Overview of Adult Intracranial Pressure (ICP) Management & Monitoring Systems

Self-Learning Packet 2003

This self-learning packet is approved for 3 contact hours for the following professionals:

1. Registered Nurses

* This packet should not be used after 8/2005.
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Purpose

The purpose of this self-learning packet is to educate critical care nurses on adult ICP management and monitoring.

Objectives

After completing this packet, the learner should be able to:

1. Discuss the protective mechanisms of the brain.
2. Discuss the significance of abnormal characteristics in cerebral spinal fluid.
3. Describe the factors that interfere with autoregulation and can lead to secondary brain injuries.
4. Calculate and interpret cerebral perfusion pressure.
5. Discuss the significance of cerebral blood flow to brain tissue.
7. Identify clinical indications for ICP monitoring.
8. Design an educational plan for the patient / family about ICP monitoring.
9. Discuss care of the patient with an ICP monitor.
10. Analyze the type of ICP waveform and it’s nursing significance.
11. Identify adjuncts to ICP monitoring.

Instructions

In order to receive 3.0 contact hours, you must:

- complete the posttest at the end of this packet
- submit the answer sheet and payment ($10.00 for Orlando Regional Healthcare employees / $20.00 for non-employees) to:
  Orlando Regional Healthcare
  Education & Development, MP 14
  1414 Kuhl Ave.
  Orlando, FL 32806
- achieve an 84% on the posttest

Be sure to complete all the information at the top of the answer sheet. You will be notified if you do not pass, and you will be asked to retake the posttest.
Introduction

Anatomy Review

The protective mechanisms of the brain include the scalp, skull (8 cranial bones), 14 facial bones, brain tissue, meninges, blood brain barrier, intravascular component (blood in blood vessels), and cerebral spinal fluid.

Figure 1: Cranial Bones

Figure 2: Cranial Vault

The cranial vault is used to describe where the cerebrum, cerebellum, and brainstem are housed.
**Figure 3: Brain Tissue**

The following figure depicts the major structures of the brain that are important to intracranial pressure monitoring.

**Figure 4: Meningeal Layers**

There are three meninges that cover the brain and spinal cord: The dura mater, the arachnoid mater, and the pia mater. The dura mater is a two-layered membrane that lines the skull and is very difficult to penetrate. There is the possibility of having a space above and below the dura mater - above the dura is called “Epidural” and below is called “Subdural.”

The next two layers, the arachnoid and the pia mater are called the leptomeninges. They are extremely thin and difficult to visualize unless there is a space between them. This area is where cerebrospinal fluid (CSF) flows around the entire brain and spinal cord. The pia mater is a mesh-like substance that covers the entire surface of the brain tissue going into the sulci and gyri (folds of the brain).
**Intravascular Component**

It is important for the brain to maintain a constant flow of blood for brain activity to occur. The arterial blood flow to the brain consists of approximately 20% of the cardiac output. The brain is supplied by 2 pair of major arteries: the right and left carotid and right and left vertebral arteries. Normal cerebral blood flow (CBF) is 750 ml/min.

The carotid arteries provide circulation to the anterior portion of the brain (frontal, temporal, parietal and occipital lobes). This accounts for approximately 80% of the blood flow to the brain. The vertebral arteries join to form the basilar artery and comprise the posterior circulation of the brain (cerebellum, brainstem, and base of occipital and temporal lobes). This accounts for approximately 20% of the blood flow to the brain. The anterior and posterior circulation function separately; however, they connect together by communicating arteries to form the Circle of Willis. In response to decreased arterial flow, the Circle of Willis can act as a protective mechanism by shunting blood from one side to the other or from front to back. This is why there is sometimes a delay in neurological signs and symptoms in patients.

**Figure 5: Arteries that supply the brain**
**Blood-Brain Barrier**

The blood brain barrier is where the capillaries meet and are surrounded by special brain cells called astrocytes. Molecules enter into these brain cells by three processes: Active transport, endocytosis, and exocytosis. However, particle size, protein-binding potential, and lipid insolubility may prevent movement across the blood-brain barrier. The barrier is very permeable to water, carbon dioxide, oxygen, glucose, and lipid soluble substances. An intact blood-brain barrier restricts the movement of larger, potentially harmful substances from the bloodstream. During ischemic or infectious states, the membrane breaks down, allowing other substances to pass into the brain.

**Venous Drainage System**

The brain is drained by cerebral veins which drain into large venous channels called venous sinuses and then into the right and left internal jugular veins. The venous sinuses are found within the folds of the dura mater. The veins and sinuses of the brain do not have valves so blood flows freely and by gravity. The face and scalp veins also can flow into the brain venous sinuses; therefore, infection can easily be spread into the dural venous sinuses and then enter into the brain.

Patient position can prevent or promote venous drainage from the brain. Head turning and tilting may kink the jugular vein and decrease or stop venous flow from the brain. This then increases the pressure inside the cranial vault. To promote venous drainage, the head must be maintained in a neutral position and the head of bed elevated up to 30 degrees.

**Cerebrospinal Fluid**

Cerebrospinal fluid (CSF) bathes the entire brain and spinal cord. Approximately 250 – 500 cc’s is produced every 24 hours in the lateral ventricles by ependymal cells (vascular cells) on the choroid plexus. The purpose of CSF is to provide nutrients, remove waste products from cellular metabolism, and act as a shock absorber. The amount of CSF in the ventricular system at one time is approximately 125 cc’s. The process of CSF production and absorption must be maintained to prevent a change of the intracranial components.

CSF is absorbed from the subarachnoid space by the arachnoid villi (tiny projections) into the venous system (refer to Figure 4). When the CSF pressure is greater than the venous pressure, the arachnoid villi drain CSF into the venous system acting as a one-way valve. As described above, patient position can prevent this gravitational flow of CSF. In addition, fluctuations in pressure commonly occur due to a change in the cardiac and respiratory cycle.

CSF can be sampled in three places: Cisternal puncture (above C1), lumbar puncture (between 3rd and 4th lumbar vertebrae), or intraventricular catheter.

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**Characteristics of Normal CSF:**

- Clear, colorless, orderless
- Specific Gravity: 1.007
- pH: 7.35
- Chloride: 120 – 130 mEq/L
- Sodium: 140 – 142 mEq/L
- Glucose (fasting): 60% of serum glucose level (50 – 705 mg/dL)
- Lactate: 10 – 20 mg/dL
- Protein:
  - Ventricular: 5 – 15 mg/dL
  - Lumbar: 15 – 45 mg/dL
- Cells:
  - WBC’s: 0 – 5/ml
  - RBC’s: None
- Normal Pressure (lateral recumbent position):
  - 60 – 180 mm of water
  - 9 – 14 mm Hg
Characteristics of Abnormal CSF:

- Bright red – indication of an acute hemorrhage
- Xanthochromia – yellowish to light red discoloration due to breakdown of RBC’s; can indicate old blood
- Cloudiness – turbidity indicates infection due to increased WBC’s or protein
- Elevated Protein – CNS tumors, viral meningitis, hemorrhage, multiple sclerosis, Guillain Barre Syndrome
- Elevated WBC’s
  - Lymphocytes – Viral or TB meningitis, multiple sclerosis, CNS tumor, herpes, syphilis
  - Granulocytes – bacterial meningitis
- Decreased Glucose – bacterial meningitis, subarachnoid hemorrhage
- Elevated Lactate – increased glucose metabolism associated with bacterial or fungal meningitis, traumatic brain injury

**Intracranial Pressure**

Intracranial Pressure (ICP) is the combination of the pressure exerted by the brain tissue, blood, and cerebral spinal fluid (CSF). Normal ICP is between 9 – 14 mm Hg. The purpose of Intracranial Pressure (ICP) monitoring is to trend the pressure inside the cranial vault. The pressure readings determine the interventions necessary to prevent secondary brain injury, which can lead to permanent brain damage and even death. If the intracranial pressure is in the range of 20 – 25 mm Hg, therapeutic interventions, medical and/or surgical, should be initiated. This is because as the ICP increases, it gradually becomes more difficult for the blood to be pumped to the head to perfuse the brain tissue.

There are several known conditions that can raise the intracranial pressure. They include space occupying lesions, hydrocephalus, subarachnoid hemorrhage, intracranial infections, severe head injury, and hypoxic or ischemic events. These can lead to what is known as intracranial hypertension (elevated ICP). This may then lead to herniation of the brain, resulting in death of the patient.

Because the skull is completely filled with the volume of the brain tissue, blood and blood vessels, and CSF, any alteration in the volume may lead to an increase in the intracranial pressure, unless the brain can compensate. Management of the patient with intracranial hypertension is based on the Monroe – Kellie Doctrine which states: *When the volume of any of the three cranial components increases, the volume of one or both of the others must decrease or the ICP will rise.*

Normally, the brain has the ability to autoregulate its blood flow by dilation and constriction of blood vessels. This ensures a constant flow of blood (750 ml/min) to all areas of the brain. There are several factors that interfere with autoregulation. These are known as the **FOUR H’s:**

- Hypoxia (PaO$_2$ < 80)
- Hypercapnia (PCO$_2$ > 35)
- Hypotension (MAP < 90)
- Hypovolemia

To maintain cerebral blood flow (CBF), it is necessary to keep cerebral perfusion pressure (CPP) in the range of 60 – 100 mm Hg. When autoregulation is impaired, the CBF fluctuates with changes in the systemic blood pressure. This may be seen in the patient that is suctioned or who coughs, which causes a rise in blood pressure, resulting in elevated ICP.
Calculating Cerebral Perfusion Pressure (CPP)

In order to determine the CPP, you need the following values:

- MAP = Mean Arterial Pressure (obtained from non-invasive or invasive monitoring).
- ICP = Intracranial Pressure (obtained from the closed ICP monitoring system).

\[
\text{MAP} = \frac{(2 \times \text{DBP}) + \text{SBP}}{3}
\]

MAP can be calculated by multiplying the diastolic blood pressure (DBP) by 2, adding the systolic blood pressure (SBP), and then dividing by 3.

To calculate the CPP, subtract the ICP from the MAP (\(\text{CPP} = \text{MAP} - \text{ICP}\)). A normal CPP is between 70 mm Hg – 90 mm Hg. If the CPP is less than 60 mm Hg, this indicates hypoperfusion.

