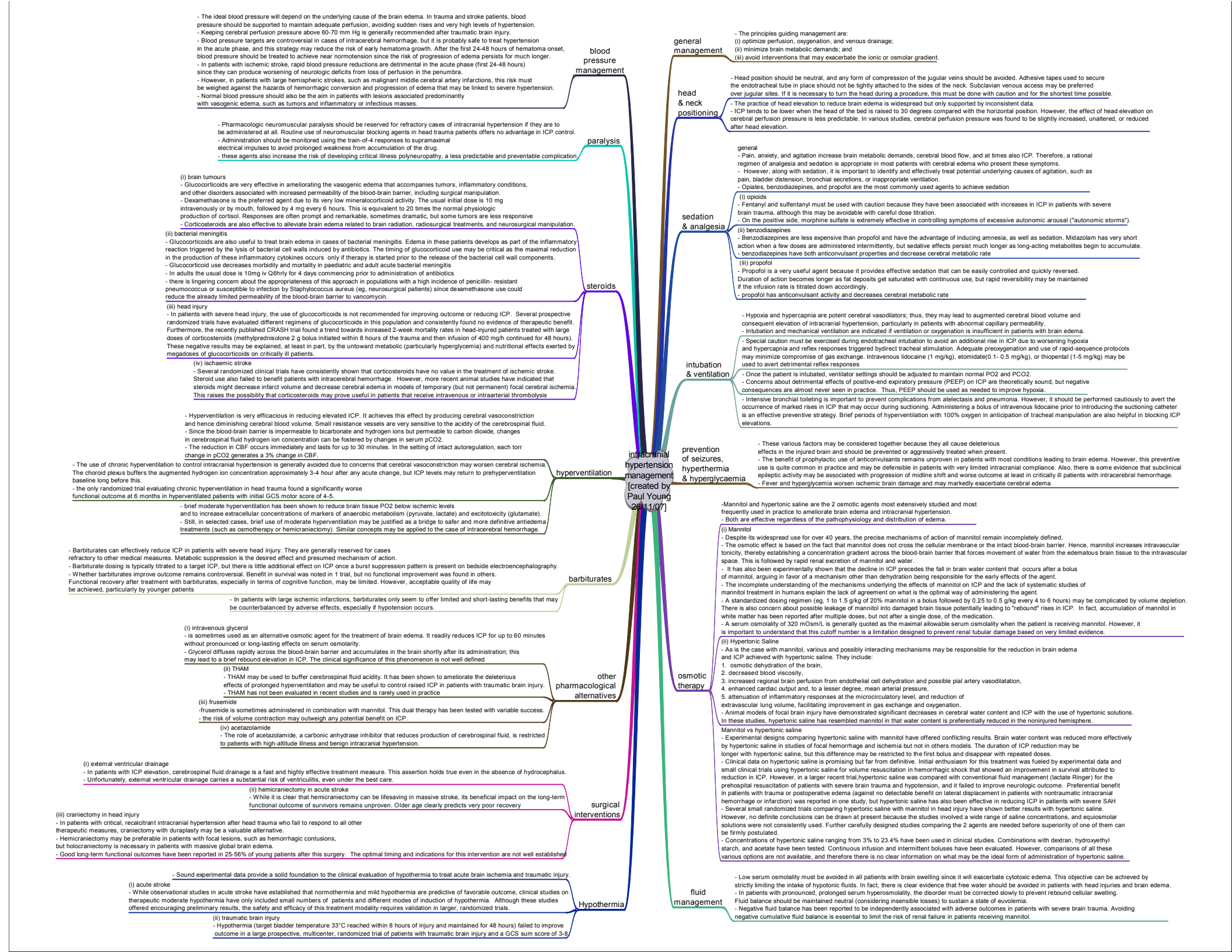
intracranial hypertension management [created by Paul Young 26/11/07]
blood pressure management
- The ideal blood pressure will depend on the underlying cause of the brain edema. In trauma and stroke patients, blood pressure should be supported to maintain adequate perfusion, avoiding sudden rises and very high levels of hypertension.
- Keeping cerebral perfusion pressure above 60-70 mm Hg is generally recommended after traumatic brain injury.
- Blood pressure targets are controversial in cases of intracerebral hemorrhage, but it is probably safe to treat hypertension in the acute phase, and this strategy may reduce the risk of early hematoma growth. After the first 24-48 hours of hematoma onset, blood pressure should be treated to achieve near normotension since the risk of progression of edema persists for much longer.
- In patients with ischemic stroke, rapid blood pressure reductions are detrimental in the acute phase (first 24-48 hours) since they can produce worsening of neurologic deficits from loss of perfusion in the penumbra.
