REVIEW ARTICLE

Clinical Value of Lead aVR

Andrés Ricardo Pérez Riera, M.D.,* Celso Ferreira, M.D., Ph.D.,*
Celso Ferreira Filho, M.D., Ph.D.,* Sergio Dubner, M.D., F.A.C.C.,†
Raimundo Barbosa Barros, M.D.,‡ Francisco Femenía, M.D.,§
and Adrian Baranchuk, M.D., F.A.C.C.,¶

From the *ABC Faculty of Medicine (FMABC), Discipline of Cardiology, Foundation of ABC (FUABC), Santo André, São Paulo, Brazil; †Cardiology Department, Maternidad Suizo Argentina, Buenos Aires, Argentina; ‡Departamento de Cardiología do Hospital de Messejana Dr. Carlos Alberto Studart Gomes; §Unidad de Arritmias. Departamento de Cardiología. Hospital Español de Mendoza. Argentina; ¶Cardiology Department, Queen's University, Kingston, Ontario, Canada

Lead aVR is the only lead in the surface ECG that does not face the “typically” relevant walls of the left ventricle. Historically, its value has been neglected most likely due to its unusual configuration and direction, which appeared to have little correlation with other more congruous and easily diagnostic frontal leads. The isolation of the unipolar leads in the Standard surface ECG presentation may also have played an important role. Even with this “unfair” neglect, we know nowadays that it is very sensitive to locate obstructed epicardial coronary arteries.

Besides helping distinguishing the culprit lesion of an infarct, lead aVR also helps recognizing other conditions that could be of clinical significance such as pericarditis, Brugada syndrome, fascicular blocks of the right branch, ectopic left atrial rhythms, etc. The purpose of this review is to revise the clinical value of lead aVR in the recognition of frequent and not so frequent clinical conditions.

Ann Noninvasive Electrocardiol 2011;16(3):295–302

aVR; unipolar limb lead; aVR sign

The conventional ECG has 12 leads. Each lead records electrical activity of the heart from different perspective. Therefore, it correlates to different anatomical areas of the heart.

aVR, aVL, and aVF are augmented unipolar leads in the frontal plane, after their inventor Dr. Emanuel Goldberger (known collectively as the *Goldberger's leads*). They are derived from the same three electrodes as leads I, II, and III with the reference lead on the limb being sensed and disconnected from the other two. Unipolar leads also have two poles, as a voltage is measured; however, the negative pole is a composite pole (Wilson's central terminal) made up of signals from lots of other electrodes. In a 12-lead ECG, all leads besides the limb leads are unipolar (aVR, aVL, aVF, V₁, V₂, V₃, V₄, V₅, and V₆). The augmented limb leads aVR, aVL, and aVF are amplified in this way because the

signal is too small to be useful when the negative electrode is Wilson's central terminal. Lead aVL is at -30° relative to the lead I axis; aVR is at -150° and aVF is at $+90^\circ$.

Lead aVR is an augmented unipolar limb lead in which the positive electrode is on the right arm. aVR offers no specific view of the left ventricle and this is why it is mostly an ignored lead. Nonetheless, the P-QRS-ST-T in lead aVR is often characteristic in various conditions. Recognizing those ECG pattern changes can improve the accuracy of clinical diagnosis.^{1–3}

ARM LEADS SWITCH AND DEXTROCARDIA

In sinus rhythm, the sequence of depolarization is directed inferiorly and toward the left. Thus

Address for correspondence: Andrés Ricardo Pérez Riera, M.D., Rua Sebastião Afonso, 885, CEP: 04417–100 Jardim Miriam, São Paulo, Brazil. Fax: (55 11) 5625-7278/5506-0398; E-mail: riera@uol.com.br

the P-wave polarity is always negative in lead aVR, positive in II, I, and aVF, and variable in III and aVL.