An acutely injured brain has a higher metabolic rate and therefore requires a higher cerebral perfusion pressure. In this case, the CPP should be maintained at a minimum of 70 mm Hg and up to 90 mm Hg. When the ICP is elevated, it is important to maintain a MAP of \(\geq 90\) mm Hg by using fluid and/or vasopressors. A Swan Ganz catheter (regular or volumetric) is usually indicated (not required) in managing the neurological patient. This can be used to monitor the MAP.

Cerebral Blood Flow

Cerebral blood flow (CBF) is the cerebral perfusion pressure divided by cerebrovascular resistance (CVR). Cerebrovascular resistance (CVR) is the pressure across the cerebrovascular bed from the arteries to the jugular veins. It is influenced by the inflow pressure (systole), outflow pressure (venous pressure), cross-sectional diameter of cerebral blood vessels, and ICP. CVR is similar to systemic vascular resistance; however, due to the lack of valves in the venous system of the brain, cerebral venous pressure also influences the CVR. CVR is the amount of resistance created by the cerebral vessels, and it is controlled by the autoregulatory mechanisms of the brain. Specifically, vasoconstriction will increase CVR, and vasodilation will decrease CVR.

Cerebral blood flow is calculated by subtracting the ICP from the MAP and dividing by the CVR or by dividing CPP by the CVR.

<table>
<thead>
<tr>
<th>Cerebral Blood Flow</th>
<th>Value</th>
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<tbody>
<tr>
<td>Average CBF</td>
<td>50 ml/100 Gm/min</td>
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<tr>
<td>Ischemia CBF</td>
<td>(&lt; 18 – 20 ) ml/100 Gm/min</td>
</tr>
<tr>
<td>Tissue death</td>
<td>(&lt; 8 – 10 ) ml/100 Gm/min</td>
</tr>
<tr>
<td>Hyperemia (CBF in excess of tissue demand)</td>
<td>(&gt; 55 – 60) ml/100 Gm/min</td>
</tr>
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</table>

CBF is affected by extrinsic and intrinsic factors. **Extrinsic factors** include systemic blood pressure, cardiac output, blood viscosity, and vascular tone. So if the MAP falls to less than 70 mm Hg, CBF will decrease. This decreased CBF will affect cerebral autoregulation, which is the major homeostatic and protective mechanism for the brain. It operates within a MAP range of 60 – 150 mm Hg. When outside this range, there is a varying of neural activity. This results in an alteration in cerebral metabolism, which consists of synaptic activity (50%), maintenance of ionic gradient – cell membrane (25%), and biosynthesis (25%) (March, K. 2002). The body responds to these demands with changes in blood flow. Remember that aerobic metabolism is critically dependent on...
oxygen in order to process glucose for normal energy production and that the brain does not store energy. Therefore, without a constant source of oxygen and energy, its supply from CBF can be exhausted within 3 minutes.

**Intrinsic factors** include PaCO₂ (pH), PaO₂, and intracranial pressure. The vessels dilate with increases in PaCO₂ (hypercarbia) or low pH and with decreases in PaO₂ (hypoxia). This vasodilatation increases CBF. Even a 1-mm Hg change in PaCO₂ will increase CBF 2 – 3% (between 20 – 80 mm Hg). The vessels constrict with decreases in PaCO₂ or high pH and with increases in local PaO₂. This vasoconstriction will decrease the CBF. In addition, intrinsic factors can change the extrinsic factors by altering the metabolic mechanisms. These changes can lead to an alteration in the CBF. For example, there can be a change from aerobic to anaerobic metabolism, which increases the concentrations of other end products such as lactic acid, pyruvic acid, and carbonic acid that causes a localized acidosis. These end products result in an increased pH which will cause an increase in CBF.

Other factors that can affect CBF include pharmacological agents (volatile anesthetic agents and some antihypertensive agents), rapid eye movement sleep, arousal, pain, seizures, elevations in body temperature, and cerebral trauma. (Hickey, 2002 p. 288).

**Compensation for Increased ICP**

The brain may try to compensate for the increase in one of the intracranial components by shunting CSF to the spinal subarachnoid space, increasing CSF absorption, decreasing CSF production, or by shunting venous blood out of the skull. Using some of these compensatory mechanisms, the brain will maintain a relatively normal ICP. When the brain has used all of these mechanisms, there will be a sharp rise in the ICP. This will lead to herniation of brain tissue downward through the Foramen Magnum (see Figure 1). As this happens, blood will cease to flow to the brain and brain tissue hypoxia, ischemia, infarction, necrosis, and death will occur.

**Treatment Modalities for Increased ICP**

There are some very simple nursing procedures and some complex medical interventions that can help maintain and lower intracranial pressure. The types of interventions used will depend on the patient’s specific clinical findings and medical history. However, the overall goal is to maintain and restore function whenever possible.

**The overall goals of the treatment modalities are:**

- Maintain the ABC’s (Airway, Breathing, & Circulation). This includes keeping the SaO₂ at 100%, PaCO₂ at 35-40 mm Hg, and the MAP >90 mm Hg. Also if you can monitor them, keep the PbtO₂ >20 mm Hg and/or the SjvO₂ >55% and <75%
- Keep the ICP < 20 mm Hg
- Give volume to maintain PCWP at 10-15 mm Hg or CVP at 5-10 mm Hg
- Add vasopressors, if needed, to maintain MAP > 90 mm Hg and to assist with CPP
- Determine optimal CPP for patient
- Keep brain temperature between 36 – 37 °C, if you have the ability to monitor
**Position**

By raising the head of the bed 15 – 30 degrees (no higher), venous drainage is promoted from the brain. Keep the patient’s head in neutral alignment with the use of rolled towels (or a soft cervical collar) and a head cradle (obtained from Central Supply). When turning, keep the patient’s hips flexed < 30 degrees; however, turning should be minimized. Greater than 30 degrees flexion of the hip increases intrathoracic pressure, which in turn decreases venous return from the brain.

**External Stimulus**

Patients in the intensive care units are often the victims of sensory overload. This poses a real danger to the patient with a neurologic alteration. The nurse must coordinate patient activities and continually monitor for signs of over-stimulation.

There are several things that can help minimize over-stimulation. Keep the door to the patient’s room closed to decrease the noise level (< 90 decibels). Restrict visitors to immediate family only. Keep the room dark, using low lighting when needed. When patient is receiving Occupational Therapy (OT) or Physical Therapy (PT), carefully monitor their ICP readings. If there is an elevation (>20 mm Hg) in the ICP, therapy should be postponed or discontinued.

**Mild Hyperventilation**

If mild hyperventilation is ordered, intubation and mechanical ventilation are required. The effects of hyperventilation can be noted less than 30 seconds from onset, and the peak effect is noted at approximately 8 minutes. The goal is to maintain the PCO$_2$ level 30 - 35 mm Hg. Maintaining the PCO$_2$ at this level will vasoconstrict the cerebral blood vessels, thereby decreasing the blood flow to the brain, which decreases the ICP according to the Monroe-Kellie Doctrine. If the PCO$_2$ level falls below 30, it can result in the opposite effect. Continuous monitoring of the patient’s End-Tidal Carbon Dioxide (ETCO$_2$) level is necessary. Correlating the ETCO$_2$ value with the patient’s arterial blood gas (ABG) value will prevent unnecessary blood draws.

The airway must remain patent, and therefore suctioning may be required at times. Prior to suctioning, the patient should be hyper-oxygenated. Then suctioning should last no more than 10 seconds, allowing a rest period to return of “normal” patient vital signs. Two or three passes with the suction catheter are recommended at one time. In addition, irritation of the ETT may cause the patient to cough, thereby elevating the ICP. An order may be obtained from the physician to instill a solution of Lidocaine down the ETT prior to suctioning to suppress the cough reflex. If the patient is orally intubated, secure the endotracheal tube tape over the patient’s ears, as this does not place any pressure on the jugular or carotid vessels.

**Diuretics**

Mannitol is the diuretic of choice. It is recommended to be given in bolus doses rather than a continuous infusion. Mannitol acts as an osmotic diuretic, pulling fluid from healthy brain cells. If there is a response, it is seen in minutes. Anticipate an order of Mannitol to be approximately 1 mg/kg. The serum sodium and osmolarity should be monitored when using Mannitol. Mannitol should be held when the serum osmolality is between 310 – 315 mOsm/Kg. It should be discontinued when the serum osmolality exceeds 320 mOsm/Kg. It should also be tapered to prevent rebound increased intracranial pressure.
Lasix, a loop diuretic, although not typically ordered, may be used. Lasix pulls excessive fluid from the vascular system and decreases the production of CSF. Baseline potassium should be documented prior to administration of lasix and the level monitored PRN.

The overall goal is to keep the patient euvoletic with the aid of hemodynamic monitoring, CVP or PA catheter. IV fluid of choice is NS with 20 mEq KCl/L.

**Sedation** (Refer to your established ICU guidelines)

The use of sedation is indicated for the neurological patient with signs of increased intracranial pressure. Sedation reduces elevated sympathetic tone and hypertension induced by movement. Sedatives should be titrated to a Riker Sedation-Agitation Scale (SAS) score of 3 – 4. Lorazepam is the anxiolytic of choice for patients expected to be mechanically ventilated for 24 hours to 5 days. Diazepam is the drug of choice for long-term anxiolysis. In addition, Lorazepam may be used for breakthrough agitation when Diazepam is utilized.

Propofol is a very useful agent in controlling intracranial hypertension following brain injury. It is recommended for use after the patient has failed conventional sedation with narcotics and benzodiazepines. The patient must be intubated and on a mechanical ventilator to maintain respiratory function. A baseline 12-lead EKG and continuous cardiac monitoring is necessary during infusion. The patient must be monitored for bradycardia and elongation of the PR or QT interval. Serum calcium levels should be maintained within normal levels and should be monitored prior to and during the infusion. The patient must also be monitored for hyperlipidemia. The infusion should be used at the lowest dose necessary to achieve the desired clinical effect and should be discontinued as soon as possible. The infusion is titrated to the desired Riker score or ICP/CPP as indicated by physician. Typical infusion rates are 25 – 50 mcg/kg/min. If the infusion rate exceeds 80 mcg/kg/min, systemic effects may begin to appear.

