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Aneurysm-related subarachnoid hemorrhage and acute subdural hematoma: single-center series and systematic review

Clinical article

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Object. Subarachnoid hemorrhage (SAH) with simultaneous acute subdural hematoma (SDH) is a severe disease. The authors' objective was to analyze the incidence, prognosis, and clinical outcome of patients suffering from aneurysm-related SAH and space-occupying acute SDH.

Methods. Between June 1999 and June 2011, data from 989 patients with aneurysm-related SAH were prospectively entered into a database. Eighteen patients (1.8%) presented with aneurysm-related SAH and space-occupying acute SDH. The treatment decision (clip or coil) was based on an interdisciplinary approach. Outcome was assessed according to the modified Rankin Scale (mRS) at 6 months and was dichotomized into favorable outcome (mRS Score 0–2) versus unfavorable outcome (mRS Score 3–6). PubMed was searched for published studies of aneurysm-related SAH and acute SDH to gain a larger population. A multivariate regression analysis was performed on the pooled data.

Results. Literature data, including the current series, revealed a total of 111 patients. Overall, 38 (34%) of 111 patients with aneurysm-related SAH and acute SDH achieved favorable outcome. Favorable outcome was achieved in 68% of patients with good-grade clinical presentation on admission (Hunt and Hess Grades I–III) versus 23% of the patients with poor-grade presentation (Hunt and Hess Grades IV and V, $p < 0.0001$). In the multivariate analysis, poor clinical condition at admission was the only predictor for unfavorable outcome ($p = 0.02$).

Conclusions. The present data confirm that patients with aneurysm-related SAH and acute SDH, even when presenting in poor clinical condition, might achieve favorable outcome. Therefore, treatment of patients with SAH and acute SDH should not be discontinued, but careful individual decision making is necessary for each patient.
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Key Words • **subarachnoid hemorrhage** • **intracranial aneurysm** • **acute subdural hematoma** • **vascular disorders**

Rupture of an intracranial aneurysm usually results in an SAH. In 2%–10.3% of patients with aneurysmal SAH, a simultaneous acute SDH can be found.[16,19] Patients presenting with both SAH and acute SDH have commonly been reported to be in a poor admission grade and have a poor prognosis.[8,14] Nevertheless, recent reports have suggested early and aggressive treatment to facilitate neurological outcome in these severely ill patients.[11,13,20] Aggressive therapy in poor-grade patients suffering from SAH is still controversially discussed. We therefore performed a retrospective analysis of our prospectively conducted database and a review of the literature to analyze factors determining outcome to guide treatment decisions.

Methods

Patient Population

Between June 1999 and June 2011, 989 consecutive patients with aneurysm-related SAH were treated at our institution. Aneurysmal SAH and acute SDH were diagnosed by CT scanning. Information including patient

Abbreviations used in this paper: ACoA = anterior communicating artery; ICA = internal carotid artery; ICH = intracerebral hemorrhage; ICP = intracranial pressure; MCA = middle cerebral artery; mRS = modified Rankin Scale; SAH = subarachnoid hemorrhage; SDH = subdural hematoma; WFNS = World Federation of Neurosurgical Societies.

characteristics on admission and during the treatment course, treatment modality, aneurysm size and location, radiological features, presence of a space-occupying acute SDH, and functional neurological outcome were prospectively entered into a computer database (version 15, SPSS; SPSS, Inc.). Patients were divided into a good-grade group (Hunt and Hess Grades I–III) and a poor-grade group (Hunt and Hess Grades IV and V) on admission. All patients included in the institutional analysis were treated by surgical clipping or endovascular coiling based on an interdisciplinary consensus in each case. We followed an early surgery strategy (within 24–48 hours) in patients in all clinical grades.[4] Patients with signs of cerebral herniation underwent CT angiography and surgical clipping with simultaneous evacuation of the space-occupying hematoma. In case of brain swelling, decompressive craniectomy was performed by removing a large bone flap, and ICP probes were inserted as reported previously.[5–7] Cranioplasty was performed more than 2 months after decompressive craniectomy in survivors.[17] Patients deemed not suitable to undergo extended surgical procedures due to critical admission status or minor mass effect of the acute SDH underwent cerebral angiography and endovascular treatment. After endovascular treatment, ICP probes were inserted, and acute SDH was evacuated within a few days using a bur hole craniotomy in all patients treated with endovascular coiling. Outcome was assessed according to the mRS after 6 months and was stratified into favorable (mRS Scores 0–2) versus unfavorable (mRS Scores 3–6).

