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Management of tracheostomized patients after poor grade subarachnoid hemorrhage: Disease related and pulmonary risk factors for failed and delayed decannulation

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A R T I C L E I N F O

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A B S T R A C T

Objective: Tracheostomy is often indicated in patients with spontaneous subarachnoid hemorrhage (sSAH). Decannulation is a major goal of neurorehabilitation, but cannot be achieved in all patients. The aim of this study was to describe the course of decannulation and to identify associated risk factors in a single-center collective.

Patients and methods: We retrospectively reviewed 87 sSAH patients with WFNS (World Federation of Neurosurgical Societies) grade III-IV, who received tracheostomy. Decannulation events and the time from tracheostomy to decannulation were recorded in a 200-days follow-up. Variables analyzed were: age, sex, WFNS grade, Fisher grade, the presence of intracerebral or intraventricular hematoma, acute hydrocephalus, aneurysm location, aneurysm obliteration (surgical vs. endovascular), treatment related complications, decompressive craniectomy, symptomatic cerebral vasospasm, vasospasm-related infarction and timing of tracheostomy. Further risk factors analyzed were preexisting chronic lung disease and pneumonia. Functional outcome was assessed by the modified Rankin Scale (mRS).

Results: The rate of successful decannulation was 84% after a median of 47 days. A higher WFNS grade and pneumonia were associated with both a prolonged time to decannulation (TTD) and decannulation failure (DF). Older age (> 60 years) and necessity for decompressive craniectomy were only associated with prolonged TTD. Outcome analysis revealed that patients with DF show a significantly ($p < 0.01$) higher rate of unfavorable outcome (mRS 3–6).

Conclusion: Successful decannulation is possible in the majority of sSAH patients and particularly, in all patients with WFNS grade III. WFNS grading, age, the necessity for decompressive craniectomy and pneumonia are significantly associated with the TTD. WFNS grade and pneumonia are significantly associated with DF. The mean cannulation time of sSAH patients is shorter in relation to stroke patients.

1. Introduction

Subarachnoid hemorrhage is a devastating disease, which is still associated with a high morbidity and mortality [1]. Especially patients with poor-grade (World Federation of Neurosurgical Societies [WFNS] grade III-V) spontaneous subarachnoid hemorrhage (sSAH) remain on the intensive care unit (ICU) for many weeks and often require prolonged mechanical ventilation [2,3]. The clinical benefit of tracheostomy in the acute ICU setting is well proven. Tracheostomy reduces complications of prolonged mechanical ventilation and facilitates the weaning phase significantly due to a reduction of airway dead space and breathing work [4,5].

In the postacute phase, one major therapeutic goal is the decannulation of sSAH patients in order to facilitate speech recovery, swallowing and oral food intake. Moreover, long-term complications of tracheostomy such as bleeding, respiratory infections, tracheal stenosis and tracheomalacia [6], can be related to the length of time the tracheostomy tube is left in place [7,8]. Additionally, long-term cannulation and decannulation failure (DF) may not only complicate the postacute phase but also seem to correlate with an unfavorable outcome

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[9].

While some studies deal with positive predictors of weaning and decannulation in heterogenous traumatic and non-traumatic brain injury patients [10,11], only poor data exist about the course of decannulation in the postacute phase of sSAH patients. To improve the decision-making with regards to neurorehabilitation, more detailed knowledge about the expected time to decannulation (TTD) and the rate of DF would be helpful.

Therefore, the aim of this study was to provide data about the disease specific course of decannulation in a cohort of SAH patients, and to analyze potential risk factors associated with long-term cannulation and DF.

2. Methods and patients

2.1. Patients

The International Classification of Diseases (ICD-10) code I60 (I60.0 through I60.9) was used to screen our medical database for patients who were admitted to our hospital due to sSAH.

We recruited patients who met the following inclusion criteria: i. patients with initial WFNS grade 3–5, ii. tracheostomy due to invasive mechanical long-term ventilation and iii. the presence of complete 200-day follow-up data regarding the issue of decannulation or DF. We excluded all patients who died in our hospital during acute care. This study was approved by the Institutional Review Board (AZ 19-207).