Right and left arm leads reversal is the most common mistake seen in ECG acquisition. If the P-QRS-T were upside down in lead I, a positive P wave in lead aVR (the *true* lead aVR is seen in aVL) strongly suggests that right and left arm leads are switched.⁴⁻⁷ A normal R-wave progression in the horizontal plane rules out dextrocardia.⁸ Otherwise, dextrocardia is the most likely diagnosis if the arm leads were correctly placed. ECG manifestations of dextrocardia are characterized by a reverse progression of R-wave voltage in the precordial leads from V₂ to V₅ with predominant negative QRS complexes in all precordial leads.^{2,7,8} (Fig. 1)

ACUTE CORONARY SYNDROME (ACS)

ST-segment elevation in lead aVR and ST-segment depression in the anterior and lateral leads suggests acute critical occlusion of the left main coronary artery (LMCA) because the ST injury vec-

tor is directed to right and upward, pointing to lead aVR.^{9,10} ST-segment depression in leads I, II, and V₄ through V₆, in association with ST-segment elevation in lead aVR identifies patients with three-vessel or LMCA critical occlusion (Fig. 2, Panel A)^{11,12}

Proper assessment of lead aVR in patients with ACS may help identifying proximal left anterior descending artery (LAD) occlusion or LMCA. Additional analysis of lead V₁ does not improve diagnostic accuracy.¹³

ST-segment elevation in lead aVR in the presence of an anterior ST-segment elevation myocardial infarction (STEMI) suggests LAD occlusion proximal to the first septal perforator branch (S1).

ST-segment elevation in lead aVR with simultaneous ST-segment depression in V₅ (VR-E + V₅-D) is a marker of ischemia due to severe LAD stenosis in patients with single-vessel disease.¹²

ST-segment elevation in lead aVR and depression in V₅ but without ST-segment elevation in V₁ strongly correlates with significant LAD and right coronary artery (RCA) stenosis, a sign of double-vessel disease.¹⁰⁻¹⁴

Elevation of the ST-segment in aVR in the setting of ACS identifies patients with severe coronary

Figure 1. True dextrocardia: mirror image. Total atriovisceral situs inversus. ECG diagnosis: SAP to the right and below, pointing at around +120°. Negative P wave in leads I and aVL, positive in lead III. Reverse progression of R wave in precordial leads V₂ to V₅.

Figure 2. *Panel A:* A 12-lead ECG of a patient with ACS by total occlusion of the left main coronary artery. Note ST-segment elevation in lead aVR and widespread ST-segment depression involving the anterolateral precordial leads from V₄ to V₆ and the inferior limb leads (mirror image). *Panel B:* A 12-lead ECG of a patient with acute pericarditis. Note ST-segment depression in leads aVR and V₁ and ST-segment concave elevation in most of the other leads.

artery disease. aVR ST-segment elevation with less ST-segment elevation in lead V₁ is an important predictor of acute LMCA obstruction.^{10–14}

ST-segment depression in lead aVR is common in patients with acute inferior myocardial infarction related to the left circumflex artery (LCx).^{14–15} ST-segment depression ≥ 0.1 mV in lead aVR, during an acute inferior myocardial infarction, presented a sensitivity and specificity of 70% and 94.3% for differentiating the culprit vessel lesion (LCx vs RCA).¹⁵

ST-segment depression in lead aVR during an inferior STEMI predicts LCx infarction or larger RCA infarction involving a large posterolateral branch.¹⁶

In the posterior (from the “old” infarct classification) and combined anterior + posterior myocardial infarction, the amplitude of the initial R wave in lead aVR is increased (>1.0 mm).¹⁷

AORTIC DISSECTION

Lead aVR may contribute to the diagnosis of this ominous entity. In acute aortic dissection Stanford type A (or DeBakey I or II) when the proximal ascending aorta is involved, ST-segment elevation in lead aVR was reported.^{2,3,18} The physiopathologic mechanism to explain this observation was the obstruction of the LMCA coronary ostium by the flap of the dissected aorta.

Atrial Ectopic Rhythm

A positive P wave in lead aVR indicates an ectopic *right atrial rhythm*. As such, P wave in lead aVL is also positive.