Systematic Review

Search Methods. To gain a larger population, we performed a literature search using the PubMed database (latest access December 2011). The following keywords were queried individually or in relevant combinations: "acute subdural hematoma," "acute subdural haematoma," "subarachnoid hemorrhage," and "intracranial aneurysm." Full-text versions were obtained from all studies that were independently reviewed and considered to be relevant by 2 authors (P.S. and J.K.). Any disagreement between these authors was resolved in consensus meetings with a third author (E.G.). The reference sections of relevant studies were searched for additional articles of interest.

Selection Criteria. We analyzed studies of patients suffering from aneurysmal SAH with simultaneous occurrence of acute SDH as well as their reference sections. Articles were included when they analyzed and reported detailed data of acute SDH and SAH as well as outcome data. Studies reporting on acute SDH in the presence of unruptured intracranial aneurysms or nonaneurysmal SDH were excluded. To analyze the level of evidence of the articles reviewed, we applied the classification system proposed by Cook et al.[2] Anecdotal single case reports and case series with detailed information exclusively provided in a limited number of patients were excluded to reduce potential superselection bias.

Data Collection and Extraction. We extracted data on level of evidence, patient characteristics, clinical condition (Hunt and Hess grade or WFNS grade) on admission, aneurysm size and location, presence and size of acute SDH, presence and degree of midline shift, signs of cerebral herniation (for example, dilated pupils), time from ictus to treatment of acute SDH, modality regarding aneurysm treatment, necessity of decompressive craniectomy, and clinical outcome. According to their initial clinical and neurological status at admission, patients were divided into 2 groups: good grade (Hunt and Hess/WFNS Grades I–III) versus poor grade (Hunt and Hess/WFNS Grades IV and V). Outcome was stratified by the reported clinical status at follow-up into favorable ("good recovery" or "moderate disability"/mRS Score 0–2) versus unfavorable ("dependent" or "dead"/mRS Scores 3–6). Data were independently extracted and verified by 2 authors (P.S. and J.K.). No disagreements were found.

Statistical Analysis

Data analyses were performed using the computer software package SPSS (version 15, SPSS, Inc.). An unpaired t-test was used for parametric statistics. Categorical variables were analyzed in contingency tables using the Fisher exact test. Results with $p < 0.05$ were considered statistically significant.

Furthermore, a multivariate analysis was performed to find independent predictors of favorable functional outcome after using binary logistic regression analysis to find confounding factors between potentially independent predictors. Variables with significant p values in the univariate analysis were considered as potentially independent variables in a multivariate analysis. A backward stepwise method was used to construct a multivariate logistic regression model in relation to favorable outcome as a dependent variable with an inclusion criterion of $p < 0.05$.

Results

Present Series

Eighteen patients (1.8%) with SAH and acute SDH were treated at our institution. Of these patients 13 underwent surgical clipping (72%) and 5 were treated by endovascular coiling (28%). Two of 5 patients who underwent cerebral angiography and endovascular treatment were in critical clinical condition and therefore were not suited to undergoing extended surgical procedures. In 3 of 5 patients who underwent endovascular treatment, acute SDH was considered to be associated with only minor mass effect. However, all patients treated endovascularly underwent additional hematoma evacuation during the course of treatment. Eight patients (44%) underwent decompressive craniectomy because of brain swelling.

Overall, favorable outcome was achieved in 6 patients (33%). In patients with a good grade at presentation, favorable outcome was achieved in 4 (80%) of 5 patients versus in 2 (15%) of 13 patients with poor-grade condition at admission (OR 22 [95% CI 1.5–314.5], $p = 0.02$). Patient characteristics, including age, sex, clinical status, angiographic and radiological findings, treatment modality, and clinical outcomes, are shown in Table 1.

