Recognition of Electrocardiographic Lead Misplacements

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Improper placement of recording electrodes on the skin can generate misleading patterns on the electrocardiogram (ECG). The alterations in the normal ECG caused by lead misplacement were reviewed. Although most clinicians can recognize the common right arm/left arm lead switch that imitates a nonsinus atrial rhythm with high anterolateral myocardial infarction, many other errors are possible. Less common lead placement errors are often difficult to detect. Exchanging the right arm and left leg leads creates what seems to be an inferior wall myocardial infarction and a nonsinus atrial rhythm in normal patients. Reversal of the right arm and right leg connections creates a unique pattern of diffuse low voltage in the limb leads. Precordial lead switches are common and can be recognized by the abnormal R wave progression that is created. (Am J Emerg Med 1993;11:403-405. Copyright © 1993 by W.B. Saunders Company)

Improper placement of recording electrodes on the skin can generate misleading patterns on the standard 12-lead electrocardiogram (ECG).[1-3] Although the common right arm/left arm lead switch is easily recognizable to most experienced clinicians, many other lead placement errors are possible. Some of the less common errors are difficult to detect, but are quite important clinically because they can mimic other conditions (eg, myocardial infarction, nonsinus atrial arrhythmias, and disorders accompanied by low voltage).[4-5] The patterns caused by ECG lead misplacement are reviewed and discussed.

ISOLATED LIMB LEAD REVERSALS

Figure 1 is a normal ECG from a 24-year-old healthy female with an echocardiographically normal heart. (All tracings that follow are from the same subject.)

Single-limb lead reversals are fairly common occurrences and often go unrecognized. Because many of these lead switches mimic other clinical conditions, their identification is imperative to avoid erroneous diagnoses. The most common and easily detected misplacement is reversal of the right-arm and left-arm lead connections. This creates a reversal of all vectors in the horizontal plane, and the ECG is altered characteristically (Figure 2). The most distinctive finding accompanying arm-lead reversal is that leads I and aVL appear as the inverse of leads V5 and V6. In an otherwise normal ECG, this can imitate a high lateral wall myocardial infarction. An additional clue is that the P wave axis is markedly abnormal.

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Figure 3 illustrates the effects of reversing the right-arm lead with the left-leg lead. This isolated switch creates what seems to be an inferior wall myocardial infarction in patients without such a pattern when the limb leads are placed correctly. Just as with the right arm-left arm lead reversal, this transposition also produces an abnormal P wave axis that may be construed as a nonsinus atrial rhythm.

Figure 4 illustrates the effects of reversing the left-arm lead with the left-leg lead. This switch creates an insignificant q wave in lead III. The tracing is otherwise unchanged.

One might assume that reversion of the lower extremity leads would also yield a markedly abnormal ECG just as transposition of the upper extremity leads does, but this is not the case. Figure 5 exemplifies a right-leg/left-leg lead reversal, which does not significantly alter the surface ECG. This particular transposition probably occurs frequently, but most likely goes undetected.

Figure 6 illustrates the typical ECG findings when the left-arm and right-leg leads are exchanged. The key to detecting this abnormality is that lead III becomes completely horizontal and is essentially devoid of electrical activity. Although the remainder of the ECG is essentially unchanged from normal, the sensitivity of limb-lead interpretation is decreased.

The final limb-lead switch is reversal of the right-arm and right-leg connections. This exchange creates a unique pattern of diffuse low voltage in the limb leads, especially in lead II, which may have such a low voltage that it appears "null" or isoelectric (Figure 7). P waves are also reduced in amplitude; this may be mistaken for a nonsinus atrial or junctional rhythm. The precordial leads remain unaffected.

PRECORDIAL LEAD REVERSALS

There are three ways in which precordial lead misplacements can affect the ECG: (1) all the leads are placed one or two interspaces too high or low on the thorax; (2) a precordial lead is switched with a limb lead; and (3) individual precordial leads are exchanged with other precordial leads. The first problem may create a pattern of poor R wave progression that mimics an old anterior or anteroseptal myocardial infarction. Repeating the ECG with recordings intentionally made one or two spaces too high or too low, along

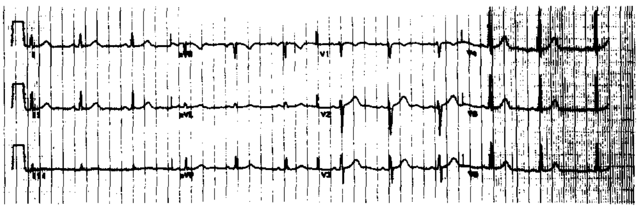


FIGURE 1. Normal ECG.

