THE BENEFITS OF CAPNOGRAPHY
IN PRE-HOSPITAL CARE:
AN INTEGRATIVE LITERATURE REVIEW

AS VANTAGENS DA CAPNOGRAFIA
NO PRÉ-HOSPITALAR:
UMA REVISÃO INTEGRATIVA DA LITERATURA

LOS BENEFICIOS DE LA CAPNOGRAFÍA
EN EL CONTEXTO PREHOSPITALARIO:
UNA REVISIÓN INTEGRATIVA DE LA LITERATURA

Tiago Nobre Dias[1], Carla Alexandra de Sousa Boura Santos Cristino[1],

Tiago de Oliveira Almeida Augusto[1], Nuno Miguel da Silva Rente[1],

Susana Manageiro Pereira[1], Rui Miguel Lopes Alves[1].

[1]National Institute of Medical Emergency, Southern Regional Delegation, Lisbon.

ABSTRACT

Introduction: Capnography is an important method for continuous and noninvasive monitoring of the partial pressure of carbon dioxide (CO_2) exhaled by the patient, being increasingly used in the pre-hospital setting. Thus, the present study aims to investigate the main benefits of capnography in the pre-hospital setting.

Methodology: For the present study, an Integrative Literature Review was developed, using the following MeSH and key words: (("Capnography") AND ("Prehospital Care") AND ("Nursing")) and their corresponding terms in Portuguese in the PubMed, Medline, and CINAHL databases, yielding a total of 57 of which 27 articles were submitted for full text reading.

Results: After applying the inclusion and exclusion criteria, 9 articles were selected. Through the analysis of the results, several advantages of using capnography in the pre-hospital environment were identified, namely monitoring the correct placement of the endotracheal tube; assessing the quality of cardiopulmonary resuscitation; recognising and predicting the return of spontaneous circulation; the ability to diagnose and prognose the patient as well as identifying diseases and other conditions, such as sepsis, which may put patients at risk of life.

Conclusion: There are many advantages to using capnography as a method for monitoring respiratory function in the pre-hospital setting and have the knowledge that this tool is important for nurses, taking into account evidence-based practice.

Keywords: Capnography; Nursing; Pre-hospital Care.

RESUMO

Introdução: A capnografia constitui um importante método de monitorização contínua e não invasiva da pressão parcial de dióxido de carbono (CO_2) exalada pelo paciente, sendo cada vez mais utlizada em contexto pré-hospitalar. Deste modo, o presente trabalho tem como objetivo investigar quais as principais vantagens da capnografia em contexto pré-hospitalar.

Metodologia: Para o presente estudo desenvolveu-se uma Revisão Integrativa da Literatura, realizando-se uma pesquisa com os seguintes termos MeSH e chave de pesquisa: (("*Capnography*") AND ("*Prehospital care*") AND ("*Nursing*")) e seus correspondestes em português nas bases de dados PubMed, Medline e CINAHL, obtendo-se um total de 57 artigos, tendo sido submetidos para leitura do texto integral, 27 artigos.

Resultados: Após a aplicação dos critérios de inclusão e exclusão, foram selecionados 9 artigos. Através da análise dos resultados foram identificadas várias vantagens da utilização da

capnografia em ambiente pré-hospitalar, nomeadamente, a monitorização da correta colocação do tubo endotraqueal; a avaliação da qualidade da reanimação na paragem cardiorrespiratória; o reconhecimento e previsão do regresso da circulação de forma espontânea; a capacidade de diagnóstico e prognóstico do paciente assim como a identificação de doenças e outras condições, como a septicemia, que podem colocar os pacientes em risco de vida.

Conclusão: São inúmeras as vantagens encontradas para a utilização da capnografia como método de monitorização da função respiratória em contexto pré-hospitalar, sendo importante para o enfermeiro o conhecimento desta ferramenta, tendo em conta a prática baseada na evidência.

Palavras-chave: Assistência Pré-hospitalar; Capnografia; Enfermagem.

RESUMEN

Introducción: La capnografía constituye un importante método de monitorización continua y no invasiva de la presión parcial de dióxido de carbono (CO_2) exaltada por el paciente, siendo cada vez más utilizada en el contexto prehospitalario. Así, el presente estudio pretende investigar las principales ventajas de la capnografía en el contexto prehospitalario.

Metodología: Para el presente estudio, se desarrolló una Revisión Integrativa de la Literatura, utilizando los siguientes MeSH y palabras clave: ((*"Capnography"*) AND (*"Prehospital care"*) AND (*"Nursing"*)) y sus correspondientes términos en portugués en las bases de datos PubMed, Medline y CINAHL, arrojando un total de 57 artículos, de los cuales 27 artículos fueron sometidos a la lectura del texto completo.

Resultados: Después de aplicar los criterios de inclusión y exclusión, se seleccionaron 9 artículos. Mediante el análisis de los resultados, se identificaron varios beneficios del uso de la capnografía en el entorno prehospitalario, a saber, la supervisión de la correcta colocación del tubo endotraqueal; la evaluación de la calidad de la reanimación cardiopulmonar; el reconocimiento y la predicción del retorno de la circulación de forma espontánea; la capacidad de diagnosticar y pronosticar al paciente, así como la identificación de enfermedades y otras condiciones, como la sepsis, que pueden poner en riesgo la vida de los pacientes.

