

The ECG and other matters of the heart

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Contents

1	Anatomy and physiology	1
2	History	3
3	12-lead EKG	3
4	Journal club	6
5	Other	6
	EMG for any skeletal muscle, EKG for cardiac muscle only	

1 Anatomy and physiology

- Cardiovascular system:
 - Heart, lungs, arteries, capillaries, veins
 - Pulmonary artery/vein are the exceptions
- Heart
 - Right/left atria (upper chambers)
 - Right/left ventricles (lower chambers)
 - Valves: keep blood from backing up
 - Special conduction system: SA, AV nodes, Purkinje fibers
- Blood flow:
 - Right atrium -> (gravity) right ventricle -> pulmonary artery -> lungs -> pulmonary vein -> left atrium -> left ventricle

- Atria contract simultaneously
- Ventricles contract simultaneously (called **systole**, relaxation called **diastole**)
- Higher the blood pressure, the harder your heart has to work
- Heartbeat sound from opening and closing of valves
- Left ventricle is pushing much more blood, so it's bigger than the right
- Cardiac action potential:
 - Action potential is 100x longer than that of skeletal muscle; opening of K^+ channels is delayed
 - K^+ and Ca^{++} are very important for people who have heart problems
 - Long refractory period: always twitches no tetanic contractions
 - Parts of heart are self-exciting:
 - * Automaticity foci
 - * Pacemakers
 - Atria and ventricles electrically insulated from each other, so they contract in sequence
 - * Except at AV node
 - Propagation through the heart: starts at sinus node (SA node), propagates across atrium, reaches AV node, pauses there, then ventricles contract
 - * AV node has bundle branches that branch around the ventricles, and terminate in Purkinje fibers; need good simultaneous action across a large area
 - Multiple possible automaticity foci can act as pacemakers if needed: SA node, several locations in atria, AV junction, Purkinje fibers
 - * Faster pacemaker suppresses slower pacemakers (**overdrive suppression**)
 - * Each potential pacemaker has a preferred (inherent rate)

2 History

- Rheoscopic frog: guessed that the heart is electrically controlled, used frog as a detection device
- First EKG on dog, then person (1880's)
- First proper EKG: Einthoven
 - For each heartbeat, got three waves: P wave, QRS complex, T wave
 - * P wave: atrial depolarization, contracting
 - * QRS complex: ventricular depolarization
 - * T wave: ventricular repolarization
 - Vulnerable part of the heart cycle; automatic defibrillator avoids this
 - * ST segment: very important for diagnosing heart attacks
 - * Occasional U wave: seen sometimes, due to hypokalemia, hypercalcemia
- Traditional EKG on paper, $1\text{mV} = 10\text{mm}$, $25\text{mm} = 1\text{sec}$
 - Don't mess to the paper

3 12-lead EKG

- 12 signals, not 12 electrodes
 - 9 or 10 electrodes
- Same system since 1930's, a lot of redundancy and not optimal, very historically based
- See the same system from different angles, redundancy can help confirm results
- Takes up a lot of storage due to the redundancy, can try to compress the information
- Same skin prep as EMG
- First three leads: limb leads (Einthoven's triangle), arms and left foot

- I, II, III
- Augmented limb leads (same three electrodes, Goldberg): use pair of electrodes as common ground
 - AVR, AVL, AVF
- Other six leads: chest leads (Wilson)
 - V1-V6, **precordial leads**
 - Use average of limb leads as ground
 - V1, V2 right side of the heart
 - V5, V6 left side of heart
 - V3, V4 interventricular septum
 - "Typical" EKG is V5, V6 since left side of the heart
- Diagnostic information:
 - Heart rate
 - * **Bradycardia** (low heart rate), **tachycardia** (high heart rate)
 - * Sinus rhythm (resting heart rate) generated by SA node
 - * Heart rate is also known as "R-R" (R-wave to R-wave) time
 - * Heart rate variability: action of autonomic nervous system
 - Aside: sympathetic (fight/flight) vs. parasympathetic (e.g., eating, rest)
 - Lack of variability indicative of pathology
 - Bad rhythms
 - * Multiple active pacemakers, e.g., atrial flutter causing multiple p-waves
 - * Escape rhythms: pacemaker escapes overdrive suppression and starts to pace causing inverted p-waves
 - * Escape beats: same as escape rhythms, but for a single beat
 - Literal "heart skips a beat" – can be due to a hormone rush
 - Is dangerous if it affects the T-wave
 - * Premature ventricular contraction (PVC), ventricle not completely filled, problematic if it happens at a T-wave
 - * Atrial fibrillation ("A fib"): multiple pacemakers trying to pace the heart at the same time

- Continuous chaotic atrial spikes, irregular ventricular rhythm, no p-wave
 - Can be genetic, also "holiday meal"
- * Ventricular fibrillation: a bunch of places on the ventricles try to pace the heart
 - Worse than atrial fibrillation
 - Totally erratic EKG
 - Can be caused by hitting T-wave
- * External defibrillators:
 - 3-10msec pulse
 - Few thousand volts
 - Tens of amps
 - Not during T-wave
 - Cannot defibrillate flat line; defibrillator is for abnormal pattern
 - If heart stops, adrenaline to kick start heart
 - Cardioversion
- * Heart block: pacing not propagating correctly through the heart: R has two peaks
- **Myocardial infarction:** heart attack
 - * **Infarction:** obstruction to the blood supply to an organ or tissue, causing local death of the tissue
 - * Blockage of flow in coronary artery
 - * **Ischemia:** no blood flow: inverted T waves, significant Q waves
 - * Take an aspirin: thins the blood
 - * Part of the heart muscle dies
 - * Can irritate ventricular pacemakers, leading to arrhythmia
 - * In men:
 - Crushing chest pain, chain down left arm
 - Unexplained heartburn
 - * In women: harder to detect
 - * Mean QRS points down and to the left, because of the left ventricle; if heart attack, then some heart tissue dies and the QRS changes
 - Look at lead I and aVF

- Different people may have different original heart configurations
- * If ST segment is higher than the baseline, indication of heart attack
- * Bypass surgery to get rid of blockage
- * Or angioplasty (balloon to move blockage out of the way) and stent
- * ST segment below baseline: angina (stress test – current flow blocked)
- **Hypertrophy**: heart getting bigger
 - * Might be indicative of a pathology
 - * Vectors turn towards the hypertrophy
 - * Most info from lead V1
 - * May just be exercise training: regular (smooth) thickening (**athlete's heart**)
- **Hypertrophic cardiomyopathy**: thickening of the septum (wall dividing left/right) of the heart
 - * Interferes with proper blood flow
 - * May happen in young athletes; genetic
 - * Cure: cannot exercise

4 Journal club

- University of Delaware is good for physical therapy
- Difference between neuromuscular function vs. neuromuscular control
- Very non-specific hypothesis: lesser specificity in injured legs
- One of the strongest points of this paper: inclusion criteria: if any abnormality, then gave physical therapy until the abnormality was resolved (reduce confounding factors), therefore only differences are caused by neuromuscular activity

5 Other

- **Heart murmur**: when valves don't close fully, cause turbulent flow, can be heard (murmur)

- Read Kurt Vonnegat