Original Paper

Cerebrovascular Diseases

Cerebrovasc Dis 2006;21:159–165
DOI: 10.1159/000090527

Received: June 8, 2005
Accepted: September 19, 2005
Published online: December 23, 2005

Predictive Factors for Tracheostomy in Neurocritical Care Patients with Spontaneous Supratentorial Hemorrhage

Hagen B. Huttner[a] Martin Kohrmann[a] Christian Berger[a]
Dimitrios Georgiadis[b] Stefan Schwab[a]

Departments of Neurology, [a]University of Heidelberg, Heidelberg, Germany, and [b]University of Zurich, Zurich, Switzerland

Key Words
Tracheostomy · Intracerebral hemorrhage · Hydrocephalus

Abstract
Background: Up to 30% of patients with supratentorial intracerebral hemorrhage (ICH) require mechanical ventilation during the course of treatment. For these patients, tracheostomy is necessary in cases of protracted weaning. As only limited data exist about predictors for a tracheostomy in patients with ICH, the aim of this study was to investigate the frequency of tracheostomy and clinical findings that increase the risk for a tracheostomy in patients with supratentorial hemorrhage. ***Methods:*** A total of 392 patients with supratentorial ICH were analyzed. The parameters age, gender, chronic obstructive pulmonary disease (COPD), Glasgow Coma Scale on admission, ganglionic or non-ganglionic localization, presence of ventricular hemorrhage, hydrocephalus, hematoma volume, and hematoma evacuation were investigated. The effects on the end-point tracheostomy were analyzed using multivariate regression analyses. ***Results:*** The overall need for tracheostomy was 9.9% (16.3% in patients with ganglionic hemorrhage versus 2.8% in patients with non-ganglionic hemorrhages). 31% of the ventilated patients required tracheostomy. The risk for tracheostomy was increased eightfold in patients who developed hydrocephalus. The presence of ventricular blood, in general, showed no significant impact on the need for tracheostomy, whereas hemorrhage extending into the third and fourth ventricles in conjunction with hydrocephalus increased the risk for tracheostomy. The hematoma volume correlated positively with the risk for tracheostomy. ***Conclusions:*** Our study demonstrates that approximately 10% of patients with ICH require tracheostomy during the course of their disease. Presence of COPD, hematoma volume, ganglionic location of the hematoma, and the development of hydrocephalus are predisposing factors for tracheostomy.

Introduction

Intracerebral hemorrhage (ICH) accounts for 10–15% of all strokes [1]. Morbidity and mortality in ICH patients are higher than in ischemic stroke [2]. As a general rule, one third of ICH patients are discharged from hospital with no or only minor deficits, one third with severe disability, and one third die immediately or during the hospital stay. The 1-year mortality of ICH ranges between 37

KARGER

Fax +41 61 306 12 34
E-Mail karger@karger.ch
www.karger.com

1015–9770/06/0213–0159$23.50/0

Accessible online at:
www.karger.com/ced

Hagen B. Huttner, MD
Department of Neurology – ICU, University of Heidelberg
Im Neuenheimer Feld 400, DE–69120 Heidelberg (Germany)
Tel. +49 6221 563 7782, Fax +49 6221 564 671
E-Mail hagen.huttner@med.uni-heidelberg.de

and 47% [3]. Prognostic factors for poor outcome are (i) an initially reduced level of consciousness, (ii) a large hematoma size, (iii) ventricular hemorrhage, and (iv) age [4–9].

Almost 30% of ICH patients require mechanical ventilation during their hospital stay [10, 11]. Especially in cases of prolonged ventilation, an early tracheostomy entails potential benefits, such as secure airways with decreased airway resistance and more efficient airway suctioning, shorter weaning duration, reduced ventilator-associated pneumonia, improved patient comfort with enhanced patient mobility, and an increased potential for speech and oral feeding [11–13]. In neurological settings, tracheostomy is indicated primarily in patients with decreasing levels of consciousness, inadequate cough or pharyngeal protection reflexes, or prolonged weaning [14, 15].

