Electrocardiogram interpretation skills among healthcare professional and related factors: a review on myocardial infraction cases

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ABSTRACT

Acute Coronary Syndrome (ACS) is a major cause of death and disability worldwide. In spite of the advance of many other diagnostic techniques of biomarkers and imaging, the 12-lead electrocardiogram (ECG) remains the gold standard for early identification and management of ACS. The aim of this study was to determine the HCPs interpretation skills on 12 lead ECG especially in Myocardial Infarction cases. Primary research of ECG interpretation skill of HCPs and related factors were identified by searching electronic databases and bibliographies. Sixteen articles were identified based on inclusion and exclusion criteria. Variations were found on ECG interpretations among HCPs. Moreover it was found that training, experience & seniority and AMI mimicking pattern influence ECG interpretation skills among HCPs and decision making for thrombolytic therapy.

1. Introduction

The electrocardiogram (ECG) is the most significant and conclusive noninvasive diagnostic procedure that is used to help the health care team in diagnosing and monitoring cardiac electrical system function (Birnbaum et al., 2013; Osborn & Watson, 2011). In addition, the 12-lead ECG remains the gold standard for early identification and management of an acute coronary syndrome (ACS) (Amsterdam et al., 2014; Ibanez et al., 2017).

Globally, ACS remains responsible of causes of burden disease and the leading cause of death in the world (Sanchis-Gomar, Perez-Quilis, Leischik, & Lucia, 2016; Vedanthan, Seligman, Fuster, Weiner, & Kravis, 2015). The most common form of ACS is the ST Elevation Myocardial Infarction (STEMI) (Hodzic, Perla, Iglica, & Vucijak, 2018). Performing early diagnosis of Myocardial Infarction (MI) is crucial to delivering appropriate care (Trivedi, Schuur, & Cone, 2009). In spite of the advance of Computerized Electrocardiographic Analysis and its limitations (Schläpfer & Wellens, 2017), rapid diagnosis and treatments relies heavily on the clinicians' ability to identify myocardial infarction on a 12-lead electrocardiogram. Thus, there is an expectation for health care professional to have the knowledge and understanding of ECG interpretation. This review sought to identify and analyze literature which identified recent research on the ability of Health Care Professionals (HCPs) to interpret 12 lead electrocardiograms (ECGs) on Myocardial Infraction (MI).

2. Method

The CINAHL (Index to Nursing and Allied Health Literature), Medline/OVID and ProQuest were accessed using the key words: electrocardiography, electrocardiogram, accuracy, interpretation, myocardial infarction. The selection criteria included primary research articles in the English language. Primary research articles published between 2001 and 2016 were searched using combination of the keywords of electrocardiogram and interpretation and myocardial infarction and HCPs, 16 articles were found which included 4 different groups including nurses, paramedics, physicians and residents. These 16 articles consisted of 15 quantitative studies and one mixed methodology research.

3. Results and Discussion

Many factors influence HCPs interpretation's ability to read ECG. Findings from this integrated literature review indicate that training, experience & seniority and AMI mimicking pattern influence ECG interpretation skills among HCPs and decision making for thrombolytic therapy.

3.1. Paramedics

The studies reviewed show that paramedics have a high performance on ST-segment Elevation Myocardial Infarction (STEMI) identification with range of sensitivity from 80% to 97% and specificity from 85.4% to 97% (Feldman, Brinsfield, Bernard, White, & MacIejko, 2005; Le May et al., 2006; Levis & Koskovich, 2010; Trivedi et al., 2009; Whitbread, Leah, Bell, & Coats, 2002). In these studies, sensitivity was defined as the number of correct interpretation of STEMI and specificity was equivalent to the ability to correctly identify non ischemic ECGs. A high sensitivity and specificity of STEMI recognition on these studies demonstrated that paramedics can independently identify those patients with STEMI without review by a base hospital physician. Furthermore, the accuracy of paramedics was also compared to physicians on a prospective observational study. The result suggested that there was a good agreement among paramedics, emergency physicians and cardiologist in regard to the overall accuracy of STEMI identification. This study confirmed that paramedic's 12-lead ECGs interpretations are as accurate as physicians (Feldman et al., 2005).

Clinical decision of thrombolytic therapy is the major outcome of the studies reviewed. Paramedics responsible to made clinical decision based on electrocardiogram finding on pre-hospital setting. One cohort study by Le May et al (2006) examined paramedics' decision making ability to decide whether the patient was eligible for thrombolytic therapy. This study resulted in sensitivity 92%, specificity 97%, a positive predictive value (PPV) of 73%, and negative predictive value (NPV) of 99%. These finding demonstrated that paramedics in this study are very accurate and safe in their ability to identify patients whose need immediate thrombolysis.

