Original Article

ECG lead misplacement by colour – What difference does it make?

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ABSTRACT

Background: Coronary artery disease (CAD) and deaths from CAD are on the increase in sub-Saharan Africa. As a result the number of ECGs being recorded is increasing. Lead misplacement is associated with changes in the ECG recording, some of which can mimic significant clinical conditions. A large body of research on limb lead misplacement is available. However I have not been able to source any research on lead misplacement in which misplacement has occurred according to the colour of the leads.

Objectives: To investigate the differences in the 12-lead ECG which occur when lead misplacement by their colour has occurred.

Materials and Methods: A series of 12-lead ECGs were recorded on a healthy male volunteer. These included an ECG in which all leads were correctly attached followed by ECGs with lead misplacement based on their colour (Red: right arm – V1, Yellow: left arm – V2, Green: left leg – V3, Black: right leg – V5).

Results: The most dramatic differences occurred when the yellow leads (left arm and V2) were misplaced as well as when the green leads (left leg and V3) were misplaced.

Conclusion: It is important that those responsible for recording and interpreting ECGs are familiar with all types of lead misplacement including those in which the misplacement by the colour of the leads has occurred. A larger study should be performed to determine the consistency of these changes or the presence of others, not previously recorded.

Keywords: ECG, lead, misplacement, colour.

The incidence of coronary artery disease amongst the African population is on the increase[1],and accounts for 9.2% of deaths in Africa[2], compared with 42% of deaths worldwide[3]. It is the leading cause of death in the African population over the age of 45 years[4]. It is projected that deaths from coronary artery disease in sub-Saharan Africa will have increased by 50% by 2030[5]. Such is the disease burden due to coronary artery disease that Ikem *et al*. refer to it as the "new epidemic in sub-Saharan Africa"[6].

The number of patients presenting to hospital with symptoms suggestive of acute coronary syndrome (ACS) and other conditions, in which an electrocardiogram (ECG) is required, is likely to increase accordingly. Doctors and nurses caring for these patients must be able to recognise signs suggestive of lead misplacement[7]. A large body of research on limb lead misplacement is available. However despite the consequences of lead misplacement I have not been able to source any research in which lead misplacement has occurred according to the colour of the leads.

The 12-lead ECG is recorded by placing 10 electrodes on predetermined anatomical locations[8]. Electrodes attach to the skin and are connected to the ECG machine via the ECG cables while leads are the vectors between the electrodes e.g. lead I is the vector between the right arm and left arm electrodes. The colour of the ECG cables and the limbs to which they attach are increasingly becoming universal and are the same colour as one of the precordial leads (red connected to the right arm, yellow to the left arm, green to the left leg and black is attached to the right leg). Unintentional electrode interchanges, by their colour, can occur[9]. This is an important yet preventable source of error. The terms

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"electrode", "lead" and "ECG cable" are often used interchangeably. To avoid confusion the term "lead" is used throughout the remainder of this paper.
The purpose of this brief paper is to describe the ECG appearances resulting from misplacement of ECG leads according to their colour.

MATERIALS AND METHODS:

A pilot study was conducted to determine if any significant differences occur when the ECG leads were misplaced according to their colour and whether a larger study would be likely to increase our knowledge base any further. A series of 12-lead ECGs were recorded on a healthy male volunteer using a GE Mac 3500 ECG machine. These included an ECG in which all 12 leads were correctly attached followed by ECGs with lead misplacement based on their colour (Red: right arm – V1, Yellow: left arm – V2, Green: left leg – V3, Black: right leg – V5). All ECGs in this pilot study were recorded on the same male volunteer. This was done to exclude ECG differences between subjects, whether normal variants or due to coronary artery disease. This, if present, would result in differences in baseline ECG findings from normal and as a result the changes identified following lead misplacement by colour would also differ.
If significant differences are documented in this pilot study then a larger study will be required to determine the consistency of these changes or the presence of other differences not previously recognised.

