Increased Intracranial Pressure

2.0 Contact Hours

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Increased Intracranial Pressure

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Objectives:

At the completion of this course, the learner will be able to:

1. Identify the effects of increased intracranial pressure on brain tissues.
2. Recognize normal intracranial pressure (ICP) and cerebral perfusion pressure (CPP) levels.
3. Recognize signs and symptoms of increased ICP.
4. Identify nursing interventions during intracranial monitoring.
5. Identify nursing interventions to reduce ICP.

Anatomy

The bony skull protects the brain but is also an inflexible container as well. Any increase in the contents of the cranium will cause pressure on brain tissue causing decreased perfusion, ischemia, and if untreated, death.

About 80 to 150ml of cerebrospinal fluid (CSF) is present in circulation around the brain and spinal cord at any given time. Four spaces in the brain, the ventricles, contain cells which make CSF at the rate of about 20 ml per hour. CSF circulates from the lateral ventricles down to the third and fourth ventricles and from here to the bottom of the spinal cord and back up to the cerebral cortex where it is reabsorbed by the arachnoid villi in the subarachnoid space at the same rate as it is produced. CSF bathes the brain and spinal cord to protect and transport oxygen, glucose and other chemicals from the blood to the tissues and waste from tissue metabolism to the blood.

Blood is supplied to the brain by the internal carotid and vertebral arteries, circulates within the brain and returns to the heart via the internal jugular veins. It takes 50 ml of blood to properly supply each 100g of brain tissue. If circulating blood volume within the brain decreases to below 20ml/100g of tissue, ischemia occurs, and below 10 ml/100g cellular death occurs. About 150 ml of blood normally circulates within the cranium at any one time. Cerebral perfusion pressure (CPP) is the pressure driving blood into the brain. It should be maintained above 70 mm Hg for proper perfusion of brain tissues. There is a blood-brain barrier around the brain capillaries that prevent harmful substances, proteins, most antibiotics, and some drugs from diffusing across the capillary walls to brain cells. Toxins, inflammation, and trauma to brain tissue will cause the blood-brain barrier to fail.

Pathophysiology

There are four ways in which the contents of the cranium can increase and result in increased pressure on the brain:

- CSF production is increased and/or reabsorption is decreased
- Blood flow to the brain is increased or venous drainage of blood is decreased
- A mass in the brain tissue caused by an abscess, tumor, or hematoma develops
- Edema of the brain from tissue trauma occurs

The production of CSF is constant and increased production rarely occurs. An obstruction to the flow of CSF can occur as the result of a tumor, edema of the brain, hematoma, or infection. The arachnoid villi which absorb CSF into the blood stream can become blocked by blood, byproducts of infection or inflammation of the meninges causing an increase in the amount of CSF present, increasing pressure on the brain.

Hemorrhages can cause a hematoma that acts as a mass in the brain causing pressure. Injury to brain tissues causes a breach in the blood-brain barrier and extra fluids leak into the brain causing edema of the tissues. Compression of the jugular vein or a clot in a vein causes engorgement of the blood vessels in the brain. Abnormally high pressure in the thorax or abdomen restricts venous drainage from the brain to the heart. All of these mechanisms result in an increased amount of blood in the brain and increased pressure upon brain tissues.

The resultant increase of pressure within the cranium constricts the flow of blood to the cells. Brain cell ischemia causes vasodilation with an increase in blood supply to the brain and even more pressure within the cranium leading to even more ischemia and cellular death. Cellular necrosis allows fluids to leak out of cells causing more edema. Thus a harmful cycle occurs over and over when increased intracranial pressure occurs from intracerebral hemorrhages or large hemispheric infarctions.

The brain tries to compensate for increases in pressure by pushing CSF out of the cranium, decreasing production, and increasing absorption. Vasoconstriction tries to limit the amount of circulating blood. When the limits of brain compliance are reached, intracranial pressure rapidly increases until symptoms occur. The amount of volume increase and the rate of increase added to the volume of the cranium before the insult determine how fast symptoms will occur.

