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Image-guided transcranial Doppler sonography for monitoring of vasospasm after subarachnoid hemorrhage

A. Neulen[a,*], E. Prokesch[a], M. Stein[a], J. König[b], A. Giese[a]

[a] Department of Neurosurgery, University Medical Center, Johannes-Gutenberg-University of Mainz, Langenbeckstrasse 1, 55131 Mainz, Germany
[b] Institute of Medical Biostatistics, Epidemiology and Informatics (IMBEI), University Medical Center, Johannes-Gutenberg-University of Mainz, Obere Zahlbacher Straße 69, 55131 Mainz, Germany

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ABSTRACT

Objectives: Transcranial Doppler ultrasound (TCD) is a standard method for bedside vasospasm monitoring after subarachnoid hemorrhage (SAH). Image guidance has previously been shown to reduce intra- and interobserver variability of this method. The aim of the present study was to compare image-guided and conventional TCD in vasospasm monitoring after SAH.
Patients and methods: 418 TCD exams of 24 consecutive SAH patients registered in a database were evaluated. Of these, 130 image-guided exams were identified which had been performed on the same day as conventional Doppler exams. These matched pairs were taken for statistical analysis. Data were tested statistically using the sign test applied at patient level to aggregated data.
Results: The rate of complete exams (both M1, A1, P1 segments) was significantly higher in image-guided exams (92% vs. 74%, $p < 0.001$), and the superiority of image-guided exams was significantly related to smaller sizes of the temporal bone window. There were more exams with Doppler sonographic vasospasm (mean flow velocity > 120 cm/s) in image-guided exams (38% vs. 33%) which, however, did not reach statistical significance.
Conclusion: Image-guidance leads to a standardization of serial TCD exams, which resulted in significantly more complete exams, most prominent in patients with poor temporal bone windows, and a higher detection rate of Doppler sonographic vasospasms. Image-guided TCD therefore has the capability to improve bedside vasospasm monitoring after SAH.

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1. Introduction

Spontaneous subarachnoid hemorrhage (SAH), mostly caused by rupture of an intracranial aneurysm, is a frequent clinical case in neurosurgical intensive care. Posthemorrhagic cerebral vasospasm (CVS), which may lead to cerebral infarctions, is a major factor influencing morbidity, mortality, and patient outcome [1]. It frequently occurs during the first 2 weeks after SAH, with a higher incidence in young patients [2]. Early recognition of CVS allows timely treatment and, in this way, has the potential to improve patient outcome.

Commonly, transcranial Doppler sonography (TCD) is used for bedside monitoring of SAH patients for elevated blood flow velocities, which correlate with angiographic vasospasm with high sensitivity and specificity [1,3]. However, disadvantages of the method are (i) missing bone windows in a subset of patients [4,5], and (ii) its high intra- and interinvestigator variability, especially in inexperienced investigators [6]. We and others have previously reported that image guidance systems, which are used in many neurosurgical facilities for intraoperative neuronavigation, offer the possibility of "guided" TCD exams by registering the position of the patients head and tracking the Doppler probe [7–11]. In this way the positions of Doppler probe and sample volume can be displayed real-time based on previously acquired volume imaging data. This allows reproducible detection of intracranial arterial segments through defined bone windows in serial exams and therefore has the potential to reduce the rate of missing bone windows as well as intra- and interinvestigator variations. However, CVS monitoring after SAH with image-guided or conventional TCD have not been compared.

The aim of the present study was therefore to analyze conventional and image-guided TCD used for CVS monitoring of SAH patients regarding (i) detection rates of Doppler sonographic vasospasm, (ii) completeness of exams, and (iii) influence of the temporal bone window in an observational study.

* Corresponding author.
E-mail address: axel.neulen@unimedizin-mainz.de (A. Neulen).

