Dissertation:

Paroxysmal Sympathetic Hyperactivity following Severe Pediatric Brain Injury

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Abstract

Problem Statement: Individuals that suffer from severe brain injury can develop a complicating phenomenon that appears as autonomic instability and muscle over activity and is referred to as *paroxysmal sympathetic hypersensitivity (PSH)*. PSH following severe pediatric brain injury may be associated with a poorer recovery trajectory and quality of life.

Long-Term Goal: The broad goal for the program of research is to develop interventions aimed at improving clinical outcomes for children who have suffered a brain injury, with a particular focus on ways to mitigate symptoms for PSH.

Specific Aims:

Specific Aim 1: To describe the different characteristics between children that have suffered a severe brain injury and exhibit PSH compared with children that have suffered a severe brain injury in the absence of PSH.

Specific Aim 1.2: To describe characteristics of children who transitioned to rehabilitation following severe brain injury compared with those who do not transition to rehabilitation.

Specific Aim 1.3: To determine if there is an association with transition to rehabilitation following PSH and severe pediatric brain injury.

Specific Aim 2: To determine the influence of PSH following severe pediatric brain injury as a predictor of lower cognitive function.

Hypothesis: PSH following pediatric brain injury will be a significant predictor of lower cognitive function.

Specific Aim 3: To determine the influence of PSH following severe pediatric brain injury as a predictor of poorer motor function.

Specific Aim 4: To determine the influence of PSH following severe pediatric brain injury as a predictor of longer hospital length of stay.

Specific Aim 5: To explore nursing documentation of a PSH event and describe the clinical nursing interventions and care being provided to a child that has suffered a severe brain injury and is exhibiting PSH.

Methodology: The study used a secondary analysis of an established clinical dataset of children (*N*=83) who had suffered a brain injury and had not regained consciousness prior to admission to an academic children's hospital rehabilitation center for Aims 1-4. Multiple regression models were used to estimate the effects of PSH on the continuous outcomes of motor and cognitive function and length of stay. Logistic regression was used to estimate the effect of PSH on transition to rehabilitation. To address Aim 5, ten children were randomly selected from the dataset and the nursing progress notes were reviewed using directed content analysis.

Results: The PSH group had significantly longer acute care (p=0.024) and total lengths of stay (p=0.034) compared with the non-PSH group. There was not a significant difference in cognitive and motor function or transition to rehabilitation or rehabilitation length of stay between the PSH and non-PSH groups after controlling for age and etiology of injury. The nursing progress notes revealed that the priority nursing interventions to manage these symptoms included medication administration, facilitation of family presence, and strategies to target auditory, tactile, and visual stimuli.

Conclusions: Empirically grounded interventions need to be developed and tested that achieve better outcomes for children and their families following brain injury.

Chapter 1: Introduction

Background

The Centers for Disease Control and Prevention have declared brain injury a public health emergency in the United States because of the estimated 1.7 million traumatic brain injuries (TBI). TBIs are a contributing factor in 30.5% of all injury-related deaths and account for over $76 billion in health-related costs annually. TBI is reported most commonly in children ages 0-4, adolescent's ages 15-19, and adults over 65 years of age (1).

An injury to the brain may be traumatic or non-traumatic. Falls, motor vehicle accidents, bike accidents, gunshot wounds, sports injuries, assaults, military, or workplace injuries can cause TBIs, while non-traumatic injuries can be caused by stroke, seizures, tumor, infection, hypoxia, or toxic exposures (1). The leading causes of brain injuries in child vary by specific age groups. Motor vehicle crashes are the leading cause of brain injuries in children and young adults 5-24 years of age. However, assaults were the leading cause for children 0-4 years of age (1).

Children less than 14 years of age who suffer a TBI account for almost half a million emergency department visits annually, 75% of which are classified as mild TBI. However, the remaining 25% are moderate to severe brain injuries, resulting in significant motor and cognitive impairment for those who experience this level of injury (1).

Most individuals who sustain a brain injury will regain consciousness (spontaneous arousal and awareness), although some will not. Specifically, in the United

States alone an estimated 315,000 individuals who have suffered a severe brain injury have not regained consciousness, of which an estimated 40% are children (2). Depending upon the severity of the brain injury, secondary complications can emerge, potentially hindering the recovery trajectory.

Those individuals who have not regained consciousness following brain injury can develop a complicating phenomenon of autonomic instability and muscle over activity. Authors writing about this phenomenon use different nomenclatures. However for this dissertation, the phenomenon will be referred to as *paroxysmal sympathetic hyperactivity (PSH).* PSH presents clinically as a cluster of symptoms, which includes hyperthermia (recurrent fever without a source of infection), hypertension, tachycardia, tachypnea, diaphoresis, and/or dystonia (3-8). The conceptual definition most recently proposed by Dr. Ian Baguley and a consensus work group define *PSH* as " a syndrome recognized in a subgroup of survivors of severe acquired brain injury, of simultaneous paroxysmal transient increases in sympathetic (elevated heart rate, blood pressure, respiratory rate, temperature, sweating), and motor (posturing) activity (8)." PSH has been reported in non-traumatic and TBIs with differing etiologies (e.g., motor vehicle accident, pedestrian versus car, fall, stroke, tumor) (9-13). Adults as well as children have been reported to demonstrate features of this phenomenon after severe brain injury (5-7, 14-15)

A child's developing brain can be influenced by experiences and interactions with the environment. When the brain is injured, the developmental trajectory is compromised. Age or developmental level at the time of brain injury may be associated with the recovery trajectory. Additionally, the impact of PSH on the developing brains of children

who suffer brain injury is unknown given that the cerebral cortex does not reach full maturity until the third decade of life, making the structures of a developing brain more vulnerable to environmental influences (16-17).

When a child suffers a brain injury, the normal course of developmental trajectory is altered. Most of the injuries reported by the CDC are considered mild and result in few long-term deficits, if any. However, children who suffer moderate to severe brain injury (25% of injuries reported) have residual cognitive and motor deficits (1). There has been debate if a child's developing brain is plastic or more vulnerable when a brain injury occurs at a young age. Plasticity has been proposed and is a traditional view perceived by clinicians and researchers in the field of neuroscience (17-19); there is evidence that also supports that vulnerability during critical developmental periods can result in prolonged and devastating cognitive and motor deficits (16-17, 20). The question that arises is whether the phenomenon of PSH is similar in children and adults or different because of the developing brain. This dissertation addresses this debate and seeks to provide clarification of the recovery trajectory following severe brain injury in children complicated by PSH.

In adults with brain injury, PSH is associated with poorer clinical outcomes, including longer hospitalizations, poorer cognitive and motor function, increased infections, a need for tracheostomy, longer duration of amnesia, and increased estimated hospital costs (3-5, 21). Few studies, however, have explored PSH in children with brain injury (6, 7, 14, 22); therefore, little is known about the outcomes of children who experience PSH. Furthermore, in children there have been limited studies exploring PSH and the impact on the recovery trajectory.

The present dissertation study is warranted and will fill a gap in the literature. The current secondary data analysis will focus on a different sample then the two previous retrospective pediatric studies described, i.e., children following brain injury who have not regained consciousness, which will provide additional evidence of the association between PSH and clinical outcomes. The study will also use three instruments that were included in the evaluation process (Rancho Los Amigos Scale, Functional Independence Measure for Children, The Western Neuro Sensory Scale Profile) and administered by trained providers. Further research on PSH and outcomes in children with brain injury is needed to improve nursing care and quality of life for this population of children and their families. PSH following pediatric brain injury is a topic that has not been prioritized in nursing and leaves a gap in the literature. If PSH is associated with poorer outcomes following brain injury in children, nursing care and interventions could play a pivotal role in symptom management and promoting recovery.

Theoretical Framework

The Symptom Management Theory (SMT) provides a theoretical framework for the study and the phenomenon of PSH (23). The model was introduced in 1994 and developed by faculty at the University of California-San Francisco School of Nursing. The SMT is a multidimensional dynamic process for the management of symptoms that is used to provide a framework for symptom research and clinical practice (23). The present study is the first of its kind, laying the foundation for further studies related to symptom management, brain injury, and children.

Specific Aims

Pediatric brain injury has been associated with negative outcomes that persist beyond the acute hospitalization, impacting cognitive and motor function throughout the lifespan and exponentially increasing hospital costs (averaging greater than $2.5 billion per year) (24). PSH following severe pediatric brain injury may be associated with a poorer recovery trajectory and quality of life. The present dissertation study is a secondary analysis of an established clinical dataset of children who suffered a brain injury and did not regain consciousness prior to admission to an academic Children's Hospital Rehabilitation Center. The broad goal for this program of research, grounded by the Symptom Management Theory (SMT), is to identify interventions targeted at improving symptoms and outcomes in children following brain injury. There are several gaps in the literature related to prognosis, nursing interventions, and care of children who have sustained a brain injury and develop PSH. The major objective of the present study is to provide additional information regarding the characteristics and prognosis of children who have suffered severe brain injury and developed PSH. A secondary objective is to explore nursing interventions documented to manage PSH. The results will generate new knowledge regarding the relationship between PSH prognoses in children following severe brain injury. In addition, the study describes characteristics of this elusive phenomenon and the nursing interventions being applied to manage the symptoms of PSH. Table 1 outlines the specific aims and the relationship between constructs, variables, instruments, and administration time.

Impact

Children who suffer severe brain injuries can have life-long disabilities. The present study uses secondary analysis of a clinical dataset and addresses gaps in the literature by focusing on a unique sample of children with severe brain injury who have not regained consciousness prior to admission to an academic children's rehabilitation center and required maximum care and dependence on their family and society. The analysis reveals unknown factors regarding the elusive phenomenon of PSH, creating the potential to improve outcomes. Further research on PSH and associated outcomes in children with brain injury is needed to improve nursing care and quality of life for this vulnerable population of children, their families, and the community. Future targeted nursing interventions may include standard, novel, and complementary health practices to prevent, manage, and treat symptoms of PSH while also improving the recovery trajectory. By improving symptoms and outcomes in this population, the care and financial burden for families and the community might be alleviated.

The following chapters present research findings specific to the aims of the study. Chapter 2 reviews the literature, describes PSH following severe brain injury, and highlights research needs in children with PSH. This chapter is titled "Paroxysmal Sympathetic Hyperactivity: Autonomic instability and muscle over activity following severe brain injury" and has been submitted and is under review by *Brain Injury.* Chapter 3 is titled "A retrospective analysis of paroxysmal sympathetic hyperactivity following pediatric brain injury" and describes the quantitative results of Aims 1-4. The plan is for this manuscript to be submitted to *Brain Injury*. Chapter 4 is titled "Paroxysmal Sympathetic Hyperactivity: An exploratory evaluation of nursing interventions," and

describes the theoretical framework and nursing interventions documented to manage PSH (Aim 5). The plan is for this manuscript will be submitted to the *Journal of Neuroscience Nursing*. Chapter 5 identifies key findings for each aim and what these findings suggest for nurses and providers of children who have suffered a severe brain injury and exhibit PSH. Additionally, the present study's limitations and implications for future research are examined in Chapter 5.