Normal intracranial pressure (ICP) is up to 15mm Hg. Brain cell injury occurs above 20 to 25mm Hg. As pressure rises without treatment, the contents of the cranium may be pushed sideways or down into the tentorial notch. Herniation of brain tissue laterally across the midline can tear tissues and cause pressure on one side of the brain. Herniation downwards causes pressure on the brainstem and when severe, causes death.

Signs and Symptoms

Signs and symptoms of increased intracranial pressure depend on the status of brain compliance and autoregulation and the patient's place along the continuum of brain damage. When ICP increases slowly papilledema may be the first sign. Papilledema is a swelling of the optic nerve at its entrance into the back of the eyeball. When ICP rises rapidly, papilledema occurs late in the process. Other signs and symptoms of increased intracranial pressure depend on the cause and can include:

- Headache
- Blurred or double vision, pupil dilation and lack of response to light, deviated gaze, nystagmus
- Vomiting
- Seizures
- Changes in level of consciousness: anxiety, agitation, disorientation, or sleepiness progress to decreased responsiveness and unconsciousness.
- Loss of motor function or abnormal function, unilateral or bilateral depending on the location of the injury, which can include involuntary movements, tremors, attempts to remove noxious stimulus, withdrawal from stimulus, decorticate or decerebrate posturing, or hemiparesis and hemiplegia.
- Hypo or hyperthermia
- Abnormal respiratory patterns
- Cardiac dysrhythmias
- Tachycardia
- Hypertension
- Widened pulse pressure

Diagnostic Tests

The patient with signs of increasing ICP needs emergency evaluation and rapid treatment to limit brain damage. An eye exam with an ophthalmoscope will check for signs of papilledema. LOC and neurological function are measured. A CT scan of the brain is the quickest way to look for brain pathology. If the CT scan is indecisive, an MRI is done. The cervical spine is also x-rayed or scanned to check for injury. If needed an EEG or lumbar puncture is done along with serum electrolytes and a toxicology screen.

Medical Treatment

Increased intracranial pressure is life-threatening and intervention will be rapid to avoid further brain tissue ischemia. The airway is first secured and the patient is intubated and ventilated if needed. Cardiac status is stabilized and any seizures will be controlled. Sedation is given for agitation to lower ICP. Hyperventilation to a $PaCO_2$ of 30-35 mm

Hg to reduce ICP via vasoconstriction may be used prior to the initiation of ICP monitoring. This is a temporary measure and can cause a rebound of increased ICP.

IV fluids are given to correct hypovolemia, electrolyte abnormalities and cerebral perfusion pressure (CPP) to >70mm Hg. . Isotonic fluids such as normal saline or Plasmalyte-A are used or colloids, hypertonic saline, or blood may be given. Diuretics such as mannitol or furosemide help to decrease edema of the brain caused by trauma or stroke. Vasopressors may be ordered to reduce the cycle of vasodilation and increased brain edema. If a tumor is present glucocorticoids may be given to reduce ICP by decreasing edema.

Hypo and hyperthermia will be managed by antipyretics, cooling, or warm blankets. Blood glucose is normalized to prevent further cerebral edema. An NG tube and urinary catheter are used to decrease pressure in the abdomen to encourage cerebral vascular drainage.

Intracranial Pressure Monitoring

The decision to insert a catheter into the cranium to measure ICP is made based on the severity of signs and symptoms and the results of the CT scan. ICP monitoring is done to guide therapy aimed at reducing the amount of brain injury by decreasing ICP to < 20 mm Hg and CPP > 70mm Hg. CPP can be calculated by subtracting the ICP from the mean arterial blood pressure (MAP - ICP = CPP). Maintenance of proper ICP and CPP levels provides the best patient outcome and has reduced mortality from severe head injury from 50% to 30 to 40%. ICP monitoring helps to guide nursing interventions to keep stimuli that raise ICP to a minimum. It will also signal the need to drain CSF to reduce ICP as needed.

