USE OF EXTERNAL VENTRICULAR DRAIN FOR MEASUREMENT OF INTRACRANIAL PRESSURE IN PRONE PATIENTS WITH NEUROGENIC ACUTE RESPIRATORY DISTRESS SYNDROME

Department of Physician Assistant, School of Health and Medical Sciences, Seton Hall University

Kristina M. Dauernheim PA-S, Amanda F. Di Piazza PA-C

BACKGROUND

- External ventricular drains (EVD) are used for cerebrospinal fluid (CSF) diversion and drainage in patients with subarachnoid hemorrhage (SAH) and in traumatic brain injury (TBI) for the evaluation and management of elevated intracranial pressure (ICP).
- Patients with SAH or TBI may suffer from neurogenic pulmonary edema resulting in acute respiratory distress syndrome (ARDS).
- Central nervous system injury triggers a release of catecholamines that induce integrity changes to the endothelium of the pulmonary vasculature, resulting in pulmonary edema which may progress to ARDS [3].
- A common treatment for ARDS is prone positioning, which poses a risk of elevating ICP due to impaired jugular venous outflow [13].
- There is a paucity of reports concerning the concomitant use of EVD for ICP monitoring and CSF diversion in SAH or TBI patients who are prone positioned for the treatment of neurogenic ARDS, highlighting a need for our study.

HYPOTHESIS

With EVD placement, patients with SAH or TBI undergoing treatment for ARDS by prone positioning will not have experienced significant elevations in ICP.

METHODS

We conducted a retrospective chart review for case series of eight patients admitted to the Hackensack University Medical Center Surgical Intensive Care Unit between 2016 and 2019 with SAH or TBI.

Inclusion Criteria

- Diagnosed with SAH or TBI confirmed by CT scan of the head without contrast
- EVD was placed for neuromonitoring prior to the initiation of prone positioning
- Patient was diagnosed with neurogenic ARDS with PaO_2/FiO_2 ratio of 200 or less
- Patient had bilateral pulmonary infiltrates on frontal chest radiograph
- Patient was turned to the prone position for treatment of ARDS

Exclusion Criteria

- Patient was not diagnosed with SAH or TBI
- Patient did not develop SAH or TBI
- Patient did not develop neurogenic ARDS
- Patient was not prone positioned
- Patient did not have an EVD placed prior to prone positioning

The mean and standard deviation for ICP, cerebral perfusion pressure (CPP) and mean arterial pressure (MAP) were calculated for prone and supine positions. EVD output was recorded in mL/day, and mean output was calculated for each patient. Three independent t-tests were performed for ICP, CPP and MAP. *p*-values of LT 0.05 were considered statistically significant.

RESULTS

Six patients suffered SAH secondary to aneurysm rupture, arteriovenous malformation rupture, or intratumoral bleed. Two patients presented with SAH secondary to TBI. Patients that did not tolerate prone positioning for a minimum of 16 hours due to elevations in ICP had shorter proning sessions. Post-proning, patient 2 failed to have an improvement in neurologic examination and was transitioned to hospice care by family. Demographic and clinical characteristics are represented in **Table 1.**

Table 1. Patient demographic and clinical characteristics

Patient	Age (years)/ Gender	Race	Initial CTH Without Contrast	Average Time Spent Prone (hours/session)	Number of Prone Sessions	Outcome
1	33/F	Asian Indian	Spontaneous SAH secondary to AVM rupture	14.8	3	Alive
2	50/M	White	Aneurysmal SAH	15.5	4	Deceased
3	49/F	Asian Indian	Aneurysmal SAH	16	2	Alive
4	54/M	White	Aneurysmal SAH	16	4	Alive
5	56/F	White	Aneurysmal SAH	19.1	9	Alive
6	48/M	White	Traumatic SAH	10.3	8	Alive
7	20/M	White	Traumatic SAH	16	5	Alive
8	73/M	White	Spontaneous intratumoral IVH with SAH	14.8	5	Alive

AVM arteriovenous malformation; *CTH* computed tomography head; *IVH* intraventricular hemorrhage; *F* female; *M* male; *SAH* subarachnoid hemorrhage.

Supine ICP values were not significantly different compared with prone ICP values. The mean CPP and mean MAP differed significantly between the two positions, see **Table 2**.

Table 2. Prone and supine mean ICP, CPP and MAP results

Variable	Mean Pressure (mmHg)	*p*-value
Prone ICP	12.6 ± 4.6	0.786
Supine ICP	12.3 ± 5.1	
Prone CPP	81.4 ± 23.0	< 0.001
Supine CPP	97.2 ± 14.1	
Prone MAP	93.5 ± 16.4	0.011
Supine MAP	82.1 ± 21.4	

CPP cerebral perfusion pressure; *ICP* intracranial pressure; *MAP* mean arterial pressure; *mmHg* millimeters of Mercury.

Table 3 shows the EVD output for each patient in milliliters per day (mL/day) for each day that the patient was turned to the prone position.
In **Table 4**, each patient's average EVD output was represented as mean ± standard deviation in mL/day.

