Solutions to Homework Assignment - Module 6

1. [20 points] Where on the EKG waveform would you expect to see an indication of atrial repolarization? Briefly explain.

Atrial repolarization occurs during ventricular depolarization (see, e.g., VSL[13], Figure 12.14; VSL[14), Figure 12.17). Since the electrical signal of ventricular depolarization (the QRS complex) is so much larger than the electrical signal of atrial repolarization (ventricular mass > atrial mass) the atrial repolarization signal is, in effect, "lost" within the QRS complex – it is there, but isn't seen on the EKG (B&L[6+], page 310 and Figure 16-26; B&L[7], page 323 and Figure 16.26).

2. [20 points] What would be the effect on the cardiac fast action potential of an increase (as compared to its normal value – see, e.g., video 3, slide 5) in g_{IK1} at values of membrane voltage between approximately -10 to +10 mV? Briefly explain.

In the normal situation (video 3, slide 4) I_{K1} begins to increase late in phase 2 of the fast AP, peaks at the end of phase 2/beginning of phase 3, then returns to baseline early in phase 4 (and remains at baseline for the remainder of phase 4). Note that, except for the "bump" in I_{K1} (as described; see also Video 3, slide 4) near the end of phase 2/beginning of phase 3, during the majority of phase 2 g_{IK1} is essentially zero. If g_{IK1} were increased at near-zero (i.e., ±10 mV) values of membrane potential more (vs. normal) K^+ would flow outward during the early and middle portions of phase 2, repolarizing the membrane sooner and thereby reducing the duration of, and possibly increasing the (negative) slope of, phase 2 of the cardiac fast action potential. See B&L[6+], pp 295 – 298; B&L[7], pp 307 - 310.

3. [20 points] Describe/discuss/explain the mechanism(s) that cause conduction velocity within the AV node to be lower than in other myocardial tissue.

Conduction velocity depends on AP amplitude, the rate of change of membrane voltage (dV_m/dt) during phase 0, and the resting membrane potential (B&L[6+], pp 299 – 301; B&L[7], pp 312 - 313). Conduction delay in the AV node is due primarily to delay in the AN and N regions of the node, where APs are slow response APs (B&L[6+], Figure 16-1 B and pp 306 - 307; B&L[7], Figure 16-1 B and pp 318 - 319). So – resting membrane potentials are "high" (-60 mV) and phase 0 rate of change is also "low" (≈ 5 V/sec) – see B&L[6+], page 306 or B&L[7], page 319 – these factors result in a (relatively) slow conduction velocity through the AV node. For additional details, and for a discussion of anatomic factors that might also account for the (relatively) low conduction velocity through the AV node see, for example, Hoffman BF, Circ 1961 24:506-517 and/or King JH et al., Frontiers in Phsyiol 2013 article 154.

Rev 0, 10/13/17 - from Rev 5 of 10/162016, updated to refer to B&L[7]
Rev 1, 8/5/18 - update to 601; no changes to content
Rev 2, 10/15/18 - minor (cosmetic) change to Q5 response

4. [20 points] What would be the effect(s) on the cardiac pacemaker action potential of a partial blockage of the "funny" Na current? Briefly explain.

The "funny" sodium current, I_f, is responsible for the early portion of the slow depolarization (phase 4) of the pacemaker AP (Ca^{2+} current through T-type calcium channels is responsible for the final portion of phase 4). So – if I_f were partially blocked phase 4 would have a shallower slope early; this would prolong the time taken to reach threshold (for firing an AP), resulting in a reduced heart rate. See B&L[6+], Figure 16-19 and pp 304 – 305; B&L[7], Figure 16.19 and pp 316 - 318.

5. [20 points] What would be the effect of an increased conduction velocity through the AV node on the EKG waveform? Briefly explain.

An increased conduction velocity through the AV node would reduce the conduction delay through the node; this would, in turn, reduce the delay between atrial depolarization and ventricular depolarization. On the EKG this would be seen as a reduction in the P-R interval (see B&L[6+], Figure 16-26 and page 310; B&L[7], Figure 16.26 and page 323). There should be no change in heart rate as a result of the reduced AV conduction delay (heart rate is normally set by the firing rate of the SA node), so the R-R interval should not be affected. The T wave is indicative of ventricular repolarization; it should not be affected (shape or time delay between T and QRS) by the increased conduction velocity through the AV node.

Speculation
A reduction in conduction delay through the AV node shortens the time delay between the P wave and the QRS complex, but should not affect the time between atrial depolarization and atrial repolarization. So – atrial repolarization should occur later (exactly when depends on the change in the AV conduction delay) within the QRS complex. If so, then, depending on the timing and the amplitude of the signal attributable to atrial repolarization, the shape and or duration of the trailing edge of the QRS complex might be visibly affected.

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