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Table 1: *Specific Aims and the relationship between constructs, variables, instruments, and administration time*

Specific Aim 1: To describe the different characteristics between children that have suffered a severe brain injury and exhibit PSH compared with children that have suffered a severe brain injury in the absence of PSH			
Specific Aim 1.2: To describe characteristics of children who transitioned to rehabilitation following severe brain injury compared to those that do not transition to rehabilitation.			
Specific Aim 1.3: To determine if there is an association with transition to rehabilitation following PSH and severe pediatric brain injury.			
Hypothesis: Children that exhibit PSH following severe brain injury will have a decreased rate of transition to rehabilitation compared with children following severe brain injury in the absence of PSH after controlling for age and etiology of brain injury.			
Construct	Variable	Instrument	Administration
Characteristics of children	Age Age group Cost data Days post injury Gender Geographical region Grados depth of lesion score Etiology of Injury Ethnicity Initial Glasgow Coma Score Insurance Medical comorbidities (seizures, spasticity) Mortality Readmission within 30 days Transition to Rehabilitation Combined cognitive and motor function	1. Electronic medical record 2. Clinical data repository 3. Total functional independence measure for children (Weefim) score	Admission Weefim administered once transitioned to rehabilitation status and discharge from rehabilitation

<table>
<tr><td colspan="4">Specific Aim 2: To determine the influence of PSH following severe pediatric brain injury as a predictor of lower cognitive function</td></tr>
<tr><td colspan="4">Hypothesis: PSH following pediatric brain injury will be a significant predictor of lower cognitive function when compared with children following severe brain injury in the absence of PSH after controlling for age, gender, and etiology of brain injury</td></tr>
<tr><td>Construct</td><td>Variable</td><td>Instrument</td><td>Administration</td></tr>
<tr><td>Cognitive function</td><td>1. Cognitive/memory skills:
Attention
Being aware of one's surroundings,
Organizing
Planning, following through on decisions
Solving problems
Judgment
Reasoning
Awareness of problems
Ability to remember things before and after the brain injury
2. Arousal, attention, auditory response, expressive communication, and visual response
3. Communication social cognition:
Comprehension
Expression
Social Interaction
Problem solving
Memory</td><td>1. Rancho Los Amigos Scale (RLA)
2. Western neuro sensory stimulation profile (WNSSP)
3. Weefim Cognitive score (Q14-18)</td><td>1. RLA on admission & discharge from institution
2. (WNSSP) on admission & discharge from institution
3. Weefim once transitioned to rehabilitation status and discharge from rehabilitation status</td></tr>
<tr><td colspan="4">Specific Aim 3: To determine the influence of PSH following severe pediatric brain injury as a predictor of poorer motor function.</td></tr>
<tr><td colspan="4">Hypothesis: PSH following pediatric brain injury will be a significant predictor of poorer motor function when compared with children following severe brain injury in the absence of PSH after controlling for age, gender, and etiology of brain injury.</td></tr>
<tr><td>Construct</td><td>Variable</td><td>Instrument</td><td>Administration</td></tr>
<tr><td>Motor function</td><td>Self care:
Eating
Grooming Bathing
Dressing
Toileting
Bladder management
Bowel management
Mobility:
Transfers
Locomotion</td><td>Weefim (Q 1-13)</td><td>Once transitioned to rehabilitation status and discharge from rehabilitation status</td></tr>
</table>

Specific Aim 4: To determine the influence of PSH following severe pediatric brain injury as a predictor of longer hospital length of stay.			
Hypothesis: Children who exhibit PSH following severe brain injury will have a longer hospital length of stay (acute, rehabilitation, and total length of stay) compared with children following severe brain injury in the absence of PSH after controlling for age, gender, and etiology of brain injury.			
Construct	Variable	Instrument	Administration
Length of stay at an academic children's hospital rehabilitation center	Acute length of stay Rehabilitation length of stay Total length of stay	Electronic Medical Record	Discharge from institution
Specific Aim 5: To explore nursing documentation of a PSH event and describe the clinical nursing interventions and care being provided to a child that has suffered a severe brain injury and is exhibiting PSH.			
Construct	Variable	Instrument	Administration
Nursing documentation in the medical record	Qualitative data	Electronic medical record	During entire hospitalization at the institution

Chapter 2: Paroxysmal sympathetic hyperactivity: Autonomic instability and muscle over activity following severe brain injury

This manuscript has been submitted for publication to *Brain Injury* and is under review

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Abstract

Background: Children who suffer from moderate to severe brain injury can develop a complicating phenomenon known as paroxysmal sympathetic hyperactivity (PSH), characterized by autonomic instability and identified clinically as a cluster of symptoms that can include recurrent fever without a source of infection, hypertension, tachycardia, tachypnea, agitation, diaphoresis, and dystonia. Studies with adults have demonstrated that this cluster of symptoms is associated with poorer clinical outcomes (prolonged hospitalizations, poorer cognitive and motor function). However, there have been limited studies in children with PSH.

Objective: To present a literature review regarding PSH following severe brain injury and highlight research needs in children with PSH.

Methodology: Electronic databases (CINAHL, Ovid Medline, Web of Science, and Google Scholar) were searched.

Results: Thirty-one research articles met the criteria for inclusion. Several themes emerged regarding the phenomenon of interest during the review: nomenclature, symptoms, management, and differences between children and adults.

Implications: The majority of the research regarding PSH following severe brain injury has been descriptive in nature. Few studies, however, have explored PSH in children with brain injury; therefore, little is known about whether the outcomes of children with PSH are different and, if so, in what ways.

The Centers for Disease Control and Prevention (CDC) estimate an annual incidence of 1.7 million traumatic brain injuries (TBIs) in the United States. Because TBIs are a contributing factor in 30.5% of all injury-related deaths, the CDC has declared brain injury a public health emergency. TBIs most commonly occur among children ages 0-4 years, adolescents ages15-19 years, and adults over 65 years of age. Children under 14 years of age who experience a TBI account for almost half a million emergency department visits annually (1). While 75% of TBIs are classified as mild, the remaining moderate and severe brain injuries result in significant motor and cognitive impairment.

Most individuals who sustain a brain injury will regain consciousness, although some will not. In the United States alone, an estimated 315,000 individuals who have suffered a severe brain injury have not regained consciousness; among those, an estimated 40% are children (2). Depending upon the severity of the brain injury, secondary complications can emerge, which hinder the recovery trajectory.

Individuals who have suffered moderate to severe brain injury and do not regain consciousness can develop a complicating phenomenon of autonomic instability and muscle over activity. Authors writing about this phenomenon use different nomenclatures, but the phenomenon will be referred to here as paroxysmal sympathetic hyperactivity (PSH). PSH presents clinically as a cluster of concurrent symptoms, including hyperthermia (recurrent fever without a source of infection), hypertension, tachycardia, tachypnea, diaphoresis, and/or dystonia (3-8). Ian Baguley and a consensus work group recently proposed a conceptual definition of PSH as ‘a syndrome recognized in a subgroup of survivors of severe acquired brain injury, of simultaneous paroxysmal transient increases in sympathetic (elevated heart rate, blood pressure, respiratory rate,

temperature, sweating), and motor (posturing) activity (8)'. PSH has been reported in non-traumatic and TBIs with differing etiologies (e.g., motor vehicle accident, pedestrian versus car, fall, stroke, and tumor) (9-13). Adults as well as children have been reported to demonstrate features of this phenomenon after severe brain injury (5-7, 14-15).

Among adults with brain injury, PSH is associated with poorer clinical outcomes, including longer hospitalizations and poorer cognitive and motor function (3, 5, 16). However, few studies have explored PSH in children with TBIs (6, 7, 14, 17); therefore, little is known about the outcomes of children who experience PSH. The purpose of this article is to present a literature review regarding PSH following severe brain injury and to highlight research needs in children with PSH.

Background

Research is beginning to focus on outcomes related to PSH following severe brain injury. Although single case studies dating back to the 1950s describe PSH, the state of the science remains descriptive in nature and the phenomenon illusive to clinicians and researchers. Much research focuses on recognizing and understanding the phenomenon and the various medical treatment modalities being used. The lack of uniform nomenclature to describe this phenomenon poses a challenge to communication among clinicians and researchers. The resulting confusion and disagreement regarding cases reported should be evaluated carefully.

In 1929, Penfield first reported a phenomenon in which he labeled the clinical events following brain injury as 'diencephalic autonomic seizures' (18). His case describes a women who had suffered a brain injury in childhood and presented with severe headaches and intermittent "attacks" wherein she would develop acute episodes of

vasodilation, lacrimation, diaphoresis, salivation, dilation of the pupils, increased blood pressure and heart rate, decreased respiration rate, hiccupping, and shivering, which led to Cheyne-Stokes respirations. An autopsy later revealed that this patient had a tumor located in the third ventricle. Penfield postulated that the autonomic dysfunction could be caused by the tumor pressing on the thalamus. Although some clinicians credit Penfield with the first case report of what is now referred to as PSH, his case differs from subsequent cases in the literature because the woman regained consciousness intermittently between episodes (11, 19). Although similar, this case should not be confused with PSH, which is a different phenomenon observed after severe brain injury.

In 1956, Strich presented cases with severe brain injury who died after prolonged coma (i.e., had not regained consciousness) and had episodes of agitation, diaphoresis, hyperthermia, tachycardia, tachypnea, and posturing (20). He described these events as brain stem attacks, which are comparable to cases currently reported by Baguley and colleagues (3). Despite these proposed diagnostic criteria, others still report variations in symptom parameters (5, 14, 15, 17). The varying nomenclature and definitions could stem from the lack of certainty related to the theory behind the phenomenon.

Disconnection Theory can explain the pathophysiology of PSH, which results in a disconnection of the pathways in the brain because of structural damage following injury (21). The disconnection results in a disruption of the normal autonomic regulatory control mechanism, thus resulting in autonomic instability. Sites of dysfunction have been postulated to include the brain stem, midbrain, cortical centers, and associated diffuse axonal injury (3, 5, 15). Others suggest that there are no specific radiological findings associated with PSH or with increased intracranial pressure (16). An association between

sympathetic over activity and nociceptive stimuli has also been reported (16, 22). Neuropathic pain has also been attributed to the occurrence of PSH (9).

Furthermore, the responses of the autonomic nervous system to external stimulation may well be different in younger individuals than older (15). In adults, the reported incidence of PSH ranges from 8-33% following brain injury (5, 9, 10, 16, 23). Both Kirk and colleagues (6) and Krach and colleagues (7) have reported the pediatric prevalence of PSH as 13-14% following brain injury, although there have been no prospective pediatric studies to document the incidence. In the adult literature, evidence exists as to a decreased incidence of PSH, which may be related to the treatment focus and improved procedures used following brain injury; however, there are no pediatric studies to confirm this trend (10). Baguley and colleagues have suggested that PSH may represent a 'treatable contributor to secondary brain damage,' highlighting the need for prevention, management, and treatment strategies for PSH (8).

Methods

Data sources

Electronic databases (CINAHL, Ovid Medline, Web of Science, and Google Scholar) were searched using the following key terms: *adult and child, autonomic dysfunction, brain injury, dysautonomia, fever, hypertension, and nursing intervention*. The search was initially limited to 10 years (2005-2015), but later expanded to include articles that were frequently cited in the articles reviewed.