TABLE 1: Patient characteristics in the present series*

Case No.	Age (yrs), Sex	Aneurysm Location	Aneurysm Size (mm)	H&H Grade at Admission	Aneurysm Treatment	Size of aSDH (mm)	Size of MLS (mm)	Time to aSDH Evacuation (hrs)	Primary DC	Functional Outcome After 6 Mos
1	49, M	MCA	6	II	coil	5	5	37	no	favorable
2	42, F	MCA	5	IV	coil	6	6	2	no	favorable
3	44, F	ACoA	6	V	clip	7	8	5	yes	favorable
4	55, F	MCA	13	II	clip	1	1	20	no	favorable
5	49, F	ICA	5	V	coil	4	4	7	no	death
6	43, F	ICA	7	V	coil	10	9	22	no	death
7	75, F	ICA	7	V	clip	9	3	12	no	unfavorable
8	69, M	MCA	13	V	coil	12	8	1	no	death
9	48, M	ACoA	4	V	clip	3	6	3	yes	death
10	47, F	ICA	9	IV	clip	4	7	6	yes	unfavorable
11	65, F	ICA	15	V	clip	9	11	4	yes	death
12	43, M	ICA	5	IV	clip	6	9	49	no	unfavorable
13	65, F	ACoA	8	III	clip	5	7	18	yes	death
14	57, M	MCA	14	V	clip	16	14	3	no	unfavorable
15	58, F	ICA	4	V	clip	13	17	1	yes	unfavorable
16	42, M	ICA	10	II	clip	6	10	14	no	favorable
17	35, F	ICA	7	III	clip	5	9	5	yes	favorable
18	49, F	MCA	11	V	clip	3	14	12	yes	unfavorable

* aSDH = acute SDH; DC = decompressive craniectomy; H&H = Hunt and Hess; MLS = midline shift.

Search Results

The PubMed search including a search within the reference lists yielded 254 articles, of which 87 were considered to be relevant after filtering out duplicates and applying our selection criteria. After review of the remaining articles, 9 studies reporting on a total of 93 patients met inclusion criteria (Fig. 1).[3,8–11,13–15,20] No manuscripts classified as Evidence Level I, II, or III were found. All included articles were classified as retrospective case studies and therefore as Evidence Level IV or V. Detailed data on time to treatment of acute SDH, size of acute SDH, necessity of decompressive craniectomy, signs of cerebral herniation, and aneurysm size and location were provided only by a few of the reviewed studies.

Literature data, including the present series, revealed a total of 111 patients suffering from SAH and acute SDH. Overall, 38 (34%) of 111 patients achieved a favorable outcome in the pooled data. Patient characteristics, treatment modality, and neurological outcome are detailed in Table 2.

Neurological Grading at Admission

Twenty-eight patients (25%) were in a good grade and 83 patients (75%) were in a poor grade at admission. Favorable outcome was achieved in 19 (68%) of 28 good-grade patients and in 19 (23%) of 83 poor-grade patients (OR 7.1 [95% CI 2.8–18.3], $p < 0.0001$).

Aneurysm Size and Location

Data on aneurysm size were available in 38 patients. The mean aneurysm size was 9.6 ± 6.9 mm (± SD). Patients who achieved favorable outcome had smaller aneurysms (mean 7 ± 3.6 mm) than patients who achieved an unfavorable outcome (mean 11.4 ± 8.2 mm, $p = 0.049$). Aneurysms were located in the ICA in 44 patients (40%), in the MCA in 41 patients (37%), and in the ACoA in 26 patients (23%).

Time to Treatment, Treatment Modality, and Signs of Cerebral Herniation

Data regarding the time between ictus and treatment of acute SDH were available in 33 patients. The mean time to treatment of acute SDH was 26.3 ± 86.5 hours. Patients who achieved a favorable outcome were treated within 12.9 ± 11.1 hours, and patients who achieved an unfavorable outcome were treated within 36.2 ± 114 hours ($p = 0.45$).

Information on aneurysm treatment modality was available in all patients. Eighty-three patients (75%) underwent surgical clipping, and 13 patients (12%) underwent endovascular coiling. However, 15 patients (14%) did not undergo any aneurysm treatment due to their critical clinical condition. Compared with patients who underwent aneurysm treatment, none of the 15 patients without aneurysm treatment survived (OR 20.4 [95% CI 1.2–351.3], $p = 0.002$). Thirty-two (39%) of 83 patients who underwent surgical clipping achieved favorable outcome versus 6 (46%) of 13 patients who underwent endovascular treatment ($p = 0.8$). Data on the size of acute SDH were available in 22 patients. The size of acute SDH did not differ between patients treated surgically and those treated endovascularly (8.7 ± 5.2 and 7.7 ± 3.1 mm, respectively; $p = 0.7$).

