The Volume of the Third Ventricle as a Prognostic Marker for Shunt Dependency After Aneurysmal Subarachnoid Hemorrhage

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■ BACKGROUND: **Hydrocephalus is a common sequelae of aneurysmal subarachnoid hemorrhage (aSAH). However, in daily routine it is difficult to predict a patient's need for ventricular shunt placement in the course of the disease.**

■ OBJECTIVE: **The purpose of this study was to identify radiologic predictors for development of a shunt-dependent hydrocephalus after aSAH.**

■ METHODS: **A cohort of 217 patients with aSAH with adequate pretreatment computed tomography (CT) imaging was retrospectively reviewed. All variables, including demographic data, treatment, and initial CT imaging were gathered and grading was performed using Hunt and Hess, Graeb, LeRoux, and modified Fisher scores. Analysis of the radiographic parameters consisted of straight measurement and three-dimensional volumetry using manual segmentation. Univariate and multivariate statistical analyses were performed to identify predictive parameters.**

■ RESULTS: **Of 217 patients, 36 (17.5%) required a ventricular shunt (VS). A receiver operating characteristic analysis between the volume of the third ventricle and shunt-dependent hydrocephalus showed a significant cutoff at a volume of 2.3 cm^3 with a 4.3-fold higher risk for shunt dependency (P < 0.001). However, the treatment modality and classification according to the mentioned scores were not associated with the need for VS after aSAH. In univariate and multivariate analysis, the volume of the third ventricle on admission remained a significant prognostic marker for the need of a VS.**

■ CONCLUSIONS: **Our data suggest that the volume of the third ventricle in the initial CT is a strong predictor for shunt dependency after aSAH.**

INTRODUCTION

Hydrocephalus is a common sequela of aneurysmal subarachnoid hemorrhage (aSAH), with reported frequencies ranging from 6% to 67%.[1-6] It is considered a pathophysiologic consequence of intracranial blood, leading to blockage of circulation or impaired resorption of cerebrospinal fluid (CSF). In the acute phase of aSAH, hydrocephalus is addressed by placement of external ventricular drainage (EVD). From the cohort of patients needing an EVD, 6%–40% require permanent ventricular shunt (VS) placement.[4,6,7] Known risk factors for shunt dependency are high Fisher grade,[4,8-10] presence of intraventricular hematoma,[4,8,11,12] excessive need for CSF drainage,[8,13,14] and patient's age.[4,14,15] A common strategy to determine shunt dependency is to decrease the daily amount of drained CSF under close monitoring of the patients.[16] The indication for VS is widely based on imaging parameters and clinical aspects and is difficult to predict. Therefore, a more objective selection of patients in need of VS placement is desirable.

Most patients with aSAH are initially diagnosed by a noncontrast computed tomography (CT) scan, and therefore, we aimed our study at parameters that could be determined on this initial imaging. The purpose of our study was to identify radiologic predictors of development of a shunt-dependent hydrocephalus

Key words
- 3D volumetric analysis
- Aneurysm
- Subarachnoid hemorrhage
- Third ventricle
- Ventriculoperitoneal shunt

Abbreviations and Acronyms
aSAH: Aneurysmal subarachnoid hemorrhage
CSF: Cerebrospinal fluid
CT: Computed tomography
EVD: External ventricular drainage
mFisher: modified Fisher
VS: Ventricular shunt

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after aSAH. Volumetric measurement was chosen because it is reliable, reproducible, and less susceptible to tilt affections.

METHODS

A retrospective cohort study was performed including patients treated between January 2009 and June 2015 at our department. A total of 217 patients were eligible for analysis. All variables, including demographic data, treatment, need for VS, and initial CT imaging were gathered from medical data records and grading was performed using Hunt and Hess, Graeb, LeRoux, and modified Fisher (mFisher) scores using the initial CT.[17-20] The main outcome variable was the need for VS after aSAH. The data presented in this article were gained in a clinical context, and the indications described later reflect our standard clinical approach. All patients gave their informed consent for the surgical procedure. In addition, we consulted the local ethics board, which confirmed that it was not necessary to seek formal approval for the presented analysis.

