POLSKI
PRZEGLĄD CHIRURGICZNY
2015, 87, 4, 189–193

10.1515/pjs-2015-0043

DE GRUYTER
OPEN

NEUROGENIC PULMONARY EDEMA INDUCED BY SUBARACHNOID HEMORRHAGE:; CASE REPORT ON DIAGNOSTIC AND THERAPEUTIC IMPLICATIONS

GUENTER WEISS[1], FRANK MEYER[2]

Intensive Care Unit, Municipal Hospital in Magdeburg, Germany[1]
(Department of General, Abdominal and Vascular Surgery, University Hospital in Magdeburg, Germany[2]

An exemplary rare case of neurogenic pulmonary edema induced by intracranial hemorrhage was reported including diagnostic and therapeutic implications as well as management recommendations. A 35-year old man who was treated first by a neurosurgical approach because of a subarachnoid hemorrhage (bore hole trepanation) and subsequently on a surgical intensive care unit because of severe postoperative hemodynamic, cardiocirculatory, and pulmonary disruptions. To monitor cardiopulmonary condition and treatment effects, a Swan-Ganz catheter was placed in the pulmonary artery, since after trepanation, a critical cardiopulmonary status developed during postoperative mechanical ventilation and catecholamine administration. This condition was indicated by neurogenic pulmonary edema detected by control chest X-ray film and high oxygen load in the inspiratory air required for sufficient arterial oxygenation. After use of high positive end-exspiratory pressure (PEEP) (initially directed against neurogenic lesion), adaptation of initial dobutamine doses, initiation of norepinephrine administration, and substitution of fluids, the patient's blood pressure finally rose sufficiently to sustain regular cerebral blood perfusion and achieve better arterial oxygenation. Thus, the patient‘s cardiopulmonary condition stabilized and temporary cardiac insufficiency could be overcome. Subsequently, it became possible to decrease PEEP according to requirements to prevent or limit cerebral edema and to diminish catecholamine doses.
Key words: neurogenic pulmonary edema, subarachnoidal hemorrhage, catecholamine

Neurogenic pulmonary edema is a relatively rare but life-threatening event that, if misdiagnosed or misinterpreted, can be problematic for successful outcome. Its prompt diagnosis and appropriate treatment, which initially conflicts with therapeutic guidelines for the basic neurogenic disorder, are essential to maintain cardiopulmonary function and avoid fatal outcome.

We report based on the current references and crucial literature from the past the successful treatment of a patient with neurogenic edema induced by subarachnoid hemorrhage and with a combination of pathophysiologic conditions that were contradictory in their therapeutic requirements. Use of high positive end-exspiratory pressure (PEEP) and high oxygen concentration during artificial respiration resolved pulmonary problems indicated by possible decrease of oxygen load in the inspiratory air. The aim of this strategy is to break through the lack of oxygen load of the blood by improving pulmonary function as first-line treatment before focussing on the basic cerebral lesion.

CASE REPORT

A 35-year old man had been referred to our Department of Surgery from a regional hospital for initiation of neurosurgical treatment after diagnosis of subarachnoid hemorrhage. The emergency physician reported transient hypertension to 300 mm Hg of systolic blood pressure. Evaluation with cerebral computed tomography (CCT) demonstrated subarachnoid hemorrhage with suspicious bleeding out

of a ruptured aneurysm. The hemorrhage was decompressed with bore hole trepanation in each hemisphere for drainage into the third and fourth ventricles and for continuous monitoring of intracranial pressure.

The patient was admitted to the surgical ICU, being anesthetized, mechanically ventilated, and receiving analgesic and narcotic medications. His medical history was significant for extensive body building, anabolic drug abuse, and hypertonus. He required 100% oxygen load in the inspiratory air (PaO_2, 9.1 kPa), with no PEEP during mechanical ventilation. Systolic blood pressure was measured at 100 mm Hg, with a tendency to fall (central venous pressure, 7 cm H_20). A diagnostic chest film (fig. 1a) revealed diffuse pulmonary edema, which was interpreted as being induced by the pathophysiologic condition of the central nervous system. Electrocardiogram showed only strain of the right heart, while laboratory parameters such as the myocardial-specific isoenzyme creatinine kinase (12% of total creatinine kinase) and troponin T (0.89 ng/ml) were elevated abnormally on day 1. The patient was treated with increasing doses of dobutamine (Dobutamin Solvay® 250, Solvay Arzneimittel, Hannover, Germany), to 18 µg/kg/min, and diuretics, but this regimen had no elevating effect on blood pressure. Therefore, administration of norepinephrine (0.35 µg/kg/min; Arterenol®, Hoechst, Frankfurt/Main, Germany) was initiated and the dobutamine dose was reduced to 3.8 µg/kg/min, resulting in appropriate systolic blood pressure of 140 mm Hg. Thus, administration of nimodipine (Nimotop® S, Bayer, Leverkusen, Germany) for prophylaxis against cerebral vasospasms became possible. Using PEEP of 8 cm H_2O improved blood oxygenation rapidly (PaO_2, 15.5 kPa) with oxygen load of the inspiratory air during ventilation (FiO_2) of 50%. Monitoring of intracerebral pressure showed repeated values below 30 cm H_2O.