2.2. Clinical data collection

We collected sociodemographic data (age, sex) of the included patients. The patients were dichotomized into "younger age" (< 60 years) and "older age" (> = 60 years). Disease-specific predictors for long-term cannulation and DF analyzed were as follows: WFNS grade, Fisher grade, the presence of intracerebral or intraventricular hematoma, acute hydrocephalus, aneurysm location, method of aneurysm obliteration (surgical vs. endovascular), treatment related complications, decompressive craniectomy, symptomatic cerebral vasospasm (sCVS) and vasospasm related infarction. Moreover, we reviewed the patients for preexisting chronic lung diseases (restrictive or obstructive) and the occurrence of pneumonia as well as the timing of tracheostomy.

Pneumonia was defined using the following clinical criteria: new or progressive pulmonary infiltration on chest x-ray plus at least two of the following variables: fever > 38 °C or hypothermia < 36 °C, leukocytosis or leukopenia, and purulent respiratory secretions [12].

We defined "early tracheostomy" as tracheostomy during the first 7 days after admission.

Functional outcome was analyzed using the modified Rankin Scale (mRS 0–6), which was assessed at discharge, after 3 months, and after 6 months. The outcome was stratified into favorable outcome (mRS 0–3) and unfavorable outcome (mRS 4–6).

2.3. Tracheostomy

Bronchoscopically guided percutaneous dilatational tracheostomy [13] was performed in all included patients using the "Ciaglia Blue Rhino" (Cook Medical, Bloomington, IN, USA). The indication for tracheostomy was based on a poor neurological state at admission and the anticipated need for long term mechanical ventilation. All cannulations were performed by an experienced surgeon.

2.4. Decannulation protocol

After the acute treatment phase, the tracheostomized sSAH patients were transferred to a neurologic rehabilitation unit (NRU). Decannulation was performed at our neurointensive care unit or at the NRU according to a decannulation protocol, which was completed by a senior neurologist and a speech and language therapist.

Before decannulation the following conditions had to be fulfilled: i. the ability to breathe without assistance for at least 48 h with stable arterial blood gases or $SpO_2 > 95\%$ in ambient air, respectively, ii. capping of the unblocked tracheostomy tube for at least 24 h, iii. clinical presence of reactive cough and the ability to manage secretions, iv. sufficient swallowing function. Fibro-endoscopic assessment was used in case of swallowing dysfunction. The detailed decannulation protocol is provided in Appendix A.

DF was defined as the failure to reach successful decannulation during the first 200 days after tracheostomy. Patients with a need for reintubation or recannulation after decannulation during the 200 day period were also allocated as DF.

2.5. Statistical analysis

Statistical analysis was performed using the software package IBM® SPSS® (version 24.0). Differences in categorical variables between the groups were compared by chi-square test or Fisher's exact test. The TTD during the follow-up period was calculated using Kaplan-Meier analysis. Kaplan-Meier plots were used to visualize the TTD for different groups. The median TTD was compared between the groups using the log rank test. The factors associated with TTD were determined using a multivariate cox proportional hazard model. In the multivariate Cox stepwise regression analysis we included all variables that were identified in univariable analysis with a p value of less than 0.1. Differences were regarded statistically significant at $p < 0.05$.

3. Results

87 patients participated in this study, fulfilling all inclusion criteria (Fig. 1). The SAH-related characteristics are shown in Table 1. The tracheostomy rate for our patients with poor grade sSAH was 99/207 (48%). We had a loss of follow-up data in 4 patients.

Successful decannulation was achieved in 73 patients (84%), whereas DF occurred in 14 patients. In all cases of DF, patients did not fulfill the clinical criteria, which are defined in the decannulation protocol utilized. No cases of reintubation or recannulation were observed.

We found a significantly higher proportion of patients being treated for pneumonia in the DF group (100%) in relation to patients who underwent successful decannulation (68%) (p = 0.017).

Moreover, we found significantly more patients with a poor neurological state at admission (WFNS grade IV−V) in the DF group (p = 0.047). Table 2 provides information about the analysis of different variables between these groups.

The median TTD was 47d (CI 0.95: 39–55). WFNS grade (III – V), age (< 60y vs. > 60y), decompressive craniectomy and the occurrence of pneumonia clearly delineate the patients with regard to TTD; other parameters analyzed did not show any significant differences (Table 2). Log rank analysis showed that older age, poor WFNS grade (IV–V) and occurrence of pneumonia are significantly associated with a longer TTD (p = 0.011) (Fig. 2).

