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Effect of Mechanical Chest Percussion on Intracranial Pressure: A Pilot Study

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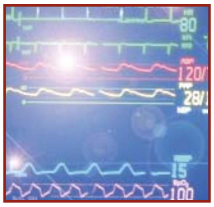

EFFECT OF MECHANICAL CHEST PERCUSSION ON INTRACRANIAL PRESSURE: A PILOT STUDY

By DaiWai M. Olson, RN, PhD, CCRN, Suzanne M. Thoyre, RN, PhD, Stacey N. Bennett, RN, MSN, ACNP, Joanna B. Stoner, RN, and Carmelo Graffagnino, MD, FRCP

Background Treatment of brain injury is often focused on minimizing intracranial pressure, which, when elevated, can lead to secondary brain injury. Chest percussion is a common practice used to treat and prevent pneumonia. Conflicting and limited anecdotal evidence indicates that physical stimulation increases intracranial pressure and should be avoided in patients at risk of intracranial hypertension.

Objectives To explore the safety of performing chest percussion for patients at high risk for intracranial hypertension.

Methods A total of 28 patients with at least 1 documented episode of intracranial hypertension who were having intracranial pressure monitored were studied in a prospective randomized control trial. Patients were randomly assigned to either the control group (no chest percussion) or the intervention group (10 minutes of chest percussion at noon). Intracranial pressure was recorded once a minute before, during, and after the intervention.

Results Mean intracranial pressures for the control group before, during, and after the study period (14.4, 15.0, and 15.9 mm Hg, respectively) did not differ significantly from pressures in the intervention group (13.6, 13.7, and 14.2 mm Hg, respectively).

Conclusions Mechanical chest percussion may be a safe intervention for nurses to use on neurologically injured patients who are at risk for intracranial hypertension. (*American Journal of Critical Care.* 2009;18:330-335)

EBR Evidence-Based Review on pp 336-337.

This article is followed by an *AJCC* Patient Care Page on page 338.

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Each year, nearly 1.4 million people in the United States experience some form of brain injury.[1] Patients with brain injury are at risk for numerous complications during the acute phase of their illness.[2] Treatment of severe brain injury is likely to require airway management with mechanical ventilation, and severe injuries often result in patients experiencing prolonged periods of mechanical ventilation, a situation that increases their risk for nosocomial pneumonia.[3-5] Treatment during the early phase is focused primarily on the prevention of secondary brain injury, and intracranial pressure (ICP) monitoring is an integral part of this therapy.[6-8] Interventions to treat and prevent pneumonia have not been adequately assessed with respect to their effects on ICP.

Pulmonary care incorporates a wide array of nursing procedures to improve oxygenation and ventilation,[9] including elevation of the head of the bed, oral care, turning the patient, repositioning the patient, chest percussion, and airway management.[3] Most commonly, chest percussion is performed to open blocked alveoli and increase the surface area of the lung, thereby promoting gas exchange at the cellular level. Chest percussion can be performed manually or mechanically.[10] With manual chest percussion, the practitioner cups his or her hands and repeatedly claps the patient's lateral and posterior thoracic region. Alternatively, many beds in the intensive care unit have programmable rotation and percussion modes capable of providing mechanical chest compression (forceful bursts of air against the inferior surface of the mattress).

ICP is an expression of the pressure exerted against the inside of the skull by the combination of blood, cerebrospinal fluid (CSF), and brain tissue.[11] Fluctuations in ICP are the result of an increase or decrease in one or more of these volumes without a corresponding change in one or more of the other volumes.[12] Normal ICP is generally considered to be less than 15 mm Hg, and intracranial hypertension is generally classified as a pressure greater than 20 mm Hg.[12] Episodes of intracranial hypertension are associated with an increased risk of secondary brain damage, which occurs after the primary injury when one or more parts of the brain are deprived of oxygen and nutrients.[7,8] Procedures that directly reduce ICP include active drainage of CSF, osmotic therapy, and positioning with the patient's head elevated and the head and neck in good alignment.[12-14] Currently, no gold standards are available to define the minimum value at which ICP treatment should be started, but a value of 20 to 25 mm Hg is reported as the upper limit by which treatment should begin.[12,15]

Normal ICP is less than 15 mm Hg and intracranial hypertension is greater than 20 mm Hg.