Up to now, no studies on the frequency of and predicting factors for tracheostomy in ICH patients are available. We hypothesized that factors which affect prognosis and outcome of ICH patients may also account for an increased risk for a tracheotomy. The present study aims to identify parameters which predispose to a prolonged weaning phase and to define clinical factors indicating the need for early tracheostomy in patients with supratentorial ICH.

Methods

Patient Selection

The source of the present study was a prospectively organized database of our department. We enrolled all patients diagnosed with spontaneous supratentorial ICH within 24 h of symptom onset who were treated on our stroke and intensive care units between January 2000 and December 2004 by conducting the following steps: (i) of altogether 962 ICH patients, patients with spontaneous supratentorial hemorrhage were isolated (n = 707). Patients with ICH related to oral anticoagulant therapy were excluded (n = 56), as well as sub-, epidural and subarachnoid hemorrhages (n = 44), and ICH due to trauma or tumors (n = 53); (ii) of the remaining 554 patients, in a second step, we excluded those patients with an unfavorable prognosis and 'do not resuscitate' orders who did not receive treatment due to herniation signs on admission in combination with severe comorbidity or absent consent of relatives for neurocritical care (n = 117); (iii) furthermore, all patients who received intraventricular fibrinolytic therapy for clot lysis were not considered (n = 23); (iv) all patients with incomplete data or insufficient medical records were excluded (n = 22). 392 patients remained for analysis. We determined the clinical parameters by reviewing the medical records and the neuroradiological parameters by reviewing the CCT and MRI scans.

Selection of Variables

The following variables were extracted from the database: age, gender, Glasgow Coma Scale (GCS) on admission and discharge, history of chronic obstructive pulmonary disease (COPD), mechanical ventilation, and tracheostomy. Age was classified into (i) younger than 55 years, (ii) between 55 and 70 years, and (iii) over 70 years. The GCS was classified into (i) 3–7, (ii) 8–12, and (iii) 13–15 [16].

Neuroradiologic Data

ICH was diagnosed immediately after hospital admission by CCT (Siemens Somatom Volume zoom, Erlangen, Germany) or MRI (Siemens Symphony, 1.5 Tesla). We categorized the hematoma site into ganglionic and not-ganglionic, whereas ganglionic localization included thalamic hematomas, and the not-ganglionic localization was defined to include either 'lobar' hematomas (i.e. ICH arising predominantly from the cortex and/or subcortical region), or 'deep' hemorrhages (i.e. ICH being located periventricular but supraganglionic). If intraventricular hemorrhage (IVH) was present, the involved ventricles were noted using the GRAEB score [17]. Hydrocephalus was determined by enlargement of the lateral ventricles on CCT scan upon admission or follow-up CCT within 12 h independently by two physicians [18]. Hydrocephalus was evaluated by measuring the bicaudate index (considered present when it exceeded the 95th percentile for age) and the mean temporal horn diameter [19]. Combination of enlarging lateral ventricles on follow-up scans in association with diminishing external CSF spaces and deterioration of vigilance was considered as clinical relevant hydrocephalus. In sedated and ventilated patients, consensus about presence of relevant hydrocephalus was obtained by the neuroradiologist, neurologist and neurosurgeon on duty. ICH volume was calculated using the initial CCT or MRI scan according to the formula for ellipsoids ($A \times B \times C/2$, with A, B, C representing the respective radius in all three dimensions), which has been demonstrated to estimate hematoma volume reliably [20, 21]. In cases of growth of the ICH on follow-up CCT, that CCT possessing the largest hematoma volume was used if the patient had not already received tracheostomy by that time. The hematoma volumes are given in cm^3 and were classified into small (<25 cm^3), middle (25–60 cm^3), and large (>60 cm^3) [16].