Furthermore, the multivariate Cox regression analyses confirmed that the variables older age (HR 2.11 [1.22–3.64], p = 0.007), WFNS grade IV-V (HR 2.04 [1.11–3.74], p = 0.022), decompressive craniectomy (HR 2.16 [1.23–3.77], p = 0.007) and occurrence of pneumonia (HR 2.00 [1.18–3.42], p = 0.011), were independently associated with longer TTD (Table 3).

Outcome analysis revealed that all patients with DF exhibited an unfavorable outcome (mRS 3–6), even at 6 month follow-up, while successfully decannulated patients showed a significantly lower rate (0.65) of unfavorable outcomes over the same period (p = 0.007) (Table 4).

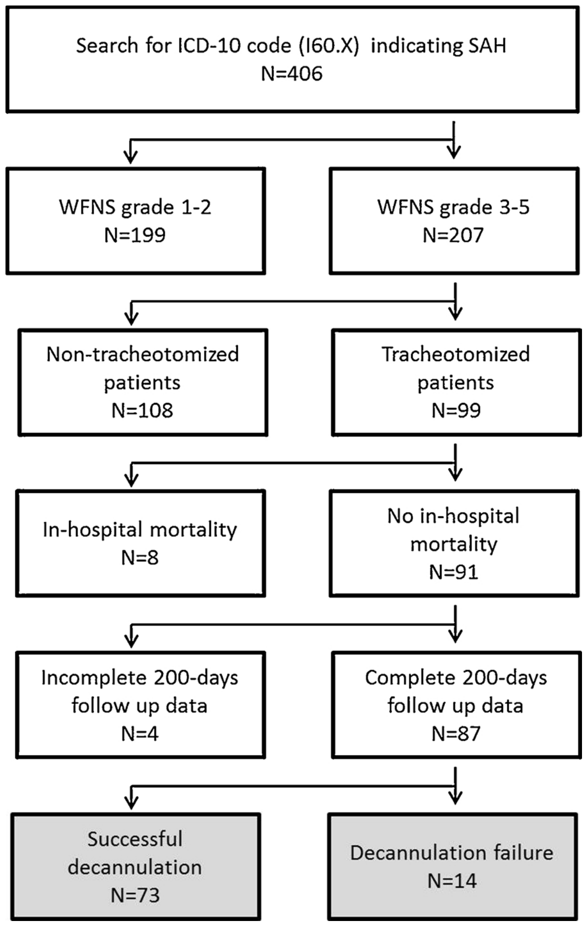

Fig. 1. Flow chart for patient inclusion. *ICD* International Classification of Diseases, *SAH* subarachnoid hemorrhage, *WFNS* World Federation of Neurosurgical Societies.

Table 1
SAH related characteristics of included patients.

Number of patients	87
Median age (years [IQR])	56 [48 – 66]
Sex (no.[%])	
Female	64 [73.6]
Male	23 [26.4]
WFNS grade (no.[%])	
III	15 [17.2]
IV	35 [40.2]
V	37 [42.5]
Fisher grade (no.[%])	
1	0 [0]
2	1 [1.1]
3	14 [16.1]
4	72 [82.8]
Intraventricular hemorrhage (no.[%])	60 [69.0]
Intracerebral hemorrhage (no.[%])	42 [48.3]
Aneurysm localization (no.[%])	
Anterior circulation	70 [80]
Posterior circulation	16 [18.4]
No aneurysm	1 [1.1]

SAH Subarachnoid hemorrhage, *IQR* Interquartile range, *WFNS* World Federation of Neurosurgical Societies.

4. Discussion

Tracheostomy is a common procedure in neurocritical care of stroke patients. Tracheostomy rates in heterogeneous stroke cohorts, including sSAH patients, vary between 4% and 35% [14–17]. Our presented tracheostomy rate of 48% appears high in comparison, but it should be noted that our analysis was restricted to patients suffering from poor grade sSAH (WFNS III-V).

Several studies deal with potential risks, the optimal technique or timing, or the safety of tracheostomy in sSAH patients [18–22]. But only poor data exist about the time course of decannulation and the rate of successful decannulation in sSAH patients. Some studies showed that the rate for successful decannulation of neurocritical patients is around 35% [23,24]. However, patients with sSAH are underrepresented in these studies and a subgroup analysis indicated that the course of decannulation seems to differ significantly between sSAH patients and patients who suffer from other neurocritical diseases [23]. In relation to these heterogeneous collectives, our analysis did show that the rate of successful decannulation is markedly higher in sSAH patients (85%), even in those with poor initial neurological states (WFNS grade III-V). However, one should be aware that a successful decannulation does not automatically precede a favorable outcome. In fact, our data show that only 35% of the decannulated patients are classified as mRS 1–3 after 6 months (Table 4). On the other hand, DF worsens the functional outcome of neurocritical patients substantially [23]. In our analysis, we found that all patients with decannulation failure exhibited an

Table 2
Patient characteristics in relation to successful decannulation and decannulation failure.

