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Victoria Shink
DePaul University, victoriashink@yahoo.com

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Amanda Galik, BSN, RN and Victoria Shink, BSN, RN

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DePaul University School of Nursing

NorthShore University Health System School of Nurse Anesthesia

Project Committee

Pamela Schwartz, DNP, CRNA – Chairperson

Julia Feczko, DNP, CRNA – Committee Member

Author Information

Amanda Galik, BSN, RN and Victoria Shink, BSN, RN are DNP candidates at

DePaul University School of Nursing and

NorthShore University HealthSystem School of Nurse Anesthesia.

Authors are on track for degree completion in August 2020.

Amanda Galik can be reached at 219-743-5077 or mandygalik@yahoo.com.

Victoria Shink can be reached at 815-954-9338 or victoriashink@yahoo.com.

Abstract

Lumbar cerebrospinal fluid (CSF) drains are invasive interventional devices implemented for patients suffering from neurosurgical and complex aortic conditions. CSF drain management can be an infrequent task for anesthesia providers. Infrequent exposure can lead to inadvertent mismanagement leaving the patient vulnerable to increased morbidity and mortality. The purpose of this study was to develop a reference tool for basic intraoperative management of lumbar CSF drains and determine if CRNA and SRNA knowledge was improved with its use. This study utilized a pre-test/post-test design. The pre-test revealed significant knowledge gaps in content crucial for safe drain manipulation and management. Improvement in post-test mean scores after the introduction of the reference tool were noted when compared to pre-test mean scores for questions 2 through 10. This study revealed a statistically significant (p-value <0.001) increase in overall mean scores from 72.89% to 85.79% after the implementation of the reference tool.

Key words: anesthesia, intraoperative, lumbar cerebrospinal fluid drain, neuroscience, cardiothoracic

Introduction

Lumbar cerebrospinal fluid drains are invasive interventional devices implemented for patients suffering from a traumatic brain injury, intracerebral hemorrhage, cerebral edema, and high risk neurosurgical and aortic procedures.[1,2,3,4,5] While the use of lumbar drains for complex aortic procedures is a newer practice that is becoming more common place in today's operating environment, the use of cerebrospinal fluid drains (more commonly external ventricular drains [EVDs]) has long been considered the gold standard for CSF diversion and intracranial pressure monitoring in neurosurgical patients.[1] Lumbar cerebrospinal fluid drains are temporary drains placed into the lumbar subarachnoid space for the purpose of externally diverting CSF to maintain perfusion pressures in a target range and protect against cerebral or spinal ischemia.[2,3,4,5]

Cerebral ischemia is a life threatening complication that can lead to the loss of functioning brain tissue, resulting in significant morbidity and mortality.[1]Spinal ischemia creates transient or permanent neurologic deficits, such as paraplegias and paralysis, which can again result in significant morbidity and mortality.[2,3,4,5] While lumbar CSF drains facilitate improved cerebral and spinal perfusion, these are not without risk. Over or under drainage of CSF can result in devastating injuries to the brain and spinal cord. Over drainage of CSF can result in collapse of the ventricles of the brain.[1] Under drainage can result in increased spinal perfusion pressure resulting in paralysis or neurologic deficits as well as increased ICP.[1,2,3,4,5] Elevated ICP can result in reduced cerebral perfusion pressure and lead to cerebral ischemia.[1]

Cerebrospinal fluid drain management can be an infrequent task for anesthesia providers that work outside of the neurosurgical specialty.[2,6] Lacking an established skill set and knowledge promotes inadvertent mismanagement of CSF drains, leaving the patient vulnerable

to a secondary insult.[1] Unfamiliarity with the needs of a high acuity patient creates a high stress environment that can further decrease performance.[6] In addition, a complex operating room environment with multiple distractions and staff turnover create a "perfect storm" for human error leading to morbidity and mortality.[7]

In a comprehensive multi-continent study, 599 anesthesiologists were surveyed on management practices of patients presenting with EVDs.[8] The majority reported no clinical competency or continued education for management of EVDs, approximately 70% reported annual drain management of less than 25 patients, 25% reported awareness of the Society of Neuroscience in Anesthesiology and Critical Care (SNACC) guidelines, and only 21% reported formal training in EVD management.[8] In addition, 40% of anesthesia providers included in this study reported knowledge of adverse events occurring in relation to the drain management.[8] Of the providers surveyed, 83% expressed interest in having additional training tools available.[8] Implementation of insertion protocols had a statistically significant reduction in infection rates with placement of cerebrospinal fluid drains.[9] The use of checklists and management "bundles" is recommended to reduce complications and human errors.[7,10]

To date, there are no known studies that have developed a reference tool to guide anesthesia providers intraoperatively in the management of lumbar CSF drains. However, many studies do stress the importance of reference tools, checklists, and protocols to minimize complications and optimize patient outcomes.[7,8,9,10] The purpose of this study was to evaluate if the introduction of a reference tool which served as a guideline for basic drain maintenance and manipulation improved the anesthesia provider's knowledge. The investigators aimed to answer the following research question: In anesthesia providers, how does the implementation of a

lumbar CSF drain reference tool effect providers' knowledge to care for patients with lumbar CSF drains?

