Fluid and Electrolyte Abnormalities in Neurosurgical Patients

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Scope

- Concepts of osmolality and fluid management in neurosurgical patients
- Common electrolyte disorders in neurosurgical patients
- Hypo / Hypernatremia

Osmolality and Oncotic Pressure

- Osmolality
- Hyponatremia and Hypernatremia
- Mannitol
- Colloid oncotic pressure (COP)

Volume status

- Volume status
  - Hypervolemia → cerebral edema
  - Hypovolemia → hypotension → cerebral perfusion pressure & cerebral edema

Crystalloids

<table>
<thead>
<tr>
<th>Solution</th>
<th>mOsm/L</th>
<th>mEq/L</th>
<th>gm/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSS/2 (0.45% NaCl)</td>
<td>154</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>3% D/W</td>
<td>278</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSS (0.9% NaCl)</td>
<td>308</td>
<td>154</td>
<td>154</td>
</tr>
<tr>
<td>5% D/NSS/2</td>
<td>405</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>3% D in Lactate Ringer’s solution</td>
<td>525</td>
<td>150</td>
<td>109</td>
</tr>
<tr>
<td>2% D in Lactate Ringer’s solution</td>
<td>561</td>
<td>154</td>
<td>154</td>
</tr>
<tr>
<td>3% NaCl</td>
<td>1026</td>
<td>513</td>
<td>513</td>
</tr>
<tr>
<td>7.5% NaCl</td>
<td>2566</td>
<td>1285</td>
<td>1285</td>
</tr>
<tr>
<td>25% Mannitol</td>
<td>1598</td>
<td></td>
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</table>
Fluids to control ICP and brain swelling
- Mannitol
  - 0.25 – 1.0 gm/kg/dose
  - Precautions – overdose, significant cardiovascular disease, renal insufficiency
- Fluid restriction
- Resuscitation fluid
  - Isotonic crystalloids + colloids
  - Hypertonic saline solutions

Mannitol
0.25 – 1.0 gm/kg/dose
Precautions – overdose, significant cardiovascular disease, renal insufficiency
Fluid restriction
Resuscitation fluid
Isotonic crystalloids + colloids
Hypertonic saline solutions

Effect of fluid restriction on serum osmolality in neurosurgical patients

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Na (mEq/L)</th>
<th>K (mEq/L)</th>
<th>Ca (mEq/L)</th>
<th>Osmolarity (mOsm/L)</th>
<th>Oncotic pressure (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFP</td>
<td>168</td>
<td>76</td>
<td>5.2</td>
<td>≈ 300</td>
<td>21</td>
</tr>
<tr>
<td>5% albumin</td>
<td>290</td>
<td></td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Dextran (10%) in NSS</td>
<td>154</td>
<td>154</td>
<td></td>
<td>≈ 310</td>
<td>61</td>
</tr>
<tr>
<td>Dextran (6%) in NSS</td>
<td>154</td>
<td>154</td>
<td></td>
<td>≈ 310</td>
<td>19</td>
</tr>
<tr>
<td>Hetastarch (6%) in NSS</td>
<td>154</td>
<td>154</td>
<td></td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>Hetastarch (10%) in NSS</td>
<td>154</td>
<td>154</td>
<td></td>
<td>≈ 310</td>
<td>82</td>
</tr>
</tbody>
</table>

Colloids

Conclusions
- Hypoosmolality (e.g., hyponatremia) causes brain edema
- Hypotonic (included salt-free glucose-containing) fluid administration should be avoided
- Precautions of mannitol use – overdose, significant cardiovascular disease, renal insufficiency

Scope
- Concepts of osmolality and fluid management in neurosurgical patients
- Common electrolyte disorders in neurosurgical patients
- Hypo / Hypernatremia
350 Aneurysmal SAH in 22 Italian Neurological centers

<table>
<thead>
<tr>
<th>Factor</th>
<th>%</th>
<th>Favourable outcome (%)</th>
<th>p</th>
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<tbody>
<tr>
<td>Age</td>
<td>54</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Intracranial hypertension</td>
<td>14</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Vasospasm</td>
<td>10</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td>10</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Central ischemia</td>
<td>82</td>
<td>26</td>
<td>40</td>
</tr>
<tr>
<td>Neurological deterioration</td>
<td>28</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>Hypnotremia</td>
<td>82</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Preoperative embolization</td>
<td>24</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Pretreatment embolization</td>
<td>29</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>Seizures</td>
<td>26</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td>Myoclonus</td>
<td>20</td>
<td>6</td>
<td>40</td>
</tr>
<tr>
<td>Neurogenic pulmonary edema</td>
<td>14</td>
<td>4</td>
<td>50</td>
</tr>
</tbody>
</table>

Hyponatremia

- Serum Na < 135 mEq/L
- 50 – 50% of SAH, 36 – 58% of bacterial meningitis
- Symptoms — non-specific
  - Headache, anorexia, N/V, confusion, lethargy
  - Impaired response to stimuli, asterixis
  - Seizures, cerebral edema, apnea, coma, and death