Table 3. EVD output in mL/day for each patient

Patient	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
1	280	301	279						
2	211	228	253	225					
3	204	275							
4	327	275	231	297					
5	292	287	280	230	285	200	168	221	239
6	131	164	210	186	181	196	221	203	
7	317	94	31	68	20				
8	54	52	84	88	8				

Table 4. Mean EVD output

Patient	Mean ± SD EVD Output
1	286.7 ± 12.4
2	229.3 ± 17.5
3	239.5 ± 50.2
4	282.5 ± 40.4
5	244.7 ± 44.1
6	186.50 ± 28.6
7	106.0 ± 121.6
8	57.2 ± 32.1

DISCUSSION

- Patients had an average ICP value of approximately 12 mmHg, with no significant difference between either position of prone or supine. Therefore, the use of EVD to divert excess CSF to mitigate elevations in ICP as they occurred was successful.
- An inverse relationship existed between the average prone CPP and average prone MAP. This relationship supports that despite neuromonitoring and CSF diversion with EVD, there existed a decrease in CPP with a resultant increase in MAP to maintain adequate cerebral perfusion in the prone patient.
  - The decrease that occurred in the average prone CPP remained slightly above the upper limit of normal for CPP of 60 to 80 mmHg.
  - Adequate MAP was maintained in both conditions, with MAP values within the normal range of 70 to 100 mmHg [15].
  - It can be deduced that there were limited adverse effects on cerebral blood flow while patients were in the prone position due to the maintenance of near-normal physiologic levels for CPP and MAP.
- EVD output was reported in Table 3 and Table 4 to indicate patency of the drain. Patients 1 through 7 presented to our facility with acute, first-time intracranial pathology which may account for higher CSF output when compared to patient 8, who presented with a known history of an intracranial tumor further complicated by intraventricular hemorrhage resulting in SAH.
- It was concluded that in each case, the EVD was patent since there was no statistically significant difference between ICP values for either position, indicating that the EVD was successful in mitigated elevations in ICP as they occurred.

CONCLUSION

The use of EVD was successful for monitoring ICP and CSF diversion to improve neurologic outcomes in prone patients with neurogenic ARDS secondary to SAH or TBI.

REFERENCES

1. Miller C, Tummala RP. Risk factors for hemorrhage associated with external ventricular drain placement and removal. J Neurosurg 2017;126:289-97.
2. Roth C, Ferbert A, Deinsberger W, Kleffmann J, Kästner S, Godau J. Does prone positioning increase intracranial pressure? A retrospective analysis of patients with acute brain injury and acute respiratory failure. Neurocrit Care 2014;21:186-91.
3. Mrozek S, Constatin JM, Geeraerts T. Brain-lung crosstalk: implications for neurocritical care patients. World J Crit Care Med 2015;4:163-78.
4. Bernard GR, Artigas A, Brigham KL, et al. Report of the American-European consensus conference on ARDS: definitions, mechanisms, relevant outcomes and clinical trial coordination. J Crit Care 1994;9:72-81.
5. Guérin C. Prone positioning acute respiratory distress syndrome patients. Ann Transl Med 2017;5:289-94.
6. Guérin C, Reignier J, Richard JC, et al. Prone positioning in severe acute respiratory distress syndrome. N Engl J Med 2013;368:2159-68.
7. Albert RK, Hubmayr RD. The prone position eliminates compression of the lungs by the heart. Am J Respir Crit Care Med 2000;161:1660-5.
8. Galiatsou E, Kostanti E, Svarna E, et al. Prone position augments recruitment and prevents alveolar overinflation in acute lung injury. Am J Respir Crit Care Med 2006;174:187-97.
9. Scholten EL, Beitler JR, Prisk GK, Malhotra A. Treatment of ARDS with prone positioning. Chest 2017;151:215-24.
10. Mancebo J, Fernández R, Blanch L, et al. A multicenter trial of prolonged prone ventilation in severe acute respiratory distress syndrome. Am J Respir Crit Care Med 2006;173:1233-9.
11. Reinprecht A, Greher M, Wolfsberger S, Dietrich W, Illievich U, Gruber A. Prone position in subarachnoid hemorrhage patients with acute respiratory distress syndrome: effects on cerebral tissue oxygenation and intracranial pressure. Crit Care Med 2003;31:1831-8.
12. Naidech AM, Bassin SL, Garg RK, Ault ML, Bendok BR, Batjer HH. Cardiac troponin I and acute lung injury after subarachnoid hemorrhage. Neurocrit Care 2009;11:177-82.
13. Robba C, Bragazzi NL, Bertuccio A, Cardim D, Donnelly J, Sekhon M. Effects of prone position and positive end-expiratory pressure on noninvasive estimators of ICP: a pilot study. J Neurosurg Anesthesiol 2017;29:243-50.
14. Dennis LJ, Mayer SA. Diagnosis and management of increased intracranial pressure. Neurol India 2001;49:S37-50.
15. Armstead WM. Cerebral blood flow autoregulation and dysautoregulation. Anesthesiol Clin 2016;34:465-77.