3.3: The Delta Ratio

3.3.1: Definition

This Delta Ratio is sometimes useful in the assessment of metabolic acidosis\(^1,2,3,4\). As this concept is related to the anion gap (AG) and buffering, it will be discussed here before a discussion of metabolic acidosis. The Delta Ratio is defined as:

\[
\text{Delta Ratio} = \frac{\text{Increase in Anion Gap}}{\text{Decrease in bicarbonate}}
\]

Others\(^5\) have used the delta gap (defined as rise in AG minus the fall in bicarbonate), but this uses the same information as the delta ratio and has not offer any advantage over it.

3.3.2: How is this useful?

In order to understand this, consider the following:

If one molecule of metabolic acid (HA) is added to the ECF and dissociates, the one H\(^+\) released will react with one molecule of HCO\(_3^-\) to produce CO\(_2\) and H\(_2\)O. This is the process of buffering. The net effect will be an increase in unmeasured anions by the one acid anion A\(^-\) (ie anion gap increases by one) and a decrease in the bicarbonate by one.

Now, if all the acid dissociated in the ECF and all the buffering was by bicarbonate, then the increase in the AG should be equal to the decrease in bicarbonate so the ratio between these two changes (which we call the delta ratio) should be equal to one. The delta ratio quantifies the relationship between the changes in these two quantities.
Example 3.3.1

If the AG was say 26 mmols/l (an increase of 14 from the average value of 12), it might be expected that the 
\( \text{HCO}_3^- \) would fall by the same amount from its usual value (ie 24 - 14 = 10 mmols/l). If the actual \( \text{HCO}_3^- \) value was different from this it would be indirect evidence of the presence of certain other acid-base disorders (see Guidelines below).

**Problem**

A problem though: the above assumptions about all buffering occurring in the ECF and being totally by bicarbonate are not correct. Fifty to sixty percent of the buffering for a metabolic acidosis occurs intracellularly. This amount of \( H^+ \) from the metabolic acid (HA) does not react with extracellular \( \text{HCO}_3^- \) so the extracellular \( [\text{HCO}_3^-] \) will not fall as far as originally predicted. The acid anion (ie A') however is charged and tends to stay extracellularly so the increase in the anion gap in the plasma will tend to be as much as predicted.

Overall, this significant intracellular buffering with extracellular retention of the unmeasured acid anion will cause the value of the delta ratio to be greater than one in a high AG metabolic acidosis.

**Caution**

Inaccuracies can occur for several reasons, for example:

- Calculation requires measurement of 4 electrolytes, each with a measurement error
- Changes are assessed against 'standard' normal values for both anion gap and bicarbonate concentration.

Sometimes these errors combine to produce quite an incorrect value for the ratio. As an example, patients with hypoalbuminaemia have a lower 'normal' value for anion gap so using the standard value of 12 to compare against must lead to an error. Do not over-interpret your result and look for supportive evidence especially if the diagnosis is unexpected.

### 3.3.3: Guidelines for Use of the Delta Ratio

Some general guidelines for use of the delta ratio when assessing metabolic acid-base disorders in provided in the table below.

<table>
<thead>
<tr>
<th>Delta Ratio</th>
<th>Assessment Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.4</td>
<td>Hyperchloreaemic normal anion gap acidosis</td>
</tr>
<tr>
<td>0.4 - 0.8</td>
<td>Consider combined high AG &amp; normal AG acidosis BUT note that the ratio is often &lt;1 in acidosis</td>
</tr>
</tbody>
</table>
### Delta Ratio

<table>
<thead>
<tr>
<th>Delta Ratio</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>Usual for uncomplicated high-AG acidosis Lactic acidosis: average value 1.6 DKA more likely to have a ratio closer to 1 due to urine ketone loss (esp if patient not dehydrated)</td>
</tr>
<tr>
<td>&gt; 2</td>
<td>Suggests a pre-existing elevated HCO₃⁻ level so consider: • a concurrent metabolic alkalosis, or • a pre-existing compensated respiratory acidosis</td>
</tr>
</tbody>
</table>

### Warning

Be very wary of over-interpretation - Always check for other evidence to support the diagnosis as an unexpected value without any other evidence should always be treated with great caution.

### A high ratio

A high delta ratio can occur in the situation where the patient had quite an elevated bicarbonate value at the onset of the metabolic acidosis. Such an elevated level could be due to a pre-existing metabolic alkalosis, or to compensation for a pre-existing respiratory acidosis (ie compensated chronic respiratory acidosis). With onset of a metabolic acidosis, using the 'standard' value of 24 mmol/l as the reference value for comparison when determining the 'decrease in bicarbonate' will result in an odd result.

### A low ratio

A low ratio occurs with hyperchloraemic (or normal anion gap) acidosis. The reason here is that the acid involved is effectively hydrochloric acid (HCl) and the rise in plasma [chloride] is accounted for in the calculation of anion gap (ie chloride is a 'measured anion'). The result is that the 'rise in anion gap' (the numerator in the delta ratio calculation) does not occur but the 'decrease in bicarbonate' (the denominator) does rise in numerical value. The net of both these changes then is to cause a marked drop in delta ratio, commonly to < 0.4
**Lactic acidosis**

In lactic acidosis, the average value of the delta ratio in patients has been found to be is 1.6 due to intracellular buffering with extracellular retention of the anion. As a general rule, in uncomplicated lactic acidosis, the rise in the AG should always exceed the fall in bicarbonate level.

**Diabetic ketoacidosis**

The situation with a pure diabetic ketoacidosis is a special case as the urinary loss of ketones decreases the anion gap and this returns the delta ratio downwards towards one. A further complication is that these patients are often fluid resuscitated with 'normal saline' solution which results in an increase in plasma chloride and a decrease in anion gap and development of a 'hyperchloremic normal anion gap acidosis' superimposed on the ketoacidosis. The result is a further drop in the delta ratio.

**References**