Clinical Management

All patients received standard medical treatment according to an institutional protocol for ICH, including hematoma evacuation on an individual basis (n = 41). Patients requiring mechanical ventilation during the course of treatment were sedated with midazolam and fentanyl. Presence of COPD was defined and treated according to published guidelines [22, 23]. Ventricular drainage (EVD) was initiated in all patients showing evidence of occlusive hydrocephalus [24]. Pneumonia was diagnosed clinically, radiographically and by increased infectious parameters, and primarily treated using β-lactam antibiotics or gyrase inhibitors.

Weaning Protocol and Tracheostomy Protocol

The weaning protocol was as follows: weaning, in general, was started in every ventilated patient as soon as complications of ICH (hydrocephalus or aspiration pneumonia) were adequately treated. In cases of severe pneumonia, weaning was deferred until (i) FiO_2 levels were $\leq 40\%$ to reach pO_2 levels of >70 mm Hg, (ii) the positive end-expiratory pressure was ≤ 8 cm H_2O, and (iii) the ratio of

Table 1. Clinical and neuroradiologic characteristics of all patients and separated for lobar vs. ganglionic localization

Characteristic	All patients (n = 392)	Ganglionic hemorrhage (n = 212)		Non-ganglionic hemorrhage (n = 180)	p value
		all	thalamic/non-thalamic		
Gender					
Male	58%	60%		55%	0.8212
Female	42%	40%		45%	
Age					
<55	12%	7%		18%	0.1222
55–70	66%	71%		60%	0.2262
>70	22%	22%		22%	0.9245
GCS					
3–7	24%	35%		11%	0.0420
8–12	30%	20%		42%	0.5274
13–15	46%	45%		47%	0.9866
Volume					
<25 cm^3	46%	56%	43/66%	34%	0.0252
25–60 cm^3	26%	14%	14/14%	40%	0.0075
>60 cm^3	28%	30%	27/32%	26%	0.6254
Ventricular hemorrhage	42%	48%	45/50%	35%	0.1055
Lateral ventricle	42%	48%	45/50%	35%	0.1055
Third ventricle	30%	38%	43/34%	21%	0.0872
Fourth ventricle	22%	32%	34/30%	10%	0.0468
GRAEB score (median)	7	8	8/9	5	0.8225
Hydrocephalus	16%	22%	23/22%	9%	0.0802

inspiratory and expiratory time was ≤1:2. In all cases of protracted or futile weaning, tracheostomy was performed after 12 days of endotracheal intubation. However, if patients had been extubated and needed to be re-intubated because of global respiratorial insufficiency, up to overall 2 extubation attempts were warranted before tracheostomy was performed. Necessary re-intubation due to progredient aspiration was considered as presumably protracted weaning. In these cases, tracheostomy was performed within 3 days after re-intubation. In some of these patients we did not strictly follow our institutional protocol for tracheostomy and some patients did not receive tracheostomy until day 15 (n = 7). Generally, patients were extubated as soon as GCS reached levels of 8 and higher and in the presence of adequate brainstem reflexes.

Statistical Analysis

All statistical analyses were performed on a personal computer using the StatView software package (StatView 5.0, SAS, Cary, N.C., USA; www.statview.com). χ^2, Fisher's exact and Mann-Whitney U-test were used to determine associations between categorized variables. A value of $p < 0.05$ was considered statistically significant. Data are presented as mean ± SD or median and range as appropriate.

The influence of various parameters on tracheostomy was assessed using multivariate logistic regression analysis. A backward selection procedure was applied to obtain a model with only four explanatory variables. p value and odds ratios (OR) for each previously eliminated variable were evaluated by reinstituting that variable into the model. The parameters initially included in the model were age, gender, presence of COPD, GCS on admission, localization of ICH, presence of ventricular hemorrhage with distinction between the various ventricles, presence of hydrocephalus, increase in hematoma volume, and hematoma evacuation (univariately tested parameters were considered statistically significant if $p < 0.1$). The model obtained showed a Hosmer-Lemeshow goodness-of-fit value of $p = 0.376$. With special reference to the hematoma location, we a priori decided to calculate a second multivariate logistic regression model including all patients with ganglionic hemorrhage.

