Electrocardiography Pitfalls and Artifacts: The 10 Commandments

Many potential pitfalls can adversely affect the interpretation of 12-lead ambulatory and telemetry electrocardiograms (ECGs). Artifacts, for example, are a common finding in patients who require ECG monitoring. Artifacts are defined as ECG abnormalities that may be due to sources other than the electrical activity of the heart. Failure to correctly distinguish between an arrhythmia and artifact can result in misdiagnosis and unnecessary therapeutic interventions.

The most common causes of artifacts originate from internal (physiological) and external (non-physiological) sources (Table 1). Artifacts created from these sources can simulate arrhythmias such as atrial flutter and ventricular tachycardia.

Electrode misplacement is another common artifact. Such misplacement may lead to changes in ECG morphology that could potentially be interpreted as ischemic in origin. Electrode misplacements can also mimic serious arrhythmias and lead to misdirected therapeutic decisions.

Table 1. Most frequent causes of electrocardiographic artifact and other pitfalls

<table>
<thead>
<tr>
<th>Internal (physiological)</th>
<th>External (non-physiological)</th>
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<tbody>
<tr>
<td>Muscular activity: allows electronic filtration (small spikes)</td>
<td>Electromagnetic interference: (wide isoelectric line)</td>
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<tr>
<td>Patient motion: does not allow electronic filtration (large swings, usually by stretching the epidermis)</td>
<td>Light fixtures</td>
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<tr>
<td>Electrocautery</td>
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<tr>
<td>Electrical devices in the room</td>
<td>Cable and electrode malfunction</td>
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<tr>
<td>Insufficient amount of electrode gel</td>
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<tr>
<td>Fractured wires</td>
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<tr>
<td>Inappropriate filter settings</td>
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<tr>
<td>Loose connections</td>
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<tr>
<td>Misplaced leads</td>
<td></td>
</tr>
<tr>
<td>Accumulation of static energy</td>
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</tbody>
</table>

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PRIME POINTS

• Artifacts are common in patients who require ECG monitoring.

• Artifacts can simulate arrhythmias such as atrial flutter and ventricular tachycardia and lead to inappropriate treatment.

• Electrode and lead misplacements are another common pitfall and can lead to ECG changes that may be interpreted as ischemic in origin and can mimic serious arrhythmias.

• A simplified algorithm (REVERSE is the mnemonic) may help clinicians correctly identify both suspected electrode misplacements and artifacts.
is a relatively frequent finding in ECGs done in outpatient clinics (0.4%) and is even more common in intensive care units (4%). The correct position for precordial ECG electrodes is illustrated in Figure 1.

Several telltale clues can help clinicians identify potential signs of electrode misplacements and artifacts. In this article, we introduce an algorithm that we developed to assist nurses and physicians in rapidly recognizing those clues and review 10 of the most common ECG pitfalls and artifacts.

Algorithm to Identify ECG Electrode Misplacements or Artifacts (REVERSE)

The indicators of electrode misplacements or artifacts that clinicians need to look for can be easily remembered by using the mnemonic REVERSE (Table 2). With this mnemonic in mind, careful and systematic examination of ECGs will help rule out problems with the recording.

We describe the 10 most common ECG pitfalls and artifacts seen in our practice, presented in the form of commandments. All the ECG examples provided for this review were run at 25 mm/s, 10 mm/mV, and 100 Hz.

ECG Pitfalls and Artifacts: The 10 Commandments

1. You shall not reverse the electrodes: reversal of left arm and right arm electrodes

Reversing the electrodes is one of the most common errors made when placing the ECG on a patient. Such reversal produces leads I and AVL with reverse polarity of all normal deflections (negative P wave, QRS complex, and T wave). In addition, polarity is reversed in lead AVR (positive P and QRS; Figure 2). The differential diagnosis is dextrocardia (the heart is positioned on the right side). In dextrocardia, however, the progression of the R wave in precordial leads is reversed, whereas with electrode reversal, the progression is normal.5