Materials and Methods

This study was reviewed and approved by the International Review Board at DePaul University prior to implementation.

Study Design

This study utilized a pre-test/post-test design with an educational reference tool. Participants were first presented with a list of 3 demographic questions, followed by the pre-test which contained 10 multiple-choice questions (Table 3). The reference tool created by the authors of this study, titled Intraoperative Management of Lumbar CSF Drains: A Reference Tool (Figure 1), was then presented and available for download. The post-test followed contained the same 10 multiple-choice questions as the pretest (Table 3). Participants were encouraged to use the educational reference tool on the post-test to best simulate real-time ability to find needed information. The content of both the pre- and post-test as well as the educational reference tool were reviewed for content validity by a panel of 5 anesthesia experts in the areas of nurse anesthesia practice, cardiac anesthesia, neuroanesthesia, and the education of SRNAs. Qualtrics® was used for data collection to allow for the de-identification of information and maintenance of the anonymity of participants throughout the study.

Sample

A convenience sample was utilized for this study. Inclusion criteria included members of the Facebook group "CRNAs and SRNAs" who were either 1) Certified Registered Nurse Anesthetists (CRNAs) or 2) Student Registered Nurse Anesthetists (SRNAs) who were currently enrolled in a nurse anesthesia program. Exclusion criteria for this study included any CRNAs or

SRNAs who were not members of the Facebook group "CRNAs and SRNAs" as well as any SRNA members who were not currently enrolled in a nurse anesthesia program. At the time of study implementation, there were 25,700 members in this group.

Instruments and Data Collection Procedure

The recruitment post was placed on the private Facebook group "CRNAs and SRNAs" which provided a brief introduction to the study and a link for completion for a total of two times, 1 week apart. The Qualtrics® link remained open for a total of 2 weeks. By clicking the link, participants were directed to the Qualtrics® program and a screen displaying the information sheet containing study information. Participants then clicked on the "I agree" button to consent to participating in this study. This then directed them to the demographic survey and pre-test.

The multiple-choice demographic survey included questions regarding years of anesthesia practice, anesthesia specialty, and estimated number of drains managed yearly. The pre-test consisted of multiple-choice questions regarding positioning of the lumbar CSF drain, CSF pressure readings, drainage output, perfusion pressure values, and other lumbar CSF drain management questions. Once the pretest was completed, participants clicked the "next" button at the bottom of the screen and the reference tool appeared. Intraoperative Management of Lumbar CSF Drains: A Reference Tool (Figure 1) was available for review and able to be downloaded by the participants. The reference tool contained information regarding the purpose of lumbar CSF drains and their intraoperative management guidelines (i.e. positioning, drainage output, assessment, and cautionary statements). Information contained in the reference tool was sourced from current textbooks, an extensive review of the literature, and SNACC guidelines. Once participants downloaded the reference tool, they clicked the "next" button at the bottom of the

screen and were then directed to the post survey in which they were encouraged to use the reference tool for answering questions. This post-test contained the same set of multiple-choice questions as the pre-test.

Results

Demographics

A total of forty anesthesia providers participated in this study. Two of the forty participants failed to complete a post-test and were excluded from the study results (N= 38). Twenty-five of the thirty-eight participants were CRNAs (65.8%) and the remaining thirteen participants were SRNAs (34.2%) (Table 1). Participants were broken down into groups based on years of practice, specialty, and exposure to lumbar CSF drains. Of the CRNAs who completed this study, experience ranged from two years or less (n=8), two to five years (n=4), five to ten years (n=7), and greater than 10 years (n=6) (Table 1). Three CRNAs specialized in neurosurgery. One CRNA specialized in obstetric anesthesia. No other specialties were identified. Exactly half (n=19) of the participants had never managed a lumbar CSF drain intraoperatively and 42.1% of participants (n=16) managed no more than five drains per year (Table 2). The remaining participants (n=3) managed ten to fifteen drains per year or greater (Table 2).

