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Aneurysmal intracerebral hematoma: Risk factors and surgical treatment decisions

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ABSTRACT

Objectives: Intracerebral hematoma (ICH) complicates the course of aneurysmal subarachnoid hemorrhage (SAH). To date, there are no unique guidelines for management of aneurysmal ICH. The aim of this study was to identify risk factors for and impact of aneurysmal ICH with special attention on treatment decisions derived from ICH volume.

Patients and Methods: All patients admitted with aneurysmal SAH between 2003 and 2016 were eligible for this study. Various demographic, clinical and radiographic characteristics of patients were correlated with the occurrence and volume of ICH in univariate and multivariate manner. The associations between ICH volume and the need for surgical procedures and functional outcome were also analyzed.

Results: 991 patients were included into final analysis. ICH occurred in 301 (30.4%) cases. Location in the middle cerebral artery (MCA, $p < 0.001$, aOR = 7.04), WFNS grade 4–5 ($p < 0.001$, aOR = 4.43), rebleeding before therapy ($p = 0.004$, aOR = 2.45), intracranial pressure over 20 mmHg upon admission ($p = 0.008$, aOR = 1.60) and intraventricular bleeding ($p = 0.008$, aOR = 1.62) were independently associated with ICH presence. In turn, WFNS grade 4–5 ($p < 0.001$) and MCA aneurysms ($p < 0.001$) were the only independent predictors of ICH volume. According to the receiver operating characteristic curves, the clinically relevant cutoff for additional surgical interventions (decompression/hematoma evacuation) was 17 mL. ICH occurrence and ICH volume ≥17 mL independently predicted poor outcome at 6 months after SAH (defined as modified Rankin Scale > 3).

Conclusion: Of over 30 tested variables, the location of the ruptured aneurysm in the MCA remains the major risk factor for occurrence and volume of ICH. Given the presence of brain swelling and other bleeding components of SAH, surgical intervention on aneurysmal ICH is indicated at lower volume values, than it is generally accepted for spontaneous ICH.

1. Introduction

Intracerebral hematoma (ICH) due to rupture of intracranial aneurysm (IA) occur in 10–38% of cases with subarachnoid hemorrhage (SAH) [19,25,22,17,12,2,10,16]. It is commonly accepted that aneurysmal ICH complicates the natural course of disease and is connected to increased morbidity and mortality [19,25,22]. The mass effect caused by the hematoma might lead to a prolonged intracranial pressure (ICP) known as one of the possible contributors to early brain injury (EBI) [21]. IA of the anterior circulation especially located in the middle cerebral artery (MCA) [19,1,27,16] but also in the anterior cerebral artery (ACA) [25,1] have been identified as risk factors for ICH occurrence. Recent studies focused on identification of additional patient- and IA–related risk factors for aneurysmal ICH. Premorbid conditions like arterial hypertension, diabetes and smoking as well as administration of antiplatelet drugs prior to ictus have been correlated with ICH occurrence [12,10,27,16]. Alongside with IA location as acknowledged ICH predictor, size and morphology of ruptured IA have also been analyzed as potential risk factors, however with conflicting results [12,10,16]. It has been reported that SAH patients with an additional ICH are more likely to present with poor initial clinical condition [25,10,27,16] and develop rebleeding prior to treatment [25,16].

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In contrast, there is less evidence on predictors and clinical impact of ICH size. In particular, there are no unique recommendations for SAH patients on treatment decisions derivable from the volume of ICH. Critical volume for aneurysmal ICH associated with poor outcome has been reported at 25 mL, however upon applying arbitrary cutoff values [22,15]. Larger IA size, location in the MCA and administration of aspirin prior to bleeding event have been mentioned as risk factors for larger ICH volume in one study [10].

The aim of this study was to elucidate independent risk factors for occurrence and especially volume of aneurysmal ICH in a large single center series. Furthermore, we aimed to investigate factors influencing the neurosurgical management of aneurysmal ICH, as well as associations with SAH outcome.

2. Material and methods

All patients admitted to our institution between January 2003 and June 2016 with an aneurysmal SAH were eligible for this study. Approval for this study was given by the institutional review board. Afterwards, it was registered in the German Trial Register (DRKS, Unique identifier: DRKS00008749).

2.1. SAH treatment regime

Our institutional policy included early IA occlusion within 24 h, when applicable. Decision about microsurgical or endovascular treatment was made upon interdisciplinary consensus. Patients with acute hydrocephalus were treated by diversion of cerebrospinal fluid using external ventricular or lumbar drainage. In cases of SAH with ICH, decision about surgical decompression and/or hematoma evacuation was made by neurosurgeon on duty based on individual judgment of space occupying effect of the bleeding and clinical condition of the patient.

Post treatment imaging by computed tomography (CT) of the head was performed during the first 24 h after treatment. Further imaging was performed as necessary.

