Typical example of pseudo LBBB and acute myocardial infarction theoretical considerations

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The author does not report any conflict of interest regarding this presentation

ECGs from Smith et al.(**Smith SW, Dodd KW, Henry TD, Dvorak DM, Pearce LA. Diagnosis of ST-elevation myocardial infarction in the presence of left bundle branch block with the ST-elevation to S-wave ratio in a modified Sgarbossa rule. *Ann Emerg Med* 2012;60:766-76**.) doi: 10.1016/j.annemergmed.2012.07.119

Mistake in this conrestone paper !!!!!!!

Dear Dr Smith: Do you admit the mistake made in your 2012 classic manuscript?
Thak in advance
Andrés Ricardo Pérez-Riera MD PhD São Paulo BrazIL

Yes, I've been waiting for someone to notice that. You are the first one.

I only noticed it after the paper was published.

Stephen W. Smith

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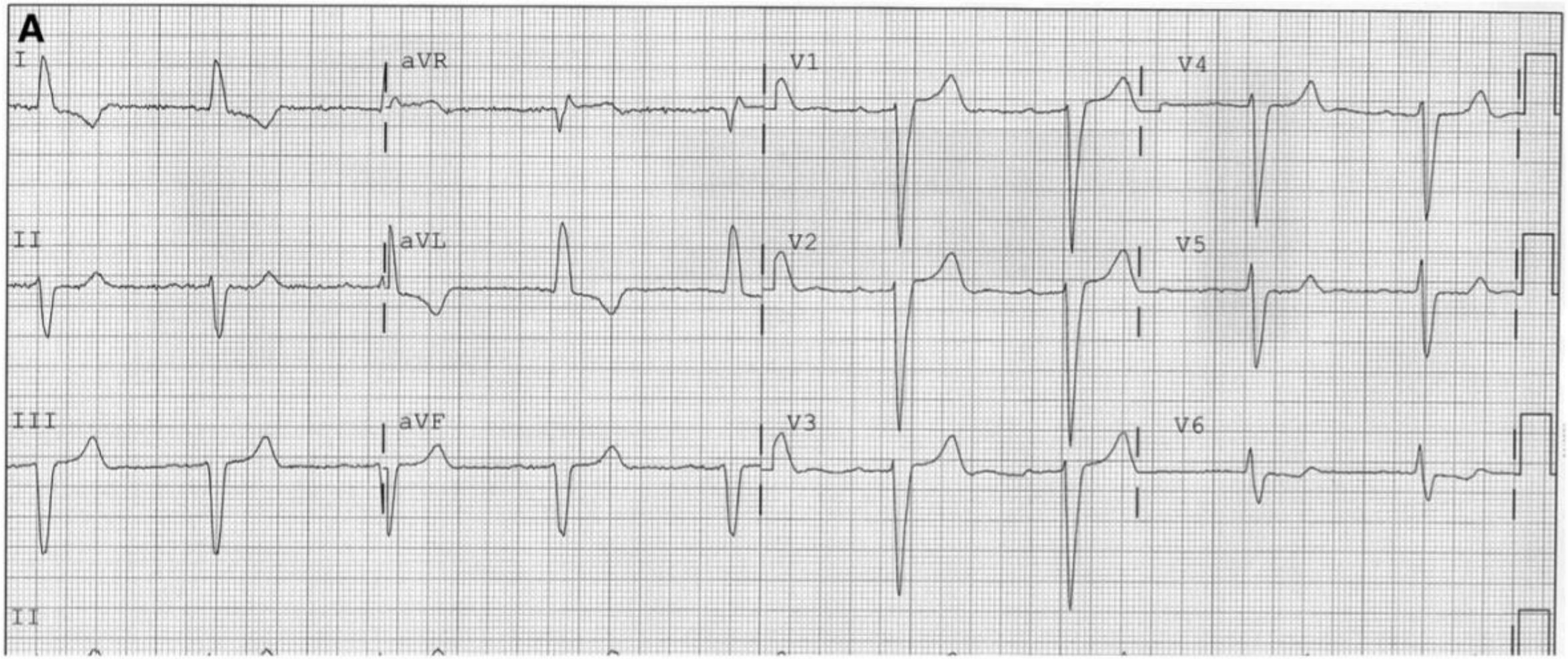
Este es um grande admite com la humildad de los sábios el error cometido



A. The patient's baseline ECG with left bundle branch block. Maximum ST elevation at the J point is 2 mm in lead V2, with an ST/S ratio of 2/230.087. B

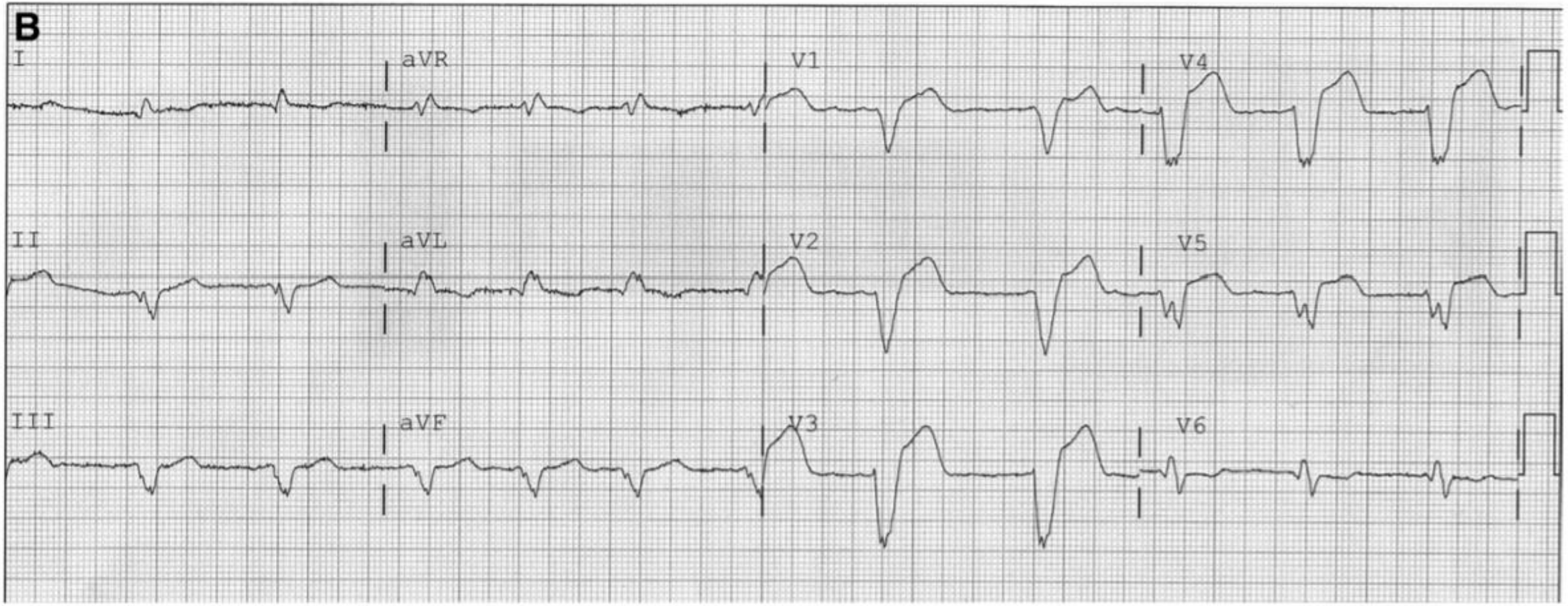


Figure 3. *B*, The patient's ECG when he presented with chest pain. There is no concordant ST deviation (no concordant ST-segment elevation or ST depression). Maximum ST-segment elevation is higher but still less than 5 mm (4.5 mm) and thus does not meet even the unweighted Sgarbossa criteria (it does not earn 2 points). However, ST/S ratios in V1 to V3 were, respectively, 2.5/–9.5=−0.26, 4.5/−12=−0.38, and 3/−9.5=−0.32; all 3 are less than −0.25 but only 1 needs to be so to fulfill the new criteria. This patient was taken for emergency angiography and PCI of a 100% acute left anterior descending artery occlusion.

the significance of ST depression depends on the preceding R-wave amplitude.[46-48] T-wave to QRS amplitude ratio distinguishes left ventricular "aneurysm" morphology (persistent ST elevation after previous myocardial infarction) from acute STEMI,[49,50] and R-wave to T-wave amplitude ratio distinguishes early repolarization from acute STEMI.[51] Madias et al[52] showed that 8 of 128 (6%) patients with left bundle branch block without acute myocardial infarction had at least 1 lead in V1 to V3 with at least 5-mm ST-segment elevation. They did not calculate a ratio but did show one example that had a very deep S-wave and an ST to S-wave ratio of less than −0.25. In another study of patients with baseline left bundle branch block (without acute myocardial infarction) and greater than or equal to 5-mm discordant ST-segment elevation, the mean preceding S wave was 46 mm (range 28.0 to 71.0 mm), for a ratio consistently less than −0.25.[11] Of 223 consecutive ED patients with left bundle branch block without acute coronary occlusion, ST/S ratio was more specific than an absolute value of greater than or equal to 5 mm.[53] Figure 2 shows the baseline ECG of a patient with left bundle branch block without ischemia; it shows 7 mm of ST-segment elevation but also a (–)53-mm S-wave, for an ST/S ratio of −0.13. Our

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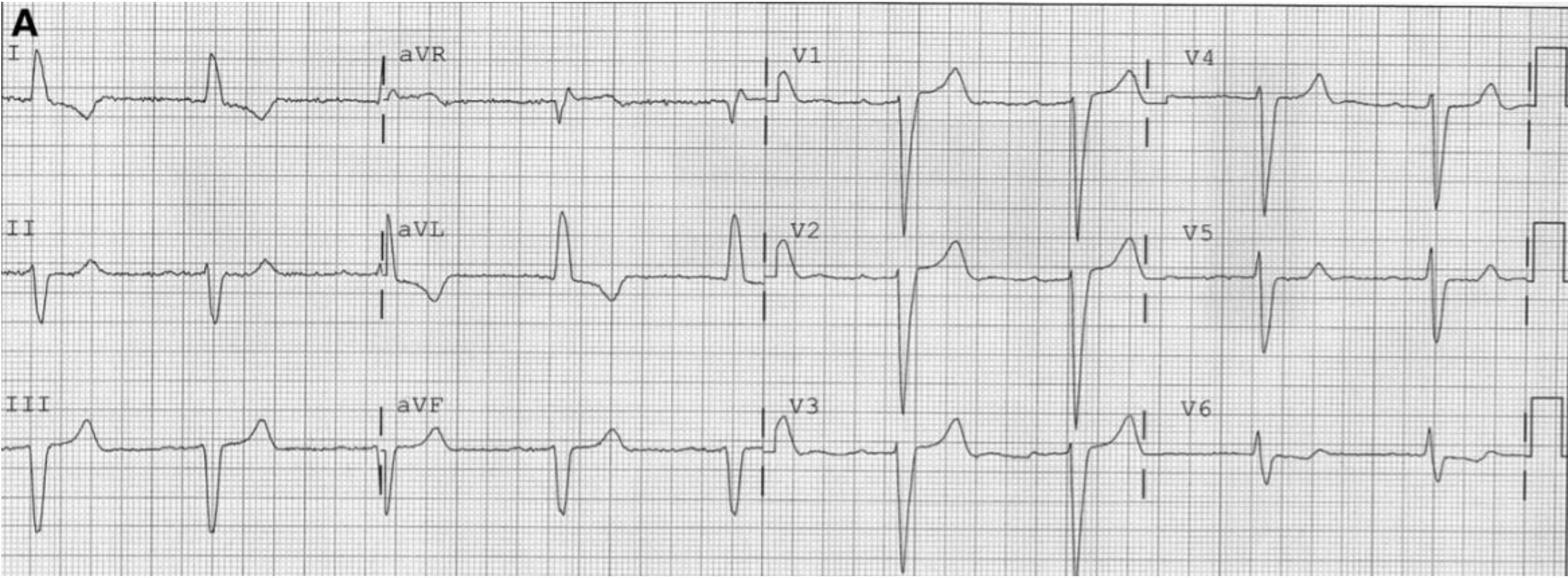
51. Smith SW, Khalil A, Henry TD, et al. Electrocardiographic differentiation of early repolarization from subtle anterior STsegment elevation myocardial infarction. Ann Emerg Med. http://dx.doi.org/10.1016/j.annemergmed.2012.02.015.
52. Madias JE, Sinha A, Agarwal H, et al. ST-segment elevation in leads V1-V3 in patients with left bundle branch block (LBBB). J Electrocardiol. 2001;34:87-88
53. Smith SW, Bertog SC, Lathrop LM, et al. ST/S ratio distinguishes left bundle branch block from left bundle branch block with simultaneous anterior myocardial infarction [abstract]. Acad Emerg Med. 2006;13(5 suppl):S160-S161.
11. Madias JE, Sinha A, Ashtiani R, et al. A critique of the new STsegment criteria for the diagnosis of acute myocardial infarction in patients with left bundle branch block. Clin Cardiol. 2001;24:652-655.

And now our analysis in next slides.....

