Needs Assessment, Knowledge Translation and Barriers to Implementing EEG monitoring Technology in Critical Care

by

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A thesis submitted in conformity with the requirements for the degree of Master of Science, Health Services Research
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Needs Assessment, Knowledge Translation and Barriers to Updating
Best Practices in Neurocritical Care

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Abstract

**Background:** The neurological examination in critically ill patients is limited due to decreased level of consciousness and sedating medications. Electroencephalography (EEG) can be used to monitor brain injury; however, availability is limited.

**Methods:** To determine the perceived need for EEG monitoring in the ICU and its current availability, we used rigorous methodology to develop and disseminate a survey to 199 Canadian critical care physicians.

**Results:** Of 103 (52%) respondents (77% academic practice; 83% adult focus), 75% stated EEG monitoring should be a standard of care; yet, 75.5% were unable to obtain an EEG in an optimal timeframe. Technology under-use was exacerbated during non-standard working hours and greater in adult institutions. Perceived barriers to optimal care were lack of EEG technicians, physicians to interpret EEG and finances.

**Conclusion:** Sub-optimal availability of EEG represents an important gap in the care of neurologically injured patients. Specific barriers represent targets for quality improvement.
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1 Neurological Disease

Neurological disease has a substantial impact on individual health, health care system resources and Canadian society overall. The World Health Organization’s Global Burden of Disease study (1996) estimates that neurological disorders account for approximately 38.3% of the world’s disability-adjusted life years (a measure of the years of life lost due to premature mortality and the years of healthy life lost due to disability). The Canadian Institute for Health Information (CIHI) estimates that neurological conditions accounted for 10.6% of disability-adjusted life years in Canada in 2000-2001 - the fourth leading cause of disability-adjusted life years, just behind cancer and cardiovascular disease (CIHI, 2007). It is estimated that 11 of the most common neurological diseases accounted for $8.8 billion (7%) of the total cost of illness in Canada for 2000-2001. CIHI (2007) is concerned that the Canadian Health System may not be prepared to cope with the predicted increase in neurological diseases as the population ages and lives longer. The most severe neurologic injuries most commonly result from a combination of traumatic and non-traumatic brain injury. They are routinely treated in the setting of an intensive care unit (ICU). Although life saving and illness reversing for many conditions, there are few mechanisms to monitor brain function and hence a distinct lack of timely therapies for brain injury. Care in an ICU is expensive, itself consuming between 0.5-1% of the entire gross domestic product of some countries (Fowler, Adhikari & Bhagwanjee, 2008). As a result it is vitally important to determine how health care providers can minimize the effects neurological disease has on patients, in order to promote individual health and recovery; in addition to attempting to lessen the burden of neurological disease on the health care system and society in general.

1.1 Critical Care Medicine

The Canadian Critical Care Society (2009) describes an intensive care unit (ICU) as a specialized hospital unit that is equipped to provide highly specialized care, continuous observation and monitoring for critically ill or injured patients. In North America, services provided usually include around the clock nursing care, access to specialized equipment and a nurse-to-patient ratio of no greater than 1 to 2 (Wunsch et. al., 2008). Virtually all severely injured neurological conditions require care in this setting. When caring for patients with neurological injuries, the primary goal of a critical care clinical team is to prevent, detect and
treat secondary insults to the brain after the primary injury has occurred, often through the use of medications, surgical interventions and other technologies (Claassen & Mayer, 2002; Castillo, 2001).

1.2 Managing and Treating Neurological Disease in the ICU

Specialized care for neurologically critically ill patients as a medical specialty was practically nonexistent 25 years ago, but has grown into an integral component of critical care, neurology and neurosurgery training programs (Ropper, Gress, Diringer, Green, Mayer & Bleck, 2004). This field is characterized by the treatment of patients who experience physiological and pathophysiological changes to the brain such as changes in cerebral blood flow, intracranial pressure, and brain electrical activity. In order to detect, follow and treat these changes over time, there must be sufficient mechanisms – through physical examination or technology - to monitor brain function. Despite this clear necessity, and very much unlike cardiac, respiratory and other organ monitoring, the monitoring of brain function after injury is frequently still a ‘black box’ in the ICU. There is still very little to no continuous monitoring (Hirsch, 2004). Further complicating our ability to monitor changes in function is the concomitant need or desire to use sedating medications that may further impair level of consciousness and the neurologic physical examination. These factors make the neurological exam difficult to interpret and further highlight the vital importance of continuous monitoring as one of the only ways to detect dynamically changing brain function after injury.

Anatomically, the skull is a closed, rigid container that serves to protect the brain which it encases (Ropper et. al., 2004). Brain tissue occupies approximately 80-90% of the matter within the skull, is nourished and perfused by blood and bathed in cerebral spinal fluid, which take up the remaining volume. The brain is unable to store glucose or oxygen, so a constant supply of nutrients is essential for function and neuronal survival (Littlejohns & Bader, 2005). The Monro-Kellie Hypothesis describes the volume-intracranial pressure relationships for the aggregates of brain blood volume brain matter and cerebral spinal fluid (Mokri, 2001). The hypothesis states that the total volume of the contents held within an inflexible skull remain constant: if the volume of one component were to increase, there would be compensation through a decrease in volume of the other two components. There is a precarious balance between intracranial pressure and the ability to perfuse the brain with blood. An increase in
volume within the skull due to post-injury inflammation, collections of blood or tumor cause an increase in intracranial pressure (ICP) and hence a decrease in the ability of nourishing blood to reach the brain and a subsequent risk of neurological injury.

Communication within the brain occurs through synaptic activity between neurons (Daube & Rubin, 2009). Synaptic activity occurs through a complex process of ion gradient changes and can be recorded as an electric potential. Neural function can be assessed by measuring these electrical potentials. Changes in electrical activity or the waveforms generated on recordings can indicate changes in neural function. Methods for monitoring the brain and its function are explored further in Chapter Two.

1.3 Types of Neurological Disease seen in the ICU

It is important to understand the types of primary and secondary neurological injuries commonly seen in the ICU in order to develop treatment strategies, critical care pathways, and for monitoring quality of care (Chen, Yeh, Lien, Shen & Chu, 2001; Bleck et. al., 1993). ICU admission diagnoses for neurologically impaired or injured patients include: impaired consciousness from many etiologies; changing neurological physical examination; neuromuscular weakness requiring ventilator support (such as myasthenia gravis or Guillain-Barré syndrome); repetitive seizures (status epilepticus); severe ischemic stroke; encephalopathies from many causes; intracerebral hemorrhage; subarachnoid hemorrhage; central nervous system infections; traumatic brain injuries and others. Secondary to initial injury, Bleck and colleagues (1993) found that approximately 12% of patients admitted to the ICU developed a subsequent neurological complication which resulted in an increased risk of in-hospital mortality as well as an increased length of stay in the ICU. The leading causes of secondary central neurologic injury were a variety of encephalopathies, seizures, hypoxic-ischemic injury and other types of stroke syndromes (Bleck et.al., 1993).

1.4 Traumatic Brain injury

The Brain Trauma Foundation (2011) defines Traumatic Brain Injury as “...a sudden trauma, often a blow or jolt to the head, [that] causes damage to the brain.” Understanding traumatic brain injury and its causes are also important as the resulting injuries often lead to high levels of morbidity, disability, mortality, and a physical and mental burden on survivors that has
tremendous economic consequences for the health care system (Pickett, Simpson, & Brison, 2004).

Traumatic brain injuries are often classified into two categories: penetrating (open skull or exposed brain) brain injuries and non-penetrating (the skull remains closed) brain injuries (Kolb & Whishaw, 2003). In non-penetrating injuries, the area of the brain that is immediately impacted can become bruised or injured; however, unlike open head injuries that sometimes allow room for decompression of tissue under pressure, closed head injuries often result in brain swelling or intracranial hemorrhages, causing additional bruising and injury. Additionally, shearing injuries, caused by the rapid movement of the brain upon impact, can result in both bleeding and wide-spread damage of neuronal fibers. The collection of blood and tissue injury induced edema are especially dangerous as this additional fluid does not have space to expand within the skull and often results in further injury to the brain (Kolb & Whishaw, 2003).

While hospitals may be seeing fewer patients with traumatic brain injuries, the severity of the injuries is increasing. Colantonio and colleagues (2009) found that 75% of traumatic brain injuries requiring hospitalization in Ontario were the result of falls and motor vehicle accidents and although the number of hospitalizations due to traumatic brain injury have decreased steadily between 1992 and 2002 (8831 to 5999 hospitalizations per year), the severity of the injuries has increased, which results in more severely brain injured patients being admitted to the ICU. In 1992-93, 75% of traumatic brain injuries were considered mild while only 54% of traumatic brain injuries in 2001-02 were considered mild (Colantonio, Croxford, Farooq, Laporte & Coyte, 2009).

1.5 Stroke

There are two major types of stroke that occur: ischemic and hemorrhagic (CIHI, 2009). Ischemic stroke occurs when blood flow to the brain is blocked. These blockages often occur when plaques of cholesterol and other material break away from the blood vessel wall in the heart, aorta and carotid arteries and flow in the bloodstream to the ends of these vessels – the small arteries and capillaries of the brain. This end-vessel blockage prevents oxygen and nutrients from reaching tissue and results in cellular death if not quickly restored. Hemorrhagic stroke occurs when blood vessels in the brain rupture and is often a consequence of long-standing hypertension and vascular disease, or occasionally due to specific aneurysmal
weakening or abnormal artery-to-vein connections (arteriovenous malformations). As with traumatic brain injury, bleeding caused by rupturing blood vessels can be directly toxic to brain tissue. This type of vessel injury is often associated with a degree of constriction (spasm) of nearby blood vessels and further reduction in blood flow (Kolb & Whishaw, 2003).

Stroke and cerebrovascular disease are the third leading cause of death in Canada (after cancer and heart disease) resulting in approximately 15 000 deaths a year (CIHI, 2009). More than half of the patients who survive stroke are left with substantial disability and require some form of assistance with day-to-day activities. In 2007/2008 approximately 30 000 patients over the age of 20 were hospitalized for stroke and the rate of stroke visits to emergency departments was 1.4 per 1,000 Ontario population (Hall et. al., 2010). The average length of stay for adult patients was between 6 and 7 days, with a long rightward tail of patients with exceptionally long lengths of stay and a resultant large number of hospital-days.

Stroke syndromes are not isolated to older adults. In children (0-18 years of age), it is estimated that ischemic stroke incidence rates were 2.25 per 100 000 children and 1.38 per 100 000 children for hemorrhagic strokes (Hall et. al., 2010). Average hospital length of stay for children ranged between 11 and 16 days depending on the type of stroke; again, a substantial burden on the health care system

1.6 Anoxic Brain injury

Anoxic brain injury, also referred to as anoxic/hypoxic-ischemic encephalopathy, occurs when the brain is deprived of oxygen for several minutes (CIHI, 2007). Anoxic brain injury can result from the above mentioned conditions in addition to injuries such as cardiac arrest (ischemia and anoxia), birth anoxia injury in neonates, near drowning, and carbon monoxide poisoning (anoxia), among others. Among patients who experience cardiac arrest and are resuscitated, anoxic-ischemic brain injury is the leading cause of mortality and morbidity. Anoxic brain injury in neonates occurs at a rate of 1-8 per 1000 live births, carries a 20% mortality rate and a 25% rate of neurological deficit in surviving children (CIHI, 2007). Among patients with cardiac arrest, the initial treatment involves stabilizing the underlying cardiac problem and preventing secondary injury to the brain.
One of the most common neuroprotective treatments being explored is therapeutic hypothermia, where the patient’s body temperature is lowered to 32-34°C for approximately 24 hours (Freeman, Biewend & Barrett, 2007). It is thought that the brain consumes oxygen at a lower rate when cooled and is therefore able to tolerate a lower rate of cerebral perfusion without damage. During this time, patients are usually sedated and chemically paralyzed in order to prevent shivering, thermogenesis and rewarming; thus, their clinical examination does not aid in determining their underlying neurological function and any hope of detecting impaired function and ongoing injury must occur through other forms of neuro-monitoring.

1.7 Encephalitis

Encephalitis refers to inflammation of the brain that can be caused by a wide range of disorders, including viral or bacterial infections or more widespread inflammatory disorders (Bloom & Morgan, 2006). Acute encephalitis syndrome may include symptoms of fever, change in mental status, confusion, disorientation, loss of speech, new seizure onset and coma (Jmor, Emsley, Fischer, Solomon & Lewthwaite, 2008). While case definitions of encephalitis differ, making surveillance challenging, it is estimated that in North America and Europe incidence rates are 10.5-13.8 per 100,000 for children and 2.2 per 100,000 for adults (Jmor et al., 2008). Acute encephalitis is often considered a medical emergency and patients are frequently treated in the ICU (Polhill & Soni, 2007). Treatments are often supportive in nature, with some antiviral therapies currently being explored for specific types of encephalitis. As a result of limited specific treatment options, prevention of secondary brain injury through monitoring and supportive care is the hallmark of treatment.

1.8 Seizures in the ICU

As a result of medications (certain anti-anxiety and delirium drugs), procedures (neurosurgery most specifically), and medical complications (such as central nervous system infection), seizures are a common neurological complication in the ICU - even among patients who have never previously experienced a seizure. Because patients in ICU often receive sedating medications that can mask the symptoms of seizures and obscure the neurological exam, we usually have no way to detect such events through routine observation (Varela, 2010). Seizure incidence rate estimations range between 3-8% in the adult general hospital population (Alroughani, Javidan, Qasem & Alotaibi, 2009). Variations in incidence rates may be due to the
retrospective nature of most studies, small sample sizes, and EEG recording times of varying length. In a retrospective study of 570 adult and pediatric patients that underwent continuous EEG monitoring, 19% of patients experienced seizures and 92% were exclusively non-convulsive, making detection very challenging without such EEG monitoring. Eighty-eight percent of patients experienced their first seizure within 24 hours and 12% within 48 hours of recording onset (Claassen, Mayer, Kowalski, Emerson & Hirsch, 2004). Non-convulsive seizures were more commonly detected in patients under 18 years old, when there was a history of epilepsy, brain tumor, central nervous system infection, a recent neurosurgical intervention or anoxic brain injury.

Seizures are also common in children admitted to a pediatric ICU ranging from 7-44% (Shahwan, Bailey, Shekerdemian & Harvey, 2010; Jette, Claassen, Emerson & Hirsch, 2006). The most common admission diagnoses for children with non-convulsive status epilepticus were anoxic brain injury, underlying metabolic disease, infection, intracranial hemorrhage and change in antiepileptic medication. In children who experience status epilepticus in the ICU, it has been estimated that between 17-34% of children monitored with EEG experience only non-convulsive seizures that would have been missed without EEG recording (Tay et al., 2006; Jette, Claassen, Emerson & Hirsch, 2006).

In the adult ICU population, it is estimated that non-convulsive seizures occur in 8-48% of patients (Friendman, Claassen & Hirsch, 2009). Predictors of non-convulsive seizures in adults include coma at the time of cEEG initiation, a history of convulsive seizures prior to monitoring, central nervous system infection, brain tumor and recent neurosurgical intervention (Hirsch, 2004). Another, more recent study, found that vascular disease and anoxic brain injury were the most common cause of status epilepticus in adult ICU patients (Drislane, Lopez, Blum & Schomer, 2008).

Non-convulsive seizures have been linked to increased morbidity and mortality for ICU patients (Vespa et al., 2002; Dennis et al., 2002; DeLorenzo et al., 1998). In a study of 91 ICU patients with status epilepticus, 68 were treated with antiepileptic drugs with improvement seen in 38 (56%) patients after treatment; however, a delay in diagnosis and treatment was common if EEG was not commenced soon after clinical suspicion (Drislane, Lopez, Blum & Schomer, 2008). It is important to highlight again that without continuous monitoring, non-convulsive seizures in
both adult and pediatric ICU patients go unnoticed and untreated. This can lead to a delay in diagnosis and secondary neurological injury that might have been prevented.

1.8.1 Neurophysiology of Seizures

Seizures are a result of excessive, abnormal, and synchronous neuronal activity within the brain (Millet, 2009). The International League Against Epilepsy’s (ILAE) Commission Report (2009) outlines how seizures can be systematically classified the underlying pathophysiology of the seizure source.

1.8.2 Types of Seizures

Primarily, there are two types of seizures: partial (or focal brain electrical hyperactivity) and generalized (wide-spread brain electrical hyperactivity) (Varelas, 2010). These two seizure types differ in the amount of cortical matter they involve. The physiological mechanism that propagates each seizure type is also unique. Partial seizures generally involve a specific area of the cortex that can be localized and only spreads to connecting cortical structures. The symptoms of partial seizures vary greatly, but can include repetitive blinking or lip smacking, jerking hand movements, or altered consciousness where the patient seems to be nonresponsive or “absent”. Generalized seizures reflect electrographic activity across the entire cortex. Patients experiencing generalized seizures almost always experience loss of consciousness without focal features (Varelas, 2010). Status epilepticus is defined as prolonged or frequently repeated seizures without return to baseline.

Status epilepticus is a common reason for patients with seizure disorder or neurological injury to be admitted to the ICU (Drislane, 2005; McAuley, Moore, Labiner & Spinells, 2002). Status epilepticus (either continual or rapidly recurring) can involve seizures that are focal or generalized in origin. Seizures are either convulsive or non-convulsive. With convulsive seizures, patients exhibit clinically observable symptoms, while in non-convulsive status epilepticus there are no outward, clinically observable symptoms. It is increasingly recognized that non-convulsive seizures and non-convulsive status epilepticus occur in both pediatric and adult ICU patients and that the presence of non-convulsive seizures and non-convulsive status epilepticus can have deleterious effects on patient outcomes (Friedman, Claassen & Hirsch, 2009; Hirsch, 2004; Alroughani, Javidan, Qasem & Alotaibi, 2009). The absence of usual signs
and symptoms of seizures is not predictive and, without the use of continuous monitoring technologies such as EEG, there is no way to detect such events through routine observation. Furthermore nonconvulsive seizures are much more common than convulsive seizures in the ICU and require EEG for their detection.