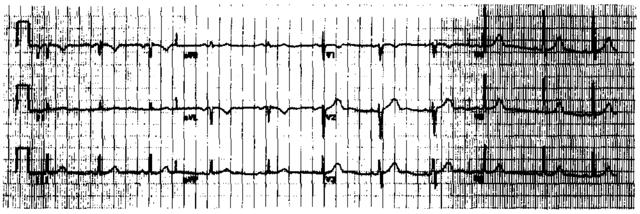


FIGURE 2. Right arm-left arm lead switch.

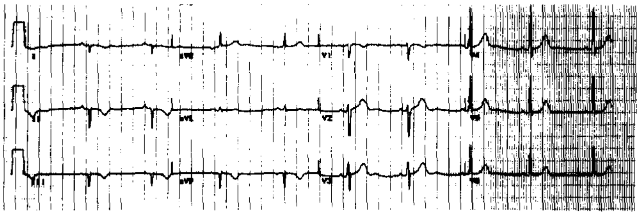


FIGURE 3. Right arm-left leg lead switch.

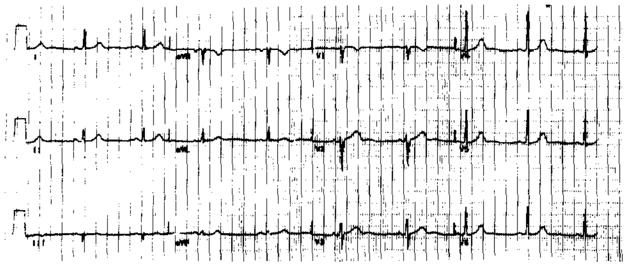


FIGURE 4. Left arm-left leg lead switch.

FIGURE 5. Right leg-left leg lead switch.

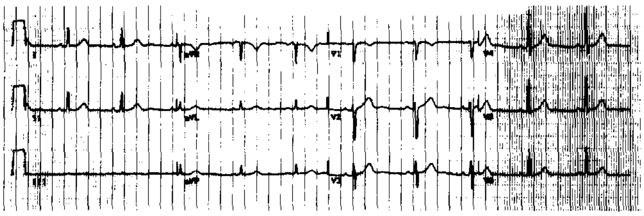


FIGURE 6. Left arm-right leg lead switch.

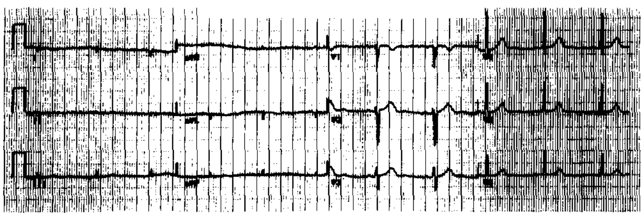


FIGURE 7. Right arm-right leg lead switch.

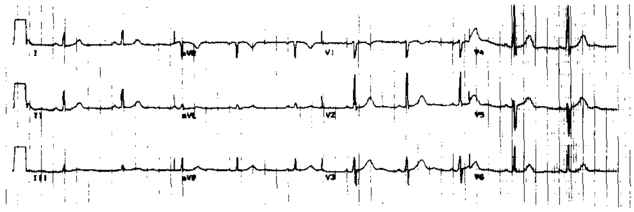


FIGURE 8. V_2-V_5 lead switch.

with normal lead placement, will usually clarify the situation. The second problem is rarely noted, because most modern ECG equipment records three or more leads simultaneously, and the precordial wires are often physically attached to one another. The rare abnormalities produced by the myriad possible exchanges of limb and precordial leads will not be discussed in this review.

The third problem, which is an exchange of two or more precordial leads with each other, is common. The best way to recognize it is to detect an isolated abnormal progression of the R wave. The R wave should become incrementally larger and the S wave should become smaller from V1 to V6 in normal tracings. Figure 8 illustrates reversal of leads V2 and V5, and shows the obvious break in precordial progression.