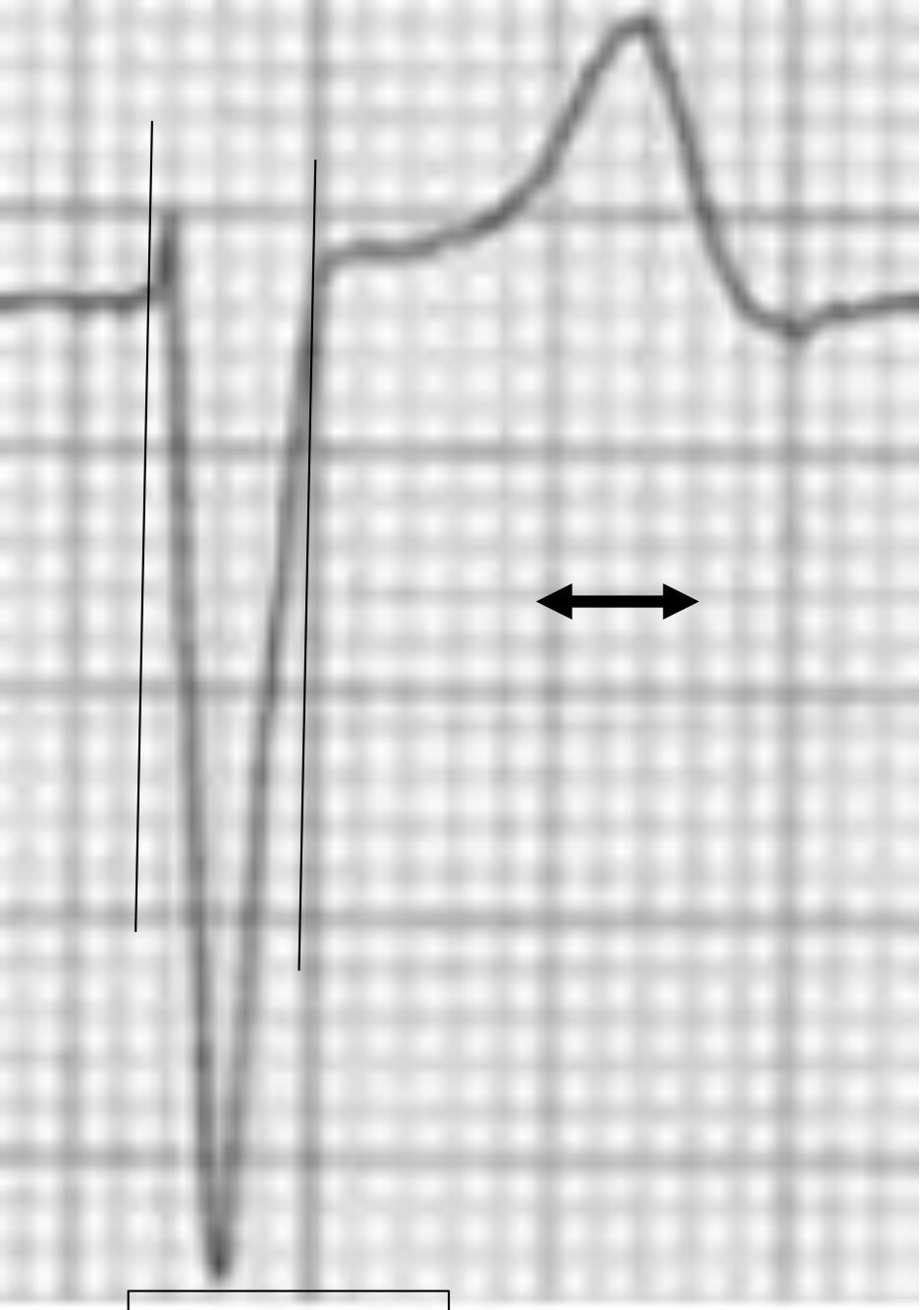
Andrés ECG analysis



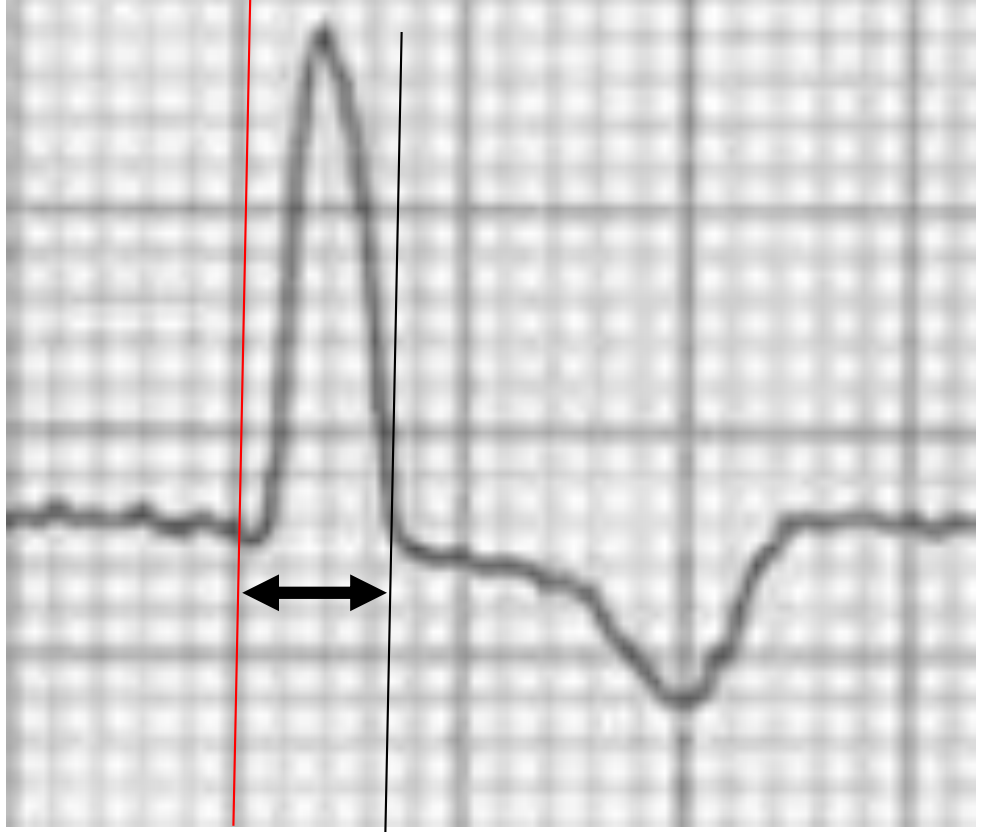
A, The patient's baseline ECG with apparent left bundle branch block. QRS duration 122ms, without notched or slurring in at least two contiguous lateral leads **atypical or pseudo** LBBB((absence of stricter Straus´s criteria) + Left anterior fascicular block(LAFB): extreme left axis deviation(QRS axis -55°), SIII>SII, and rS in V_5-V_6. Maximum ST elevation at the J point is 2 mm in lead V2, with an ST/S ratio of 2/230.087

Conclusion: pseudo LBBB+ LAFB + LVH without LBBB.

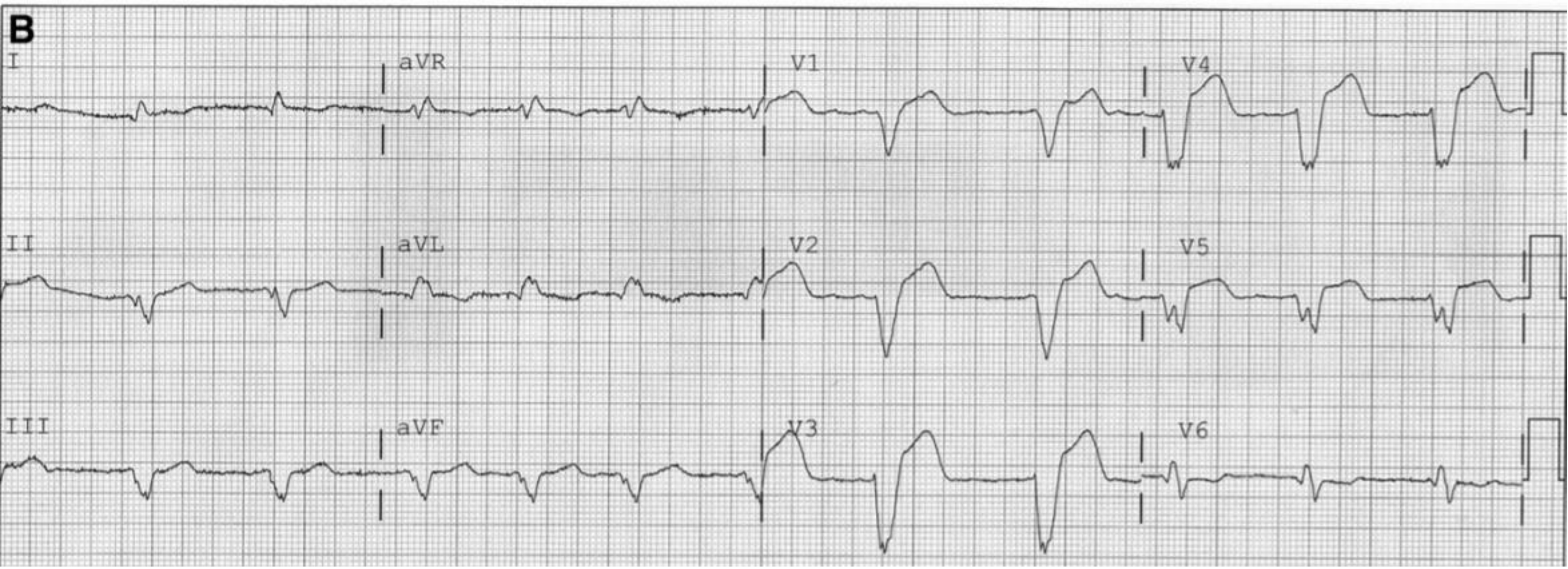
ECG from Smith et al.(**Smith SW, Dodd KW, Henry TD, Dvorak DM, Pearce LA. Diagnosis of ST-elevation myocardial infarction in the presence of left bundle branch block with the ST-elevation to S-wave ratio in a modified Sgarbossa rule. *Ann Emerg Med* 2012;60:766-76**.)



QRSd= 122 ms



QRSd= 120ms



B, The same patient's ECG when he presented with chest pain. There is no concordant ST deviation (no concordant ST-segment elevation or ST depression). Maximum ST-segment elevation is higher but still less than 5 mm (4.5 mm) and thus does not meet even the unweighted Sgarbossa criteria (it does not earn 2 points). However, ST/S ratios in V1 to V3 were, respectively, 2.5/–9.50.26, 4.5/120.38, and 3/9.50.32; all 3 are less than 0.25 but only 1 needs to be so to fulfill the new criteria. Low QRS voltage in the frontal plane. Wide fragmented QRS. Observation: It is not Cabrera's sign This sign is used to diagnose AMI in the setting of a LBBB. It consists of notching at 40 ms in the upslope of the S wave in lead V3 and V4. This sign has a poor sensitivity of 27% for AMI.

This patient was taken for emergency angiography and PCI of a 100% acute left anterior descending artery occlusion.

