Cardiac conduction system is a group of specialized cardiac muscle cells in the walls of the heart that send signals to the heart muscle causing it to contract.

Hemodynamics is the dynamics of blood flows in the cardiovascular system, which includes the systemic circulation and the pulmonary circulation. The right heart (right atrium and right ventricle) pumps blood into the pulmonary circulation. The left heart (left atrium and left ventricle) pumps blood into the systemic circulation.
Cardiac Muscle

- microfibrils
- myocyte
- nucleus
- intercalated disc

sarcomere

- Z band
- thin filament (actin)
- thick filament (myosin)
- A band

Action Potential

- inward Na⁺ current
- outward K⁺ current
- Ca²⁺ current

membrane potential (mV)

- absolute refractory period
- relative refractory period

0

-90

300 ms
Dutch doctor and physiologist Willem Einthoven (1860–1927) invented the electrocardiogram (ECG) in 1903 and received the Nobel Prize in Medicine in 1924. The action potential propagation in the heart can be represented by a 3D dipole that changes its magnitude and direction over time. The 12-lead ECG uses 10 electrodes placed on the patient's limbs and on the surface of the chest. The overall magnitude of the 3D dipole is then measured from 12 different angles ("leads") and is recorded over a period of time (usually 10 seconds). The Einthoven's Triangle is an equal-lateral triangle on the frontal plane consisting of the three standard leads (I, II, and III). The six chest leads are on the transverse plane, which is orthogonal to the frontal plane.
12-Lead ECG

<table>
<thead>
<tr>
<th>PLANE</th>
<th>Lead Type</th>
<th>Lead Name</th>
<th>+</th>
<th>–</th>
<th>GND</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Standard leads</td>
<td>Lead I</td>
<td>LA</td>
<td>RA</td>
<td>RA, LA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead II</td>
<td>LL</td>
<td>RA</td>
<td>RA, LL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead III</td>
<td>LL</td>
<td>LA</td>
<td>RA, LL tied together</td>
</tr>
<tr>
<td></td>
<td>Augmented leads</td>
<td>aVL</td>
<td>LA</td>
<td>RA</td>
<td>RA, LL tied together</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aVR</td>
<td>RA</td>
<td>RA</td>
<td>LA, LL tied together</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aVF</td>
<td>LL</td>
<td>LA</td>
<td>LA, RA tied together</td>
</tr>
<tr>
<td></td>
<td>Chest leads</td>
<td>V1</td>
<td>V1</td>
<td></td>
<td>Wilson central</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V2</td>
<td>V2</td>
<td></td>
<td>(LA, RA, LL tied together)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V3</td>
<td>V3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V4</td>
<td>V4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V5</td>
<td>V5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V6</td>
<td>V6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pathophysiology & Clinical Applications

ECG 02 @13:10, 6/10 pain, no Tx
ECGs are normally printed on a grid. The horizontal axis represents time and the vertical axis represents voltage. The standard values on this grid are as follows: A small box is 1 mm × 1 mm and represents 0.1 mV × 0.04 seconds. A large box is 5 mm × 5 mm and represents 0.5 mV × 0.20 seconds. The "large" box is represented by a heavier line weight than the small boxes. The ECG waveform is usually proceeded by a reference pulse, which has an amplitude of 1 mV and a duration of 0.2 s.

Example of an ECG board exam question

A 55-year-old woman with chest pain and unstable vital signs is brought in to you by emergency medical services. The paramedics obtained electrocardiography (ECG) en route to your facility (see Figure). What do the ECG findings demonstrate?