Article selection

Only articles written in the English language were reviewed. Articles included quantitative and qualitative research. Research designs included case studies, descriptive, observational, case controlled, comparative, retrospective, and prospective. No randomized controlled trials were identified for review. Selected articles focused on the phenomenon of autonomic instability and muscle over activity following severe brain injury, and nursing interventions related to vital sign management after brain injury. Articles that addressed nursing interventions related to other aspects of brain injury care (e.g., ICP monitoring) were excluded.

Results

Article descriptions

Thirty-one research articles met the criteria for inclusion. The majority discussed studies using quantitative methods (n = 29). There were several common evaluation instruments used to measure cognitive and motor function. The most frequently used instruments were the Glasgow Coma Scale (n = 9), Glasgow Outcomes Scale (n = 7), Disability Rating Scale (n = 4), Level of Cognitive Function Scale (n = 4), Functional

Independence Measure (*n* = 3), and the Functional Independence Measure for Children (*n* = 2). The studies reviewed did use common instruments and the study results are generalizable.

Study quality

A limitation of several studies was the small sample sizes. The majority of studies used a convenience sample from a single recruitment site, often an intensive care unit. Additionally, the lack of uniform terminology and varying definitions of PSH hinder advancement of the science and fosters continued disagreement between clinicians and researchers regarding the phenomenon.

Themes identified

Several themes emerged regarding the phenomenon of interest during the review: nomenclature, symptoms, management, and differences between children and adults. Each of these themes is evaluated further.

Nomenclature

Researchers have coined a variety of nomenclatures when defining autonomic instability and muscle over activity. The most frequently noted terminologies included dysautonomia (*n* = 11*)*, paroxysmal autonomic instability with dystonia (*n* = 3*)*, storming (*n* = 2*)*, central autonomic dysfunction (*n* = 1), diencephalic seizure (*n* = 1), and paroxysmal sympathetic hyperactivity (*n* = 3). Specifically, in the nursing literature only two review articles used the term ‘storming’ (24, 25). Recently an international expert consensus group, led by Ian Baguley from Australia, promoted the term PSH to identify the key features of the phenomenon in adults (8).

Symptoms

Regardless of the etiology of an individual's brain injury, symptoms often first appear in the intensive care unit and may persist for weeks to months after injury if the individual does not regain consciousness (14). The parameters for vital signs (hyperthermia, hypertension, tachypnea, and tachycardia) were not consistent among studies. The most variable vital sign was temperature, with values across studies ranging from 38–39ºC (3, 5-6, 15, 22).

There is no agreement regarding how many symptoms must be present during an episode. Baguley and colleagues strongly recommend that 5 out of 7 features (hyperthermia, hypertension, tachypnea, tachycardia, agitation, diaphoresis, and/or dystonia) must be present with episodes lasting for at least 2 weeks post-injury, for at least 3 consecutive days, and persist despite treatment of alternative differential diagnosis (3, 8). However, hemodynamic parameters differ by age group in children, thus Baguley's proposed criteria could not be applied to the pediatric patient population. A spectrum of severity could resolve this debate because symptoms could be present in clusters or in combination based on the severity or pattern of the brain injury (8). Additionally, a spectrum of severity could take into account the unique differences in the pediatric population. A single intervention may not be sufficient to target the entire cluster of symptoms, but multiple interventions may address the different components with better success.

Management and treatment

Unfortunately, uniform management and treatment options for PSH episodes are lacking. Medical case studies report a wide variety of medications used to treat targeted

symptoms and report that medications can decrease sympathetic features of PSH (3, 6, 11-13, 23, 31). Nutrition and increased caloric requirements have been highlighted by one case series, arguing that morbidity may be decreased by aggressive nutritional intervention (32). One manuscript proposed an algorithm for PSH management that included a team huddle, clear documentation, review, and the development of a treatment plan (33). An adult study promisingly reported improvement with rehabilitation and medication administration (36).

There have been no published nursing studies focusing on early recognition or targeted interventions to manage symptoms. Nursing studies have described nursing judgments and routine nursing interventions performed when caring for an individual who has suffered a brain injury (26-27, 34). Standardized patient care guidelines that focus on nursing interventions and prevent delayed treatment, do not exist.

Nurses interventions that are performed when taking care of an individual that has suffered a brain injury consist of neurophysiological interventions, psychosocial interventions, injury prevention interventions and interventions to maintain therapeutic milieu (26). Different nursing intervention options are available once hyperthermia is determined, including acetaminophen, cold saline administration, application of ice packs and cooling blankets, and administration of tepid bathes (27-29). Studies to evaluate efficacy and effectiveness of these in PSH are needed.

Differences between children and adults

The effects of PSH on the developing brains of children with brain injury are unknown given that the cerebral cortex does not reach full maturity until the third decade of life, making the structures of a developing brain vulnerable to environmental

influences (35). In children, vital sign parameters are based on age and developmental stage. Therefore, adult criteria cannot be generalized and different criteria must be developed for children, leaving a gap in the evidence (14). A case series of adolescents with severe brain injury reported that at no time during the evaluation period were heart rate, blood pressure, temperature, and respiratory rate simultaneously elevated into the clinically significant range. Additionally, there were no group patterns detected. These individuals did demonstrate rhythmic patterns in hyperthermia, hypertension, tachypnea, and tachycardia, but the overall event was typically characterized by only one or two variables (temperature, blood pressure, respiratory rate, heart rate) (17).

There are limited studies exploring PSH in children and the effect on their recovery trajectory. Kirk and colleagues (6) and Krach and colleagues (7) have reported a poorer recovery trajectory for children following PSH as defined by prolonged rehabilitation hospitalizations and poorer cognitive and motor function. Both research groups performed retrospective chart reviews of children with brain injury admitted to a rehabilitation center (6-7). Unfortunately, no studies targeting specific interventions to treat or manage PSH were identified among children, highlighting another gap in knowledge.

Discussion

Important findings in this literature review were identified regarding PSH following brain injury. The literature is inconsistent regarding uniform terminology and diagnostic criteria. It is promising that an international expert consensus group has been formed to provide guidance and recommendations to clinicians and researchers. Unfortunately, the focus of the work of this group is limited to adults (8). The adult

evidence cannot be universally applied to children, warranting collaborations between researchers in the pediatric field of brain injury to explore PSH further in children.

Persons of all ages who have suffered severe brain injury can develop the complicating phenomenon known as PSH. Studies on adults with brain injury reveal that PSH is associated with poorer cognitive and motor outcomes and interferes with the recovery trajectory (3, 5, 16). In children, there is developing evidence that the same association exists (6, 7). However, additional prospective adult and pediatric studies are warranted to understand PSH fully and to determine if the phenomenon is truly a distinct clinical phenomenon or simply a cluster of symptoms in response to the injury.

PSH following brain injury is a topic that has not been prioritized in nursing research and leaves a gap in the literature. If PSH is associated with poorer outcomes following brain injury in adults and children, nursing care and interventions could play a pivotal role in managing symptoms and promoting recovery. Nursing studies are needed to identify potential contributing factors and targeted interventions to prevent and manage PSH. Moreover, being proactive with symptom management can potentially improve outcomes after brain injury.

Conclusion

To date, the majority of the research regarding PSH following severe brain injury has been descriptive in nature. Several adult studies have determined the association between PSH and individuals' poor motor and cognitive impairment. Few studies, however, have explored PSH in children with brain injury; therefore, little is known about whether the outcomes of children with PSH are different and, if so, in what ways. Further investigation is needed to study PSH symptoms and the association of these

symptoms with outcomes in children with brain injury. Research studies are needed to target interventions that improve clinical outcomes for individuals (children and adults) who have suffered a brain injury and experience PSH.

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Chapter 3: A retrospective analysis of paroxysmal sympathetic hyperactivity following severe pediatric brain injury

The plan is for this manuscript to be submitted to *Brain Injury* for publication

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Abstract

Background: There are several gaps in the literature related to the prognosis and care of children who have sustained a brain injury and develop PSH.

Objective: To generate new knowledge regarding the characteristics and prognosis of children that have suffered severe brain injury and develop PSH.

Methodology: Secondary analysis of an established clinical dataset of children who had suffered a brain injury and had not regained consciousness prior to admission to an academic children's hospital rehabilitation center.

Results: The PSH group had a significantly longer acute care length of stay (p=0.024) and total length of stay (p=0.034) compared to the non-PSH group. There was not a significant difference in cognitive and motor function or transition to rehabilitation between the PSH and non-PSH groups after controlling for age and etiology of injury.

Implications: Factors have been revealed regarding the elusive phenomenon of PSH, creating the potential to improve outcomes.

Introduction

Brain injury is a public health emergency and the Centers for Disease Control and Prevention have reported that the total rate of emergency department (ED) visits, hospitalizations, and deaths related to traumatic brain injury have continued to increase over the past ten years. Alarmingly, the estimated rate (ED visits, hospitalizations, death) in 2010 was 823.7 per 100,000, up from 521.0 per 100,000 in 2001 (1). Children (0-4 years of age) and adolescents (14-19 years of age) are at increased risk of suffering a traumatic brain injury and sustaining prolonged complications that lead to life-long disabilities (1).

Paroxysmal sympathetic hyperactivity (PSH) is a confounding phenomenon that occurs after severe brain injury when a child has not regained arousal or awareness. PSH presents clinically as a cluster of symptoms that includes hyperthermia, hypertension, tachycardia, tachypnea, diaphoresis, and/or dystonia (2-7). This symptom cluster following severe brain injury has been associated with prolonged hospitalizations and worse cognitive and motor function in adults (2, 5, 8-10). Developing evidence in pediatrics points to a similarly dismal outcome (6-7). Only a few studies have explored PSH in children following brain injury; therefore, outcomes for children with PSH are limited, leaving a gap in the literature (6-7, 11-12). Further investigation is needed related to PSH and the association of these symptoms with outcomes in children with brain injury.

There are several gaps in the literature related to the prognosis and care of children who have sustained a brain injury and develop PSH. The major objective of the present study was to generate new knowledge regarding the characteristics and prognosis

of children that have suffered severe brain injury and develop PSH. The Symptom Management Theory (SMT) provides a foundation for the study (13). A major strength of the SMT is that it is a multidimensional, dynamic process for the management of symptoms that is used to provide a framework for symptom research and clinical practice. The results of the present study will provide clarity regarding the relationship between PSH prognoses in children following severe brain injury. The study used a secondary analysis of an established clinical dataset of children who had suffered a brain injury and had not regained consciousness prior to admission to an academic children's hospital rehabilitation center. The specific aims were: To describe the different characteristics between children that have suffered a severe brain injury and exhibit PSH compared with children that have suffered a severe brain injury in the absence of PSH. To describe characteristics of children who transitioned to rehabilitation following severe brain injury compared with those who do not transition to rehabilitation. To determine if there is an association with transition to rehabilitation following PSH and severe pediatric brain injury and to determine the influence of PSH following severe pediatric brain injury as a predictor of lower cognitive function, poorer motor function and longer hospital length of stay.