Overall Results

Utilizing Statistical Package for Social Sciences (SPSS) 25, each question was coded a score of 1 for correct response and 0 for incorrect response. The sum of the responses was calculated, divided by the total possible correct score (10), and then multiplied by 100. An overall mean score (%) was computed for each pre-test and post-test question. Individual paired t-tests were conducted for each question. The difference in the overall mean scores of pre-test

and post-test results was then determined by a paired t-test. The difference in pre-test results (M= 72.89%) and post-test results (M= 85.79%) was statistically significant (p-value <0.001).

Table 3 illustrates the pre and post-test results and highlights the significant findings during comparison. Questions 3, 4, 5, and 6 were statistically significant and demonstrated the greatest improvement on the post-test (Table 3). Questions 3 and 4, which focused on *phlebostatic axis location* and *normal CSF pressure*, demonstrated a statistically significant improvement in mean scores from pre- to post-test with p-values <0.05. Questions 5 and 6, which focused on the *minimal interval to record CSF drainage* and *minimum MAP needed to maintain a SCPP of 80 mmHg,* demonstrated very statistically significant improvement in mean scores from pre- to post-test with p-values= 0.001 or less. Question 7, which focused on the *recommended hourly drainage of CSF,* demonstrated an improved post-test mean score of 18.4%; however, this was not found to be statistically significant. Question 1 focused on the *correct stopcock position to drain CSF*. It was the only question with a lower mean post-test result, but it was not statistically significant (Table 3).

Years of Practice and Specialization

Years of practice and specialization did not exhibit an impact on performance. Both SRNAs and CRNAs with varying levels of experience demonstrated overall unchanged (n=7) or higher (n=27) mean post-test scores when compared to the pre-test (Table 4). Sixteen percent (n=4) of CRNAs who completed this study revealed lower overall mean post-test scores as compared with pre-test scores, however, reported experience varied amongst this group (Table 4). In addition, the majority of the sample (n=34) reported no specialization in practice (Table 5). The remaining 4 reported neuroanesthesia specialization (n=3) and obstetric anesthesia

specialization (n=1). With such a small sample of participants being specialized, no conclusions can be drawn regarding specialization.

Number of Lumbar CSF Drains Managed Yearly

The majority of study participants reported never managing a lumbar CSF drain intraoperatively (n=19) or having managed 1-5 a year (n=16) (Table 3). Of these participants who have never managed a lumbar CSF drain or have managed less than 5 a year, 74.3% (n=26) demonstrated higher overall mean post-test scores when compared to the pre-test (Table 6). The remaining 25.7% (n=9) was divided between lower overall mean post-test scores (n=4) and unchanged scores (n=5). Participants who reported management of 10 or greater lumbar CSF drains a year represented the minority of the sample (n=3). Results demonstrated unchanged (n=2) or improved scores (n=1) in this subgroup (Table 6).

Discussion

The purpose of this study was to evaluate if the introduction of a reference tool, which served as a guideline for basic drain manipulation, improved the anesthesia provider's knowledge. The study's findings revealed a statistically significant (p-value <0.001) increase in overall mean scores from 72.89% to 85.79% after the implementation of the reference tool. This established an improvement in knowledge for both SRNAs and CRNAs despite specialization, years of experience, and yearly number of lumbar drains managed.

While lumbar CSF drains are implemented to improve patient outcomes, these drains are not without risk. Recent literature demonstrated limited education or competency in CSF drain manipulation and limited exposure to CSF drains intraoperatively amongst anesthesia providers. [8] Literature also revealed provider perception of a need for additional educational tools regarding CSF drain management as well as knowledge of adverse events to patients with CSF drains in

relation to mismanagement.[8] Consistent with the current literature, this study demonstrated CSF drain management to be an infrequent task with significant knowledge gaps amongst practicing CRNAs and SRNAs, regardless of specialty and years of experience. The pre-test revealed significant knowledge gaps in many question areas including normal CSF pressure values, drain positioning, perfusion pressure calculations, drain troubleshooting, stopcock position, and drainage guidelines. This content is crucial for safe drain manipulation, and the inadvertent mismanagement of lumbar CSF drains can leave the patient vulnerable to increased morbidity and mortality.

The use of checklists, reference tools, and protocols have long been used to optimize patient outcomes and minimize potential complications.[7,9,10] Yet, at the implementation of this study, no existing developed educational tools or checklists were found regarding the manipulation of lumbar CSF drains despite the established knowledge gaps amongst the literature. The development of the evidence-based reference tool (Figure 1) as used for this study demonstrated overall improvement in knowledge in CRNAs and SRNAs regarding lumbar CSF drain management. This is exhibited by the improvement in post-test mean scores after the introduction of the reference tool when compared to pre-test mean scores for questions 2 through 10. Questions 3, 5, 6, and 7 were the lowest scoring pre-test mean values demonstrating a substantial knowledge gap, however, these questions also had the greatest improvement in post-test mean scores.