Results

Clinical and Radiologic Findings on Hospital Admission

We included a total of 392 patients (mean age 66 ± 13 years). The median GCS on admission was 11 (3–15). The mean hematoma volume was 26 ± 21 cm^3. In addition, 42% of the patients suffered from IVH (table 1).

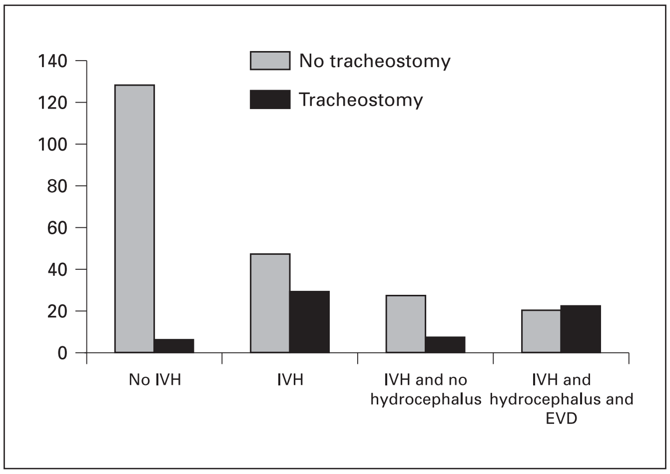

Fig. 1. Incidence of tracheostomy of patients with ganglionic hemorrhages. The difference between patients with and without IVH was significant (Mann-Whitney U-test: $p < 0.05$). The sub-analysis of patients with IVH (with no hydrocephalus vs. presence of hydrocephalus) revealed a significantly higher frequency of tracheostomies in the group with hydrocephalus (Mann-Whitney U-test: $p < 0.05$).

Hematoma volume was evaluated based on CT findings in 92%, and based on MRI in 8% of the cases.

Frequency of Tracheostomy

Of all 392 patients included, 124 patients required mechanical ventilation either during the clinical course or were already admitted intubated and ventilated. 39 patients (i.e. 9.9% of all patients and 31% of the ventilated patients) received a tracheostomy. Frequency of tracheostomy was significantly higher in ganglionic hemorrhages (16.4%; no significant differences between thalamic (15.3%) and non-thalamic hemorrhages (17.2%)) than in non-ganglionic hemorrhages (2.3%; Mann-Whitney U-test: $p < 0.04$).

Hereupon, the frequency of tracheostomy was sub-analyzed for patients with only ganglionic hemorrhage with respect to IVH and hydrocephalus (fig. 1). Patients without IVH received a tracheostomy significantly less often (4.6%) than patients with IVH (38%). Further analysis of only the patients with IVH (n = 76) revealed that more than every second patient (52.2%) with IVH and hydrocephalus required tracheostomy, whereas IVH without hydrocephalus was associated with a tracheostomy rate of 19.5%.

Predictive Factors for Tracheostomy

First, data from all included patients with supratentorial hemorrhage were subjected to a univariate regression analysis (table 2a). Of the parameters tested, (i) age, (ii) COPD, (iii) the ganglionic location, (iv) GCS on admission, (v) hematoma volume, (vi) IVH, and (vii) hydrocephalus were significant for the end-point tracheostomy (upper part, 'unadjusted'). In the multivariate analysis, only the parameters (i) COPD, (ii) hematoma volume, (iii) hydrocephalus, and (iv) ganglionic localization showed significant impact on the risk for a tracheostomy (lower part, 'adjusted').