ECG criteria in non-complicated Complete LBBB correlation with VCG in the HP

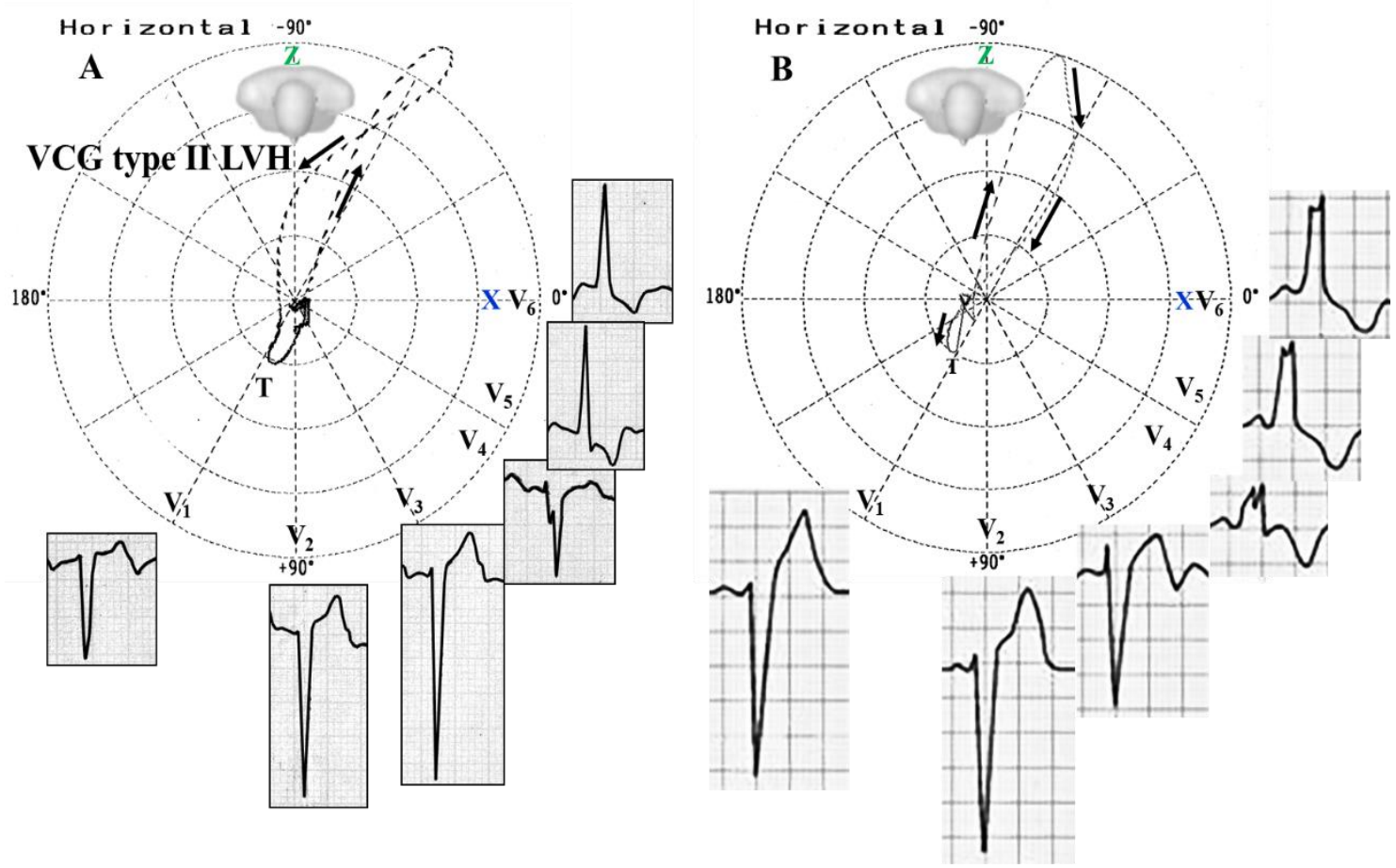
1. Supraventricular command: If the rhythm is sinus, the PR interval is ≥ than 120 ms.
2. **QRS duration** QRS duration≥120ms in adults, ≥100ms between 4 to 16years of age and ≥ 90ms in children less than 4 years of age. If New York Heart Association Class II-IV heart failure is present, and LVEF≤35%, ECG QRS width ≥ 120 ms in the presence of LBBB, cardiac resynchronization therapy is indicated. Reevaluation of the data of cardiac resynchronization trials and electrophysiologic findings in LBBB provided evidence that "true" LBBB requires a QRS width of ≥130 ms (in woman) and ≥140 ms (in man). In "true" LBBB, after the 40th ms of the QRS notched/slurred R waves are characteristic in minimum two of I, aVL, V1, V2, V5 and V6 leads, in addition to a ≥40 ms increase of the QRS complex, as compared to the original QRS complex. In contrast, slowly and continuously widened "LBBB like" QRS patterns are mostly occur in LVH or in a metabolic/infiltrative disease(**Préda 2013**). Cardiac resynchronization therapy (CRT) has emerged as an attractive intervention to improve left ventricular mechanical function by changing the sequence of electrical activation. Unfortunately, ≈ 30% of patients receiving CRT do not benefit (non-responders) but are subjected to device complications and costs. Thus, there is a clear need for better selection criteria. Three key studies have suggested that $^1/_3$ of patients diagnosed with LBBB by conventional ECG criteria may not have true complete LBBB, but likely have a combination of LVH and LAFB. **Observation**: Current criteria for CRT eligibility include a QRS duration ≥ 120 ms. However, studies have suggested that only patients with LBBB benefit from CRT, and not patients with RBBB or nonspecific intraventricular conduction delay. Strauss et al (**Strauss 2011**) review the pathophysiologic and clinical evidence supporting why only patients with complete LBBB benefit for Cardiac Resynchronization Therapy (CRT). Additionally, they review how the threshold of 120 ms to define LBBB was derived subjectively at a time when criteria for LBBB and RBBB were mistakenly reversed. These authors propose stricter criteria for complete LBBB that include a QRS duration ≥ 140 ms for men and ≥ 130 ms for women, along with mid-QRS notching or slurring in ≥ 2 contiguous leads. Further studies are needed to reinvestigate the electrocardiographic criteria for complete LBBB and the implications of these criteria for selecting patients for CRT. biopsy. For this entity, the term latent cardiomyopathy had been suggested previously. New strict LBBB criteria increase the specificity of complete LBBB diagnosis in the presence of LV hypertrophy/dilatation and incomplete LBBB, which is critical for selecting CRT patients (**Galiotti 2013**). In patients with guideline-defined LBBB, the absence of ECG markers of residual left bundle conduction was predictive of a greater improvement in LV function with CRT. An r wave ≥1 mm in lead V1 (r-V1) and/or a q wave ≥1 mm in lead aVL (q-aVL) is used to identify patients with residual LB conduction (**Perrin 2012**). In patients with conventional wider LBBB morphology, the presence of mid-QRS notching or slurring is a strong predictor of better response to CRT (**Tian 2013**). The typical surface ECG feature of LBBB is a prolongation of QRS above 110 ms in combination with a delay of the ventricular activation time, or “R –wave peak time” (old intrinsecoide deflection) in left lateral leads V5 and V6 of more than

1.60 ms and no septal q waves in leads I, V5, and V6 due to the abnormal septal activation from right to left. LBBB may induce abnormalities in left ventricular performance due to abnormal asynchronous contraction patterns which can be compensated by biventricular pacing (resynchronization therapy). Asynchronous electrical activation of the ventricles causes regional differences in workload which may lead to asymmetric hypertrophy and left ventricular dilatation, especially due to increased wall mass in late-activated regions, which may aggravate preexisting left ventricular pumping performance or even induce it. Of special interest are patients with LBBB and normal left ventricular dimensions and normal LVEF at rest but who may present with an abnormal increase in pulmonary artery pressure during exercise, production of lactate during high-rate pacing, signs of ischemia on myocardial scintigrams (but no coronary artery narrowing), and abnormal ultrastructural findings on myocardial biopsy. For this entity, the term latent cardiomyopathy had been suggested (**Breithardt 2012**).

Recently Bertaglia et al (**Bretaglia 2017**) verified in the so called CRT MORE registry that stricter Straus´s definition of LBBB(defined as: QRS ≥ 140 ms for men and ≥130 ms for women, QS or rS in V1-V2, mid-QRS notching or slurring in ≥2 contiguous leads.) did not improve response to CRT in comparison to the current AHA definition. In this manuscript were defined as responders patients showing a relative decrease of ≥15% in left ventricular end-systolic volume (LVESV) at 12 months. Studies have identified sub-populations of non-LBBB patients that respond to CRT, such as those with first degree AV block (PR interval ≥ 230 ms), with RBBB and concomitant left-sided delay and those with significant burden of right ventricular pacing(**Belkin 2017**). ECG may play a role in predicting CRT response. QRS width and atrial flutter/atrial fibrillation before CRT and ECG axis change post-CRT could be used to predict CRT response: **1)** The proportion of female and LBBB is significantly higher CRT responders; **2)** QRS width ≥140 ms is significantly higher in CRT responders; **3)** Post-CRT prominent axis change were found to be independent predictors of CRT responders.; **4)** The proportion of atrial fibrillation/ atrial flutter is significantly low in CRT responders group than in non-responder group(**Guo 2016**).

Patients with LBBB have a very prolonged Q-LV interval (The QLV interval is defined as the measurement from the onset of the QRS width of the surface ECG to the first large positive or negative peak of the LV electrogram (EGM) during a cardiac cycle. QLV EGM will be taken from either the LV pacing lead and/or .014 wire). Mid-QRS notching in lateral leads strongly predicts a longer Q-LV interval in L-IVCD patients. Patients with R-IVCD constitute a subgroup of patients with a long Q-LV interval. n L-IVCD, mid-QRS notching/slurring showed the strongest correlation with a longer Q-LV interval, followed, in decreasing order, by QRS duration >150 ms and R-wave peak time >60 ms. Isolated mid-QRS notching/slurring predicted Q-LV interval >110 ms in 68% of patients. Patients with LBBB have a very prolonged Q-LV interval. Mid-QRS notching in lateral leads strongly predicts a longer Q-LV interval in L-IVCD patients. Patients with R-IVCD constitute a subgroup of patients with a long Q-LV interval (**Pastore G 2016**).

A) Pseudo LBBB: LVH VCG type II **B) True LBBB: CRT- responders**



A) Pseudo LBBB ECG/VCG from CRT non-responder fulfilling inclusion criteria for major CRT clinical trials with QRSd of at least 120 ms (in this example exactly 120 ms), broad R wave in I, aVL, V_5 and, V_6, discordant ST segments and T waves, and absence of Q waves in I, V_5 and, V_6. Also, the features broad mid-QRS notching or slurring of the R wave in the left leads I, aVL and V5-V6 in the strict Strauss' criteria are missing. Additionally, this VCG differentiates from true CLBBB by absence of middle-final delay (obligatory in true LBBB).

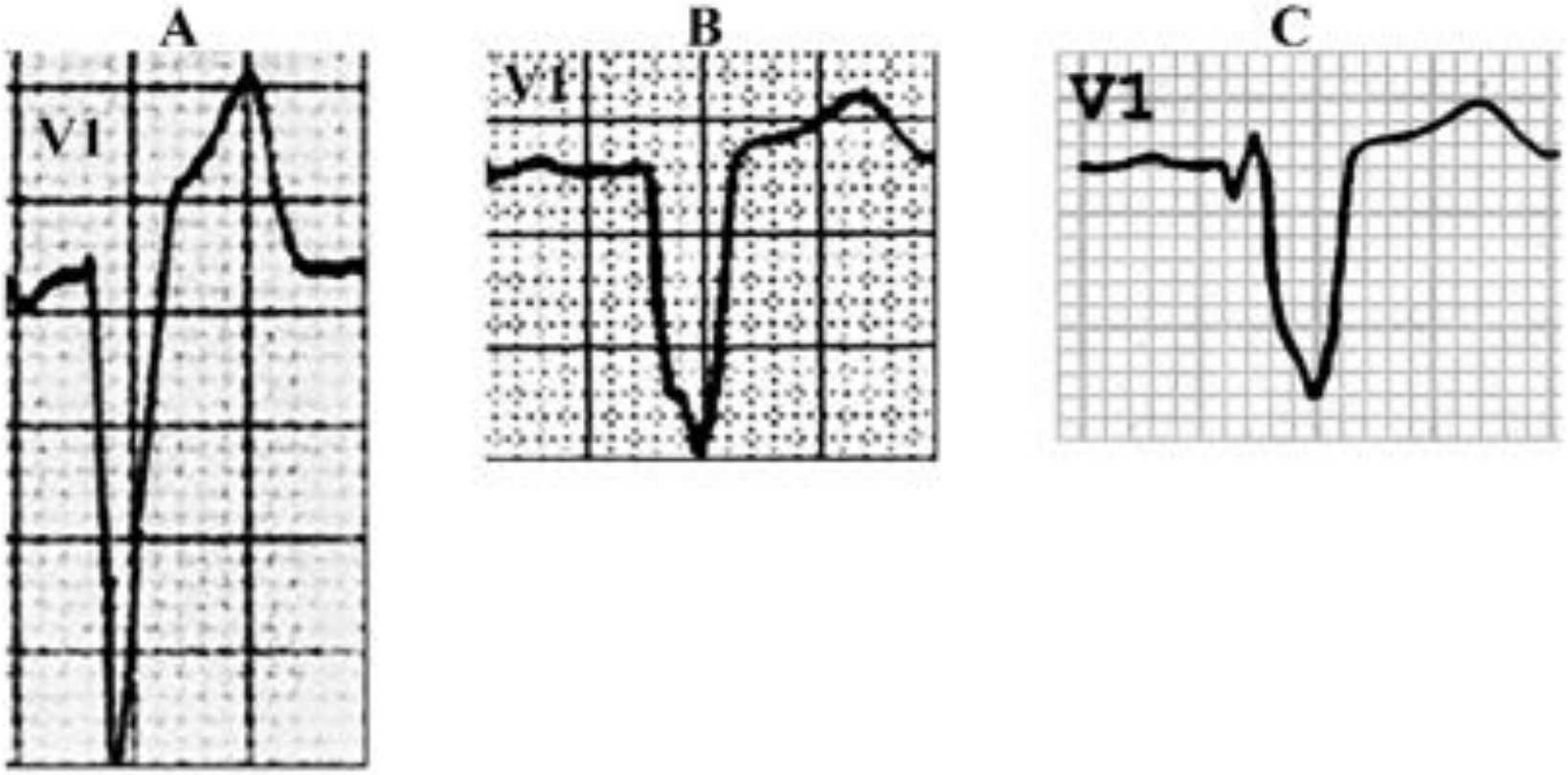
B) The QRS loop shape is elongated and narrow; the main body of the QRS loop is inscribed posteriorly and to the left within the range - 90 to -40°; conduction delay noted in the mid and terminal portion; the main body of QRS loop is inscribed clockwise (CW); the magnitude of the max QRS vector is increased above normal exceeding 2mV; ST segment and T wave vector are directed rightward and anteriorly (opposite to QRS-loop).

Table ECG variable definitions of LBBB used in different clinical and research settings

AHA/ACCF/HRS recommendations (Surawicz et al., 2009)	**≥120 ms**	• **Wide notched or slurred R wave in leads I, aVL and V_5-V_6** • **Occasional RS pattern in V_5-V_6 by displaced transition of QRS complex and other cause** • **Absence of q waves in leads I, V_5-V_6** • **R-wave peak time >60 ms in leads V_5-V_6 but normal in leads V_1 to V_3** • **Discordant ST segment and T waves.**
Strauss´s strict criteria definition (Strauss, Selvester, & Wagner, 2011)	**≥140 ms in men** **≥130 ms in women**	• QS or rS in V_1 and V_2 and • Mid-QRS notching or slurring in ≥2 contiguous leads of V_1, V_2, V_5, V_6, I and aVL
AHA/ACCF/HRS Class 1 Recommendation for CRT (Epstein et al., 2013)	**≥150 ms**	"LBBB morphology" as per AHA/ACCF/HRS recommendations (Surawicz et al., 2009)
ESC Class 1 Recommendation for CRT (Brignole et al., 2013)	**≥ 120 ms**	• QS or rS in V_1; • Wide (frequently notched or slurred) R wave in leads I, aVL, V_5 or V_6; • Absence of q waves in leads V_5 and V_6.
ECG inclusion criteria for various major landmark CRT trials COMPANION (Bristow et al., 2004)	**≥120 ms**	Comparison of Medical Therapy, Pacing, and Defibrillation in Heart Failure; CARE-HF = Cardiac Resynchronization in Heart Failure
CARE-HF (Cleland et al., 2005)	**120–150 ms + echo dyssynchrony**	CARE-HF
MADIT-CRT (Moss et al., 2009)	**≥130 ms**	Multicenter Automatic Defibrillator Implantation Trial with Cardiac Resynchronization Therapy.
RAFT (Tang et al., 2010)	**≥120 ms**	Resynchronization -Defibrillation for Ambulatory Heart Failure Trial.