For optimization of monitoring and treatment of cardiopulmonary function and circulation, a Swan-Ganz catheter (1) was inserted into the pulmonary artery, which detected cardiac output and pulmonary-circulatory wedge pressure (PCWP) within normal range; the pulmonary artery median pressure (PAMP, 23 mm Hg) and heart index (2, 3) were elevated (systemic vascular resistance [SVR], slightly decreased, but within normal range) (tab. 1). Catecholamine doses could be diminished continuously until the fourth day, with simultaneous substitution of fluids from day 2 on under permanent catheter-based monitoring of pressure within the pulmonary artery. Two days later, a chest film demonstrated a decrease in edematous irregularities of the pulmonary tissue (fig. 1b), which prompted us to decrease PEEP and, subsequently, to initiate a mechanical ventilation method more appropriate to the requirements of subarachnoid hemorrhage. In addition, it became possible to decrease stepwise the oxygen load of the inspiratory air down to about 40%. On day 6, tracheotomy was executed because of expected long-lasting need for mechanical ventilation.

Interval CCT control on day 5 indicated an infarction in the circulation of the right median cerebral artery and the initial stage of cerebral edema. Transcranial Doppler ultrasonography showed vascular spasm of the cerebral arteries, with more pronounced find-

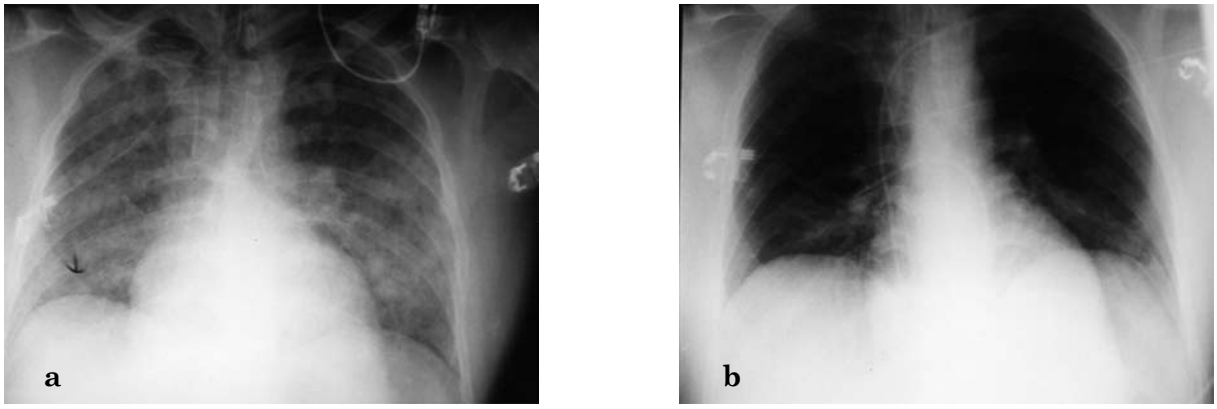

Fig. 1. Chest X-ray. a) at the time of admission: diffuse pulmonary edema was revealed, b) on day 2: decrease of edematous irregularities of pulmonary tissue was found

Table 1. Physical and circulatory parameters of the patient during administration of norepinephrine (0.35 μg/kg/min) and dobutamine (3.8 μg/kg/min) 12 hours after initial neurosurgical intervention and admittance at the surgical intensive care unit