Effects of Hyponatremia

Normal brain (normal osmolality)

Immediate effects of hypotonic state

- Water gain (low osmolality)
- Rapid adaptation
  - Loss of Na, K, and Cl (low osmolality)
- Loss of organic osmolyte (low osmolality)

Rapid therapy (rapid correction of the hypotonic state)

Chronic demyelination

Immediate therapy (rapid correction of the hypotonic state)

Chronic adaptation

Loss of Na, K, and Cl (low osmolality)

Proper therapy (slow correction of the hypotonic state)

Measurement of serum osmolality

- Sodium or blood glucose
- Measurement of serum osmolality
- Management of hyponatremia

Causes of Hyponatremia in neurosurgical patients

- Neurosurgical causes
  - Subarachnoid hemorrhage
    - CSW > SIADH
  - Intracranial mass lesions
  - Subdural hematoma
    - SIADH
  - Supratentorial tumors
    - SIADH
  - Intracranial abscess
    - SIADH
  - Postoperative
  - Transphenoidal resection of pituitary mass
    - Rebound excessive ADH from overtreatment of DI
  - Bacterial meningitis
    - SIADH
  - Resection of acoustic neuroma
    - CSW

- Neurosurgical causes
  - CSW: cerebral salt wasting
  - SIADH: syndrome of inappropriate ADH release

Clinical features of SIADH and CSW

<table>
<thead>
<tr>
<th>Clinical features</th>
<th>SIADH</th>
<th>CSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracellular fluid volume</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>←</td>
<td>↑</td>
</tr>
<tr>
<td>Serum albumin</td>
<td>←</td>
<td>↑</td>
</tr>
<tr>
<td>Serum BUN/creatinine</td>
<td>←</td>
<td>↓</td>
</tr>
<tr>
<td>Serum potassium</td>
<td>←</td>
<td>↓</td>
</tr>
<tr>
<td>Serum urea acid</td>
<td>↓</td>
<td>←</td>
</tr>
<tr>
<td>Central venous pressure</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Heart rate</td>
<td>←</td>
<td>↑</td>
</tr>
<tr>
<td>Urine sodium</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Urine volume</td>
<td>↓</td>
<td>←</td>
</tr>
</tbody>
</table>

Clinical features of SIADH and CSW

- Measure serum osmolality
- Measure serum sodium
- Measure urine osmolality
- Measure urine sodium
- Measure effective volume status
- Nephrogenic diabetes insipidus
- Order fluid restriction
- Provide adequate fluid and osmotic replacement
- Nephrogenic diabetes insipidus
- SIADH
- CSW
- SIADH
- CSW

Acute postoperative hyponatremic encephalopathy

- Common in women
- Convulsion, coma, respiratory arrest, and death
- Can occur after neurosurgery for brain tumor, particularly after transphenoidal resection of pituitary tumor (common in Cushing’s disease)
  - Prevalence 8–35%
  - Symptomatic 2–20%

Treatment of hyponatremia

- SIADH – fluid restriction or hypertonic saline infusion, V2 receptor antagonist
- CSW – 0.9% NaCl or hypertonic saline infusion
- Rate of correction – 0.5 meq/L/hr (<10–12 mEq/L/day)
  - Follow up serum sodium every 6 hr
  - Hypertonic saline infusion – stuporous or seizure

Hyponatremia

- Serum Na >145 mEq/L
- Causes of hyponatremia
  (1) Na load (e.g., 7.5% NaHCO₃)
  (2) Hypotonic fluid losses – renal (DI, mannitol) or non-renal
- Approach?
  - Urine osmolality – < or >300 (sp.gr. 1.010)
- Treatment
  - Na load – furosemide
  - Hypotonic fluid losses – fluid replacement

Hypernatremia

- Serum Na >145 mEq/L
- Causes of hypernatremia
  (1) Na load (e.g., 7.5% NaHCO₃)
  (2) Hypotonic fluid losses – renal (DI, mannitol) or non-renal
- Approach?
  - Urine osmolality – < or >300 (sp.gr. 1.010)
- Treatment
  - Na load – furosemide
  - Hypotonic fluid losses – fluid replacement

Conclusions

- Most common causes in neurosurgical patients
  - Hyponatremia – CSW, SIADH
  - Hypernatremia – mannitol, low fluid intake
- Investigations
  - Hyponatremia – serum and urine osmolality, urine sodium
  - Hypernatremia – urine osmolality
  - Hypokalemia – serum and urine osmolality, urine potassium

Conclusions

- Treatment of hyponatremia
  - SIADH – fluid restriction
  - CSW – NSS infusion
  - Hypertonic saline – stuporous and seizure
  - Rate of correction – 0.5 mEq/L/hr
- Treatment of hypokalemia
  - Maximum concentration (peripheral vein) – 60 mEq/L
  - Maximum rate – 10 mEq/hr

Thank you for your attention