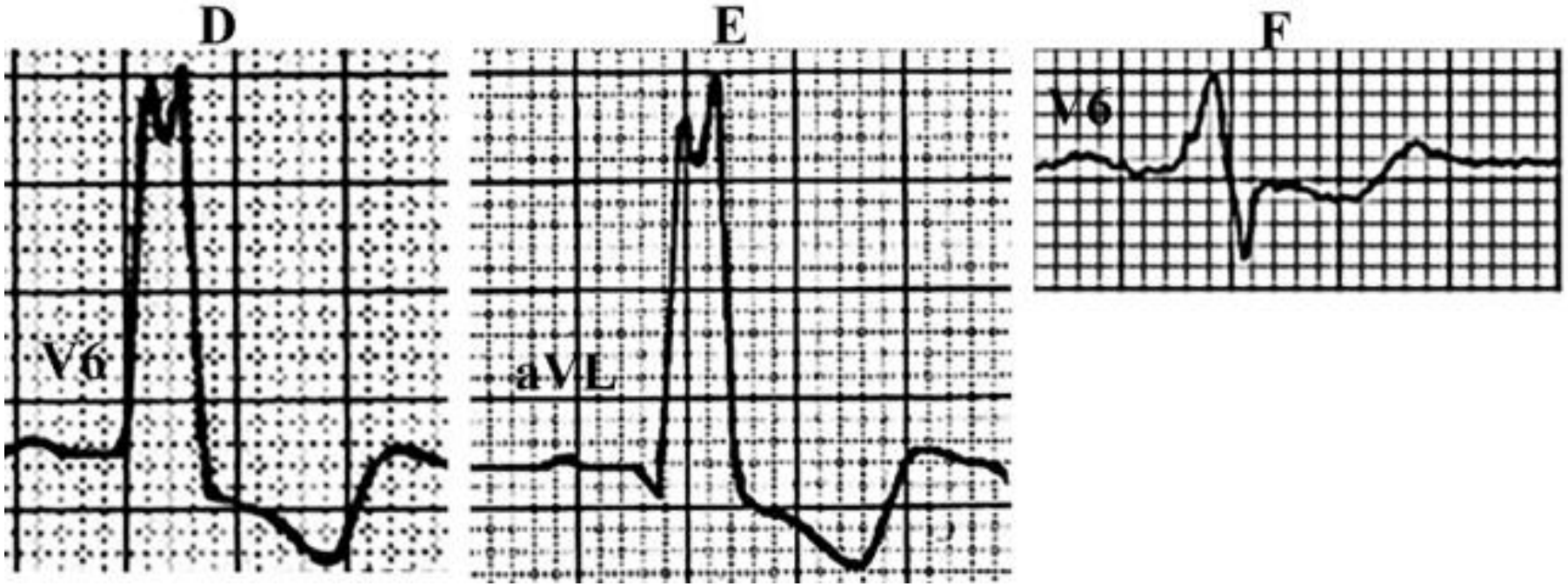
3. Dominant S wave in right precordial leads or QS pattern. QRS complexes on right precordial leads (V_1 and V_2) total or predominantly negative: rS, QS or qrS.

QRS complexes in the right precordial leads (V_1-V_2) total or predominantly negative: rS (70%), QS (>29%) or qrS (<1%) (Figure **A, B, C**). An initial r wave of ≥1 mm in lead V1 suggests intact left to right ventricular septal activation with existing conduction over the left bundle branch. This also identifies LBBB patients at low risk of complete heart block during right heart catheterization. These findings indicate that an initial r wave of ≥1 mm in lead V_1, present in a ≈28% of ECGs with classically defined LBBB, may constitute a new exclusion criterion when defining complete LBBB (**Padanilam 2010**). An increase of the voltage of the initial R wave in V_1 is occasionally seen with infarction of the ventricular septum in complicated LBBB.



rS in ≈70% (A), QS in >29% (B) and qrS in <1% (C)

4. Monophasic, broad notched or slurred R wave, recorded slowly in the left leads: I, aVL, V_5 - V_6



"Tower"with notch ('M'-shaped) R wave

There may be initial narrow q in aVL and exceptionally in I, however, never in V_5 and V_6

As the ventricles are activated sequentially (first right, then left) rather than simultaneously, this produces a broad or notched ('M'-shaped) R wave in the lateral leads (D). Additionally, there may be initial narrow q in aVL and exceptionally in I, but never in V_5 and V_6 (E). Occasionally, there is an Rs or RS pattern in V_5 and V_6,(F) which may indicate:

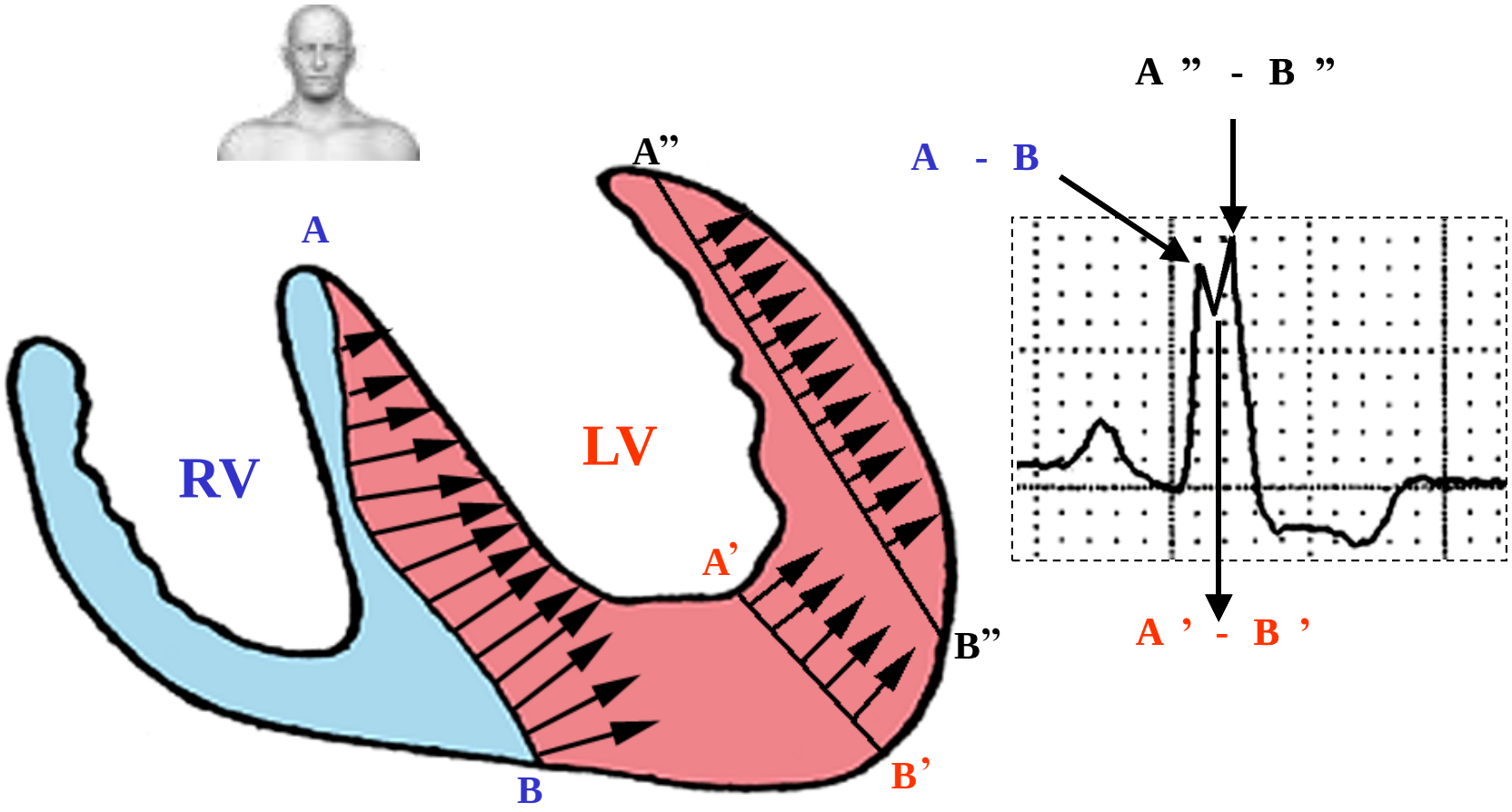
a) Displacement of the precordial transition zone of the QRS complex to the left;

b) Associated right ventricular hypertrophy (RVH);

c) Associated LAFB;

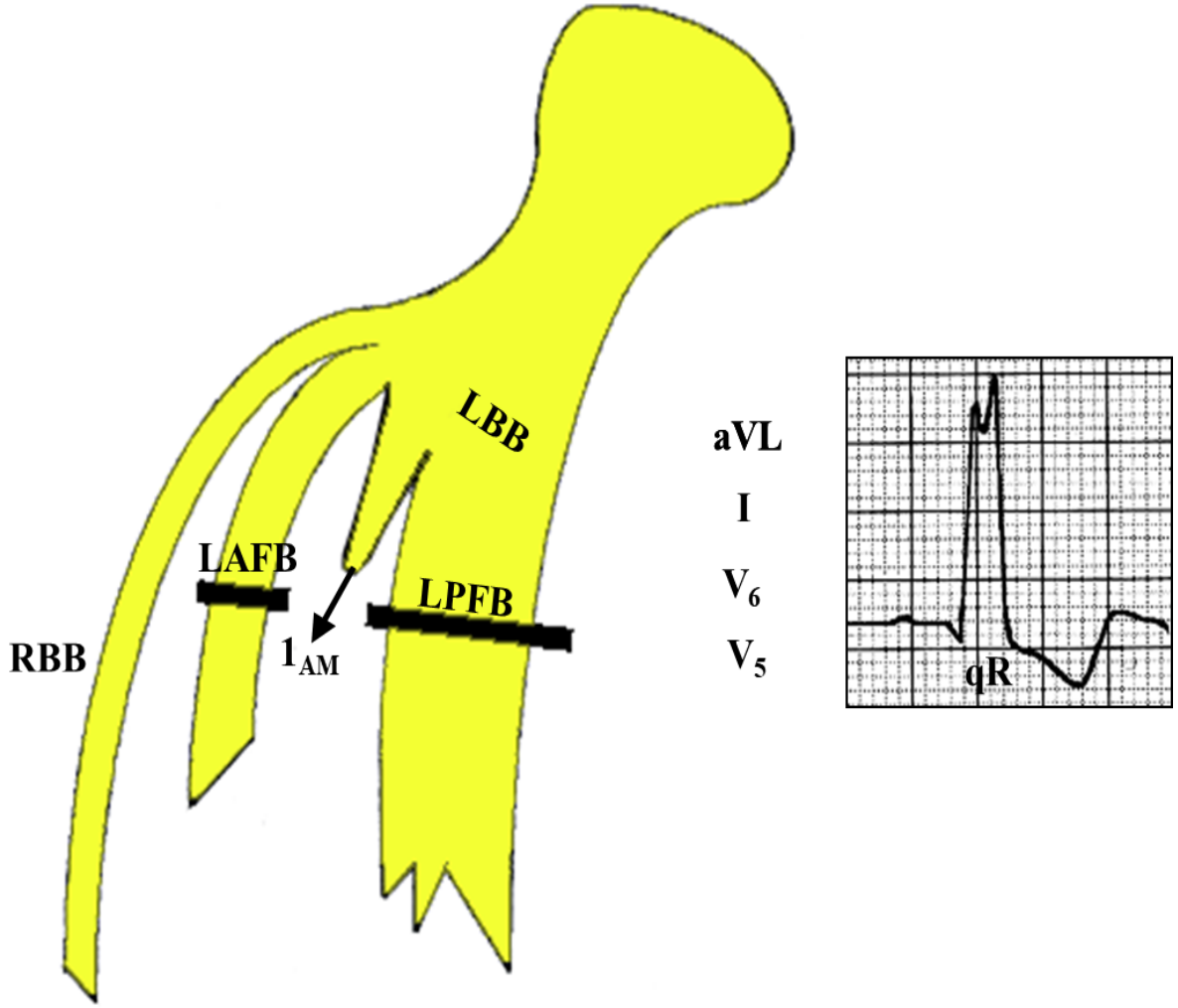
d) Associated myocardial infarction of the LV free wall (F).