This study provides the first educational reference tool of its kind to be utilized for anesthesia providers while managing lumbar CSF drains. This reference tool has the potential to improve the practice of CRNAs and SRNAs caring for patients with lumbar CSF drains as it provides a quick resource for the pertinent elements of drain manipulation. The education of

CRNAs and SRNAs can be facilitated with the use of this study's materials as significant knowledge gaps were identified prior to the introduction of the reference tool and resulted in overall improvement in knowledge. In addition, the developed tool may be able to be utilized to guide the development of institutional policies for lumbar CSF drain management for anesthesia providers.

A limited sample size (N=38) and social media distribution limiting the number of participants are two limitations that presented in this study. The majority of the participants in this study were SRNAs and CRNAs without specialization (N=24) and managed 5 or less lumbar CSF drains yearly (N=35). A higher powered study would potentially provide a greater demographic range allowing for generalizability of the study to the categorized groups. Additionally, only questions 3 through 6 proved statically significant when comparing pre- and post-test mean scores. While the validity of the tool is established, the validity of the questions which were not found to be statistically significant is questionable. Despite these limitations, the evidence-based developed reference tool has established overall statistical significance in improvement in knowledge amongst CRNAs and SRNAs regarding lumbar CSF drain manipulation.

This study presents several opportunities for further research in the nurse anesthesia community. As this study was executed on a solely online platform, it would be useful to evaluate the reference tool's effectiveness for CRNAs and SRNAs intraoperatively in real time. Additionally, conducting a larger multi-institutional study may provide a larger sample size allowing for further evaluation of the reference tool's effectiveness on improving knowledge amongst anesthesia providers. Lastly, CRNA and SRNA's evaluation of the developed reference

tool's ease and usefulness would allow for input towards potential revisions, and should be considered in future research.

Overall, the results of this study showed statistically significant improvement in post-test scores when compared to pre-test scores. Therefore, a reference tool for basic lumbar CSF drain manipulation can improve the anesthesia provider's knowledge when the goal is to provide optimal patient care. The reference tool is effective at improving knowledge for SRNAs and CRNAs, regardless of specialty or years of experience.

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Figure 1. Reference tool for intraoperative management of lumbar CSF drains

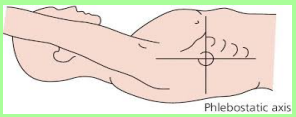
<table>
<tr><td colspan="2">INTRAOPERATIVE MANAGEMENT OF LUMBAR CSF DRAINS:
A REFERENCE TOOL
In accordance with The Society of Neuroscience in Anesthesiology and Critical Care Guidelines</td></tr>
<tr><td colspan="2">PURPOSE OF LUMBAR DRAINS[2,11,12,13]</td></tr>
<tr><td colspan="2">• Monitor cerebrospinal fluid (CSF) pressure and drain CSF to an intracranial or spinal pressure goal.
• Prevent elevated intracranial pressure (ICP) during neurosurgical surgery and interventional radiology procedures
• Maintain spinal cord perfusion pressure (SCPP) during thoracic abdominal aortic aneurysm repair and spinal surgery</td></tr>
<tr><td colspan="2">INTRAOPERATIVE MANAGEMENT[2,11,12,13]
Always verify management plan, pressure, and drainage goals with surgeon</td></tr>
<tr><td colspan="2">Label Lumbar Drain Tubing and/or Apply Colored Port Caps</td></tr>
<tr><td colspan="2">Connect Transducer Cable</td></tr>
<tr><td colspan="2">Confirm Head of Bed and Final Patient Position with Surgical Team</td></tr>
<tr><td colspan="2">Level Transducer at Phlebostatic Axis (right atrium) and Zero
• 4th intercostal space at the mid-anterior-posterior diameter of the chest wall
• Head of bed <60 degrees
• Use Carpenter's Bubble or Laser Level
• Avoid visual leveling if possible
 
