Serum potassium and arrhythmias†

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Alterations in serum potassium levels are a common occurrence in clinical practice and entail a significant proarrhythmic risk. The present review is a short tutorial meant to assist clinicians in the pathophysiological interpretation of arrhythmias caused by dyskalaemia.

Keywords Tutorial • Serum potassium • Arrhythmia mechanisms

The proarrhythmic effect of serum potassium (K⁺) abnormalities (hypo- or hyper-kalaemia) is, because of its practical relevance, familiar to all clinicians. The knowledge of the underlying mechanisms may help in identifying appropriate therapeutic interventions. To this end, it is useful to consider the following.

- Extracellular K⁺ concentration ([K⁺]o) affects K⁺ currents.
- The parameters directly depending on K⁺ currents are the level and stability of diastolic membrane potential (E\text{diast}) and action potential duration (APD).
- Depolarization of E\text{diast} may reduce the availability of the Na⁺ current (I\text{Na}), thus impairing impulse propagation.

The next question to address is how [K⁺]o affects K⁺ currents. K⁺ currents are proportional to:

- the electromotive force (e.m.f.) driving K⁺ through the channel;
- the conductance (G_K) of the channel.

Low [K⁺]o increases the e.m.f., but decreases G_K (arrows in Fig 1). The dependency of electrophysiological parameters on these factors is as follows.

- E\text{diast} is sensitive to both e.m.f. and G_K, thus it has complex dependency on [K⁺]o (curve in Figure 1).
- Repolarization rate is strongly affected by G_K; thus, the lower the G_K, the longer the APD.

Figure 1 shows that, although both low and high [K⁺]o may lead to depolarization of E\text{diast}, this results from reduced G_K in the former and from reduced e.m.f. in the latter. Moreover, low [K⁺]o will impair repolarization. As a consequence, hypo- and hyper-kalaemia may lead to similar E\text{diast} changes, but facilitate arrhythmias with different mechanisms. With the aim to illustrate this concept, the relation in Figure 1 is divided in four regions...
(A–D), and the arrhythogenic mechanisms most likely associated with each region are reported in Table 1.

[\text{[K}^+\text{]}_o] abnormalities may also cause arrhythmias by direct or indirect interference with drug action. For instance, low [\text{[K}^+\text{]}_o] enhances digitalis inhibition of the Na\(^+\)/K\(^+\) pump,\(^1\) and \(E_{\text{diast}}\) depolarization facilitates blockade of Na\(^+\) channels by local anaesthetic agents.

### Table 1 Arrhythogenic mechanisms related to potassium abnormalities (curve region as in Figure 1)

<table>
<thead>
<tr>
<th>Curve region</th>
<th>Clinical setting</th>
<th>Arrhythogenic mechanisms</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Diuretic therapy</td>
<td>Low (G_K) makes (E_{\text{diast}}) unstable. This leads to supernormal excitability and enhanced focal activity (triggered or automatic), in spite of hyperpolarization. APD is prolonged, and repolarization reserve is reduced (EADs facilitation). Although APD dispersion may be increased, focal mechanisms are more likely</td>
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<tr>
<td>B</td>
<td>Normal [\text{[K}^+\text{]}_o] range</td>
<td>No arrhythmia facilitation</td>
</tr>
<tr>
<td>C</td>
<td>Renal failure</td>
<td>Proximity to excitation threshold may prevail on increased (G_K), thus causing supernormal excitability. Conduction velocity may be normal or slightly reduced because of decreased (I_{\text{Na}}) availability. APD is shortened. Both changes may facilitate re-entry</td>
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<tr>
<td>D</td>
<td>Acutely ischaemic myocardium</td>
<td>Excitability and conduction are severely depressed (reduced (I_{\text{Na}}) availability); APD is shortened, but post-repolarization refractoriness may ensue. At very high ([K^+]<em>o), propagation may become (I</em>{\text{CaL}})-dependent (‘slow’ action potentials) and automaticity (based on (I_{\text{CaL}}) or steady-state (I_{\text{Na}})) may develop. Both focal mechanisms and re-entry are facilitated</td>
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APD, action potential duration; \(E_{\text{diast}}\), diastolic potential; \(G_K\), conductance of \(K^+\) channels; EADs, early afterdepolarizations; \([K^+]_o\), extracellular \(K^+\) concentration.

### References