1.8.3 EEG and Seizures

Continuous electroencephalographic monitoring (CEEG) is a technology used to monitor an injured brain over a prolonged period of time (>24 hours); however, the availability of cEEG monitoring is limited (Hirsch, 2004). Routine EEG monitoring (often a 20 minute long recording) can be used in the absence of cEEG; yet, it has been observed that routine EEG tests often have a lower rate of detecting seizures and epileptiform abnormalities compared with cEEG monitoring. Claassen and colleagues (2004) found that patients who were in a coma at the time of cEEG initiation needed greater than 24 hours of recording to detect the first seizure. Continuous EEG has been used to monitor non-convulsive seizures and to aid in the management of pharmacological coma and seizure suppression. As explained, the neurological examination in critically ill patients is often limited due to decreased level of consciousness because of the primary illness and necessity for sedation medication. Continuous EEG monitoring can help clinicians overcome these limitations through longer recording times and potentially under varying degrees of sedation.

Application of cEEG allows clinicians to identify when the brain is at risk and intervene before permanent damage is sustained, but is still used infrequently in the ICU (Hirsch, 2004). With evidence suggesting prolonged seizures result in brain damage if not detected and treated (Vespa et al, 2010), it is important to address the perceived need for EEG, and barriers for standard and continuous EEG monitoring before there can be a plan to implement cEEG monitoring programs in Canadian ICUs.

1.9 Why Study Seizures and Continuous EEG?

As we have seen through our review of the literature, a large proportion of seizures that occur among critically ill patients are non-convulsive in nature, can occur hours after EEG recording is initiated and can lead to deleterious outcomes in patients. Many of these seizures would go unnoticed and untreated if cEEG monitoring was not commenced; yet, it can be difficult to
obtain a prolonged EEG recording outside of typical weekday working hours (9:00-17:00 hours, Monday to Friday) (Kaplan, 1999). Delay to diagnosis is also a problem, with one study finding that a median delay of 48 hours was common in ICU patients with non-convulsive status epilepticus resulting in delayed treatment (Drislane, Lopez, Blum & Schomer, 2008). Minimizing secondary neurological injuries that can occur in already compromised critically ill patients is of utmost consequence.
2 Reviewing ICU Available Neuromonitoring Technologies

A literature review was conducted to determine the types of technology currently used to monitor an injured brain in an ICU setting, the frequency of use for various technologies, and the specific patient populations routinely monitored. The focus of this background ‘scoping’ review was to determine how various technologies are used, and to potentially identify some of the gaps in research for each technology. A review can be a rigorous way of exploring the current body of scientific literature to identify all relevant data in an organized and transparent fashion (Greenhalgh et. al., 2005). It is important for an author to avoid bias in writing a review article by first taking a broad perspective of the question or topic and narrowing the focus according to the available literature and not prior beliefs (Green, Johnson & Adams, 2001). Literature reviews can subsequently serve as a valuable and efficient summary of the literature for other readers.

Research Question for Background Scoping Review: What types of Neuromonitoring technology are used in the Intensive Care Unit to monitor an injured brain?

Methods

The literature was systematically reviewed to identify technologies used for neurological monitoring of critically ill patients. Past research has found that neuromonitoring is potentially underused or lacking in the ICU (Hirsch, 2004; Rohlwink & Figaji, 2010). In other work, neuromonitoring has shown promise for improving patient diagnosis and treatment but many questions remain unanswered. We perceived that this general area would benefit from both a scoping review to identify the breadth of literature and past investigation into neuromonitoring of critically ill patients; and also, a formal needs assessment study for neuromonitoring among clinicians. MEDLINE, Embase and the Cochrane Online Library were searched using the following terms: ("Intensive care" OR "critical care" OR "ICU") AND ("Technology" OR "Monitor" OR "Monitoring") AND ("Neurology" OR "neurosurgery" OR "brain" OR "neurologie") (Appendix 1). Results were limited to articles published after the year 2000 and articles written in English. A total of 561 articles were selected for further review based on title and abstract content. The abstracts of each article were read in entirety. In order to select specific papers to inform our study question we use the following inclusion criteria: clinical
trials, meta-analysis, randomized controlled trials, and observational studies (cohort studies, case-control studies, interrupted time series). Other systematic reviews were examined if they were accompanied by a well-described methodology. Non-systematic reviews, commentaries, clinical practice guidelines, surveys, case reports and consensus panels were not included in this review. Furthermore, selection was limited to articles focused on human research (for both adult and pediatric patients), studies with a minimum of 30 subjects, and technology that monitors the brain in an ICU setting only. The abstract review narrowed the search to 264 articles for which full articles were pulled to verify whether the article fit the inclusion criteria outlined above. A total of 99 articles and 44 abstracts for which full articles were not available were reviewed independently by two reviewers. A total of 72 articles were selected (Appendix 7). The articles were categorized based on the technology they examined.
This scoping review suggested that there are several types of technology used to monitoring an injured brain in the ICU, the most common of these being: EEG, intracranial pressure (ICP) monitoring, brain tissue oxygenation and cerebral perfusion pressure (CPP) monitoring, intracerebral microdialysis, CT scanning, transcranial Doppler, somatosensory evoked potentials (SSEP), and magnetic resonance imaging. The studies included in the review assessed
technology use in many different ICU patient populations including: traumatic brain injury patients; patients with congenital heart disease; patients with cerebral aneurysm and stroke; patients that have experienced cardiac arrest; and, patients that have experienced seizures.

Consensus discussions around the use of ICP, CPP, blood oxygenation and transcranial Doppler monitoring in the ICU have occurred and guideline statements for these types of neuromonitoring have been previously published (Andrews et.al., 2008); however, the potential utility of EEG monitoring has been less fully explored and summarized. It is known that a large proportion of seizures that occur among critically ill patients are non-convulsive in nature and would go unnoticed and untreated if cEEG monitoring was not commenced. While technologies such as SSEP and monitoring of optic nerve diameter are still being studied in ICU patients and therefore has a limited number of studies available that fit our search criteria, EEG was the most studied technology in this review, yet guidelines on its use in the ICU seem to be absent.

**Important Findings for EEG monitoring**

In an ICU environment, a neurological examination is often limited due to decreased level of consciousness resulting from the primary illness and sedation medication. Continuous EEG monitoring can help clinicians overcome some of these limitations. Applications of cEEG allow clinicians to identify when the brain is at risk and possibly intervene before permanent damage is sustained. Interestingly, in this scoping review, research related to technologies used for seizure detection had the greatest number of articles of all available neuromonitoring technologies with the broadest set of patient etiologies studied; yet, the frequency of EEG, and especially cEEG use is thought to be very limited (Hirsch, 2004).

Overall, the body of literature suggests EEG can be used in critically ill patients with varying diagnoses and may be useful in diagnosing vasospasm, in detecting seizures, and diagnosing the neurological status of critically ill patients. The literature also focuses on ways to overcome barriers of EEG use through the examination of sophisticated technology and computer programs that can make reading the EEG easier. While the literature suggests that EEG recording is in fact feasible in an ICU setting, it does not address whether its use improves patient outcomes. Some research suggests that EEG is most useful in diagnosing and informing treatment options or changes in drug therapy, especially when refractory *status epilepticus* is suspected. It is commonly suggested the prospective outcome studies are needed to assess the
impact of EEG use on critically ill patients and finalize whether EEG should be a standard of care. Despite a lack of outcome studies, the literature suggests that EEG is useful in patient care, yet gaps in its use remain. To fully understand the current state of EEG use and the barriers to implementing EEG monitoring, the remaining portion of this study will attempt to document perceived frequency, utility and barriers of EEG use in Canadian Hospitals.
3 Knowledge Translation in the ICU

Previous chapters have outlined the potential importance of EEG monitoring in ICU care, yet, literature and expert opinion suggest there are gaps in the care provided to neurocritically injured patients, including an inability to obtain a timely EEG recording (Kaplan, 1999), and therefore delays in diagnosing seizure activity (Drislane, Lopez, Blum & Schomer, 2008). In this next chapter we examine complementary frameworks that guide analysis of gaps and decision making about corrective action, reasons or factors that contribute to these gaps in care and we will explore quality improvement strategies that may improve the care of neurologically critically injured patients.

3.1 Gaps in Care - Not a Unique Issue for the Neurologically Injured Patient

Gaps in care are not unique to the neurocritical care environment. A US national survey found that adults receive only 58% of recommended preventative care and only 55% of the recommended “best-practice” treatments for which they are eligible (McGlynn, Asch, Adams, Keesey, Hicks, DeCristofaro & Kerr, 2003). On average, children received approximately 41% of the indicated preventative care and 47% of recommended treatments (Mangione-Smith et.al., 2007). This underuse of health services leads to missed opportunity for illness prevention, medical complication detection, adverse events, patient morbidity and potentially mortality. By knowing where services are lacking, we can investigate the underlying reasons and make improvements.

3.2 Bridging the Gap

As described by Romanow (2002) in order for health care in Canada to be sustainable, it must be flexible and adapt to the changing needs of Canadian citizens. The report emphasizes the importance of research and technology assessment as this is the basis for driving change in the health care system. The intensive care unit (ICU) consumes a significant and growing portion of a hospital’s resources and budget (Scales & Laupacis, 2007). Studying a new technology, such as frequent or continuous EEG monitoring systems for at-risk patients in the ICU will undoubtedly uncover some of the barriers to implementing best-practices as well as gaps in knowledge translation among individuals, institutions and populations. It is important to
understand where these barriers exist, how they have been overcome in some instances, and how to bridge the gap between knowing and doing in a critical care environment.

Unless knowledge about incidence, risk factors, diagnosis and treatment are put into action, best practices will not be adopted by physicians and institutions (Graham & Tetroe, 2007). The World Health Organization describes this as the “know-do gap” (WHO, 2009) and explains that there is a gap between knowledge and what is actually done in medical practice. This gap exists at the individual, institutional and population level and can result in a decrease in the quality of care being delivered. The World Health Organization (2009) has adapted 5 key strategies for improving this gap – all of which are broadly relevant and applicable to our question:

- Improving access to the world’s health information through World Health Organization Publication and libraries.
- Translating knowledge into policy and action through good practise, assisting public health agencies in developing the capacity to convert knowledge into policy, and promoting evidence based decision making.
- Sharing and applying experiential knowledge by improving methods of sharing information and utilizing peer networks.
- Leveraging e-Health and technology in countries where possible.
- Fostering an enabling environment for knowledge translation to take place.

Similarly, the knowledge-to-action cycle was developed to aid in transferring research findings into practice (Graham et.al., 2006). The cycle (Figure 2, Graham et.al., 2006) describes two distinct phases: the knowledge creation phase and the knowledge implementation phase. When combined, the two phases depict the process of creating and applying knowledge, including overcoming barriers inhibiting knowledge exchange. As described by the Canadian Health Services Research Foundation, “knowledge exchange is collaborative problem-solving between researchers and decision makers that happens through linkage and exchange. Effective knowledge exchange involves interaction between knowledge users and researchers and results in mutual learning through the process of planning, producing, disseminating, and applying
existing or new research in decision-making” (CIHR, accessed May 2, 2011). By combining this definition with the knowledge-to-action cycle model it is clear that in order to bridge the gap, knowledge creation and implementation must be a linked process that involves key stakeholders and developed from lessons learned over time, in order to be successfully put into practice. These two models demonstrate the importance of applying research to practice. For research pertaining to the use of EEG in neurocritical care, it will be important to disseminate any research findings if change is to be made. The strategies described above could a) help identify barriers in implementing EEG monitoring and b) identify potential solutions for overcoming these barriers.

Figure 2. Knowledge to Action Cycle (Graham et.al., 2006).
3.3 Identifying Barriers to ICU Technology Use

The ICU is a unique medical care environment that treats a broad spectrum of very sick patients (Canadian Critical Care Society, 2009). As a result of the complex care provided, the ICU presents distinct challenges and opportunities for health care professionals. The complex nature of critical illness has lead to the development of many technologies designed to monitor organ function. For example, critically ill patients routinely have continuous monitoring of many vital signs: blood pressure; heart rate; respiratory rate; temperature; hemoglobin oxygen saturation; urine output; and intravenous and intra-arterial catheters that permit frequent sampling of laboratory tests to monitor organ function (coagulation and blood counts, kidney and liver function, etc.). As well, there are other patient and system level technologies designed to minimize medical error, increase patient safety, and improve flow of this information among the healthcare team; yet, these technologies are not used in all ICUs (Colpaert et al., 2010). For example, a recent survey found that only 46% of ICUs in Ontario utilized electronic medication administration records, 26% used electronic physician and nursing notes and only 22% used electronic medication order entry systems. In order to implement and disseminate the appropriate use of technology in the ICU, it is important to understand the types of barriers that may hinder this process.

3.3.1 Educational Barriers

Several papers highlight inadequate education of care providers as a significant barrier to implementing evidence-based practices in the ICU (Abbott et al, 2006; Anger & Szumita, 2006; Berenholtz & Pronovost, 2003). ICU physicians have a wide variety of training backgrounds and most have no specialized training in neurology or neuro-critical care. Training in specific neuro-monitoring techniques may therefore be unfamiliar and underutilized by physicians. ICU physicians may also be unaware of the potential prevalence of seizures among all ICU patients. A recent international study found that 83% of neurologists utilize EEG monitoring at least once per month for critically ill patients (Abend et al, 2010). Young (2006) suggests that ICU physicians do not consider EEG monitoring because they are uneducated with its use, technology, and interpretation. Introducing physicians to EEG and continuous EEG monitoring through education strategies may be one mechanism to overcome barriers in technology uptake for critically ill patients. For physicians less familiar with EEG, Young and colleagues (2009)
examined the use of a simplified EEG monitoring procedure that applies fewer monitoring electrodes and in more conveniently accessible locations as compared to standard EEG techniques. This simplified technology could be easily used by nurses and physician not previously educated in standard EEG techniques and can be used when standard equipment is not available.

While having one physician in an ICU specialized in neurocritical care might be helpful to the dissemination of best monitoring and treatment practices, it is impractical to expect that each patient would be able to be assessed by such a physician in any Canadian ICU. Training ICU physicians, nurses, and technicians not only in the use of simplified EEG techniques, but also in signs and symptoms for at-risk patients may increase the opportunity for standard EEG and cEEG monitoring. This may lead to an increase in the number of seizures being detected and treated. It may also lead to a decrease in unnecessary antiepileptic drug prescription in patients that are not experiencing seizure activity (Lesser, 2009).

3.3.2 Health Technology Assessment

A deficiency of quality evaluative studies may also limit uptake of promising or proven new technologies (Young, 2006; Abend et.al., 2010). While many technologies are available in the ICU, historically, many have been implemented without the rigorous examination required for new drug therapies. As a result, physicians are sometimes uncertain whether the new technology may have unintended and harmful side-effects (Sinuff & Cook, 2003). A systematic and thorough approach to health technology assessment can improve the decision making and uptake of new technology (Ferrusi, Ames, Lim & Goeree, 2009). It has been suggested that the small market for some technologies and the short-term budgets often seen in health care are serious barriers for performing health technology assessments; yet, this presents a paradox in implementing a new technology: without the health technology assessment, technology uptake may not occur. For those wishing to advocate for certain technology use, conducting a health technology assessment may overcome some uptake barriers.

3.3.3 Economic Barriers

Economic barriers to technology implementation within hospitals are substantial and it has been suggested that these barriers prevent many physicians from utilizing cEEG monitoring
technology (Young, 2006). EEG technicians, EEG monitors, and skilled personnel to interpret recordings are expensive (Abend et al., 2010; Ferrusi et al., 2009). Without previously performed cost-effectiveness or local “business case” analyses, administrators are appropriately reluctant to allocate a budget to such technologies.

For physicians, the pay schedule for cEEG monitoring also provides a disincentive. The majority of physicians within Canada work within a fee-for-service pay system. Within the Ontario Fee Schedule (2009) a physician can charge $38.90 for the professional component of standard EEG test. For a prolonged or cEEG recording, the physician can bill for a maximum of 3 hours of recording at a rate of $14.70 per 15 minutes (maximum billing of $176.40). While this is an obvious increase in billing income, continuous tests often need to be done for >24 hours (Claassen et al., 2004). Therefore, multiple standard EEG tests over several days, each of which can be billed separately, may be preferred over more sensitive continuous EEG readings.

In summary, there may be a number of barriers in our “know-do” knowledge-to-action cycle for best practices in neuro-monitoring of critically ill patients. Very few studies have examined the role specific barriers play in EEG utilization. Based on studies for other technologies used in an ICU environment, potential barriers include but may not be limited to physician education and awareness, the quality of evidence, and economics. To better understand whether these and possibly other factors influence EEG use in the Canadian setting, we will survey physicians to identify the full range of factors and those most amenable to quality improvement. Using the results of this survey, we will then be able to identify the best possible KT strategy for overcoming barriers or gaps in care. Our survey will seek to explore barriers due to potential gaps in knowledge, skilled personnel, equipment, collaboration, and finances among a wide spectrum of Canadian critical care practitioners.
4 Methods

There is one primary hypothesis and three secondary hypotheses being explored in this study. These hypotheses could be tested in a number of different ways and the following paragraphs will explore the benefits and limitations of each.

Primary Hypothesis

There is a substantial difference between the perceived need for EEG monitoring for critically ill patients and current stated practice of EEG monitoring for critically ill patients.

Secondary Hypotheses

1) There will be substantial differences in perceived need for EEG technology in the ICU between respondents that received formalized sub-specialty training in neurocritical care and respondents that did not receive formalized sub-specialty training in neurocritical care.

2) There will be specific barriers identified that inhibit the use of EEG technology in the ICU.

3) Stated EEG use will differ between adult and pediatric ICU settings.