Information on clinical signs of cerebral herniation

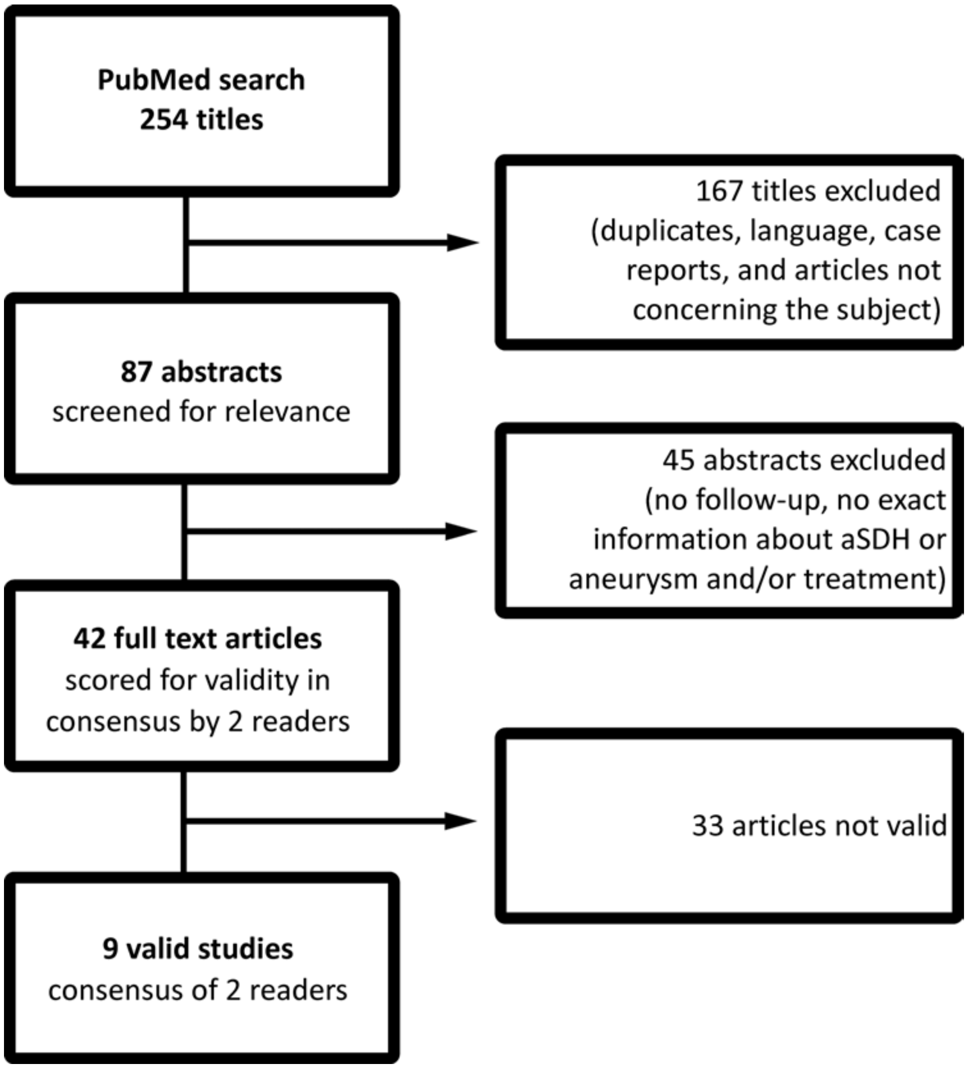

Fig. 1. Chart showing the search strategy. aSDH = acute SDH.

was available in 36 patients. Overall, 24 patients had signs of cerebral herniation. In detail, 16 patients presented with unilateral mydriasis and 8 patients with bilateral mydriasis. Favorable outcome was achieved by 7 patients with unilateral mydriasis and by 2 patients with bilateral mydriasis.

Decompressive Craniectomy

Patient data concerning decompressive craniectomy were available in 73 patients. Overall, 45 patients underwent decompressive craniectomy due to brain swelling or mass effect. Sixteen (36%) of 45 patients with decompressive craniectomy achieved favorable outcome, whereas 29 patients (64%) achieved unfavorable outcome.