We a priori decided to perform a second logistic regression focusing on ganglionic hemorrhages. Ganglionic localization was shown to be an independent risk factor for tracheostomy in the first regression model. Table 2b (upper part, 'unadjusted') provides information about the univariately tested parameters and their OR for the end-point tracheostomy in sub-analysis of patients with ganglionic ICH. Statistically significant was found to be (i) age, (ii) COPD, (iii) hematoma volume, (iv) ventricular hemorrhage, and (v) hydrocephalus. The presence of ventricular hemorrhage, in general, showed an OR of >4. Analyzing the various affected ventricles separately, no statistical significance was found if only the lateral ventricles were affected. Involvement of the third and fourth ventricle, however, revealed significant impact on the need for tracheostomy. For multivariate analysis, we chose the parameter ventricular hemorrhage and did not distinguish between the various ventricles. The multivariate analysis revealed three parameters that significantly impacted the risk for tracheostomy: (i) presence of COPD (OR 1.985; $p < 0.04$), (ii) hematoma volume (OR 1.261; $p < 0.02$), and (iii) in particular hydrocephalus (OR 8.144; $p < 0.0001$), on the other (lower part, 'adjusted').

Discussion

Our data show a significantly higher frequency of tracheostomies in patients with ganglionic hemorrhage than with non-ganglionic hemorrhage. Within the group of ganglionic hemorrhages, patients who suffered from additional hydrocephalus and therefore required an EVD showed the highest risk for tracheostomy. We were able to identify presence of COPD, hydrocephalus, and hematoma size as independent risk factors for tracheostomy.

Anatomical reasons may account for the differences between patients with ganglionic and non-ganglionic hemorrhage. Ganglionic hematomas have been shown to

Table 2. Multiple regression analysis of risk factors for a tracheostomy in patients with supratentorial (n = 392) and ganglionic (n = 212) hemorrhage

a Patients with supratentorial hemorrhage	Tracheostomy	
	OR (95% CI)	p value
Unadjusted		
Age	0.975 (0.942–0.996)	0.0977
Gender (male)	1.011 (0.972–1.268)	0.8642
COPD	4.251 (3.072–7.828)	0.0153
Location ganglionic	1.310 (1.112–2.054)	0.0215
GCS on admission	0.912 (0.845–0.977)	0.0094
Increase in hematoma volume (5-ml steps)	1.025 (1.004–1.047)	0.0222
Ventricular hemorrhage	3.895 (2.032–7.467)	<0.0001
Hydrocephalus	6.345 (3.400–11.84)	<0.0001
Hematoma evacuation	1.165 (0.842–1.414)	0.7725
Adjusted		
Age	0.621 (0.498–0.930)	0.1056
COPD	2.784 (2.106–4.043)	0.0305
Location ganglionic	1.331 (1.056–2.325)	0.0410
GCS on admission	0.961 (0.717–1.165)	0.5154
Increase in hematoma volume (5-ml steps)	1.289 (1.067–1.738)	0.0188
Ventricular hemorrhage	1.583 (0.572–2.734)	0.7365
Hydrocephalus	5.823 (1.826–21.33)	0.0102

b Basal ganglia hemorrhage	Tracheostomy	
	OR (95% CI)	p value
Unadjusted		
Age	1.082 (1.044–1.108)	0.0382
Gender (male)	1.115 (0.882–1.351)	0.8122
COPD	2.303 (1.885–4.194)	0.0931
GCS on admission	0.982 (0.878–1.098)	0.7456
Increase in hematoma volume (5-ml steps)	1.042 (1.012–1.072)	0.0055
Ventricular hemorrhage	4.289 (1.225–12.44)	0.0012
Affection of: lateral ventricle	2.202 (0.988–5.834)	0.2782
third ventricle	5.691 (3.013–10.74)	<0.0001
fourth ventricle	3.646 (1.973–6.737)	<0.0001
Hydrocephalus	6.622 (3.238–11.06)	<0.0001
Hematoma evacuation	1.165 (0.842–1.414)	0.7725
Adjusted		
Age	1.359 (0.8955–2.006)	0.2138
COPD	1.985 (1.772–3.656)	0.0397
Increase in hematoma volume (5-ml steps)	1.261 (1.163–1.502)	0.0189
Ventricular hemorrhage	2.512 (0.823–5.916)	0.3275
Hydrocephalus	8.144 (5.072–20.81)	<0.0001