**Systemic Effects of Propofol**

- Bradycardia
- Hypotension
- PR or QT elongation
- Increasing vasoactive medication requirements
- Arrhythmias
- Worsening metabolic acidosis
- Methemoglobinemia

**Barbiturate Coma (Heavy Sedation)**

Refer to your hospital’s policy and procedure regarding neurological monitoring of a patient in a barbiturate coma.

The physician may order the patient to be placed into a medicated coma, otherwise known as a barbiturate coma. Short-acting barbiturates most commonly prescribed are pentobarbital (Nembutal) or thiopental. Barbiturates act on the central nervous system by decreasing cerebral blood flow, thereby decreasing the cerebral metabolism. Barbiturates also have a systemic effect on the cardiovascular system causing the peripheral venodilation of blood vessels and the pooling of blood in the periphery. The patient MUST be intubated, placed on mechanical ventilation, and hemodynamically monitored (including continuous arterial line pressure monitoring). It is highly recommended to have a Swan Ganz catheter placed for advanced hemodynamic monitoring and to have continuous EEG (Electroencephalogram) monitoring. With the effects of the barbiturates on the cardiovascular system (hypotension and myocardial depression), the nurse must anticipate a drop in...
blood pressure and mean arterial pressure (MAP). The use of vasoactive drugs (e.g. dopamine and/or phenylephrine hydrochloride infusion) may be indicated to keep the MAP $\geq 90$ mm Hg.

With the use of barbiturates, the neurological assessment is severely diminished or lost; however, pupillary assessment can still be monitored. The brain’s electrical activity may also be monitored using an EEG machine. The nurse monitors the electrical waveforms, noting any suppression of the electrical activity. The goal is to achieve burst suppression of electrical activity of 3-6 seconds. Suppression of brain waves lasting more than 6 seconds indicates high levels of barbiturates and/or cerebral death. See the appendix for more information on EEG monitoring.

Therapy consists of administering a loading dose 10mg/kg infused over 30 minutes with a recommendation of 5mg/kg every hour for three doses. Then a maintenance dose titrated to 1–3 mg/kg/hr for a continuous infusion is needed to control ICP. Duration of barbiturate therapy for intracranial hypertension is up to 48 hours; however, it is the physician’s decision as to the length of therapy. Barbiturate levels of 30–40 mg/dL (as measured in the serum) have been shown to control ICP’s $>20$ and cause burst suppression of the EEG waveform. Barbiturate levels may be done if therapy is extended beyond 72 hours because they are stored in body fat. Liver and renal function should also be monitored as the drugs are metabolized and excreted through those systems. The half-life of pentobarbital is 15–48 hours and thiopental is 11-12 hours. Remember barbituates must be cleared from the body before a complete neurological assessment can be performed.

Neuromuscular Blocking Agents (NMBA’s) (Heavy Sedation / Paralytics)

In some hospitals, neuromuscular blocking agents (NMBA’s) are utilized in conjunction with barbiturate therapy; or NMBA’s with analgesics (Morphine Sulfate) and amnesic (Versed) as continuous IV therapy. NMBA’s act by paralyzing the muscles to decrease tissue metabolism. Continuous infusions are recommended over bolus dosing. NMBA’s utilized include:

### Long-Acting Agents

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<thead>
<tr>
<th>Medication</th>
<th>Elimination</th>
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<tbody>
<tr>
<td>Atracurium (Trancium)</td>
<td>Hofmann degradation*</td>
</tr>
<tr>
<td>Cisatracurium (Nimbex)</td>
<td>Hofmann degradation*</td>
</tr>
<tr>
<td>Doxacurium (Nuromax)</td>
<td>Kidneys and Liver</td>
</tr>
<tr>
<td>Pancuronium (Pavulon)</td>
<td>Kidneys and Liver</td>
</tr>
<tr>
<td>Pipecuronium (Arduan)</td>
<td>Kidneys and Liver</td>
</tr>
<tr>
<td>Tubocurarine (Tubarine)</td>
<td>Kidneys and Liver</td>
</tr>
<tr>
<td>Vecuronium (Norcuron)</td>
<td>Kidneys and Liver</td>
</tr>
</tbody>
</table>

### Short-Acting Agents

<table>
<thead>
<tr>
<th>Medication</th>
<th>Elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mivacurium (Mivacron)</td>
<td>Hydrolysis by plasma esterases</td>
</tr>
<tr>
<td>Rapacuronium (Raplon)</td>
<td>Kidneys and Liver</td>
</tr>
<tr>
<td>Rocuronium (Zemuron)</td>
<td>Kidneys and Liver</td>
</tr>
<tr>
<td>Succinylcholine (Anectine)</td>
<td>Kidneys and Liver</td>
</tr>
</tbody>
</table>

* Hofmann degradation is an enzymatic process that occurs when there is a change in the pH of the medication.

If barbiturate therapy is not used with NMBA’s, a continuous infusion of Morphine Sulfate and Versed is used. The nurse must monitor the patient’s Train of Four (TOF) responses using a peripheral nerve stimulator (PNS) PRIOR to beginning the infusion, with changes in dosage and per unit protocol. See the appendix for information on Train of Four.
In addition to monitoring the TOF, the nurse needs to maintain the patient’s airway and ensure adequate ventilation. This includes making sure that the Respiratory Therapist has set the ventilator alarms to detect even the slightest change in pressure, answering ALL alarms immediately, and keeping a bag-valve-mask at the bedside and with the patient at all times.

Because the patient cannot move, the nurse needs to turn the patient every two hours, provide passive range of motion, and use a pressure reducing device on the mattress, such as an air mattress. The eyes also need special care since the patient cannot blink. This may be accomplished by using eye lubrication, artificial tears, or by taping the eyes closed.

The appropriateness of discontinuing use of NMBA’s should be assessed in conjunction with the physician. This should be done every 24 hours, comparing the current assessment to the patient’s baseline condition. In addition, appropriate lab values should be monitored (LFT’s, BUN, Cr, and Creatine clearance). Refer to your hospital’s policy and procedure for frequency in monitoring and documentation of assessment findings.

**Steroids**

Although controversial, steroids such as Decadron may be administered. The theory is that the steroids stabilize the cell membrane, thereby decreasing the permeability of the brain cells to water. This aids in decreasing cerebral edema.

**Surgery**

As a last resort, the physician, after talking with the family, may take the patient to surgery. This treatment allows for removal of brain tissue to prevent herniation.

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**Intracranial Pressure Monitoring**

Intracranial pressure monitoring may be ordered by the physician so that the patient’s cranial pressure can be closely monitored and appropriate treatments initiated. The main indications for ICP monitoring are:

- Glasgow Coma Scale (GCS) < 8
- Posturing (extension, flexion)
- Bilateral or unilateral pupil dilation (except with Epidural Hematomas)
- CT Scan results showing edema and/or mid-line shift
- Physical assessment/neurological assessment findings which indicate a need for monitoring

There are two main relative contraindications. First, if the patient is “awake.” In this case, monitoring is usually not necessary since a neuro exam can be used. Second, if the patient has a coagulopathy, including DIC. If ICP monitoring is needed, steps should be taken to correct the coagulopathy, such as administering fresh frozen plasma or platelets.

**Types of ICP Monitoring**

There are several different ways to measure the pressure within the compartment of the skull. These methods may include Subdural, Parenchymal or Intraventricular intracranial pressure monitoring. They may be used to only monitor the pressure or to monitor the pressure and to drain CSF.
Subdural Drain / Monitoring

In this type, the catheter is positioned below the dura mater as seen in Figure 6. It is most frequently used to drain a sub-dural hematoma collection but can be hooked up to a fluid transducer to monitor pressure.

Advantages
- Obtains readings from subdural space
- Less Invasive

Disadvantages
- Cannot drain CSF

Figure 6: Subdural ICP Sensor

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**Parenchymal ICP Monitoring**

In this case, the catheter is positioned directly into brain tissue, penetrating through the dura mater, arachnoid, and pia mater. This can be seen in Figure 7.

The catheters available to monitor the parenchymal pressure are fiberoptic (using a light sensor to correlate to ICP waveform) or contain a microchip (correlating atmospheric pressure to ICP). The information is fed into a separate monitor before being transduced to the monitoring system. The fiberoptic catheter brand is usually transduced to a Camino monitor or Ventrix monitor manufactured by Integra Neurosciences. The microchip sensor is usually transduced to a CODMAN® ICP Express monitor manufactured by Codman and Shurtleff, Inc. All of these monitors have the capability of monitoring parenchymal and intraventricular pressures.

**Advantages**
- Obtains readings from brain tissue
- Microchip = Codman / Fiberoptic catheter = Camino, Ventrix

**Disadvantages**
- Cannot drain CSF
- Requires secondary machine / attachment to hospital monitoring system
- Moderately to highly invasive
- Subject to measurement drift
- Destroys brain tissue
- More expensive

**Figure 7: Parenchymal ICP Sensor**

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Intraventricular ICP Monitoring

In this case, the catheter is placed into one of the ventricles. The brain has four (4) ventricles, which contain CSF. There are two lateral ventricles (right and left) located in each hemisphere, a third ventricle that lies in the middle of the brain below the two lateral ventricles, and a fourth ventricle that lies between the brain stem (pons) and the cerebellum. The ventricle that is most frequently cannulated is the right lateral ventricle. Patients with a wide variety of diagnoses (e.g., head trauma, brain tumors, and hydrocephalus) may have this type of ICP monitoring system placed. In addition, patients undergoing sub-occipital (posterior–occipital/cerebellar area) craniotomy may on occasion have a 4\textsuperscript{th} ventricle ICP monitoring system placed.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtains readings from the ventricles</td>
<td>Difficult to insert into compressed or displaced ventricles</td>
</tr>
<tr>
<td>Most accurate</td>
<td>Highly invasive</td>
</tr>
<tr>
<td>Can drain CSF – to alter one of the three components of the cranial vault</td>
<td>Increased risk of infection (catheter sits in the intraventricular system)</td>
</tr>
<tr>
<td>Catheter is more flexible</td>
<td>Obstruction of fluid column may cause inaccuracy in pressure readings</td>
</tr>
<tr>
<td>Lower cost</td>
<td>Must be maintained at a fixed reference (foramen of Monro – see Figure 3)</td>
</tr>
</tbody>
</table>

Figure 8: Intraventricular catheter

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ICP Catheter Insertion

Preparation for ICP Catheter Insertion

When ICP monitoring is indicated, the neurosurgeon will obtain informed consent from the patient’s family to place a monitoring system. In an emergent situation, the family will be informed after the procedure is completed. It is very important for the family to understand the importance and purpose of ICP monitoring. The family’s level of understanding of the patient’s status and how it relates to current treatment modalities should be evaluated frequently.