RESULTS:

A normal ECG, in which all the leads were correctly positioned, was initially performed (Figure 1). Subsequent ECGs were compared against this normal ECG when determining what, if any, changes might occur as a result of lead misplacement due to colour of the cables.
Misplacement of the red cables (right arm and lead V1) did not result in any appreciable difference in the ECG as they are both located adjacent to each other (Figure 2).
Left arm and V2 cables are both yellow and when interchanged resulted in a somewhat unusual appearance (Figure 3). Deep S waves in lead I, Q waves and inverted T waves visible in lead III were observed. Lead V2 demonstrated a large dominant R wave, indicating an early transition from predominantly negative QRS complexes in V1 to predominantly positive QRS complexes in V2. These features of left arm and V2 misplacement can also be seen in pulmonary embolism[10].Inverted T waves are also evident in lead V2[9].
In misplacement of the green cables (left leg and lead V3) the main differences were seen in leads II, III and a VF and give the impression of ST elevation which can be misinterpreted as an ST elevation myocardial infarction (Figure 4). T waves in lead V3 become inverted
Finally in interchange of the black cables (right leg and V5 lead misplacement) the main change occurs in lead V5 where the height of the QRS complexes is dramatically smaller and disrupts the normal pattern of R wave progression across the chest leads (Figure 5).

DISCUSSION:

ECG lead misplacement by colour can lead to some dramatic changes with the potential for significant misinterpretation. Appearances consistent with pulmonary embolism results from interchange of the yellow leads – left arm and V2 while misplacement of the green leads (left leg and V3) can give rise to appearances similar to those seen in an inferior myocardial infarction. It is easy to see how patients with these ECG features might undergo unnecessary and expensive investigations, treatment and hospital admission. All of this would be avoided if the lead misplacement is identified. In spite of this I am not aware of any ECG interpretation book which addresses lead misplacement according to their colour.
The main change which occurs with misplacement of the black leads, right leg - V5, is a reduction in the height of the QRS

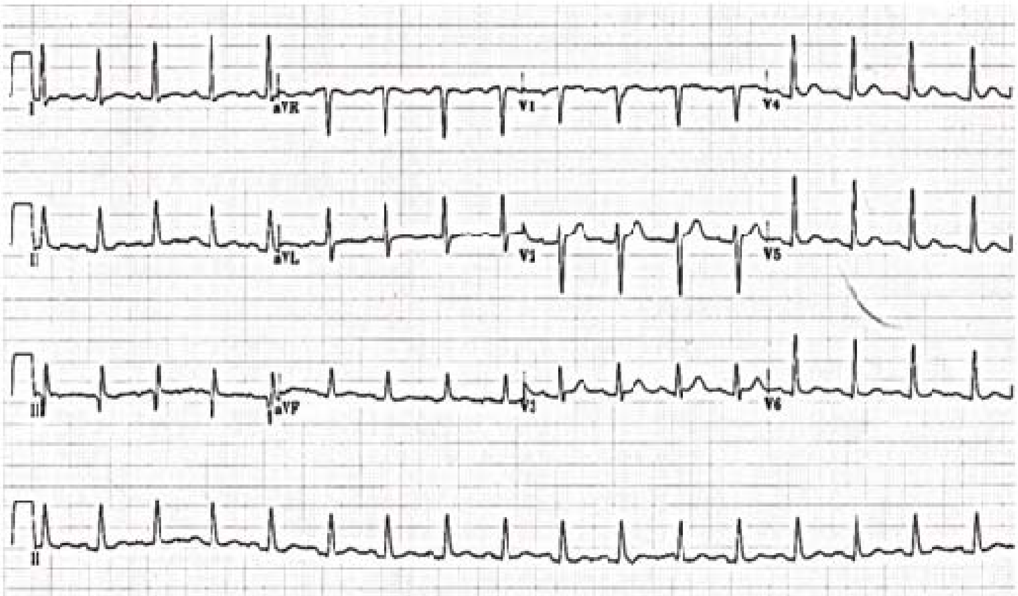

Figure (1): Normal ECG.

Figure (2): Red: Right arm and V1 lead misplacement.