	Successful decannulation	Decannulation failure	P
Number of patients	73	14	
Age (no. [%])			0.095
age < 60 years	48 [65.8]	6 [42.9]	
age > 60 years	25 [34.2]	8 [57.1]	
Sex (no. [%])			0.538
female	19 [26.0]	4 [28.6]	
male	54 [74.0]	10 [71.4]	
Chronic lung disease (no. [%])	5 [6.8]	2 [14.3]	0.313
Pneumonia	50 [68.5]	14 [100.0]	**0.017**
WFNS grade (no. [%])			**0.048**
III	15 [20.5]	0 [0.0]	
IV	29 [39.7]	6 [42.9]	
V	29 [39.7]	8 [57.1]	
Fisher grade (no. [%])			0.458
2	1 [1.4]	0 [0.0]	
3	13 [17.8]	1 [7.1]	
4	59 [80.8]	13 [92.9]	
Intraventricular hemorrhage (no. [%])	50 [68.5]	11 [78.6]	0.341
Intracerebral hemorrhage (no. [%])	35 [47.9]	7 [50.0]	0.577
Initial hydrocephalus	61 [83.6]	11 [78.6]	0.45
Aneurysm localization (no. [%])			0.08
Anterior circulation	61 [83.6]	9 [64.2]	
Posterior circulation	12 [16.4]	4 [28.6]	
No aneurysm	0 [0.0]	1 [7.1]	
Aneurysm obliteration (no. [%])			0.383
Interventional obliteration	40 [55.5]	9 [64.2]	
Surgical clipping	32 [44.4]	5 [35.7]	
Treatment related complications (no. [%])	28 [38.9]	4 [28.6]	0.318
Decompressive craniectomy (no. [%])	24 [32.9]	8 [57.1]	0.079
Symptomatic cerebral vasospasms (no. [%])	39 [53.4]	6[42.9]	0.332
Vasospasm related infarction (no. [%])	22 [30.1]	4 [28.6]	0.578
Early (< 7 days after admission) tracheostomy (no. [%])	13	2	0.55

Statistically significant differences in Chi square testing are made bold ($p < 0.05$).
WFNS World Federation of Neurosurgical Societies.