be more often associated with IVH than lobar hematomas [25]. Moreover, our data revealed the highest frequency of tracheostomies in patients with ganglionic hemorrhages with ventricular involvement and hydrocephalus, but not in cases with IVH alone. This finding likely reflects the certain amount of patients with IVH who did not develop occlusive hydrocephalus, due to IVH affecting only the lateral ventricles. Only those patients in whom the third and the fourth ventricle were affected and who consecutively developed occlusive hydrocephalus required tracheostomy significantly more often. If only lateral ventricles were affected prolonged phases of reconvalescence, complicate clinical course of treatment, and delayed discharge from hospital might result [5, 6, 9, 26], but this does not seem to influence need for tracheostomy, as anticipated in the univariate analysis. Even so, IVH in general has been shown to be associated with poor outcome, especially when occlusive hydrocephalus developed [6, 24].

In our patient series a larger ICH volume correlated with an increased rate of tracheostomies. Various studies showed that large hematoma volume and a low GCS at symptom onset resulted in worse outcome [4]. Deterioration in consciousness, associated with occurrence of large hematomas, is most likely responsible for protracted weaning and thus an increased rate of tracheostomy [11, 27]. Koh et al. [28] found a low GCS in patients on the neurological ICU to be the most important risk factor for a tracheostomy. Especially patients with respirator-associated pneumonia may benefit from an early tracheostomy [29].

Important in this regard is the impairment of respiratory control centers. In addition to the areas located in the medulla oblongata and pons, respiratory control in the midbrain, and particularly within the diencephalon have been reported to comprise essential parts of the respiratory drive [30–33]. Compressive ICH affecting these areas is likely to interfere with neuronal networks of the respiratory drive. Furthermore, the corticospinal control areas of respiratory muscles within the frontal lobe, which moreover in COPD patients are subjected to a ceiling effect [34], are at high risk of being affected by ICH, too. Although the mechanisms of supratentorial control of the respiratory drive are not yet fully understood, expansive ICH affecting the control centers possibly influences requirement of tracheostomy, which, however, has not been investigated in our series.

Taking that into account, patients with low GCS due to large hematomas who are affected by complicating hydrocephalus and suffer from COPD are at highest risk for an extended period of ventilation with all its adverse effects. Since more than every second patient in our series presenting with ganglionic hemorrhage, ventricular involvement and hydrocephalus required tracheostomy, the chance for a failure to contemporarily wean patients with these features – and thus avoid complications associated with long-term sedation – might be reduced by shortening the duration of endotracheal ventilation [11, 28, 35, 36]. In consequence, early tracheostomy might be of benefit with regard to outcome.

Our study has limitations. Due to the nature of this non-randomized and uncontrolled design, decisions in which patient and at what time point tracheostomy was performed were not consistent. We did not involve a number of parameters and confounding factors potentially influencing the requirement of a tracheostomy such as active smoking, pre-existing physical impairment, pre-existing diseases such as congestive heart failure, inconsistent treatment regimens and follow-up investigations. Furthermore, we excluded patients whose prognosis was considered to be poor or futile. Likewise, our series from the first represents a selected patient collective. Finally, we concentrated only on supratentorial ICH. However, to the best of our knowledge, this study is the first of its kind and larger randomized prospective trials are lacking.

In this study we provide information on the frequency of and predisposing factors for tracheostomy in patients with supratentorial ICH. Approximately 10% of patients with ICH require tracheostomy during the course of their disease. (i) The presence of COPD, (ii) the ganglionic hemorrhage location, (iii) the hematoma volume, and (iv) the development of hydrocephalus are predisposing factors for tracheostomy. ICH patients presenting with these features show an increased risk for protracted weaning and require tracheostomy more frequently.