4.1 Background - Collecting Healthcare Data

There are several ways of obtaining and analyzing data in health care settings in order to answer specific questions, each with specific goals, benefits and challenges.

Use of Existing Data through Health Administrative Resources

The availability of health data has increased greatly over the last decade (Griffith, 2009) and research in health care can often be conducted in a retrospective fashion without prospectively collecting new data. Publicly available data can be obtained through published research reports as well as data collection and repository agencies such as the Canadian Institute for Health Information, Statistics Canada, the Public Health Agency of Canada, among others. Using existing data can be efficient. It saves researchers time as well as potentially decreasing research costs (Griffiths, 2009). An example of this is seen in the Canadian Institute for Health
Information’s mandate, which states that the organization intends “to help improve Canada’s health system and the well-being of Canadians by being a leading source of unbiased, credible and comparable information...” (CIHI, 2010). However, existing data may not capture the variables needed to fully answer a specific research question, and for this reason is not always appropriate for certain questions in health care research.

4.1.1 Qualitative Research

Qualitative research involves a non-numerical approach to collecting data and can provide insight into how and why decisions are made. Qualitative research attempts to interpret social interactions and behaviours and the meanings people attach to these experiences (Pope & Mays, 2006). Instead of measuring results numerically, qualitative research is typically interested in answering questions through the classification of findings into themes or sub-themes en route to formulating theories. As health care inherently deals with people, qualitative research can prove essential in its direct approach to health care research. Qualitative studies can also provide a base for future quantitative studies by helping to categorize behaviours and events before researchers try to quantify them (Pope & Mays, 2006).

Data is often collected through focus group sessions, observation and interviews. One of the strengths of qualitative research is that it may involve studying subjects in their natural environment as opposed to an experimental environment (Pope & Mays, 2006). Observational qualitative studies provide insight on how people feel, react, or think about a specific research issue in real situations. Observational qualitative data collection involves placing oneself in direct contact with the group being studied and is based on the behaviours witnessed by the researcher firsthand (Weinberg, 2002). Observational qualitative data collection is appropriate in a situation where the behaviours to be observed happen in a frequent manner, within a somewhat predictable time and place (Griffiths, 2009).

4.1.2 Quantitative Research

Quantitative research is often described as a type of systematic investigation that quantifies (or assigns numbers to) the topic under study (Hoy, 2010). This makes measurement and mathematical relationship a common component of data and subsequent results. There are several types of quantitative research methodologies, all designed to test and answer a research
hypothesis, including surveys, quantitative observational studies (such as prevalence studies, cohort studies, case-control studies, before-and-after studies, interrupted time series, among others) and systematic reviews and meta-analyses of prior studies (Bruce, Pope & Stanistreet, 2008).

4.1.3 Quantitative Observational Studies

The two most common types of quantitative observational studies include cohort studies and case-control studies. Both cohort and case-control studies are longitudinal studies interested in the occurrence of disease, or an adverse-event, in a given population. Cohort studies examine subjects that are exposed to a given risk factor and then measure the rate of disease or adverse-event occurrence, if any, in the given subjects. Cohort studies can be conducted retrospectively-collecting data from a sample that has already received care or treatment in the past- and prospectively-collecting data from a sample as they receive care or treatment. Case-control studies examine subjects that have already experienced a disease or adverse-event onset (cases) and compare them to a group with similar demographics that did not get the disease or experience the adverse event (controls). Researchers then examine relationships and associations between exposure variables and the outcome(s) of interest (Stommel & Wills, 2004).

4.1.4 Systematic Reviews

Systematic reviews provide a mechanism to concisely assess a body of evidence on a particular subject and are designed to provide an accurate summary of an ever-growing body of literature (Bowling & Ebrahim, 2005). When conducting a systematic review, a structured, systematic methodology is used in order to minimize bias and collate evidence that fits specific eligibility criteria in addition to answering a specific research question (Higgins & Green, 2011). Systematic reviews are often used by clinicians and policy-makers to inform practice either by providing the best summary of the research that is available or by highlighting where gaps in literature may be addressed by future research projects. While a summary of the current evidence is beneficial, systematic reviews do not involve new data collection and can be limited by an incomplete evidence base.
4.1.5 Randomized Controlled Trials and Non-randomized Experiments

In contrast to data collected through observational methods, experimental studies manipulate study variables to determine effects on outcome (Penson & Wei, 2006). These studies are performed in a prospective manner and can largely be classified into two types: true experimental design and quasi-experimental design (Penson & Wei, 2006). Controlled trials study a group of subjects exposed to an intervention in comparison to a group that is not. The allocation of a subject to each group can be randomly assigned (for example, using a random number generator) to improve the chance that differences among subjects are randomly, as opposed to systematically, allocated to each group. With large enough sample sizes in each group, such randomly allocated differences tend to equal out. The allocation of subjects to each group can also be done in a way that is unknown to various participants in the research (the subjects, the treating clinicians, the investigators, the data collectors, the outcome assessors, etc.) and is termed ‘blinding’. In medicine, for occasions when it may be unethical or difficult to randomly assign patients to a specific treatment, quasi-experimental, or non-random, design studies are often used. Controlled trials, with or without randomization and blinding are examples of true experimental study designs. Due to the controlled nature of the interventions being studied, experimental studies are usually able to provide a more unbiased estimate of effect of the intervention under study and a higher level of evidence for a causal relationship between intervention and outcome. Although most researchers might aspire to evaluate interventions using the most unbiased form of study design, preliminary investigations of research questions and specific hypotheses usually employ other methodologies, in order to summarize existing evidence (by performing narrative, systematic reviews or meta-analyses of the existing literature), establish current (stated) practice through surveys or qualitative studies, and actual practice through observational methods (prevalence studies, prospective or retrospective cohort studies, or case-control studies).

4.1.6 Choosing a Research Approach for this Study

The research approach used depends chiefly upon the question asked (Griffiths, 2009). This study aims to collect the opinions of a nationally representative group of physicians that work in a critical care environment. When choosing the research approach for this study, time-frames and research personnel restraints restricted the study from being done in a true observational manner as we would not have the personnel or time allotted to be able to observe physicians
across multiple hospitals in Canada. As well, there is no primary data already collected on this topic that would allow us to answer the question with an existing dataset. While literature searches were completed on this topic, data assessing physician opinions on EEG and cEEG use is limited and therefore is limited on its ability to add additional new data on the subject so a systematic literature search was deemed inappropriate as the primary data collection method of this study. A point prevalence study would allow simultaneous measurement of EEG use in many Canadian ICUs; however, would be limited in the ability to ask questions with a temporal component (e.g. weekday versus weekend use) and in the ability to ask broadly about perceived need. As the study is not primarily assessing the relationship between particular variables and outcomes, a survey is the most appropriate research approach to answer the research question about differences between perceived need for EEG monitoring and stated practice.

4.1.7 Surveys

Surveys are characterised by a set of variables or items that are collected from each respondent resulting in a directly comparable dataset on a specific topic (De Vaus, 2002). Commonly classified as a type of quantitative research, surveys are useful in providing rich, factual, descriptive information on subject’s opinions, behaviours and opinions. Various types of survey designs and data collection methods can be used in survey research (Aday & Cornelius, 2006). The researcher needs to consider who the target audience is for the survey, what they want to learn from the survey, and when and where the data collection will take place before finalizing survey design.

Telephone interviews, in-person interviews, mail-out surveys and web-based surveys are the most common types of data collection in survey research (Aday & Cornelius, 2006). Often, data collection methods are combined to reach a greater number and breadth of respondents, en route to more generalizable data. Participant “response rate” (defined as the number of people that complete the survey in relation to the total number of people to whom the survey was issued) tends to be highest in personal interviews followed by telephone and internet surveys (Aday & Cornelius, 2006). Mail and Internet surveys may be beneficial when asking sensitive, opinion-based questions as they allow the respondent to answer the question in a more confidential manner.
4.2 Using Online Survey Tools in Health Care Research

Survey software is being used more commonly in healthcare survey research and programs such as Survey Monkey® make collecting internet-based data easier for researchers. Importantly, they allow large numbers of surveys to be distributed to a known respondent pool over a short period of time, with ease of subsequent contact. While online surveys have become convenient research tools, they present unique ethical considerations previously unseen by research ethics boards (Buchanan & Hvizdak, 2009). In a recent study, there were two major security issues commonly seen in research ethics reviews using online survey tools including a lack of understanding of the survey site and a lack of data security once downloaded from the web-based survey tool. Also, as online survey tools often store participants’ email or internet protocol (IP) addresses, web-surveys are rarely completely anonymous. In addition, it is difficult to completely verify whether the intended participants actually filled out the survey so samples and data may not be accurate, yet this is not a unique issue for web-based questionnaires (Buchanan & Hvizdak, 2009). Despite these limitations, online research tools are increasingly used, and for the above reasons, we incorporated this as one method of contact. For this component of the survey, Survey Monkey® software was used. It is one of the best known online software tools and is emerging as the most commonly used survey tool in healthcare. As we will describe below, response rate and generalizability is typically enhanced through a multi-modal approach to questionnaire administration and we combined numerous online and postal mail-outs to this end.

4.3 Survey Development in Healthcare

Conducting research through the use of self-administered surveys is a widely used technique in academic research; however, surveys have many limitations. Two of the biggest challenges in survey research include (1) methodologically rigorous development of a valid survey and (2) achieving high response rates and ensuring the sample of respondents represents the population in question.
4.3.1 Design

A good survey is the result of good planning (Aday & Cornelius, 2006). A survey must be developed in a rigorous fashion to ensure that it is designed to answer the research question at hand in a reliably and valid manner. Several survey methodologies have been described to assist in the development of self-administered surveys and are described in Figure 3 (Sierles, 2003; Lumsden & Morgan, 2005; Burns et. al., 2008). Each step is further explored in the methods section of this paper.

Figure 3. Survey Design Methodology
As described in the literature (Sierles, 2003; Lumsden & Morgan, 2005; Burns et. al., 2008), the first step in successful survey development is to clearly define research objectives and questions that the survey will be used to answer. Clearly defined research questions also aid in the development of survey items by ensuring each item serves a purpose and answers a specific question. Our initial general topic of research was focused on technology use in critically ill patients. Our primary research questions were defined through an iterative process. A panel of experts in the field of critical care medicine, neurology, neurosurgery and health services research was assembled to assess the survey objectives and develop the survey questions as well as advise on the overall content and design of the survey.

4.3.2 Assembling an Expert Panel

As described in the NIH Consensus Development Program, the DELPHI and Nominal Group technique (Ferguson, 1996; Campbell, Braspenninck, Hutchinson & Marshall, 2003), panel members should include practicing health professionals that would be users of the question or technology being discussed. Panel members should have limited and declared conflicts of interests such as strong advocacy positions regarding the technology or potential financial gains to be had through the use of the technology in question. Ideally, panel members should also not be involved in the final decisions on whether or not the technology will be implemented.

Our panel members were selected based on these principles as well as by who was interested in the topic and who was known to the researcher team. Two adult intensive care specialists with advanced training in neurocritical care and neuromonitoring were asked and agreed to act as panel members. An ICU physician familiar with the patient population and the survey audience, as well as having expertise in health services research methodology, also agreed to be a panel member. Two adult intensive care specialists and one pediatric intensive care specialist with advanced training in neurocritical care and neuromonitoring, agreed to act as consulting members of the panel during the final stages of survey development. A statistician, unfamiliar with the use of EEG or cEEG monitoring, was consulted after the completion of the pilot testing to review the survey design and ensure that data was being sought that could lead to statistical comparisons. Consultation with a knowledge translation expert was conducted for the dissemination strategy portions of this study. The knowledge translation specialist was not a part of the initial survey development.
4.3.3 Defining Research Objectives and Hypotheses

In order to identify primary research questions, the expert panel ascertained that it is important to understand why this technology is not being used within the ICU. The literature was again searched for potential barriers that exist in using EEG technology in the ICU. Interviews were conducted with panel members that routinely use the technology in their practice to further identify practical and experiential barriers encountered in implementing EEG and cEEG. Once a list of barriers was identified and the interviews were completed, research questions were emailed to each of the panel members. They were asked to identify the questions that were 1) most feasible to answer through a survey of health care practitioners, 2) would add value to the body of literature and 3) questions that, if answered, would help inform health care practitioners about the barriers on implementation of EEG programs within their institutions (McGlynn & Asch, 1998).

Potential research questions centered on the following topic areas:

- *Current knowledge about EEG and/or cEEG monitoring and seizure occurrence in critically ill patients;*

- *Resources and feasibility for implementing new programs focused on technology in acute care environments;*

- *The need for expertise and personnel in implementing new programs focused on technology in acute care environments;*

- *Current healthcare practitioner views on the need for EEG and/or cEEG monitoring in the acute care environments.*

The panel identified that the primary objectives of a survey on EEG and cEEG technology should center on: 1) The **knowledge** of physicians on the frequency and importance of seizures in critically ill patients and the operating characteristics of EEG and cEEG; 2) the **utility** or importance placed on using EEG technology in the ICU; 3) the perceived **current use** of EEG and cEEG in Canadian ICUs; and, 4) specific **barriers** that may inhibit EEG monitoring programs from being implemented in the ICU. Once the objectives were defined, three final
research questions, each addressing one of the objectives of the survey, were outlined by the panel:

1. What are clinicians’ awareness of the frequency and seriousness of seizures in critically ill patients?
2. What value do clinicians place on EEG and cEEG (e.g. do clinicians believe that use of EEG or cEEG might lead to improved care of their brain injured patients)?
3. What are the stated practices of EEG and cEEG use?
4. What are the barriers to incorporating EEG and cEEG in practice given a clinical need?

The objectives and research questions were used to inform the development of survey items as well as the overall design of the survey. In addition to identifying research questions, the expert panel decided upon one primary research hypothesis and three secondary hypotheses that, based on literature and common expert opinion, should be answerable by the developed survey.

1) There will be a substantial difference between the perceived need for EEG monitoring for critically ill patients and current stated practice of EEG monitoring for critically ill patients (primary hypothesis).
2) There will be substantial differences in perceived need for EEG technology in the ICU between respondents that received formalized sub-specialty training in neurocritical care and respondents that did not receive formalized sub-specialty training in neurocritical care.
3) There will be barriers identified that inhibit the use of EEG technology in the ICU.
4) The use of EEG will differ between adult and pediatric ICU settings.

4.4 Development

4.4.1 Item Generation

To begin the process of developing survey items, articles relating to brain monitoring technology were searched for topics and issues occurring around the use of brain monitoring technology (including EEG and cEEG monitoring) in the ICU. After an initial list of questions was generated, items were reviewed and new items were added to the list of survey items to fill in any potential gaps. The wording of the items was also assessed. Item wording should reflect
the level of measurement appropriate for analysis (Aday & Cornelius, 2006), should contain closed-ended questions, should avoid vague wording and should not be condescending or convey judgment or preference (Sierles, 2003). The survey items needed to be appropriate for both adult and pediatric physicians and in the case of a clinical scenario question, needed to be tailored for each specific patient population. The list of potential items, including a list of appropriate demographic questions and characteristics, was circulated via email amongst the expert panel for review and this process continued until no new items could be generated and redundancy was met – approximately 20 iterations of the survey items were circulated and commented upon.

Through this process of item development, domains under which items could be grouped in the final survey design were identified. These included: Knowledge, Perception of Need, Capacity, Clinical Scenarios and Demographic Data. Separate categories were also identified for questions pertaining to standard EEG and cEEG monitoring. Knowledge items addressed physician familiarity of seizure occurrence in the ICU as well as physician familiarity with using and interpreting EEG monitoring. Capacity items addressed the availability of EEG technology and interpretation within respondent institutions; including barriers to EEG implementation. Perception of Need and Clinical Scenario items assessed the opinion of physicians responding to the survey and whether or not they believe EEG monitoring should be used within the ICU and with what patient population. Clinical scenario questions were constructed in both an adult and pediatric appropriate formats. Demographic questions about patient populations, practice environment and years of practice were asked at the end of the survey as demographic information can be used to perform subgroup analysis of the survey respondents (Aday & Cornelius, 2006).

4.4.2 Item Reduction

After the list of survey items was developed, a second round of survey review was completed to reduce the number of items within the survey. The survey items were subsequently grouped into six domains: Knowledge, Capacity for Standard EEG, Capacity for Continuous EEG, Perceptions of Need, Clinical Scenarios and Demographic Information.

The domains used within this survey partially overlap the barriers to implementing EEG in the ICU by Young (2006). Young (2006) suggests that ICU physicians are often not exposed to the
neurophysiological training needed to conduct EEG monitoring. A lack of knowledge may lead to a decrease in the use of EEG monitoring. Also, Young (2006) suggests that economical barriers and a lack of high quality evidence may lead to decreases in the availability of EEG technology in ICU settings. The domains of this survey outline the possible barriers to implementing EEG monitoring in the ICU (2006).

Once items were grouped, the survey was circulated to the panel of experts by email and the panel was asked to identify items that were 1) redundant, and 2) that overlapped with each other. Once completed, the sample survey was sent to two clinicians who specialized in the field of EEG monitoring and interpretation, for further feedback and critique. The goal of the item reduction phase of survey development was to ensure that each topic was adequately addressed while making the survey as concise as possible. Our goal was to use a limited number of items per domain, in order to decrease the length of time required to complete the survey. Surveys with fewer items will more likely be answered by respondents (Fox, 1994). The average response rate time for the entire survey for the pilot group was 9.3 (standard deviation [SD] = 2.0) minutes. A total of 39 potential survey items were identified by the end of the review process.

4.4.3 Design

Survey items and response formats were organized into a paper-based survey tool as well as being uploaded into Survey Monkey ® software. Questions and answers were formatted into multiple choice questions or seven-point Likert scale answers ranging from completely disagree to completely agree. As suggested by Sierles (2003) it is advantageous to use a 5-to 9-point Likert scale as the data collected can be used for higher level statistical analysis. Higher item Likert scale data may be treated as interval data, which allows for parametric testing to be conducted where as a 2-point Likert scale produces nominal or categorical data and limits data precision as well as analyses that can be conducted.

