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REVIEW

A Review of Carbon Dioxide Monitoring During Adult Cardiopulmonary Resuscitation

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Although high quality cardiopulmonary resuscitation is one of the most significant factors related to favourable outcome, its quality depends on many components, such as airway management, compression depth and chest recoil, hands-off time, and early defibrillation. The most common way of controlling the resuscitation efforts is monitoring of end-tidal carbon dioxide. The International Liaison Committee on Resuscitation suggests this method both for in-hospital and out-of-hospital cardiac arrest. However, despite the abundant human and animal studies supporting the usefulness of end-tidal carbon dioxide, its optimal values during cardiopulmonary resuscitation remain controversial. In this review, the advantages and effectiveness of end-tidal carbon dioxide during cardiopulmonary resuscitation are discussed and specific target values are suggested based on the available literature.

Keywords End-tidal carbon dioxide • Monitoring • Capnometry • Capnography • Resuscitation • Adults.

Introduction

Cardiac arrest (CA) is the most urgent emergency characterised by significant mortality and poor prognosis, which is responsible for approximately 1000 deaths per day in Europe and the United States [1,2]. Despite recent advances in cardiopulmonary resuscitation (CPR), only 20% of patients will survive after in-hospital cardiac arrest, while in the prehospital setting, survival rate decreases dramatically to less than 10% [2]. In either setting, however, survivors often sustain severe neurological injury, resulting in poor neurological outcome [3–6].

High quality CPR is one of the most significant factors defining outcome, with an abundance of evidence indicating that it is a pre-requisite for improving survival rates [6]. The quality of CPR depends on many components, such as airway management, compression depth and chest recoil, hands-off time, and early defibrillation; the combination of these components aims at providing the best possible substitution of the pre-arrest blood flow. During optimal CPR, however, the cardiac output is between 25 and 40% of pre-arrest values: with the coronary arteries receiving 5-15% of this amount, while the peak systolic arterial pressure and mean pulmonary artery pressure range between 60-80 mmHg and 40 mmHg, respectively [7]. As a result, several invasive and non-invasive techniques have been proposed during the last decades for determining the quality of CPR and especially the effectiveness of chest compressions.

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Monitoring of end-tidal carbon dioxide ($ETCO_2$) during CPR was first reported by Kalenda who studied three cardiac arrest patients and reported that $ETCO_2$ decreased when the compressor got tired and that $ETCO_2$ increased significantly after return of spontaneous circulation (ROSC) [8]. Ten years later, Gudipati et al. reported that $ETCO_2$ monitoring during CPR may indicate ROSC and the effectiveness of cardiac massage, and may serve as a prognostic indicator of CPR success [9]. Since then, numerous human and animal studies have shown the usefulness of $ETCO_2$ during CPR and the significant difference in its values between survivors and non-survivors. End-tidal carbon dioxide highly correlates with cardiac output, myocardial blood flow, aortic diastolic pressure, coronary perfusion pressure, cardiac index, and cerebral perfusion pressure [10–12]. It may also provide data regarding ventilation and tissue metabolism [9]. As a result, the European Resuscitation Council (ERC) and the American Heart Association (AHA) favour the use of capnographs in advanced CPR [6,13]. The aim of this review is to present the advantages and effectiveness of $ETCO_2$ during CPR, as well as potent limitations of the technique.

Methods

This paper is a narrative review. The literature search was performed using PubMed, CINAHL, and Scopus databases from 1980 until now. The inclusion criteria were 'capnography', 'capnograph', 'capnometry', 'expired carbon dioxide', 'end-tidal carbon dioxide', 'cardiopulmonary resuscitation', and 'cardiac arrest'. All articles not available in English and case reports were excluded, while cross-referencing was performed using the bibliographies from the articles obtained. The authors completed the literature search and selected by consensus the studies based on inclusion criteria as judged by title, abstract and complete manuscript, identifying 401 citations. Paediatric studies were not included. Information was extracted from each included article on the study's inclusion criteria, while data extraction was performed in duplicate by the two authors and any disagreements were resolved by discussion. Assessment of the articles for the stated criteria based on title, abstract or full text resulted in 42 articles, which were selected for the final review (Fig. 1).