Methodology

Research Design

The present study used a retrospective, correlational secondary analysis of a clinically established dataset of children who had suffered a severe brain injury. The clinical dataset (1998-2012) was established at UVA Children's Hospital Kluge Children's Rehabilitation Center (KCRC) with the purpose of documenting and

monitoring clinical outcomes after a child had suffered a severe brain injury and had not regained consciousness prior to admission to KCRC.

Setting and Subjects

The KCRC was the primary referral facility from 1957-2011 providing inpatient acute care and rehabilitation services to children who suffered brain injuries in Central Virginia and the surrounding areas (Southwest Virginia, Tidewater, and Northern Virginia). The providers, nurses, therapists, educators, and support staff were nationally recognized for their pediatric rehabilitation expertise. The dataset included 40 clinical variables from 83 children. The computer software package nQuery Advisor 7.0 (Statistical Solutions Ltd, Dublin Ireland) was used to conduct a power analysis using several regression models. Given the number of predictors, following Hsieh, Bloch, and Larsen (1998), the sample size was inflated from 75 to 83 to retain at least 80% power at an $\alpha = 0.050$ (14). The sample of children ranged in age from 2 months to 21 years. Traumatic and non-traumatic etiologies, males and females, and all races/ethnicities were included. The average total length of stay for the children in the sample was 82.73 days (SD=39.1).

Variables and Measures

Demographic characteristics of the children included age, age group (<10 years of age or >10 years of age), gender, geographic region, Grados scale, etiology of injury, initial Glasgow Coma Scale, type of insurance (Medicaid, Medicare, private, or unknown), medical comorbidities (receiving seizure prophylaxis, spasticity management, and/or receiving medications to promote arousal/awareness), mortality, and race. The race variable was assumed based on visual appearance. The Grados scale is a

classification of the depth of brain lesion and has been used to predict severity of injury, with higher scores indicating more severe injury (15). The Glasgow Coma Scale is used to assess level of consciousness (16). There was no morality during admission to KCRC; the mortality variable was after discharge and continues to be collected to date. Data related to costs, days post injury, ethnicity, and readmissions unfortunately were not available for the sample.

The dependent variables of interest included motor and cognitive function, length of hospitalization, and transition to rehabilitation. These variables have been defined in the literature as predictors of recovery trajectory following brain injury in children (6-7). The instruments used to assess cognitive (Rancho Los Amigos Scale, Western Neuro Sensory Scale Profile) and motor (Functional Independence Measure for Children) function have demonstrated appropriate psychometric properties; however, the instruments were not administered as part of a rigorous prospective research study, but were administered as standard practice at the KCRC and were obtained retrospectively (17-21).

The Rancho Los Amigos Scale (RLA) (level of cognitive functioning scale or LCFS) is an observational, descriptive scale of the eight stages of cognitive function following brain injury. This global index is used to describe an individual's level of arousal, awareness, and interaction with the environment: 1=no response; 2=generalized response; 3=localized response; 4=confused and agitated; 5=confused and inappropriate; 6=confused and appropriate; 7=automatic and appropriate; and 8=purposeful and appropriate (18). For the present study, this scale was documented in the medical record by an experienced pediatric nurse practitioner and/or attending medical provider and was

based on his/her clinical expertise as part of routine assessments of children with brain injuries.

The Functional Independence Measure for Children (Weefim) is an instrument used to measure the need for assistance and document severity of disability in children. Initially, the Weefim was limited to children ages 6 months to 7 years old; however, the instrument has been standardized for use in adolescents. For the present study, certified therapists administered and documented the results in the chart as part of routine assessments of children with brain injuries. This instrument was only administered if a child successfully transitioned to rehabilitation. In addition, children under 6 months of age were excluded from the WeeFim analysis because the instrument is not deemed reliable or valid in that age group (19-21).

The Western Neuro Sensory Scale Profile (WNSSP) was developed to assess individuals with severe cognitive impairment following brain injury (RLA scores 1, 2, or 3). This scale is used to monitor and predict small changes in individuals who have not regained consciousness (17). In the present study, the WNSSP was administered and documented in the medical record by a credentialed speech language pathologist, who administered the instrument as part of routine assessments of children with severe brain injuries.

Data Collection Protocol

The dataset was established and maintained electronically from retrospective chart review. The hospitalization and rehabilitation courses of patients were not altered in any way. The individuals who entered the data and performed the chart reviews did not discuss the variables with the medical providers or staff taking care of the children; this ensured that there was no bias in data collection. The presence of PSH was determined by

clinical diagnosis and/or the presence of medication treatment and documentation by the attending medical provider at KCRC in the medical record. The University of Virginia Institutional Review Board approved the establishment and management of the dataset, as well as the statistical analysis plan for the present study.

Statistical Analysis

Data were analyzed using SPSS version 22. Descriptive statistics (means and standard deviations or frequencies and proportions) were computed for the demographic variables and by the presence or absence of PSH (any PSH [yes/no]). Bivariate tests (chi-square for categorical variables; *t*-tests for normally distributed continuous variables, and Mann-Whitney U tests for skewed continuous variables) were performed to compare demographic and recovery trajectory variables between children with PSH and those without PSH.

Logistic regression was used to estimate the effect of PSH on transition to rehabilitation (yes/no), while taking age, gender, and etiology of brain injury into account. Multiple regression was used to estimate the effect of PSH on the continuous outcomes of motor (Weefim) and cognitive function (RLA, WNSSP) and length of stay (in acute care, in rehabilitation, and total), while taking age, gender, and etiology of brain injury into account. Data were transformed using LOG10 when assumptions were not achieved. Two-tailed tests with $\alpha = 0.05$ were used for all analyses.

Results

Demographic characteristics of the total sample between PSH and non-PSH groups are reported in Table 1. There was a significant difference in spasticity treatment per PSH group (p=0.048). There were no significant differences in mean age, gender,

geographic region, Grados scale, etiology of injury, initial Glasgow coma scale, insurance type, medical comorbidities (those who received seizure prophylaxis or those who received low response medications to promote arousal and awareness), mortality, race, or transition to rehabilitation. Given that there were no differences in PSH group based on gender, this variable was excluded from the regression models.

Characteristics of children who transitioned to rehabilitation and those who did not are reported in Table 2. There was a significant difference in age ($p<0.001$), etiology of injury ($p=0.03$), and those who received low response medications to promote arousal and awareness ($p=0.001$) based on rehabilitation status. Transition to rehabilitation did not make a difference based on gender, geographical region, Grados scale, initial Glasgow coma scale, insurance type, medical comorbidities (those who received seizure prophylaxis or treated for spasticity), mortality, or race.

The majority of the sample transitioned to rehabilitation with a mean admission total Weefim score of 27.80±10.80 and a mean discharge total Weefim score of 53.65±27.43. There was not a significant difference between those who transitioned to rehabilitation and those who did not (Table 3). After controlling for age and etiology of injury, there was not a significant difference between those that transitioned to rehabilitation following PSH ($p=0.214$). Additionally, there was not a significant difference in admission total Weefim score ($p=0.319$) or discharge total score Weefim ($p=0.759$) after controlling for age and etiology of injury. Children who exhibited PSH following severe brain injury did not have a decreased rate of transition to rehabilitation compared with children with a severe brain injury in the absence of PSH after controlling for age and etiology of brain injury.

There was a significant difference in admission WNSSP score between the PSH and non-PSH groups (p=0.012). There was no significant difference in admission RLA scores, discharge RLA scores, discharge WNSSP scores, admission Weefim cognitive scores, or discharge Weefim cognitive scores between PSH groups (Table 3). PSH was a significant predictor after controlling for age and etiology of brain injury in terms of admission RLA scores (p=0.038) and discharge RLA scores (p=0.044). However, after controlling for age and etiology of brain injury, PSH was not a significant predictor in admission WNSSP scores (p=0.69), discharge WNSSP scores (p=0.547), admission Weefim cognitive scores (p=0.129), or discharge Weefim cognitive scores (p=0.326).

There were no significant differences between admission and discharge Weefim self-care or mobility scores between PSH groups (Table 3). After controlling for age and etiology of injury, PSH was not a significant predictor in admission Weefim self-care scores (p=0.454), admission Weefim mobility scores (p=0.123), discharge Weefim self-care scores (p=0.860), or discharge Weefim mobility scores (p=0.306). PSH following pediatric brain injury was not a significant predictor of poorer motor function when compared with children with a severe brain injury in the absence of PSH after controlling for age and etiology of brain injury.

There was a significant difference in acute care length of stay (p=0.024) and total length of stay (p=0.034) by PSH status (Table 3). However, there was not a significant difference in rehabilitation length of stay by PSH group (p=0.473) (Table 3). Children who exhibited PSH following severe brain injury had a longer acute care length of stay (p=0.022) and total length of stay (p=0.013) compared with children with a severe brain injury in the absence of PSH after controlling for age and etiology of brain injury. PSH

was associated with an increased acute care length of stay by 20.99 days. Additionally, PSH was associated with an increase in total length of stay by 18.89 days. After controlling for age and etiology of brain injury, PSH was not associated with an increase in rehabilitation length of stay (p=0.720).

Discussion

The PSH and non-PSH groups had only one difference revealed in this analysis; the PSH group had an increased frequency of individuals receiving management for spasticity. Spasticity is a condition and form of hypertonia characterized by muscle tightness and stiffness. While dystonia, a form of abnormal muscle tone characterized by hypertonia and irregular movements is a symptom in the cluster of symptoms of PSH; thus, it is reasonable to suspect that more individuals in the PSH group would exhibit abnormal muscle tone.

The children who transitioned to rehabilitation had more differences compared with those who did not. The group who did not transition to rehabilitation was younger in age (mean age 10.06) compared with those who did (mean age 18.03). When a child suffers a brain injury, the normal course of development is altered. There has been debate whether a child's developing brain is plastic or vulnerable when a brain injury occurs at a young age. Plasticity has been proposed and is a traditional view perceived by clinicians and researchers in the field of neuroscience (22-24). Additionally, there is evidence that supports that vulnerability during critical developmental periods can result in prolonged and devastating cognitive and motor deficits (22, 25-26). The results of the present study contribute additional information related to the debate in the literature regarding age and

prognosis. This study reports that the younger the age of the child, the less likely to transition to rehabilitation.

There was a significant difference between etiology and rehabilitation groups. Eighty-five percent of those who transitioned to rehabilitation had suffered traumatic brain injuries. In the group who failed to transition, 34.5% suffered an acquired or non-traumatic brain injury. It has been speculated in the literature that children who sustain acquired brain injuries have a poorer recovery trajectory then those with traumatic injuries (27). Another difference between groups was among those who received low response medication to promote arousal and awareness. Those who received low response medication had an increased frequency to transition to rehabilitation compared with those who did not receive low response medication. It is important to acknowledge that in 2006 the KCRC published results of a randomized control trial that used dopamine agonist medications to promote arousal and supported the use of low response medications in children following severe brain injury (28). Following that study, there was a practice shift and the use of low response medications became standard practice.

Promisingly, PSH was not a significant predictor in cognitive and motor function after controlling for age and etiology of injury. Additionally, PSH was not associated with transition to rehabilitation after controlling for age and etiology of injury. The lack of differences could be related to the significant differences between lengths of stay at the rehabilitation center. The PSH group had significantly longer acute care and total lengths of stay, which could have allowed for continued recovery of function, thus allowing for transition to rehabilitation at a later date. The present study is the first to demonstrate that although PSH is a complicating phenomenon following severe brain injury in children,

motor and cognitive improvements can be gained. Children who suffer PSH following a severe brain injury do make progress, but it takes time.