Prior to placement of the ICP catheter, it is extremely important to have the following laboratory values: CBC with Platelet Count, PT / PTT, and Electrolytes. These values must be within normal limits, and all coagulopathies MUST be corrected prior to placement. The neurosurgeon will also need to have a copy of the patient’s CT Scan at the bedside to refer to, if needed, during insertion. In addition, since ICP catheter insertion is a highly invasive procedure, it is recommended that patients with ICP monitoring systems or CSF drainage systems receive antibiotics prophylactically.

The neurosurgeon placing an ICP catheter will consider which is the patient’s dominant hemisphere when determining where to place the catheter. The dominant hemisphere controls the speech center and motor pathways. This is important because with the insertion of the ICP catheter brain tissue is destroyed. As a rule, the majority of the population is left hemisphere dominant, as demonstrated by being right-handed. Therefore, the neurosurgeon will place the ICP catheter on the right side of the brain. In addition, since the majority of left-handed people still present with their speech and motor center in the left hemisphere, the neurosurgeon would still place the ICP catheter on the right side of the brain.

Equipment Necessary for ICP Catheter Insertion

A sterile environment is necessary due to the invasiveness of the procedure and the lack of defense mechanisms once the brain is penetrated. Insertion of an ICP catheter may be done in the operating room or, in an emergent situation, at the bedside (in the Emergency Room or Intensive Care Unit).

Sterile equipment - necessary for all types of catheters

The following equipment is needed for all types of catheter insertions. Additional equipment is listed under each of the catheter types.

- **Gown**
- **Betadine**
- **Lidocaine with epinephrine**
- **Mask**
- **Clippers, razors**
- **Bath towels for head elevation**
- **Sterile gloves**
- **Foam tape**
- **Suture (3-0 nylon preferable)**
- **Towels**
- **Benzoin**
- **Needle driver**
- **4 x 4**
- **Betadine ointment**

Parenchymal Catheter Insertion Equipment:

The following will be needed for parenchymal catheter insertions.

- **Monitor – Interface control unit**
- **Kit:**
  - ICP express transducer cable
  - Microsensor basic kit
  - Microsensor control unit cable
  - Microsensor skull bolt kit
  - External drainage system
  - Ventricular catheter kit
Intraventricular Catheter Insertion Equipment:

- Intraventricular catheter
- Drainage bag
- Twist drill disposable kit or ventriculostomy tray
- “No flush” transducer (stopcock at the end) primed with Preservative Free Normal Saline (PFNS)
- External drainage bag

**Note:** The catheter must remain sterile and all systems must be balanced and calibrated prior to insertion into the patient.

**Patient Preparation for Procedure**

Appropriate patient preparation is essential. Preparation includes monitoring the ABC’s (airway, breathing, circulation). Maintaining an open airway is extremely important and intubation is indicated if the patient’s Glasgow Coma Scale is < 8.

Positioning is also important. The patient must be in a supine position with the head elevated on a folded towel, keeping the head midline. The patient should be at the top edge of the bed with the headboard of the bed removed. The head of the bed should be elevated to 30 degrees.

The patient must be prepped prior to insertion. This is done by shaving the patient’s hair (usually non-dominant right side). Then, using sterile gloves, scrub the area with a Betadine scrub brush or Betadine soaked 4 x 4’s for several minutes. Then allow to air dry. The shaved hair should be placed in a plastic container labeled with the patient information to be saved and given to patient or family member.

The patient cannot move his head during the insertion of the ICP catheter. Therefore, sedation and/or neuromuscular blockade agent may be required prior to and during the procedure. The physician will order the type and dose.

**ICP Catheter Insertion**

The physician will apply a mask, hat, sterile gown, and new sterile gloves. Anyone in the room during the insertion procedure must also wear a hat, mask, and gloves to maintain the sterile environment.

The physician prepares the ICP catheter and ICP kit. The physician then instills a local anesthetic in the area the procedure is going to be performed. Usually Lidocaine 1% with Epinephrine (1:100,000) is used to prevent bleeding of the scalp veins/arteries. It is important to avoiding bleeding since even a small amount of scalp blood can track down the ICP catheter and increase the pressure inside the cranial vault.

The physician then makes a hole in the skull. During this, the nurse will need to hold the patient’s head still to avoid any movement. The physician then makes an incision about 2-3 inches away from the hole. He then inserts the catheter and places the catheter and tracks the catheter under the skin to the hole. This helps in the prevention of infection. The procedure is completed by suturing the burr hole site, applying Betadine ointment at the catheter exit, prepping the skin with tincture of Benzoin, covering the site with a sterile 2 X 2, and securing with foam tape.
**Documentation of Insertion and Post-Insertion**

It is important for both the nurse and physician to document regarding the insertion procedure. Items that the nurse should include are listed below.

- Pre-procedure neurological assessment
- Medications given to patient prior to and during procedure
- Conditions under which ICP catheter is inserted
- Type of procedure/catheter placed (reference number, if applicable)
- Catheter location (i.e. right or left, frontal, parietal, or occipital)
- Post-procedure neurological assessment
- Opening pressures
- Calculation of cerebral perfusion pressure (CPP)
- Characteristics of CSF (color, clarity, flow and quantity)
- If ICP elevated, what treatment was ordered by MD
- If CPP < 60, what treatment was ordered by MD
- Waveform
- Level of the transducer – foramen of Monro (outer canthus of eye, top of ear, or tragus of ear)
- Level of the bag (place the “O”-Zero on the scale level with the foramen of Monro, slide the chamber on the drainage bag to the prescribed level – usually 20 mm Hg, make sure collection bag is clamped off). *See section on intraventricular ICP monitoring system example for a diagram of this.*
- Condition of the dressing
- HOB position
- Any procedure performed on the drainage system during insertion, such as irrigation and/or sampling
Monitoring Equipment Set Up

Each monitoring system has its own catheters, sensors, cables, and monitors. The appendix of this packet will provide a guide for how to set up several of the common systems. However, always follow the manufacturer’s guidelines and your institution’s policy and procedures when setting up monitoring equipment.

In general, components of ICP pressure monitoring systems are non-compressible tubing, 3-way stopcock, transducer, preservative free normal saline fluid, monitor and connecting cable. The transducer converts pressure into a digital signal for display on the monitor. Zeroing the monitor eliminates the influence of atmospheric pressure and increases accuracy. When zeroed, the transducer must be level to the foramen of Monro to eliminate the effects of gravity. These two actions will validate the measurement obtained.

Parenchymal ICP Monitoring System Example:

Camino Parenchymal ICP Monitoring System

**Intraventricular ICP Monitoring System Example:**

Direct cannulation of the ventricles allows for drainage of both CSF and ICP monitoring. The catheter is hooked directly up to a “NO FLUSH” fluid transducer. The fluid used is Preservative Free Normal Saline (PFNS). The transducer is connected directly to the bedside monitor. The transducer is then placed at the level of the foramen of Monro. This is located at the outer canthus of the eye, at the top of the ear, or at the tragus of the ear. For every inch of discrepancy between the level of the transducer and the pressure source, there is an error of approximately 2 mm Hg.

When using an ICP drainage system, you should not have a pressure pack attached since this can result in an increase in ICP. In addition, to help prevent infection and system damage, keep all stopcocks capped and use luer-lock connections.
Components of the ICP Waveform

The ICP waveform is a significant part of the neurological assessment. Cerebral compliance (the ability of the three cranial components to maintain normal pressure) can be identified by the morphology of the waveform. Hence, it is important to document the waveform each shift including any noted morphologic changes. The waveform arises from the pulsation of the arterial blood through the cerebral arterial vessels. The normal ICP waveform is a sawtooth pattern. The waveform has three notches of importance – P1, P2, and P3.

- **P1** is known as the percussion wave. It is significant in that it reflects the arterial pressure (transmitted through the choroid plexus) and is sharply peaked and fairly consistent in amplitude.
- **P2** is known as the tidal wave. It is variable and indicates cerebral compliance. If it elevates or exceeds the level of the P1 waveform and the ICP remains elevated despite medical treatment, there will be a marked decrease in cerebral compliance.
- **P3** is known as the dicrotic wave. It is significant in that it reflects the venous pressure and immediately follows the dicrotic notch on the arterial waveform.

Normal ICP Waveform

Waveform Types

When trended over time (1-2 minutes), there are three distinct types of ICP waveforms. There are A Waves or Plateau Waves, B Waves, and C Waves.

**A Waves or Plateau Waves** are significant. These waves correlate with a patient who has cerebral hypoxia, ischemia, and possible areas of infarction. These indicate decreasing cerebral compliance or advanced intracranial hypertension. The patient will exhibit symptoms of neurologic dysfunction as noted by examination. This waveform is seen in a patient with an ICP 50 – 100 mm Hg.
**B Waves** are not significant and are often associated with the respiratory cycle. They are intermittent elevations in the pressure of 20 – 50 mm Hg that is not sustained.

<table>
<thead>
<tr>
<th>Scale</th>
<th>mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td>Minutes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

**B Waveform:** Pressure peaks 20 – 50 mm Hg

**C Waves** are not significant and are considered normal. They are related to the systemic changes of the arterial pressure. This includes pressures up to 20 mm Hg.