2. You shall not treat the ECG, treat the patient: artifact mimicking ventricular tachycardia

The possibility of tremor or other interference inducing an artifact that mimics ventricular tachycardia should be considered when the ECG does not match the patient’s clinical findings. A normal heart rate obtained by pulse or auscultation in an asymptomatic patient at the same time the ECG shows apparent ventricular tachycardia confirms the diagnosis. Reduction of the tremor by holding the limb or placing the electrodes on the torso will reduce interference.2,6,7 “Tracking” the R-R intervals is helpful if they can be identified.
before the pseudo–ventricular tachycardia. Look for R-R intervals that continue into the wide complex rhythm to see the presence of normal ventricular depolarizations throughout the pseudo–ventricular tachycardia. With careful measuring to see where normal beats should be, they will often “jump out” at the observer and become obvious, whereas at first glance they may be completely obscured. Pseudo–ventricular tachycardia has 3 characteristic signs⁴ (Figure 3):

3. You shall not reverse the electrodes: reversal of left arm and left leg electrodes
   Amplitude of the P wave in lead I greater than in lead II and/or P-wave terminal positive component in lead III (Abdollah sign) will confirm reversal of the left arm and left leg leads.⁵ Confirmation with a second ECG is usually required (Figure 4).

4. You shall not reverse the electrodes: reversal of precordial leads (V₁ and V₆)
   The most common reversal of the precordial leads is an exchange of V₁ and V₆. The way to recognize this problem is by assessing the R-wave progression in the precordial leads. Normally, the R wave will increase its amplitude from V₁ to V₆ and the S wave will decrease its amplitude. In the reversal situation, a tall R wave can be seen in V₁ and a deep S wave in V₆.⁶⁻¹³ Potential diagnostic misinterpretations include right bundle branch block, old posterior myocardial infarction, right ventricular hypertrophy, and left-sided accessory pathways (Figure 5).

5. You shall check if the patient is calm and quiet: tremor
   Tremor-induced artifact may mimic supraventricular arrhythmias (atrial flutter/atrial fibrillation) or if the artifact has sufficient amplitude, it can also mimic ventricular tachycardia and ventricular fibrillation. The correct diagnosis can be made on the basis of simple observations such as the presence of the pseudoarrhythmia when the patient moves (tremor). Careful analysis may reveal discrete components of the QRS complexes (matching the

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**Table 2** REVERSE mnemonic: an easy approach to remember the most frequent causes of electrocardiographic artifacts and pitfalls

<table>
<thead>
<tr>
<th>Abnormal finding</th>
<th>Significance</th>
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<tbody>
<tr>
<td>R wave is positive in lead aVR (P wave also positive)</td>
<td>Reversal of left arm and right arm electrodes</td>
</tr>
<tr>
<td>Extreme axis deviation: QRS axis between +180° and -90° (negative R wave in lead I, positive R wave in AVF)</td>
<td>Reversal of left arm and right arm electrodes</td>
</tr>
<tr>
<td>Very low (&lt;0.1 mV) amplitude in an isolated limb lead (isolated “flat” lead)</td>
<td>Reversal of right leg and left arm or right arm electrodes</td>
</tr>
<tr>
<td>Exchanged amplitude of the P waves (P wave in lead I greater than in lead II)</td>
<td>Reversal of left arm and left leg electrodes</td>
</tr>
<tr>
<td>R wave abnormal progression in the precordial leads (predominant R wave in V₁, predominant S wave in V₆)</td>
<td>Reversal of precordial electrodes (V₁ through V₆)</td>
</tr>
<tr>
<td>Suspect dextrocardia (negative P waves in lead I)</td>
<td>Left arm-right arm electrode reversal</td>
</tr>
<tr>
<td>Eliminate noise and interference (artifact mimicking tachycardias or ST-T changes)</td>
<td></td>
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</tbody>
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**Figure 2** Reversal of electrodes for left arm and right arm. Note reverse polarity (arrows) in leads I and AVL (negative P, QRS, and T deflections). Note also reverse polarity in AVR (positive P and QRS deflections).
previous R-R intervals if present) through the pseudoarrhythmia (‘notches sign’).\textsuperscript{8,14-16} Misinterpretation of tremor-induced artifact may lead to serious medical errors such as the initiation of long-term use of anticoagulants for pseudo– atrial fibrillation.\textsuperscript{17} Figure 6 shows pseudo– atrial flutter that was a tremor-induced artifact.