The first brain windowed CT scan of each patient after admission with at least 40 slices was analyzed. Imaging had to be within 24 hours after onset of clinical symptoms. Patients were excluded if there was absence of imaging or presence of imaging from referral hospitals leading to technical issues regarding the analysis. After external diagnosis of SAH, some patients were further examined only with digital subtraction angiography and therefore had to be excluded from the analysis. Imaging data was analyzed using Icoserve Advanced Imaging Management (V.1.8.8.34 [ITH Icoserve Technology for Healthcare GmbH, Innsbruck, Austria]) and iPlanNet (V. 3.1 [Brainlab Inc., Feldkirchen, Germany]) using manual segmentation (**Figure 1**).

Treatment regarding surgical or endovascular therapy was assigned according to a local treatment algorithm, which is based on interdisciplinary consensus.

The radiologic assessment, including straight measurement and three-dimensional volumetry as well as the assessment of the amount of subarachnoid and ventricular blood, was performed by 1 neurosurgeon who was blinded regarding the patient's clinical course and later shunt dependency. The linear measures of ventricular size were assessed by the maximum bifrontal distance and the maximum width of the third ventricle. Blood distribution and amount were assessed using the LeRoux score,[17] the Graeb score,[18] and the mFisher score.[19]

Statistical analyses were conducted using IBM SPSS Statistics (version 21 [IBM Corp., Armonk, New York, USA]). Differences with a P value of less than 0.05 were considered statistically significant. In the univariate analysis, group differences were determined using the χ^2 test for dichotomized variables. Continuous variables were analyzed using the independent samples t test and the Mann-Whitney U test, as appropriate. In multivariate analysis, binary logistic regression analysis was performed to identify predictive parameters. Receiver operating characteristic analysis was used to calculate sensitivity and specificity.

Patients receiving VS later in the course of aSAH were considered as being shunt dependent. The decision for VS placement was based on increasing ventricular size and clinical deterioration of patients (regardless of the absence or closure of an EVD). Neurologic deterioration solely caused by angiographic confirmed vasospasm was not considered as shunt dependency.

RESULTS

Demographics

The 217 patients were aged 56.5 years (median, range 20—87 years) with a male/female ratio of 1:2.

Hunt and Hess grades were distributed as follows: 152 patients presented with a grade between 1 and 3 ($n = 152$, 70.0%) and 65 patients with a grade of 4 or 5 ($n = 65$, 30.0%).

Aneurysm distribution favored the anterior communicating artery ($n = 96$, 44.2%) and medial cerebral artery ($n = 51$, 23.5) (**Table 1**) location. An EVD had to be placed in 110 patients (50.7%) and 36 patients (19.9%) were found to be shunt dependent.

Radiologic Variables

As presented in **Table 2**, the amount of subarachnoidal blood according to mFisher grading did not differ significantly

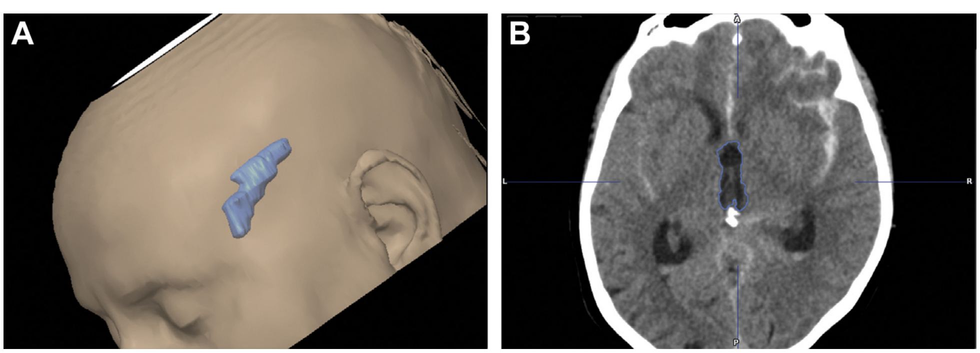

Figure 1. (**A**) Three-dimensional volumetry using the axial computed tomography scan on admission. (**B**) Measurements taken in the axial computed tomography scan on admission. A, anterior; L, left; P, posterior; R, right.