- However, in patients with large hemispheric strokes, such as malignant middle cerebral artery infarctions, this risk must be weighed against the hazards of hemorrhagic conversion and progression of edema that may be linked to severe hypertension.
- Normal blood pressure should also be the aim in patients with lesions associated predominantly with vasogenic edema, such as tumors and inflammatory or infectious masses.
paralysis
- Pharmacologic neuromuscular paralysis should be reserved for refractory cases of intracranial hypertension if they are to be administered at all. Routine use of neuromuscular blocking agents in head trauma patients offers no advantage in ICP control.
- Administration should be monitored using the train-of-4 responses to supramaximal electrical impulses to avoid prolonged weakness from accumulation of the drug.
- these agents also increase the risk of developing critical illness polyneuropathy, a less predictable and preventable complication
steroids
(i) brain tumours
- Glucocorticoids are very effective in ameliorating the vasogenic edema that accompanies tumors, inflammatory conditions, and other disorders associated with increased permeability of the blood-brain barrier, including surgical manipulation.
- Dexamethasone is the preferred agent due to its very low mineralocorticoid activity. The usual initial dose is 10 mg intravenously or by mouth, followed by 4 mg every 6 hours. This is equivalent to 20 times the normal physiologic production of cortisol. Responses are often prompt and remarkable, sometimes dramatic, but some tumors are less responsive
- Corticosteroids are also effective to alleviate brain edema related to brain radiation, radiosurgical treatments, and neurosurgical manipulation.
(ii) bacterial meningitis
- Glucocorticoids are also useful to treat brain edema in cases of bacterial meningitis. Edema in these patients develops as part of the inflammatory reaction triggered by the lysis of bacterial cell walls induced by antibiotics. The timing of glucocorticoid use may be critical as the maximal reduction in the production of these inflammatory cytokines occurs only if therapy is started prior to the release of the bacterial cell wall components.
- Glucocorticoid use decreases morbidity and mortality in paediatric and adult acute bacterial meningitis
- In adults the usual dose is 10mg iv Q6hrly for 4 days commencing prior to administration of antibiotics
- there is lingering concern about the appropriateness of this approach in populations with a high incidence of penicillin- resistant pneumococcus or susceptible to infection by Staphylococcus aureus (eg, neurosurgical patients) since dexamethasone use could reduce the already limited permeability of the blood-brain barrier to vancomycin.
(iii) head injury
- In patients with severe head injury, the use of glucocorticoids is not recommended for improving outcome or reducing ICP. Several prospective randomized trials have evaluated different regimens of glucocorticoids in this population and consistently found no evidence of therapeutic benefit. Furthermore, the recently published CRASH trial found a trend towards increased 2-week mortality rates in head-injured patients treated with large doses of corticosteroids (methylprednisolone 2 g bolus initiated within 8 hours of the trauma and then infusion of 400 mg/h continued for 48 hours). These negative results may be explained, at least in part, by the untoward metabolic (particularly hyperglycemia) and nutritional effects exerted by megadoses of glucocorticoids on critically ill patients.
(iv) ischaemic stroke
- Several randomized clinical trials have consistently shown that corticosteroids have no value in the treatment of ischemic stroke. Steroid use also failed to benefit patients with intracerebral hemorrhage. However, more recent animal studies have indicated that steroids might decrease infarct volume and decrease cerebral edema in models of temporary (but not permanent) focal cerebral ischemia. This raises the possibility that corticosteroids may prove useful in patients that receive intravenous or intraarterial thrombolysis
hyperventilation
- Hyperventilation is very efficacious in reducing elevated ICP. It achieves this effect by producing cerebral vasoconstriction and hence diminishing cerebral blood volume. Small resistance vessels are very sensitive to the acidity of the cerebrospinal fluid.
- Since the blood-brain barrier is impermeable to bicarbonate and hydrogen ions but permeable to carbon dioxide, changes in cerebrospinal fluid hydrogen ion concentration can be fostered by changes in serum pCO2.
- The reduction in CBF occurs immediately and lasts for up to 30 minutes. In the setting of intact autoregulation, each torr change in pCO2 generates a 3% change in CBF.
- The use of chronic hyperventilation to control intracranial hypertension is generally avoided due to concerns that cerebral vasoconstriction may worsen cerebral ischemia. The choroid plexus buffers the augmented hydrogen ion concentration approximately 3-4 hour after any acute change, but ICP levels may return to prehyperventilation baseline long before this.