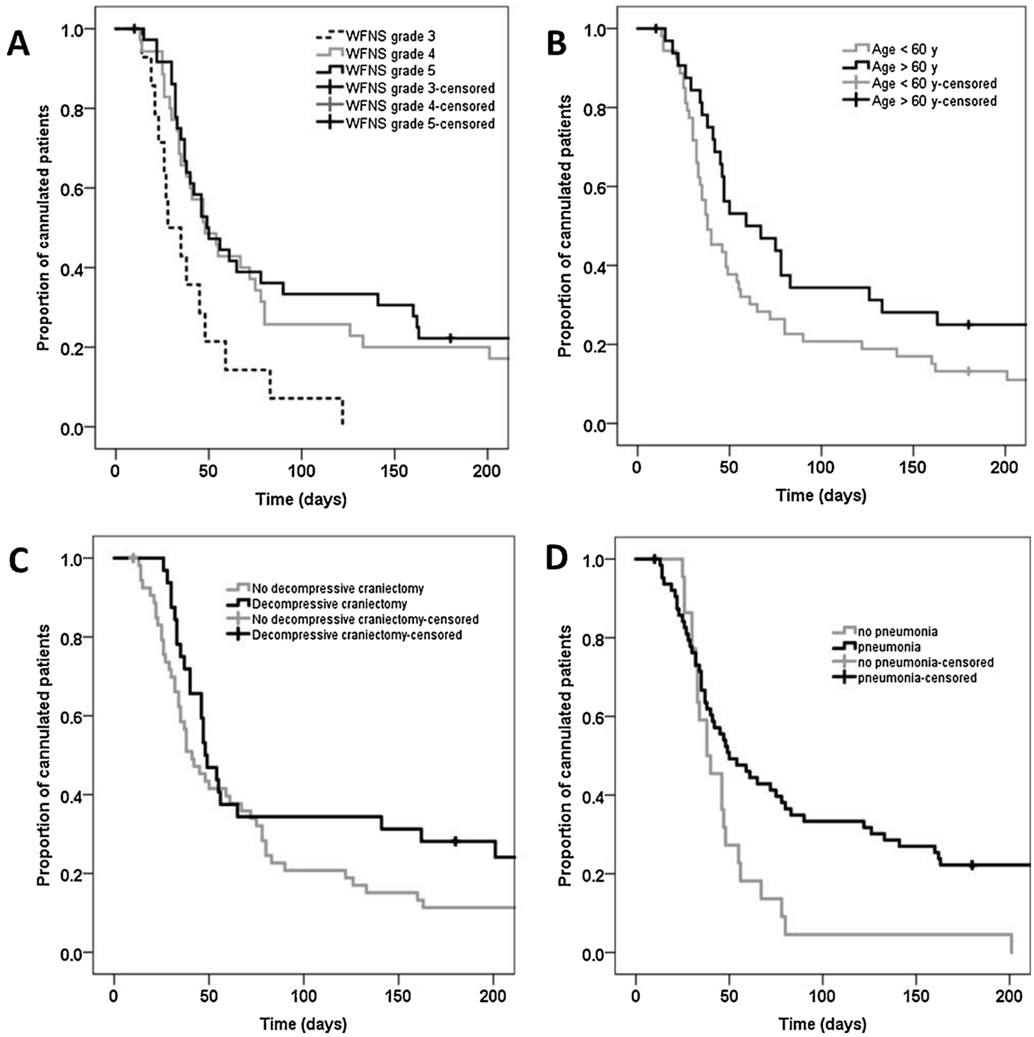

Fig. 2. Kaplan Meier plots showing the cumulative probability for decannulation in relation to initial WFNS grading (A) and patient age (B). *WFNS* World Federation of Neurosurgical Societies.

unfavorable outcome after 6 months.

To identify possible predictive factors for the occurrence of DF, we compared both groups regarding different known risk factors for an unfavorable outcome. In this analysis, a lower WFNS grade was the only factor, which was significantly associated with successful decannulation (Table 2). It should be particularly emphasized that all patients with WFNS grade III could be successfully decannulated. While the association of successful decannulation with a low WNFS grade and a subsequently better initial neurological state might be expected according to the literature [25,26], the missing association between decannulation and patient age is unexpected. Older age is a known predictor of unfavorable outcome in sSAH patients [26]. Regarding the risk factors for DF, *Schneider et al.* determined the patient's age to be an important predictor in a mixed stroke population [23]. Our data show that the clinical course of sSAH patients does not necessarily follow the expected course of other stroke patients and that the patient's age seems to be of minor impact.

In our study, we found a significantly higher rate of pneumonia in the DF group. Nosocomial pneumonia is associated with prolonged weaning duration and longer hospitalization [27]. With regard to SAH patients, a positive correlation between VAP and DF has not yet been described. The significant association of pneumonia and DF in our study might have been influenced by a higher rate of microaspiration of oropharyngeal secretions in patients with a poor initial neurological state (WFNS grade III-V), as patients with impaired consciousness are particularly at risk for developing pneumonia [28,29]. Studies have confirmed that nosocomial pneumonia is a common complication, especially in poor-grade SAH patients, who require continuous sedation and long-term mechanical ventilation [18,30]. Nonetheless, the overall rate of pneumonia in our collective (74%) appears high. However, it should be considered that the patients included had a high risk for pneumonia due to various reasons. All patients required long-term ventilation, continuous sedation and were tracheostomized. Moreover, all patients received enteral nutrition via nasogastric tubes and needed multiple intrahospital transports for radiographic diagnostics [31].

Our study also provides disease-specific data about the median TTD in sSAH patients. The observed median TTD (47 d) is hard to compare to the given ranges for other neurocritical patients (68–74 d), as most of the studies deal with mixed neurointensive populations or vary regarding the definition of TTD [32,33]. However, it seems that the median TTD of sSAH patients (47 d), particularly those with WFNS grade III (28 d), is shorter compared to other severe stroke patients. With regard to the short cannulation time in WFNS grade III patients, one could argue whether extubation trials might be promising in this specific condition. But while successful extubation trials might be favorable concerning the patient's outcome, an extubation failure may worsen the patients' functional outcome [34,35].