3.2. Physicians

A high level of myocardial infarction diagnostic interpretation skill by physicians has been found on three studies (Brady, Perron, & Chan, 2001; Jayroe et al., 2009; Vijayaraghavan et al., 2007). The literatures showed that the physicians were divided into two groups, which are cardiologist physicians and non-cardiologist physicians.

Variations were found on ECG interpretations among cardiologist. One trial (Jayroe et al., 2009) has compared the ECG interpretation skills among experienced electrocardiographers from North America, Europe and Israel to differentiate between ST-segment elevation of myocardial infarction (STEMI) and non-ischemic ST elevation (NISTE). This study found sensitivity of 50% to 100%, specificity of 73% to 97% (average 85%), false positive rate 3% to 29% and false negative rate 0% to 50%. There were wide variations among experienced electrocardiographers when interpreting ECGs as indicating STE. Variation also found when they distinguishing STEMI from NISTE and the reason for which PPCI were recommended for the patient by the individual readers (7.8% to 33%).

The interpretation skills of non-cardiologist physicians were examined by (Brady et al., 2001). This survey determined the ability of emergency physician's (EP's) to find the cause of ST-segment elevation (STE) in a hypothetical chest pain patient. This study revealed that the overall rate of correct interpretation of the ECGs was 94.9% (4,782 correct interpretations out of 5,038 instances) and the rates of misinterpretation ranged from 9% (LBBB, 52 misinterpretations) and 72% (LVA, 330 misinterpretations). Authors (Salerno, Alguire, & Waxman, 2003) support the finding that several

studies of non-cardiologists identified 87% to 100% of ECGs showing acute myocardial ischemia. From this they diagnosed 57% to 95% of ST-segment abnormalities, and correctly measured about 25% of PR and QT intervals, and diagnosed abnormal ST-segment and T-wave abnormalities 57% to 97%.

Reference (Vijayaraghavan et al., 2007), assessed both cardiologist and non-cardiologist physicians. The authors found modest agreement between core-lab (one of three non-cardiologist physicians) and sites (practicing clinicians including emergency physicians, internist ad cardiologist and did not include in house officers) on the interpretation of the admission ECG. Overall concordance between core-lab and site interpretation of the admission ECG was 62%. Thus, there was disagreement of admission ECG classification in 38% of all patients.

Those result above supported by (Salerno et al., 2003). This systematic review showed that the use of expert electrocardiographer as the "gold standard" was common features of most ECG interpretation studies. The reviewed studies used the expert of cardiologist as the standard to compare the ECG interpretation accuracy to the subject of the studies. The use of cardiologist as the expert could be difficult since cardiologist interpretation often vary and didn't agree among their colleagues. Because cardiologists do not agree on many aspects of ECG interpretation, authors (Salerno et al., 2003) recommended the use of Kappa statistics (Ҡ) and control groups of cardiologists for future studies examining non cardiologist or computer interpretation.

3.3. Resident

Several studies (Berger et al., 2005; Boltri, Hash, & Vogel, 2003; De Jager, Wallis, & Maritz, 2010; Hoyle, Walker, Thomson, & Bailey, 2007; Salerno et al., 2003) found that overall resident competency to read ECGs was low. For example, study (Berger et al., 2005) noted that only 40% of residents gave the correct answer for diagnosing myocardial infarction. But these studies have several limitations due to small sample size and lack of generalisation. But (Hoyle et al., 2007) found that the accuracy of Acute Myocardial Infarction (AMI) identification was high (91%). This finding was supported by (Salerno et al., 2003) who found twelve articles which specifically assessed on resident physician interpretation skills. The authors found a high level of accuracy on resident's ability for ECG interpretation. Resident physicians detected 96% of abnormal ECGs, and correctly identified inclusion criteria for thrombolytic therapy 73% to 84% of the time, demonstrated 36% to 80% of ECG diagnoses as determined by expert electrocardiographers and discovered 38% of technical ECG abnormalities.

3.4. Nurses

In the reviewed literature, only one study was found which investigate the nurse's ability to interpret ECG on AMI case (Stephens, Anderson, Carey, & Pelter, 2007). A secondary analysis from a primary study used a pre test/post test design assesses the nurse's ability to interpret 12 leads ECG for Acute ST-segment Elevation Myocardial Infarction (STEMI) pattern. From 75 participants of nurses working in three different units (Emergency Department, Coronary Care Unit and Telemetry unit) found that only little percentage (20%) of all participants in this study who can identify the present or absent of myocardial ischemia correctly from the scenarios. This study also found that none of the participants were able to correctly identify the lead involved or the location of Myocardial Infarction. This study also suggested that nurses from Emergency Department and the Coronary Care Unit more often correctly identified ischemia with ST-segment elevation compared with nurses from telemetry unit.