<table>
<thead>
<tr>
<th>Scale</th>
<th>mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Minutes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

**C Waveform:** Rhythmic waves occurring with changes in ventilation and blood pressure

**Ongoing Monitoring of Waveforms**

Part of your ongoing assessments and documentation includes monitoring ICP waveforms. Remember that you need to zero the monitor prior to obtaining measurements. Zeroing the monitor eliminates the influence of atmospheric pressure and increases accuracy. When zeroed, the transducer must be level to the foramen of Monro to eliminate the effects of gravity. These two actions will validate the measurement obtained. Although the monitor will give you a numeric display of pressure, the interpretation of the ICP waveform must be performed to validate the numeric display. The scale used is dependent on the digital signal on the monitor and must be set to the appropriate number to achieve accurate interpretation. The ICP also must be interpreted taking into consideration the patient’s diagnosis, neurological exam, and treatment plan. Patient waveforms may indicate the following problems: dampening, poor compliance, intracranial hypertension, and lost autoregulation.
In order to interpret a waveform, you must first understand the paper and the corresponding units of measure. Monitor paper is made up of small and large measured boxes in millimeters. The smallest boxes are 1-mm wide and 1-mm high. The horizontal axis of the paper relates to time. Time is in seconds. The constant speed at which it records is 25 mm/sec. At this speed 0.04 sec = 1 mm, which is one small box. Five small boxes (0.04 seconds) equals one large box, which represents 0.2 seconds. Five large boxes represents one second. Fifteen large boxes equal an interval of three seconds. Thirty large boxes represents six seconds.

The scale for the amplitude will vary depending on your settings. The amplitude or height is made up of 4 small boxes, instead of 5 small boxes. Each small box is equal to $\frac{1}{4}$ of the scale used, so if the scale is 0/10/20/30 then each small box is equal to 2.5 mm Hg. The highest scale that can be used is 0/60/120/180.

To measure the ICP, draw an imaginary line across the waveform just above the dicrotic notch. Then compare to the scale at the left. In the above case, the ICP would be 70 mm Hg.

**Sample Waveforms**

The strip below indicates that the patient has two ICP monitoring systems. The type of catheter (ventriculostomy or parenchymal) is unknown. Documentation of catheter type will be found in the patient’s medical record. In analyzing waveform number 1, the first thing evident is that the waveform is above the scale. Analysis should stop at this point. Validity of the number to the waveform is not accurate. The scale must be changed so the waveform is within the scale. In analyzing waveform number 2, the waveform is at the top of the scale. Again, analysis should stop at this point. The waveform peak at the top of the scale could possibly dampen the waveform. The scale must be changed so the waveform is fully within the scale. Once the scale is changed, analysis can continue.
This next strip indicates that there are two ICP monitors in place. In analyzing waveform number 1, the waveform is within the scale (20, 50, 60). The components of the ICP waveform P1, P2, and P3 can be identified. The ICP calculated from the strip can therefore be compared with the digital readout on the monitor to check for accuracy. In analyzing waveform number 2, notice that the waveform is flattened (scale 10, 20, 30). To troubleshoot this problem, you need to know if the ICP catheter is a ventriculostomy. If it is, the dampened waveform may indicate that it is open to drain, the stopcock may be turned, the catheter may be clogged, or the patient may have herniated brain tissue in that hemisphere. If it is a parenchymal ICP catheter, the catheter may be cracked or dislodged.

**Troubleshooting abnormal or dampened waveform and/or negative numbers:**
1. Check system set-up
2. Check system for air bubbles, clots, or brain tissue in tubing & transducer
3. Zero and recalibrate
4. Check scale and labels for accuracy
5. Check filter on drainage bag for wetness
6. Check patency of the catheter by observing for flow of CSF. Lower the drainage bag below the foramen of Monro
7. Observe the response to jugular vein compression. A transient rise in ICP will be observed with compression. If no increase, the accuracy of the pressure readings should be questioned as the catheter may be occluded.

The strip below shows one ICP waveform with the ECG. There is no scale associated with this waveform. The analysis of the waveform cannot be validated without the scale. The waveform shows all the components, P1, P2, and P3. Note that P2 is above P1 which indicates intracranial hypertension and decreased intracranial compliance. However, without a scale, the analysis is incomplete.
This monitor strip shows an a-line and ICP waveform. Note the scale is inaccurate for both the a-line and ICP waveform since the waveforms are above the scales. These waveforms cannot be validated with the digital signal from the monitor. If the ICP exceeds the maximum scale available on the monitor, waveform analysis must proceed without validation. Focus instead on the patient’s clinical presentation and the three notches (P1, P2, and P3). In this instance, the patient’s ICP is 133, HR 60 bpm, Cuff BP 190/88, pupils are 6 mm and fixed bilaterally, and there is no motor response to central noxious stimulus. This clinical presentation suggests the patient is demonstrating signs of non-compliance and beginnings of herniation. Note that P2 is greater than P1 which also indicates a decrease in intracranial compliance.

Care of ICP Catheters

Always refer to your hospital’s policy and procedure manual for further reference on care of ICP catheters. This packet presents a general guideline only.

CSF is sterile and all procedures involving catheter care must maintain sterility. Dressings should be sterile gauze with occlusive tape on the edges for ventriculostomies. On occasion, the MD will place his own dressing. The dressings are changed by the nurse when no longer occlusive. When changing the dressing, the nurse must wear a mask and sterile gloves. The site is swabbed with betadine in a circular motion, from the center (catheter) outward (surrounding skin). The patient’s skin is prepped with tincture of benzoin, and foam tape applied. The dressing is secured with perma-type pink tape around the edges to conform to the curvature of the cranium.

Ongoing Documentation

Accurate, ongoing documentation is essential to trend patient condition. The following are guidelines for documentation of nursing measures and observations. Patient condition and/or unit guidelines may dictate more or less frequent documentation.

- ICP (hourly)
- Calculation of CPP (hourly)
- Documentation of waveform and type each shift (q12 hr)
- Level of drainage bag (hourly)
- Color and character of CSF, if applicable (q4h and prn)
- Pupils & GCS level (per unit policy and patient condition)
- Interventions and responses (during and after each intervention)
When to Notify the MD

The physician should be notified whenever any of the following occur or whenever the situation warrants.

- Decrease in level of consciousness (an early sign of deterioration)
- CSF suddenly becomes bloody (sign of re-bleeding)
- CSF leaking around catheter (increased risk of infection)
- No waveform after troubleshooting
- Pupillary changes, such as dilation (a late sign of ↑ ICP)
- ICP catheter falls out (if this happens, place a sterile dressing over site)

Collecting Samples From CSF Drains

At times, samples may need to be collected for analysis. Collection of CSF is performed only by a RN after proven competency.

Equipment to collect CSF Sample:

- Sterile gloves
- Sterile Betadine soaked gauze or prep
- Mask
- 3cc syringe (no needle)
- Sterile specimen collection container

Procedure:

1. Obtain MD Order
2. Apply mask and sterile gloves
3. Position stopcock in draining position, off to the transducer
4. Cleanse port closest to the insertion site on the ventriculostomy drainage system for 1 minute with betadine allowing to air dry
5. Gently withdraw 0.8 cc to a maximum of 3.0 cc’s of CSF, avoiding undue pressure.
6. If any resistance is met while drawing the specimen, DO NOT ATTEMPT TO DRAW ANY FURTHER
7. Place CSF in the sterile container, label properly, and deliver to the lab immediately
8. Return stopcock to ICP monitoring position

Documentation:

The nurse needs to document the procedure, date, time, and amount of CSF removed and sent to the lab. The waveform prior to the procedure and after the procedure should also be documented. If any variances occur, the physician should be notified, and notification should be documented.
Irrigating the Ventriculostomy Catheter (going to the patient)

Irrigation is performed to clear debris (clots or brain tissue) or fibrin deposits from the ICP catheter to allow better waveform transmission and drainage of CSF. This is often considered to be an advance practice procedure; therefore, only physicians or ARNP’s and PA’s under a neurosurgeon’s guidance may irrigate/instill a solution into the ventriculostomy. In some cases, it may be performed by a RN, but only after proper instruction and with a physician order. Please refer to your hospital’s policy and procedure manual for further reference.

Any practitioner who performs ventriculostomy irrigation must be familiar with ICP dynamics and the potential adverse outcomes from both a nonfunctioning ventriculostomy and from irrigation of the catheter.

**Equipment:**
- Sterile gloves
- Sterile Betadine soaked gauze or prep
- Mask
- 3 cc syringe with 21 guage needle
- Irrigation solution – non bacteriostatic PFNS (preservative free normal saline)

**Procedure:**
1. Obtain MD’s order to irrigate with PFNS
2. Draw up ordered amount of preservative-free solution
3. Apply mask and sterile gloves
4. Cleanse injection port, closest to the insertion site, on the ventriculostomy drainage system for 1 minute with betadine and allow to air dry
5. Clamp ventriculostomy drain with the clamp attached to the setup
6. Prior to injection make sure the system is free of air bubbles, then inject the preservative solution gently
7. DO NOT aspirate since this may pull brain tissue into the catheter
8. Reopen the drain per MD order
9. Observe drainage and waveform
10. If the amount of irrigant does not return or the drainage does not return to normal, notify the physician

**Documentation:**
The practitioner should document the procedure, date, and time. This should include the type and amount of irrigation, the waveform pre and post-procedure, and the pressure recordings. The physician should be notified of any variances, and notification should be documented.
Potential Complications from ICP Catheters & CSF Drains

Over-Drainage

Over-drainage can collapse the ventricles resulting in false readings. It can be caused by:
- The patient sitting up suddenly
- Having the HOB raised higher than the drainage bag system
- Leaving the drainage bag system open to drain for a sustained period resulting in slit or collapsed ventricles

To avoid over-drainage of the ventricles, check the level of the drainage bag and direction of the stopcock every time you check the patient. If the patient is conscious, instruct the patient not to sit up suddenly, but to call for assistance. Monitor for signs and symptoms of over-drainage of CSF, which includes a spinal headache. There is usually no decrease in LOC unless a subdural hematoma or pneumocephalus (air in the cranial vault) has occurred. Treatment consists of closing the stopcock to drainage, lowering the head of the bed to a normal position, and continuing to monitor the waveform.

Under-Drainage

Under-drainage can result in dilated ventricles, thereby elevating the ICP. It can be caused by:
- Clogging of the ventricular catheter by tissue
- Purulent drainage or blood clots
- Not having the drainage bag system set at the correct level

To avoid under-drainage of the ventricles, check the level of the drainage bag and amount of CSF drainage frequently. Notify the physician if the drainage appears to have stopped or slowed significantly (e.g. from 10cc/hr to 2cc/2hrs). Monitor for signs and symptoms of under-drainage, which include headache, nausea, vomiting, decreasing level of consciousness, pupil dilation (late sign), and brain herniation from excessive elevation of ICP.

