Cerebral Blood Flow, Autoregulation and Oxygenation in Pediatric Diabetic Ketoacidosis
M.S. Vavilala, J Roberts, K Schenkman, D Shaw, L.D. Martin, A.M. Lam
University of Washington and Children’s Hospital and Regional Medical Center, Seattle, WA

Background: Little is known about the pathogenesis of cerebral edema in pediatric diabetic Ketoacidosis (DKA). We examined cerebral blood flow (CBF), cerebral autoregulation, and cerebral oxygenation in 5 children with DKA and altered mental status (AMS). We tested the following hypotheses:
1. Vmca is decreased in children with DKA and cerebral edema,
2. Cerebral autoregulation is impaired in some children with DKA and this impairment results in cerebral edema,
3. Children with cerebral edema secondary to DKA have decreased mean brain oxygen saturations.

Methods: After IRB approval, subjects were enrolled if they met the following criteria: Age < 18 years, DKA and altered mental status, and a triad of pH < 7.25, serum glucose > 300 mg/dL and serum HCO3- < 15 meq/L. Transcranial Doppler ultrasonography, cerebral oximetry and computed tomography (CT) of the head were used to examine CBF and autoregulation, cerebral oxygenation and cerebral edema respectively.

Results: In 5 children with DKA and AMS,
1. Vmca was increased NOT decreased relative to MAP and CO
2. Cerebral autoregulation was impaired (4/5) early and normalized by 36 hours (Figure 1).
3. Hyperemia at 6 hours, but not at 36 hours, was associated with impaired cerebral autoregulation (Table 1).
4. Although cerebral saturations were increased in two patients early compared to 36 hrs, cerebral saturations did not predictably correlate with ARI or Vmca CO2.
5. Compared to recovery at 36 hours, CT at 6 hours demonstrates measurable cerebral swelling.

Conclusions: In children with DKA and AMS,
1. Cerebral swelling may be related to hyperemia, and NOT ischemia.
2. Impaired autoregulation may be related to hyperemia.

Clinical Implications:
1. The practice of aggressive fluid replacement (during hyperemia + impaired cerebral autoregulation) in children with DKA and AMS may be undesirably associated with cerebral edema.

<table>
<thead>
<tr>
<th>Pt (y)</th>
<th>pH pvCO2</th>
<th>MAPe</th>
<th>Vmca</th>
<th>ARI</th>
<th>pH pvCO2</th>
<th>MAPe</th>
<th>Vmca</th>
<th>ARI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>7.25</td>
<td>59 → 49</td>
<td>63 → 55</td>
<td>0.25</td>
<td>7.37</td>
<td>32</td>
<td>110 → 93</td>
<td>67 → 67</td>
</tr>
<tr>
<td>11</td>
<td>7.23</td>
<td>70 → 55</td>
<td>70 → 61</td>
<td>0.40</td>
<td>7.36</td>
<td>35</td>
<td>68 → 41</td>
<td>97 → 102</td>
</tr>
<tr>
<td>15</td>
<td>7.01</td>
<td>65 → 50</td>
<td>106 → 90</td>
<td>0.31</td>
<td>7.34</td>
<td>34</td>
<td>81 → 61</td>
<td>73 → 73</td>
</tr>
<tr>
<td>16</td>
<td>7.24</td>
<td>62 → 50</td>
<td>48 → 38</td>
<td>0.0</td>
<td>7.33</td>
<td>40</td>
<td>80 → 52</td>
<td>45 → 55</td>
</tr>
<tr>
<td>17</td>
<td>6.91</td>
<td>72 → 52</td>
<td>126 → 95</td>
<td>0.11</td>
<td>7.26</td>
<td>24</td>
<td>84 → 55</td>
<td>56 → 56</td>
</tr>
</tbody>
</table>

Table 1: Autoregulation Results at 6 vs. 36 hours after PICU admission of 5 children with DKA and AMS. AMS = altered mental status, pH and PvCO2 are venous blood gas samples, MAPe = mean arterial pressure at the external auditory meatus, mVmca = mean middle cerebral artery flow velocity, mARI = mean autoregulatory index. ARI ≥ 0.4 = intact cerebral autoregulation and ARI < 0.4 = impaired cerebral autoregulation, CT= computed tomography of the head. Vmca is high relative to MAPe and CO2. ARI normalized by 36 hours.

Figure 1: ARI at 6 vs. 36 hours. ARI = autoregulatory index; ARI > 0.4 = intact. ¾ of patients had intact autoregulation at 6 hours. ARI improved in all patients.