Monophasic R wave of slow recording in left leads I, aVL, V_5 and V_6 and electrophysiological explanation



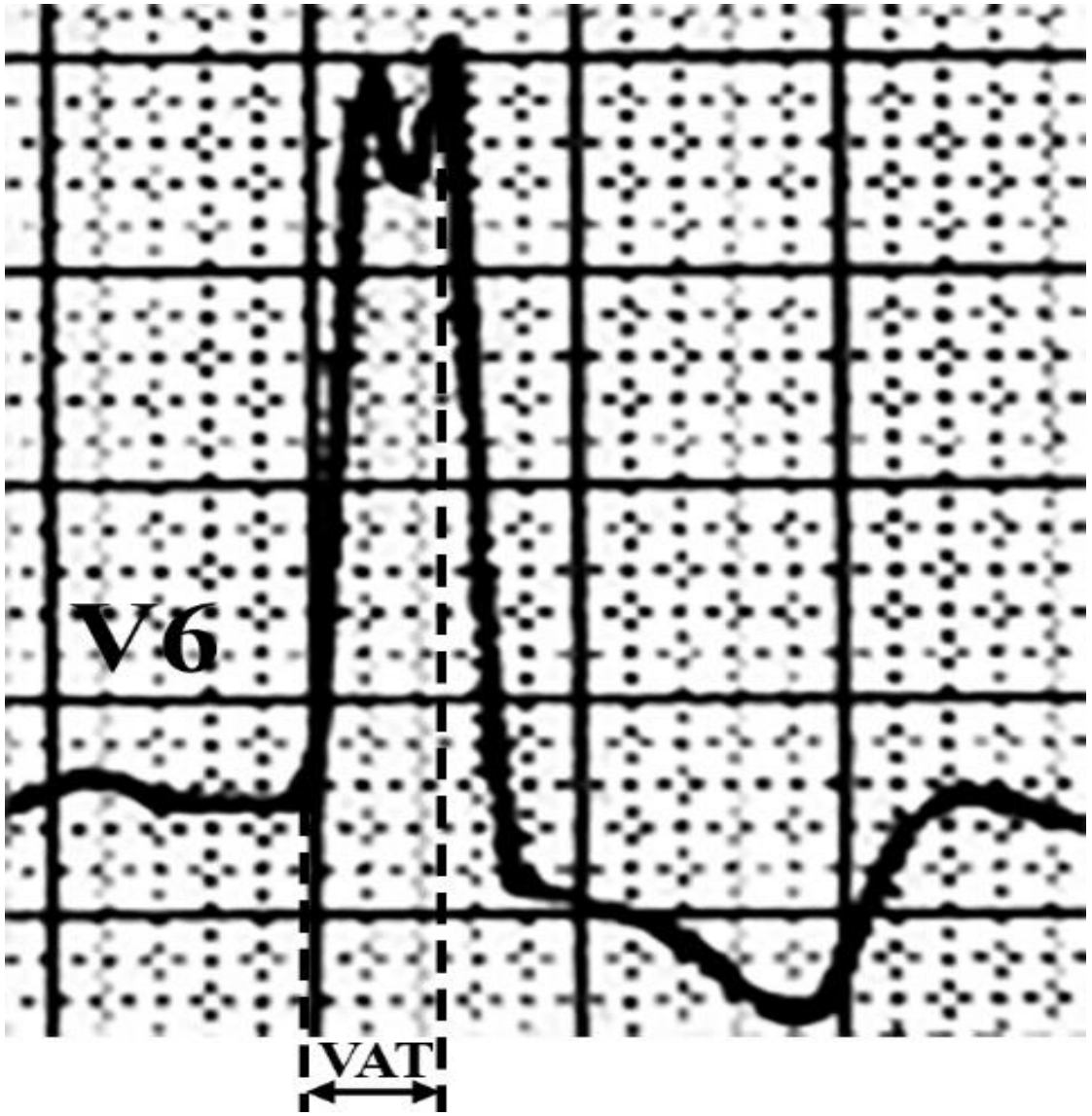
Septal depolarization from right to left makes a wide A-B wave front; however, when the stimulus reaches the central portion of the LV (cavity), it suffers a marked decrease in wavefront width (A’-B’) responsible for the notch in the apex of R wave. Next, the wavefront reaches the LV free wall increasing again the width of the wavefront (**A”-B”**), responsible for the second apex of R wave. In the severe hypertrophies of the free wall, this second apex presents a higher voltage related to the first one.

Figure shows an explanation for atypical LBBB with initial q wave in left lateral leads.



Outline of CLBBB with initial q wave in the left lateral leads (**Medrano, Brenes, De Micheli, & Sodi-Pallares, 1970**). The left septal fascicle (LSF) emerges before the bifascicular block area, preserving the first 10 ms septal vector, anteromeadial (I_{AM}) vector or Penaloza-Tranchesi vector (**Penaloza & Tranchesi, 1955**). In these cases, the initial ventricular activation is normal, heading to the right and the front with qR in left leads (atypical CLBBB). LBB: left bundle branch; RBBB: right bundle branch; LAFB: left anterior fascicular block; LPFB: left posterior fascicular block; LSF: left septal fascicle; I_{AM}: first anteromedial vector.

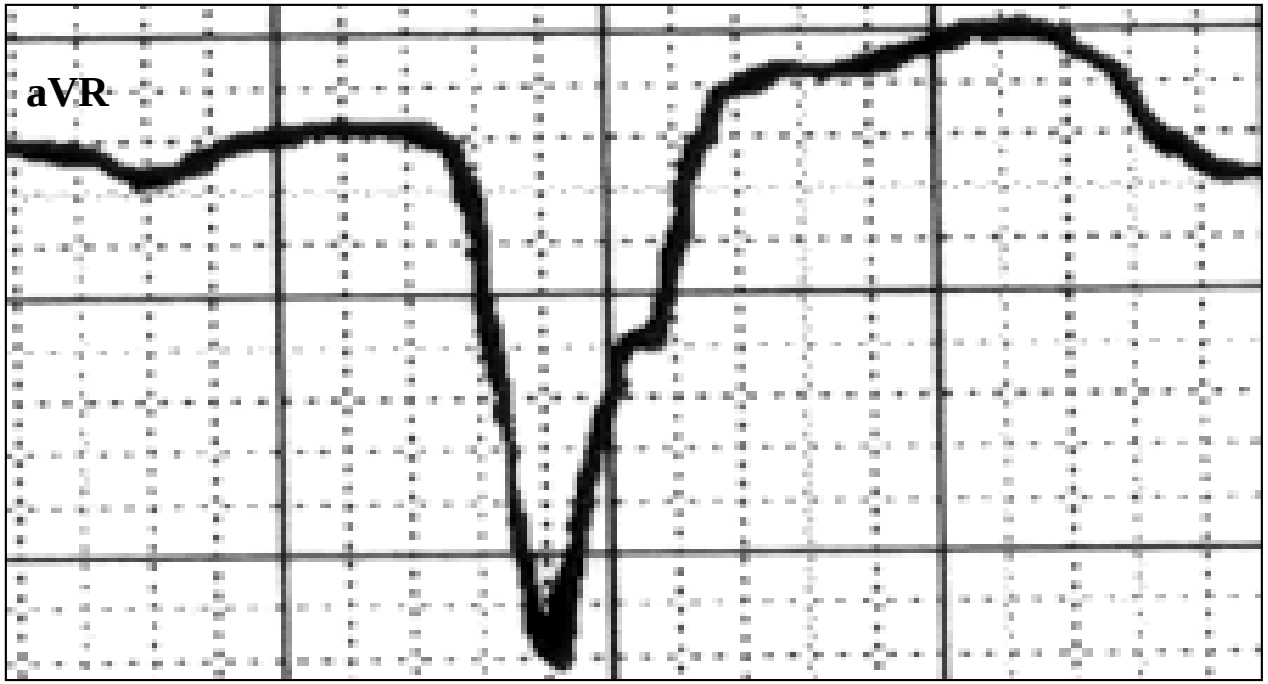
ProlongueD Ventricular Activation Time (VAT) in left lateral leads



VAT ≥ 60 ms

Ventricular activation time (VAT) or R-Wave Peak Time(old intrinsecoide deflection) ≥60 ms in I and V_5-V_6 but normal in V_1-V_2 and V_3, when small initial r waves can be discerned in the right precordial leads.

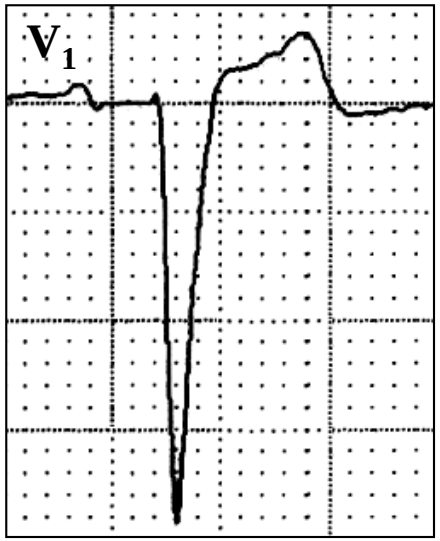
QS pattern almost constantly followed by ST-segment elevation and a positive T wave in aVR.



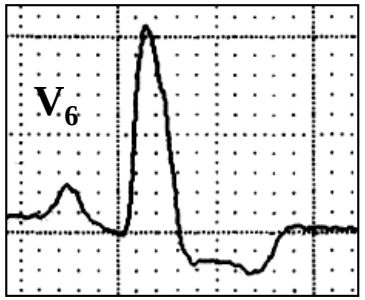
QS

QRS complex of the QS type almost constant in aVR.

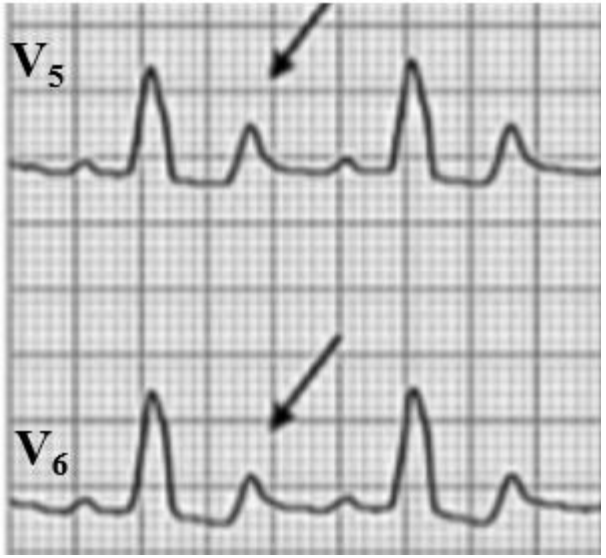
Repolarization in V_1 and V_5 -V_6 in complete LBBB: secondary repolarization abnormalities



Depressssed ST segment and/or negative T wave in leads with negative QRS (negative concordance) are abnormal (**Sgarbossa 1996; Gunnarsson 2001**).



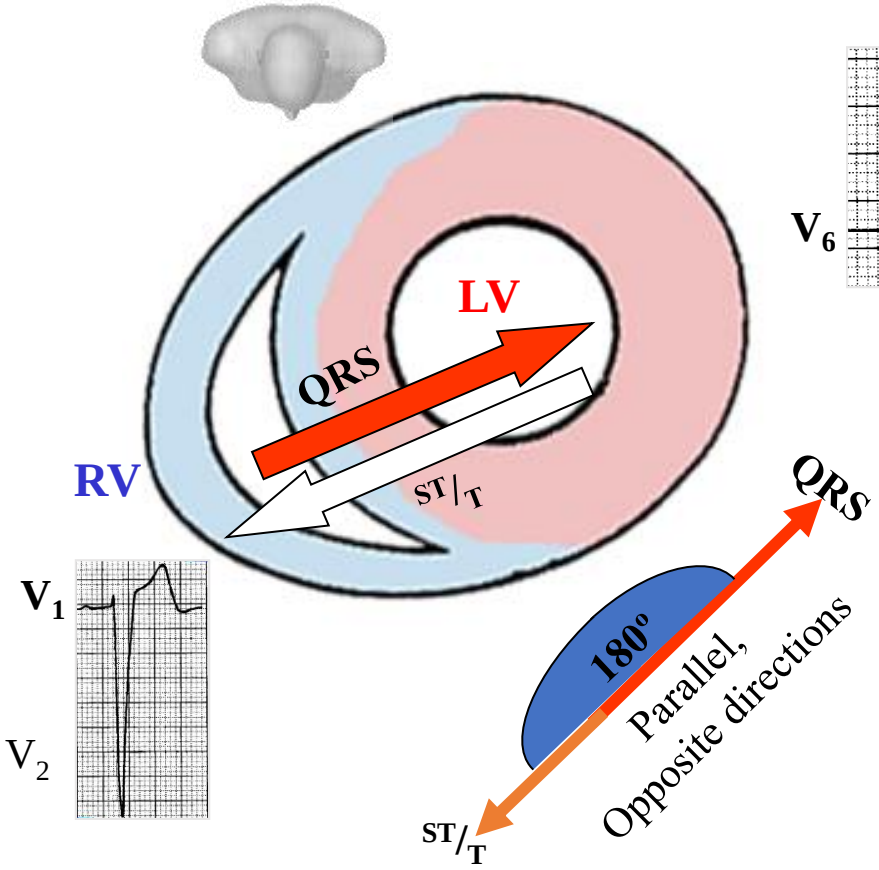
ST and T waves usually (≈ 70% of cases of LBBB opposite in direction to QRS "appropriate discordance"

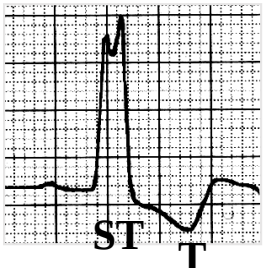


Positive T waves in leads with upright QRS may be normal (positive concordance) It is observed in ≈ 30% of cases of LBBB

Abnormalities in the ST segment and T wave that occur as the direct result of changes in the sequence and/or duration of ventricular depolarization, manifested electrocardiographically as changes in QRS shape and/or duration, are referred to as secondary repolarization abnormalities. Recognition of secondary repolarization abnormalities is usually not difficult. In left bundle-branch block, the ST- segment and T-wave vectors are generally directed opposite to the mean QRS vector.