A wide array of nursing procedures and medical therapies can be used to prevent secondary injury.[12,16-18] Secondary brain injury is theorized to be triggered by the inflammatory response in the brain.[8] Increased vascular and cellular permeability results in cerebral edema, ischemia, and impaired autoregulatory mechanisms. The release of cytokines, decreased production of adenosine triphosphate, increased lactic acidosis, and the intracellular influx of ions results in increased cell death, which in turn results in reinitiation of the inflammatory response.[12,19] The goals of therapy are to control ICP and improve perfusion to the brain.[8] Greater likelihood of ICP monitoring is associated with improved outcomes.[20] Nurses interpret and respond to cues that patients are at increased risk for secondary brain injury and select the most appropriate plan of action available.

Secondary brain injury is thought to be triggered by the brain's inflammatory response.

Given the wealth of information on care of patients receiving mechanical ventilation, the lack of attention to pulmonary care is arguably negligent. Withholding pulmonary therapy procedures must be justified by some reason. Recommendations of the Centers for Disease Control and Prevention include elevating the head of the

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bed to prevent aspiration pneumonia as a category II recommendation, and frequent repositioning remains a category IB (strongly recommended) recommendation.[21] In a review article of randomized controlled trials for kinetic therapy and continuous lateral rotational therapy, Marik and Fink[22] reported that turning patients resulted in a decrease in occurrence of nosocomial pneumonia, and patients who were turned more than 40° had the greatest benefit in risk reduction. Mahanes and Lewis[23] cited the lack of clinical trials specific to neurologically compromised patients receiving mechanical ventilation and echoed the sentiments of Wijdicks and Borel,[24] who concluded that more appropriate respiratory care may result in improved outcomes for neurocritically ill patients.

Nurses must balance the need for pulmonary care and prevention of increased ICP.

The purpose of this pilot study was to explore the effects of nurse-initiated mechanical chest percussion on intracranial pressure. We hypothesized that chest percussion would not result in an elevation of ICP and is a safe procedure to perform on patients who are at risk for intracranial hypertension. We addressed the conflicting concerns that nurses face when balancing 2 needs: the need to perform pulmonary care and thereby improve pulmonary status and the need to prevent secondary brain injury due to increased ICP.

Methods

Setting

The study was conducted in the 16-bed neurocritical care unit at Duke University Medical Center, Durham, North Carolina. The study was reviewed and approved by the hospital's institutional review board. Patients were unable to provide consent because of their injuries; therefore, consent was obtained from each patient's legal representative or family member.

Chest percussion had no significant effect on ICP.

Sample and Study Period

Patients were considered eligible if they were having ICP monitored, had had documentation of elevated ICP, were already on a specialty bed (SPO2RT beds, Hill-Rom, Batesville, Indiana), had been admitted with a neurological or neurosurgical diagnosis, and had been receiving chest percussion as part of their treatment. Patients were excluded if they were less than 18 years old or were prisoners. A total of 30 consecutive patients were enrolled in the study and 28 completed it; 2 patients had ICP monitoring stopped before the data collection period, did not complete the study, and were excluded from the analysis. ICP monitoring included an intraventricular catheter (Medtronic Inc, Minneapolis, Minnesota) connected to an external drainage chamber (Accudrain, Integra Lifesciences, Plainsboro, New Jersey).