Input			Results		
Height	=	180 cm	SV	=	75 ml
Weight	=	96 kg	SVR	=	781 dyn-s/cm^5
Pulmonary artery wedge pressure	=	11 mm Hg	PVR	=	113 dyn-s/cm^5
(16: 50)			LVSW	=	80 g m / m^2 BSA
Central venous pressure	=	6 mm Hg	RVSW	=	17 g m / m^2 BSA
(16: 50)					
Cardiac output	=	8,5 L/min HI		=	3.9 L/min/m^2
(16: 58)			SVI	=	35 ml/ m^2
Heart rate	=	113 beats/min	SVRI	=	1,687 dyn s m^2/ cm^5
Median arterial pressure	=	89 mm Hg	PVRI	=	244 dyn s m^2/ cm^5
Pulmonal arterial median pressure	=	23 mm Hg	LVSWI	=	37 g m / m^2 BSA
			RVSWI	=	8 g m / m^2 BSA
			BSA	=	2,16 m^2

Legend: SV – stroke volume, SVR – systemic vascular resistance, PVR – pulmonary vascular resistance, LVSW – left ventricular stroke work, RVSW – right ventricular stroke work, HI – heart (cardiac) index, SVI – stroke volume index, SVRI – systemic vascular resistance index, PVRI – pulmonary vascular resistance index, LVSAI – left ventricular stroke work index, RVSAI – rigth ventricular stroke work index, BSA – body surface area

ings on the right side. Clinically, synergistic convulsive extension was observed. After stabilization of the neurologic condition with normal intracranial pressure (12 cm H_2O), a weaning maneuver was initiated on day 7. Early in the patient's course, we had started enteral nutrition via nasogastric tube, which was well tolerated. On day 14, an interventional radiologist, using a minimally invasive procedure with coils, successfully occluded an aneurysm of the vertebral artery (fig. 2a,b) near the basilar artery. There were no further postinterventional complications or complaints from the patient. After appropriate stabilization, he was referred to a clinic for subsequent treatment and rehabilitation. Final physical examination revealed that the patient was increasingly compliant and cooperative. Responding to stimuli, he opened his eyes properly on command. No peripheral neurologic deficits were found.

DISCUSSION

Severe cardiopulmonary problems often accompany lesions of the central nervous system (CNS). In particular, neurogenic pulmonary edema can occur in patients with subarachnoid hemorrhage and those with brain injury (3, 4). The pathogenesis has not been completely clarified, but according to published observa-

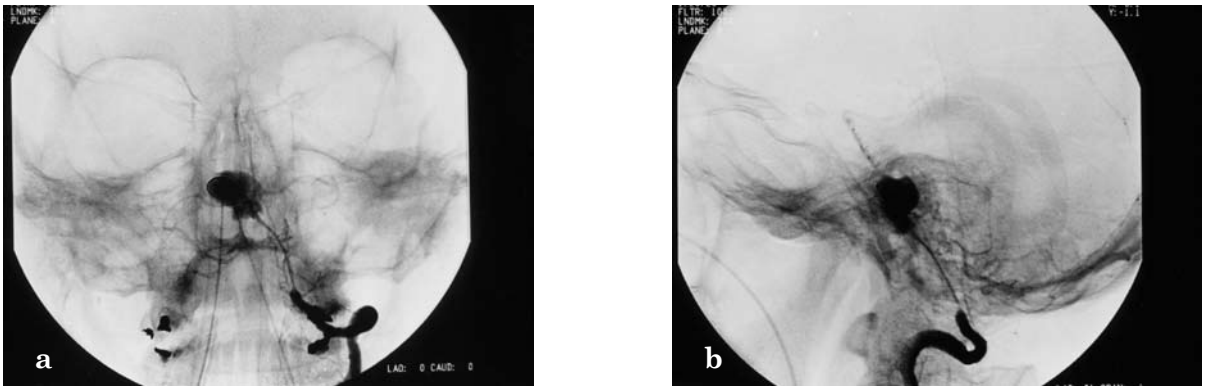

Fig. 2. Cerebral angiography shows an aneurysm of the vertebral artery in the frontal (a) and lateral (b) image. a) at the time of admission: diffuse pulmonary edema was revealed, b) on day 2: decrease of edematous irregularities of pulmonary tissue was found

tions and concepts, it appears to develop by the following pathophysiologic mechanisms:
- increased permeability of pulmonary vessels due to release of neuropeptides,
- pulmonary vasoconstriction due to excessive release of catecholamines in the case of cerebromedullary damage, and
- temporary insufficiency of the left ventricle due to disseminated necrotic areas of the myocardium (5-18).