In focal right atrial tachycardia the P-wave configuration in lead aVR can easily differentiate the site of origin. Right atrial tachycardia arising from the *crista terminalis* can be differentiated from the tricuspid annulus and the septum away from the tricuspid annulus by analyzing the P-wave configuration in lead aVR. A negative P wave in lead aVR identified *crista terminalis* atrial tachycardia with a sensitivity of 100% and a specificity of 93%.¹⁹ Right atrial tachycardia arising from the appendage can also demonstrate negative P wave in lead aVR.²⁰

Acute Pericarditis

During the initial phase of pericarditis (<6 weeks); ST-segment elevation (<5 mm) with superior concavity is frequently seen on 12-lead ECG.

ST-segment changes can be subtle and usually present in several leads simultaneously, excluding V₁. PR-segment elevation in lead aVR is a hallmark of acute pericarditis.^{2,3,21}

Occasionally, ST-segment depression can be observed in leads aVR, V₁, as well as in the right accessory precordial leads (V₃R, V₄R, and V₅R) as part of a reciprocal phenomena.²² (Fig. 2, Panel B)

ACUTE TCA INTOXICATION

Clinical and electrocardiographic manifestations of TCA overdose are well known and previously described^{2,3,23,24}: ECG changes in lead aVR may help in recognizing this clinical condition. Increased R-wave voltage and R/s ratio in lead aVR, also reported as prominent R wave in lead aVR, are maybe the most frequently observed ECG changes in patients with TCA intoxication.²⁴ (Fig. 3)

DIFFERENTIAL DIAGNOSIS BETWEEN TYPICAL ATRIOVENTRICULAR NODE REENTRANT TACHYCARDIA (AVNRT) AND AV RECIPROCATING TACHYCARDIA (AVRT)

A simple algorithm in patients with regular narrow complex tachycardia using a single-lead aVR allows distinguishing AVNRT from AVRT. Zhong

et al.²⁵ have recorded 12-lead ECGs in 154 adult patients referred for electrophysiology study and radiofrequency ablation, during sinus rhythm and narrow QRS complex tachycardia. One of the three criteria that were found to be useful discriminators of the tachycardia mechanism involved the aVR lead: ST-segment elevation in lead aVR predicted AVRT in 83% of the cases (sensitivity 71%; specificity 83%).²⁵

DIAGNOSIS OF "RIGHT VENTRICULAR END CONDUCTION DELAY" (RECD)

Prominent final R wave in lead aVR is characteristic of RECD, and useful criteria to differentiate it from left anterior fascicular block (LAFB).²⁶ There is no anatomical confirmation that the right bundle is divided in three branches as the left bundle is, however; the isolated block of one of the three contingent or right branch divisions inside the right ventricle free wall, is generically called RECD.²⁷

Electro-vector-cardiographic (ECG/VCG) diagnosis of RECD remains somehow speculative.²⁷ The only constant element is the presence of the final right end conduction delay, located in the superior, middle, or inferior portions of the QRS loop in the frontal plane, which could be the consequence, or not, of a dromotropic disorder (Fig.4, Panels A and B).

In most cases, RECD corresponds to a *normal variant* and its clinical interest lies in the fact that it causes ECG/VCG patterns that are easily confused with LAFB and left posterior fascicular block. Additionally, it may mimic morphologies that resemble electrically inactive areas both in the anterior and the inferior walls, the ECG/VCG of the Brugada Syndrome (BrS), and some concealed forms of Arrhythmogenic Right Ventricular Cardiomyopathy/Dysplasia.²⁸

BRUGADA SYNDROME

Prominent final R wave in lead aVR (≥ 3 mm), also known as *the aVR sign*, it was described as a possible risk marker of arrhythmic event when associated with a spontaneous Type 1 ECG Brugada pattern.^{2,3,28,29} (Fig. 5)

In the vectorcardiogram, RECD can be located in the right superior quadrant of the frontal plane, corresponding to the territory of the superior or subpulmonary fascicle of the right branch (right

Figure 3. ECG changes associated with acute TCA intoxication.