The study period began at 11:50 AM, after consent had been obtained. Data on vital signs (heart rate, blood pressure, respiratory rate, and oxygen saturation) were collected for 10 minutes on all 28 patients to provide baseline values for mean ICP. During the intervention phase (noon-12:10 PM), patients were randomized to either receive no chest percussion (control group) or receive 10 minutes of mechanical chest percussion starting at exactly noon (intervention group). Data on all 28 patients' vital signs were collected during this 10-minute period. Chest percussion was standardized as 10 minutes of automated percussion with the head of the bed elevated 30°; no additional interventions were performed during chest percussion (eg, suctioning, repositioning, administering medications). Data on vital signs also were collected for 10 minutes after the intervention phase (12:10-12:20 PM) for comparison, and the study was terminated at 12:20 PM.

In order to enhance internal validity, invasive pressure monitors (arterial and ICP) were zero calibrated, and the ICP transducer was leveled to the external auditory canal; each patient was monitored while he or she was supine with the head of the bed elevated 30° from horizontal. No osmotic diuretics (eg, mannitol) or infusions of hypertonic saline were administered during the 30-minute study period; this time was selected because the physicians' rounds would already have been completed and the patient would be available for the study. The noon hour was selected because that hour was the time least likely to be affected by other variables that we theorized might influence ICP. Members of the nursing staff were instructed to minimize physical stimuli (eg, suctioning, turning, physical examination) until after the study period. Scheduled doses of medications that decrease ICP (eg, mannitol and hypertonic saline) were withheld until after the study period (12:20 PM).

Data collection included baseline characteristics and vital signs (heart rate, respiratory rate, blood pressure, body temperature, ICP, cerebral perfusion pressure, and oxygen saturation) measured once each minute from 11:50 AM to 12:20 PM. Data were obtained from the displayed bedside monitoring system (GE Solar 8000i, General Electric Healthcare, Waukesha, Wisconsin) in the intensive care unit.

Additionally, for patients with CSF drainage ordered, any instances when CSF was drained to decrease the ICP were observed and recorded; CSF drainage was performed by opening the stopcock for 1-minute intervals. Electronic workbooks in Microsoft Excel were used for data storage.

Results

Of the 28 patients who completed the study, 15 were assigned to the control group and 13 were assigned to the intervention group. The patient pool was balanced between whites (n = 13) and African Americans (n = 13); 1 patient was Asian and 1 was Native American. The racial/ethnic mix of this sample was deemed representative of the population from which the sample was obtained (Table 1). Mean age in the control group (56.2 years) did not differ significantly from that in the intervention group (52.9 years); patients were 22 to 87 years old.

The primary question of safety was addressed by testing the hypothesis that chest percussion does not result in an increase in ICP. In an effort to explore safety fully, hypothesis testing was done by using 2-way analysis of variance for median and mean values to explore within- and between-subject models.[25,26] Mean and medial values were determined for the 10-minute epoch before chest percussion was performed on the intervention group (11:50 AM-noon), during chest percussion (noon-12:10 PM), and after chest percussion was performed on the intervention group (12:10-12:20 PM). The between-patients models were insufficient to reject the null hypothesis for the omnibus test of difference in mean ICP ($F = 0.19$, $P = .83$) or median ICP ($F = 0.14$, $P = .87$). Similarly, the data were insufficient to reject the null hypothesis of a difference in mean or median for any of the 3 time epochs (Table 2). A nurse opted to drain CSF in 3 instances in the control group and 2 instances in the intervention group. During each instance, the ventriculostomy drain was open to gravity for 1 minute.

Table 1
Demographic variables for both groups[a]

Variable	Control (n = 15)	Intervention (n = 13)
Age, mean (range), y	56.2 (22-79)	52.9 (28-87)
Male, %	46.7	53.8
Race		
White	8	5
African American	6	7
Other	1	1
Postinjury day, mean (range)	4.4 (2-13)	4.5 (1-11)
Admission diagnosis		
Subarachnoid hemorrhage	8	4
Intracranial hemorrhage	3	4
Traumatic brain injury	3	4
Brain tumor resection	1	0
Acute ischemic stroke	0	1

[a] Values are number of patients, unless otherwise indicated.