Discordant LBBB or "appropriate discordance": the ST segments and T waves go in the opposite direction to the main vector of the QRS complex





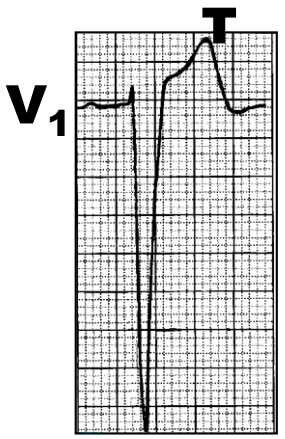
Depression upwardly convex of ST segment in left leads (I, aVL, V_5- V_6). It is called secondary repolarization abnormalities or "appropriate discordance".

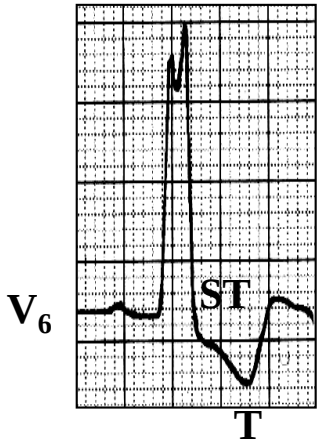
ST segment elevation upwardly convex in V_1 and V_2

Outline representing ventricular repolarization in CLBBB not complicated. Secondary alteration of ventricular repolarization is observed with QRS/ST-T angle near the 180º. The ST- segment and T-wave vectors are generally directed opposite to the mean QRS vector. The distinction between primary and secondary repolarization abnormalities is clinically relevant because primary abnormalities indicate changes in the repolarization characteristics of ventricular myocytes whereas secondary changes do not. The designation of the ST- and T-wave abnormalities as primary or secondary is appropriate, and it is recommended that automated interpretative algorithms be programmed to identify them.

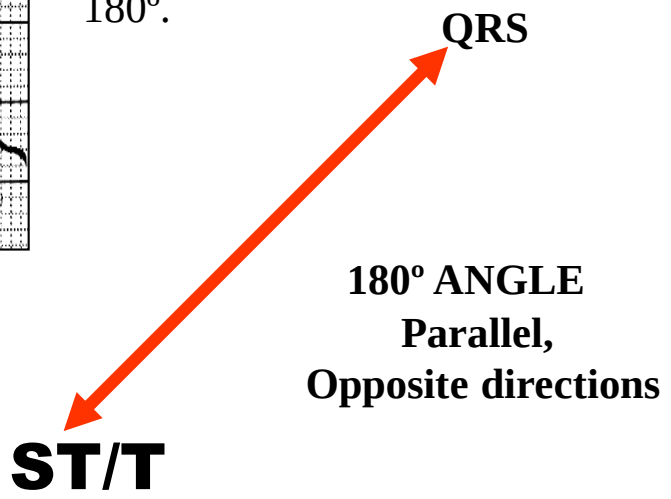
Ventricular repolarization in Uncomplicate Complete LBBB ≈ 70% of cases)

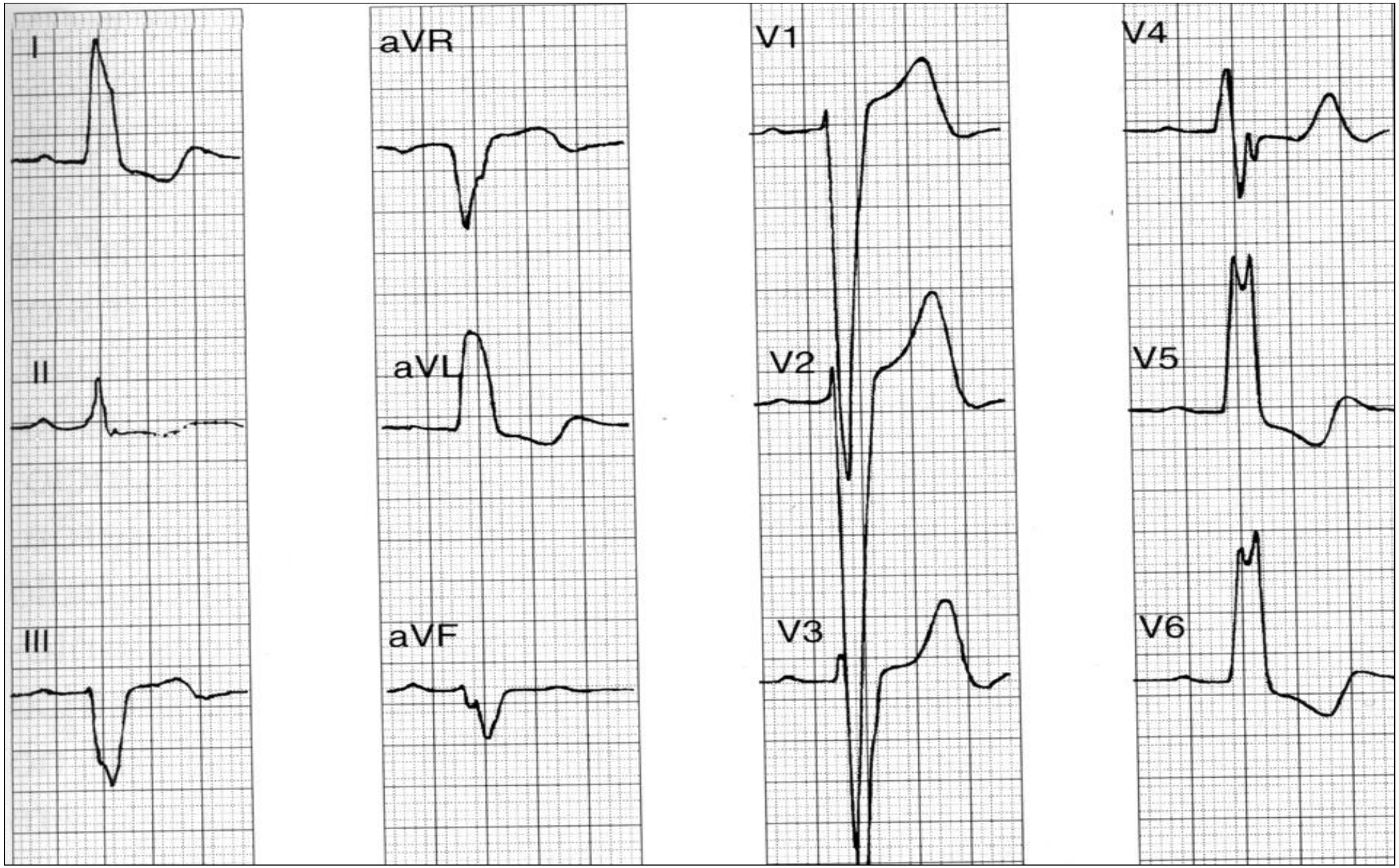
The ST- segment and T-wave vectors opposite to a greater deflection of QRS: positive from V_1 to V_3 and negative in left leads I, aVL, V_5 and V_6. These are Secondary Repolarization Abnormalities with wide QRS-ST-T angle and normal ventricular gradient. The classic ventricular gradient concept introduced by Wilson et al (**Wilson 193**1) in 1931 is of some theoretical interest concerning primary versus secondary repolarization abnormalities. Ventricular gradient in a single ECG lead is the net time integral of the ECG voltage from the beginning of the P wave to the end of the U wave. Its spatial counterpart is the ventricular gradient vector determined from the orthogonal XYZ leads. The practical utility of the ventricular gradient in differentiating primary from secondary repolarization abnormalities has not been demonstrated (**Surawicz,1988**). When the direction of the QRS axis is normal, an abnormal direction of the T-wave axis is generally an indication of primary repolarization abnormalities.





Outline representing ventricular repolarization in not complicated CLBBB. Secondary alteration of ventricular repolarization is observed with QRS/ST-T angle near the 180º.



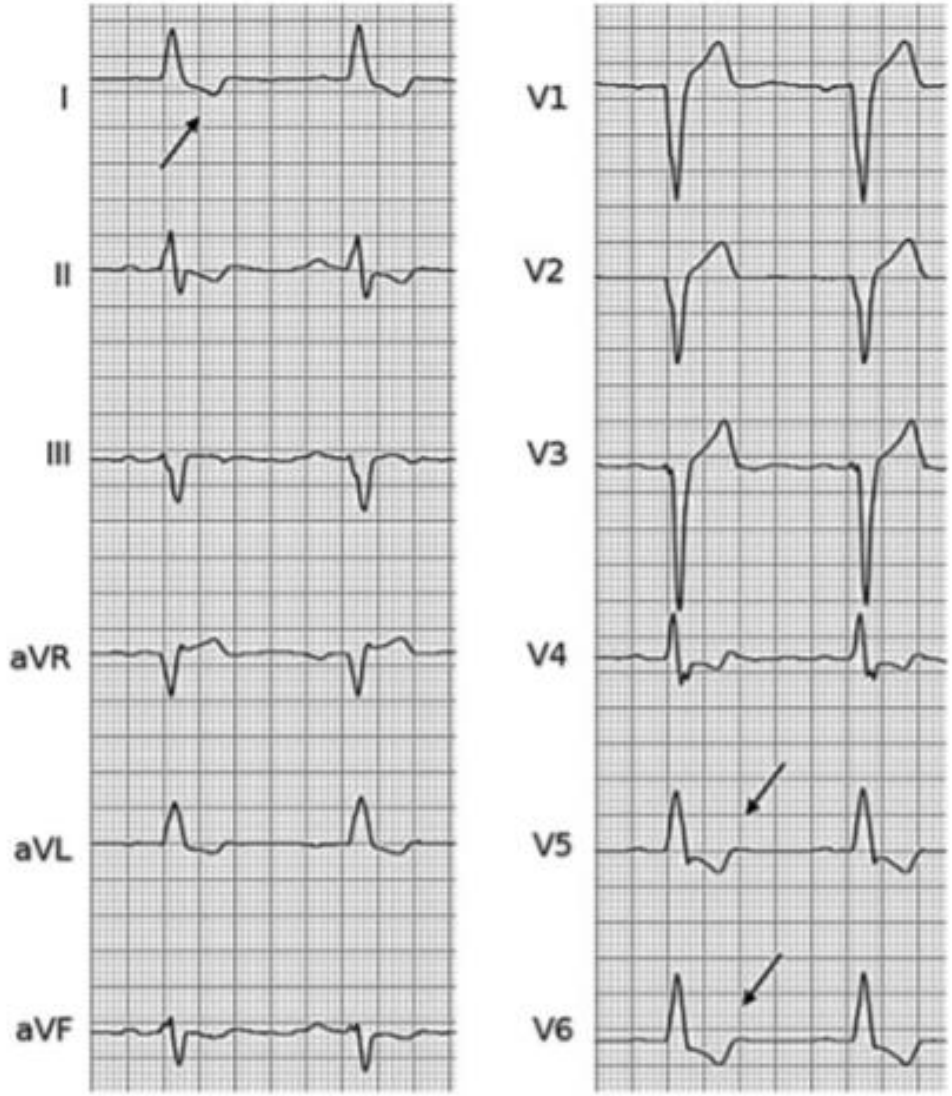


ECG tracings (25 mm/second; 10 mm/1 mV) showing discordant LBBB, characterized by ST-segment depression followed by a negative T wave in leads I and V_5 or V_6. In discordant LBBB there is ST-segment depression followed by negative asymmetrical T waves in at least two of the lateral leads I and V_5 or V_6 and concomitant positive T-waves in the right precordial leads.

The ST- segment and T-wave vectors are more frequently opposite to the predominant deflection of the QRS: positive from V_1 to V_3 and negative in left leads I, aVL, V_5 and $V_{6:}$ “apporpiate discordance”. These are secondary repolarization abnormalities with a wide ^{QRS}-$_{ST-T}$ angle and normal ventricular gradient. The classic ventricular gradient concept introduced by Wilson et al in 1931(**Wilson, Macleod, & Barker, 1931**) is of theoretical interest concerning primary versus secondary repolarization abnormalities. The ventricular gradient in a single ECG lead is the net time integral of the ECG voltage from the beginning of the P wave to the end of the U wave. Its spatial counterpart is the ventricular gradient vector determined from the orthogonal XYZ leads. The practical utility of the ventricular gradient in differentiating primary from secondary repolarization abnormalities has not been demonstrated (**Surawicz, 1988**). When the direction of the QRS axis is normal, an abnormal direction of the T-wave/loop axis is generally an indication of primary repolarization abnormalities.

