ECG IN CAD: TYPE, SEVERITY, AND PROGNOSIS

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I TYPE OF ISCHEMIA AND HIGH-RISK STEMI EQUIVALENTS (ESC 2023 ACS / ACC-AHA 2025 ACS GUIDELINES)

- **Transmural Ischemia (STEMI / Acute Coronary Occlusion):**
  - **Morphology and Cut-offs (4th Universal Definition of MI):** New **ST-segment elevation (STE)** measured at the **J-point** in at least **two contiguous leads**: **2.5 mm or greater** in men under 40 years, **2.0 mm or greater** in men 40 years or older, or **1.5 mm or greater** in women in **leads V2–V3**, and **1.0 mm or greater** in all other leads (or **0.5 mm or greater** in posterior leads **V7–V9** [1.0 mm in men under 40 years] and right-sided leads **V3R–V4R** [1.0 mm in men under 30 years]).
  - **Anatomical Territories: V1–V2** (Septal), **V1–V4** (Anterior — **LAD**), **I, aVL, V5–V6** (Lateral — **LCx** or First Diagonal), **II, III, aVF** (Inferior — **RCA** [80–85%] or **LCx** [15–20%]), **V3R–V4R** (Right Ventricle — Proximal **RCA**), and **V7–V9** (Posterior/Inferobasal — **LCx** or **RCA**).
- **Subendocardial Ischemia (NSTE-ACS):**
  - **Morphology:** New **horizontal or downsloping ST-segment depression of 0.5 mm (0.05 mV) or greater** in two contiguous leads and/or **T-wave inversion greater than 1.0 mm** in two contiguous leads with prominent R waves or R/S ratio greater than 1. Unlike ST-elevation, **isolated ST-depression does not localize** the culprit coronary territory (e.g., lateral V4–V6 ST-depression reflects subendocardial ischemia driven by elevated LV end-diastolic pressure).
- **Diffuse Subendocardial / Global Ischemia (Left Main, Proximal 3-Vessel Disease, or Severe Proximal LAD):**
  - **Morphology:** Widespread horizontal/downsloping **ST-segment depression (1.0 mm or greater) in 6 or more leads** (maximal in leads **I, II, and V4–V6**) accompanied by reciprocal **ST-segment elevation (1.0 mm or greater) in lead aVR** (and often V1), where **STE in aVR exceeds STE in V1**.
- **Wellens Syndrome (Critical Proximal LAD Subocclusion / Reperfused Occlusion):**
  - **Morphology:** Recorded during a **pain-free interval** (with normal or minimally elevated troponin and no precordial Q waves): **Type A (25 percent)** shows **biphasic (initial positive, terminal negative) T waves in V2–V3**; **Type B (75 percent)** shows **deep (greater than 2 to 3 mm), symmetrical inverted T waves in V2–V3** (often extending to V1–V4). Indicates a critical proximal LAD stenosis with high risk of imminent extensive anterior wall MI; **exercise stress testing is strictly contraindicated**, and early invasive coronary angiography is mandatory.
- **de Winter T-Wave Pattern (Acute Proximal LAD Occlusion — STEMI Equivalent):**
  - **Morphology:** Present in approx. 2 percent of acute proximal LAD occlusions: **1 to 3 mm upsloping ST-segment depression at the J-point in leads V1–V6** continuing into **tall, prominent, symmetrical peaked T waves**, often accompanied by 0.5 to 2 mm ST-elevation in lead aVR. Unlike hyperacute T waves, this pattern is static until reperfusion and mandates immediate activation of the catheterization laboratory (**Primary PCI**).
- **Isolated Posterior (Inferobasal) MI and Sgarbossa Criteria (Other STEMI Equivalents):**
  - **Posterior MI: Horizontal ST-depression in leads V1–V3** with **tall, broad R waves (R/S ratio greater than 1 in V2, R duration greater than 40 ms)** and **upright precordial T waves**, confirmed by **ST-elevation of 0.5 mm or greater in posterior leads V7–V9**.
  - **LBBB / Ventricular Paced Rhythm (Modified Sgarbossa / Smith Criteria): Concordant ST-elevation of 1 mm or greater** in leads with a positive QRS (5 points), **concordant ST-depression of 1 mm or greater in leads V1–V3** (3 points), or **excessively discordant ST-elevation with an ST/S-wave ratio of -0.25 or less** (STE at least 25 percent of the preceding S-wave depth) in any lead with at least 1 mm STE.