The multivariate Cox regression analyses revealed older age, WFNS grade, decompressive craniectomy and the occurrence of pneumonia as independent factors influencing TTD.

Table 3
Univariate and multivariate analysis of different variables concerning the time to decannulation.

		Univariate analysis		Multivariate analysis	
	Median TTD [CI-0.95]	Log rank χ^2	P	HR [CI-0.95]	P
Age		3.735	0.049		0.007
< 60 years	38 [27-49]			2.11 [1.22-3.64]	
≥60 years	59 [23-98]				
Sex		1.493	0.222		
Female	45 [36-54]				
Male	61 [32-90]				
Chronic lung disease		1.217	0.27		
yes	78 [29-127]				
no	46 [37-55]				
Pneumonia		6.433	0.011		0.011
yes	50 [32-68]			2.00 [1.18 – 3.42]	
no	38 [27-49]				
WFNS grade		9.112	0.011		0.022
III	28 [13-43]			WFNS IV-V:	
IV	48 [32-64]			2.04 [1.11-3.74]	
V	49 [33-65]				
Intraventricular hemorrhage		0.305	0.581		
yes	46 [35-57]				
no	48 [41-54]				
Intracerebral hemorrhage		0.425	0.514		
yes	48 [38-58]				
no	41 [28-54]				
Aneurysm localization		0.968	0.325		
Anterior circulation	47 [40-54]				
Posterior circulation	38 [25-60]				
Aneurysm obliteration		0.482	0.487		
Surgery	46 [35-56]				
Interventional	46 [20-72]				
Treatment complication		0.395	0.53		
yes	67 [25-109]				
no	42 [33-51]				
Decompressive craniectomy		2.739	0.098		0.007
yes	48 [39-57]			2.16 [1.23-3.77]	
no	41 [30-52]				
Symptomatic CVS		1.521	0.217		
yes	40 [28-52]				
no	48 [37-59]				
Vasospastic infarction		0.969	0.325		
yes	65 [49-81]				
no	40 [31-49]				
Initial hydrocephalus		0.001	0.978		
yes	46 [36-56]				
no	48 [30-66]				
Timing of tracheostomy		0.017	0.896		
early (< 7 days)	46 [33-59]				
late (≥7 days)	47 [38-56]				

Data comparisons were made using log rank test for univariable analysis and Cox-regression analysis was used for multivariable analysis. Statistically significant differences are made bold ($p < 0.05$).
CVS cerebral vasospasm, *TTD* Time to decannulation, *WFNS* World Federation of Neurosurgical Societies.

Firstly, it is not surprising that WFNS grade III is independently associated with early decannulation as our data showed that low WFNS grading is associated with the occurrence of successful decannulation. As pneumonia complicates mechanical ventilation and prolongs the weaning phase, a significantly longer TTD was also to be expected. Only a relatively small proportion of our SAH patients (7/87; 8.05%) had a preexisting chronic lung disease. Therefore this condition had no significant impact on DF or TTD, although a trend towards a higher likelihood of DF and a longer TTD was apparent in this study.

Table 4
Functional outcome.

	Successful decannulation	Decannulation Failure	P
mRS (3-month)			0.202
Favorable outcome	12 [16.9]	0 [0.0]	
Unfavorable outcome	59 [83.1]	14 [100]	
mRS (6-month)			**0.007**
Favorable outcome	18 [34.6]	0 [0.0]	
Unfavorable outcome	34 [65.3]	14 [100]	
Case fatality rate (6-month)	2 [3.8]	3 [21.4]	0.035

Statistically significant differences in Chi square testing are made bold ($p < 0.05$).
mRS modified Rankin Scale.

Interestingly, we found two additional factors (age and the necessity for decompressive craniectomy) which showed no association with DF, but did show a significant association with TTD. Both factors seem to extend the TTD without increasing the risk of DF.

These results are consistent with previous studies, showing that age and the necessity for decompressive craniectomy are known risk factors for a poorer functional outcome and a lower probability of successful decannulation in neurocritical stroke patients [23,36,37].

While several authors propagate the beneficial effects of early tracheostomy in neurocritical stroke cohorts and even in sSAH cohorts [18,20], we cannot support this theory as we found no correlation between the timing of tracheostomy, the TTD, or the occurrence of DF. But we have to consider that a potential bias may result from non-standardized decision-making regarding this issue in our analysis. However, the discussion regarding the optimal timing of tracheostomy in sSAH patients remains open.