Furthermore, (Drew et al., 2005) recommends that nurses should possess the ability to interpret 12 lead electrocardiograms including identifications of the correct leads, anatomic location or amplitude of ST elevation. The clinicians caring for hospitalised Acute Coronary Syndromes (ACS) patients should possess this ability. In addition, practice standards for electrocardiographic monitoring in hospital settings guideline from AHA also recommend ideal requirement skill for nursing staff to be able to work in each hospital unit with cardiac monitoring. The requirements include understanding of specific ECG abnormalities, general concepts of electrophysiology and monitoring skill (Drew et al 2005).

A study by Kremser & Lyneham (2007) introduce the issue on nurses initiated thrombolysis that require nurses to be able to read ECG to make clinical decision on patient eligibility on thrombolytic therapy. ECG reading skills also important for nurses since the studies found high rates

misinterpretation of the ECG in the Emergency service which lead for less use of evidence based treatment and caused high rates of in hospital and 1 year mortality (Hoyle et al., 2007). There is a significant lack of the research evidence in the literature on the ability of the nurses to read 12 lead electrocardiograms on AMI. The literature incorporated in this review suggests there is still a lot of work that needs to be done in exploring the nurse's ability to read electrocardiogram on AMI.

3.5. Training

Eight articles (Berger et al., 2005; Boltri et al., 2003; Feldman et al., 2005; Hoyle et al., 2007; Le May et al., 2006; Pelter, Carey, Stephens, Anderson, & Yang, 2010; Stephens et al., 2007; Whitbread et al., 2002) suggested that training improves the skill to read ECGs. Reference (Stephens et al., 2007) found that nurses who took a 12-lead ECG course and received ischemic interpretation training tended to have a higher score on ECG interpretation. Four studies who identify paramedics' skill to interpret electrocardiogram agree that training improves paramedics' ability to interpret ST elevation myocardial infarction. Another study also showed that there was an improvement in the accuracy of ECG interpretation with advancing years of emergency medicine training in Victoria (Hoyle et al., 2007).

Two studies, as in (Levis & Koskovich, 2010; Pelter et al., 2010) found that education enhance the ability of ECG interpretation on AMI. One prospective study used pre-test/post-test design found that education improves the nurse's skill to read ECG (Pelter et al., 2010). Authors in this study used a hand held paper tool to determine if the tool helped nurses to identify the present of ST elevation myocardial infarction (STEMI), location and leads. The result showed that nurses' ability to identify STEMI location improves significantly when using the MI Rule Visions™ tool. In this study is, the tool is formatted for use with a 12-lead ECG printed in a 3×4 format. When the 12-lead ECG is placed properly in the tool, labels related to location and specific leads can then be identified.

The above findings are supported by (Levis & Koskovich, 2010) who conducted a prospective, randomised, non-blinded study to examine the ability of first year paramedic students to detect ST-segment elevation myocardial infarction on a 12-lead electrocardiogram. They compared an intervention group who get handout plus a three-hour presentation session with a control group who get a handout only. They found that structured ECG STEMI presentation provided by an emergency medicine physician improved the ability of first-year paramedic students to accurately detect STEMI on pre-hospital 12-lead ECGs. In addition these paramedic students maintained these skills over a five-month period.

The research by (Stephens et al., 2007) suggests that nurses skill to identify ECG with and without ischemia should be the focus education. Given this, the authors recommended that nurses need more education focused on some specific areas to monitor MCI including: (1) ST-segment elevation myocardial ischemia definition in 12-lead ECGs; (2) non ischemic ST-elevation common pattern; (3) detection of over time changes by using serial ECGs; (4) appropriate units of measure to ensure accurate and efficient interpretation; and (5) communication of ECG findings. These conclusions were also supported by (Salerno et al., 2003) who stated that training in ECG interpretation should include:

'Knowledge of the pathophysiology of the electrocardiographic abnormalities; the skill to recognise common normal, abnormal, and technical artifact pattern and the opportunity to apply this knowledge in bedside clinical decision making'. In addition he stated a thorough understanding of cardiac anatomy, physiology and properties can provide a framework for understanding and interpreting cardiac rhythms (Salerno et al., 2003). Reference (Drew et al., 2005), also recommend that nurses should possess the ability to read 12 lead electrocardiograms including identifications of the correct leads, anatomic location (i.e., anterior, inferior, and lateral), or amplitude (millimeters, mm) of ST elevation. The skills to assess ECGs for these characteristics are an essential skill that clinicians caring for hospitalized Acute Coronary Syndromes patients.

