Title: TISSUE pH RELIABLY FOLLOWS CARDIAC INDEX DURING ENDOTOXEMIA

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INTRODUCTION - Clinicians need reliable trend monitors for cardiac index (CI) when caring for critically ill patients. Many clinicians follow heart rate (HR) and mean arterial pressure (MAP). However, the body's homeostatic reflexes may blunt the response of HR and MAP to changes in CI. Inadequate perfusion to peripheral tissue initiates anesthetic metabolism and lactic acid production with a concomitant rise in hydrogen ion concentration \([\text{H}^+]\) and a decrease in pH. Local tissue pH (TPh) monitoring should therefore detect changes in CI. We designed a study to test the reliability of continuous monitoring variables — HR, MAP and tissue pH — in tracking changes in CI.

Methods - We studied 9 female mongrel dogs, weighing 12 to 16 kgs. Anesthesia was induced with ketamine 100mg and atropine 0.4mg and maintained with pancuronium 2mg and pentobarbital 15 mg/kg. Normal blood gas tensions and temperature were maintained. Tissue pH was measured with a TPh electrode (Biochem pH monitor, Milwaukee WI) in the subcutaneous tissue of the thigh. We subjected the dogs to E. Coli 055:B5 endotoxin (1.75–3.0 mg/kg) when the animals were hemodynamically stable. The three putative tracking variables HR, MAP, and TPh were monitored continuously before (control) and for four hours after endotoxin injection along with intermittent thermolilution cardiac index. We converted pH values into hydrogen ion concentrations \([\text{H}^+]\). Data were analyzed using one way ANOVA with repeated measures and the multiple comparison method of Bonferroni. Changes from baseline control values were assumed significant at the p<0.05 level. Correlation analysis was used to test for the degree of agreement between tracking variable and CI.

Results - All data are shown as mean ± SD. Significant changes from baseline values are noted with an (*). CI (Fig 1) fell significantly following endotoxin. Changes in tissue \([\text{H}^+]\) (Fig 1) closely reflected changes in CI. In contrast, HR showed little change until late in the study and MAP was significantly different from control values only at 1 hour following endotoxin, after which it returned to baseline due to a marked rise in systemic resistance (not shown).

Figure 1

Figure 2

The table demonstrates the correlation between cardiac index and the tissue \([\text{H}^+]\) for each animal. Figure 3 is an example of the association between CI and tissue \([\text{H}^+]\) for one such animal.

Table - Correlation coefficients (CI vs tissue [H^+])

<table>
<thead>
<tr>
<th>Dog</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>0.75</td>
<td>0.80</td>
<td>0.75</td>
<td>0.97</td>
<td>0.90</td>
<td>0.72</td>
<td>0.92</td>
<td>0.94</td>
<td>0.80</td>
</tr>
<tr>
<td>P</td>
<td>0.05</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Figure 3

Discussion - Tissue pH provides a valuable trend monitor at low priority tissues where inadequate perfusion results in acid production and a low pH. Thus, as a continuous monitor it enables early detection of low flow state before irreversible damage is caused. The relatively poor tracking ability of HR and MAP reflect the global nature of these variables. Systemic hypotension and tachycardia may be initial signs in endotoxemia but may return to normal values as the peripheral vessels constrict reflexly to maintain perfusion pressure. The reliability and sensitivity of tissue pH monitoring in detecting changes in cardiac index leads us to suggest that its use in clinical monitoring during unstable hemodynamic states such as endotoxemia should be considered.