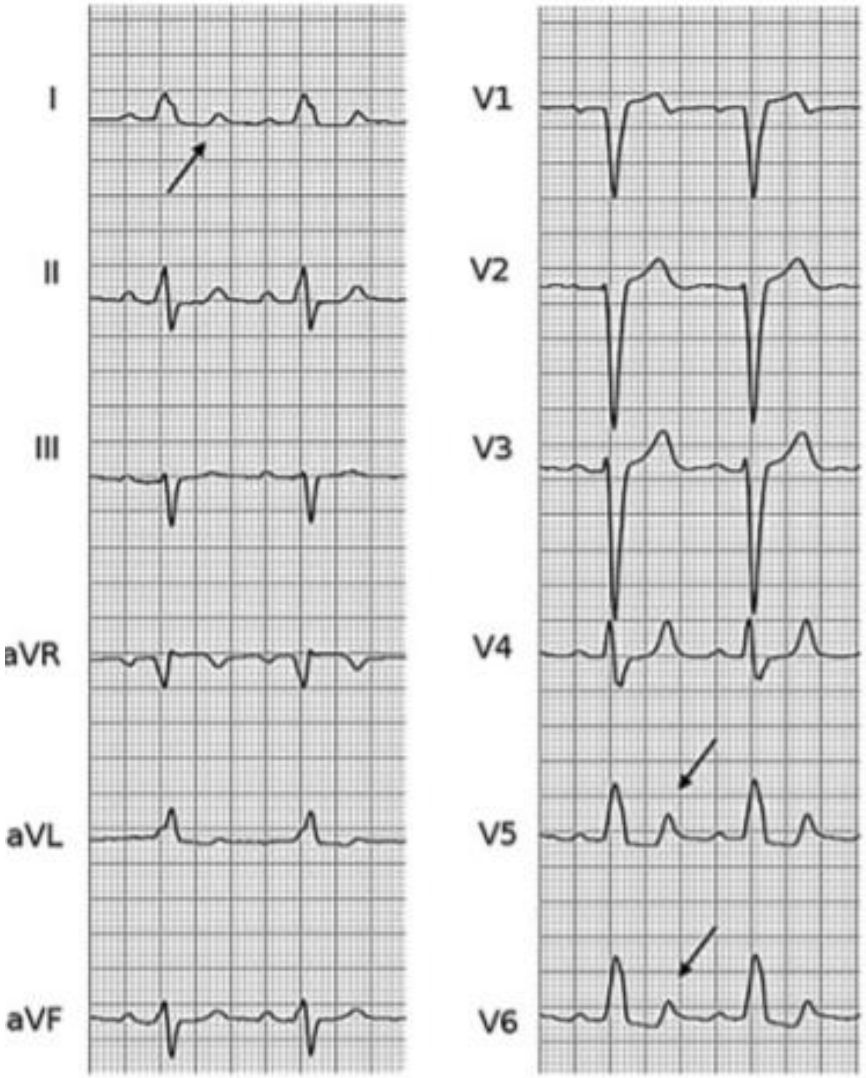
When QRS complexes in the left/lateral leads and the ST-segment/T-wave have the same polarity, the term concordant LBBB repolarization is used, and this is observed in 28 to 32% of cases (Padeletti et al., 2018). The definition of concordant LBBB is T-wave orientation concordant with QRS complex with a positive/diphasic T wave in at least two of the leads I and V5 or V6 (**Padeletti et al., 2018**)

Discordant LBBB (dLBBB) or "appropriate discordance": the ST segments and T waves go in the opposite direction to the main vector of the QRS complex



ECG tracings (25 mm/second; 10 mm/1 mV) showing discordant LBBB, characterized by ST-segment depression followed by a negative T wave in leads I and V_5 or V_6 (arrows). dLBBB definition: ST-segment and T-wave orientation discordant with QRS complex) is characterized by an ST-segment depression followed by negative T waves in lateral leads I and V_5 or V_6 (at least in two of these three leads) and concomitant positive T-wave in rignt precordial leads.

Concordant LBBB (cLBBB)

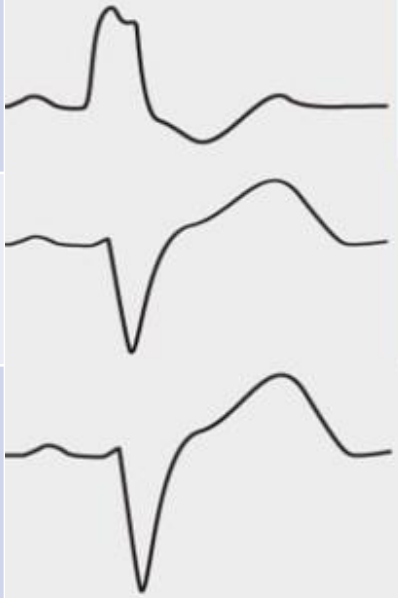
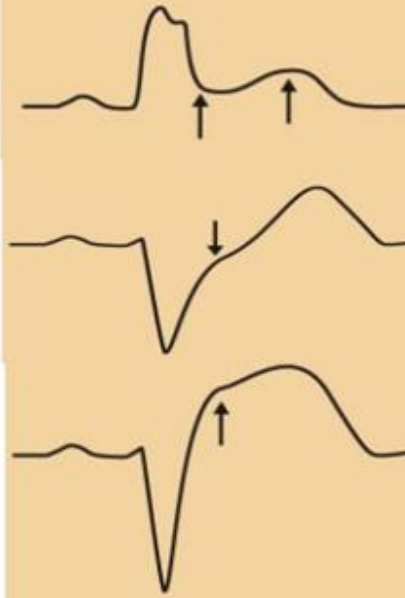


ECG showing concordant LBBB, characterized by a positive T wave in leads I and V_5 or V_6 (arrows). cLBBB definition: T-wave orientation concordant with QRS complex is characterized by a positive/diphasic T wave in leads I and V_5 or V_6 (at least in two of these three leads) **(Padeletti L 2018**);. What is the clinical significance of dLBBB versus cLBBB? . **Table next two slides** shows the clinical implications of both repolarization patterns in LBBB. Discordant and concordant left bundle branch block (dLBBB/cLBBB) are characterized by negative or positive T waves, respectively, in lateral leads.

Table	Concordant LBBB (cLBBB) positive T wave in ead I or V5, V6	Discordant LBBB (dLBBB) negative T wave in lead I or V5, V6
% distribution	≈ 28-30%	≈ 68-70% c
Age	Significantly youger	Significantly older. The only independent variable at multivariate analysis
LV mass index (g/m^2)	Less	Greater
LVEF(%)	Better(mean 51%)	Lower mean 36% (**Khalil 2016**)
LV end-diastolic (mm)	Less	Greater
Renal function Creatinine (mg/dL)	Better	Worse
Neurohormonal activation	Less	Higher
Plasma level of BNP (ng/L)	Less	Greater
Norepinephrine NE (ng/L)	Less	Greater
Severity of the disease	Less	Greater
New York Heart Association class	Less	Higher
Degree of LV dysfunction and dilatat.	Less	Higher
QRSd	Less (mean 151ms)	Wider((mean 160 ms)(**Khalil 2016**)
Left atrium (LA) size	Less (mean 40 cm^2)	Larger LA size (mean 45 cm^2) (**Khalil 2016**)
Moderate and severe tricuspid regurgitation ,	Less	Higher

	Concordant LBBB (cLBBB) positive T wave in ead I or V5, V6	Discordant LBBB (dLBBB) negative T wave in lead I or V5, V6
Underwent Coronary Artery Bypass Grafting (CABG)	Less frequent	More frequently.
Moderate to severe mitral and tricuspid regurgitation	Less frequent	More frequent
Bi-ventricular dyssynchrony	Less prominet	More prominent
Prognosis	Better	Wrose (**Padeletti 2018**)
Benefit of cardiac resynchronization therapy	Lees	Greater (**Padeletti 2018**)
Occurrence of VT/VF	Less frequent	More frequent without statistic significance (**Padeletti 2018**)

Table Sgarbossa Electrocardiogram Criteria for the Diagnosis of MI in the Presence of LBBB(Tabas 2008; Neeland 2012)

ECG criteria	Assigned point value	Sensitivity %	Specificity %	Positive likelihood	Negative likelihood	These complexes show the normal (expected) appearance of LBBB.	These complexes show ischemic manifestations in the setting of LBBB.
ST-elevation of ≥1 mm and concordant(in the same direction) with the QRS complex	5 points	20% (18-23%)	98% (97-99%)	7.9(4.5 – 13.8)	0.81(0.78-085)	Normal LBBB 	Ischemic LBBB 
ST-segment depression ≥1 mm in lead V_1, V_2, or V_3	3 points						
ST elevation ≥5 mm and discordant(in the opposite direction) with the QRS complex	2 points	41% (37-45%)	85% (82-88%)	2.0 (4.5 – 1.1 3.8)	0.81(0.67-099)		

Sensitivity, specificity, and positive and negative likelihood ratios are presented as summary statistics (95% confidence intervals) for score of ≥3 and ≥2. ST-segment deviation is measures at the J point. Concordance and discordance of ST segments are determined by comparison with the main direction of the QRS complex. Each criteria gives 2 to 5 points. Studies shows tha a cut-off≥ 3 points yields a sensitivity of 20 to 36% and specificity of 90-98%.

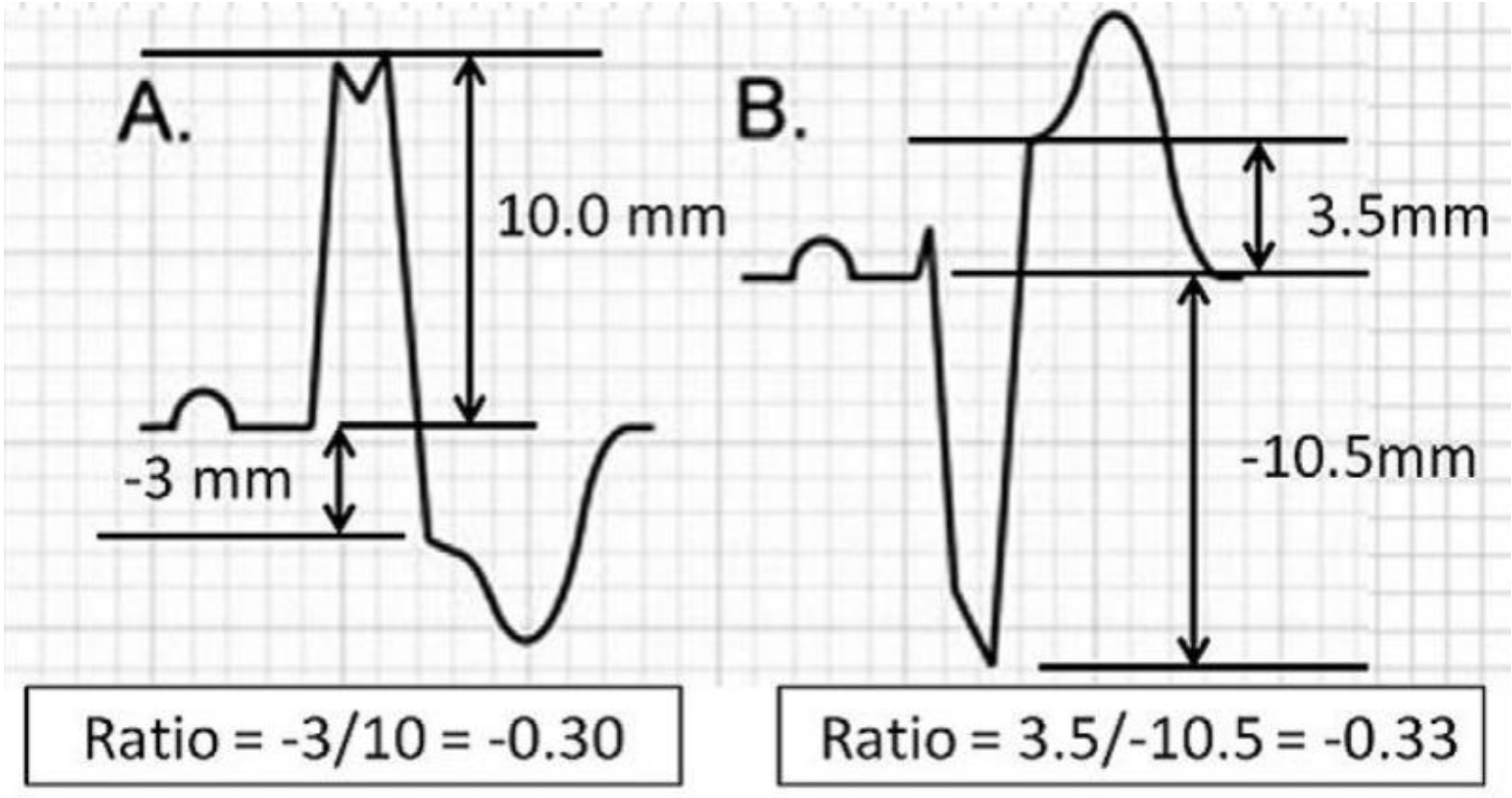
VCG and ECG criteria to distinguish new from old LBBB

There are no established criteria to differentiate new from old CLBBB. Differentiate these LBBB patterns is very important for the management of patients with LBBB in acute coronary syndrome scenario (**Shvilkin 2010**). A significant proportion of patients with LBBB in acute MI scenario with a culprit lesion and positive biomarkers, immediate catheterization with the intent for primary percutaneous coronary intervention for all patients is indicated presenting with suspected ST-segment elevation myocardial infarction, ischemic symptoms, and presumed new LBBB, particularly if concordant ST-segment elevation is present. The table bellow shows the main clue ECG differences between new and old LBBB :

	The new LBBB	The old LBBB
T-vector magnitude	**Larger: 1.20 +/- 0.07 mV**	**Smaller: 0.71 +/- 0.01 mV**
QRS/T vector magnitude ratio	**Lower: 1.79 +/- 0.03**	**Major: 3.92 +/- 0.04**
The ratio of deepest S to largest T wave in precordial leads (Max S/T)	**Smaller: 1.66 +/- 0.05**	**Major 3.54 +/- 0.08**

A decision rule using QRS/T <2.25 and Max S/T <2.5 had 100% sensitivity and 96%-68% specificity in diagnosing new LBBB, including subsets of patients with tachycardia and ischemia.