References

1 Cheung RT, Zou LY: Use of the original, modified, or new intracerebral hemorrhage score to predict mortality and morbidity after intracerebral hemorrhage. Stroke 2003;34:1717–1722.

2 Qureshi AI, Tuhrim S, Broderick JP, Batjer HH, Hondo H, Hanley DF: Spontaneous intracerebral hemorrhage. N Engl J Med 2001;344:1450–1460.

3 Daverat P, Castel JP, Dartigues JF, Orgogozo JM: Death and functional outcome after spontaneous intracerebral hemorrhage. A prospective study of 166 cases using multivariate analysis. Stroke 1991;22:1–6.

4 Franke CL, de Jonge J, van Swieten JC, Op de Coul AA, van Gijn J: Intracerebral hematomas during anticoagulant treatment. Stroke 1990;21:726–730.

5 Hemphill JC 3rd, Bonovich DC, Besmertis L, Manley GT, Johnston SC: The ICH score: a simple, reliable grading scale for intracerebral hemorrhage. Stroke 2001;32:891–897.

6 Liliang PC, Liang CL, Lu CH, Chang HW, Cheng CH, Lee TC, Chen HJ: Hypertensive caudate hemorrhage prognostic predictor, outcome, and role of external ventricular drainage. Stroke 2001;32:1195–1200.

7 Nilsson OG, Lindgren A, Brandt L, Saveland H: Prediction of death in patients with primary intracerebral hemorrhage: a prospective study of a defined population. J Neurosurg 2002;97:531–536.

8 Tuhrim S, Dambrosia JM, Price TR, Mohr JP, Wolf PA, Heyman A, Kase CS: Prediction of intracerebral hemorrhage survival. Ann Neurol 1988;24:258–263.

9 Tuhrim S, Horowitz DR, Sacher M, Godbold JH: Volume of ventricular blood is an important determinant of outcome in supratentorial intracerebral hemorrhage. Crit Care Med 1999;27:617–621.

