Risk Factors for Chronic Subdural Hematoma Recurrence Identified Using Quantitative Computed Tomography Analysis of Hematoma Volume and Density

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- OBJECTIVE: **Chronic subdural hematoma (CSDH), a common condition in elderly patients, presents a therapeutic challenge with recurrence rates of 33%. We aimed to identify specific prognostic factors for recurrence using quantitative analysis of hematoma volume and density.**

- METHODS: **We retrospectively reviewed radiographic and clinical data of 227 CSDHs in 195 consecutive patients who underwent evacuation of the hematoma through a single burr hole, 2 burr holes, or a mini-craniotomy. To examine the relationship between hematoma recurrence and various clinical, radiologic, and surgical factors, we used quantitative image-based analysis to measure the hematoma and trapped air volumes and the hematoma densities.**

- RESULTS: **Recurrence of CSDH occurred in 35 patients (17.9%). Multivariate logistic regression analysis revealed that the percentage of hematoma drained and postoperative CSDH density were independent risk factors for recurrence. All 3 evacuation methods were equally effective in draining the hematoma (71.7% vs. 73.7% vs. 71.9%) without observable differences in postoperative air volume captured in the subdural space.**

- CONCLUSIONS: **Quantitative image analysis provided evidence that percentage of hematoma drained and postoperative CSDH density are independent prognostic factors for subdural hematoma recurrence.**

Key words
- Chronic subdural hematoma
- Computed tomography
- Density
- Multiple regression
- Recurrence
- Volume

Abbreviations and Acronyms
CSDH: Chronic subdural hematoma
CT: Computed tomography

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INTRODUCTION

Chronic subdural hematoma (CSDH) is a common form of intracranial hemorrhage that mainly affects older patients. The occurrence of CSDH in this patient group causes various diagnostic and therapeutic problems, and as the world population becomes progressively older, the overall incidence is expected to increase.[1] The etiology, progression, and recurrence of CSDH appear to be complex, and this complexity is mirrored in the literature. Although various studies have tried to identify risk factors for recurrence, and various factors potentially associated with recurrence of CSDH have been investigated, results have been inconsistent or even controversial. The results of studies that used a regression model to identify significant prognostic factors are summarized in Table 1. Most of these studies usually identify various radiographic parameters as prognostic, such as the width of the hematoma, midline shift, gross hematoma density, or internal architecture of the hematoma. However, these factors are highly prone to observer bias and do not take into account the configuration of the hematoma. Moreover, such an approach results in fragmentation of the morphology of the hematoma as a factor, allowing for subjective estimations or misleading assumptions. For example, a hematoma with a relatively small total volume and a minor space-occupying effect may still manifest with a local (e.g., high parietal) width that is greater than that of a much more voluminous hematoma with a constant width throughout its height.

When treated adequately, CSDH usually has a favorable prognosis.[11] For patients with symptoms or signs of brain compression, surgical evacuation is the treatment of choice.[12] Various procedures are employed, including craniostomy with 1

Table 1. Studies Investigating Risk Factors for Recurrence of Chronic Subdural Hematoma Using a Regression Model

Study	Sex	Age	AH	DM	LD	Cerebrovascular Disease	Coronary Disease	Renal Disease	Dementia	Alcohol	Anticoagulation	Smoking	Atrophy	Seizures	Etiology	Days from Trauma	VPS
Yamamoto et al., 2003[2]	●	●	●	✓	●	●	●			●	●	●		✓	●	●	
Stanišić et al., 2005[3]	●														●	●	
Torihashi et al., 2008[4]	●	●	●	●			●				●						
Chon et al., 2012[5]	●	●	●	✓	●	●	●				✓		●	✓	✓		
Stanišić et al., 2013[6]	●	●		●			●			●	●						
Ohba et al., 2013[7]	●	●									✓						
Huang et al., 2014[8]	●	●	●	●		●	●	●		●	●		●		●		
Adachi et al., 2014[9]	●	●	●	●		●	●			●	●						
Lin et al., 2014[10]	●	●							●								
Present series, 2016	●	●	●	●		●		●	●	●	●			●	●	●	●

AH, arterial hypertension; DM, diabetes mellitus; LD, liver disease; VPS, ventriculoperitoneal shunt; ●, studied, statistically not significant; ✓, studied, statistically significant.

*Midline shift postoperatively.

†Density evaluated qualitatively only.

‡Calculated as XYZ/2.

§Irrigation with artificial cerebrospinal fluid.

burr hole and closed system drainage (i.e., twist-drill craniostomy), craniostomy with 2 burr holes and irrigation, and mini-craniotomy.[13,14] Although CSDHs are considered surgically "for beginners," a significant recurrence rate of 2.3%–33% is still reported, regardless of the method used, revealing a not so trivial disease.[6,12] Thus, there is a pressing need to improve the assessment of various clinical, radiologic, and surgical factors that affect the risk of and serve as prognostic markers for hematoma recurrence. In this study, we set out to identify clinical and radiographic predictors associated with the recurrence of CSDH using computer-assisted volumetric analysis. To assess the radiographic factors in the most objective way possible and avoid arbitrary classifications and thresholds, we used quantitative analysis of hematoma and air volumes and hematoma density, performed separately by 2 investigators (P.S. and A.M.).

MATERIALS AND METHODS

We retrospectively analyzed 195 patients with 227 CSDHs who were admitted to the Department of Neurosurgery, University Hospital of Cologne, Germany, between January 2011 and December 2014. CSDHs were diagnosed in all patients using thin-slice (3-mm) computed tomography (CT). Before intervention, anticoagulant and antiplatelet drugs were discontinued, and their effects were actively reversed using vitamin K, prothrombin complex concentrates, plasma, or platelets. Coagulation status was evaluated through controlling the activated partial thromboplastin time and international normalized ratio values as well as with the platelet function analysis (PFA-100) test. Demographic and clinical data considered in the analysis included sex, age, various comorbidities, use of antiplatelets or anticoagulants, alcohol abuse, ventriculoperitoneal shunt in situ, history of trauma, interval between trauma and surgery, and preoperative Glasgow Coma Scale score (Table 2).

Radiologic and Quantitative Analysis

For 145 CSDHs for which complete imaging series were available, we used computer-assisted volumetric analysis to measure the volume of the preoperative CSDH and the postoperative residual fluid and air trapped in the subdural cavity (Figure 1). For each axial CT slice, the hematoma margins were traced using iPlan software (Brainlab AG, Feldkirchen, Germany). Volumes were calculated as the product of the area traced and the corresponding slice thickness. The sum of each slice volume gave the total hematoma or air volume in cubic millimeters. Additionally, we calculated the average density, expressed in Hounsfield units over the entire hematoma volume, using the mean of the density for the traced hematoma of each slice. Calculations were based on the last preoperative and first