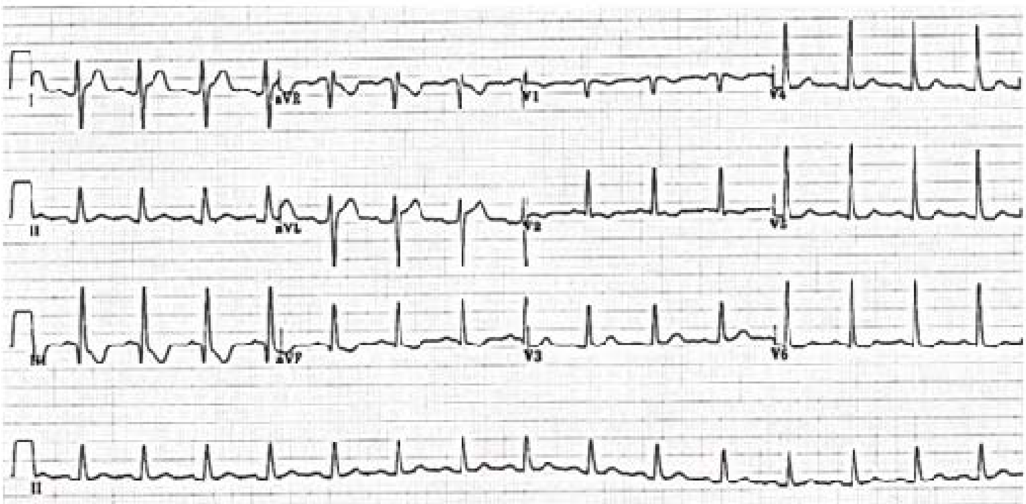

Figure (3): Yellow: Left arm and V2 lead

Figure 4: Green: Left leg and V3 lead

Figure 5: Black: Right leg and V5 lead misplacement.

complexes in lead V5 which disrupts the normal pattern of R wave progression across the chest leads making it easily recognisable. The right leg electrode can be placed anywhere on the body, except on a limb on which another electrode is attached, without altering the appearance of the ECG[11,12]. If, however, the right leg lead is interchanged with any of the other limb leads the characteristic ECG appearance is seen as a near flat line in leads I[13], II[14] or III[15].

However, not all examples of lead misplacement, such as right arm – V1 misplacement, will cause significant ECG changes. Bond reported a 17% - 24% chance that the diagnosis on ECG will be different if a lead misplacement has occurred or if an artefact is present[16].

The frequency of electrode misplacement has been shown to increase with increasing acuity of patient care and urgency of recording. Rudiger et al reported a 10-fold increase in lead misplacement errors in ECGs performed on patients in the intensive care unit compared with those in an outpatient clinic[17]. In addition the American Heart Association (AHA) 2010 guidelines for the management of ACS states that an ECG should be performed, within ten minutes of arrival to hospital, on all patients who present with possible ACS[8]. The combination of compliance with the AHA guidelines and the urgency of the patients' condition is likely to result in higher rates of lead misplacement. Early recognition of lead misplacement is vital to minimise error.

ECG lead misplacement should be considered if ECG features suggestive of lead misplacement are present or if the ECG features are not in keeping with the clinical condition. The ECG should be repeated before treating the patient.The ECG should always be interpreted in the context of the patient's history and clinical findings and not looked at in isolation. Previously recorded ECGs should be reviewed where possible. Strategies to reduce the incidence of lead misplacement should be pursued. Thaler et al achieved a 75% reduction in electrode misplacement in their intensive care unit through demonstration of errors made and attending a 45 minute teaching session on electrode misplacement[18].

It is likely that lead misplacement occurs in every medical department or emergency centre. What is not known is how frequent this occurs. Experts are not immune from failure to recognise lead misplacement. In a study by Haisty et al twenty five board-certified cardiologists failed to interpret an ECG which was normal apart from right arm - right leg electrode misplacement[19]. None of them noted the abnormality even though right arm – right leg misplacement right has a characteristic flat line appearance in lead II.

CONCLUSION:

ECG lead misplacement by colour can lead to some dramatic changes with the potential for significant misinterpretation. It is important that those responsible for recording and interpreting ECGs are familiar with all types of lead misplacement including those in which the misplacement by the colour of the leads has occurred. A larger study should be performed to determine the consistency of these changes or the presence of others, not previously recorded.

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