There are several limitations that need to be acknowledged given the retrospective, correlational design of the present secondary analysis. All variables included in the dataset were obtained from retrospective chart review. The instruments collected were administered for clinical purposes and were not part of a rigorous clinical trial. As previously mentioned, the existing clinical dataset did not include some variables of interest (i.e., data related to costs, days post injury, ethnicity, and readmission). Additionally, the race demographic variable was not self-reported. PSH was based on clinical assessment, judgment, and documentation. This method of determining PSH has been used in other studies (6-7); however, this method could underestimate the prevalence in this population because recognition, identification, management, and treatment of PSH can vary based on the provider. According to the literature, in adults, the prevalence of PSH is reported between 8-33% following brain injury (8-10, 29). Both Kirk and colleagues (6) and Krach and colleagues (7) have reported the pediatric prevalence of PSH as 13-14%, although there have been no prospective pediatric studies to document the incidence of PSH (6-7). The present study reports a higher prevalence (47%) following severe brain injury in children. Additionally, the present study uses a sample that is unique and different from previous studies. The prevalence may be higher then previously reported because the children in the sample had not regained consciousness prior to admission to KCRC. Thus, the results obtained in the present study contribute new knowledge related to the prevalence of PSH in children who have suffered severe brain

Conclusion

Children who suffer severe brain injuries can have life-long disabilities. The present study addresses gaps in the literature by focusing on a unique sample of children with severe brain injury who had not regained consciousness and required maximum care. Results of the present study have revealed factors regarding the elusive phenomenon of PSH, creating the potential to improve outcomes. Further research on PSH and associated outcomes in children with brain injury is needed to improve the care and quality of life of this vulnerable population of children, as well as their families and communities. Future targeted interventions may include standard, novel, and complementary health practices to prevent, manage, and treat symptoms of PSH while also improving the recovery trajectory. By improving symptoms and outcomes in this population, the care and financial burden for families and the community can potentially be alleviated.

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Table 1: *Demographic characteristics between PSH and non-PSH groups*

Characteristic	**Total Sample (*N*=83)**	**PSH (*n*=39) 47%**	**Non-PSH (*n*=44) 53%**	***P*-value**
Age	15.25 ± 7.56	15.13 ± 7.50	15.35 ± 7.69	0.884
Gender				
Male	66.3% (55)	74.4% (29)	59.1% (26)	0.142
Female	33.7% (28)	25.6% (10)	40.9% (18)	
Geographic Region				
Charlottesville	3.6% (3)	0%	6.8% (3)	
Remote	45.8% (38)	46.2% (18)	45.5% (20)	
Surrounding Counties	20.5%(17)	23.1% (9)	18.2% (8)	0.782
Midrange	19.3%(16)	20.5% (8)	18.2% (8)	
West Virginia	2.4% (2)	2.6% (1)	2.3% (1)	
Other U.S. State	3.6% (3)	2.6% (1)	4.5% (2)	
Unknown	4.8% (4)	5.1% (2)	4.5% (2)	
Grados Scale	4.03 ± 1.9	4.06 ± 1.85	4 ± 1.97	0.897
Etiology of Injury				
Traumatic	78.3% (65)	79.5%	77.3% (34)	0.807
Non-Traumatic	21.7% (18)	20.5%	22.7% (10)	
Initial Glasgow Coma Scale	3.97±1.142	3.75 ± 1.07	4.24 ± 1.2	0.202
Insurance				
Medicaid	26.5% (22)	30.8% (12)	22.7% (10)	
Medicare	3.6% (3)	2.6% (1)	4.5% (2)	0.891
Private	54.8%(46)	53.8% (22)	56.9% (25)	
Unknown	14.5% (12)	12.8% (5)	15.9% (5)	
Medical Comorbidities				
Seizure Prophylaxis	54.2%(45)	61.5% (24)	47.7% (21)	0.208
Spasticity	57.8% (48)	69.2% (27)	47.7% (21)	0.048*
Low Response Medications	84.3% (70)	89.7% (35)	79.5% (35)	0.202
Mortality				
Alive	89.4% (74)	87.2% (34)	90.9% (40)	0.661
Deceased	6% 95)	7.7% (3)	4.5% (2)	
Unknown	3.6 (3)	5.1% (2)	2.3% (1)	
Race				
Black	14.5% (12)	15.4 (6)	13.6 (6)	
Hispanic	4.8% (4)	5.1 (2)	4.5 (2)	0.942
White	69.9% (58)	71.8 (28)	68.2 (30)	
Other	7.2% (6)	5.1 (2)	9.1 (4)	
Unknown	3.6 (3)	2.6 (1)	4.5 (2)	
Transition to Rehabilitation				
Yes	65.1%(54)	59%(23)	70.5% (31)	0.274
No	34.9% (29)	41% (16)	29.5% (13)	

*=*p*-value <0.05

Table 2: *Characteristics of children who transitioned to rehabilitation and those who did not*

Characteristics	**Transitioned (*n*=54) 65.1%**	**Did not Transition (*n*=29) 34.9%**	***P*-value**
PSH			
Yes	42.6% (23)	55.2% (16)	0.274
No	57.4% (31)	44.8% (13)	
Age	18.03 ± 5.40	10.06 ± 8.33	<0.001*
Gender			
Male	63% (34)	72.4% (21)	0.385
Female	37% (20)	27.6% (8)	
Geographical Region			
Charlottesville	5.6% (3)	0%	0.564
Remote	48.1% (26)	41.4% (12)	
Surrounding Counties	18.5% (10)	24.1% (7)	
Midrange	16.7% (9)	24.1% (7)	
West Virginia	1.9% (1)	3.4% (1)	
Other U.S. State	5.6% (3)	0%	
Unknown	3.7% (2)	6.9% (2)	
Grados Scale	4.25 ± 1.72	3.50 ± 2.24	0.139
Etiology of Injury			
Traumatic	85.2% (46)	65.5% (19)	0.038*
Non-Traumatic	14.8% (8)	34.5% (10)	
Initial Glasgow Coma Scale	4.10 ± 1.21	3.50 ± 0.756	0.395
Insurance			
Medicaid	25.9% (14)	27.6% (8)	0.502
Medicare	3.7% (2)	3.4% (1)	
Private	53.7% (29)	58.7% (17)	
Unknown	16.7% (9)	10.3% (3)	
Medical Comorbidities			
Seizure Prophylaxis	51.9% (28)	58.6% (17)	0.555
Spasticity	51.9% (28)	69% (20)	0.132
Low Response Medications	94.4% (51)	65.5% (19)	0.001*
Mortality			
Alive	92.6% (50)	82.8% (24)	0.236
Deceased	3.7% (2)	10.3% (3)	
Unknown	1.9% (1)	6.9% (2)	
Race			
Black	9.3% (5)	24.1% (7)	0.484
Hispanic	5.6% (3)	3.4% (1)	
White	74.1% (40)	62.1% (18)	
Other	7.4% (4)	6.9% (2)	
Unknown	3.7% (2)	3.4% (1)	

*=*p*-value <0.05

Table 3: *Clinical outcomes between PSH and non-PSH groups*

	Total sample	PSH	Non-PSH	***P*-value**
Transition to Rehabilitation Yes No	 65.1%(54) 34.9% (29)	 59%(23) 41% (16)	 70.5% (31) 29.5% (13)	0.274
Admission Total Weefim	27.80 ± 10.80	28.83 ± 8.61	27.03 ± 12.26	0.12
Discharge Total Weefim	53.65±27.43	52.83±27.73	54.26±27.03	0.85
Admission RLA	2.64±0.695	2.49±0.683	2.79 ± 0.682	0.053
Discharge RLA	4.48±1.596	4.18 ± 1.587	4.74 ± 1.575	0.110
Admission WNSSP	13.88±17.39	9.59 ± 10.761	17.86 ± 21.273	0.012*
Discharge WNSSP	46.10±32.08	45.13 ± 32.356	46.96 ± 32.422	0.841
Admission Weefim Cognitive	9.89±4.471	10.78 ± 4.011	9.23 ± 4.738	0.209
Admission Weefim Self Care	10.96±5.114	11.14 ± 4.673	10.84 ± 5.478	0.549
Admission Weefim Mobility	7.65±4.755	8.61 ± 5.805	6.94 ± 3.741	0.101
Discharge Weefim Cognitive	17.19±7.845	17.96 ± 18.298	16.61 ± 7.579	0.539
Discharge Weefim Self Care	22.56±13.696	21.74 ± 11.887	23.16 ± 15.062	0.710
Discharge Weefim Mobility	15.09±9.806	15.91 ± 11.111	14.48 ± 8.858	0.756
Acute Care Length of Stay	54±41.836	64.92 ± 44.30	44.32 ± 37.41	0.024*
Rehabilitation Length of Stay	29.1±32.181	27.46 ±32.98	30.58 ± 31.76	0.473
Total Length of Stay	82.73±39.1	92.36 ± 42.43	74.20 ± 34.14	0.034*

*=*p*-value < 0.05

Chapter 4: Paroxysmal sympathetic hyperactivity in children: An exploratory evaluation of nursing interventions

The plan is for this manuscript to be submitted to *Journal of Neuroscience Nursing* for publication

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Abstract

Background: Paroxysmal sympathetic hyperactivity (PSH) produces symptoms of autonomic instability and muscle over-activity; however, the majority of nursing interventions used in clinical practice are anecdotal and not based on research.

Objective: To report nursing documentation of PSH events, and to describe the clinical nursing interventions and care provided to a child who has suffered a severe brain injury and is exhibiting PSH. The secondary objective was to demonstrate how the Symptom Management Theory (SMT) can serve as a framework for research related to brain injury and PSH.

Methodology: A retrospective chart review using direct content analysis. The nested sample of ten charts was chosen from a larger quantitative study of 83 children who had suffered severe brain injuries with and without PSH. Ten children were randomly selected from this dataset and the nursing progress notes were reviewed. Textual analysis of verbatim nursing progress notes was used to describe nursing interventions that were utilized and documented for this patient population.

Results: The priority nursing interventions to manage these symptoms included medication administration, facilitation of family presence, and strategies to target auditory, tactile, and visual stimuli. The sample demonstrated different individual patterns of interventions. Additionally, individual subjects demonstrated different patterns of interventions.

Implications: While tactile interventions were documented most frequently, there was not a uniform approach to interventions. The SMT can be useful to provide a framework that organizes and tests clinical care and management of PSH strategies.

Background

Paroxysmal sympathetic hyperactivity (PSH) is a symptom cluster that has been defined in the literature as recurrent fever without a source of infection, hypertension, tachycardia, tachypnea, agitation, diaphoresis, and dystonia. This cluster of symptoms can present following severe brain injury in children and adults (Kirk, Shoykhet, Jeong, Tyler-Kabara, Henderson, Bell et al., 2012; Krach, Kriel, Morris, Warhol & Luxenburg, 1997; Baguley, Perkes, Fernandez-Ortega, Robinstein & Hendricks., 2014). PSH produces symptoms of autonomic instability and muscle over-activity; however, the majority of nursing interventions used in clinical practice are anecdotal and not based on research.

