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Analysis of extracellular brain chemistry during percutaneous dilational tracheostomy: A retrospective study of 19 patients

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ABSTRACT

Objective: The purpose of this study was to analyze changes in brain tissue chemistry around percutaneous dilational tracheostomy (PDT) in patients with acute brain injury (ABI) in a retrospective single-center analysis.
Patients and methods: We included 19 patients who had continuous monitoring of brain tissue chemistry and intracranial pressure (ICP) during a 20 h period before and after PDT. Different microdialysis parameters (lactate, pyruvate, lactate pyruvate ratio (LPR), glycerol and glutamate) and values of ICP, cerebral perfusion pressure (CPP) and brain tissue oxygenation ($PBrO_2$) were recorded per hour. Mean values were compared between a 10 h period before PDT (prePDT) and after PDT (postPDT).
Results: Mean values of cerebral lactate, pyruvate, LPR, glycerol and glutamate did not differ significantly between prePDT and postPDT. In addition, the rate of patients, which exceeded the known threshold was similar between prePDT and postPDT. Only one patient showed a strong increase of cerebral glycerol during the postPDT period, but analysis of subcutaneous glycerol could exclude an intracerebral event. ICP, CPP and $PBrO_2$ did not exhibit significant changes.
Conclusions: We could exclude the occurrence of cerebral metabolic crisis and the excess release of cerebral glutamate and glycerol in a series of 19 patients. Our results support the safety of PDT in patients with ABI.

1. Introduction

The use of tracheostomy in critical care patients, requiring long term mechanical ventilation is well established [9,21]. In the treatment of patients with severe acute brain injury (ABI) long-term ventilation is used widely, due to a poor conscious state or for specific neuroprotective effects [16,23].

This frequently arises the question of necessity, timing and technique of tracheostomy in those patients. Various publications recommend a generous use in patients with an ABI and propose an early implementation. Percutaneous dilational tracheostomy (PDT) has been accepted as the preferred technique. Nevertheless, use of PDT to ABI patients has to be proven not only with regard to general complications, but also to possible burdens to the vulnerable acute injured brain.

The impact of PDT on intracranial pressure (ICP), cerebral perfusion pressure (CPP) and brain tissue oxygenation has been analyzed in multiple previous studies [2,12–15,20,30] as cerebral hypertension and cerebral hypoxia worsen the neurological outcome [7,19]. Whereas some studies show almost unchanged ICP, CPP and $PBrO_2$ values during PDT [2,12], others demonstrated slight elevation of ICP and lowering of CPP [13–15,20,30]. Overall, most authors conclude, that the risk of PDT in ABI patients is acceptable with regard to the ICP, CPP and $PBrO_2$.

In addition to the above-mentioned parameters, cerebral metabolic derangements (increase of lactate, increase of lactate/pyruvate ratio, decrease of glucose) [18,26,28,31] and the excess release of glutamate [27,32] or glycerol [10], have been shown to be correlated to poor neurological outcome and cerebral ischemia. Yet, no information about the impact of PDT to the brain tissue chemistry, measured by bedside cerebral microdialysis exists. PDT in ABI patients may provoke occurrence of secondary brain injury (SBI) in an ICP independent mechanism.

The aim of this study was to analyse the brain tissue chemistry during PDT to search for possible threats of PDT to the acute injured brain, which might be occurring although intracranial pressure monitoring is stable.

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2. Patients and methods

2.1. Patients and clinical management

We screened all adult patients who underwent PDTs on a single-center neurointensive care unit during a 2 year period. Inclusion criteria were continuous monitoring of intracranial pressure and brain tissue chemistry in a 20 h period around PDT. Patients with incomplete data (missing rate for a single microdialysis parameter of more than 0.25) and additional surgeries during the analyzed period were excluded. Written consent was given by the ethics committee of the University of Luebeck (reference 17-031A). The analyzing period of 20 h has been chosen to exclude as many non PDT related influences as possible but to capture probably all PDT related events. All patients suffered from either one of the following neurosurgical diseases: subarachnoidal hemorrhage (SAH), traumatic brain injury (TBI) and intracerebral hemorrhage (ICH). Patients were treated following current guidelines with deep sedation, mechanical ventilation and intracranial monitoring at the time of PDT. The decision for tracheostomy was given by an experienced neurosurgeon in all cases. Indications for PDT were based on a poor neurological state and anticipated need for mechanical ventilation greater than 10 days. All patients were stable in term of prior ICP and CPP values. We used “Blue Rhino” technique of Ciaglia (Cook Medical, Bloomington, IN, USA) in all patients as described elsewhere [3]. All tracheostomies were performed by an experienced surgeon. According to our clinical protocol surgery time and occurrence of complications were recorded routinely. Major complications were defined as life threatening events like hypoxia, incidentally loss of airway or vascular injuries, minor complications as non-life threatening events like multiple punctures or self-limiting bleedings.