If all of the precordial leads are reversed (ie, placed V6 through V1) as observed in Fig 9, the tracing could be confused with a posterolateral myocardial infarction or mirror image dextrocardia. In the latter condition, also known as situs inversus, the left atrium, left ventricle, and aortic arch are located on the right side of the body. Therefore, the normal progression of the precordial R wave and regression of the S wave is reversed. The ECG diagnosis of dextrocardia always includes abnormalities in the limb leads, whereas simply switching the precordial connections does not. In addition to abnormal precordial waves, lead I characteristically shows negativity of the P wave, QRS complex, and the T wave. Therefore, when one suspects complete transposition of the precordial leads, lead I will enable differentiation from true dextrocardia.

Because modern ECG equipment clusters the limb leads independent of the precordial connections, intertwining the two sets is unusual from a practical standpoint. Because mixing of the precordial and limb leads would theoretically create countless combinations that are unlikely to occur in clinical practice, their description will not be covered.

CONCLUSION

Detection of lead reversals often requires a keen eye and a high index of suspicion. If there is a marked discrepancy in

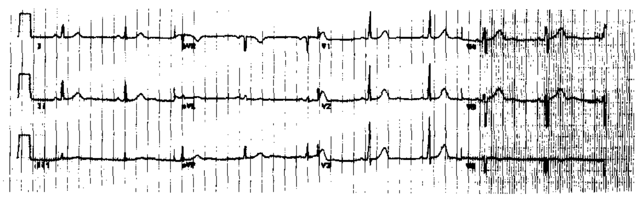
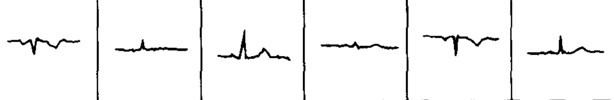
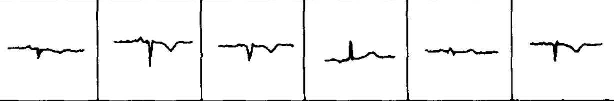
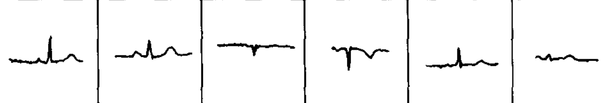
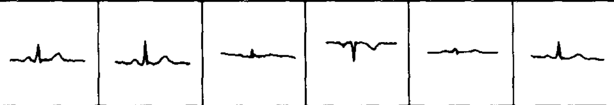
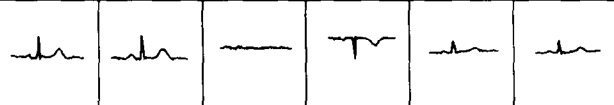
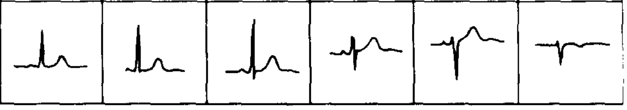


FIGURE 9. Complete reversal of precordial leads.

TABLE 1. Summary of the Alterations in the Normal ECG Pattern Caused by Common Lead Reversals and Misplacements

Leads reversed	ECG pattern	Clinical mimic	LEAD: I, II, III, AVR, AVL, AVF
RA, LA	Inverted P waves II, III, aVF; large q-wave in I, aVL; leads I and aVL appear as inverse of V5-6	Non-sinus atrial rhythm; old lateral myocardial infarction	
RA, LL	Inverted P waves II, III, aVF; large q-waves II, III, aVF	Non-sinus atrial rhythm; old inferior wall myocardial infarction	
LA, LL	Insignificant q-wave in III	None	
RL, LL	No change	None	
LA, RL	Low voltage lead III	None	
RA, RL	Diffuse low voltage in all limb leads, especially lead II; non-sinus atrial or junctional rhythm	Conditions characterized by diffuse low voltage	
Precordial lead reversals	Break in normal R-wave progression from V1-6	Mirror-image dextrocardia or posterolateral myocardial infarction	

the ECG pattern among leads that reflect electrical activity in a similar anatomical location (eg, if the pattern in leads I and VL is different from that of V5 and V6) or unusually low voltage in one or more limb lead, then limb lead reversal should be suspected. When lead reversal is suspected but not proven, comparison of the suspicious tracing with a prior ECG or the recording of a new tracing that is verified to be technically perfect will often clear up the mystery. Table 1 summarizes the common electrocardiographic lead misplacements.

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