Patient data concerning decompressive craniectomy and signs of cerebral herniation were available in 34 patients. Eighteen (78%) of 23 patients with decompressive craniectomy versus 4 (36%) of 11 patients without decompressive craniectomy (OR 6.3 [95% CI 1.3–30.5], $p = 0.03$) had signs of cerebral herniation.

Age

The mean ages of patients achieving favorable and unfavorable outcomes were 54 ± 11 and 58 ± 14 years, respectively ($p = 0.2$).

Multivariate Analysis

We performed a multivariate logistic regression analysis of those variables significantly associated with functional outcome in patients with SAH and acute SDH. Additionally, we included variables that have been reported to influence functional outcome in the literature. The multivariate regression model did illustrate the variable "poor grade SAH at admission" (OR 15.6 [95% CI 1.5–164]; $p = 0.02$) as an independent and significant predictor for unfavorable outcome after aneurysm-related SAH and acute SDH (Nagelkerke $R^2 = 0.34$).

Discussion

Subarachnoid hemorrhage with simultaneous acute SDH is a severe disease. However, data regarding treatment and outcome in the clinical setting are scarce due to the rarity of this entity.[9,12] We therefore analyzed our in-

TABLE 2: Systematic review and present series*

		No. of Patients (%)						
				Aneurysm Treatment				
Authors & Year	Evidence Level	Included in Further Analysis	No. w/ Good Grade At Admission	Clip	Coil	No Treatment	DC	No. w/ Favorable Outcome
Kamiya et al., 1991	IV	13	5 (38)	7	0	6	NA	5 (38)
Inamasu et al., 2002	V	5	1 (20)	4	0	1	NA	2 (40)
Ohkuma et al., 2003	IV	13	3 (23)	7	0	6	NA	1 (8)
Gelabert-Gonzalez et al., 2004	V	4	0	4	0	0	4	1 (25)
Westermaier et al., 2007	V	7	0	2	5	0	5	4 (57)
Kocak et al., 2009	V	10	5 (50)	9	0	1	NA	4 (40)
Marbacher et al., 2010	V	7	2 (29)	5	1	1	6	5 (71)
Oh et al., 2011	V	23	4 (17)	21	2	0	11	6 (26)
Otani et al., 2011	V	11	3 (27)	11	0	0	11	4 (36)
present study	V	18	5 (27)	13	5	0	8	6 (33)
total		111	28 (25)	83 (75)	13 (12)	15 (13)	45 (62)	38 (34)

* NA = not applicable.

stitutional data and performed a literature review to gain a larger population.

The present series indicates that patients with SAH and acute SDH might achieve favorable outcomes. In the pooled analysis, a good grade at presentation was significantly associated with favorable outcome ($p < 0.0001$). However, at least 23% of poor-grade patients achieved a favorable outcome.

Risk Factors for Acute SDH Due to Aneurysm Rupture

A recent study by Biesbroek et al.[1] found that older age and location of the ruptured aneurysm at the posterior communicating artery, as well as sentinel headache and ICH, were significantly associated with a higher risk of acute SDH in patients with ruptured aneurysms. In the present analysis, aneurysm were located in the ICA in 40% of patients with acute SDH and SAH. However, additional data on specific aneurysm location, sentinel headache, and ICH were not included in the majority of articles in the current literature review. It was suggested that the perianeurysmal environment influenced the characteristic of bleeding resulting from aneurysm rupture. It was further suggested that aneurysms protruding into the basal cisterns might result in rupture of the arachnoid membrane, leading to acute SDH, whereas aneurysms surrounded by brain tissue, for example, MCA aneurysms, might be associated with an increased risk of ICH. Vertebrobasilar aneurysms are separated by a thick, so-called Liliequist membrane, which might be a barrier for the development of acute SDH.

Aneurysmal acute SDH in patients with ruptured intracranial aneurysms was present in 3.6% of the patients with SAH in the study by Biesbroek et al.[1] In the present series, 1.8% of patients with ruptured intracranial aneurysms suffered from acute SDH. The difference in the incidence of aneurysmal acute SDH between these studies may result from different definitions of acute SDH. While all patients with radiological evidence of acute SDH were included by Biesbroek et al.,[1] only patients with radiologically confirmed acute SDH treated by surgical evacuation were included in the present study.