Figure 4. Panel A: Possible anatomical distribution of the three hypothetical fascicles (contingents) of the right branch of the His bundle inside the right ventricle free wall. Panel B: Vectorcardiogram of a right end conduction delay located in the superior, middle, and inferior portions of the frontal plane, respectively.

ventricular outflow tract [RVOT] between -100° and 160°). The location of this delay explains the recording of prominent R wave in lead aVR. Larger studies are needed to confirm the value of this sign as a risk marker in BrS.

Right Ventricular Overloading

Lead aVR faces the basal, infundibular, RVOT, or crista supraventricularis regions. An R wave in lead aVR >5 mm (RVOT) and a Q/R ratio in lead

aVR ≤ 1 ; have been found as right ventricular overloading criteria.^{30,31}

DIFFERENTIAL DIAGNOSIS OF WIDE QRS COMPLEX TACHYCARDIAS

Vereckei et al³² blindly analyzed 483 wide QRS complex tachycardias of which 351 were ventricular tachycardia (VT), 112 supraventricular tachycardias (SVT), and 20 preexcited tachycardias.

Figure 5. Type 1 ECG Brugada pattern (“coved type”) with superior right end conduction delay (RECD) and positive “aVR sign”: final R wave of aVR ≥ 3 mm. RECD in frontal plane in a patient with BrS. ECG/VCG correlation (lower panel).

The authors used a novel single-lead aVR algorithm following four successive steps:

- (1) First step: Presence of an initial R wave in lead aVR? If yes; VT.
- (2) Second step: Presence of any initial R or Q wave >40 ms? If yes; VT.
- (3) Third step: Presence of a notch or the descending limb of a negative onset and predominantly negative QRS? If yes; VT (notching on the initial downstroke of a predominantly negative QRS complex).
- (4) Fourth step: Ventricular activation-velocity ratio $(v[i]/v[t]) \leq 1$ the vertical excursion (in millivolts) recorded during the initial $(v[i])$ and

terminal $(v[t])$ 40 ms of the QRS complex. If yes; VT.

If any of criteria 1 to 3 were present, VT diagnosis could be established. The aVR algorithm presented greater sensitivity and negative predictive value for diagnosing VT when compared to the classic Brugada criteria.

The Value of Reversed Lead aVR ($-aVR$)

Case and Moss³³ have recently proposed some modifications to the current frontal plane ECG leads. One of them is a 180° degree alteration in the configuration of lead aVR (to $-aVR$) to make

it more "accessible" to common understanding. The new reversed lead aVR (–aVR) will now be presented at +30° between the traditional Lead I (at 0°) and Lead II (at + 60°). This simple alteration of the recording will simplify the recognition of patterns that can affect this lead, as recognized by this manuscript and others.^{2,3,33} The analysis of the ST segment and the T wave in –aVR will be simpler and easier to understand and the relationship of these changes to the two contiguous leads (I and II) will provide more detailed evidence of the extent of illness involving these electrical areas.³³

CONCLUSIONS

For the time being the unipolar lead aVR has been neglected. As outlined in this brief review, lead aVR is valuable in the differential diagnosis of various cardiovascular conditions. Recognizing the ECG pattern changes in aVR is crucial in the interpretation toward correct diagnosis and appropriate clinical decision making.

The authors do not report any conflict of interest regarding this work.

Glossary of Abbreviations

ACS: Acute Coronary Syndrome
AVNRT: AV Node Reentrant Tachycardia
AVRT: AV Reentrant Tachycardia
BrS: Brugada Syndrome
ECG: Electrocardiogram
LAD: Left Anterior Descending Artery
LAFB: Left Anterior Fascicular Block
LCx: Left Circumflex Artery
LMCA: Left Main Coronary Artery
LPFB: Left Posterior Fascicular Block
RBBB: Right Bundle Branch Block
RECD: Right Ventricular End Conduction Delay
RVOT: Right Ventricular Outflow Tract
STEMI: ST-Segment Elevation Myocardial Infarction
VCG: Vectorcardiogram

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