The within-subject differences in mean ICP across the 3 time epochs also were not significant ($P = .96$). The data (Table 3) were explored for comparison of slopes by using the general linear model. No evidence of unequal slopes was apparent across all 3 time periods combined ($F = 0.55$, $P = .46$) or for the 10 minutes during which the intervention group received chest percussion ($F = 0.10$, $P = .76$).

There was no difference in the rate of ICP change between groups.

Discussion

The small size of the study sample limits the ability to generalize results, but does provide credibility for further testing of the effects of mechanical chest percussion on ICP. In this study, chest percussion was performed at a set time during the day; although this arrangement enhances internal validity, it does not reflect the reality of practice and leads to additional questions of interest. What is the effect of chest percussion when ICP is already elevated? Does the degree of sedation or severity of brain injury alter

Table 2
Comparison of mean and median values of intracranial pressure (ICP) in the control and intervention groups before, during, and after chest percussion

	ICP, mean (SD), mm Hg			ICP distribution, mm Hg					
				Control			Intervention		
Time	Control	Intervention	*P*	25th quartile	Median	75th quartile	25th quartile	Median	75th quartile
Before, 11:50 AM-noon	14.4 (4.6)	13.6 (8.4)	.77	11.5	14.0	18.0	7.5	10.5	18.0
During, noon-12:10 PM	15.0 (4.8)	13.7 (7.4)	.57	12.0	16.5	19.0	8.5	10.5	20.0
After, 12:10 PM-12:20 PM	15.9 (5.7)	14.2 (8.5)	.55	11.0	17.0	19.5	8.0	12.0	21.0

Table 3
Summary of mean values for intracranial pressure

	Group					
	Control			Intervention		
Subject No.	Before	During	After	Before	During	After
1	12.6	13.5	20.9			
2	17.0	17.2	17.5			
3	16.6	16.5	16.9			
4				8.4	8.2	6.1
5	a	10.7	11.4			
6	22.0	20.2	18.8			
7				18.8	19.2	20.3
8				8.0	7.9	13.5
9				22.4	25.2	24.7
10				6.0	3.5	1.9
11				11.7	12.1	11.7
12				10.5	8.9	10.8
13				19.3	24.4	23.3
14	5.9	6.0	4.4			
15				14.3	14.9	13.6
16	11.8	12.6	14.0			
17	15.3	16.9	14.9			
18	20.2	22.3	24.7			
19				8.3	9.0	9.7
20	19.2	20.0	14.1			
21				9.7	9.4	10.1
22	13.2	14.9	21.6			
23	16.6	18.0	23.2			
24	13.0	18.2	16.9			
25	10.1	9.2	7.1			
26				35.1	25.2	31.9
27	8.1	8.4	11.7			
28				4.8	10.0	8.4

[a] Missing data (ventriculostomy open or not level).

the effects of chest percussion on ICP values? Does mechanical chest percussion differ from manual chest percussion when ICP is the outcome variable?

In this study, the sampling rate was once per minute, and data from 10 minutes of sampling were averaged for analysis of variance. ICP values are dynamic and may change markedly in less than 1 minute (eg, the patient coughs and the ICP quickly increases more than 30 mm Hg but decreases back to the baseline level in less than 20 seconds). Because of the sampling rate, the data may not reflect an adequate number of sudden elevations. We did not explore maximum and minimum ICP values because the sampling rate does not provide a true reflection of these values. Equally, increasing the sampling rate would be expected to increase the certainty of the mean values used in the analysis.[27]

In patients with brain injury who require ICP management, ICP values increase over time if left untreated. However, the rate and pattern of increase has not been described and would theoretically depend on the patient, the diagnosis, and the severity of the injury. We compared mean values for groups of patients and observed a slight increase in ICP values over time for both the control group and the intervention group (Table 2). A larger sample may be beneficial in providing data to statistically control for individual changes from baseline.