4.4.4 Pre-testing and Pilot testing

A small group of 6 critical care physicians and neurologists were chosen to evaluate the survey as a pre-test cohort as they mirrored the respondent characteristics that would be sought in the final survey sample. This group was asked to judge the relative merit of each survey item, the
design and ease of the survey format and response format, as well as identify any redundancies that may exist within the survey items. A cover letter was included in the pre-test survey (Edwards et al., 2009), which outlined the intent of the survey, the approximate time it would take to complete the survey, and contact information for the graduate student conducting the survey should the respondents have any questions or comments (Edwards et al., 2009) (Appendix 4). Comments from the pre-test group lead to several format changes within the survey layout as well as minor item adjustment (Appendix 2 and Appendix 5). These adjustments were reviewed by the panel of experts prior to the survey being sent out for pilot testing.

Van Teijlingen and Hundley (2001) define a pilot study as a ‘trial run’ or the ‘trying out’ of the research instrument. The benefit of conducting a pilot study is that it may provide advanced warning about problems that may occur in the research instrument and whether the proposed methods or instruments being used are appropriate for answering the research question. Pilot tests are also another way of ensuring the research tool is valid, reliable, as well as a way of identifying practical problems within the research methodology. In survey research, pilot testing can be used to ensure the wording of the questions and the answer format are well structured and usable.

A group of 33 colleagues were selected for the pilot test group. This group was similar to the sampling frame that would be used in the final survey dissemination (Van Teijlingen & Hundley, 2001). The pilot test survey was administered through email contact for ease and speed of dissemination. Reminder emails were sent out three weeks after initial emails to non-respondents and additional reminder emails were sent out four weeks after the first reminder email to remaining non-respondents. To increase response rates individual invitation emails sent by the principal clinician investigator (Edwards et. al., 2009) were sent to non-respondents five weeks after the last reminder email was sent through Survey Monkey. All electronic contact was done through Survey Monkey software.

As a method of ensuring survey reliability, pilot test respondents were sent a retest survey (identical format and questions as the initial survey received by respondents). Item responses were compared to the initial responses to determine the consistancy of the response. Results from the pilot test advised the final survey content, the final structure of the survey format and
the final sample size of the survey (see below for the results and the sample size calculations—changes made to the survey can be found in Appendix 2).

**4.4.5 Clinical Sensibility Testing**

As part of the pilot testing phase, respondents were asked to answer clinical sensibility questions upon completion of the survey. These questions were not to be included in the final survey dissemination, but they are a way of evaluating the face validity and clarity of the survey tool (Burns et al, 2008; Appendix 3). The clinical sensibility questions were adapted from the questions outlined in the Burns (2008) paper and addressed issues of response format, whether responses and questions were easily understood, whether the questions will provide useful data, and whether survey items are redundant or missing. The goal of clinical sensibility testing is to determine how well the items address the survey objectives (Burns, 2008).

**4.4.6 Ethics and Confidentiality**

Ethics approval for the survey portion of this thesis was received through the Sunnybrook Hospital Research Ethics Board (project Identification Number: 227-2010) as well as the University of Toronto Research Ethics Board (Protocol Reference #25712). By responding to the survey, respondents explicitly indicated their consent to survey participation, which was outlined in the survey cover letter.

Data was collected and stored on a password protected and encrypted laptop that remained in a physically locked office when not in use. Data was stripped of any potentially identifying data (e.g. computer IP addresses, email addresses) and back-up data will be stored on an encrypted and password protected usb key that remained in a physically locked office when not in use. Upon completion of the survey, email and postal addresses will be deleted and the data will be retained with no identifying data for statistical analysis for a period of five years, by the graduate student supervisor, in accordance with institutional policies.

**4.5 Variables Collected**

A copy of the survey can be seen in Appendix 4. The questions on the survey include the following:
Knowledge, Capacity, Perception of Need, Patient Population, and Availability of EEG Questions

Knowledge

1. Which type of seizure is more common in ICU patient?
2. Brain damage occurs within 3 hours of uncontrolled generalized non-convulsive seizures
3. Non-convulsive seizures occur in what proportion of traumatic brain injury patients in ICU?
4. I can diagnose seizures, including non-convulsive seizures, clinically in critically ill patients without EEG support.
5. Continuous EEG is a more sensitive means of detection of seizures compared to routine EEG.

Capacity

6. I believe those performing EEG testing in my hospital view critically ill patients suspected of having seizures as a priority.
7. I believe collaboration between neurology specialists and critical care specialists enhances the performance of EEG among critically ill patients.
8. Technical capacity for standard EEG studies in critically ill patients is available in the hospital where I practice.
9. Interpretation of standard EEG recordings performed in the ICU is available in the hospital where I practice.
10. Standard EEG is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital.
11. Interpretation of standard EEG is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital.
12. For critically ill patients with suspected non-convulsive status epilepticus, I am able to obtain a standard EEG within the first 3 hours after clinical suspicion.
13. I am able to obtain a standard EEG as quickly as I believe is optimal for patient care.
14. Technical capacity for continuous EEG monitoring in critically ill patients is available in the hospital where I practice.
15. Interpretation of continuous EEG recordings performed in the ICU is available in the hospital where I practice.
16. Continuous EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital.
17. Interpretation of continuous EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours of weekdays) for critically ill patients in my hospital.
18. For critically ill patients with suspected non-convulsive status epilepticus, I am able to obtain a continuous EEG within the first 3 hours after clinical suspicion.
19. I am able to obtain a continuous EEG as quickly as I believe is optimal for patient care.
20. I believe a lack of physicians able to interpret EEG recordings in my hospital is a barrier to performing continuous EEG.
21. I believe a lack of EEG technician time is a barrier to performing continuous EEG in my hospital.
22. I believe a lack of equipment is a barrier to performing continuous EEG in my hospital.
23. I believe a lack of financial resources is a barrier to performing continuous EEG in my hospital.

**Perceptions of Need**

24. I believe that standard EEG should be considered a standard of care for comatose critically ill patients.
25. I believe that continuous EEG monitoring should be considered a standard of care for comatose critically ill patients.
26. I believe that EEG is adequately utilized in critically ill patients at my hospital.
27. I believe standard EEG monitoring does not provide recordings of sufficient quality to be useful.
28. I believe continuous EEG monitoring does not provide recordings of sufficient quality to be useful.

**Patient Populations in whom to use EEG**

I would perform some form of EEG in the following patients for whom an alternative diagnosis for the condition has not been found:

29. Unexplained *Coma* (Glasgow Coma Score <9) in any critically ill patient.
30. Uncontrolled **Seizures** (convulsive or non-convulsive) in any critically ill patient.

31. A critically ill patient with **Traumatic Brain Injury** and unexplained alteration in level of consciousness.

32. A critically ill patient with **Subarachnoid Hemorrhage** and unexplained alteration in level of consciousness.

33. A critically ill patient with **Anoxic Brain Injury** and unexplained alteration in level of consciousness.

34. A critically ill patient with **Encephalitis** and unexplained alteration in level of consciousness.

35. A critically ill patient with **Stroke** and unexplained alteration in level of consciousness.

36. A critically ill patient with **Sepsis** and unexplained alteration in level of consciousness.

37. Other

**Clinical Scenarios**

**Consider the following clinical scenario (Adults):**

An 80 kg 64 year old male with a prior stroke presents with **status epilepticus** on Thursday evening and is treated with 4 mg of lorazepam intravenously, followed by 1 g of intravenous dilantin, is then sedated with a propofol infusion, intubated and admitted to the ICU. While clinically sedated, a standard EEG is performed on Friday mid-day after interrupting the propofol infusion. The neurology consultant reads this EEG by late-afternoon, detects residual electrographic seizure activity, and advises to increase the propofol infusion rate, an additional 500 mg of dilantin intravenously and 150 mg dilantin intravenously three times daily for 4 days (96 hours), then to be reassessed.

38. When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

39. In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

Consider how this scenario would play out if this patient were to have been admitted on a Sunday evening...

40. When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
E. Within 72 hours after the change in therapy is implemented (on Thursday)
F. After 96 hours after the change in therapy is implemented (on Friday)

41. In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
Consider the following clinical scenario (Pediatrics):

A 5 year-old boy presents with status epilepticus on Thursday evening and is treated with 0.1 mg/kg of lorazepam intravenously, followed by 20 mg/kg of intravenous Dilantin (and 20 mg/kg of intravenous phenobarbital) He is then sedated with a midazolam infusion and intubated and admitted to the ICU. While clinically sedated, a standard EEG is performed on Friday mid-day. The neurology consultant reads this EEG by late-afternoon, detects residual electrographic seizures, and advises to increase the midazolam infusion rate, give an additional of 10 mg/kg Dilantin intravenously and then 3 mg/kg Dilantin intravenously three times daily for 4 days (96 hours), then to be reassessed.

42. When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

43. In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

Consider how this scenario would play out if this patient were to have been admitted on a Sunday evening...
44. When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
E. Within 72 hours after the change in therapy is implemented (on Thursday)
F. After 96 hours after the change in therapy is implemented (on Friday)

45. In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
E. Within 72 hours after the change in therapy is implemented (on Thursday)
F. After 96 hours after the change in therapy is implemented (on Friday)

Demographic Data
We’d now like to ask you a few questions to help us better understand the above responses:
46. In the past 12 months, how many critically ill patients do you estimate that you have treated? (Circle one)
1-50      51-99             100-149       150-199        200-250       >250
47. In the past 12 months, how many critically ill patients do you estimate you have monitored with standard EEG? (Circle one)

0  1-10  11-20  21-30  31-40  >40

48. In the past 12 months, how many critically ill patients do you estimate you have monitored with continuous EEG? (Circle one)

0  1-10  11-20  21-30  31-40  >40

49. How many years since you graduated from medical school: __________

50. For Which patients do you routinely provide critical care (check all that apply)

□ General Medical Patients
□ Surgical Patients
□ Neurologically Injured Patients
□ Neurosurgical Patients
□ Traumatically Injured Patients
□ Transplantation Patients
□ Cardiovascular Surgery Patients
□ Pediatric Patients

51. Which of the following ICUs do you work? (check all that apply)

□ Community based ICU?
□ University-affiliated ICU?

52. What is your primary specialty? (check all that apply)

□ Anaesthesiology
□ Internal Medicine / medical subspecialties
□ Neurology
□ Paediatric Medicine
□ Neurosurgery
□ Surgery / other surgical subspecialties
□ Emergency Medicine
☐ Other (please specify):

______________________________________________________

53. Do you consider yourself to have formal sub-specialty training in neuro-critical care?
YES/NO

4.6 Final Survey Design

The final survey comprised 45 items focused on the use of cEEG and EEG monitoring by pediatric and adult critical care physician. There were 8 additional demographic questions asked at the end of the survey. The survey items and demographic questions were grouped into the following domains: Knowledge, Perception of Need, Availability of EEG, Capacity, Clinical Scenarios and Demographic Data. Separate categories were also identified for questions pertaining to standard EEG and cEEG monitoring. Knowledge items addressed physician familiarity of seizure occurrence in the ICU as well as physician familiarity with using and interpreting EEG monitoring. Capacity items addressed the availability of EEG technology and interpretation within the institution the physician practices. Perception of Need and Clinical Scenario items addressed the opinion of physicians responding to the survey and whether or not they believe EEG monitoring should be used within the ICU and with what patient cohort.

4.6.1 Sampling Frame

This survey follows a non-probability or a non-random design for sampling survey respondents. This type of design is typically used when researchers are unable to estimate the probability of a given individual has of being included in the sample frame. Purposive sampling, a type of non-probability framework that targets individuals who meet certain criteria (for example, physicians who treat critically ill patients), was used as the sample framework. Respondents were selected based on their medical specialty and level of medical education. The criteria used to select respondents included having expertise in treating critically ill patients who may suffer from neurological insults. Typically, such respondents encompass critical care physicians and neurologists that work in proximity to or consult upon patients admitted to an ICU, at either a university-affiliated or non-university-affiliated hospital, and had completed their medical training, including residency specialty. Physicians-in-training (e.g. medical students, residents, sub-specialty fellows), and nurses, other allied health care professionals in critical care medicine where not included in the survey sample because they are not ultimately most responsible in
ordering and acting upon EEG testing, and because of the broad heterogeneity in trainees and practical difficulty in identifying and contacting this group.

4.6.2 Sample Size Estimation

When calculating a sample size for a national survey, it is important that the sample is sufficient in size to allow the results to be generalizable to the entire population, respecting the potential for differences based upon respondent characteristics such as geography, level of training, experience, specialty, etc. As well, sample sizes should be sufficient to allow statistical comparisons, where appropriate, in order to provide answers to questions and research hypotheses with an acceptable degree of certainty.

One-Sample T-Test Power Analysis

A one-sample t-test power analysis (formula 1) was calculated using data collected in the pilot-testing phase of the survey design. Survey questions that could be used to answer the primary hypothesis (“there will be a substantial difference between the perceived need for EEG monitoring for critically ill patients and current stated practice of EEG monitoring for critically ill patients”) were identified and responses from pilot testing were used to estimate the sample size for the final survey dissemination. Answers from the clinical scenario as well as the questions: “I believe that EEG is adequately utilized in critically ill patients at my hospital” paired with “I believe that EEG monitoring should be considered a standard of care for comatose critically ill patients” and “Technical capacity for continuous EEG monitoring in critically ill patient is available in the hospital where I practice” paired with “I am able to obtain a standard EEG as quickly as I believe is optimal for patient care” were identified as major study variables for the primary research hypothesis. These questions were paired and were compared using one-sample t-test power analysis.

\[
N_d = \frac{(z_{\alpha / 2} + z_{\beta})^2 \sigma_d^2}{\delta_d^2}
\]

Formula 1. Formula for estimating sample size for descriptive survey design

\[ N_d = \text{number of pairs} \]

\[ \sigma_d = \text{standard deviation for difference in pairs} \]
\[ \delta_d = \text{difference in means that we want to detect} \]

For \( \alpha=0.05 \), \( z_{1-\alpha/2} = 1.96 \) and for \( \beta=0.1 \), \( z_{1-\beta} = 1.28 \)

Answers from the clinical scenario question were used first to calculate sample size estimations. The entire study population was used in the calculation and an approximate population of 500 ICU physicians was used. A confidence level of 95% and a desired level of precision of 0.05 were used for each calculation. Using pilot survey data, a very small sample size of 8 respondents from a theoretically anchored population of 500 potential critical care respondents (Fowler RA, personal communication regarding the total potential population of critical care physician respondents) achieves 90% power to detect a difference of -2.0 between the null hypothesis mean of 0.0 and the alternative hypothesis mean of 2.0 with an estimated standard deviation of 1.5 and with a significance level (alpha) of 0.05 using a two-sided one-sample t-test.

Due to the performance of the pilot survey and subsequent small calculated sample size, other key variables were also explored. “I believe that EEG monitoring should be considered a standard of care for comatose critically ill patients” and “I am able to obtain a standard EEG as quickly as I believe is optimal for patient care” were used in the second calculation. The calculation parameters used in the first sample size estimation were kept consistent for the second calculation and completed using the following.

**McNemar Test Power Analysis**

It was agreed upon by the graduate student thesis supervisor, graduate student conducting the survey and the statistician that the small sample size estimations, as found through the one sample t-test power analysis, were not useful for a national survey, because, as suggested by Leary (2004) if these sample sizes were to be used, sampling error would likely occur and the sample may not mirror or be generalizable to the population, even if there was sufficient confidence in the differences reported for the sampled respondents. In order to avoid this potential challenge to generalizability, other sample size formulas were explored.

A McNemar Test for power analysis was completed to potentially identify a sample size for a more realistically generalizable survey. The McNemar test is a statistical test that compares the proportions for two correlated dichotomous variables and uses a two by two contingency table to determine whether
row and column marginal frequencies are equal (Schork & Williams, 1980). A sample size of 84 pairs achieves 80% power to detect an odds ratio of 3.0 between the clinical scenario question answers comparing optimal and actual care using a two-sided McNemar test with a significance level of 0.05.

*Anticipating Necessary Adjustments to the Sample Size Calculation*

Response rates among physicians are typically lower than response rates of the general public, often by 10% or more (Flanigan, McFarlan & Cook, 2008). It has been found that surveys among physicians in Ontario that did not utilize incentive strategies or combined mail-out survey strategies received a response rate of 48% (Thorpe et. al., 2009). While efforts were made to maximize response rates, when calculating sample sizes, conservative response rate estimates of 50% were used (i.e. \[ \frac{84}{0.50} = 198 \]) participants. Also, as it was desired that the survey results be generalizable to the population of ICU physicians across Canada, a larger, more conservative sample size estimation was used. Participants were selected from an internal mailing list of pediatric and adult ICU physicians across Canada. The list was compiled by a mixed methods Canada wide, hospital-by-hospital email/internet/telephone “snowball” sampling search for physicians treating critically ill patients -in June-August 2008. The list was verified in June-August 2009 and likely represents the one of the most comprehensive and generalizable critical care focused physician registries in Canada (Rob Fowler, personal communication). It was assumed that since the list had not been updated for over one year, some of the email and mailing addresses would be no longer be valid, making these participants irrelevant. A total of 265 physicians on the list had both email and mailing addresses available. To allow for both email and postal mail-out, and to ensure at least 198 potential participants, it was decided that this would be the final sample that would receive a survey invitation. Surveys that were returned as a result of an invalid mailing or email address were removed from the final respondent denominator.

