LOCALIZATION OF ACCESSORY PATHWAY IN WPW SYNDROME WITH SURFACE ECG

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I THE PHYSIOLOGICAL BASIS (THE DELTA WAVE VECTOR RULE)

- **Anatomical Basis of Pre-Excitation:** In Wolff-Parkinson-White (WPW) syndrome, an accessory atrioventricular pathway (**Bundle of Kent**) conducts atrial impulses directly to the ventricular myocardium, bypassing the physiological decremental delay of the AV node. Consequently, the surface QRS complex during sinus rhythm is a **fusion beat** resulting from early eccentric activation of the basal ventricular myocardium via the accessory pathway (**the initial slurred Delta wave**) and subsequent normal His-Purkinje activation (forming the terminal QRS).
- **The Fundamental Vector Rule:** The **initial 20 to 40 milliseconds of the Delta wave vector points AWAY from the ventricular insertion site of the accessory pathway** along the mitral or tricuspid annulus:
- Leads overlying the pathway insertion record a **negative (QS or Qr) Delta wave**.
- Leads directly opposite the pathway insertion record a **tall positive Delta wave**.
- **Prerequisite for Accurate ECG Localization:** Algorithms (**Arruda, Fitzpatrick, Chiang, Pambrun, and Easy-WPW**) require **manifest pre-excitation (QRS duration typically 120 ms or greater with a clear delta wave)**. In left lateral pathways (which are far from the sinus node and experience minimal pre-excitation at rest) or intermittent pre-excitation, **vagal maneuvers, atrial pacing, or cautious IV Adenosine** (with a defibrillator immediately available due to the risk of adenosine-induced atrial fibrillation with rapid pre-excited ventricular response) slows AV nodal conduction to maximize delta wave expression.

II STEP 1: LEFT-SIDED (MITRAL) VS. RIGHT-SIDED (TRICUSPID) PATHWAYS (LEAD V1 AND PRECORDIAL TRANSITION)

- **Positive Delta Wave and Dominant R Wave (R/S > 1) in Lead V1 (“Type A WPW” / Pseudo-RBBB Pattern):**
  - **Vector Direction:** Initial activation travels **from Posterior/Left to Anterior/Right** toward lead V1.
  - **Pathway Location: Left-Sided (Mitral Annular) Accessory Pathway** (accounting for 55 to 60 percent of all accessory pathways—most commonly **Left Lateral / Left Free Wall**), or occasionally a posterior/left posteroseptal pathway.
  - **Negative or Isoelectric Delta Wave and Dominant S Wave (R/S < 1; LBBB Pattern) in Lead V1 (“Type B WPW”):**
  - **Vector Direction:** Initial activation travels **from Anterior/Right to Posterior/Left** away from lead V1.
  - **Pathway Location: Right-Sided (Tricuspid Annular) or Septal Accessory Pathway**:
  - **Early Precordial R/S Transition (by Lead V2 or V3):** Indicates a **Septal Pathway** (Posteroseptal, Midseptal, or Anteroseptal/Para-Hisian).
  - **Late Precordial R/S Transition (at Lead V4, V5, or V6):** Indicates a **Right Free-Wall (Right Lateral / Right Anterior) Pathway**.

III STEP 2: ANTERIOR (SUPERIOR) VS. POSTERIOR (INFERIOR) PATHWAYS (INFERIOR LEADS II, III, AVF)

- **Positive Delta Waves in All Inferior Leads (II, III, and aVF):**
  - **Vector Direction:** Activation proceeds superior-to-inferior (+30 to +90 degrees).
  - **Pathway Location: Anterior (Superior) or Anterolateral / Anteroseptal (Superoparaseptal) Pathway**.
  - **Negative Delta Waves (QS complexes) in Inferior Leads (II, III, and aVF — “Pseudo-Inferior Infarction Pattern”):**
  - **Vector Direction:** Activation proceeds inferior-to-superior (-30 to -90 degrees) away from the diaphragmatic surface.
  - **Pathway Location: Posteroseptal (Inferoparaseptal) or Posterior (Inferior) Pathway** (the single most common ECG mimic of an old inferior myocardial infarction on board exams).

IV STEP 3: SPECIFIC QUADRANT LOCALIZATION AND THE ARRUDA ALGORITHM

A Left-Sided (Mitral) Pathways (Positive Delta/QRS in V1, or R/S >= 1 in V2)

- **Left Lateral / Left Anterolateral Pathway (Most Common Overall — ~50% of all APs): Negative or isoelectric Delta wave in Lead I and/or Lead aVL** (“pseudo-lateral MI pattern”), **Strongly Positive Delta and QRS in V1 through V6**, and normal/positive inferior leads.
- **Left Posterolateral / Left Posterior Pathway: Positive Delta wave in Lead I**, **Positive in V1**, and **Negative Delta waves in III and aVF** (often positive or isoelectric in II).