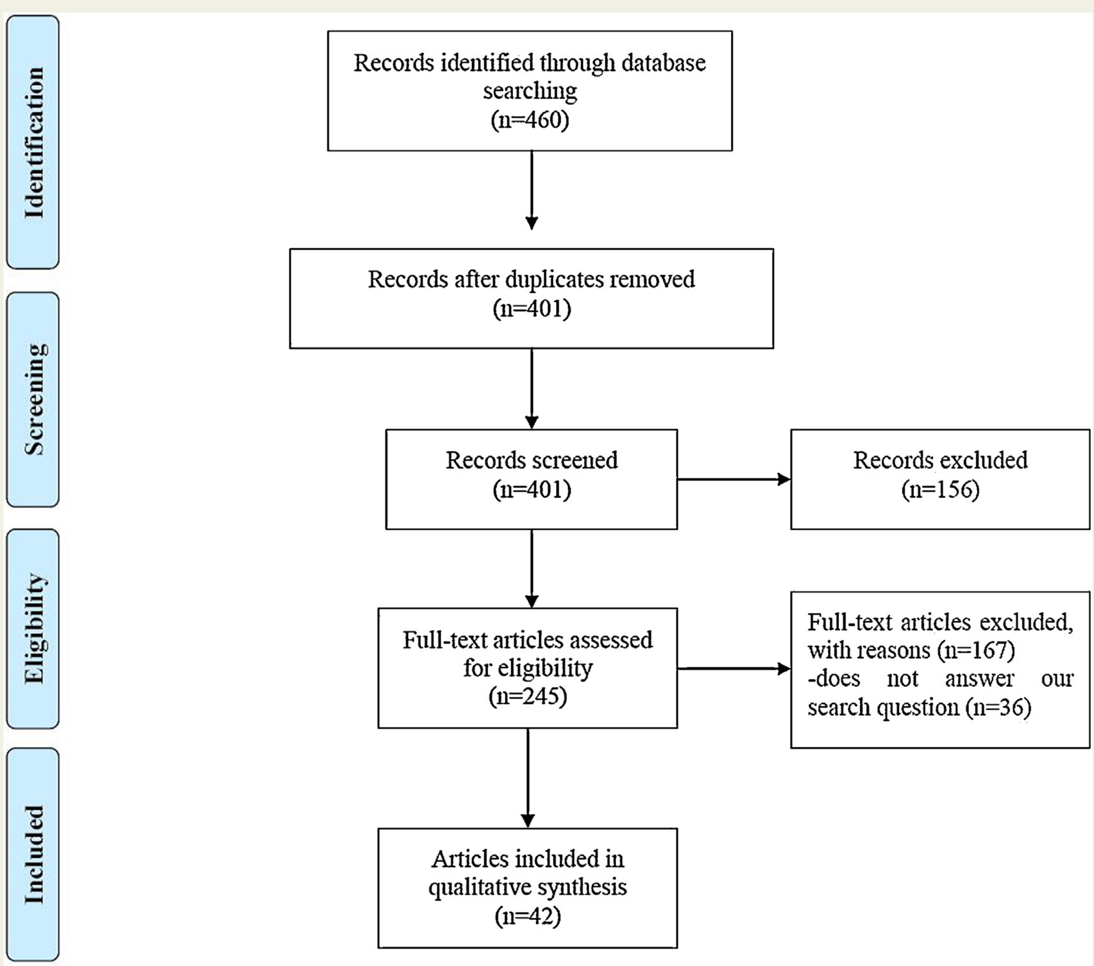

Fig. 1 Flow chart of the search and selection procedure of studies.