If the drainage system is blocked, it may need to be irrigated. Ensure that the drainage bag is at the appropriate level, then obtain an order from the neurosurgeon to irrigate the ICP drainage system (not the patient’s catheter) with preservative free normal saline. If this does not improve the drainage, notify the neurosurgeon. The ventricular catheter may need to be irrigated (refer to ICP Catheter Irrigation section). If the patient has an intraventricular bleed, the physician may choose to irrigate with thrombolytic therapy to maintain patency of the catheter. Remember irrigation of the patient’s catheter is an advanced procedure that is not routinely performed by the nurse.

Infections

Infections of the brain can be lethal. Meningitis and ventriculitis are the two main infections associated with ICP monitoring. The risk of infection is related to the penetration of the catheter through the protective mechanisms of the brain as discussed previously. It is important that the patient receive prophylactic antibiotics with an ICP monitor/drain of any type. In addition, avoiding infections of ICP monitors begins with **good handwashing** prior to patient contact and observing sterile technique during ICP care. Maintaining a **closed** monitoring system is also very important.

As part of the nurses’ ongoing assessments, signs of infection should be assessed. Specifically, monitor for signs and symptoms indicating meningeal irritation: nuchal rigidity (pain upon neck flexion), fever (temp > 103), photophobia (sensitivity to light), Bruzinski’s sign (when flexing the neck, the legs bend at the hips), and Kernig’s sign (unable to straighten the knees when flexing the
legs at the hip). Treatment of infection includes prophylactic antibiotics, antipyretics, and routine (QOD) sampling (cultures, protein, glucose and cell count) of CSF.

**Removal of the ICP Catheter**

The physician will determine when the catheter will be removed, and the procedure is to be performed only by a physician. As part of the removal process it is necessary to place a suture at the burr hole site to prevent the leakage of CSF. The physician may also decide to use a local anesthetic prior to placing the stitch. Once stitched, Betadine ointment is applied and a sterile 2 X 2 dressing is placed to cover the site. The site should be observed for leakage of CSF and reported to the physician immediately. If the site continues to drain, another stitch may need to be placed. The scalp is also observed for swelling which may indicate CSF leaking above the bone and beneath the scalp.

**Adjuncts to ICP Monitoring**

In the future, the devices covered in this section will likely become more widely used. These devices would provide added information regarding the status and function of the brain, specifically as it relates to oxygenation and perfusion.

**Transcranial doppler - Non-invasive monitoring**

Transcranial doppler (TCD) is a non-invasive way to measure blood flow to specific areas of the brain. This device measures velocity and indicates vasoconstriction or dilation, altering blood flow. An increase in CVR (vasoconstriction due to decreased CO$_2$) will increase the pulsatility of the blood flow and decrease velocity as indicated on the waveform. This results in a decrease in cerebral blood flow. A decrease in CVR (vasodilation due to increased CO$_2$) will decrease the pulsatility of the blood flow and increase the velocity as indicated on the waveform. This results in an increase in cerebral blood flow.

There are four windows in the cranium to measure blood flow. When used transtemporal, it measures the blood flow from the middle cerebral artery (MCA) at a depth 30 – 60 mm with flow towards the probe and from the anterior cerebral artery at a depth of 60 – 80 mm with flow away from the probe. When used transforaminal (transoccipital), it measures the blood flow from the vertebral arteries at a depth of 60 – 90 mm with flow away from the probe and from the basilar artery at a depth of 90 – 120 with flow away from the probe. When used transorbital, it measures the blood flow from the ophthalmic artery at a depth of 40 – 50 mm with flow towards the probe and from the carotid siphon at a depth of 65 – 75 mm with direction toward the probe; however, it could be bi-directional. When used transmandibular, it measures the blood flow from the internal carotid artery (ICA).

TCD is utilized to monitor patients for vasospasm, arteriovenous malformation feeders, changes in ICP, hyperemic flow, and changes in patients with head trauma. Vasospasm can occur in any patient with head trauma due to subarachnoid hemorrhage. Vasospasm occurs approximately 3 to 7 days after a subarachnoid hemorrhage. Normally, peak velocities are seen between 7 to 12 days, and then there is a decrease in velocity a few days after the peak. If the velocities continue to increase from day to day, there is a poorer prognosis for the patient.

<table>
<thead>
<tr>
<th>Mean Velocities in Vasospasm</th>
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<tbody>
<tr>
<td>Normal Velocities</td>
<td>30 – 80 cm/sec</td>
</tr>
<tr>
<td>Mild</td>
<td>&lt; 120 cm/sec</td>
</tr>
<tr>
<td>Moderate</td>
<td>120 – 200 cm/sec</td>
</tr>
<tr>
<td>Severe</td>
<td>&gt; 200 cm/sec</td>
</tr>
</tbody>
</table>
Cerebral Oxygenation Monitoring

Jugular Bulb Venous Oxygen Saturation (SjvO\textsubscript{2}) Monitoring (invasive monitoring)

SjvO\textsubscript{2} is real-time, continuous monitoring of venous oxygen saturation of blood returning from the ipsilateral half of the brain to the heart. It is a method for detecting cerebral ischemia and monitoring the effects of treatment for increased intracranial pressure (ICP). It is measured by placing a 4F-oximetry catheter retrograde into the internal jugular vein. The technique for SjvO\textsubscript{2} monitoring is similar in many ways to the monitoring of mixed venous oxygen saturation using a PA catheter. SjvO\textsubscript{2} monitoring is indicated in patients with severe acute brain injury. The oximetry catheter should be placed on the side of the most severe injury or on the right side if the injury is diffuse.

Normal SjvO\textsubscript{2} is 0.55 – 0.75. The determinants of SjvO\textsubscript{2} are arterial oxygen content (CaO\textsubscript{2}), cerebral oxygen consumption, and cerebral blood flow. SjvO\textsubscript{2} indicates the relative balance of cerebral oxygen consumption and delivery.

**Interpretation of SjvO\textsubscript{2} values:**

- **SjvO\textsubscript{2} values < 50 – 55% indicates cerebral oligemia (low CBF).** Low values indicate a low level of oxygen delivery for the current cerebral oxygen consumption. Decreases in SjvO\textsubscript{2} may be caused by high brain oxygen consumption related to seizure activity or agitation. Decreases are also caused by anemia, arterial hypoxemia, or decreases in cerebral blood flow. Notify physician for sustained values of SjvO\textsubscript{2} < 0.50 in association with SpO\textsubscript{2} > 0.92 for > 15 minutes.

- **SjvO\textsubscript{2} values > 70 – 75% indicates cerebral hyperemia (high CBF).** Increases in SjvO\textsubscript{2} may be caused by hyperoxia or decreased cerebral oxygen consumption related to sedation or sleep. May result in increased ICP from vascular engorgement. Hyperemia may also indicate an increasing underlying ischemia and dying brain tissue that does not extract oxygen.

**Note:** It is important to verify that the catheter reading is accurate and not due to the occurrence of artifacts in the measurement caused by movement of the catheter within the jugular bulb. Malposition of the catheter or active or passive mobilization of the patient’s head or neck may cause inaccurate readings. The light intensity bar (SQI) cannot be used to determine accuracy of the SjvO\textsubscript{2} value.

LICOX\textsuperscript{®} Monitor

The LICOX\textsuperscript{®} Monitor measures the oxygen partial pressure (PbtO\textsubscript{2}) of brain tissue. The LICOX\textsuperscript{®} parenchymal catheter is inserted into white matter. It is able to provide an early indication of differences between brain tissue oxygen supply and demand. It is a sensitive indicator for outcome prediction.

The physician will decide on placement based on what type of patient information is needed. If placed in the uninjured side, this will reflect global information relating to cerebral oxygenation. If placed in tissue around the injured site, this may reflect the changes in cerebral oxygenation.

Normal PbtO\textsubscript{2} is > 30 mm Hg, with a range of 25-50 mm Hg. If PbtO\textsubscript{2} is < 15 for 30 minutes or < 10 mm Hg for 10 minutes, the risk of death increases. Furthermore, ischemia is reported at ranges of < 8 – 12 mm Hg, high mortality when < 5 mm Hg, and neuronal death when ≤ 2 mm Hg.
This device allows for treatment to be targeted at improving delivery and to decrease consumption. Delivery of oxygen to the brain can be improved by improving oxygen content of blood through correcting anemias or increasing the FIO$_2$. The flow of blood can be improved through the use of fluids, vasopressors, adjusting the PaCO$_2$ and treating increased ICP. The consumption of oxygen can be decreased through sedation/paralysis, analgesia, and temperature regulation. The effectiveness of these interventions can then be quickly assessed using this type of monitoring device.

**Summary**

Appropriate care and management of the patient with increased ICP and ICP monitoring can greatly influence patient outcomes. Understanding how treatments affect ICP and what the monitoring strips reveal about ICP can help to provide better patient care. Remember to always refer to your hospital’s policy and procedures and unit guidelines since care of patients can vary by institution.
**Education & Development Answer Sheet**

Complete all lines and PLEASE PRINT

<table>
<thead>
<tr>
<th>Orlando Regional Healthcare Employee: ( ) No ( ) Yes</th>
<th>Employee #</th>
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Please also complete the self-learning packet evaluation at the end of the packet.