Nursing studies regarding symptom management following brain injury remain descriptive in nature, and PSH-specific nursing studies are lacking. Routine nursing interventions performed for individuals following brain injury have been documented; however, the relationship of the intervention with associated outcomes has not been explored (McNett & Ganakis, 2010). Standardized patient care guidelines are limited, contributing to a delay in nursing prioritization of interventions and treatment (Thompson, Kirkness & Mitchell, 2007). To date, there has been a lack of nursing studies conducted with the goal of focusing on recognition or targeted interventions to manage PSH. Thus, there is no solid foundation of evidence-based interventions for management of PSH and no literature suggesting how should nurses intervene in managing these symptoms.

Nursing care priorities following brain injury have been described as monitoring blood pressure, oxygen saturation, and temperature (McNett & Ganakis, 2010). Once hyperthermia is present, nursing interventions including acetaminophen and cold saline administration, application of ice packs and cooling blankets, and administration of tepid bathes have been used to alleviate fever (Brown, Udomphorn, Suz &Vavilala., 2008; Fink, Kochanek, Clark & Bell., 2012; Thompson, Kirkness & Mitchell., 2007; Rockett & Thompson, 2015). However, nursing studies to evaluate effective interventions in PSH are desperately needed given that PSH presents as a cluster of symptoms.

Objectives

Based on the lack of evidence in the literature to guide practice, the question remains, what are nursing strategies that are being employed in clinical practice when symptoms of PSH are present? The primary objectives of this exploratory study, grounded by the Symptom Management Theory as a framework, were to report nursing documentation of PSH events, and to describe the clinical nursing interventions and care provided to a child who has suffered a severe brain injury and is exhibiting PSH. The secondary objective was to demonstrate how the Symptom Management Theory can serve as a framework for research related to brain injury and PSH.

Symptom Management Theory

Symptom Management Theory (SMT) can serve as a framework for research related to brain injury and PSH. The model was introduced in 1994 and developed by faculty at the University of California-San Francisco School of Nursing. A major strength of the SMT is that it is a multidimensional, dynamic process for management of symptoms, which has provided a framework for symptom research and clinical practice.

This theory guides clinical interventions for single symptoms as well as symptom clusters. Symptoms affect health and can disrupt the recovery process after illness or injury. Nursing care and interventions need to be developed to treat these symptoms.

There are three main concepts of the SMT, which include symptom experience, management strategies, and outcomes. In addition, the nursing domains of person, environment, and health/illness are also incorporated. Another strength is that the relationships and connections between the concepts provide a structure that can test hypotheses (Dodd, Janson, Facione, Faucett, Foelicher, Humphreys, Lee et al., 2001; Humphreys, Lee, Carrieri-Kohlman, Puntillo, Faucett, Janson et al., 2008).

The evidence supporting the application of the SMT in the pediatric population is developing. The SMT has been applied to pediatric cancer and asthma studies and has successfully guided study design (Humphreys et al., 2008; Linder, 2010; Newcombs, 2010). Researchers have agreed that additional applications are needed to advance utility of the model in pediatric symptom management research. Using the SMT as a conceptual framework may help investigate PSH both from a symptom cluster perspective and as a concept to promote family-centered nursing care.

PSH Symptom Experience

A symptom experience may include more than one symptom or a cluster of symptoms. PSH is an elusive phenomenon first reported in the literature by Strich in 1956. Strich (1956) describes episodes of agitation, diaphoresis, hyperthermia, tachycardia, tachypnea, and posturing after severe brain injury and were initially labeled brainstem attacks. Since then, multiple nomenclatures have been coined to describe these events. These symptoms first appear within days after injury and may persist for weeks to

months following the injury if an individual does not regain consciousness (Blackman, Patrick, Buck & Rust, 2004). Unfortunately, at this time there is not a uniform criterion regarding vital sign parameters and how many symptoms need to be present during an episode, however, a spectrum of severity could be the answer to this debate. Symptoms could be present in clusters or in combination based on the severity or pattern of the brain injury.

The symptom experience of PSH within the context of the SMT includes perception of the symptom, evaluation, and response. Although perceptions cannot be obtained from the child who has suffered a severe brain injury and exhibits PSH (individual is unconscious), a strength of the model is that it allows for the interpretation by the parent and/or caregiver of a nonverbal individual's symptoms. Evaluation of the symptoms is complex and requires thoughtful consideration of how these symptoms may be affecting the individual in a negative manner especially in an individual that has impaired arousal and awareness. The nurse and/or caregiver can provide valuable insight regarding the perception, evaluation, and response to the symptoms that encompass a PSH episode.

Management Strategies

The management of symptoms begins with an assessment, although the subjective individual's perspective cannot be obtained in the case of PSH (individual is unconscious). As stated previously, the model allows for the interpretation by the parent or caregiver of a nonverbal individual who may be experiencing symptoms (Dodd et al. 2001). Another strength is that the model takes into consideration environmental and developmental influences that may impact management strategies such as physical,

social, and cultural circumstances.

Unfortunately, management and treatment options for episodes of PSH are lacking and nursing care is practical in nature because of limited evidence. There are a few medical case studies that have reported different medications used to treat and control targeted symptoms of PSH (Kirk et al., 2012; Shrinivasan, Lim, & Thirugnanam., 2007; Tanti, Gasperinin & Rossini 2005; Wang & Manley, 2008), however, more nursing studies are needed to address the gap in the literature.

Symptom management strategies within the SMT seek to decrease negative outcomes associated with the symptom experience. Nursing strategies pertaining to PSH should seek to reduce the frequency of episodes, minimize the severity of symptoms, or relieve distress associated with the symptoms. The domains of the person, environment, and health status should be taken into consideration when developing targeted interventions.

Outcomes

In adults with brain injury, PSH is associated with poorer clinical outcomes, including longer hospitalizations and poorer cognitive and motor function (Baguley, Nicholls, Felmingham, Crroks, Gurka & Wade, 1999; Hendricks, Heeren & Vos., 2010; Tanti, Gasperinin & Rossini., 2005). There are only two published studies exploring PSH and the effects on recovery trajectory in children. Kirk and colleagues (2012) and Krach and colleagues (1997) have reported a poorer recovery trajectory for children as defined by prolonged rehabilitation hospitalizations and poorer cognitive and motor function.

Outcomes within the SMT need to be assessed following the implementation of a symptom management strategy. For example, previous applications of the model in

intervention studies have demonstrated improved outcomes related to (1) better physical and mental functioning, (2) improved quality of life, (3) shorter hospital stay, (4) quicker return to work, (5) greater productivity, (6) less cost to the individual, family, health care system, or employer (Humphreys et al., 2008). The success of a nursing intervention for a child with severe brain injury with PSH could be determined if the frequency, severity, and distress is decreased. However, the ultimate goal is to improve functional (cognitive and motor) outcomes following severe brain injury in children by implementing evidence-based nursing interventions.

Successful intervention strategies may target different aspects of the individual's symptoms (Dodd et al. 2001). Pertaining to PSH, symptoms include recurrent hyperthermia, hypertension, tachycardia, tachypnea, diaphoresis, and/or dystonia. However, a single intervention may not be sufficient to target the whole cluster of symptoms, but multiple interventions may seek to address the different components with better success.

While additional research needs to be conducted to evaluate the relationships, Figure 1 provides a visual representation of how the SMT can be applied to PSH. The proposed hypothesis is that the physical environmental, which includes auditory, tactile, and visual stimuli, could affect the symptom experience of PSH, influencing the clinical outcomes and recovery trajectory. Interventions need to begin exploring the relationship between specific stimuli and PSH. Nursing studies are needed that seek to reduce symptoms and improve the quality of life of children who have suffered severe brain injuries. However, what are the clinical nursing strategies that are being applied in practice to manage PSH symptoms despite the lack of guidance from the literature?

Research Methodology

A retrospective chart review using direct content analysis was conducted (Hsieh, & Shannon, 2005). The sample included ten children who had suffered devastating brain injuries, exhibited PSH, and were admitted to an academic Pediatric Rehabilitation Center on the East Coast. The nested sample of ten charts was chosen from a larger quantitative study of 83 children who had suffered severe brain injuries with and without PSH with an average acute care length of stay of 64.92 days. The dataset included 40 clinical variables and was established with the purpose of tracking clinical outcomes. Ten children were randomly selected from this dataset and the nursing progress notes were reviewed during the time admitted to the rehabilitation center.

Textual analysis of verbatim nursing progress notes was used to describe nursing interventions that were utilized and documented for this patient population. Documented nursing interventions regarding PSH management following brain injury were coded. Descriptive statistics were obtained.

Results

The mean age was 9.88 ± 8.23 years and the majority of the sample was male (60%). The majority of the sample suffered severe traumatic brain injuries (80%) and sixty percent regained consciousness and transitioned to rehabilitation.

The nursing progress notes revealed that the most frequent symptoms that were documented were agitation, hyperthermia, tachycardia, hypertension, and increased tone. The priority nursing interventions to manage these symptoms included medication administration, facilitation of family presence, and strategies to target auditory, tactile,

and visual stimuli. The sample demonstrated different individual patterns of interventions (Figure 2). Additionally individual subjects demonstrated different patterns of interventions (Figure 3).

Medication Administration

The frequency of medication administration as a directed intervention to manage symptoms related to PSH occurred 31 times over the course of an average acute length of stay of 64.92 days for nested group. The individualized administration frequency ranged from 0-10 occurrences (Table 1). There were several medications administered during these events to manage symptoms, including Acetaminophen, Clonidine, Diazepam, Ibuprofen, Metoprolol, Oxycodone, Seroquel, Simethicone, Toradol, and Trazodone. Acetaminophen administered for hyperthermia and Clonidine administered for hypertension and agitation were documented most frequently.

Family Presence

Family presence was an intervention that was also utilized (Table 1). Frequency of interventions documented ranged from 0-3 per patient. Specific interventions included mother holding or rocking the child, assisting with repositioning, and presence at bedside. A specific example stated, “Calmed when held by mother.”

Tactile Stimuli

Tactile stimuli reducing interventions were the number one documented priority to alleviate symptoms. Individual frequencies ranged from 0-16, totaling 76 documented interventions for the sample (Table 1). Specific interventions are outlined in Table 2. Repositioning was the number one tactile intervention that was documented, followed by management of bowel and bladder incontinence.

Auditory and Visual Stimuli

Auditory and visual stimuli were also a concern, but prioritized less then mitigating tactile stimuli. However, auditory interventions were documented for three individuals while visual stimuli interventions were documented for two individuals (Table 1). Specific interventions are outlined in Table 2.

Discussion

The retrospective direct content analysis of ten children's electronic medical records who had suffered devastating brain injuries provides new knowledge of documented nursing interventions that were used to alleviate symptoms of PSH. Medication administration, family presence, and reduction of tactile, auditory, and visual stimuli were the intervention priorities that arose from the analysis. The top priority for nursing care was targeting tactile stimuli, with 76 documented occurrences. Nurses commonly intervened by modifying the physical environment and removing perceived potentially adverse stimuli. Although modifying the physical environment is within the nursing purview and skill set, the effectiveness remains unknown.