4.6.3 Response Rates

As surveys are being used more frequently, there is a risk that health care professionals may become inundated by survey requests, leading to lower response rates (Flanigan, McFarlane & Cook, 2008). Low response rates can lead to a survey becoming less generalizable to the sampled population. In addition, low response rates can introduce a (self) selection bias into the survey results that are obtained making the information gained from the survey less reliable, internally valid, and, as we will see, less applicable to the true breadth of the intended audience (Thorpe et al, 2009).
4.6.4 Generalizability

Certain patient populations, commonly children, women, and the elderly, are often excluded or underrepresented in many clinical investigations without justification for exclusion being given (Van Spall, Toren, Kiss & Fowler, 2007). Exclusion can lead to missing data elements for patient groups that make up a large proportion of patients regularly treated in a clinical setting, leading to limited generalizability of the results (Blijker, et. al., 2002; Fossa & Skovlund, 2002). For example, in order to increase the generalizability of the survey results to children, who receive care from pediatric critical care physicians, we included this group in our development process, the pilot test group, and the final survey dissemination. Also, an attempt was made to include ICU physicians from both academic, university-affiliated hospitals and urban, community-based hospitals in the final sample as the majority of patients receive their care in non-academic settings, yet the majority of research is conducted in academic, tertiary-care urban centres.

4.7 Final Dissemination and Maximizing Survey Response Rates

There are several strategies that can be used to increase response rates when disseminating a survey. In a recent Cochrane review (Edwards et. al., 2009), methods for increasing response rate to postal and electronic surveys are discussed in detail. A total of 481 trials that evaluated 110 different ways of increasing response rates for postal surveys were identified. In postal surveys, the most effective ways of increasing response rates were: using monetary or non-monetary incentives; recorded delivery over standard delivery; a teaser of the envelope (for example, stating the participant will benefit by opening the envelope); pre-notification of the survey; follow-up contact; unconditional (as opposed to conditional) incentives; shorter questionnaires; providing a second copy of the questionnaire at follow up; mentioning an obligation to respond; and, university sponsorship. Personlized questionnaires, hand-written addresses, stamped return envelopes and an assurance of confidentiality also increased response rates in postal surveys. In a randomized trial by Olivarius and Andreasen (1995), there were no difference in survey response rates depending on which day of the week the survey was sent out. Our postal mail-based survey utilized all possible such features above.
A total of 32 trials evaluating 27 different ways of increasing response rates in electronic surveys were identified (Edwards et. al., 2009). Response rates increased with the use of the following: surveys with non-monetary incentives; surveys that were shorter in length; that included a statement that others had responded; were focused upon a perceived more interesting topic; when survey results were offered; surveys with the use of a white background; among surveys that were personalised; and, those used a simple header. Deadlines as well as including a picture in the email also increased response rates. Our web-based survey utilized all possible such features above.

Beebe and colleagues (2007) found that a mixed-methods approach of mail and web-based survey dissemination methods increased overall response rates and provides a more representative sample when surveying physicians. Web-based and mail-based surveys allow for a national target population and have been shown to produce data of comparable quality of personal interview surveys (Aday & Cornelius, 2006).

Thorpe and colleagues (2009) acknowledge that surveys which provide an incentive for participation generally have higher response rates. The authors speculate that this is the result of a sense among participants that the incentive compensates for the time it takes to complete the study. In this study by Thorpe et al, response rates rose from 48% with no incentive provided to a response rate of 76% when an incentive (gift certificate) was used. Edwards and colleagues (2009) found that non-monetary incentive strategies had a greater impact on response rates compared to monetary incentives. While the investigators of our study wanted to provide an incentive to each participant, it was not feasible to do over the internet. It was decided that participants, who indicated they would like to be included in the draw via email, would be included in a draw for an ipod nano upon completion of the survey. This methodology maintained the confidentiality of the email addresses as well as providing some incentive for participation.

Efforts were taken in the development process as well as the dissemination process to ensure response rates were between 60-70% or higher, which have been considered reasonable levels of response to decrease non-response bias (Couper, 2000; Burns et al, 2008). The finalized survey, incorporating the above best-practice response rate methodologies, was disseminated through a two-stage, mixed-methods (web and postal-based) survey dissemination process to 265
physicians across Canada who care for critically ill patients. The final sample, after subtracting respondents for whom the survey could not ultimately be delivered due to invalid email or postal addresses, was 199 physicians.

The first stage of survey dissemination was administered using Survey Monkey web-based survey technology. In order to increase response rates, personalized emails were sent prior to the survey dissemination to participants for which both mail and email information was known, knowing that not all addresses would be valid ($n=265$) (Edwards et. al., 2009). The email included information about the project, the investigator, the amount of time it would take to complete the survey, and a picture of an iPod nano (the incentive) (Appendix 4). A reminder email that included another link to the survey was sent to the participants that did not respond to the initial survey invitation. Several studies (Couper, 2000; Edwards et al, 2002; Nakash et al, 2006), including a recent Cochrane review (Edwards et.al. 2009) have shown that these preliminary efforts significantly increase response rates in web-based and postal-based surveys.

Couper (2000) suggests that participants responding to a web-based survey may not be representative of the population. Also, some studies have shown web-based surveys to yield a lower response rate (Couper, 2000; Burns, 2008), and therefore have a higher risk of response bias. In light of these findings, second rounds of survey invitations were sent through the mail to individuals that did not respond to the web-based survey. Each mailed survey included a survey booklet, a cover letter, colour photo of an iPod, an addressed pre-paid envelope in which the survey could be returned (Edwards et al., 2009). Potential participants who did not respond to web-based survey invitations were administered a survey through the mail. Reminder survey packages were mailed out to participants four weeks after the initial mailing of the survey invitation. Participants with invalid email addresses, mailing addresses, or that voluntarily opted out of the survey were removed from the final sample denominator ($n=66$) (Figure 7).

4.8 Statistical Analysis

4.8.1 Reliability

*Test-Retest Reliability*
During the pilot phase of the survey development, pilot participants that completed the initial survey were asked to complete the survey a second time, two to four weeks after the first test was completed so test-retest reliability could be assessed. Through this retest, the investigators are able to assess whether the survey, when given to the same participant twice, yields similar results (Burns et al, 2008). A total of 18 respondents were asked to complete the retest survey. The majority of responses were compared using Student t-test; the knowledge group of questions were compared using a Spearman’s rho correlation test.

4.8.2 Validity

Face Validity

Face Validity is the assessment of whether or not survey items measure what they are intended to measure (Burns et al., 2008). Face validity was completed in the item reduction and pre-test phase of survey development through focus groups with our panel of experts. Face validity was also tested during the clinical sensibility assessment completed by pilot-test respondents.

Content Validity

Content Validity is used to determine whether or not the survey items accurately assess all aspects of the topic in question. To assess whether our survey tool’s content was valid, an expert panel (consisting of experts in the field of ICU care and cEEG monitoring) was used to develop survey items. External reviewers were consulted during the pre-test phase and were specifically asked if the survey items accurately assessed cEEG needs and barriers within the ICU. Finally, as previously stated, pilot-test respondents were asked if there were any significant gaps in content during the clinical sensibility testing phase.

4.8.3 Final Survey

Raw data for all survey variables was examined for their ranges and distributions. For each variable, descriptive statistics was completed to examine the distribution of the responses. This was completed by calculating the means and standard deviations or medians and ranges of each item, as well as calculating the proportion of responses within each response category. Graphs were created for each question, visually displaying the raw responses. Raw response
distributions were used to better inform the appropriate method (parametric, nonparametric, etc.) of statistical analysis for each hypothesis.

Demographics

Means and proportions were calculated for demographic response answers. Demographics were compared for respondents that answered online versus respondents that answered by mail, and where known from prior data, for all respondents versus non-respondents (e.g. university versus non-university affiliation, gender, specialty). Comparing respondents and non-respondents was completed as a test of generalizability - if respondent demographics are similar to the sample demographics, the survey results can be considered more generalizable. Comparing online respondents and mail respondents was completed in order to determine whether a different demographic of respondents was reached through a certain type of survey format.

Primary Hypothesis

There will be a substantial difference between the perceived need for EEG monitoring for critically ill patients and current stated practice of EEG monitoring for critically ill patients.

In order to prove or disprove the primary hypothesis, questions that asked about current state of practice, whether current state of practice is optimal, and the respondent’s perceived need for both standard and continuous EEG were identified. The identified questions were organized into three categories based on how the survey questions were asked in the survey: Clinical Scenario Questions (Q 38-45), by answering questions based on a hypothetical patient scenario these questions identify perceived best practice with current available care; Comparison Questions (Q12, 18, 24 and 25), comparing answers to optimal care questions with answers for available care questions; Optimal Care Questions (Q 13, 19, 26), asking physicians whether they are able to provide what they believe is optimal care to their patients. By combining these questions and their answers, a clear picture of the current state of practice and the perceived need for standard and continuous EEG should emerge.

Clinical Scenario Question Analysis
The answers for *Clinical Scenario Questions* (Q 38-45) were grouped based on the time frame given within the answer choice. A numeric code was given to each answer, which represented the day EEG care would be provided. “Continuously” or “same day” answers were coded as day 0, “within 24 hours” was coded as day 1, “within 48 hours” was coded as day 2, “within 72 hours” was coded as day 3 and “within 96 hours” was coded as day 4. The numerical codes could then be compared and statistical analysis could be completed. The difference between the answers for “optimal care” and “when the EEG would be performed in the respondent’s institution” was calculated. This was completed to demonstrate the distribution of the difference in answers. Mean and median scores for the *overall responses* as well as the *difference in responses* were calculated. Responses for adult and pediatric care providers were calculated both together, and separately, as each group was asked a specific clinical scenario for either an adult or pediatric patient. Using their mean scores, Wilcoxon Signed-Rank Tests were completed for each comparison.

**Comparison Questions**

McNemar’s test was used to compare answers for the *Comparison Questions* (Q12, 18, 24 and 25). For standard EEG, the answers for Q12 and Q24 were compared and Q18 and Q25 answers were compared for cEEG. Answers for Comparison Questions were re-coded into a binary format where (completely agree, strongly agree and somewhat agree) = 1 and (Neither, Somewhat disagree, strongly disagree, completely disagree) = 0.

**Optimal Care Questions**

Proportions and confidence intervals were also calculated for the *Optimal Care Questions*. Responses were grouped into two categories: Agree (completely agree, strongly agree and somewhat agree) and Disagree (Neither, Somewhat disagree, strongly disagree, completely disagree). A sensitivity analysis of key questions was performed to determine the effect of including the ‘Neither Agree nor Disagree’ answer option in the Agree group.

**Secondary Hypothesis (1): Knowledge**

There will be substantial differences in perceived need for EEG technology in the ICU between respondents that received formalized sub-specialty training in neurocritical care...
and respondents that did not receive formalized sub-specialty training in neurocritical care.

Respondents were asked whether or not they have ever received formal (e.g. through a defined period in a defined neurocritical care training program) training in neurocritical care. Respondents that answered ‘no’ were grouped separately from respondents that answered ‘yes’ (n=12). The responses for the perceived need questions (Q24 & Q25) were compared using either chi-square tests or Fisher’s exact test. Fisher’s exact test can be used in place of Chi-square analysis when sample sizes and expected frequencies are less than 5 (Munro, 2005). Answers were reported for as proportions and their corresponding 95% confidence interval.

**Secondary Hypothesis (2): Barriers**

There will be barriers identified that inhibit the use of EEG technology in the ICU.

Sixteen questions were identified as Barrier questions (Q6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 22, 23, 27, 28). Responses were grouped into two categories: Agree (completely agree, strongly agree and somewhat agree) and Disagree (neither, somewhat disagree, strongly disagree, completely disagree). Proportions and confidence intervals were calculated for each of the questions. Answers were reported for as proportions and their corresponding 95% confidence interval.

**Secondary Hypothesis (3): Adult vs. Pediatric**

EEG use will differ between adult and pediatric ICU settings.

In order to assess whether or not EEG use differed in adult and pediatric ICU settings, respondents were grouped based on whether the provided care to pediatric or adult patients. Answers to Q6 and Q8-26 were compared using either chi-square tests or Fisher’s exact test. This group of questions (Q6, Q8-26) assesses the availability of standard and continuous EEG as well as barriers hindering the use of EEG technology. We report 95% confidence intervals and p values for all comparisons. We a priori specified the primary comparison question for our primary hypotheses and therefore did not adjust for multiple comparisons. For non-primary comparisons in the primary and secondary hypotheses we did not adjust for multiple comparisons.
5 Results

5.1 Pilot Testing

A total of 18 survey participants responded to the pilot testing phase of the survey (55%) and of the initial 18 responses, 11 responded to the re-test questionnaire (61%). Student t-tests were conducting for each survey item, comparing the initial survey response and the retest responses of the 11 participants that responded to both surveys. There were no items that had significantly different responses (at a significance level of 0.05). Changes that were made to the survey items were based on an analysis of the survey item qualitative responses (Appendix 5). Consensus agreement of the final survey content way reached by the research team.

5.2 Clinical Sensibility Testing

A total of 18 respondents answered the clinical sensibility questions. 50% of respondents agreed that the survey would elicit information pertaining to the use of EEG and 67% agreed that the survey was directed at important issues pertaining to EEG use in critical care (Table 1). Sixty-seven per cent of respondents agreed that to a ‘large extent’ the survey response format was easy to understand (Table 1) while 44% of respondents agreed that the survey is ‘very likely’ to identify barriers to EEG use, and an additional 28% and 22% agreed that the survey was ‘quite likely’ or ‘likely’ to identify barriers to EEG use (Figure 6). Sixty-seven per cent of respondents agreed that ‘hardly any’ of the survey items were inappropriate or redundant and 83% of respondents agreed that, at most, there were minor gaps in survey questions (Figure 4). Free text comments from the clinical sensibility testing can be seen in Appendix 5 and changes made to the survey based on the clinical sensibility testing can be seen in Appendix 2.
Figure 4. Clinical Sensibility Question: Are there important issues pertaining to your use of EEG that should be included in the questionnaire that have been omitted?

Figure 5. Clinical Sensibility Question: How many items are inappropriate or redundant?
**Table 1.**

Clinical Sensibility Questions- Answers from Pilot Test*

<table>
<thead>
<tr>
<th></th>
<th>Small extent</th>
<th>Limited extent</th>
<th>Fair extent</th>
<th>Moderate extent</th>
<th>Large extent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>To what extent are the</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>11.1% (2)</td>
<td>22.2% (4)</td>
<td>66.7% (12)</td>
<td>18</td>
</tr>
<tr>
<td>questions directed at</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>important issues pertaining</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to EEG use in Critical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Care?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To what extent are the</td>
<td>0.0% (0)</td>
<td>0.0% (0)</td>
<td>11.1% (2)</td>
<td>27.8% (5)</td>
<td>61.1% (11)</td>
<td>18</td>
</tr>
<tr>
<td>response options provided</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>simple and easily</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>understood?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 6. Clinical Sensibility Question: How likely is the questionnaire to elicit identifying barriers for EEG use in Critical Care?*
To what extent are questions likely to elicit information pertaining to your use of and experience with EEG use in Critical Care?

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>5.5%</td>
<td>1</td>
</tr>
<tr>
<td>16.7%</td>
<td>3</td>
</tr>
<tr>
<td>27.8%</td>
<td>5</td>
</tr>
<tr>
<td><strong>50.0%</strong></td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

*Bolded items represent the most common (mode) response category*

**Test-Retest Reliability**

11 of the 18 pilot test respondents (61%) completed the retest survey. T-tests were completed to analyze any differences in overall response and there were no significant differences between overall responses for each survey item. Spearman rho, and Pearson r tests were run on the knowledge set of questions, but the results were not useful because there was not enough variance in the numerical response. Answers were converted to “agree” and “disagree” and examined for changes in overall response (i.e. change from agree to disagree). None of the questions exceeded >40% change in response.

**5.3 Survey Results**

**5.3.1 Demographics**

The finalized survey was disseminated through a two-stage, mixed-methods survey dissemination process to 265 ICU physicians across Canada with a final sample \( n=199 \). A total of 45 email invitations were returned as invalid, 9 mailing addresses were returned to sender and 13 physicians opted out of participating in the survey. All of these participants were removed from the final sample denominator. A total of 103 responses were received (response rate = 52%); 91% of respondents answered the survey in entirety while 9% of returned surveys contained non-responses to some questions (Figure 7). Distributions for each question can be seen in Appendix 6. Respondents with missing or incomplete data were not excluded from the survey, but the denominators were adjusted to remove missing responses. Figure 8 demonstrates the geographical information for known respondents versus the original survey sample, with no meaningful differences identified. The adult and pediatric physician distributions were also
similar among the original sample (12% pediatric) and the known respondents (17% pediatric). There were no appreciable or substantial differences between mail-respondents and web-respondents (Table 2).

**Figure 7. Progression of Survey Participants**

- **265 participants**
  - Initial email invitations sent to 265 participants
  - 45 emails returned as invalid and 7 participants requested to opt out of the survey

- **213 participants**
  - Survey Monkey® invitations sent to 213 participants
  - Mail Surveys were sent to 135 participants that did not respond to the web-based survey

- **199 participants**
  - 9 mail surveys were return-to-sender with invalid addresses
  - 6 participants requested to opt out of the survey after receiving the mail version
**Table 2**

Web-based and Postal-based Respondent Demographics

<table>
<thead>
<tr>
<th>Subspecialty Training in Neurocritical Care (% yes)</th>
<th>Web Respondents (N=78)</th>
<th>Mail Respondents (N=25)</th>
<th>All Respondents (N=103)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since Graduating Medical School (years) (Range=5-44, N=71)</td>
<td>11% (8)</td>
<td>16% (4)</td>
<td>(100)</td>
</tr>
<tr>
<td>Community-based Practice (Range=3-39, N=24)</td>
<td>23% (18)</td>
<td>23% (6)</td>
<td>(105*)</td>
</tr>
<tr>
<td>Pediatric Critical Care Physicians (%)</td>
<td>16% (12)</td>
<td>24% (6)</td>
<td>(101)</td>
</tr>
<tr>
<td>Primary Specialty Internal Medicine and Medical Subspecialties (%)</td>
<td>51% (39)</td>
<td>50% (12)</td>
<td>(100)</td>
</tr>
</tbody>
</table>

*Respondents could select both responses
5.3.2 **Results Relating to Primary Hypothesis:** There will be a substantial difference between the perceived need for EEG monitoring for critically ill patients and current stated practice of EEG monitoring for critically ill patients.