In order to receive 3.0 contact hours, you must:

- Submit the answer sheet and payment ($10.00 for Orlando Regional Healthcare employees / $20.00 for non-employees) to:
  Orlando Regional Healthcare
  Education & Development, MP 14
  1414 Kuhl Ave.
  Orlando, FL 32806

Achieve an 84% on the post test (You will be notified if you do not pass and will be asked to retake the post test.)
**Post Test**

**Directions:** Complete this test using the answer sheet provided.

1. The three components of the cranial vault include:
   A. Brain tissue, 12 cranial nerves, blood volume
   B. Brain tissue, CSF, blood volume
   C. Brain tissue, glucose, blood volume
   D. Brain tissue, oxygen, blood volume

2. Which one of the following would interfere with the autoregulation of ICP via blood flow?
   A. Hypervolemia
   B. Hypertension
   C. Hypocapnia
   D. Hypoxia

3. You note that the CSF is cloudy. This would indicate:
   A. Old blood from a previous bleed
   B. An active bleed
   C. Infection
   D. CNS tumor

4. The most accurate method to monitor intracranial pressure is by placing a ____________ catheter.
   A. Intraventricular
   B. Parenchymal
   C. Subarachnoid
   D. Subdural

5. The nurse will recognize all of the following as indications for ICP monitoring EXCEPT:
   A. GCS of less than 8
   B. Cerebral edema on CT scan
   C. Extremity extension to noxious stimulus
   D. Periods of apnea

6. When educating the family of a patient with increased intracranial pressure, the nurse will tell them that:
   A. Assisting with range of motion exercises and relating current events to the patient may help to lower intracranial pressure
   B. A cool, dark, quiet environment will contribute to lowering the intracranial pressure
   C. Discussing the patient’s condition at the bedside will help involve the family in the rehabilitation process
   D. Environmental stimulation will help to increase the patient’s level of consciousness
7. The train of four (TOF) procedure is performed by the nurse for which intracranial hypertension treatment modality?
   A. Sedation therapy
   B. Barbiturate therapy
   C. Neuromuscular blockade therapy
   D. Osmotic diuretic therapy

8. The train of four Therapeutic goals of a patient in a barbiturate coma is noted on the EEG waveform by suppression of electrical activity for:
   A. 0 – 3 seconds
   B. 3 – 6 seconds
   C. 6 – 9 seconds
   D. 9 – 12

Match the description to the correct ICP monitoring type

9. Subdural drain
   A. Positioning into brain tissue and cannot drain CSF

10. Parenchymal
    B. Positioned in the ventricle and can drain CSF

11. Intraventricular
    C. Positioned below the dura mater and cannot drain CSF

12. The nurse would need to assemble all of the following supplies for insertion of an intraventricular catheter EXCEPT:
   A. Lidocaine with epinephrine
   B. Suture
   C. Ventriculostomy tray
   D. Pigtail cable for flushing

13. After insertion of the ICP catheter/monitor the nursing documentation should include all of the following EXCEPT:
   A. Opening pressure
   B. Appearance of CSF
   C. Level of drainage bag
   D. X-ray confirmation of placement

14. The ICP transducer should be level with the:
   A. Tip of the nose
   B. Subarachnoid space
   C. Foramen of Monroe
   D. Foramen of Magnum
15. Elevating the head of the bed and keeping the head in neutral alignment may affect ICP by:
   A. Decreasing venous return from the cerebral vessels to the heart, increasing venous congestion
   B. Increasing venous return from cerebral vessels to the heart, decreasing venous congestion
   C. Head position and alignment has no effect on intracranial pressure
   D. Increasing sympathetic stimulation and improving the level of consciousness

Match the ICP waveform component to the descriptions in questions 16-18.

16. Dicrotic wave which reflects the venous pressure
17. Percussion wave which reflects the arterial pressure
18. Tidal wave which indicates the cerebral compliance

19. The normal ICP waveform:
   A. Resembles an arterial waveform and correlates with the EKG
   B. Is related to cerebral circulatory activity
   C. Can elevate to as high as 50 mm Hg for 20 minutes
   D. Is related to cerebral electrical activity

20. An ICP waveform is trended over 1-2 minutes. Which type of waveform would indicate that the patient’s brain is not receiving enough oxygen?
   A. A waves
   B. B waves
   C. C waves
   D. All of the above
21. Which of the following waveforms indicates a decrease in compliance?

A. 

![Waveform A]

Seconds: 1 2

B. 

![Waveform B]

Seconds: 1 2

22. The ICP reading for the below ICP strip would be:

![ICP Strip]

(0/10 . 0/20 . 0/30)

A. 10  
B. 15  
C. 17.5  
D. 20

23. Which of the following adjuncts to ICP monitoring is a non-invasive method that measures blood flow to specific areas of the brain?

A. Licox monitor  
B. Cerebral oxygenation monitor  
C. Jugular bulb venous oxygen saturation monitor  
D. Transcranial doppler
The remaining questions are based on the following scenario

Mark Jones is a 30-year-old accountant who was involved in a single car motor vehicle crash while driving home from work. When the paramedics arrived, he was unresponsive, had irregular noisy respirations and a nosebleed. He was transported to the Emergency Department.

On arrival to the ED, his pupils were equal and sluggishly reactive to light. He was noted to have flexion response bilaterally to noxious stimulus and had a GCS of 5 (E – 1, V – 1, M – 3). He was orally intubated and placed on a ventilator with settings of IMV – 12, TV 800 cc, and FiO₂ – 40%.

He had a CT Scan of the head, which revealed an acute subdural hematoma. He was then transferred to the NSICU where a ventriculostomy drain was placed by a neurosurgeon and ICP monitoring was implemented.

The following data was obtained:

<table>
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<tr>
<th>HR</th>
<th>B/P</th>
<th>RR</th>
<th>ICP</th>
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<tbody>
<tr>
<td>112</td>
<td>104/62</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>96%</td>
<td>ETCO₂ - 26</td>
<td>PaCO₂ – 26</td>
<td>PaO₂ – 88</td>
</tr>
</tbody>
</table>

24. Mr. Jones’ calculated cerebral perfusion pressure is:
A. 52 mm Hg
B. 76 mm Hg
C. 90 mm Hg
D. 65 mm Hg

25. Adequate cerebral perfusion pressure is:
A. Greater than 30 mm Hg
B. Less than 60 mm Hg
C. Greater than 60 mm Hg
D. Any value less than the ICP

26. Mannitol, 25G, is ordered for Mr. Jones’ increased ICP. The nurse knows that Mannitol changes which component of the intracranial vault?
A. Brain mass
B. Blood volume
C. ICP
D. CSF

27. Which of the following values might negatively affect Mr. Jones’ outcome?
A. PaO₂ – 71
B. PCO₂ – 33
C. CPP – 49
D. MAP – 93

28. Which of the following nursing interventions could negatively affect Mr. Jones’ outcome?
A. Elevating the head of the bed 30 degrees
B. Providing all nursing care at once so he can rest
C. Control noxious stimuli
D. Keep the head and neck in neutral alignment
29. The ICP, calculated CPP and level of drainage bag should be documented with what frequency?
   A. Every 15 minutes
   B. Hourly
   C. Every 4 hours
   D. Every shift

30. The nurse obtains the following waveform. She should first:

   ![ICP Waveform](image)

   A. Reset the scale to 6/12/18 and take another reading
   B. Call the doctor to report a deterioration in the patient
   C. Check the system set up
   D. Chart the reading as 6mm Hg

31. The family of Mr. Jones is actively involved in his care. The nurse instructs the family not to set the patient up suddenly since this can cause:
   A. The ventricles to collapse
   B. A sudden decrease in ICP
   C. The ventricles to dilate
   D. The catheter to become clogged

32. The physician has ordered that a CSF sample be sent to the lab. The maximum amount that can be withdrawn is:
   A. 0.5 cc
   B. 0.8 cc
   C. 1.0 cc
   D. 3.0 cc

33. The nurse would notify the physician immediately if which of the following findings were noted in Mr. Jones?
   A. P2 exceeds the level of P1
   B. C waves are noted on trended waveform
   C. The CSF collected has a slightly yellow color to it
   D. MAP is calculated to be 95 mm Hg

**End of post test**
Appendix – EEG Waveform

Assessing the EEG waveform

An electroencephalogram is a noninvasive diagnostic procedure that records electrical activity of the brain using multiple scalp electrodes and records each tracing on graph paper for interpretation. It records frequency, amplitude, and characteristics of brain waves. A variety of conditions can produce similar waveforms. The EEG waveform can note the following neurological complications: seizures, coma, cerebral ischemia, and medications that affect neurological function. Anticonvulsants, stimulants, tranquilizers and depressants alter brain waves. Dietary stimulants such as coffee, tea, colas and chocolates also can alter brain wave activity. The EEG should compliment other anatomic diagnostic tests such as CT or MRI scans. The EEG will reflect changes in the initial amplitude, increasing or decreasing the frequency of the waveform, or isoelectric (flat waveform) and/or burst suppression.

Frequency of brain waves are based on the number of cycles per second, recorded in hertz (Hz) units. The different areas of the cerebral cortex will generate distinctive fluctuations related to the wake and sleep cycle. There are four frequency bands that are identified for interpretation of the EEG: Alpha (8 – 12 Hz), Beta (13 – 35 Hz), Theta (4 – 7 Hz), and Delta (1 – 3 Hz) rhythms.

**Alpha rhythms** are located in the occipital leads. They will decrease or be blocked by opening of the eyes, mental effort, anxiety, apprehension, and sudden noise or touch.

**Beta rhythms** are located in the frontal and central areas of the cerebral cortex. They will increase when the eyes open, mental activity, anxiety or apprehension occurs. *They are prominent in patients receiving barbiturates and benzodiazepine medication.*

**Theta rhythms** are located in the temporal lobes of the cerebral cortex. They are seen during sleep. EEG increases are seen in people over the age of 60 years relating to changes in gray or white matter.

**Delta rhythms** are not normally present in awake adults. This rhythm is seen in Stage 3 and 4 of sleep.
In reviewing the EEG waveform, one must look at the amplitude and the symmetry of the wave. The amplitude refers to the height of the EEG waveform and is measured in microvolts. Low amplitude EEG waveform is indicated by a reading less than 20 microvolts. Medium amplitude waveform is between 20 – 50 microvolts. High amplitude EEG waveform is greater than 50 microvolts. Symmetry refers to the pattern reflected by the EEG waveform recording comparing the right and left hemisphere. Electrodes are placed symmetrically over each hemisphere and are coded accordingly and identified by the following:

- **F** = Frontal – Cortical
- **C** = Central – Cortical
- **P** = Parietal – Cortical
- **T** = Temporal – Cortical
- **O** = Occipital – Cortical

Each horizontal line on the EEG paper refers to the areas listed above.

An EEG takes 45 – 60 minutes to complete and used to produce approximately 100 pages of recording paper; they are now digitally recorded. The continuous EEG monitoring for barbiturate coma is digitally recorded. The neurosurgeon and neurologist have the credentials to officially interpret data collected. The neurosurgeons read the EEG while on the unit in conjunction with their patient assessment. The neurologist reviews a clip in which 2 – 3 minutes are recorded every 5 hours for a total of 24 hours.