The patient described in this case report had an extremely hypertensive phase after an interval of multiple hours, but still prior to the neurosurgical approach to relieve cerebral edema. Shortly after this trepanation, hypotension, high-grade pulmonary insufficiency, and signs of myocardial damage indicated by elevated levels of troponin T and creatinine kinase (> 10%) occurred. The albumin concentration of bronchial secretions was 35 g/L, confirm a non-cardiac origin of the pulmonary edema (5, 8, 18). Myocardial damage, also typical of neurogenic pulmonary edema, is considered a consequence of excessive release of catecholamines with disseminated areas of cardiac necrosis (17, 19). This myocardial damage does not necessarily lead to measurable cardiac insufficiency. In the presented case, dobutamine did not show any cardiocirculatory effect. The catheter inserted into the pulmonary artery 12 hours after neurosurgical intervention showed no signs of cardiac insufficiency but did indicate normal systemic resistance and high cardiac output with high doses of vasoconstricting medication. Based on these observations, it was concluded that the patient was in a hyperdynamic cardiocirculatory state indicative of the systemic inflammatory response syndrome (SIRS) or central dysregulation associated with peripheral vasodilatation. Under these circumstances, use of norepinephrine was more efficient than dobutamine (which is recommended in the literature) (19, 20). Simultaneously, fluid volumes were balanced during the first days of hospital treatment and pulmonary edema disappeared within a few days, which was seen clinically and detected on chest film (fig. 2b).

Therefore, cardiocirculatory monitoring became imperative and, in our case, was achieved by placement of a catheter in the pulmonary artery (1); other invasive, minimally invasive, or non-invasive methods can also be used to provide adequate treatment with fluid volumes and defined doses of catecholamines for possible cardiac insufficiency or SIRS. Regulation of blood pressure is required for optimal cardiocirculatory and hemodynamic condition and becomes imperative in patients with neurogenic lesions and associated threatened or existing cerebral edema for sustaining appropriate cerebroarterial perfusion.

Usually, high values of PEEP are to be avoided in patients with high intracerebral pressure. But, in our case, PEEP of about 8 cm H_2O was required to sustain adequate arterial oxygenation in general and, in particular, for the neurons. Permanent monitoring of intracerebral pressure never demonstrated unfavorable status and is therefore suitable in such critical phases of patient's course. Our diagnostic and therapeutic approach to the complex cerebrovascular, cardiopulmonary, and – circulatory problems, including neurogenic pulmonary edema, in the case described above provided sufficient stabilization of the patient's critical condition, which allowed subsequent planned intervention for exclusion of the aneurysm.

CONCLUSION

Neurogenic pulmonary edema is considered a life-threatening complication in patients with severe craniocerebral lesions (2, 21-24) and neurological processes (25). Only by providing optimal cardiopulmonary monitoring and differentiated administration of catecholamines and substitution of fluids can the patient be spared from further unfavorable consequences or even fatal outcome. Although cardiac insufficiency may occur initially due to disseminated myocardial damage, later in the clinical course there is vasodilatation, which requires administration of vasoconstricting drugs such as norepinephrine and substitution of fluids. In cases of severe disturbance of pulmonary gas exchange, use of pressure-controlled ventilation with high values of PEEP according to specific requirements is imperative.

Acknowledgments

The authors are grateful to the colleagues of the Department of Radiology, University Hospital, Magdeburg) for providing radiological images.