Catheter Placement
Catheter placement depends on the diagnosis, whether coagulation is normal, and the amount and location of cerebral edema. The 5 locations that an ICP catheter may be placed for ICP monitoring include:

1. Intraventricular: A burr hole is made in the skull anterior to the coronal sutures and off the midline to tunnel the catheter into the anterior horn of the lateral ventricle of the nondominant hemisphere. The catheter may be tunneled under the scalp or placed through a bolt secured to the bone at the site of the burr hole. An intraventricular placement is the optimal method for ICP monitoring and CSF drainage as needed since it provides the most accurate monitoring. However it is difficult to do, can cause injury to brain tissue and infection, and can result in more loss of CSF then intended. Blood in the ventricles can clot in the catheter and occlude it.

2. Parenchymal: A catheter can be quickly and easily inserted into the brain tissue (parenchyma). Parenchymal placement (within brain tissue) is used when there is

widespread edema, coagulation problems, or the ventricles are small. CSF drainage is not possible but ICP monitoring can be done. Brain tissue may be injured and infection can also occur with this method.

3. Subarachnoid: A catheter is easily placed through a bolt into the subarachnoid space. There is less penetration of the brain with this method but CSF drainage is not possible, the catheter may become occluded by debris, and accurate monitoring of ICP is fair. Leakage of CSF can occur around the catheter.

4. Subdural: A catheter is placed through a burr hole and tunneled into the subdural space. This placement is easy but can result in catheter compression from increased ICP and monitoring accuracy is poor. CSF fluid cannot be drained.

5. Epidural: A catheter is placed through a burr hole into the epidural space. This is the most shallow and least invasive placement and does not allow CSF drainage. Monitoring accuracy is also reduced since measurement of ICP is indirect.

Transducer Systems

Transducer systems are catheters containing different methods of transforming ICP into electrical impulses that can be translated into waveforms on a monitor. There are four types of transducers systems used to monitor ICP:

1. External fluid-filled strain gauge: Pressure at the catheter tip is transferred to a diaphragm which moves, causing wires to be stretched and an electric signal to be sent to a pressure monitor beside the bed. This is an inexpensive system. It must be zeroed to atmospheric pressure and re-zeroed as defined in hospital policy and procedure. This system can be used in all placements except parenchymal

2. Internal microstrain gauge: The tip of the catheter contains a pressure sensor that transmits the electric signals to a monitor. The system is zeroed only once before it is inserted. The catheter can drift after placement and needs to be secured. It is used for intraventricular, parenchymal, and subdural placements. This system may incorporate a drain for CSF as well.

3. Fiberoptic: The catheter contains fiberoptic wires that shine a light into the brain from a diaphragm at the tip and read its reflection. The information is then transmitted to a bedside monitor. The system is zeroed only once before it is inserted. This system can be used in all placement areas and can incorporate a drain for CSF.

4. Air pouch: This system uses a bag filled with air attached to the tip of the catheter to transmit pressure signals. It recalibrates itself to zero hourly. It can be used for parenchymal and subdural placements and costs less than microstrain gauge and fiberoptic systems.

ICP waveforms

All of the transducer systems provide an ICP reading in mm/Hg as well as an ICP waveform. The waveform is a reflection of the pulsations of the brain tissue caused by arterial blood flow. Three main peaks are seen in the waveform but smaller peaks may be seen as well. Analysis of these peaks can give an indication of the state of brain compliance and autoregulation and identify the risk of a sustained increase in ICP from stimuli. The three peaks are:

1. Percussion wave or P1: This is the first and the highest of the 3 peaks, usually consistent.

2. Tidal wave or P2: This is the middle peak which varies according to intracranial compliance and state of autoregulation. It will rise when compliance is decreased or autoregulation is impaired. When this peak is elevated the ICP is likely to rise with stimuli. Elevation is considered to be

3. Dicrotic wave or P3: The third wave is followed by a return to the baseline.

ICP waveforms generally rise as ICP increases and fall as ICP decreases. All three peaks increase at first, and then P2 begins to rise until P1 is no longer seen and a general rounding of the waveform occurs.