6. \textit{You shall turn off your cell phone: electromagnetic interference}

Electromagnetic interference (EMI) with medical devices by cell phones is a well-recognized problem.\textsuperscript{18-21} Even though considerable controversy remains about the use of cell phones in hospitals, the evidence is clear that cell phones can produce EMI with many different medical devices (eg, ECG monitor, ventilator, infusion pump, dialysis machine, apnea monitor, external pacemaker, internal pacemaker, and defibrillator). The ability of a cell phone or a wireless device to induce EMI depends on the distance, the ability of medical equipment to resist EMI, and the technology of the cell phone (digital vs analog, which are the 2 basic systems cell phones use to operate, and single-band of operation vs dual and frequency band of operation).\textsuperscript{19} As shown by previous investigators,\textsuperscript{19} a 1-m (3.28 ft) distance between the source of EMI and medical devices safely eliminates EMI. Only a few cases in which cell phones and wireless devices interfered with ECG machines have been reported.\textsuperscript{20} We simulated a case created in our laboratory by activating a cell phone (digital) less than 25 cm (9.8 in) from the ECG machine acquisition module (MAC 5000 Resting ECG Analysis System, GE Medical Systems, Waukesha, Wisconsin). The rapid, sharp, and low-amplitude signals disappeared when the cell phone was removed or deactivated (Figure 7). ECG technicians and nurses should avoid using cell phones when they are recording ECGs until further research in this area is available. This limitation may also have implications for paramedics and ambulance attendants who obtain and interpret ECGs on patients in the field.

7. \textit{You shall know where the limbs are: electrodes placed on the torso}

Electrodes are placed on the torso near the extremities rather than on the limbs for different reasons.
During an emergency, placing leads on the torso reduces the time needed for undressing the patient and in most cases will allow a correct ECG diagnosis. However, in most circumstances, the torso position should not replace the standard position on the limbs. The torso position induces a change in how the electrical vectors are recorded. Pseudo–Q waves and pseudo–ST-segment elevation in the inferior leads could potentially be misinterpreted as myocardial infarction (Figure 8).

8. You shall not place telemetry electrodes on top of ECG electrodes: telemetry interference

Placing the telemetry electrodes on top of the ECG electrodes or vice versa is a common mistake. Usually, telemetry electrodes are placed in the same region where the ECG electrodes need to be placed. This superimposition of electrodes may create a distortion of the ST segment that mimics ST-segment elevation or arrhythmias due to EMI of the telemetry on the ECG machine (Figure 9).

9. You shall not reverse the electrodes: reversal of right leg and left arm or right arm electrodes

If a reversal involves the right leg and one of the arms, the recording will be zero potential difference between the legs. This pseudoasystole in an isolated lead may occur in lead II (reversal of right arm and right leg electrodes) or in lead III (reversal of left arm and right leg electrodes; Figure 10).

10. The patient should be lying down, calm and relaxed (if possible): ECG done with patient sitting at 90°

In some clinical situations (eg, decompensated heart failure, respiratory insufficiency, orthopedic limitations), the ECG must be done with the patient sitting at 90°.
recorded with the patient sitting upright or in a semi-Fowler’s position. Changing the body position can affect the QRS axis and QRS amplitude. Currently, no distinctions in the recording methods need to be made when an ECG is recorded with the patient sitting (~90°); however, recognizing slight alterations of the QRS complex may be helpful to avoid wrong interpretations. An annotation indicating the position of the patient (if different than usual) may be helpful for the physician interpreting the recordings. In this case, note the reduction of the QRS amplitude in lead III, which is a lead that is particularly sensitive to changes in diaphragmatic position (Figure 11).

**Conclusions**

The ECG is one of the most valuable tools in our daily practice. Many health care providers interpret ECGs and initiate therapeutic interventions on the basis of such interpretations. Recognizing ECG artifacts and other pitfalls will enable clinicians to avoid unnecessary therapeutic interventions and may allow them to correct the recording methods to obtain a proper ECG.

**Financial Disclosures**

None reported.

**References**

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