The American Heart Association (AHA) recommends the ideal staff proficiencies requirement to monitor patient safely and effectively (Drew et al., 2005). To be proficient in cardiac monitoring, nursing staff should perform understanding of specific ECG abnormalities, general concepts of electrophysiology and be proficient in monitoring skill. AHA recommends that nurses who have responsibility to ECG monitoring should receive specific orientation and training to the type of monitoring system being used and to the goals of monitoring for the patient. For example, in EDs,

monitoring for ST-segment is important so that patients with acute myocardial syndrome will not be inadvertently sent home (Drew et al., 2005).

Reference (Drew et al., 2005) also emphasized the important of educational program which should result in staff demonstrating competence in specific cardiac-monitoring skills. After initial orientation and training, a periodical mandatory competency evaluation of all staff should be a performed to ensure continued proficiency in critical elements of cardiac monitoring. This evaluation also could include periodic audits of electrode placement and rhythm strip interpretation. Continuing education to reinforce current knowledge and update staff on research findings and techniques should be encouraged and supported.

Another article also stressed that paramedics in this study has completed a 6-hour training course which focused on pathophysiology of the acute coronary syndrome, proper acquisition of a 12-lead ECG, and accurate ECG interpretation which highlighting on diagnostic changes associated with AMI and recognition of STEMI patterns. Paramedics were also trained on identification of common sources of misclassification such as bundle-branch block, ventricular aneurysms, pericarditis, and the early repolarisation variant. Maximising the interpretation specificity was the goal of the training program to minimize false positive STEMI identification (Feldman et al., 2005).

3.6. Experience and seniority

Reference (Stephens et al., 2007) found that nurses who deal with more ECG interpretation during their work shift were more likely to have better skill to interpret ECG. This finding was supported by (Kremser & Lyneham, 2007) who conducted a mixed methodology study to examine the theoretic and diagnostic skill of Australian nurses to decide whether the patient has a possibility to have thrombolysis or not. In addition they found that seniority may contribute to the rate of accuracy.

Three other researchers (De Jager et al., 2010; Feldman et al., 2005; Hoyle et al., 2007) also found the same result. They found that seniority contributes to the improvement of ECGs interpretation. As in (Hoyle et al., 2007) who assessed emergency medicine trainees found that seniors trainees were superior at interpreting ECGs than junior trainees. On this study all of the senior trainees 100% correctly identified AMI compared with 85.1% of junior trainees. A prospective cross-sectional study by (De Jager et al., 2010) also compared the accuracy of ECG interpretation between senior and junior group of Emergency Medicine residents. They found that the senior group had an overall average of 52.5%, while the junior group managed 42.2%. As in (Feldman et al., 2005), also stressed on the influence of experienced and motivated paramedics to the high performance of recognition of STEMI on the ECG. Reference (Trivedi et al., 2009) discover a different finding from other researchers. These finding showed none of the individual paramedic experience and comfort levels that asked about were associated with increased diagnostic accuracy. The major limitation of the study is that paramedics were tested using paper-based scenarios with only two ECGs (one normal, one STEMI).

3.7. AMI mimicking pattern

Two studies (Brady et al., 2001; Stephens et al., 2007) showed that various conditions may present with an identical electrocardiographic pattern as STEMI which lead to misinterpretation of the ECG. Reference (Stephens et al., 2007) found that nearly 50% of the nurses misinterpret early repolarisation and left bundle branch block (LBBB) ECGs pattern as ischemic. Another study (Brady et al., 2001) also revealed that the second most frequently misinterpreted STE pattern were BER (Benign Early Repolarisation) (23%). LBBB also often misinterpret as AMI although not as frequent as BER (5%). Other confound pattern on this study which mimicking AMI were LVA (Left Ventricular Aneurysm) (28%) and pericarditis (21%). Those various syndromes causing non-AMI STE may be misdiagnosed as acute infarction, which then may lead the patient to unnecessary and potentially dangerous therapies and procedures. In this study, these patterns were treated with thrombolytic agent frequently, which can certainly cause significant morbidity.

4. Conclusion

Health care professional's ECG reading skills is very important to prevent misinterpretation. The literature identifies that HCPs have varied performance on reading ECGs. Training, experience & seniority and AMI mimicking pattern are the most identified factors which may affect their skill.

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