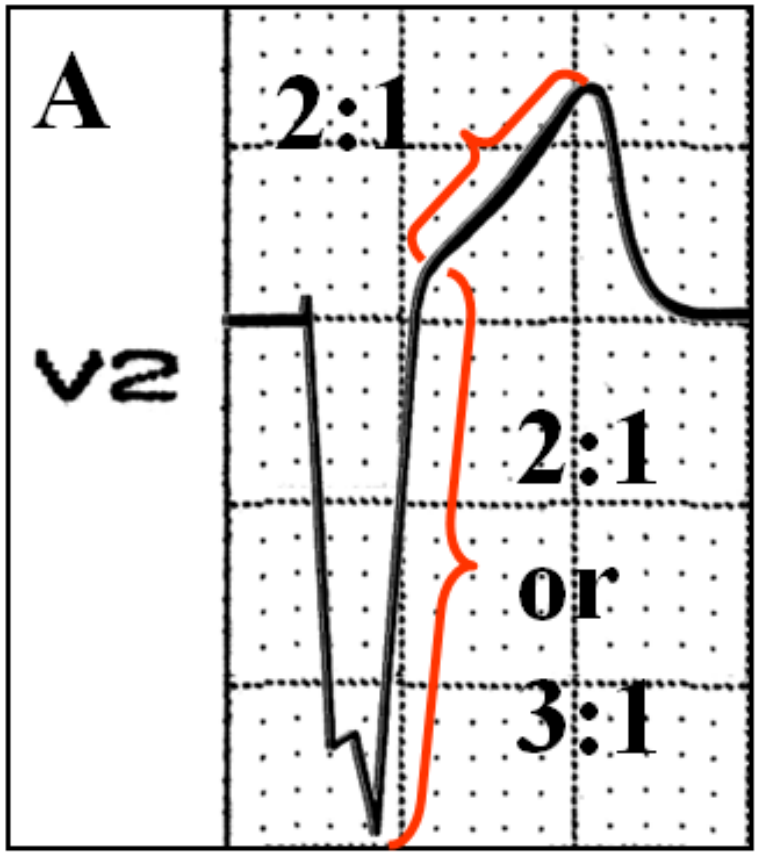
Smith et al.(**Smith 2012**) In order to improve diagnostic accuracy, developed the "modified Sgarbossa criteria," in which the original absolute 5 mm criterion is replaced with a proportion: ST elevation/S-wave amplitude of ≤ -0.25). Smith et al have modified the criteria to improve sensitivity. Smith, et al reported a new rule to replace the 3rd Sgarbossa criterion with the ST-segment elevation to S-wave depth (ST/S ratio): **excessive relative discordance exists if the ST/S ratio is less than -0.25.** This modified Sgarbossa rule increased sensitivity of the test to 91%, although specificity dropped to 90% when using the "weighted rule" (Sgarbossa >3) The authors reported improved diagnostic sensitivity from 52 to 91% in identifying angiographically proven MI but with reduced specificity compared with the original Sgarbossa criteria (90 vs. 98%). ((**Larson 2007**)It has yet to be validated, and has not been widely adopted into general practice The authors reported improved diagnostic sensitivity from 52 to 91% in identifying angiographically proven MI but with reduced specificity compared with the original Sgarbossa criteria (90 vs. 98%). The modified Sgarbossa criteria have subsequently been validated in a separate cohort(**Meyers 2015**).



Abnormal, excessive discordance, with the ST segment and T wave in the opposite direction from QRS. Method of measurement: ST segment is measured at the J point, relative to the PR segment. R wave and S wave are also measured relative to the PR segment.

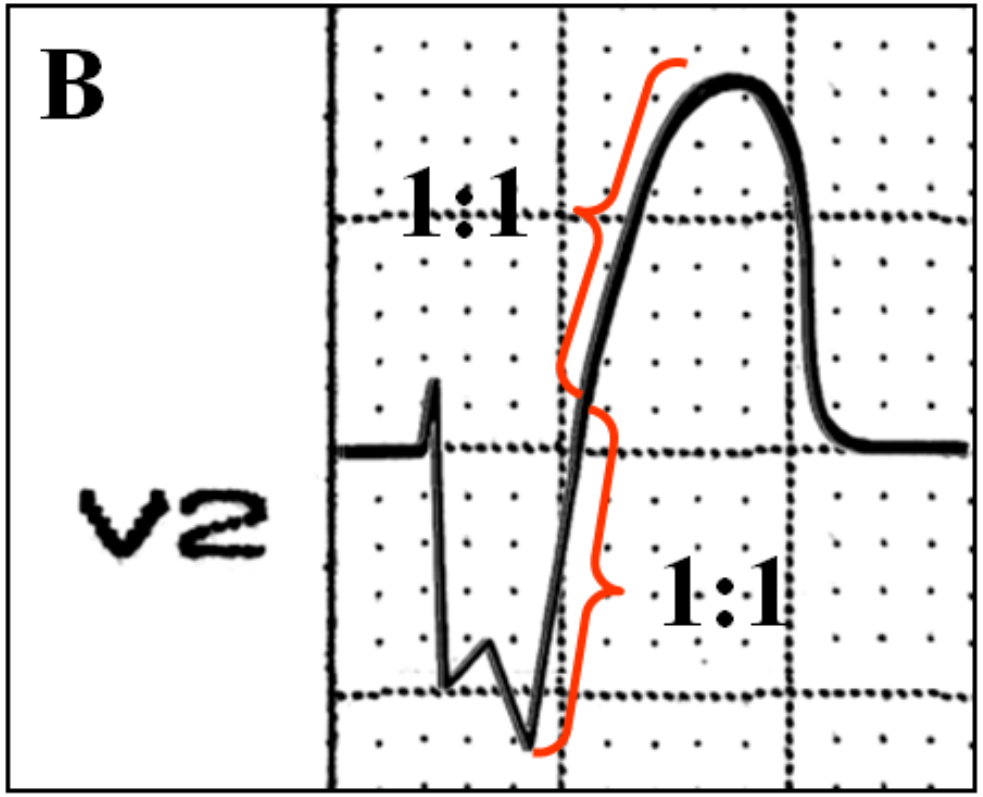
Other ECG criteria in LBBB complicated with AMI

Uncomplicated LBBB



A: Ratio of $^{QRS}/_{ST-T}$ amplitude, 2:1. ST upwardly concave.

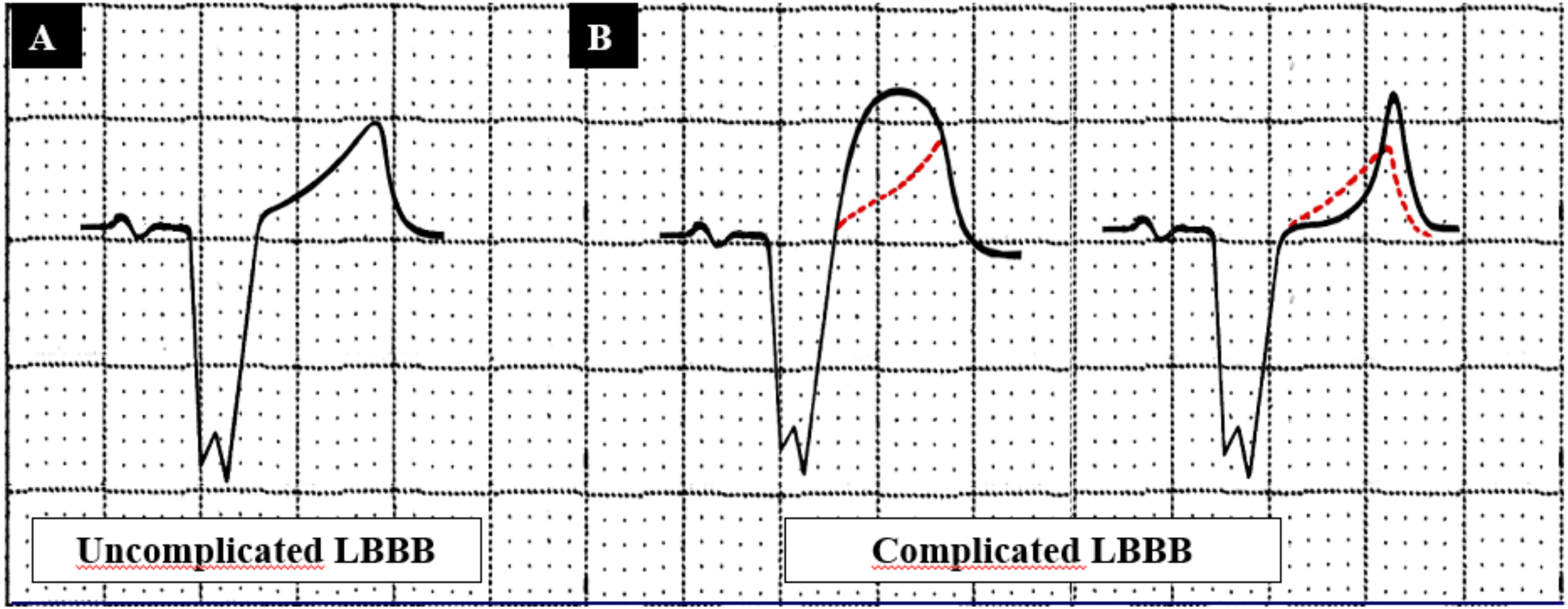
LBBB complicated with anterior MI



B: Ratio of $^{QRS}/_{ST-T}$ amplitude 1:1. ST upwardly convex.

Diminution of $^{QRS}/_{ST-T}$ ratio in lead V2: In uncomplicated LBBB, the ratio of QRS voltage to the ST segment voltage is always greater than 1. Usually 2:1 or 3:1 in V2 lead (**Dekock J, Schamroth L.1975**). During AMI the elevation of ST segment with concomitant possible reduction in the QRS voltage results in a $^{QRS}/_{ST-T}$ ratio near to 1:1.

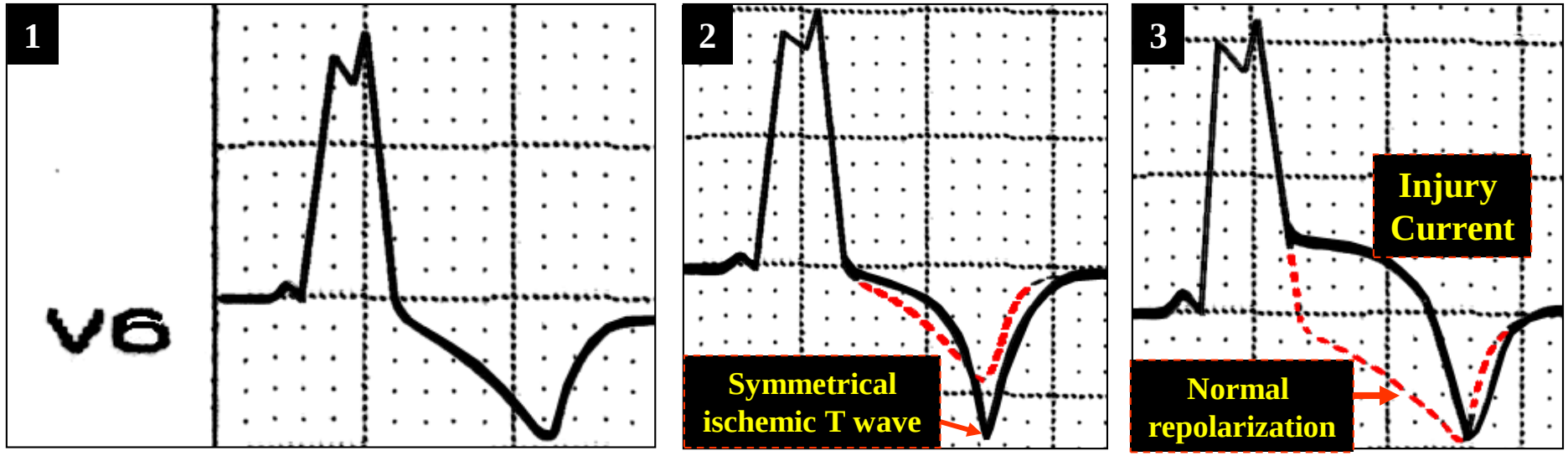
ST segment and T wave characteristics in the right precordial leads (V_1-V_2 V_3) in uncomplicated (A) and complicated LBBB (B)



- A: The elevated ST segment has a straight upward slope, or an upward slope that is minimally concave-upwards. The T wave is upright, with asymmetrical limbs and a relatively blunt apex.
- B: With AMI the ST segment elevation is exaggerated (≥5 mm) in the right precordial leads and becomes coved, convex-upward. The T wave becomes inverted and/or its limbs tend to become more symmetrical (Schamroth 1975).

Left lateral precordial leads (V_5-V_6) in uncomplicated LBBB (1) and LBBB associated to acute coronary syndrome (2, 3)

V_6 lead in uncomplicated LBBB and associated to injury, ischemia and/or infarction.



1. Habitual QRS-S/T in uncomplicated LBBB in V_6 Lead.

2. LBBB with ischemia (red dots indicate normal T shape).

3. LBBB associated to anterolateral infarction: ST segment elevation convex to the top: subepicardial injury (red dots represent normal repolarization) (**Dekock J, Schamroth L.1975**).

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