Waveform trends
Over time, the ICP waveform tracings will form trends known as A, B, and C waves:

1. A waves (plateau waves): This is an elevation of ICP pressure to between 50 and 100 mm HG that last for from 5 to 20 minutes. There is a rapid rise and fall and signal impairment of CSF flow plus impaired compliance and autoregulation. This wave is very important since it may warn of impending herniation. Patient status will show deterioration.

2. B waves: These waves are rhythmic waves that occur up to twice a minute with elevations of ICP to from 20 to 50 mm HG. They represent fluctuation in blood flow through the brain and their appearance can be normal. They are more prominent when compliance decreases and may occur prior to A waves.

3. C waves: These are rapid oscillations that occur 4 to 8 times a minute with elevations of ICP to 20mm Hg and are normal.

Nursing Care

Prepare the patient and family for the insertion of an ICP monitoring catheter. Explain the procedure, risks, answer questions, and obtain consent according to policy. Medicate the patient as ordered. Assess vital signs and neurological status to be used as a baseline.

Prepare equipment and shave the insertion site. Assist as needed with the procedure, maintaining sterile conditions. Chart the procedure, type of transducer system, locations of burr holes, tunneling and exit sites of the catheter, and initial ICP level and waveform. Do not apply triple antibiotic or betadine gel to the insertion/exit sites. Dress these sites with clear dressings, taped gauze, or a full head dressing according to policy.

Secure catheters and tubing to the patient's clothing without tension and check bolt and other connections frequently to maintain a closed system. Restrain extremities as needed according to facility policy to protect the ICP catheter from being pulled out during patient agitation. Change the dressing over the insertion site as ordered and monitor for CSF drainage. If CSF leaks, notify physician and change the dressing as needed to keep it dry.

Re-zero external fluid-filled strain gauges according to policy and procedure. The external transducer for this type of monitoring system should be carefully positioned at the level of the auditory meatus of the ear, the tragus, the top of the ear, or the outer corner of the eye. The chosen landmark should be determined at the beginning of ICP monitoring and maintained at that level for consistency of ICP levels and waveforms.

Monitor ICP, wave forms and trends at least hourly and more often as determined by patient status. If levels and waveforms change, check the monitoring lines for kinks or compression. Monitor ventilation parameters and oxygenation frequently. Keep correct I & O totals and report any imbalances. Notify the physician of ICP over 15mm Hg, CPP <70mm Hg, and any change in signs and symptoms per ordered parameters.

Monitor and manage pain and the need for sedation as required. Monitor blood pressure for hypotension when these meds are given. Allow to rest between nursing interventions. Therapeutic touching should not be limited and can lower ICP. Family visits can also lower ICP.

If CSF is drained constantly or intermittently according to ICP level you should empty or change the drainage bag according to policy. You may need to take samples of the fluid or send the entire bag of fluid for analysis when it is changed. Maintain sterile technique of the monitoring system during any manipulation. Drainage of CSF should be done over the period of time specified in the orders.

Position the patient to maximize cerebral venous blood return to the heart:

- Keep head of bed at about 30 degrees
- Keep the head and neck in the midline since rotation, flexion, or hyperextension can compress the internal jugular veins
- If present, check cervical collars for proper support without compression of the jugular veins

Minimize patient stimulation to avoid increases in ICP. Monitor the effects of suctioning, turning, coughing, Valsalva's maneuver and other stimuli. Increases in ICP

may persist for a period of time after stimulation. If necessary to turn the patient, use enough help to allow passive turning without muscle contraction
The patient may need a sedative, neuromuscular blocking agent or endotracheal lidocaine prior to procedures such as suctioning or venipuncture. Hyperventilate prior to suctioning with an increased tidal volume and oxygen for 4 breaths at 20-second intervals before suctioning. Suction once or twice and over less than 10 seconds.

Administer hyperventilation or drain CSF according to orders. Monitor for complications of monitoring including intracranial infection, abscess, and hemorrhage. Monitor for signs if deterioration, brain ischemia, herniation, and brain death.

Nursing care must center on the need to decrease ICP while keeping CPP high enough to perfuse the brain. This requires close monitoring of patient status and the effects of the various medical and nursing interventions performed on the ICP level.

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