- Pericarditis
- Left bundle branch block with Sgarbossa criteria
- De Winter syndrome
- Left main coronary occlusion

Answer: Left main coronary occlusion
ECG Sample Case: A 51-year-old woman with fatigue

GENERAL FEATURES

1. Normal ECG
2. Normal variant
3. Incorrect electrode placement
4. Artifact

P WAVE ABNORMALITIES

5. Right atrial abnormality/enlargement
6. Left atrial abnormality/enlargement

ATRIAL RHYTHMS

7. Sinus rhythm
8. Sinus arrhythmia
9. Sinus bradycardia (<60)
10. Sinus tachycardia (>100)
11. Sinus pause or arrest
12. Sinoatrial exit block
13. Atrial premature complexes
14. Atrial tachycardia
15. Atrial tachycardia, multifocal
16. Supraventricular tachycardia
17. Atrial flutter
18. Atrial fibrillation

AV CONDUCTION

19. AV block, 1°
20. AV block, 2°–Mobitz type I (Wenckebach)
21. AV block, 2°–Mobitz type II
22. AV block, 3°
23. Wolff-Parkinson-White pattern
24. AV dissociation

ABNORMALITIES OF QRS VOLTAGE OR AXIS

25. Low voltage, limb leads
26. Low voltage, precordial leads
27. Left axis deviation (> −30°)
28. Right axis deviation (> +100°)
29. Electrical alternans

VENTRICULAR RHYTHMS

30. Ventricular premature complex(es)
31. Ventricular parastysole
32. Ventricular tachycardia (3 or more consecutive complexes)
33. Accelerated idioventricular rhythm
34. Ventricular escape complexes or rhythm
35. Ventricular fibrillation

INTRAVENTRICULAR CONDUCTION

36. RBBB, complete
37. RBBB, incomplete
38. Left anterior fascicular block
39. Left posterior fascicular block
40. LBBB, complete
41. LBBB, incomplete
42. Aberrant conduction (including rate-related)
43. Intraventricular conduction disturbance, nonspecific type

Q WAVE MYOCARDIAL INFARCTION

44. Anterolateral
45. Anterior or anteroseptal
46. Lateral
47. Inferior
48. Posterior

ST, T, U WAVE ABNORMALITIES

49. Normal variant, early repolarization
50. Normal variant, juvenile T waves
51. Nonspecific ST and/or T wave abnormalities
52. ST and/or T wave abnormalities suggesting myocardial ischemia
53. ST and/or T wave abnormalities suggesting myocardial injury
54. ST and/or T wave abnormalities suggesting electrolyte disturbances
55. ST and/or T wave abnormalities secondary to hypertrophy
56. Prolonged Q-T interval
57. Prominent U waves

INTRAVENTRICULAR CONDUCTION

58. Right ventricular hypertrophy
59. Left ventricular hypertrophy
60. Combined ventricular hypertrophy

VENTRICULAR HYPERTROPHY

61. Age recent, Age indeterminate or probably minute, or acute
62. Prominent U waves

CLINICAL DISORDERS

63. Brugada syndrome
64. Digitalis toxicity
65. Torsades de pointes
66. Hyperkalemia
67. Hypokalemia
68. Hypocalcemia
69. Hypercalcemia
70. Dextrocardia, mirror image
71. Acute cor pulmonale including pulmonary embolus
72. Pericardial effusion
73. Acute pericarditis
74. Hypertrophic cardiomyopathy
75. Central nervous system disorder
76. Hypothermia

PACEMAKER FUNCTION

77. Atrial or coronary sinus pacing
78. Ventricular demand pacemaker (VVI), normally functioning
79. Dual-chamber pacemaker (DDD), normally functioning
80. Pacemaker malfunction, not constantly capturing (atrium or ventricle)
81. Pacemaker malfunction, not constantly sensing (atrium or ventricle)
82. Paced morphology consistent with biventricular pacing or cardiac resynchronization therapy
Right Bundle Branch Block

1. r wave in V1
q wave in V6

2. S wave in V1
R wave in V6

3. R' wave in V1
S wave in V6
<table>
<thead>
<tr>
<th></th>
<th>$V_1$</th>
<th>$V_6$</th>
</tr>
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<tbody>
<tr>
<td>Normal</td>
<td><img src="image" alt="Normal" /></td>
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<tr>
<td>RBBB</td>
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<tr>
<td>LBBB</td>
<td><img src="image" alt="LBBB" /></td>
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