Time of Treatment and Decompressive Craniectomy

Patients with SAH and acute SDH, similar to patients with ICH and SAH,[4] usually present in poor clinical condition and are treated urgently to avoid further brain damage. Therefore, an early and aggressive surgical evacuation strategy has been postulated previously to improve outcome.[11,13,15,20] However, patients with favorable outcome did not undergo earlier treatment of acute SDH than did patients with unfavorable outcome in the pooled analysis. Unfortunately, data on time from ictus to treatment of acute SDH were only available in a limited number of studies included in the pooled analysis. This absence of data limits statistical analysis, leading to a lack of statistical power.

In addition to early surgical evacuation of acute SDH, several studies have suggested performing decompressive craniectomy to reduce elevated ICP and improve outcome.[11,15] According to the pooled data, there was no significant association between decompressive craniectomy and favorable outcome in the multivariate analysis. However, in subgroup analyses, patients who underwent decompressive craniectomy suffered significantly more often from signs of cerebral herniation than patients without decompressive craniectomy ($p = 0.03$). Therefore, decompressive craniectomy should not be omitted in the setting of severe brain swelling in patients with SAH and acute SDH.

Signs of Cerebral Herniation

Functional outcome might only be achieved in a small number of poor-grade SAH patients with additional acute SDH, especially when signs of cerebral herniation are present.[18] Mydriasis has previously been identified as a predictor of unfavorable outcome in patients suffering from SAH.[5,6] Marbacher et al.[11] reported on 7 patients suffering from SAH and acute SDH and reported favorable outcome in 5 patients, including 2 patients with bilaterally dilated pupils. In contrast, no patient in the present series with bilaterally dilated pupils achieved a favorable outcome. However, in the multivariate analysis of the pooled data, signs of cerebral herniation were not associated with unfavorable neurological outcome. These results should be interpreted carefully because of limited data on signs of cerebral herniation throughout the literature. Furthermore, data for patients who were not treated because of poor clinical status and signs of cerebral herniation might not have been published.

Treatment Modality

If a surgical procedure is necessary to evacuate the space-occupying acute SDH, a concomitant surgical treatment of the ruptured aneurysm seems desirable to avoid a second therapeutic procedure. Nevertheless, 5 patients in the present series underwent cerebral angiography and were treated endovascularly at the same time, because of a minor mass effect of the acute SDH or their critical clinical condition. However, in some cases it is not possible to carry out aneurysm treatment due to the devastating admission status caused by SAH and acute SDH. The pooled analysis contains 15 patients who did not undergo aneurysm treatment; of these patients none survived.

Functional Outcome

Overall, 33% of patients with acute SDH and SAH in our institutional series achieved favorable outcome. Reviewing the pooled data of 111 patients, favorable outcome was achieved in 34%. In the univariate analysis, good neurological and clinical status at admission ($p < 0.0001$) and the size of the ruptured aneurysm ($p = 0.049$) were significantly associated with favorable outcome. However, in the multivariate analysis, poor clinical condition at admission was the only predictor for unfavorable outcome ($p = 0.02$). Although acute SDH due to rupture of an intracranial aneurysm is a critical condition, favorable outcome might be achieved even in poor-grade patients.

Study Limitations

The present study has several limitations. Statistical analysis was retrospective, despite prospective collection of the institutional data. Data on several variables were only available in a limited number of patients included in the systematic review. The available data are limited by a lack of randomized prospective studies and standard definitions. This might facilitate the appearance of publication and selection bias. The data analyzed were derived from retrospective studies in all cases and have been highly selected due to our selection criteria.

Conclusions

The current data confirm that good neurological grade at admission is a predictor for favorable outcome in patients with SAH and acute SDH. Therefore, treatment of patients with SAH and acute SDH should not be discontinued, but careful individual decision making is necessary for each patient.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Schuss, Güresir. Acquisition of data: Schuss, Konczalla, Platz. Analysis and interpretation of data: Schuss, Güresir. Drafting the article: Schuss. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Schuss. Statistical analysis: Schuss, Güresir. Study supervision: Vatter, Seifert, Güresir.

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