Routinely, brain waves are recorded at rest, after hyperventilation, and with photic stimulation. These are stressors and may precipitate abnormal focal or generalized brain wave changes not detectable under normal circumstances.
EEG Findings

The goal for barbiturate coma is to achieve burst suppression of electrical activity as indicated by the waveform from 3 – 6 seconds. The waveform indicates slowing and decreases in the amplitude as noted below. The nurse must correlate this information with the administration rate of medication, ICP pressures, neurological and hemodynamic assessment to determine the therapeutic range.

A “flat” EEG (complete brain wave suppression) indicates over medication or brain death. Brain death is never declared on the basis of a flat EEG. An overall comprehensive assessment correlating with other diagnostic tests would then be indicated.
Appendix – Train of Four

Train of Four (TOF) Procedure (prior to administration of NMBA):

1. Place stimulator over target nerve (ulnar, facial, or posterior tibial)
2. Negative electrode towards target site (Red to Black 2 – 3 inches apart)
3. Depress “TOF” key (4 stimuli at 0.5 second intervals indicated by 4 flashing red light signals). Do NOT remove until light stops flashing
4. Increase mA until target site responds with 4 equal twitches. Note mA at this point
5. Increase current in 10mA increments until no further increase in intensity of response – this is known as the Supramaximal Stimulation (SMS) Point. SMS is the ONLY setting used hereafter to monitor the twitch response
6. Administer the NMBA
7. Monitor the number of twitches in response to a TOF stimulation indicating the % of blockage, with the preferred level of blockade for optimal patient management at 80 – 90 %

Interpretation of TOF

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<tr>
<th># of Twitches</th>
<th>Extent of Blockade</th>
<th>Clinical Interpretation</th>
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<tr>
<td>4 out of 4 (4/4)</td>
<td>Less than 75%</td>
<td>Spontaneous recovery</td>
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<tr>
<td>3 out of 4 (3/4)</td>
<td>75 – 80%</td>
<td>Maintenance doses may be needed to extend the duration of muscle relaxation</td>
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<td>2 out of 4 (2/4)</td>
<td>80 – 90%</td>
<td>Adequate for short term relaxation and long-term mechanical ventilation</td>
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<tr>
<td>1 out of 4 (1/4)</td>
<td>90%</td>
<td>Conditions suitable for endotracheal intubation and long-term mechanical ventilation</td>
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<tr>
<td>0 out of 4 (0/4)</td>
<td>100%</td>
<td>Considered TOO HIGH a level of blockade. Turn off NMBA until 1/4 or 2/4 responses are obtained.</td>
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The electrodes can be placed at any point along the course of the ulnar nerve. It is optimal to place the electrodes approximately 2 to 3 inches apart.
Appendix - Monitoring Systems

Codman ICP Express - Parenchymal / Ventricular

**Set-up guide:**

1. Plug in and turn on Codman ICP Express Monitor.
2. Connect Codman ICP Express Monitor (Interface Control Unit) to the external patient monitor.
3. Zero the patient monitor according to the monitor manufacturer’s instructions.
4. Once monitor is zeroed, press the ICP Express Menu / Enter key to proceed.
5. Per the new prompt, press the ICP express 20 or 100 key to send a calibration signal to the patient monitor.
6. Verify the patient monitor displays the correct pressure, then press the Menu / Enter key to proceed.
7. Plug the ICP express cable into the front panel connector on the ICP Express.
8. Connect a sterile microsensor transducer to the other end of the ICP Express cable. Avoid contact with the transducer tip.
9. Wait for the ICP express to prompt “Press zero to zero transducer”.
10. Pour a small pool of sterile saline or water into the microsensor tray, place the gray tip of the microsensor just barely under the surface of the water.
11. Press the blue zero key on the ICP Express.
12. Obtain Reference Number of catheter and record on ICP transducer and patient chart.
13. Press the Menu / Enter key to proceed.
14. With the Microsensor tip still in the sterile water or saline, verify that both the ICP Express and patient monitor displays show a mean pressure of 0mmHg (+ / - 1mmHg).
15. The microsensor is now ready to implant.
Verification of zero reference value:
The Reference Number must be manually checked once per shift. The directions below explain how to do this.
1. From the standard display mode, press the Menu / Enter key to bring up the main menu.
2. Use the ↑ or ↓ keys to position the cursor on the manual zero line, then press the Menu / Enter key.
3. Use the ↑ or ↓ keys to change the three digit zero reference value until it matches the value recorded on the Microsensor connector housing or patient’s chart.
4. Press the Menu / Enter key to enter the zero reference value and return to standard display mode.
The new value is automatically updated in the internal memory of the ICP Express Cable.

Re-zeroing the patient monitor: (after sensor is implanted)
1. From the standard display mode, press the 0 key on the ICP Express front panel.
2. Wait for the external patient monitor to stabilize. If the monitor displays a value other than 0 mmHg, proceed to zero balance the patient monitor per the monitor manufacturer’s instructions.
3. Press the Menu / Enter key to resume patient monitoring.

Re-calibrating the patient monitor: (after sensor is implanted)
1. Press the 20 or 100 key on the ICP Express front panel.
2. If the 20 is selected, verify that the patient monitor displays exactly 20 mmHg. If the 100 key is selected, verify that the patient monitor displays 98 to 102 mmHg.
3. Press the Menu / Enter key to resume patient monitoring.

Changing alarm limits:
The HI and LOW mean ICP alarm limits have default values of 20 mmHg and 0 mmHg respectively. Changes can be made by:
1. From the standard display mode, press the Menu / Enter key to bring up the main menu screen.
2. Use the ↑ or ↓ keys to move the cursor to the SET ALARM LIMITS line, then press the Menu / Enter key. HI alarm limit will be displayed above the mean ICP value.
3. Use the ↑ or ↓ keys to increase or decrease the displayed HI alarm limit to the desired value. Press the Menu / Enter key to enter the value. The LO alarm limit will be displayed above the mean ICP value.
4. Use the ↑ or ↓ keys to increase or decrease the displayed LO alarm limit. Press the Menu / Enter key to enter the value and return to the standard display mode.
**Camino Monitor (Integra Neurosciences) - Parenchymal/Ventricular System**

This uses fiberoptic technology which compares light waves to ICP pressure waves.

**Set up Guide:**
1. Camino monitor **MUST** warm up
2. The Monitor must be plugged in 10 – 12 hours to fully charge battery. The battery life approximately 1 hour. If battery light illuminates, approximately 20 minutes of battery life left.
3. 3 cables from Camino
4. Power plug
5. Black cable to the catheter
6. Cable to the bedside monitor – pigtail cable from the monitor
7. MD zeros catheter to Camino with screwdriver **PRIOR** to insertion.
8. Catheter can disconnect from monitor anytime for transport

**Calibration Steps for Camino Monitor (V420):**

Monitor (camino and bedside monitor) is to be recalibrated every 4 hours and whenever disconnected from the bedside monitor. To recalibrate:
1. Push cal step button on Camino monitor and hold until 0 displayed
2. Hold the button in on 0 and push zero on the bedside monitor.
3. When both monitors read zero, release button.
4. Push and hold Cal Step monitor reads 20, wait for bedside monitor to read 20, repeat 40, 100, 200. Note there is about a 10-second delay, for the monitor to catch up.

**Troubleshooting:**
1. Check connections
2. If connected securely and monitor still says “check catheter connection,” change out the preamp cable.
3. If no change and no reading, change monitor; if no change, suspect a broken catheter.
4. If a discrepancy with ICP between V420 and bedside monitor, always read the V420, and have biomed check calibration on the bedside monitor.

**Camino Parenchymal ICP Monitoring System**

Camino MPM-1 - Parenchymal ICP pressures and temperature monitoring system (temperature catheter is not MRI compatible)


Camino MPM-1 - Ventricular ICP pressure and temperature monitoring system

**Ventrix Monitor** (Integra Neurosciences) - Parenchymal/Ventricular System

This also uses fiberoptic technology, which compares light waves to ICP pressure waves.

**Set up Guide:**
1. Turn power on
2. Connect catheter to cable
3. ZERO (prior to insertion) Push <0> and hold till “H” marches across screen
4. Calibrate to bedside monitor
   a. Push once, 0 will flash, push zero on bedside monitor, when both reading zero:
   b. Push again, flashing 25, watch bedside monitor go to 25
   c. Push again, flashing 50, watch bedside monitor go to 50
   d. Push once more-returns to monitoring

**Common Display Codes:**
1. --- Check catheter connections
2. H--- Catheter ready to be zeroed
3. E04 Catheter is already zeroed
4. E06 Fiberoptic receptacle damaged
5. E12 Dead battery
6. E08 Change Fiberoptic

**Ventrix NL 90-100 Monitor - Catheter both fiberoptic and ventricular drainage**

- 48-hr battery life
- One touch zero-balance operation
- No need to level transducer or adjust for changes in patient position
- ICP reading even if catheter is obstructed or not in ventricle
- Accurate
- Eliminates leveling, system artifacts and de-bubbling associated with fluid-filled systems
- Tunneled away from the burr hole
- Catheter MRI safe

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References


### Self-Learning Packet Evaluation

**Name of Packet:** ____________________________  **Date:** ____________________________

**Employee**  [ ]  **Non-Employee**  [ ]

**Your position?**
- RN  [ ]  Respiratory  [ ]
- LPN  [ ]  Radiology  [ ]
- Lab  [ ]  Rehab  [ ]
- Social Work  [ ]  Clin Tech  [ ]
- Other: ____________________________

**If RN/LPN, which specialty area?**
- Med/Surg  [ ]  OR/Surgery  [ ]
- Peds  [ ]  OB/GYN  [ ]
- Neonatal  [ ]  Cardiology  [ ]
- Other: ____________________________

Please take a few moments to answer the following questions by marking the appropriate boxes.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The content provided was beneficial.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2) The packet met its stated objectives.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3) The packet was easy to read.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
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</tr>
<tr>
<td>4) The posttest reflected the content of the packet.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>5) The course was:</td>
<td>[ ] Mandatory</td>
<td>[ ] Optional</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please answer the following questions:

- How long did this packet take you to complete? ____________________________

- What have you learned that you will apply in your work? ____________________________

- What was the best part of the packet? ____________________________

- What would you suggest be done differently? ____________________________

- Additional Comments: ____________________________

Thank you for your input.

Please return this evaluation to **Education & Development**, either in person or by mail:

**Mailpoint #14, 1414 Kuhl Avenue, Orlando, FL 32806**

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