**Primary Questions**

**Optimal Care Questions**

75.5% of respondents disagreed that they were able to obtain a standard EEG as quickly as believed is optimal for patient care, 95% CI [67.1-83.8%]. 82.0% of respondents disagreed that they were able to obtain a continuous EEG as quickly as believed in optimal for patient care, 95% CI [74.5-89.5%]. When asked if EEG is adequately utilized in their hospital, 75.2% of respondents disagreed, 95% CI [66.8-83.7%].

**Sensitivity Analysis**

When the answer option ‘Neither agree nor disagree’ was included in the Agree category as opposed to the Disagree category, 68.6% of respondents disagreed that they were able to obtain a standard EEG as quickly as believed is optimal for patient care, 95% CI [59.6-77.6%]. 77.0% of respondents disagreed that they were able to obtain a continuous EEG as quickly as believed in optimal for patient care, 95% CI [68.8-85.2%]. When asked if EEG is adequately utilized in their hospital, 67.3% of respondents disagreed, 95% CI [58.2-76.5%]. Between 5- 7.9% of respondents chose ‘Neither agree nor disagree’ as an answer choice for these questions.

**Secondary Questions**

**Comparison Questions**

There was a significant difference between optimal care question 12 (for critically ill patients with suspected status epilepticus, I am able to obtain a standard EEG within the first 3 hours after clinical suspicion) and available care question 24 (I believe that standard EEG should be considered a standard of care for comatose critically ill patients). 75% of respondents agreed that standard EEG should be considered a standard of care for comatose critically ill patients.
(95% CI [66.8-83.7%]), but only 32% agreed that they were able to obtain standard EEG within the first 3 hours of clinical suspicion (95% CI [59.2-77.4%]), \( p<0.0001 \).

There was a significant difference between optimal care question 18 (for critically ill patients with suspected non-convulsive status epilepticus, I am able to obtain a continuous EEG within the first 3 hours after clinical suspicion) and available care question 25 (I believe that continuous EEG monitoring should be considered a standard of care for comatose critically ill patients). 67% of respondents agreed that cEEG should be considered a standard of care for comatose critically ill patients (95% CI [58.2-76.5%]), but only 23% agreed when asked whether they were able to obtain cEEG within the first 3 hours of clinical suspicion (95% CI [69.0-85.4%]), \( p<0.0001 \).

**Clinical Scenario Questions**

**Difference in Ideal and Actual EEG Use**

56% of respondents report a difference between when they would ideally perform an EEG and when an EEG will actually be performed for patients admitted to the ICU with seizures on a Monday. Overall the EEG would actually be completed later than the identified ideal time to perform an EEG [mean difference 1.5 (SD=0.9) days, \( p<0.0001 \)].

**Influence of Day of Week on Ideal and Actual EEG Use**

73% of respondents report a difference between when they would ideally perform an EEG and when an EEG will actually be performed for patients admitted to the ICU on a Friday. Overall the EEG would actually be completed later than the identified ideal time to perform an EEG [mean difference 2.5 (SD=0.9) days, \( p<0.0001 \)], and this difference was larger than the difference for patients admitted on a Monday (\( p<0.001 \)).
5.3.3 **Secondary Hypothesis (1): Knowledge.** There will be substantial differences in perceived need for EEG technology in the ICU between respondents that received formalized sub-specialty training in neurocritical care and respondents that did not receive formalized sub-specialty training in neurocritical care.

There was no significant difference of opinions on perceived need for standard EEG \( (p=0.27) \) or cEEG \( (p=0.12) \) between physicians who received formalized sub-specialty training in neurocritical care and physicians who did not.

5.3.4 **Secondary Hypothesis (2): Barriers.** There will be barriers identified that inhibit the use of EEG technology in the ICU.

The results for all 16 barriers questions can be seen in Table 3. The margin of error was below 10% for all proportions. Overall, 71% of respondents agreed that those performing EEG testing in their hospital view ICU patients having seizures as a priority and 99% agreed that collaboration between neurology specialists and critical care specialists enhances the performance of EEG among critically ill patients. 92% of respondents indicated that their hospital has the technical capacity for standard EEG and 98% agreed that they have interpretation for standard EEG available at their hospital. 70% of respondents indicated that standard EEG is not available outside of standard business hours (0800-1700 hours on weekdays) and 67% indicated that interpretation for standard EEG is not available outside of standard business hours.

Only 45% of respondents indicated that their hospital has the technical capacity for cEEG and 47% agree that they have interpretation for cEEG available at their hospital. 70% of respondents indicate that cEEG is not available outside of standard business hours (0800-1700 hours on weekdays) and 70% indicate that interpretation for cEEG is not available outside of standard business hours.

Respondents agreed that lack of physician time (61%), lack EEG technician time (81%), lack of equipment (60%) and lack of financial resources (83%) were barriers to performing continuous EEG. The quality of standard EEG and continuous EEG were not considered barriers to care.
Table 3

Proportion of Agree and Disagree Answers to Barriers Questions

<table>
<thead>
<tr>
<th>Barrier Question</th>
<th>Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe those performing EEG testing in my hospital view critically ill patients suspected of having seizures as a priority</td>
<td>70.6%</td>
</tr>
<tr>
<td>I believe collaboration between neurology specialists and critical care specialists enhances the performance of EEG among critically ill patients</td>
<td>99%</td>
</tr>
<tr>
<td>Technical capacity for standard EEG studies in critically ill patients is available in the hospital where I practice</td>
<td>92.2%</td>
</tr>
<tr>
<td>Interpretation of standard EEG recordings performed in the ICU is available in the hospital where I practice</td>
<td>98%</td>
</tr>
<tr>
<td>Standard EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for</td>
<td>30.4%</td>
</tr>
</tbody>
</table>
critically ill patients in my hospital

Interpretation of standard EEG is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital

Technical capacity for continuous EEG monitoring in critically ill patients is available in the hospital where I practice

Interpretation of continuous EEG recordings performed in the ICU is available in the hospital where I practice

Continuous EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital

Interpretation of continuous EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours of weekdays) for critically ill
<table>
<thead>
<tr>
<th>Perception</th>
<th>Percentage</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe a lack of physicians able to interpret EEG recordings in my hospital is a barrier to performing continuous EEG</td>
<td>61.4%</td>
<td>51.9-70.9%</td>
</tr>
<tr>
<td>I believe a lack of EEG technician time is a barrier to performing continuous EEG in my hospital</td>
<td>81.2%</td>
<td>73.6-88.8%</td>
</tr>
<tr>
<td>I believe a lack of equipment is a barrier to performing continuous EEG in my hospital</td>
<td>60.4%</td>
<td>50.9-69.9%</td>
</tr>
<tr>
<td>I believe a lack of financial resources is a barrier to performing continuous EEG in my hospital</td>
<td>83.2%</td>
<td>75.9-90.5%</td>
</tr>
<tr>
<td>I believe standard EEG does not provide recordings of sufficient quality to be useful</td>
<td>20.8%</td>
<td>11.9-29.6%</td>
</tr>
<tr>
<td>I believe continuous EEG monitoring does not provide recordings of sufficient quality to be useful</td>
<td>6.9%</td>
<td>0.0-15.8%</td>
</tr>
</tbody>
</table>
5.3.5 **Secondary Hypothesis (3):** EEG use will differ between adult and pediatric ICU settings.

Responses to two questions were significantly different between the adult and pediatric respondent groups. Significantly more pediatric respondents agreed that interpretation of standard EEG is available outside of typical business hours (56% vs. 29%), \( p=0.03 \). Significantly more pediatric respondents agreed that continuous EEG monitoring should be considered a standard of care for comatose critically ill patients (94% vs. 60%), \( \chi^2 = 7.7, p=0.005 \). There was no significant difference for any other comparison questions between the two groups.

*Clinical Scenario - Difference between Adult and Pediatric Respondents*

**Difference in Ideal and Actual EEG Use**

59% of adult care respondents reported a difference between when they would like to perform an EEG and when an EEG will actually be performed for patients admitted to the ICU on a Monday. Overall the EEG would actually be completed later than the identified ideal time to perform an EEG [mean difference 1.5 (SD=0.9) days, \( p<0.0001 \)]. 44% of pediatric care respondents reported a difference between when they would like to perform an EEG and when an EEG will actually be performed for patients admitted to the ICU on a Monday [mean difference 1.9 (SD=1.0) days, \( p=0.0078 \)]. This difference between availabilities among adult and pediatric respondents was not significant (\( p=0.24 \)).

**Influence of Day of Week on Ideal and Actual EEG Use**

74% of adult care respondents reported a difference between when they would ideally perform an EEG and when an EEG will actually be performed for patients admitted to the ICU on a Friday [mean difference 2.7 (SD=0.9) days, \( p<0.0001 \)]. 67% of pediatric care respondents reported a difference between when they would like to perform an EEG and when an EEG will actually be performed for patients admitted to the ICU on a Friday [mean difference 1.7 (SD=1.0) days, \( p=0.0005 \)]. This difference between availabilities among adult and pediatric respondents was significant (\( p=0.003 \)).
Of the respondents who reported a difference between when they would like to perform an EEG and when an EEG will actually be performed for patients admitted to the ICU, all the differences were uniform in direction - the respondent would like to perform an EEG sooner than when it would actually be performed.
6 Discussion

6.1 Survey Design, Dissemination and Completion

This study aimed to collect the opinions on EEG use among a nationally representative group of physicians that work in a critical care environment. A total of 199 physicians across Canada were surveyed, with 52% responding. The results highlight differences between optimal care and the reality of EEG availability. Overall, while respondents agree that conventional and continuous EEG should be a standard of care for critically ill patients, they also agree that the availability of both types of EEG is often limited. From our results it would appear that gaps in care may be greatest for critically ill adults in comparison to pediatric patients. Opinions on perceived need for standard EEG and cEEG were consistent between physicians who have received formalized sub-specialty training in neurocritical care and physicians who have not. Some of the major barriers inhibiting the use of EEG in the ICU, as found by this survey, include: lack of EEG technician time; financial resources; and physicians able to interpret EEG monitoring. Recognizing that there is a gap in care is important and demands that quality improvement strategies be developed.

6.2 Optimal Care and Perceived Need

Three types of questions were used to explore whether or not there is a gap between respondents’ perceived need for EEG monitoring in the ICU and what current EEG practice is in respondents’ institutions.

The first set of questions explored whether or not there is a gap between respondents’ perceived need for EEG monitoring in the ICU and what current EEG practice is in respondents’ institutions and asked respondents whether they are able to obtain an EEG as quickly as they believe is optimal and whether they agree that EEG is adequately utilized in their institution. More than 75% of respondents disagreed with all three of these statements, indicating EEG is not adequately utilized in critically ill patients in the respondent’s institution and that respondents are not able to obtain standard or continuous EEG as quickly as they believe optimal for patient care.
The second set of questions (Q12 and 24 and Q18 and 25) explored whether or not there is a gap between respondents’ perceived need for EEG monitoring in the ICU and what current EEG practice is in respondents’ institutions. These questions asked the respondents whether they were able to obtain either a standard or continuous EEG within three hours and whether or not they agreed that standard and continuous EEG should be a standard of care for comatose critically ill patients. The expert development panel agreed that obtaining an EEG within three hours for a comatose critically ill patient could be considered optimal care. For both conventional and continuous EEG, respondents agreed that EEG should be a standard of care, but disagreed that they were able to obtain an EEG within three hours, indicating suboptimal care.

The final set of questions was based on a clinical scenario of a patient with suspected seizures. The respondent was asked to first indicate when they would optimally perform EEG for this patient and were then asked to indicate when the EEG would actually be performed for this patient in their institution. The clinical scenario questions were asked twice: once for a patient admitted on a Friday and once for a patient admitted on a Monday. This was done to examine for potential weekday - weekend differences in availability. The responses were analyzed separately for adult and pediatric care providers as the clinical scenario was tailored for each audience specifically.

There was a significant difference between when respondents would like to monitor their patients with EEG and when it would actually be performed. This was true for patients admitted on a Friday and on a Monday. The average time difference between optimal care and actual care for patients admitted on a Friday was two and a half days and one and a half days for patients admitted on a Monday. This demonstrates both a gap in care that is exacerbated on weekends, as one might expect for gaps due to resource limitations, and a gap that seems greatest in adult centers. Studies have found that mortality rates increase for ICU patients admitted outside of typical business hours, including weekends, so understanding this gap in care and the increased gap seen on weekends is important (Kuijsten et.al., 2010; Uusaro, Kari & Ruokonen, 2003).

A difference between the perceived need for EEG monitoring for critically ill patients and current stated practice of EEG monitoring for critically ill patients has been demonstrated in the results of this survey. There are several implications that could result from this gap in care. EEG
monitoring is the only way to monitor for non-convulsive seizures in heavily sedated or chemically paralyzed patients, and as demonstrated above, respondents are not able to access this testing in an optimal timeframe. Delay in diagnosis of non-convulsive seizures and treatment is common if EEG is not commenced right away (Drislane, Lopez, Blum & Schomer, 2008). Non-convulsive seizures have been linked to increased morbidity and mortality for ICU patients (Vespa et al., 2002; Dennis et al., 2002; DeLorenzo et al., 1998). It is important to understand that without continuous monitoring, non-convulsive seizures in both adult and pediatric ICU patients go unnoticed and untreated.

EEG can be used to monitor non-convulsive seizures and to aid in the management of pharmacological coma and any-type seizure suppression. EEG can aid in the neurological examination in critically ill patients, which is often limited due to decreased level of consciousness because of the primary illness and necessity for sedation medication. Continuous EEG monitoring helps clinicians overcome these limitations through longer recording times and potentially recording under varying degrees of sedation. Applications of cEEG allow clinicians to identify when the brain is at risk and intervene before permanent damage is sustained, but as demonstrated in the results of this survey, is limited in availability in respondent’s institutions. With evidence suggesting prolonged seizures result in brain damage if not detected and treated (Vespa et al, 2010), it is important to address the perceptions and knowledge of utility of EEG, and barriers for standard and continuous EEG monitoring before there can be an implementation plan to increase cEEG monitoring programs in Canadian ICUs.

6.3 Possible Barriers

6.3.1 Access to Technology

The survey results identified several barriers that either limit or inhibit the use of both standard and continuous EEG in the ICU. These barriers could possible lead to the gaps identified in perceived need for EEG monitoring and the current state of practice explored previously. For standard EEG, even though the technology and interpretation may be available within the institution, these services seem to be limited outside of typical business hours (e.g. 0800-1700 hours on weekdays). This suggests that fewer standard EEGs are being performed during evening and weekend hours, even though the majority of neurocritically ill patients are admitted to ICU during non-weekday periods (Cohen, Bodenham & Webster, 1993).
Access to continuous EEG is even more limited in comparison to standard EEG - only 45%-48% of respondents indicating that their institution had this capacity. Respondents also agreed (>60%) that a lack of physicians able to interpret EEG and a lack of monitoring equipment are further barriers to performing cEEG. Respondents strongly disagreed that recording quality was a barrier for either standard or continuous EEG.

Utilizing a simplified EEG system may be a way of overcoming some of the barriers relating to accessing technology. It was found that an EEG using a 4-channel sub-hairline montage demonstrated 68% sensitivity and 98% specificity for seizure detection (Young et. al., 2009). Although a potential solution, there are potential barriers to implementing this type of technology as well including training staff, the accuracy and consistency of seizure recognition by staff and the increased cost of additional equipment. This topic was not addressed in this survey; however, it is an area that should be explored in future research projects.

### 6.3.2 Economic Barriers

Resource and economic barriers to implementing best monitoring care for neuro-critically ill patients have been clearly identified in this survey. Respondents strongly (>80%) agreed that a lack of EEG technician time and lack of financial resources are barriers to performing cEEG in their institution. It has been previously suggested that these barriers prevent many physicians from utilizing EEG and cEEG monitoring technology (Young, 2006). EEG technicians, EEG monitors, and skilled personnel to interpret recordings have an associated cost (Abend et.al, 2010; Ferrusi et.al., 2009). In order to overcome these barriers, cost-effectiveness analyses or local “business cases” should be considered and conducted. Having valid cost-analyses investigating whether the technology is sustainable and beneficial may encourage administrators to allocate or increase a budget to such technologies. This survey did not assess health technology assessment specifically; however, the responses indicating that the quality of standard and continuous EEG is not a barrier suggest that concerns about technology quality may be limited, and barriers are more likely focused on personnel and finances.

### 6.3.3 Educational Barriers

As discussed by Young (2006), a lack of physician training may also be a barrier to utilizing cEEG on a regular basis. This survey found that only 12% of respondents had received
formalized sub-specialty training in neurocritical care. As indicated by the survey, a lack of physicians able to interpret EEG was considered a barrier by 61% of respondents. Educational strategies around interpreting EEG recordings may be one way of overcoming this specific barrier.

Several papers highlight inadequate education of care providers as a significant barrier to implementing evidence-based practices in the ICU (Abbott et al., 2006; Anger & Szumita, 2006; Berenholtz & Pronovost, 2003). Young (2006) suggests that ICU physicians do not consider EEG monitoring because they are not well-trained in its use and interpretation. ICU physicians have a wide variety of training backgrounds and not all are specialized in neurology or neurocritical care. Training in neuro-monitoring technologies and techniques may not have been a part of the physician’s training and are therefore unfamiliar and underutilized by the physician.

Introducing physicians to cEEG monitoring through education strategies may be another way of overcoming an educational barrier that is limiting the use of cEEG.

