to the corresponding virtual slices obtained from other modalities. Its purpose is to enhance the informative content of images produced by an ultrasound scanner by combining them with a second modality in real-time, so combining the high temporal resolution of ultrasound techniques and the high spatial resolution of CT/MR techniques.

This fusion imaging software has been used in extra-neurological applications, as abdominal ultrasound and in this setting it demonstrated a good reliability and a great improvement of focal lesion monitoring and treatment and of their identification.

Neurovascular application is in a pioneering phase even for the brain arterial circulation. Ultrasound examination of cerebral veins is a harder challenge than the one of the cerebral arteries, both for the basal scanning and for the fusion imaging technique. Particularly straight sinus and transverse sinus have a relatively low insonation rate.

The insonation rates of the main cerebral veins reported in the literature by using TCCS are [1,2]:
- BVR 84—93%
- GV 66—91%
- SRS 48—86%
- TS 35—73%

We planned this preliminary approach with the Virtual Navigator system to verify the feasibility of this strategy to increase the insonation rate of the main basal cerebral veins.

Patients and methods

Fifteen consecutive subjects (7 men and 8 women, mean age 51.5 ± 8.64 years) were chosen among patients who underwent standard TCCS examinations at our lab and had
- age >18 years
- a suitable temporal acoustic window for the arterial examination
- a recently performed intracranial MR angiography with normal venous findings.

All subjects did not have a disease of the venous system and the reasons why they underwent MRI were mainly migraine or dizziness or a control examination of a previously known nonspecific lesion pattern in the white matter.

All patients underwent a basal TCCS examination and a subsequent TCCS examination with the Virtual Navigator system. The axial scanning approach was used by TCCS from the temporal window, according to the validated scanning planes for the venous study, for the insonation of the BVR, GV, SRS and TS [2—5]. According to the reference data from
the literature, only the contralateral approach to the TS was used for this evaluation. A schematic drawing of the assessed cerebral veins and sinuses with the corresponding TCCS images is shown in Fig. 1.

The insonation rate of the BVR, GV, SRS and TS were registered both for the basal examination and for the Virtual Navigator system examination and they were compared by Mantel–Haenszel Chi-square for trend.

Experimental

Virtual Navigator is a MyLab optional license from Esaote, that provides additional image information from a second modality like CT or MR, during a clinical ultrasound session. By using the second modality the user gains security in assessing the morphology of the ultrasound image.

The Virtual Navigator system is inserted into a commercially available ultrasound machine and its use involved some sequential steps. First, the MR study was uploaded in the ultrasound platform and the Virtual Navigation software was activated. Second, the ultrasound examination was started and matched with the MR images by using a magnetic tracking system, solidary with the ultrasound probe, along a reference alignment plane. Third, the standard TCCS examination was compared with the Virtual Navigator examination, according to the validated scanning planes for the venous study, for the insonation rate of the BVR, GV, SRS and TS [2,5].

The exam steps are summarized as follows:

- CT/MR acquisition
- Data transferring and loading
- Automatic volume elaboration on the US
- Registration
- One scan plane
- Anatomical markers
- Real-time combined scanning
Table 1

<table>
<thead>
<tr>
<th>Insonated veins</th>
<th>Insonation rate (%)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basal examination</td>
<td>Virtual Navigator exam</td>
</tr>
<tr>
<td>BVR</td>
<td>26/30 (90)</td>
<td>29/30 (96.67)</td>
</tr>
<tr>
<td>GV</td>
<td>13/15 (86.67)</td>
<td>15/15 (100)</td>
</tr>
<tr>
<td>SRS</td>
<td>10/15 (66.67)</td>
<td>15/15 (100)</td>
</tr>
<tr>
<td>TS</td>
<td>19/30 (63.33)</td>
<td>26/30 (86.67)</td>
</tr>
</tbody>
</table>

In Fig. 2 there is an example of the Virtual Navigator application for the arterial circulation and in Fig. 3 the practical steps of the examination are illustrated for the venous examination.

Results

For the purposes of the comparison between the basal and fusion imaging insonation rate of the BVR, GV, SRS, TS, few assumptions should be made: first, BVR and TS are paired structures, therefore the insonation rate take into account both sides of TCCS examination (30 TS); second, GV and SRS are unpaired structures, therefore 15 veins had to be insonated.

The basal and Virtual Navigator system insonation rate are reported in Table 1, with the p value of the Chi-square for trend. The comparison between the basal insonation rate and the Virtual Navigator insonation rate showed a significant difference for the SRS (p=0.016) and for the TS (p=0.038).

Discussion

The application of the Virtual Navigator system for brain imaging has been initially tried in neurosurgery, during the surgical procedure. In this condition the ultrasound study is easy, because of the removal of the skull bone, but the real-time ultrasound images without the skull bone are not always perfectly correspondent to the neuroradiological slices, achieved before skull removal. Moreover, TCCS gives access to a limited portion of the brain anatomy thought an intact skull, but the standard insonation planes are suitable for the imaging of main intracranial arteries and veins. Its main limitation is the quality of the temporal bone window; because a suboptimal window does not allow the visualization of all intracranial large vessels. Our hypothesis is that the use of a second imaging modality as a reference could increase the number of Doppler-sampled segments of the intracranial veins and sinuses in comparison with the basal insonation rate.

Instead of acquire brain MR with surface external magnetic landmarks, as in abdominal imaging, for a better

Figure 3 Description of the three main practical steps for the TCCS insonation of the cerebral veins with the Virtual Navigator system. The third step shows an example of the insonation of the contrilateral TS.
coupling between ultrasound and radiological study, a previously performed standard brain MRI was uploaded into the machine platform. The coupling of the ultrasound planes with the corresponding reconstructed oblique MR planes was manually performed in a reference plane and the sonologist checked it in real time in the axial scanning planes. The landmarks to be correspondent in the two imaging modalities were: the petrous edge in the pontine plane, the mesencephalon and the edge of sphenoid wing in the midbrain plane, and the third ventricle and the epiphysis in the diencephalic plane. The following step was to assess the correct locking of ultrasound and MRI in coronal scanning planes.

Our basal insonation data were similar to the insonation rates reported in the literature [1,2]. The insonation rate with the Virtual Navigator system improved for all examined segments, with a significant value for SRS and TS. The insonation rate of 96.67% for the BVR is in agreement with the anatomic data about 5.6% of BVR draining into the lateral mesencephalic vein [6].

The improvement of the insonation rate of the TS is good, although only the contralateral approach was used and it is possible that adding the ipsilateral approach could cause a further improvement of the insonation rate, particularly for hypoplasic sinuses.

Conclusions

The possibility of combining the ultrasound examination with a reference modality in real time can improve the identification of the main cerebral vein and sinuses, therefore increasing their insonation rate. The result is an increase in reliability of the ultrasound examination, also multiplying the scanning planes with the guide of the neuroradiological reconstructed planes.

References