</td></tr>
<tr><td colspan="2">Obtain Baseline Pressure Value
• TO TRANSDUCE PRESSURE: Stopcock closed to drain, open to patient and transducer
• Normal CSF pressure goal: 10 mmHg or less
• Maintain mean arterial pressure (MAP) >90 mmHg to achieve SCPP of at least 80 mmHg
• SCPP= MAP-CSF Pressure</td></tr>
<tr><td colspan="2">Document Every Hour at Minimum
• Output (do not drain >15-20 ml/hour)
• Color (clear, xanthrochromic, tea colored/blood tinged, bloody. etc.)
• Clarity (clear, cloudy, milky, etc.)
• Pressure
• Drain height (relative to the zero point)
• Stopcock status: Open to patient or closed to patient</td></tr>
<tr><td colspan="2">CSF Drainage
• TO DRAIN CSF: Stopcock open to patient
• TO PREVENT CSF DRAINAGE: Stopcock closed to patient</td></tr>
<tr><td>Caution with Position Changes or Alterations In: OR Table Height, Head of Bed, Trendelenburg, Reverse Trendelenburg, Device Relocation (pole to pole)</td><td>Drain Care with Position Change
• Close lumbar drain to patient (avoid closing drain if impending herniation or closed drain not tolerated)
• Change position
• Re-level transducer</td></tr>
<tr><td>Caution with Transport</td><td>• Close lumbar drain to patient</td></tr>
<tr><td>Avoid Pressure Flushing</td><td>• Never connect to pressure bags or pressure flushing systems</td></tr>
<tr><td>Avoid Injection</td><td>• Never administer medication or agents via lumbar drain ports</td></tr>
</table>

Table 1. Years of Practice

Years of Practice	Frequency	Percent
SRNA	13	34.2
CRNA practicing 2 years or less	8	21.1
CRNA practicing 2-5 years	4	10.5
CRNA practicing 5-10 years	7	18.4
CRNA practicing 10+ years	6	15.8
Total	38	100.0

Table 2. Number of lumbar CSF drains managed per year

Number of Lumbar CSF Drains Managed Yearly	Frequency	Percent
I have never cared for a patient with a lumbar CSF drain intraoperatively	19	50.0
1-5 lumbar drains	16	42.1
10-15 lumbar drains	1	2.6
More than 15 lumbar drains	2	5.3
Total	38	100.0

Table 3. Pre-test and post-test overall mean score (%) comparison and significance

Question	Pre-Test Mean Score (%)	Post-Test Mean Score (%)	Significance (p value)
1. What is the correct stopcock position to drain cerebrospinal fluid (CSF)?	92.1%	89.5%	0.571
2. What is the correct stopcock position to obtain a CSF pressure reading?	84.2%	86.8%	0.571
3. The phlebostatic axis, also known as the zero point, is located at the_____?	71.1%	89.5%	**0.017**
4. Normal CSF pressure is approximately _____?	89.5%	100%	**0.044**
5. What is the minimum interval to record output of CSF drainage?	44.7%	71.1%	**0.001**
6. What is the minimum mean arterial pressure (MAP) goal to maintain a spinal cord perfusion pressure (SCPP) of 80 mmHg?	42.1%	84.2%	**<0.001**
7. What is the recommended maximum amount of hourly CSF drainage?	42.1%	60.5%	0.090
8. The correct calculation to determine SCPP is _____?	92.1%	94.7%	0.571
9. During position changes and transport, the lumbar drain should be _____?	94.7%	100%	0.160
10. You suddenly lose your CSF pressure waveform during a craniotomy. Your next steps include all of the following except _____?	76.3%	81.6%	0.324
Total Overall	72.9%	85.8%	**<0.001**

Table 4. Years of Practice & Difference in Post-Test and Pre-Test Scores (n = frequency)						
Question	**Difference in Post-Test Score as Compared to Pre-Test Score**	**SRNA**	**CRNA practicing 2 years or less**	**CRNA practicing 2-5 years**	**CRNA practicing 5-10 years**	**CRNA practicing 10+ years**
Total Overall Score	Lower Score	0	2	1	1	0
	No Change	3	0	0	2	2
	Higher Score	10	6	3	4	4

Table 5. Specialty & Difference in Post-Test and Pre-Test Scores (n = frequency)			
Difference in Overall Post-Test Score as Compared to Pre-Test Score	**No Specialization**	**Neuroanesthesia**	**Obstetric Anesthesia**
Lower Score	4	0	0
No Change	6	1	0
Higher Score	24	2	1

Table 6. Number of Lumbar Drains Managed & Difference in Post-Test and Pre-Test Scores (n = frequency)					
Question	**Difference in Post-Test Score as Compared to Pre-Test Score**	**I have never cared for a patient with a lumbar CSF drain intraoperatively**	**1-5 lumbar drains**	**10-15 lumbar drains**	**More than 15 lumbar drains**
Total Overall Score	Lower Score	2	2	0	0
	No Change	3	2	1	1
	Higher Score	14	12	0	1