In 2005 (Mayer, 2006), a new specialty of “Neurological Intensive Care” was recognized. Neurological intensive care training aims to ensure that physicians are educated in all aspects of treating a critical care patient with neurological injury. Being educated in cEEG techniques and technologies is included within this subspecialty. As well, attempts to simplify the technology being used have been examined. Young and colleagues (2009) examined the use of a simplified, sub-hairline EEG monitor. This simplified technology could be used by nurses and physicians not previously trained in standard EEG techniques and can be used when standard equipment is unavailable. There have been no specific knowledge translation strategies implemented or evaluated in the ICU for this specific technology and this is an area for future research.

6.4 Pediatrics vs Adults

In order to assess whether or not EEG use differed in adult and pediatric ICU settings, respondents were grouped based on whether they provided care to pediatric or adult patients. Answers to Q6 and Q8-26 were compared. This group of questions assesses the availability of standard and continuous EEG as well as barriers hindering the use of EEG technology.

The responses to two questions were significantly different between the adult and pediatric groups. Significantly more pediatric respondents agreed that interpretation of standard EEG is
available outside of typical business hours and significantly more pediatric respondents agreed that continuous EEG monitoring should be considered a standard of care for comatose critically ill patients. There were no other differences between the two groups for this set of questions.

For adult respondents, there was a significant difference between when the respondent would like to treat their patient with EEG and when it would actually be performed. This was true for patients admitted on a Friday and on a Monday. The average time difference between optimal care and actual care for adult patients admitted on a Friday was two days and one day (24 hours) for adult patients admitted on a Monday.

For pediatric respondents, there was also a significant difference between when the respondent would like to treat their patient with EEG and when it would actually be performed, although the differences were not as great in comparison to adult respondents. This was true for patients admitted on a Friday and on a Monday. The average time difference between optimal care and actual care for pediatric patients admitted on a Friday was one day and half-day for pediatric patients admitted on a Monday.

The differences demonstrated in the survey results suggest that services for standard EEG may be less readily available in the institutions of adult care respondents. However, the pediatric sample was smaller (17% of respondents, reflecting a smaller number of pediatric critical care physicians in Canada), and our estimates may be less precise than would be achievable for a larger sample. Differences between adult and pediatric institutions could also provide examples of how to overcome barriers to implementing EEG technology and how to increase the availability of standard and continuous EEG monitoring and this is also an area ripe for further comparative studies in knowledge translation.

### 6.5 Strategies for Improvement

One element that could likely be improved in the ICU is the education of physicians and nurses that are not familiar with the use of cEEG monitoring and this may help to overcome an education barrier. While having one physician specialized in neurocritical care is useful, it is unpractical to expect one physician to treat all patients at risk of seizures. Having an ICU team of nurses, physicians, and technicians that are educated in not only the use of cEEG, but more importantly the risk factors, signs and symptoms in at-risk patients may increase the amount of
patients subsequently being referred and monitored with EEG and cEEG, the number of seizures detected, and potentially lead to an improvement in patient outcomes. Correspondingly, increased monitoring may be a mechanism to decrease unnecessary antiepileptic drug prescription in patients that are not experiencing seizure activity (Lesser, 2009).

An educational strategy rooted in adult learning theory is the most practical approach to overcome an educational barrier. As suggested by Young (2006) cEEG monitoring may not be utilized because ICU physicians are not educated with its appropriateness, technologies required to conduct the test, and the correct interpretation of the cEEG recordings - ideas that are supported in the results of this survey. Anger and Szumita (2006) suggest that the development of an integrated education strategy that provides updated, periodic education programs may be a way of overcoming an education barrier. Adult learning theory implies that education should be conducted by a teacher that guides the knowledge process and learning should be based on current knowledge of the students. Learning should be active and in an environment where students learn through relevant problems in a group setting and then apply the knowledge in a work situation (Kaufman, 2003). Allowing participants to reflect on the actions during the use of the technology and after using the technology (“reflect-in-action” and “reflect-on-action”) creates cognitive dissonance if the action being performed is useful and differs greatly from what the participant was doing before. This encourages a sustainable change in behavior throughout the education process (Kaufman, 2003).

Exploring the use and development of a multi-disciplinary education team to facilitate the education strategy on an on-going basis might be a suitable approach for an ICU educational strategy. The care provided in an ICU is multidisciplinary in its approach, with a large number of stakeholders involved in providing care to a heterogeneous mixture of patients (Scales et. al., 2009). The use of multidisciplinary teams has been successful in the ICU for educational strategies in other care problems. In several studies (Abbott et.al. 2006; Billings et.al., 2006, Coopersmith et.al., 2002), the use of a multi-disciplinary education team successfully facilitated learning and change in the ICU. This strategy is appropriate as key stakeholders in this group are diverse in background and training. It has also been found that feedback from peers is more successful in evoking change compared to feedback from an outside source (Jamtvedt, Young, Kristoffersen, O’Brien & Oxman, 2006). A multidisciplinary team with members from each stakeholder group will meet this peer-feedback recommendation. It has been suggested that
situational learning is more effective than didactic learning (Davis et. al., 1999). Devlin and colleagues (2008) found that in an ICU setting, a combination of didactic learning and scenario-based education strategies significantly improved nurse recognition of delirium. A similar outcome may be achievable in physician and nurse recognition of patients at risk of non-convulsive seizures that would need EEG monitoring. Such techniques need to be considered for strategies overcoming education gaps in best-care delivery for neuro-critically ill patients.

6.6 Survey Benefits and Limitations

While the goal of this survey was to assess the opinions of physicians across Canada, it was important to the researchers that the results were generalizable to the situation of EEG monitoring in Canada. This was achieved by designing and disseminating a survey to over 199 ICU physicians in Canada.

This survey had a number of strengths. First, we carefully adhered to rigorous survey design methodology including an expert panel to generate the survey questions, item reduction, as well as four months of pre-, pilot and clinical sensibility testing of the original survey document. Second, we used a mixed-methods survey dissemination approach, which combined web-based and mail-based surveys, was taken in order to reach a broader audience. Finally, several steps including providing an incentive, sending out personalized emails prior to the web-based survey, including a cover letter that was personally signed and including a picture of the incentive, and sending out reminder emails or mail-packages were taken to increase survey response rates (Edwards et al, 2009).

These efforts resulted in a 52% response rate, which is considered to be good amongst a physician audience (Flanigan, McFarlan & Cook, 2008; Thorpe et. al., 2009). The known respondent characteristics also closely aligned with the original sample of 199 participants in both geographical information and adult and pediatric physician distributions. These results support that the survey results are generalizable to the ICU physician population in Canada.

Finally, the results of our survey are compelling. We demonstrated important differences in perceptions of optimal and actual care of neurologically impaired critically ill patients, have identified specific barriers to care and in doing so, have suggested mechanisms to overcome these barriers.
There are several limitations and specific lessons learned through the development of this survey. One of the successes of this survey was the use of mixed-methods dissemination. By combining web and mail based survey strategies, response rates were increased by an additional 15% compared to web-based surveys alone. The use of mail-based surveys helped to overcome some barriers including email filtering software that would send a survey to junk mail, or institutional filters that do not allow hospital computers to access websites such as Survey Monkey ®. However, mixed-methods dissemination does require substantially more researcher time to complete, particularly the postal mail-based component of the dissemination. In this survey only two mail-based reminders were sent out (compared to three email based survey reminders) due to time constraints. Each mail-out took approximately 20 hours to complete and six weeks to receive results back from participants. This should be a consideration for all researchers completing a mail-based survey in the future and particularly so for researchers under time constraints of a graduate school deadline. Not sending a third reminder may have lead to a decrease in response rates as it has been shown that reminder post cards significantly increase response rates (Perneger, Etter & Rougemont, 1993; Edwards et al, 2009); however, in the third email reminder of this survey only one additional response was obtained, leading us to believe that the impact of a third postal survey would be minimal. While efforts were taken to obtain a nationally representative sample, the majority of respondents were from Ontario. This may limit our findings to the entire Canadian population of ICU physicians.

Through the clinical sensibility testing portion of the pilot test, a few participants questioned whether a survey would add value to the literature on EEG use. Several free text comments focused on the fact that many of the barriers to implementing EEG care are financial or that more research pertaining to the influence of EEG on patient clinical outcomes is needed. Some of these comments included, “Continuous EEG is ideal. I am not sure a questionnaire adds value. Further evidence base for it's actual value would be useful research. Economics is the ultimate problem and this needs to be explored further. Who will pay for this? How will sufficient physicians be supported for work in this field” and “current main barrier in canada is the limited institutions training electrophysiology technicians...the current output cannot accommodate the contemporary demand”. While these comments are valid, data assessing physician opinions on EEG and cEEG use is limited. This survey was designed to identify gaps in care in the hope that any results would push research further and perhaps encourage the
undertaking of patient outcome studies. While best efforts were made to ensure this survey addresses all aspects of current EEG use and barriers to implementing EEG technology, a survey is always limited to the questions that were asked. There may have been barriers or questions that were not addressed in this survey such as assessing the number of technicians working at each hospital, the amount of equipment available at each question, and the time when the majority of the respondent’s patients are admitted to the ICU.

Overall, this survey was well received by participating physicians. Various feedback comments included, “Excellent idea and I hope you get some valuable information from it” and “Nice survey. Should document that we cannot get continuous EEG when we feel it should be a standard of care”.

6.7 Next Steps

Steps need to be taken to overcome some of the barriers to implementing EEG monitoring in the ICU. Specifically, we recommend that formal economic analyses and health technology assessment may better examine financial barriers mentioned. Second employing adult education strategies for existing critical care personnel (physicians and nurses) may be useful in overcoming a current lack of personnel available to interpret EEG recordings and increase the total number of providers able to perform EEG testing. Overall, the results from this survey highlight that care providers believe EEG monitoring is important and lacking in ICU patient care. This survey highlights the specific gaps and recommends ways forward en route to improving best care for our neuro-critically ill patients.

6.8 Conclusions

This survey on EEG monitoring in critical care has identified important differences in perceived need for EEG monitoring and existing and ability to do so. Overall, respondents believe that conventional and continuous EEG monitoring should be a standard of care, and state they are unable to obtain timely investigations and therefore deliver suboptimal patient care. Several barriers including lack of EEG technician time, lack of financial resources, a lack of physicians able to interpret EEG and a lack of monitoring equipment have been identified as barriers optimal care and these were consistent among all respondents, regardless of background training. The quality of EEG recordings and validity of information obtained was not perceived
as a barrier. We have found that gaps in care are perceived to be exacerbated during non-standard working hours and may be greatest in adult institutions. Future research should consider comparing patient outcomes with the current care model and augmented ability to perform EEG, should consider formal health technology assessment including economic analyses to address financial barriers in implementation of perceived best care, and should explore mechanisms to improve gaps in number and skill of personnel to perform and interpret EEG in our hospitals.


Billings, J.A., Keeley, A., Bauman, J., Cist, A., Coakley, E., Dahlin, C., Montgomery, P.,


Canadian Critical Care Society (2009).

Canadian Institute for Health Information. Health Indicators 2009 (Ottawa, Ont.: CIHI, 2009). Canadian Institute for Health Information. Highlights of 2008-2009 inpatient hospitalizations and emergency department visits. (Ottawa: CIHI, 2010). Canadian Institute for Health Information, The burden of neurological diseases, disorders, and
injuries in Canada (Ottawa: CIHI, 2007).


Wilkins.


Appendices

Appendix 1: Scoping Review Search Terms

<table>
<thead>
<tr>
<th>#</th>
<th>Searches</th>
<th>Results</th>
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<td>41899</td>
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<td>2</td>
<td>limit 1 to english language [Limit not valid in Mental Measurements, AVOL, Books@Ovid, FIAF Databases, Index to Foreign Legal Periodicals, International Political Science Abstract, Journals@Ovid, CLRE, SWAB, Zoological Record; records were retained]</td>
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<td>3</td>
<td>limit 2 to human [Limit not valid in Mental Measurements, AMED, AVOL, Books@Ovid, CAB Abstracts, FIAF Databases, HAPI, Index to Foreign Legal Periodicals, International Political Science Abstract, Journals@Ovid, CLRE, SWAB, Transport Database, Wilson Art Index Retrospective, Zoological Record; records were retained]</td>
<td>38902</td>
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<td>4</td>
<td>limit 3 to yr=&quot;2001&quot; [Limit not valid in Mental Measurements, FIAF Databases, CLRE; records were retained]</td>
<td>1515</td>
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</table>
Appendix 2: List of Changes Made to the Survey During Development

- Removed list of medications used to treat Seizures

- Wording of statements changed so they are positive and symmetrical with other question perspectives (e.g. *I believe performance of EEG among critically ill patients suffers due to lack of collaboration between neurology specialists and critical care specialists* changed to *I believe collaboration between neurology specialists and critical care specialists enhances the performance of EEG among critically ill patients*).

- Removed question “Nurses in my ICU are enthusiastic to learn about and adopt new technology such as continuous EEG” as there were many neither agree nor disagree answers during pilot testing.

- Changed and added additional questions to distinguish between standard and continuous EEG as initial wording was deemed unclear to pilot survey respondents.

- Added clinical scenario questions to improve ability to detect ‘real-world’ differences in perceived actual and ‘best-practice’ EEG use.

- Added additional clinical scenario question for pediatric physicians as medications and doses differ from adult patients.

- Changed data ranges for demographic questions to reflect a broader range of respondents.

- Changed questions to reflect questions arising during clinical sensibility testing including: adding a detail about discontinuing propofol to clinical scenario questions, more accurately reflecting actual clinical practice with this medication.
### Appendix 3 Clinical Sensibility Testing Questions

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<tr>
<th></th>
<th>Small extent</th>
<th>Limited extent</th>
<th>Fair extent</th>
<th>Moderate extent</th>
<th>Large extent</th>
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<tbody>
<tr>
<td>To what extent are the questions directed at important issues pertaining to EEG use in Critical Care?</td>
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<td>To what extent are the response options provided simple and easily understood?</td>
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<td>To what extent are questions likely to elicit information pertaining to your use of and experience with EEG use in Critical Care?</td>
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Are there important issues pertaining to your use of EEG that should be included in the questionnaire that have been omitted?

- [ ] Crucial Gaps
- [ ] Important Gaps
- [ ] Minor Gaps
- [ ] Minimal Gaps
- [ ] Insignificant Gaps
How many items are inappropriate of redundant?

- Very many
- Many
- Some
- A Few
- Hardly Any

How likely is the questionnaire to elicit barriers for EEG use in Critical Care?

- Very Likely
- Unlikely
- Likely
- Quite Likely
- Very Likely
Appendix 4: Finalized Survey and Cover Letter

Dear Colleague,

Caring for critically ill patients with neurologic injury is challenging. Physical examination is often confounded by sedating medications and has poor sensitivity to discover and follow complications such as seizure activity. Electroencephalogram (EEG) and continuous EEG monitoring may be an important way to monitor an injured brain; however, the availability and implementation of EEG or cEEG is often limited. We aim to better understand the following questions:

1. What is the awareness of the frequency and seriousness of seizures in critically ill patients among clinicians?
2. What utility/need do clinicians place on EEG and continuous EEG?
3. What are the barriers to incorporating EEG and continuous EEG in critical care practice given a clinical need?

Your input and knowledge are essential in helping to answer these questions. The survey should take approximately 10 minutes to complete. If you would like a copy of the results once this research project has been completed please include your email address on the bottom of the final survey sheet. Thank you for taking the time to complete this survey – your participation denotes consent to participate. As a token of our appreciation, please email corrine.davies-schinkel@utoronto.ca once you have completed the survey to be entered to win an iPod Nano.

Sincerely,
Corrine Davies-Schinkel, MSc Candidate
Martin Chapman, BIM
Antonio Capone, MD
Cecil Hahn, MD
Anna Gaglardi, PhD
Rob Fowler, MD
Interdepartmental Division of Critical Care
University of Toronto.
Use the following definition for "continuous EEG monitoring": An EEG recording of at least 24 hours in length utilizing a standard 16-channel EEG montage applied in the International 10-20 system for electrode placement.

Use the following definition for "standard EEG": An EEG recording of approximately 30 minutes in length utilizing a standard 16-channel EEG montage applied in the International 10-20 system for electrode placement.