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2. Methods

2.1. Patient population

Patients with SAH who were admitted to the neurosurgical ICU of the University Hospital of Mainz, Germany between 01 October 2011 and 31 March 2012 and received image-guided and conventional TCD exams for CVS monitoring were included. This observation period was chosen for the present study since, during this time, image-guided and conventional TCD were used in parallel. All TCD reports were filed prospectively in a database. The diagnosis of SAH was made by CT scanning and the source of hemorrhage was confirmed by CT-angiography and subsequent digital subtraction angiography. Aneurysms were treated within 24 h by

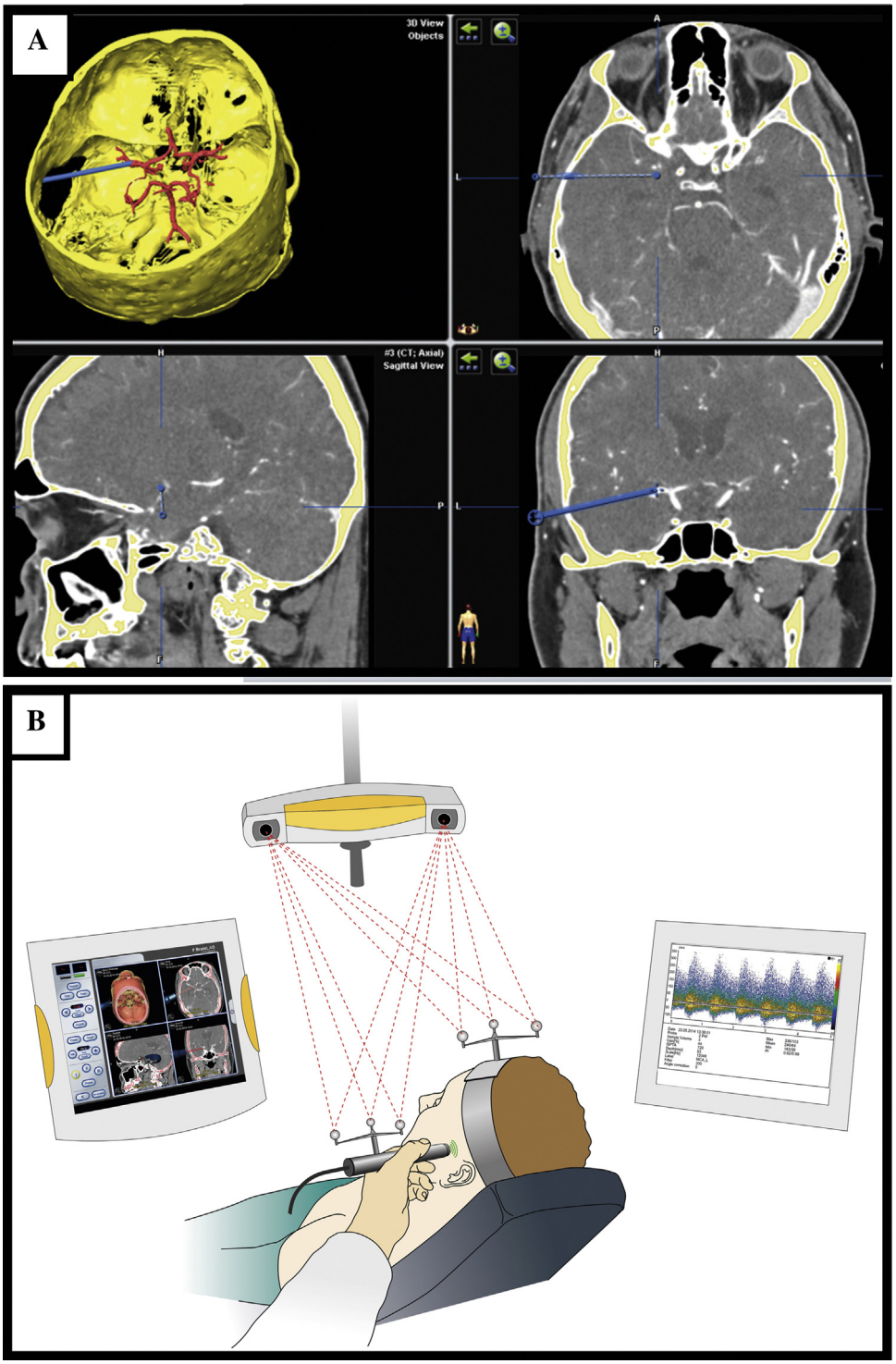

Fig. 1. Image-guided TCD.
(A) A virtual treatment plan is generated using CTA data imported to Iplan software.
(B) Doppler probe and the patients head are tracked by a camera of the image-guidance device. Using the virtual treatment plan, the Doppler probe is guided towards bone window and target vessel.

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