Vasospasm prevention therapy included oral nimodipine for 21 days and daily transcranial Doppler ultrasonography for 14 days in all cases. If cases of symptomatic vasospasm, endovascular treatment was performed by intra-arterial nimodipine application and/or transluminal catheter angioplasty, if necessary.

2.2. Data management

Patients' charts were reviewed for demographic and clinical parameters. Imaging was reviewed for all radiographic parameters.

ICH was assessed as seen on initial CT scan. For recording of the volume, the formula A*B*C/2 was used [11]. Presence of intraventricular hemorrhage (IVH) was documented. For assessment of IVH severity, the original Graeb score (oGS) was used [5]. The radiographic severity of SAH was assessed utilizing the original Fisher scale [3]. For analysis, the radiographic severity was dichotomized into low (Fisher scale 1 and 2) and high (Fisher scale 3 and 4) grades.

IA size, location and morphology were documented as seen on digital subtraction angiography (DSA). All IA that presented with daughter sac(s) (< 50% of aneurysm size) or multiple lobes (> 50% of aneurysm size) were defined as irregular. For statistical analysis aneurysms of the vertebral, basilar artery and posterior cerebral artery were amalgamated as "posterior circulation" (PC) aneurysms.

Initial clinical severity of SAH was assessed according to the world federation of neurological surgery grading system (WFNS) [24]. For statistical analysis, we dichotomized patients into good (WFNS 1–3) and poor grade (WFNS grade 4 and 5) cases.

Patient charts were reviewed for age, sex, preexisting morbidities (arterial hypertension, diabetes mellitus, smoking) and anticoagulation (vitamin k antagonists, antiplatelet therapy, new oral anticoagulants) prior to admission. Furthermore blood pressure levels (maximal and minimal values for the systolic and mean overall value for the mean arterial pressure) and ICP in case of placement of an EVD (dichotomized into increased ICP (over 20 mmHg) and not increased) at admission were documented.

All events with clinical deterioration before treatment of the IA in conjunction with new hemorrhage on CT scan were judged as rebleeding events. Rebleeding episodes on referring hospitals, during transport and at our institution were recorded.

All new hypodensities in post treatment imaging that were not connected to ICH or surgical approach were defined as de-novo cerebral infarction. New hypodensities visible on the first post-treatment CT scan, were defined as early infarcts. Accordingly, infarctions identified in the later follow-up imaging, were referred as delayed cerebral ischemia (DCI).

Need for shunt implantation due to persisting hydrocephalus was documented.

As functional endpoints, in-hospital mortality and poor outcome at 6 months after SAH (defined as modified Rankin scale (mRS) [26] > 3) were used.

2.3. Statistical analysis

Statistical analysis was performed using SPSS Version 22 for Mac (IBM Corp.). Continuous variables are given in mean +/- standard deviation (SD) if not indicated differently. They were analyzed using the Student's *t*-test for normally distributed and the Mann–Whitney U test for non-normally distributed data. Correlations between two continuous variables were analyzed by Pearson correlation. Categorical variables were analyzed using the Chi-Square-Test; for samples smaller than 5, the Fisher-Exact-Test was used. P-values smaller than 0.05 were defined as significant. Factors predictive for occurrence of ICH in univariate analysis were included in final multivariate binary logistic regression analysis. Factors associated with ICH volume were included in final multivariate linear regression analysis. For ICH volume a cutoff was identified regarding the need for further surgical intervention using the receiver operating characteristic (ROC) curve analysis. Missing data were replaced using multiple imputations.

3. Results

A total of 994 SAH patients were treated during the 13.5 years surveillance period at our institution. In 3 cases, the occurrence of an ICH was not retrospectively evaluable due to incomplete imaging/documentation. Therefore 991 patients were included into final analysis. ICH occurred in 30.4% (n = 301) of cases with a mean volume of 25.98 mL ± 32.06 mL. The following mean volumes of ICH were identified for different aneurysm locations: MCA - 44.68 mL ± 39.74 mL; ICA – 17.94 mL ± 23.87 mL; ACA – 13.89 mL ± 16.60 mL; PC 7.53 mL ± 7.60 mL (Examples for different bleeding volumes are given in Fig. 1). The highest rate of ICH occurrence had IA located in the MCA (57.7%) followed by the ACA (35.7%), whereas the internal carotid artery (ICA; 15.5%) and the PC (8.2%) presented with lower rates (see also Fig. 2). The majority of the patients were females (n = 663; 66.9%) and Caucasians (n = 948; 95.7%). The mean age at presentation was 55 years ± 14 years. 306 (30.9%) patients presented in poor initial clinical conditions and 740 (86.1% after exclusion of 132 cases with not assessable Fisher grades) with a high radiographic severity of SAH. Over half of the patients were treated by coil embolization (n = 577; 61.4%; after exclusion of 51 patients that received no treatment) and 683 (68.9%) needed cerebrospinal fluid drainage for acute hydrocephalus.

3.1. Predictors of ICH occurrence

Of the risk factors identified in univariate analysis (Table 1), IA

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