## EEG use in a Critical Care Environment
*(Please select one answer for each statement)*

<table>
<thead>
<tr>
<th>KNOWLEDGE</th>
<th>Completely Agree</th>
<th>Strongly Agree</th>
<th>Somewhat Agree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
<th>Completely Disagree</th>
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<tbody>
<tr>
<td>Which type of seizure is more common in ICU patients?</td>
<td>○ Convulsive</td>
<td>○ Non-convulsive</td>
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<td>Brain damage occurs within 3 hours of uncontrolled generalized non-convulsive seizures.</td>
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<td>Non-convulsive seizures occur in what proportion of traumatic brain injury patients in ICU?</td>
<td>0-20%</td>
<td>21-30%</td>
<td>31-40%</td>
<td>41-50%</td>
<td>51-60%</td>
<td>61-70%</td>
<td>&gt;70%</td>
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<td>I can diagnose seizures, including non-convulsive seizures, clinically in critically ill patients without EEG support.</td>
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<td>Continuous EEG is a more sensitive means of detection of seizures compared to routine EEG.</td>
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<th>CAPACITY</th>
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<td>I believe those performing EEG testing in my hospital view critically ill patients suspected of having seizures as a priority.</td>
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<td>I believe collaboration between neurology specialists and critical care specialists enhances the performance of EEG among critically ill patients.</td>
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<td>Standard EEG</td>
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<td>Technical capacity for standard EEG studies in critically ill patients</td>
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<td>patients is available in the hospital where I practice</td>
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<td>Interpretation of standard EEG recordings performed in the ICU is available in the hospital where I practice</td>
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<td>Standard EEG is available outside of typical business hours (e.g., 0800-1700 hours on weekdays) for critically ill patients in my hospital</td>
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<td>For critically ill patients with suspected non-convulsive status epilepticus, I am able to obtain a standard EEG within the first 3 hours after clinical suspicion</td>
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<td>I am able to obtain a standard EEG as quickly as I believe is optimal for patient care</td>
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<td>Continuous EEG Monitoring</td>
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<td>Technical capacity for continuous EEG monitoring in critically ill patients is available in the hospital where I practice</td>
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| I am able to obtain a continuous EEG as quickly as I believe is
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<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
<th>Completely Disagree</th>
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<td>I believe a lack of EEG technician time is a barrier to performing continuous EEG in my hospital</td>
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<td>I believe that standard EEG should be considered a standard of care for comatose critically ill patients</td>
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<td>I believe that EEG is adequately utilized in comatose critically ill patients at my hospital</td>
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<td>I believe standard EEG monitoring does not provide recordings of sufficient quality to be useful</td>
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<tr>
<td>I would perform some form of EEG in the following patients for whom an alternative diagnosis for the condition has not been found</td>
<td></td>
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<tr>
<td>Unexplained Coma (Glasgow Coma Score &lt;9) in any critically ill patient</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Uncontrolled Seizures (convulsive or non-convulsive) in any critically ill patient</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

A critically ill patient with Traumatic Brain Injury and unexplained alteration in level of consciousness

A critically ill patient with Subarachnoid Hemorrhage and unexplained alteration in level of consciousness

A critically ill patient with Anoxic Brain Injury and unexplained alteration in level of consciousness

A critically ill patient with Encephalitis and unexplained alteration in level of consciousness

A critically ill patient with Stroke and unexplained alteration in level of consciousness

A critically ill patient with Sepsis and unexplained alteration in level of consciousness

Other (write in): ___________________________________________
Consider the following clinical scenario (Adults):

An 80 kg, 64-year-old male with a prior stroke presents with status epilepticus on Thursday evening and is treated with 4 mg of lorazepam intravenously, followed by 1 g of intravenous midazolam. He is then sedated with a propofol infusion, intubated, and admitted to the ICU. While clinically sedated, a standard EEG is performed on Friday mid-day after interrupting the propofol infusion. The neurology consultant reads this EEG by late afternoon, detects residual electrographic seizure activity, and advises to increase the propofol infusion rate, an additional 500 mg of midazolam intravenously and 150 mg of dilantin intravenously three times daily for 4 days (96 hours), then to be reassessed.

When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

Consider the following clinical scenario:

Consider how this scenario would play out if this patient were to have been admitted on a Sunday evening...

When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
E. Within 72 hours after the change in therapy is implemented (on Thursday)
F. After 96 hours after the change in therapy is implemented (on Friday)

In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
E. Within 72 hours after the change in therapy is implemented (on Thursday)
F. After 96 hours after the change in therapy is implemented (on Friday)
Consider the following clinical scenario (Pediatrics):

A 5 year-old boy presents with status epilepticus on Thursday evening and is treated with 0.1 mg/kg of lorazepam intravenously, followed by 20 mg/kg of intravenous Dilantin [and 20 mg/kg of intravenous phenobarbital]. He is then sedated with a midazolam infusion and intubated and admitted to the ICU. While clinically sedated, a standard EEG is performed on Friday mid-day. The neurology consultant reads this EEG by late-afternoon, detects residual electrographic seizures, and advises to increase the midazolam infusion rate, give an additional of 10 mg/kg Dilantin intravenously and then 5 mg/kg Dilantin intravenously three times daily for 4 days (96 hours), then to be re-assessed.

When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Saturday)
D. Within 48 hours after the change in therapy is implemented (on Sunday)
E. Within 72 hours after the change in therapy is implemented (on Monday)
F. After 96 hours after the change in therapy is implemented (on Tuesday)

Consider how this scenario would play out if this patient were to have been admitted on a Sunday evening...

When do you believe it would be optimal to next perform EEG monitoring for this patient? (Circle one)

A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
E. Within 72 hours after the change in therapy is implemented (on Thursday)
F. After 96 hours after the change in therapy is implemented (on Friday)

In your institution, when is it most likely that an EEG would next be performed for this patient? (Circle one)
A. Continuously until there is no evidence of seizure activity
B. Within hours after the change in therapy is implemented (later the same day)
C. Within 24 hours after the change in therapy is implemented (on Tuesday)
D. Within 48 hours after the change in therapy is implemented (on Wednesday)
E. Within 72 hours after the change in therapy is implemented (on Thursday)
F. After 96 hours after the change in therapy is implemented (on Friday)

We’d now like to ask you a few questions to help us better understand the above responses:

In the past 12 months, how many critically ill patients do you estimate that you have treated? (Circle one)
1-50 51-99 100-149 150-199 200-250 >250

In the past 12 months, how many critically ill patients do you estimate you have monitored with standard EEG? (Circle one)
0 1-10 11-20 21-30 31-40 >40

In the past 12 months, how many critically ill patients do you estimate you have monitored with continuous EEG? (Circle one)
0 1-10 11-20 21-30 31-40 >40

How many years since you graduated from medical school: __________
For Which patients do you routinely provide critical care (check all that apply)

- General Medical Patients
- Surgical Patients
- Neurologically Injured Patients
- Neurosurgical Patients
- Traumatically Injured Patients
- Transplantation Patients
- Cardiovascular Surgery Patients
- Pediatric Patients

Which of the following ICUs do you work?(check all that apply)

- Community based ICU?
- University-affiliated ICU?

What is your primary specialty?(check all that apply)

- Anaesthesiology
- Internal Medicine / medical subspecialties
- Neurology
  - Paediatric Medicine
  - Neurosurgery
  - Surgery / other surgical subspecialties
  - Emergency Medicine
  - Other (please specify): ________________________________

Do you consider yourself to have formal sub-specialty training in neuro-critical care?  YES / NO

If yes, please specify the nature of this training: ________________________________

THANK YOU VERY MUCH.
Appendix 5 Clinical Sensibility Test Questions Free Text Comments

Are there important issues pertaining to your use of EEG that should be included in the questionnaire that have been omitted?

- “Who interpret the continuous EEG in your unit”
- “That an EEG should be performed after propofol has been D/C for about two hours”
- “Continuous EEG is ideal. I am not sure a questionnaire adds value. Further evidence base for it's actual value would be useful research. Economics is the ultimate problem and this needs to be explored further. Who will pay for this? How will sufficient physicians be supported for work in this field?"
- “More questions about reasons why physician interpretation is an issue - number of neurologists vs number comfortable reading complex EEG's”
- “We perform continuous EEG monitoring in over 100 ICU patients per year. I suggest changing the response options for this question to capture greater range of responses.”
- “Medical legal liability of cEEG lag in reporting”
Appendix 6 Survey Question Response Distributions - Raw Responses

Q1 - Which type of seizure is more common in ICU patients?

<table>
<thead>
<tr>
<th></th>
<th>Total Number of Responses</th>
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<tbody>
<tr>
<td>convulsive</td>
<td>35</td>
</tr>
<tr>
<td>non convulsive</td>
<td>67</td>
</tr>
</tbody>
</table>
Q2- Brain damage occurs within 3 hours of uncontrolled generalized non-convulsive seizures

<table>
<thead>
<tr>
<th>Response</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>completely agree</td>
<td>12</td>
</tr>
<tr>
<td>strongly agree</td>
<td>33</td>
</tr>
<tr>
<td>somewhat agree</td>
<td>31</td>
</tr>
<tr>
<td>neither agree nor disagree</td>
<td>18</td>
</tr>
<tr>
<td>somewhat disagree</td>
<td>3</td>
</tr>
<tr>
<td>strongly disagree</td>
<td>5</td>
</tr>
<tr>
<td>completely disagree</td>
<td>1</td>
</tr>
</tbody>
</table>
Q3- Non-convulsive seizures occur in what proportion of traumatic brain injury patients in ICU?
Q4 - I can diagnose seizures, including non-convulsive seizures, clinically in critically ill patients without EEG support
Q5- Continuous EEG is a more sensitive means of detection of seizures compared to routine EEG
Q6 - I believe those performing EEG testing in my hospital view critically ill patients suspected of having seizures as a priority

<table>
<thead>
<tr>
<th>Response</th>
<th>15</th>
<th>32</th>
<th>25</th>
<th>4</th>
<th>9</th>
<th>11</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>strongly agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>somewhat agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>neither agree nor disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>somewhat disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>strongly disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>completely disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q7- I believe collaboration between neurology specialists and critical care specialists enhances the performance of EEG among critically ill patients.
Q8- Technical capacity for standard EEG studies in critically ill patients is available in the hospital where I practice.
Q9- Interpretation of standard EEG recordings performed in the ICU is available in the hospital where I practice.
Q10-Standard EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital
Q11- Interpretation of standard EEG is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital
Q12- For critically ill patients with suspected status epilepticus, I am able to obtain a standard EEG within the first 3 hours after clinical suspicion.
Q13- I am able to obtain a standard EEG as quickly as I believe is optimal for patient care.
Q14- Technical capacity for continuous EEG monitoring in critically ill patients is available in the hospital where I practice
Q15 - Interpretation of continuous EEG recordings performed in the ICU is available in the hospital where I practice.
Q16- Continuous EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours on weekdays) for critically ill patients in my hospital
Q17- Interpretation of continuous EEG monitoring is available outside of typical business hours (e.g. 0800-1700 hours of weekdays) for critically ill patients in my hospital
Q18- For critically ill patients with suspected non-convulsive status epilepticus, I am able to obtain a continuous EEG within the first 3 hours after clinical suspicion.

<table>
<thead>
<tr>
<th>Response</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>completely agree</td>
<td>4</td>
</tr>
<tr>
<td>strongly agree</td>
<td>11</td>
</tr>
<tr>
<td>somewhat agree</td>
<td>8</td>
</tr>
<tr>
<td>neither agree nor disagree</td>
<td>3</td>
</tr>
<tr>
<td>somewhat disagree</td>
<td>11</td>
</tr>
<tr>
<td>strongly disagree</td>
<td>23</td>
</tr>
<tr>
<td>completely disagree</td>
<td>41</td>
</tr>
</tbody>
</table>
Q19- I am able to obtain a continuous EEG as quickly as I believe is optimal for patient care
Q20 - I believe a lack of physicians able to interpret EEG recordings in my hospital is a barrier to performing continuous EEG.
Q21- I believe a lack of EEG technician time is a barrier to performing continuous EEG in my hospital
Q22- I believe a lack of equipment is a barrier to performing continuous EEG in my hospital.
Q23- I believe a lack of financial resources is a barrier to performing continuous EEG in my hospital.
Q24- I believe that standard EEG should be considered a standard of care for comatose critically ill patients
Q25- I believe that continuous EEG monitoring should be considered a standard of care for comatose critically ill patients
Q26- I believe that EEG is adequately utilized in critically ill patients at my hospital

<table>
<thead>
<tr>
<th>Response</th>
<th>2</th>
<th>9</th>
<th>14</th>
<th>8</th>
<th>28</th>
<th>23</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>completely agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>strongly agree</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>somewhat agree</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>neither agree nor disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>somewhat disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>strongly disagree</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>completely disagree</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Q27- I believe standard EEG does not provide recordings of sufficient quality to be useful
Q28: I believe continuous EEG monitoring does not provide recordings of sufficient quality to be useful
Q29-36- I would perform some form of EEG in the following patients for whom an alternative diagnosis for the condition has not been found

- Unexplained Coma (Glasgow Coma Score <9) in any critically ill patient
- Uncontrolled Seizures in any critically ill patient
- A critically ill patient with Traumatic Brain Injury and unexplained alteration in level of consciousness
- A critically ill patient with Subarachnoid Hemorrhage and unexplained alteration in level of consciousness
- A critically ill patient with Anoxic Brain Injury and unexplained alteration in level of consciousness
- A critically ill patient with Encephalitis and unexplained alteration in level of consciousness
- A critically ill patient with Stroke and unexplained alteration in level of consciousness
- A critically ill patient with Sepsis and unexplained alteration in level of consciousness
Continuously until there is no evidence of seizure activity

- Within hours after the change in therapy is implemented (later the same day)
- Within 24 hours after the change in therapy is implemented (on Saturday)
- Within 48 hours after the change in therapy is implemented (on Sunday)
- Within 72 hours after the change in therapy is implemented (on Monday)
- After 96 hours after the change in therapy is implemented (on Tuesday)

<table>
<thead>
<tr>
<th>Optimal time to perform next EEG</th>
<th>61</th>
<th>14</th>
<th>4</th>
<th>1</th>
<th>2</th>
<th>0</th>
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</thead>
<tbody>
<tr>
<td>When next EEG will actually be done</td>
<td>11</td>
<td>9</td>
<td>8</td>
<td>2</td>
<td>41</td>
<td>8</td>
</tr>
</tbody>
</table>

Q38&39- Answers for Adult Clinical Scenario Question- Patient Admitted on Friday: Difference between Optimal time to Perform EEG and When it Would Actually be Completed
Continuously until there is no evidence of seizure activity
Within hours after the change in therapy is implemented (later the same day)
Within 24 hours after the change in therapy is implemented (on Tuesday)
Within 48 hours after the change in therapy is implemented (on Wednesday)
Within 72 hours after the change in therapy is implemented (on Thursday)
After 96 hours after the change in therapy is implemented (on Friday)

| Optimal time to perform next EEG | 58 | 16 | 5 | 1 | 2 | 0 |
| Time when next EEG will actually be done | 13 | 16 | 36 | 6 | 4 | 4 |

Q40&41- Answers for Adult Clinical Scenario Question- Patient Admitted on Monday: Difference between Optimal time to Perform EEG and When it Would Actually be Completed
Continuously until there is no evidence of seizure activity

Within hours after the change in therapy is implemented (later the same day)

Within 24 hours after the change in therapy is implemented (on Tuesday)

Within 48 hours after the change in therapy is implemented (on Wednesday)

Within 72 hours after the change in therapy is implemented (on Thursday)

After 96 hours after the change in therapy is implemented (on Friday)

<table>
<thead>
<tr>
<th>Optimal time to perform next EEG</th>
<th>14</th>
<th>4</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
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</thead>
<tbody>
<tr>
<td>Time when next EEG will actually be performed</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
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</table>

Q42 & 43 Answers for Pediatric Clinical Scenario Question - Patient Admitted on Friday: Difference between Optimal time to Perform EEG and When it Would Actually be Completed
Continuously until there is no evidence of seizure activity

Within hours after the change in therapy is implemented (later the same day)

Within 24 hours after the change in therapy is implemented (on Tuesday)

Within 48 hours after the change in therapy is implemented (on Wednesday)

Within 72 hours after the change in therapy is implemented (on Thursday)

After 96 hours after the change in therapy is implemented (on Friday)

<table>
<thead>
<tr>
<th>Optimal time to perform next EEG</th>
<th>Within hours after the change in therapy is implemented (later the same day)</th>
<th>Within 24 hours after the change in therapy is implemented (on Tuesday)</th>
<th>Within 48 hours after the change in therapy is implemented (on Wednesday)</th>
<th>Within 72 hours after the change in therapy is implemented (on Thursday)</th>
<th>After 96 hours after the change in therapy is implemented (on Friday)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Time when next EEG will actually be performed</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Q44&45- Answers for Pediatric Clinical Scenario Question- Patient Admitted on Monday: Difference between Optimal time to Perform EEG and When it Would Actually be Completed
Q46- In the past 12 months, how many critically ill patients do you estimate that you have treated?
Q47- Number of Patients Treated with Standard and Continuous EEG over the Last 12 months by the Responding Physician
Q50- For Which patients do you routinely provide critical care (check all that apply)

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
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<tbody>
<tr>
<td>General Medicine</td>
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<tr>
<td>Surgical</td>
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<tr>
<td>Neurologically Injured</td>
<td>78</td>
</tr>
<tr>
<td>Neurosurgical</td>
<td>55</td>
</tr>
<tr>
<td>Traumatically Injured</td>
<td>53</td>
</tr>
<tr>
<td>Transplantation</td>
<td>30</td>
</tr>
<tr>
<td>Cardiovascular Surgery</td>
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</tr>
<tr>
<td>Pediatric</td>
<td>18</td>
</tr>
</tbody>
</table>
Q51- Which of the following ICUs do you work? (check all that apply)

<table>
<thead>
<tr>
<th>Hospital Type</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community Based</td>
<td>24</td>
</tr>
<tr>
<td>University-Affiliated</td>
<td>81</td>
</tr>
</tbody>
</table>
Q52- What is your primary specialty? (check all that apply)

<table>
<thead>
<tr>
<th>Medical Specialty</th>
<th>Number of Responses</th>
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</thead>
<tbody>
<tr>
<td>Anaesthesia</td>
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<tr>
<td>Internal Medicine / medical subspecialties</td>
<td>51</td>
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<tr>
<td>Neurology</td>
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</tr>
<tr>
<td>Paediatric Medicine</td>
<td>14</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>0</td>
</tr>
<tr>
<td>Surgery / other surgical subspecialties</td>
<td>6</td>
</tr>
<tr>
<td>Emergency Medicine</td>
<td>3</td>
</tr>
</tbody>
</table>
Q53- Do you consider yourself to have formal sub-specialty training in neuro-critical care?

<table>
<thead>
<tr>
<th></th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>12</td>
</tr>
<tr>
<td>no</td>
<td>88</td>
</tr>
</tbody>
</table>
Appendix 7. Scoping Review Bibliography

**Adult:** 55 Articles

**Pediatric:** 17 Articles

** indicates Pediatric Article

**ICP Monitoring (16 Articles)**


of the Society of Critical Care Medicine and the World Federation of Pediatric Intensive and Critical Care Societies,


**Brain tissue Oxygenation & CPP (13 Articles)**


Intracerebral Microdialysis (2 Articles)


Seizure Detection: EEG standard, continuous and other (23 Articles)


**SSEP (2 Articles)**


**Transcranial Doppler (4 Articles)**


**MRI (1 Article)**

**CT (12 Articles)**


neuroimagen y monitorizacin de la presin intracranial como factores pronostico.]

Medicina Intensiva, 25(1), 8-13.


Other (2 Articles)


Multimodal monitoring (1 Article)

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