Each patient had individualized patterns of nursing interventions. While tactile interventions were documented most frequently, there was not a uniform approach to interventions. More studies are needed to determine patterns of nursing interventions in the context of PSH. The SMT can be useful to provide a framework that organizes and tests clinical care and management of PSH strategies. As the most frequent symptoms that were documented in the nursing notes were concerns for agitation, hyperthermia, tachycardia, hypertension, and increased tone, different management strategies are being randomly applied. While a single intervention may not be sufficient to manage the cluster

of symptoms that encompasses PSH, a bundle of interventions may be developed to target the different single symptoms.

To date, there have been no studies that have documented specific nursing interventions that pertain to PSH. The present study begins to address this gap. Limitations of the study should be acknowledged. The sample size was small but methods were purposefully chosen in response to a limited sample size. Additionally, nurses document by exception and it is possible that interventions may have been provided without documentation in the medical record. Nursing care and interventions that promote comfort or alleviate unpleasant symptoms could have been deemphasized and performed intuitively without documentation. A prospective nursing study is warranted to further explore nursing strategies related to PSH and continue to report and verify interventions and outcomes. Additionally, further evaluation is needed related to dose, duration, and intensity of nursing strategies related to patient outcomes.

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Table 1: Frequencies of intervention by individual during admission to the rehabilitation center

Subject	Medications	Family Presence	Tactile Stimuli	Auditory Stimuli	Visual Stimuli
1	4	1	12	0	0
2	1	3	11	0	0
3	1	1	1	0	0
4	1	3	13	0	0
5	0	1	0	0	0
6	5	2	8	3	2
7	3	2	7	0	0
8	10	3	16	1	0
9	1	0	3	1	1
10	5	1	5	0	0

Table 2: Description of strategies

Auditory stimuli	Tactile Stimuli	Visual Stimuli
1. Decrease noise 2. Limit the number of individuals at bedside	1. Being held or rocked 2. Cold wash cloth applied 3. Decrease room temperature 4. Fan used 5. Managing incontinence of stool or urine 6. Providing and promoting general hygiene (bathing and mouth care) 7. Repositioning 8. Removing bedding and restrictive clothing	1. Decreasing light exposure

Figure 1: PSH following pediatric brain injury adapted from the UCSF Symptom Management Model

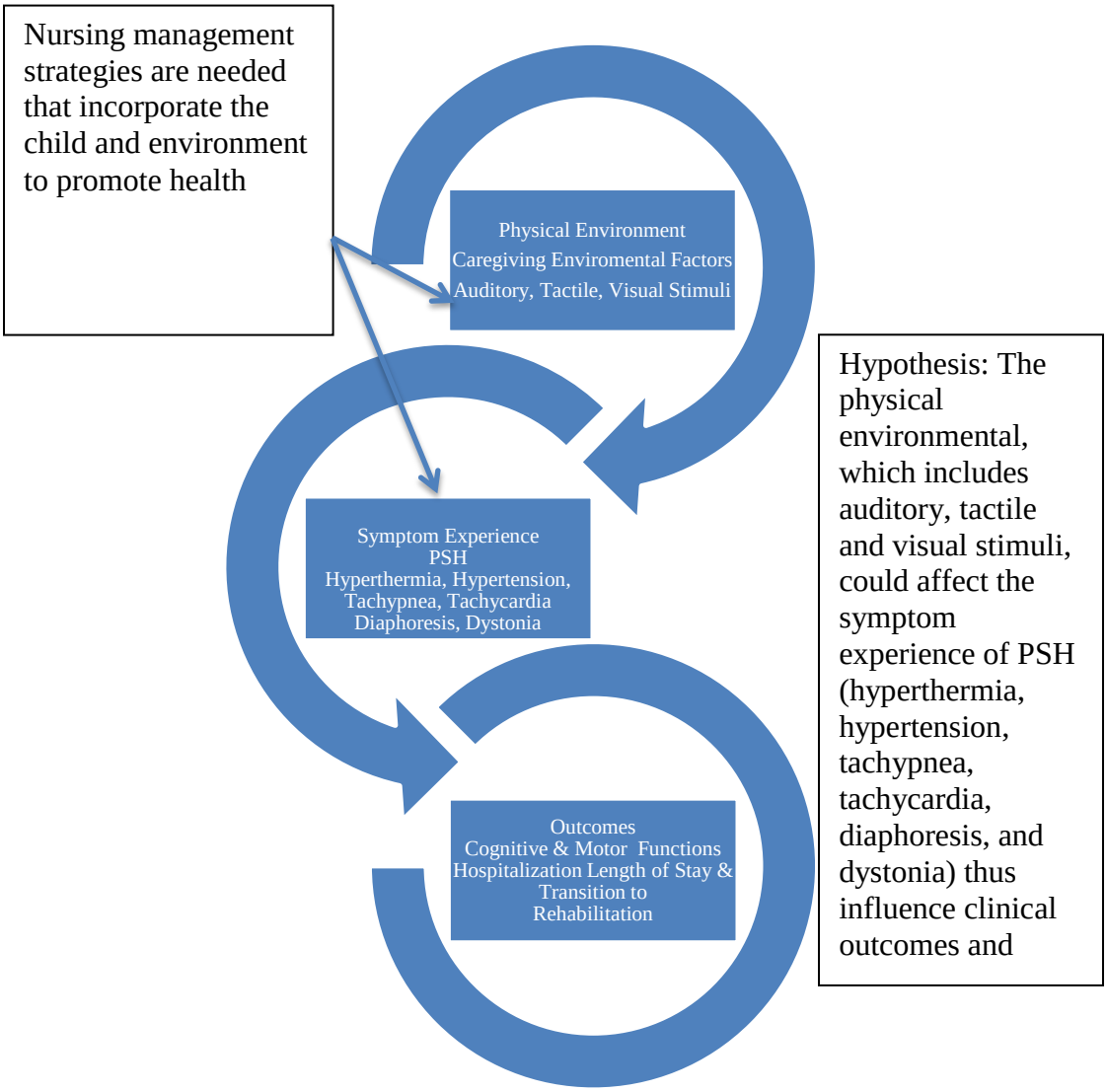
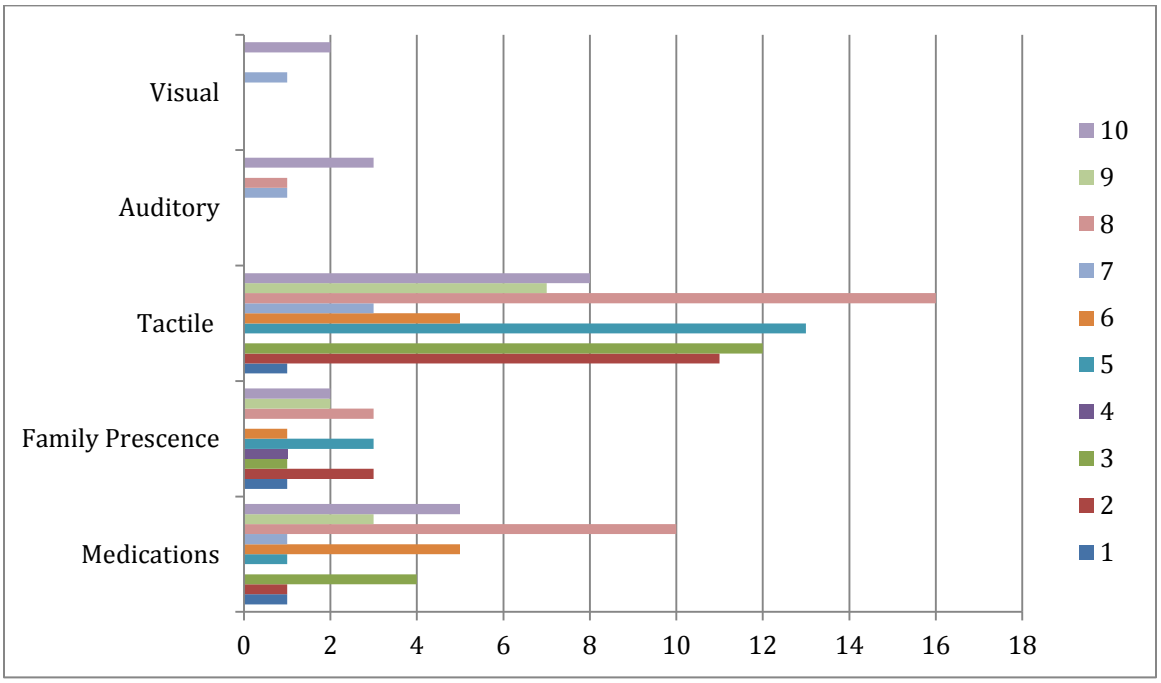


Figure 2: Individual frequencies of interventions compared with the group



Legend: Figure 2 visually demonstrates the individual frequencies of interventions compared to group. Each color is an individual subject (1-10). Visual, auditory, tactile, family presence and medications are the nursing interventions.

Figure 3: Individual patterns of subjects

1. MTF
2. MTMTVTMFATMTMATVTVAF
3. TFTTTMTTTTFTFTT
4. TTMTMFTTTMTTTTTMTM
5. F
6. TTTTTFFTMTTFTTTTT
7. TMTMTTFMTMM
8. TTAMVT
9. TTTTMMTTTMTMMTTMTFAMTMTTMTFTMFM
10. MTTFMTTTMTFT

Legend: Figure 3 reveals of individual patterns of interventions by subjects (A=auditory stimuli, F=family presence, M=medication, T=tactile stimuli, V=visual stimuli). Each subject has a different pattern of interventions.

Chapter 5: Discussion and Conclusion

This dissertation has provided additional information regarding the characteristics, prognosis, and nursing interventions in children who have suffered severe brain injury and developed PSH. Guided by the Symptom Management Theory (SMT) and the available evidence, five specific aims were formulated for this dissertation. The introductory chapter provided an overview and outlined the specific aims that were addressed. The impact and innovation of the dissertation were also highlighted in Chapter 1. Chapter 2 went on to provide a comprehensive review of the literature regarding PSH in adults and children while emphasizing the potential differences between adults and children and gaps in the literature. Chapter 3 described the different characteristics between children who exhibit PSH and those who do not. Chapter 4 demonstrated how the SMT can be applied to PSH and children. Additionally, Chapter 4 described nursing interventions that have been documented to manage PSH in children. In this final chapter, key findings for each specific aim will be synthesized. The relevance to clinical practice will also be outlined. Lastly, the limitations of the study and implication of the results for future research will be discussed.

Aim 1

Specific Aim 1 had 3 components: (1) to describe the different characteristics between children who have suffered a severe brain injury and exhibit PSH compared with children who have suffered a severe brain injury in the absence of PSH; (2) to describe characteristics of children who transitioned to rehabilitation following severe brain injury compared with those who did not transition to rehabilitation; and (3) to determine if there is an association with transition to rehabilitation following PSH and severe pediatric brain injury. The hypothesis was children who exhibit PSH following severe brain injury will

have a decreased rate of transition to rehabilitation compared with children with a severe brain injury in the absence of PSH after controlling for age, gender, and etiology of brain injury.