We did not assess mechanical chest percussion as a targeted therapy for reducing ICP. Instead, the intervention was timed to occur at a specific time of day and did not depend on the patient. The ICP values for both the control and intervention groups increased over time, and this pattern is consistent with that reported for patients who had CSF drainage.[11,28] A more thorough discussion of methods of reducing ICP over time is provided by Mauritz et al.[29] Although we found no significant difference in the rate of change, the mean and median ICP values in patients who received chest percussion increased at a slower rate than they did in patients who did not receive chest percussion.

Conclusions

This pilot study provides early evidence that chest percussion may be safe to perform on patients who are at risk for intracranial hypertension. This study was designed to test the null hypothesis (chest percussion does not alter ICP) and to determine the safety of chest percussion when chest percussion was randomly assigned at a specific time of day. An earlier single-subject study[30] indicated a decrease in mean ICP during several episodes of chest percussion. The concept of chest percussion as a means of reducing ICP warrants further investigation. Our findings provide an early signal that chest percussion is not detrimental to ICP and may be helpful in promoting pulmonary care. Because of the small sample size in our study and a prior study in which ICP values were lower during chest percussion, the phenomenon of chest percussion directly affecting ICP values warrants further study.

FINANCIAL DISCLOSURES
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Evidence-Based Review and Discussion Points

By Ruth Kleinpell, RN, PhD

Evidence-Based Review (EBR) is the journal club feature in the *American Journal of Critical Care.* In a journal club, attendees review and critique published research articles: an important first step toward integrating evidence-based practice into patient care. General and specific questions such as those outlined in the "Discussion Points" box aid journal club participants in probing the quality of the research study, the appropriateness of the study design and methods, the validity of the conclusions, and the implications of the article for clinical practice. When critically appraising this issue's EBR article, found on pp 330-335, consider the questions and discussion points outlined in the "Discussion Points" box. Visit **www.ajcconline.org** to discuss the article online.

This article, "Effect of Mechanical Chest Percussion on Intracranial Pressure: A Pilot Study," by Olson and colleagues, sought to determine the effect of mechanical chest percussion on intracranial pressure (ICP) in a total of 38 patients who had at least 1 documented episode of ICP and who were having intracranial pressure monitoring. A randomized study design was used to assign patients to either the control group, which had no chest percussion, or the intervention group, which had 10 minutes of chest percussion conducted. Intracranial pressure was recorded once a minute before, during, and after the chest percussion intervention, which was standardized as 10 minutes of automated percussion with the head of the bed elevated 30°. Mean values of intracranial pressure were compared between groups. A slight increase in ICP values over time was observed in both the control and intervention groups, but no difference was found between the groups.

Investigator Spotlight

This feature briefly describes the personal journey and background story of the EBR article's lead investigators, discussing the circumstances that led them to undertake the line of inquiry represented in the research article featured in this issue.

DaiWai Olson

The idea for lead investigator DaiWai Olson's research study sprang from a disagreement about treatment options for a patient in his unit who had intracranial hypertension and whose lungs were failing.

"We started doing mechanical chest percussion on this patient because we had nothing else to offer, and we were amazed by the results," he explained. "This spurred us to take a scientific step backward and to start over by asking, Is it safe to perform mechanical chest percussion with intracranial hypertension?"

Olson and his colleagues found even more surprises when they started doing research on this question. An unexpected difficulty was that some nurses felt the study should not be conducted because they believed chest percussions were bad for intracranial pressure.

"The unexpected plus was the set of MDs who supported our work," Olson noted. Another positive surprise was the number of nurses who wanted to help recruit patients and do data collection. This situation required learning how to get nurses certified by the investigative review board, which in turn led to learning how to organize and track all the study personnel.