REFERENCES

1. *Cohen Arazi H, Nani S, Giorgi M* et al.: Swan Ganz catheter. Experts opinion. *Medicina* (B Aires) 2014; 74(4): 326-32.
2. *Gekka M, Yamaguchi S, Kazumata K* et al.: Hemorrhagic onset of hemangioblastoma located in the dorsal medulla oblongata presenting with tako-tsubo cardiomyopathy and neurogenic pulmonary edema: a case report. *Case Rep Neurol* 2014; 6(1): 68-73.
3. *Schwarz S, Schwab S, Keller* E et al.: Neurogenic disorders of heart and lung function in acute cerebral lesions. *Nervenarzt* 1997; 68(12): 956-62.
4. *Touho H, Karasawa J, Shishido H* et al.: Hypoxemia in the acute stage of hypertensive intracerebral hemorrhage, with special reference to increased extravascular lung water. *Neurol Med Chir* (Tokyo) 1989; 29(8): 724-27.
5. *Brambrink AM, Dick WF:* Neurogenic pulmonary edema. Pathogenesis, clinical picture and therapy. *Anaesthesist* 1997; 46(11): 953-63.
6. *Chen HI, Huang HS, Yang JG* et al.: Vasodilator and oxidant scavanger in the neurogenic pulmonary edema induced by cerebral compression. *Chin J Physiol* 1992; 35(2): 123-31.
7. *Chen HI:* Hemodynamic mechanisms of neurogenic pulmonary edema. *Biol Signals* 1995; 4(3): 186-92.
8. *Germonpre PR, Joos GF, Pauwels RA:* Characterization of the neurogenic plasma extravasation in the airways. *Arch Int Pharmacodyn Ther* 1995; 329(1): 185-203.
9. *Hall SR, Wang L, Milne B* et al.: Intrathecal lidocaine prevents cardiovascular collaps and neurogenic pulmonary edema in a rat model of acute intracranial hypertension. *Anesth Analg* 2002; 94(4): 948-53.
10. Hamdy O, Maekawa H, Shimada Y et al.: Role of central nervous system nitric oxide in the development of neurogenic pulmonary edema in rats. *Crit Care Med* 2001; 29(6): 1222-28.
11. *Hirabayashi A, Nishiwaki K, Shimada Y* et al.: Role of neuropeptide Y and its receptor subtypes in neurogenic pulmonary edema. *Eur J Pharmacol* 1996; 296(3): 297-305.
12. *Inobe JJ, Mori T, Ueyama H* et al.: Neurogenic pulmonary edema induced by primary medullary hemorrhage: a case report. *J Neurol Sci* 2000; 172(1): 73-76.
13. *Keegan MT, Lanier WL:* Pulmonary edema after resection of a fourth ventricle tumor: possible evidence for a medulla-mediated mechanism. *Mayo Clin Proc* 1999; 74(3): 264-68.
14. *Mc Clellan MD, Dauber IM, Weil JV:* Elevated intracranial pressure increases pulmonary vascular permeability to protein. *J Appl Physiol* 1989; 67(3): 1185-91.
15. *Nesterova MA, Chuiko AA, Sokolova RI* et al.: Evidence for an antihypertensive factor from the adrenal medulla of SHR modulating neurogenic vasoconstriction. *Acta Physiol Scand* 1999; 167(3): 195-202.
16. *Pender ES, Pollack CV Jr:* Neurogenic pulmonary edema: case reports and review. *J Emerg Med* 1992; 10(1): 45-51.
17. *Sato K, Masuda T, Kikuno T* et al.: Left ventricular asynergy and myocardial necrosis accompanied by subarachnoid hemorrhage: contribution of neurogenic pulmonary edema. *J Cardiol* 1990; 20(2): 359-67.
18. *Smith WS, Matthay MA:* Evidence for a hydrostatic mechanism in human neurogenic pulmonary edema. *Chest* 1997; 111(5): 1326-33.
19. *Mayer SA, Fink ME, Homma S* et al.: Cardiac injury associated with neurogenic pulmonary edema following subarachnoid hemorrhage. *Neurology* 1994; 44(5): 815-20.
20. *Deehan SC, Grant IS:* Haemodynamic changes in neurogenic pulmonary oedema: effect of dobutamine. *Int Care Med* 1996; 22(7): 672-76.
21. *Sedy J, Kuneš J, Zicha J:* Pathogenetic mechanisms of neurogenic pulmonary edema. *J Neurotrauma* 2014 Dec 13. (Epub ahead of print).
22. *Dai Q, Su L:* Neurogenic pulmonary edema caused by spontaneous cerebellar hemorrhage: A fatal case report. *Surg Neurol Int* 2014; 5: 103.
23. *Manto A, De Gennaro A, Manzo G* et al.: Early endovascular treatment of aneurysmal subarachnoid hemorrhage complicated by neurogenic pulmonary edema and Takotsubo-like cardiomyopathy. *Neuroradiol J* 2014; 27(3): 356-60.
24. *Satoh E, Tagami T, Watanabe A* et al.: Association between Serum Lactate Levels and Early Neurogenic Pulmonary Edema after Nontraumatic Subarachnoid Hemorrhage. *J Nippon Med Sch* 2014; 81(5): 305-12.
25. *Sweeney M, Rubin J, Hopkins SE:* Neurogenic pulmonary edema in pediatric multiple sclerosis: patient report and summary of cases. *Pediatr Neurol* 2014; 51(3): 426-29.

Received: 31.01.2015 r.
Adress correspondence: Prof. Dr. F. Meyer, Department of Surgery, University Hospital,
Otto von Guericke University, Leipziger Strasse 44, D-39120 Magdeburg, Niemcy
e-mail: frank.meyer@med.ovgu.de