Findings revealed that the PSH group and non-PSH groups had only one difference. The PSH group had an increased frequency of individuals who were receiving management for spasticity. This finding is plausible because dystonia and spasticity are abnormal forms of muscle tone. Both are clinical features of hypertonia in children. It is understandable that children who suffer from PSH would have an increased frequency of hypertonia requiring management compared with those who did not exhibit PSH. Surprisingly, additional differences were not discovered.

Additional comparisons revealed that children who transitioned to rehabilitation had more differences compared with those who did not. This study demonstrated that there as an increase in frequency of older children transitioning to rehabilitation compared with younger children. There was also a significant difference between the etiology of brain injury and transition to rehabilitation. Children who suffered traumatic brain injuries had an increased frequency transitioning to rehabilitation compared with those who suffered acquired brain injuries. This also provides additional evidence supported by the literature that children who sustain acquired brain injuries have a poorer recovery trajectory then those with traumatic injuries (1). Another difference between rehabilitation groups was among those who received low response medication to promote arousal and awareness. Individuals receiving low response medications had an increased frequency transitioning to rehabilitation compared with those who did not receive this

treatment, which corresponds with the literature that the use of low response medications should be standard practice following severe brain injury (2).

The hypothesis was supported that children with PSH do have different characteristics than those who do not; however, children who were able to transition to rehabilitation had more pronounced differences. The differences that were identified can help clinicians when speaking with other members of the health care team and family members regarding the road to recovery and potential expectations. An example would be, if a child has suffered an acquired brain injury and has not regain consciousness during the acute hospitalization, the family and health care team will need to discuss options of transition home or to an alternate long-term living facility. The literature and this study has identified that acquired brain injuries are less likely to transition to rehabilitation then an individual that suffered a traumatic brain injury (1).

Aim 2-4

Specific Aim 2 was to determine the influence of PSH following severe pediatric brain injury as a predictor of lower cognitive function. The hypothesis was that PSH following pediatric brain injury would be a significant predictor of lower cognitive function when compared with children following severe brain injury in the absence of PSH after controlling for age, gender, and the etiology of brain injury. However, this hypothesis was not supported; there was not a significant difference in cognitive function between the PSH and non-PSH groups after controlling for age and etiology of injury. The results revealed that children could make cognitive improvements despite having suffered severe brain injuries and exhibiting PSH. Therapies and interventions to promote cognitive recovery are needed and should be encouraged even in the population that

suffered a severe brain injury and exhibit PSH. Individualized intensive cognitive therapy may focus on communication, comprehension, cognition, thinking, orientation, attention, and memory, and organization, problem solving and reasoning. Specific interventions could include assessing and facilitating visual and auditory awareness, attention, and localization, monitoring periods of wakefulness and arousal, assessing and facilitating purposeful movement, interactions, and manipulation of objects, assessing and facilitating comprehension and follow-thru of basic commands. Assessing and facilitate choice making, communication of acceptance/refusal, indication of basic needs, and communication of yes/no. Alternative means of functional communication should be considered with the incorporation of alphabet, word, and/or picture boards and modified signs and/or gestures.

Specific Aim 3 was to determine the influence of PSH following severe pediatric brain injury as a predictor of poorer motor function. The hypothesis was that PSH following pediatric brain injury would be a significant predictor of poorer motor function when compared with children following severe brain injury in the absence of PSH after controlling for age, gender, and etiology of brain injury. The hypothesis was not supported; there was not a significant difference in motor function between the PSH and non-PSH groups after controlling for age and etiology of injury. These results demonstrate that motor gains can be achieved in children who suffer severe brain injuries and exhibit PSH. Targeted motor therapy and interventions can be beneficial in this vulnerable patient population and gains can be achieved. Examples of motor therapy interventions could include evaluation for an appropriate wheelchair, determine which method(s) of transfers between bed and wheelchair are most appropriate, consider use of

equipment to facilitate functional physical skills (mobile arm supports, tilt table or stander, partial body weight supported treadmill, and other positioning devices), address and prevent contractures (obtain passive range of motion measurements, stretching, serial casting, splinting, positioning program, aquatic therapy), address tone management and make postural modifications, assess and facilitate postural control, assess and facilitate purposeful movement of neck, trunk, and extremities, assess endurance, sleep/wake cycle, and tolerance for stimulation. Interventions and therapies should also include activities of daily living skills which could include, assessing and facilitating basic oral skills (movement of oral structures for eating and speech production, ability to safely manage a variety of food and liquid textures), assess gag reflex, suckle response, swallow and risk of aspiration, and assessment for appropriate bath/toilet equipment.

Specific Aim 4 was to determine the influence of PSH following severe pediatric brain injury as a predictor of hospital length of stay. The hypothesis was that children who exhibit PSH following severe brain injury will have a longer hospital length of stay (acute, rehabilitation, and total length of stay) compared with children following severe brain injury in the absence of PSH after controlling for age, gender, and etiology of brain injury. This hypothesis was supported. The PSH group had significantly longer acute care and total lengths of stay compared with the non-PSH group.

While this study demonstrated that there was not a significant difference in cognitive and motor function between the PSH and non-PSH groups after controlling for age and etiology of injury, the longer lengths of stay could have contributed to and allowed for ongoing recovery of function and transition to rehabilitation later on in the course of treatment. Previous adult studies have reported that PSH is associated with

poorer clinical outcomes, including longer hospitalizations, worse cognitive and motor function, increased infections, need for tracheostomy, longer duration of amnesia, and increased estimated hospital costs (3-6). Kirk and colleagues (7) and Krach and colleagues (8) have reported poorer recovery trajectory for children following PSH as defined by prolonged rehabilitation hospitalizations and worse cognitive and motor function. This study is the first to demonstrate that although PSH is a complicating phenomenon following severe brain injury in children however, motor and cognitive improvements can be gained over time. These improvements in motor and cognitive function provide the opportunity for interventions to be developed and implemented to improve quality of life in this vulnerable patient population. Future targeted interventions may include standard, novel and complementary health practice to prevent, manage, and treat symptoms of PSH.

Aim 5

Specific Aim 5 was to explore nursing documentation of PSH events and describe the clinical nursing interventions and care being provided to a child who had suffered a severe brain injury and was exhibiting PSH. This exploratory aim generated new knowledge of documented nursing interventions that were used to alleviate symptoms of PSH. Medication administration, family presence, and reduction of tactile, auditory, and visual stimuli were the intervention priorities. It remains unknown if the nursing interventions that were selected were to decrease perceived noxious stimuli (visual, auditory and tactile). Additionally, it is unclear if the interventions were effective and what the target outcome was. Developmentally appropriate care is important to implement into clinical practice and the care of a child. The nursing interventions

described in this study did not necessarily highlight the importance of developmentally appropriate nursing strategies. Nursing strategies may need to be developed that differ based on age to manage PSH. For example, it would be developmentally appropriate to incorporate a favorite stuffed animal into a nursing strategy for a toddler, but this type of intervention would not necessarily be developmentally appropriate for a teenager. The best friend of a teenager would be more appropriate to incorporate into the strategy then a beloved stuffed animal.

Implications for Clinical Practice

The SMT, which has directed symptom research in adults, provided the foundation for this dissertation, which was one of the first applications of the model to evaluate pediatric brain injury. The goals of symptom management are to decrease negatively associated outcomes. Successful intervention strategies may target different aspects of the individual's symptoms (in the case of PSH recurrent hyperthermia, hypertension, tachycardia, tachypnea, diaphoresis, and dystonia). However, a single intervention may not be sufficient to target the whole cluster of symptoms; multiple interventions may target the different components of the symptom cluster with better success. The model outlines relationships and connections between key concepts that can provide structure when considering future interventions related to PSH.

Being proactive with symptom management by targeting nursing care and interventions could improve outcomes after brain injury. The findings of this dissertation have addressed a gap in the literature by focusing on a unique sample of children with severe brain injury who require maximum care and dependence on their families and society. The results revealed that PSH is associated significantly longer acute and total

length of stays compared to children that do not exhibit PSH following severe brain injury. However, motor and cognitive improvements can be made, creating the potential to improve outcomes and the understanding of the relationship between PSH and the recovery trajectory.

While medication administration, family presence, and change in tactile, auditory, and visual stimuli were the intervention priorities of nurses, prospective exploration and evaluation is needed to further assess efficiency and efficacy in clinical practice. A future study that explores environmental factors (tactile, auditory, and visual stimuli) associated with PSH is warranted in order to develop nursing strategies to predict and manage symptoms of PSH. Symptom management strategies targeting environmental factors may improve the recovery trajectory following severe pediatric brain injury.

Limitations of the Research

There are several limitations that need to be acknowledged given the design of this dissertation. A retrospective, correlational design, using secondary analysis was selected given the availability of a unique clinical dataset of children who had suffered severe brain injury. However, all variables included in the dataset were obtained from retrospective chart review. There were some variables of interest that were not available (i.e., data related to costs, days post injury, ethnicity, and readmission). Additionally, PSH was based on clinical assessment, judgment, and documentation by the provider in the medical record. This method could have underestimated the prevalence. However, this method of determining PSH has been used in other studies and has been acceptable in the literature.

The exploratory aim reviewed only a small sample (*n*=10) of the patients exhibiting PSH. The retrospective nature of the nursing documentation also could have contributed to potentially incomplete information. It is important to highlight that nurse's document by exception, meaning only when there is variation from the norm. Since was a retrospective analysis of nursing documentation, interventions could have been provided without documentation in the medical record. Nursing care and interventions that promoted comfort or alleviated unpleasant symptoms could have been overlooked and considered standard of care and, thus, not documented.

Future Research

To advance the development of the science in the field of pediatric brain injury and PSH, prospective nursing studies are warranted. As previously explained, few studies have explored the outcomes of PSH in children with brain injury. Moreover, there are no studies exploring potential environmental factors that trigger PSH in children. Identifying potentially modifiable environmental, nociceptive stimuli (auditory, tactile and visual) related to nursing care is necessary for developing interventions.

The next study proposes to identify physical environmental nociceptive stimuli that could hinder recovery for children who are exhibiting PSH following severe brain injury. The broad goal for this program of research remains to develop and test interventions to improve outcomes in children following brain injury. This goal is supported by the secondary data analysis performed in this dissertation, children following PSH can recovery but at a different pace and nursing interventions to manage the symptoms are varied without scientific merit. The major objective is to use mixed methodology to explore environmental factors in the care environment of the hospitalized

child who has suffered severe brain injury and the potential association of these environmental factors (auditory, tactile, visual) with PSH. This naturalistic exploratory study will provide an in-depth evaluation of environment factors associated with PSH and will lay the foundation for future nursing interventions by seeking to identify noxious stimuli. By using mixed-methods, the proposed study will measure quantitative physical characteristics (light, noise, temperature) coupled with data from semi-structured interviews with family members and bedside nurses and intensive periods of environmental immersion embedded as a part of the qualitative approach to study the elusive PSH phenomenon following severe brain injury in children.

Brain injury in childhood can disrupt normal development and cause life-long disabilities. Nursing scientists in this field need to focus on alleviating symptoms that may hinder the recovery trajectory. Empirically grounded nursing interventions and strategies need to be developed and tested that achieve better outcomes for children and their families following brain injury.

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