10 Gujjar AR, Deibert E, Manno EM, Duff S, Diringer MN: Mechanical ventilation for ischemic stroke and intracerebral hemorrhage: indications, timing, and outcome. Neurology 1998; 51:447–451.
11 Qureshi AI, Suarez JI, Parekh PD, Bhardwaj A: Prediction and timing of tracheostomy in patients with infratentorial lesions requiring mechanical ventilatory support. Crit Care Med 2000;28:1383–1387.
12 Leitch EA, Moran JL, Grealy B: Weaning and extubation in the intensive care unit. Clinical or index-driven approach? Intensive Care Med 1996;22:752–759.
13 Boynton JH, Hawkins K, Eastridge BJ, O'Keefe GE: Tracheostomy timing and the duration of weaning in patients with acute respiratory failure. Crit Care 2004;8:R261–R267.
14 Heffner JE, Hess D: Tracheostomy management in the chronically ventilated patient. Clin Chest Med 2001;22:55–69.
15 Dupont H, Le Port Y, Paugam-Burtz C, Mantz J, Desmonts M: Reintubation after planned extubation in surgical ICU patients: a case-control study. Intensive Care Med 2001; 27:1875–1880.
16 Schwarz S, Hafner K, Aschoff A, Schwab S: Incidence and prognostic significance of fever following intracerebral hemorrhage. Neurology 2000;54:354–361.
17 Graeb DA, Robertson WD, Lapointe JS, Nugent RA, Harrison PB: Computed tomographic diagnosis of intraventricular hemorrhage. Etiology and prognosis. Radiology 1982;143: 91–96.
18 Naidich TP, Schott LH, Baron RL: Computed tomography in evaluation of hydrocephalus. Radiol Clin North Am 1982;20:143–167.
19 Van Gijn J, Hijdra A, Wijdicks EF, Vermeulen M, van Crevel H: Acute hydrocephalus after aneurysmal subarachnoid hemorrhage. J Neurosurg 1985;63:355–362.
20 Kothari RU, Brott T, Broderick JP, Barsan WG, Sauerbeck LR, Zuccarello M, Khoury J: The ABCs of measuring intracerebral hemorrhage volumes. Stroke 1996;27:1304–1305.
21 Gebel JM, Sila CA, Sloan MA, Granger CB, Weisenberger JP, Green CL, Topol EJ, Mahaffey KW: Comparison of the ABC/2 estimation technique to computer-assisted volumetric analysis of intraparenchymal and subdural hematomas complicating the GUSTO-1 trial. Stroke 1998;29:1799–1801.
22 Bach PB, Brown C, Gelfand SE, McCrory DC: Management of acute exacerbations of chronic obstructive pulmonary disease: a summary and appraisal of published evidence. Ann Intern Med 2001;134:600–620.
23 Fabbri L, Caramori G, Beghe B, Papi A, Ciaccia A: Chronic obstructive pulmonary disease international guidelines. Curr Opin Pulm Med 1998;4:76–84.
24 Diringer MN, Edwards DF, Zazulia AR: Hydrocephalus: a previously unrecognized predictor of poor outcome from supratentorial intracerebral hemorrhage. Stroke 1998; 29: 1352–1357.
25 Lipton RB, Berger AR, Lesser ML, Lantos G, Portenoy RK: Lobar vs. thalamic and basal ganglion hemorrhage: clinical and radiographic features. J Neurol 1987;234:86–90.
26 Becker KJ, Baxter AB, Cohen WA, Bybee HM, Tirschwell DL, Newell DW, Winn HR, Longstreth WT Jr: Withdrawal of support in intracerebral hemorrhage may lead to self-fulfilling prophecies. Neurology 2001;56:766–772.
27 El-Ad B, Bornstein NM, Fuchs P, Korczyn AD: Mechanical ventilation in stroke patients – is it worthwhile? Neurology 1996;47:657–659.
28 Koh WY, Lew TW, Chin NM, Wong MF: Tracheostomy in a neuro-intensive care setting: indications and timing. Anaesth Intensive Care 1997;25:365–368.
29 Heffner JE: Tracheotomy application and timing. Clin Chest Med 2003;24:389–398.
30 Makris M, Greaves M, Phillips WS, Kitchen S, Rosendaal FR, Preston EF: Emergency oral anticoagulant reversal: the relative efficacy of infusions of fresh frozen plasma and clotting factor concentrate on correction of the coagulopathy. Thromb Haemost 1997;77:477–480.
31 Horn EM, Waldrop TG: Suprapontine control of respiration. Respir Physiol 1998;114:201–211.
32 Hida W: Role of ventilatory drive in asthma and chronic obstructive pulmonary disease. Curr Opin Pulm Med 1999;5:339–343.
33 Oliviero A, Corbo G, Tonali PA, Pilato F, Saturno E, Dileone M, Versace V, Valente S, Di Lazzaro V: Functional involvement of central nervous system in acute exacerbation of chronic obstructive pulmonary disease. A preliminary transcranial magnetic stimulation study. J Neurol 2002;249:1232–1236.
34 Hopkinson NS, Sharshar T, Ross ET, Nickol AH, Dayer MJ, Porcher R, Jonville S, Moxham J, Polkey MI: Corticospinal control of respiratory muscles in chronic obstructive pulmonary disease. Respir Physiol Neurobiol 2004;141:1–12.
35 Croshaw R, McIntyre B, Fann S, Nottingham J, Bynoe R: Tracheostomy: timing revisited. Curr Surg 2004;61:42–48.
36 Rabinstein AA, Wijdicks EF: Outcome of survivors of acute stroke who require prolonged ventilatory assistance and tracheostomy. Cerebrovasc Dis 2004;18:325–331.