- the only randomized trial evaluating chronic hyperventilation in head trauma found a significantly worse functional outcome at 6 months in hyperventilated patients with initial GCS motor score of 4-5.
- brief moderate hyperventilation has been shown to reduce brain tissue PO2 below ischemic levels and to increase extracellular concentrations of markers of anaerobic metabolism (pyruvate, lactate) and excitotoxicity (glutamate).
- Still, in selected cases, brief use of moderate hyperventilation may be justified as a bridge to safer and more definitive antiedema treatments (such as osmotherapy or hemicraniectomy). Similar concepts may be applied to the case of intracerebral hemorrhage.
barbiturates
- Barbiturates can effectively reduce ICP in patients with severe head injury. They are generally reserved for cases refractory to other medical measures. Metabolic suppression is the desired effect and presumed mechanism of action.
- Barbiturate dosing is typically titrated to a target ICP, but there is little additional effect on ICP once a burst suppression pattern is present on bedside electroencephalography.
- Whether barbiturates improve outcome remains controversial. Benefit in survival was noted in 1 trial, but no functional improvement was found in others. Functional recovery after treatment with barbiturates, especially in terms of cognitive function, may be limited. However, acceptable quality of life may be achieved, particularly by younger patients
- In patients with large ischemic infarctions, barbiturates only seem to offer limited and short-lasting benefits that may be counterbalanced by adverse effects, especially if hypotension occurs.
other pharmacological alternatives
(i) intravenous glycerol
- is sometimes used as an alternative osmotic agent for the treatment of brain edema. It readily reduces ICP for up to 60 minutes without pronounced or long-lasting effects on serum osmolarity.
- Glycerol diffuses rapidly across the blood-brain barrier and accumulates in the brain shortly after its administration; this may lead to a brief rebound elevation in ICP. The clinical significance of this phenomenon is not well defined
(ii) THAM
- THAM may be used to buffer cerebrospinal fluid acidity. It has been shown to ameliorate the deleterious effects of prolonged hyperventilation and may be useful to control raised ICP in patients with traumatic brain injury.
- THAM has not been evaluated in recent studies and is rarely used in practice
(iii) frusemide
-frusemide is sometimes administered in combination with mannitol. This dual therapy has been tested with variable success.
- the risk of volume contraction may outweigh any potential benefit on ICP.
(iv) acetazolamide
- The role of acetazolamide, a carbonic anhydrase inhibitor that reduces production of cerebrospinal fluid, is restricted to patients with high-altitude illness and benign intracranial hypertension.
surgical interventions
(i) external ventricular drainage
- In patients with ICP elevation, cerebrospinal fluid drainage is a fast and highly effective treatment measure. This assertion holds true even in the absence of hydrocephalus.
- Unfortunately, external ventricular drainage carries a substantial risk of ventriculitis, even under the best care.
(ii) hemicraniectomy in acute stroke
- While it is clear that hemicraniectomy can be lifesaving in massive stroke, its beneficial impact on the long-term functional outcome of survivors remains unproven. Older age clearly predicts very poor recovery
(iii) craniectomy in head injury
- In patients with critical, recalcitrant intracranial hypertension after head trauma who fail to respond to all other therapeutic measures, craniectomy with duraplasty may be a valuable alternative.
- Hemicraniectomy may be preferable in patients with focal lesions, such as hemorrhagic contusions, but holocraniectomy is necessary in patients with massive global brain edema.
- Good long-term functional outcomes have been reported in 25-56% of young patients after this surgery. The optimal timing and indications for this intervention are not well established
Hypothermia
- Sound experimental data provide a solid foundation to the clinical evaluation of hypothermia to treat acute brain ischemia and traumatic injury.
(i) acute stroke
- While observational studies in acute stroke have established that normothermia and mild hypothermia are predictive of favorable outcome, clinical studies on therapeutic moderate hypothermia have only included small numbers of patients and different modes of induction of hypothermia. Although these studies offered encouraging preliminary results, the safety and efficacy of this treatment modality requires validation in larger, randomized trials.
(ii) traumatic brain injury
- Hypothermia (target bladder temperature 33°C reached within 8 hours of injury and maintained for 48 hours) failed to improve outcome in a large prospective, multicenter, randomized trial of patients with traumatic brain injury and a GCS sum score of 3-8
general management
- The principles guiding management are:
(i) optimize perfusion, oxygenation, and venous drainage;
(ii) minimize brain metabolic demands; and
(iii) avoid interventions that may exacerbate the ionic or osmolar gradient.
head & neck positioning
- Head position should be neutral, and any form of compression of the jugular veins should be avoided. Adhesive tapes used to secure the endotracheal tube in place should not be tightly attached to the sides of the neck. Subclavian venous access may be preferred over jugular sites. If it is necessary to turn the head during a procedure, this must be done with caution and for the shortest time possible.