II ASSESSMENT OF SEVERITY AND CULPRIT LOCALIZATION

- **Sum of ST-Segment Deviation and Lead Burden:** The arithmetic **sum of ST-segment elevations** across all leads and the **total number of leads showing ST deviation (greater than 6 to 8 leads)** correlate directly with the **myocardial area at risk** and 30-day mortality.
- **Reciprocal ST-Segment Depression:** Presence of reciprocal ST-depression in remote leads (e.g., inferior ST-depression in anterior STEMI, or I/aVL ST-depression in inferior STEMI) excludes benign pericarditis/early repolarization and signifies a **larger area of myocardium at risk, higher incidence of multivessel disease, lower LVEF, and higher mortality**.
- **Pathological Q Waves:** Defined by the 4th UDMI as a Q-wave duration of **20 ms (0.02 s) or greater** or **QS complex in leads V2–V3**, or a Q wave of **30 ms (0.03 s) or greater and 1 mm (0.1 mV) or deeper** in two contiguous leads of any other lead group. Early appearance of Q waves within 6 hours of symptom onset reflects faster microvascular necrosis and reduced myocardial salvage, though it does **not** preclude emergency reperfusion.
- **Proximal vs. Distal Culprit Localization Rules:**
  - **Proximal LAD (Proximal to First Septal [S1] and First Diagonal [D1]):** STE in V1–V4 **plus** STE in **aVR**, STE in **V1 greater than 2.5 mm**, new **RBBB**, or **ST-depression of 1 mm or greater in II, III, and aVF** (whereas LAD occlusion distal to S1 and D1 shows STE in V2–V6 without inferior reciprocal ST-depression).
  - **RCA vs. LCx in Inferior STEMI: RCA occlusion** shows **STE in Lead III greater than Lead II** (injury vector directed rightward and inferiorly at +120 degrees) and **reciprocal ST-depression in Lead I and aVL** (plus STE in **V4R** if proximal RCA); **LCx occlusion** shows **STE in Lead II equal to or greater than Lead III** (vector at +60 degrees) with **isoelectric or elevated ST-segment in Lead I, aVL, and V5–V6**.

ECG Sign / Grade	Defining Criteria	Anatomical / Prognostic Significance
Sclarovsky-Birnbaum Grade 1 Ischemia	Tall, symmetrical **hyperacute T waves** only; no ST-elevation	Earliest reversible ischemia; smallest final infarct size if reperfused
Sclarovsky-Birnbaum Grade 2 Ischemia	**ST-elevation** WITHOUT terminal QRS distortion (S wave preserved in V1–V3)	Intermediate ischemia progression; good salvage with timely primary PCI
Sclarovsky-Birnbaum Grade 3 Ischemia	**Terminal QRS Distortion:** Loss of S wave in leads with rs configuration (**V1–V3**), or **J-point amplitude >=50% of R-wave height** in qR leads	Loss of Purkinje protection / absent collaterals; **rapid necrosis, large infarct, no-reflow, low LVEF, and high mortality**
ST-Segment Resolution (STR) at 60–90 min	**Complete STR (>=70%)**, Partial (30–69%), or **Absent (<30%)**	**>=70% STR** confirms microvascular tissue reperfusion (TIMI Myocardial Perfusion Grade 3); **<30% STR** indicates failed epicardial reperfusion or **microvascular no-reflow**

III PROGNOSTIC MARKERS ON THE 12-LEAD ECG

- **Terminal QRS Distortion (Sclarovsky-Birnbaum Grade 3 Ischemia):** Defined as the **disappearance of the S wave** in leads that normally have a terminal S wave (**leads V1–V3**), or a **J-point height emerging at 50 percent or more of the R-wave amplitude** in leads without an S wave. Reflects severe transmural ischemia extending to the relatively ischemia-resistant subendocardial Purkinje fibers (due to absent collateral flow or ischemic preconditioning), independently predicting **larger infarct size, microvascular obstruction, lower LVEF, and higher mortality**.
- **ST-Segment Resolution (STR) Post-Reperfusion (Schröder Criteria):** Measured **60 to 90 minutes** after fibrinolysis or primary PCI in the single lead with maximal baseline ST-elevation (or sum of ST-elevations):
  - **Complete STR (70 percent or greater resolution):** Strongest bedside marker of successful **microvascular myocardial tissue perfusion** and favorable long-term survival.
  - **Absent STR (less than 30 percent resolution) (or less than 50 percent in the single worst lead at 60–90 min post-fibrinolysis):** Indicates either **failed fibrinolysis** (Class I indication for immediate **Rescue PCI**) or **microvascular obstruction ("no-reflow")** despite a patent epicardial artery (TIMI 3 epicardial flow with impaired myocardial blush).
- **Intraventricular Conduction Blocks:** New **Right Bundle Branch Block (RBBB)** or **Left Bundle Branch Block (LBBB)** (especially when accompanied by **LAFB** in anterior STEMI) indicates extensive septal necrosis supplied by the first septal perforator of the proximal LAD, carrying a **high risk of cardiogenic shock, complete heart block, and in-hospital mortality** (ESC 2023 recommends a primary PCI strategy, as for STEMI, in patients with RBBB or LBBB and symptoms suggestive of ongoing myocardial ischemia).
- **Ventricular Tachyarrhythmias: Early sustained VT or VF** (within 48 hours of STEMI onset) increases **in-hospital mortality** (due to association with larger infarcts) but does **not** predict long-term recurrent sudden cardiac death (and is not an indication for an ICD), whereas **late sustained VT/VF (occurring after 48 hours)** driven by scar re-entry carries high long-term mortality and is a **Class I indication for secondary-prevention ICD**.
- **Fragmented QRS (fQRS):** Defined by Das et al. as the presence of an **additional R wave (R') or notching in the nadir of the R or S wave** (or more than 1 R' in two contiguous leads corresponding to a major coronary artery territory in a narrow QRS less than 120 ms). Represents heterogeneous zig-zag conduction around **peri-infarct myocardial scar**, serving as an independent predictor of ventricular arrhythmias, sudden cardiac death, and mortality.

KEY REFERENCES

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