"Nurses are the most wonderfully giving scientists," said Olson. "The team I worked with was composed 100% of volunteers. I think there are millions of nurses out there who really, honestly want to improve patient care. They want to know the *right* way to do things, and they are willing to go the extra mile to help find the answers. There are also a few thousand nurses who just love to argue, and they are a great resource, too. After all, science is part argument. These nurses are a great source of study design and thinking outside the research box."

Olson has advice for future researchers: "This is not the most advanced high-tech study ever conducted; it comes from a simple question. Any nurse out there could have asked it. Ultimately, any nurse could have done the study. After you read the article, in fact, you will find yourself saying, 'Hell, I could've done this!' And the response is, yes, you can do important research that will be published."

Information From the Authors

DaiWai Olson, RN, PhD, CCRN, lead author of this EBR article, stated that the idea for conducting the study arose from clinical discussions.

"Like many topics, this one started out as an argument over whether or not nurses should be using percussion in this patient population. Arguments turn to discussions and then become the fodder for science."

Olson shared additional information about the project, including that it took 7 months to complete data collection and that group assignment was based on randomization.

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He explained, "We used randomization without replacement; we created a set of cards, and after obtaining consent we drew 1 card from the set and that defined the subject's group."

The study's results report that a nurse opted to drain cerebrospinal fluid in 3 instances in the control group and 2 instances in the intervention group in response to elevated ICP. "Although this practice limited the internal validity of the study—because not all nurses took the same actions in response to ICP changes—it was decided by the research team that at this early stage of investigation we would get more buy-in from staff (that is, they would help us complete the study) if we did not limit their ability to make practice decisions," said Olson.

The level of positive end-expiratory pressure (PEEP) or mechanical ventilator settings were not considered in the study. Olson explained: "We did not record PEEP values. It's an interesting notion because PEEP increases central venous pressure (CVP) and CVP is a determinant of ICP.

"Future work might benefit from looking at more variables. In this case, we opted not to record PEEP because it was not the actual ICP value that we were interested in measuring as our outcome; rather, it was the change in ICP. However, it is possible that mechanical chest percussion impacts ICP differently at different levels of PEEP, CO_2, mean airway pressure, and so on. Can you see how much more work is still left to do?"

Implications for Practice

The results of the study indicated that whereas mechanical chest percussion slightly elevated ICP, there were no differences between the mean values for control and intervention patients. This finding demonstrated that chest percussion may be a safe intervention for nurses to use with patients who have neurological injuries.

Olson said that the results of the study help to further inform nurses about the impact of clinical interventions for patients with brain trauma. He warned, "It is too soon to draw full conclusions, but the body of evidence (small as it is) suggests that nurses may safely use mechanical chest percussion for patients who are at risk for elevated ICP."

According to Olson, readers of the *American Journal of Critical Care* can best use the information from the study for clinical practice considerations. "The best use is to consider mechanical chest percussion as an option. Nurses will still need to closely and carefully monitor ICP, but at least mechanical chest percussion is in the arsenal," he said.

About the Author
Ruth Kleinpell is contributing editor of the Evidence-Based Review section. She is a professor in the Rush University College of Nursing, a teacher-practitioner at the Rush University Medical Center, and a nurse practitioner with Our Lady of the Resurrection Medical Center, Chicago, Illinois.

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Discussion Points

A. Description of the Study
- ❑ What was the purpose of the research?
- ❑ What is its clinical significance to nursing?

B. Literature Evaluation
- ❑ What previous research has been conducted on the impact of mechanical ventilation and pulmonary care on ICP?

C. Sample
- ❑ What were the study's inclusion and exclusion criteria?

D. Methods and Design
- ❑ What type of research design was used for the study?
- ❑ How were data collected?
- ❑ How were the data on ICP collected during the intervention?

E. Results
- ❑ What differences in ICP were found between the control and intervention groups?
- ❑ How did mechanical percussion influence intracranial pressure readings?

F. Clinical Significance
- ❑ What are the implications of this study for clinical practice?
- ❑ How does the study extend the evidence base for care of mechanically ventilated patients with brain injury?