B Posteroseptal (Inferoparaseptal) Pathways (Negative Delta in II, III, aVF)

- **Left vs. Right Posteroseptal Differentiation:** Both show **deep negative Delta waves in III and aVF**. If **Lead V1 is positive** (or R/S >= 1 in V2 with a steep R-wave transition between V1 and V2), it favors a **Left Posteroseptal** insertion (approached transseptally/retrogradely); if **V1 is negative with R/S < 1 in V2**, it favors a **Right Posteroseptal** insertion near the coronary sinus ostium.
- **Subepicardial Coronary Sinus / Middle Cardiac Vein Diverticulum Pathway (Arruda Crucial Step 1): Negative Delta wave in Lead II** (in addition to III and aVF) combined with a **Steeply Positive Delta wave in Lead aVR** identifies a subepicardial posteroseptal pathway located within the **Coronary Sinus (CS) or Middle Cardiac Vein (MCV)**, which requires ablation **inside the coronary sinus venous system** rather than the endocardium.

C Right Septal and Right Free-Wall Pathways (Negative Delta/QRS in V1)

- **Anteroseptal / Para-Hisian (Superoparaseptal) Pathway: Negative or isoelectric Delta wave in V1 and V2** (with R/S transition at V3), **Strongly Positive Delta wave in all three inferior leads (II, III, aVF)**, and **Positive in Lead I and aVL**. Lies within millimeters of the compact **AV Node and His Bundle** at the apex of the Triangle of Koch, carrying the **highest risk of iatrogenic Complete Heart Block during catheter ablation (1 to 3 percent)** (often treated with **Cryoablation** rather than RF for reversible ice-mapping safety).
- **Midseptal Pathway:** Negative V1, R/S transition at V2–V3, with discordant inferior leads (positive in II, isoelectric/negative in III, positive/isoelectric in aVF); also lies inside the Triangle of Koch with high AV block risk.
- **Right Free-Wall (Right Lateral) Pathway: Deeply Negative Delta and QRS in V1 and V2**, **Late precordial R/S transition at V4 to V6**, and **Strongly Positive Delta wave in Lead I and aVL**.

Accessory Pathway Location	Lead V1 (Delta / QRS)	Precordial Transition (R > S)	Inferior Leads (II, III, aVF)	Lateral Leads (I, aVL)	Key Ablation Access & Exam Pearl
Left Lateral (Free Wall) (Most common ~50%)	**Positive** (RBBB-like)	V1	Positive (or II+, III+/-)	**Negative or Isoelectric in I and aVL**	**Transseptal** (or retrograde aortic); >95% success
Posteroseptal (Right or Left) (~25%)	Negative (Right PS) or Positive (Left PS)	**Rapid transition at V2**	**Negative (QS) in III, aVF (and II)**	Positive in I and aVL	Mimics **inferior MI**; if **Lead II negative + aVR positive** -> **Coronary Sinus / MCV**
Right Free Wall (Lateral) (~10%)	**Negative** (LBBB-like)	**Late transition (V4–V6)**	Variable (Ant: +; Post: -)	**Strongly Positive in I and aVL**	Associated with **Ebstein Anomaly**; steerable long sheath needed for stability
Anteroseptal / Para-Hisian (~5–10%)	**Negative / Isoelectric**	V3	**Strongly Positive in II, III, aVF**	Positive in I and aVL	Near **His Bundle**; **1–3% risk of Complete Heart Block** (consider **Cryoablation**)

V PRACTICAL CONSIDERATIONS IN THE INDIAN CLINICAL CONTEXT

- **Ebstein Anomaly and Multiple Right-Sided / Mahaim Pathways:** Up to **20 to 30 percent of patients with Ebstein Anomaly have WPW syndrome**. Because of congenital downward displacement and discontinuity of the septal and posterior tricuspid leaflets, these patients invariably harbor **Right Free-Wall or Right Posteroseptal pathways (often multiple in 30 to 50 percent of cases)**, as well as **decremental atriofascicular (Mahaim) fibers** (which conduct only antegradely with an LBBB morphology and left axis deviation during antidromic AVRT).Furthermore, the baseline PR interval in Ebstein + WPW may appear falsely normal because gigantic right atrial intra-atrial conduction delay offsets the short P-delta interval.
- **Catheter Ablation Strategy and Counseling:** Surface ECG localization directly dictates pre-procedural planning in the EP laboratory: **Left Lateral pathways** require **transseptal puncture** (with heparinization to ACT >300 seconds) or retrograde transaortic access and carry >95 percent cure rates with near-zero AV block risk, whereas **Right Anteroseptal (Para-Hisian) and Midseptal pathways** require explicit pre-procedural counseling regarding a **1 to 2 percent risk of permanent pacemaker dependency**.

KEY REFERENCES

- **Arruda MS, McClelland JH, Wang X, et al.:** Development and validation of an ECG algorithm for identifying accessory pathway ablation site in Wolff-Parkinson-White syndrome, *Journal of Cardiovascular Electrophysiology*, 1998.
- **Brugada J, Katritsis DG, Arbelo E, et al.:** 2019 ESC Guidelines for the management of patients with supraventricular tachycardia, *European Heart Journal*, 2020.
- **Crinion D, Baranchuk A:** Algorithms Used to Localize Accessory Pathways in Wolff-Parkinson-White Syndrome, *JACC: Clinical Electrophysiology*, 2020.