- The practice of head elevation to reduce brain edema is widespread but only supported by inconsistent data.
- ICP tends to be lower when the head of the bed is raised to 30 degrees compared with the horizontal position. However, the effect of head elevation on cerebral perfusion pressure is less predictable. In various studies, cerebral perfusion pressure was found to be slightly increased, unaltered, or reduced after head elevation.
sedation & analgesia
general
- Pain, anxiety, and agitation increase brain metabolic demands, cerebral blood flow, and at times also ICP. Therefore, a rational regimen of analgesia and sedation is appropriate in most patients with cerebral edema who present these symptoms.
- However, along with sedation, it is important to identify and effectively treat potential underlying causes of agitation, such as pain, bladder distension, bronchial secretions, or inappropriate ventilation.
- Opiates, benzodiazepines, and propofol are the most commonly used agents to achieve sedation
(i) opioids
- Fentanyl and sulfentanyl must be used with caution because they have been associated with increases in ICP in patients with severe brain trauma, although this may be avoidable with careful dose titration.
- On the positive side, morphine sulfate is extremely effective in controlling symptoms of excessive autonomic arousal ("autonomic storms").
(ii) benzodiazepines
- Benzodiazepines are less expensive than propofol and have the advantage of inducing amnesia, as well as sedation. Midazolam has very short action when a few doses are administered intermittently, but sedative effects persist much longer as long-acting metabolites begin to accumulate.
- benzodiazepines have both anticonvulsant properties and decrease cerebral metabolic rate
(iii) propofol
- Propofol is a very useful agent because it provides effective sedation that can be easily controlled and quickly reversed. Duration of action becomes longer as fat deposits get saturated with continuous use, but rapid reversibility may be maintained if the infusion rate is titrated down accordingly.
- propofol has anticonvulsant activity and decreases cerebral metabolic rate
intubation & ventilation
- Hypoxia and hypercapnia are potent cerebral vasodilators; thus, they may lead to augmented cerebral blood volume and consequent elevation of intracranial hypertension, particularly in patients with abnormal capillary permeability.
- Intubation and mechanical ventilation are indicated if ventilation or oxygenation is insufficient in patients with brain edema.
- Special caution must be exercised during endotracheal intubation to avoid an additional rise in ICP due to worsening hypoxia and hypercapnia and reflex responses triggered bydirect tracheal stimulation. Adequate preoxygenation and use of rapid-sequence protocols may minimize compromise of gas exchange. Intravenous lidocaine (1 mg/kg), etomidate(0.1- 0.5 mg/kg), or thiopental (1-5 mg/kg) may be used to avert detrimental reflex responses
- Once the patient is intubated, ventilator settings should be adjusted to maintain normal PO2 and PCO2.
- Concerns about detrimental effects of positive-end expiratory pressure (PEEP) on ICP are theoretically sound, but negative consequences are almost never seen in practice. Thus, PEEP should be used as needed to improve hypoxia.
- Intensive bronchial toileting is important to prevent complications from atelectasis and pneumonia. However, it should be performed cautiously to avert the occurrence of marked rises in ICP that may occur during suctioning. Administering a bolus of intravenous lidocaine prior to introducing the suctioning catheter is an effective preventive strategy. Brief periods of hyperventilation with 100% oxygen in anticipation of tracheal manipulation are also helpful in blocking ICP elevations.
prevention of seizures, hyperthermia & hyperglycaemia
- These various factors may be considered together because they all cause deleterious effects in the injured brain and should be prevented or aggressively treated when present.
- The benefit of prophylactic use of anticonvulsants remains unproven in patients with most conditions leading to brain edema. However, this preventive use is quite common in practice and may be defensible in patients with very limited intracranial compliance. Also, there is some evidence that subclinical epileptic activity may be associated with progression of midline shift and worse outcome at least in critically ill patients with intracerebral hemorrhage.
- Fever and hyperglycemia worsen ischemic brain damage and may markedly exacerbate cerebral edema.
osmotic therapy
-Mannitol and hypertonic saline are the 2 osmotic agents most extensively studied and most frequently used in practice to ameliorate brain edema and intracranial hypertension.
- Both are effective regardless of the pathophysiology and distribution of edema.
(i) Mannitol
- Despite its widespread use for over 40 years, the precise mechanisms of action of mannitol remain incompletely defined.