2.2. Intracranial monitoring (ICP, $PBrO_2$, brain tissue chemistry)

All patients (19/19) in this study had a parenchymal pressure monitoring catheter (Camino® Intracranial Pressure Monitoring Kit, Integra™) and a intracerebral microdialysis catheter (70 Microdialysis Bolt Catheter, M Dialysis AB). A subgroup of patients (18/19) had an additional brain tissue oxygen probe (LICOX®, Integra™). All catheters were inserted through a single bolt system (LICOX® Triple Lumen Introducer Kit, Integra™) and were located in the frontal white matter of the most affected hemisphere. Additional extracerebral microdialysis catheter (70 Microdialysis Bolt Catheter, M Dialysis AB) were placed subcutaneously. For bedside microdialysis we used a 107 microdialysis pump (M Dialysis AB) with a flow rate of 0.3 µL/min and the CMA 600 microdialysis analyzer (M Dialysis AB). Vials were changed hourly. Results of microdialysis analyzer were recorded hourly as well as ICP and $PBrO_2$.

2.3. Data collection

Patient demographics, diagnosis and day on which PDT was performed were noted. The following hourly data were collected for all included patients: microdialysis analysis of lactate, pyruvate, glycerol and glutamate, ICP, $PBrO_2$, mean arterial pressure (MAP), oxygen saturation (SPO_2), cerebral perfusion pressure (CPP). Additional values of subcutaneous microdialysis were at our disposal. Blood gas analyzes in the 20 h period around PDT were searched for concentration of serum glucose. Thresholds for microdialysis parameters were defined, regarding the recent literature [11]. Limits of ICP, CPP, $PBrO_2$, MAP, SPO_2 and serum glucose were determined analog to current guidelines [5].

2.4. Statistical analyses

De-identified data were analysed using the software IBM® SPSS® (version 24.0). Results are presented as means ± standard deviation (SD). Non parametric Man-Whitney *U* test was used for comparing the results of microdialysis parameters, results of intracranial monitoring and vital signs between a 10 h period before and after PDT. Statistical significance was accepted at $p < 0.05$.

3. Results

3.1. Baseline characteristics and PDT

19 patients (13 males and 6 females) fulfilled the inclusion criteria. Most common diagnosis were subarachnoidal hemorrhage (9/19) and traumatic brain injury (7/19). 3/19 patients suffered from intracerebral hemorrhage. Median age was 45 (Range 22–64) and the surgery lasted a median time of 4.9 min (1.9–12.0). PDR were performed at the median day of 6 (2–11) after patients admission. No major complication but 3 minor complications occurred (2 cases of multiple punctures and 1 case of self-limiting bleeding).

3.2. Intracranial monitoring (ICP, CPP, $PBrO_2$)

We collected the data from ICP and CPP Monitoring in all patients (19/19). Complete data from brain tissue oxygenation ($PBrO_2$) were at disposal for 18/19 patients. There are no significant differences ($p > 0.05$) between the pre-PDT and post-PDT period within the mean ICP, CPP and $PBrO_2$ (Table 1). Fig. 1 displays the course of the analyzed parameters during the analyzed period. One patient showed intracranial hypertension in the pre-PDT period as in the post-PDT period, transient decrease of CPP could be seen in 3 patients after PDT but only in 2 patients before (Table 1). $PBrO_2$ is continuous above the known threshold of 10 mmHg in all analyzed patients (18/18).

Table 1
Mean values of brain tissue chemistry and intracranial monitoring and number of patients, whose values exceeded the thresholds. Statistical significance was accepted at $p < 0.05$.

		total	10 h before PDT	10 h afterPDT	P-value
Glutamate	mean [µmol] (SD)	10.1 (12.3)	11.0 (13.3)	9.2 (11.2)	0.71
	no. > 10 µmol/l	5/18	5/18	5/18	
Glycerol	mean [µmol] (SD)	92.9 (220.3)	64.4 (51.1)	121.6 (305.7)	0.11
	no. > 150 µmol/l	3/19	2/19	3/19	
Lactate	mean [mmol/l] (SD)	3.1 (2.1)	3.2 (2.1)	3.0 (2.0)	0.35
	no. > 4 mmol/l	4/19	4/19	4/19	
Pyruvat	mean [µmol] (SD)	122.2 (71.9)	128.3 (73.5)	116.4 (70.0)	0.07
	no. < 50 µmol/l	2/19	2/19	2/19	
LPR	mean	25.7 (12.6)	24.7 (10.0)	26.8 (14.6)	0.86
	LPR > 40	3/19	3/19	3/19	
	LPR > 25	7/19	5/19	6/19	
ICP	mean	12.3 (6.6)	11.3 (6.1)	12.2 (6.9)	0.18
	no. > 20 mmHg	1/19	1/19	1/19	
CPP	mean	77.1 (12.8)	77.6 (12.0)	76.7 (13.5)	0.16
	no. < 55	3/19	2/19	3/19	
$PTiO_2$	mean	29.8 (15.2)	28.2 (11.6)	31.3 (18.0)	0.29
	no. < 10 mmHg	0/19	0/19	0/19	