There are several limitations to this study. A major limitation arises from its retrospective study design, causing some informational bias. The decision-making for tracheostomy depended on our described clinical practice and may differ from other centers. Especially in regard to patients with WFNS grade III, only those patients underwent tracheostomy, which demonstrated a higher risk for long-term mechanical ventilation. Thus, our results are not applicable to all sSAH patients.

Although all decannulation procedures followed a standardized protocol with swallowing and cough assessments, we cannot provide data about validated assessment scores. Moreover, we have not analyzed the individual causes for DF, nor did we collect information about complications that occurred during the rehabilitation phase. Further studies may address the incidence of different causes in the group of sSAH patients showing DF.

We did not include patients with good grade sSAH, who had a need for tracheostomy due to severe complications, because the impact of those complications is difficult to estimate.

The strength of our analysis is the uniform collective, which only included patients with sSAH and similar neurological states (WFNS grade III-V).

Our analysis gives detailed information about the course of decannulation in poor grade sSAH patients. We could show that successful decannulation is possible in the majority of sSAH patients and in particular, in all patients with WFNS grade III. WFNS grading, age and the necessity for decompressive craniectomy are significantly associated with the TTD. In relation to other severe stroke patients, a shorter cannulation time can be observed in sSAH patients.

Appendix A

See Fig. A1.

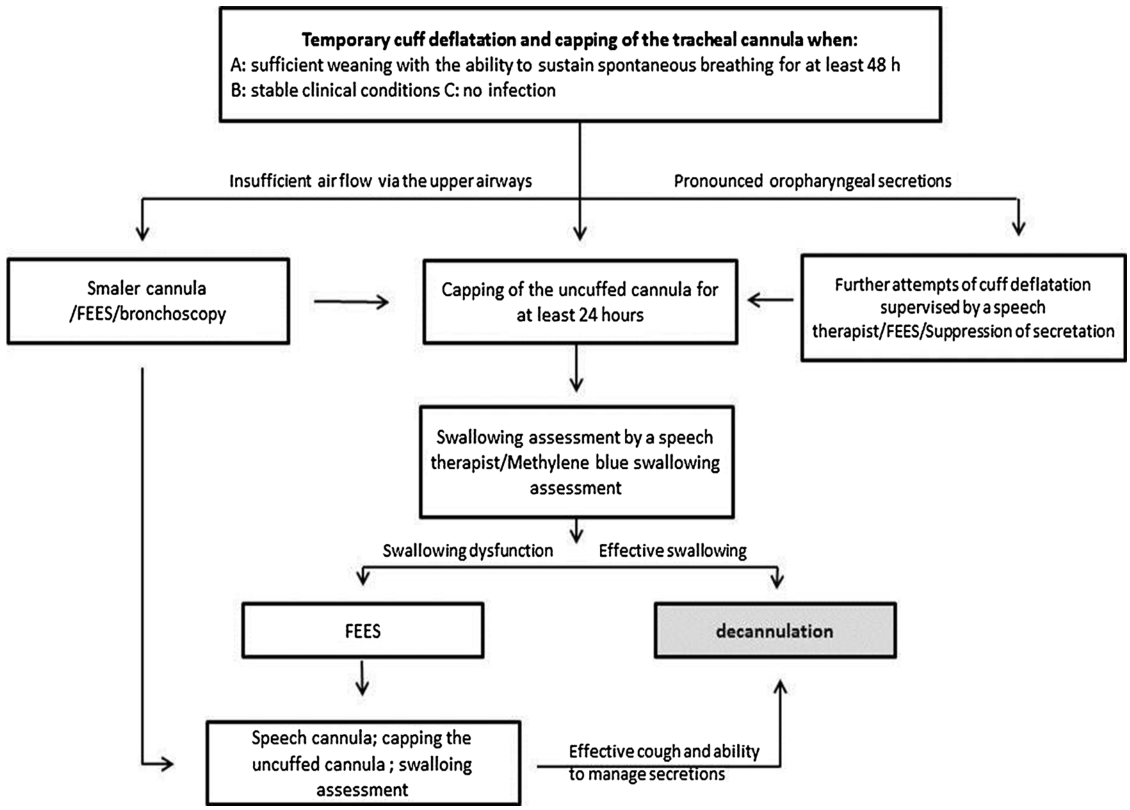

Fig. A1. Flow-chart of our standardized decannulation protocol. *FEES* Fiberoptic Endoscopic Evaluation of Swallowing.

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