- The osmotic effect is based on the fact that mannitol does not cross the cellular membrane or the intact blood-brain barrier. Hence, mannitol increases intravascular tonicity, thereby establishing a concentration gradient across the blood-brain barrier that forces movement of water from the edematous brain tissue to the intravascular space. This is followed by rapid renal excretion of mannitol and water.
- It has also been experimentally shown that the decline in ICP precedes the fall in brain water content that occurs after a bolus of mannitol, arguing in favor of a mechanism other than dehydration being responsible for the early effects of the agent.
- The incomplete understanding of the mechanisms underlying the effects of mannitol on ICP and the lack of systematic studies of mannitol treatment in humans explain the lack of agreement on what is the optimal way of administering the agent.
- A standardized dosing regimen (eg, 1 to 1.5 g/kg of 20% mannitol in a bolus followed by 0.25 to 0.5 g/kg every 4 to 6 hours) may be complicated by volume depletion. There is also concern about possible leakage of mannitol into damaged brain tissue potentially leading to "rebound" rises in ICP. In fact, accumulation of mannitol in white matter has been reported after multiple doses, but not after a single dose, of the medication.
- A serum osmolality of 320 mOsm/L is generally quoted as the maximal allowable serum osmolality when the patient is receiving mannitol. However, it is important to understand that this cutoff number is a limitation designed to prevent renal tubular damage based on very limited evidence.
(ii) Hypertonic Saline
- As is the case with mannitol, various and possibly interacting mechanisms may be responsible for the reduction in brain edema and ICP achieved with hypertonic saline. They include:
1. osmotic dehydration of the brain,
2. decreased blood viscosity,
3. increased regional brain perfusion from endothelial cell dehydration and possible pial artery vasodilatation,
4. enhanced cardiac output and, to a lesser degree, mean arterial pressure,
5. attenuation of inflammatory responses at the microcirculatory level, and reduction of extravascular lung volume, facilitating improvement in gas exchange and oxygenation.
- Animal models of focal brain injury have demonstrated significant decreases in cerebral water content and ICP with the use of hypertonic solutions. In these studies, hypertonic saline has resembled mannitol in that water content is preferentially reduced in the noninjured hemisphere.
Mannitol vs hypertonic saline
- Experimental designs comparing hypertonic saline with mannitol have offered conflicting results. Brain water content was reduced more effectively by hypertonic saline in studies of focal hemorrhage and ischemia but not in others models. The duration of ICP reduction may be longer with hypertonic saline, but this difference may be restricted to the first bolus and disappear with repeated doses.
- Clinical data on hypertonic saline is promising but far from definitive. Initial enthusiasm for this treatment was fueled by experimental data and small clinical trials using hypertonic saline for volume resuscitation in hemorrhagic shock that showed an improvement in survival attributed to reduction in ICP. However, in a larger recent trial,hypertonic saline was compared with conventional fluid management (lactate Ringer) for the prehospital resuscitation of patients with severe brain trauma and hypotension, and it failed to improve neurologic outcome. Preferential benefit in patients with trauma or postoperative edema (against no detectable benefit on lateral displacement in patients with nontraumatic intracranial hemorrhage or infarction) was reported in one study, but hypertonic saline has also been effective in reducing ICP in patients with severe SAH
- Several small randomized trials comparing hypertonic saline with mannitol in head injury have shown better results with hypertonic saline. However, no definite conclusions can be drawn at present because the studies involved a wide range of saline concentrations, and equiosmolar solutions were not consistently used. Further carefully designed studies comparing the 2 agents are needed before superiority of one of them can be firmly postulated.
- Concentrations of hypertonic saline ranging from 3% to 23.4% have been used in clinical studies. Combinations with dextran, hydroxyethyl starch, and acetate have been tested. Continuous infusion and intermittent boluses have been evaluated. However, comparisons of all these various options are not available, and therefore there is no clear information on what may be the ideal form of administration of hypertonic saline.
fluid management
- Low serum osmolality must be avoided in all patients with brain swelling since it will exacerbate cytotoxic edema. This objective can be achieved by strictly limiting the intake of hypotonic fluids. In fact, there is clear evidence that free water should be avoided in patients with head injuries and brain edema.
- In patients with pronounced, prolonged serum hyperosmolality, the disorder must be corrected slowly to prevent rebound cellular swelling. Fluid balance should be maintained neutral (considering insensible losses) to sustain a state of euvolemia.
- Negative fluid balance has been reported to be independently associated with adverse outcomes in patients with severe brain trauma. Avoiding negative cumulative fluid balance is essential to limit the risk of renal failure in patients receiving mannitol.