Conclusión: El uso de la capnografía como método de monitorización de la función respiratoria en el contexto prehospitalario tiene muchas ventajas y el conocimiento de esta herramienta es importante para el personal de enfermería, teniendo en cuenta la práctica basada en la evidencia.

Descriptores: Aténcion Prehospitalaria; Capnografía; Enfermería.

INTRODUCTION

Capnography is a method of continuous and non-invasive monitoring of the partial pressure of carbon dioxide (CO_2) exhaled by the patient over time. In addition to the numerical value of CO_2 that is exhaled, capnography also provides a graphic record of CO_2 elimination and respiratory rate in real time, through a monitor called a capnograph. In this way, the capnograph provides continuous information on exhaled CO_2, the graphic record of its elimination (the capnogram) and the patient's respiratory rate[1,2]. Capnography is a clinically safe and approved non-invasive method[3].

By using capnography, the patient's ventilation status is monitored in real time. In this way, health professionals can identify potential complications at the respiratory level, such as airway obstruction, hyperventilation, hypoventilation, or apnea. This means of evaluation thus allows a corresponding response, through changes in clinical care, such as reassessing the patient or providing supplemental oxygen[4].

Despite pulse oximetry as an indispensable method for correct patient monitoring, and an indicator of respiratory function, it nevertheless has some limitations, such as the immediate detection of episodes of respiratory depression, especially in procedures in which it is not possible to observe the chest movements, or when supplemental oxygen is administered. Although this delay in detecting respiratory compromise is tolerated in several situations, in people with associated pathologies, this limitation can prove to be a problem[1]. In turn, capnography enables earlier detection of situations of respiratory failure or respiratory depression. Detecting problems at an early stage triggers timely intervention at the onset of an adverse respiratory event, which can help prevent deterioration to a more critical point, or even fatality[5]. Among other advantages of this method, it is highlighted that it is a non-invasive, relatively inexpensive and easy to maintain method[4].

Capnography is mandatory in the current in-hospital anesthetic practice, and it is currently recommended in the pre-hospital setting[6]. Intubation should not, therefore, be forgotten in pre-hospital situations, as the practice with supraglottic airway devices is becoming more and more frequent. In fact, nurses, in addition to other health professionals, assist more and more incidents in a pre-hospital context, using capnography to monitor the airways[7].

In the pre-hospital emergency context, the nurse is actively involved in the first patient care and should be aware of the importance of capnography in this phase. By using capnography, the nurse has the necessary information to assess the patient's respiratory status and thus be able to intervene in the most appropriate way[8]. Thus, this present article aims to assess what are the main advantages of capnography in a pre-hospital context, carrying out an integrative literature review.

For this present work, Evidence-Based Practice (EBP) is of interest. EBP can be defined by clinical decision making, based on the best available evidence, the professional judgment of the clinician, the patient's perception and also the context in which care is provided[9]. Other authors consider EBP to be the conscious, explicit and judicious use of the best and most current scientific evidence in making clinical decisions about the provision of care, taking into account the individual needs or the needs of the population in question[10].

The Integrative Literature Review (ILR) emerges as the method that underlies the EBP, as it allows the incorporation of evidence into clinical practice[11] through research, critical evaluation and synthesis of available evidence on an investigated topic, comprehensively, contributing to the deepening of knowledge of the topic investigated[12].

METHODOLOGY

To deepen knowledge about the advantages of capnography in a pre-hospital environment, an integrative literature review will be carried out, using the Joanna Briggs Institute methodology as a reference.

For the construction of the research question, the research terms were used according to the PCC terminology (Population, Concept, Context) Chart 1↗.

Taking this into account, the following guiding question for this ILR was formulated: "What are the advantages of using capnography, in people who need respiratory monitoring, in a pre-hospital context?"

The research was carried out using the following MeSH terms and search keys: (("Capnography") AND ("Prehospitalar") AND ("Nursing")) and their correspondents in Portuguese in the PubMed, Medline and CINAHL databases, obtaining a total of 57 articles were subsequently submitted for analysis, according to the inclusion and exclusion criteria shown in Chart 2↗.

After analysis according to the inclusion and exclusion criteria, 27 articles were read in full, of which 9 were selected for this ILR. Figure 1↗ shows the flowchart, according to the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[13], describing each of the phases until reaching the final number of articles included.

RESULTS

Nine articles were selected for this ILR, which met the previously identified inclusion criteria. A descriptive summary of the main aspects of each of the studies is presented in Chart 3↗.

DISCUSSION

Capnography is widely used in the pre-hospital context, as well as in the emergency departments, being of great importance for verifying the correct intubation of the patient, to prove the effectiveness of cardiopulmonary resuscitation, as well as being essential in neonatal and pediatric transport, in the military transport and within the scope of the operating room[14]. Capnography includes the non-invasive measurement of CO_2, providing information on ventilation, perfusion, and metabolism in spontaneously breathing intubated patients. Since the 1990s, capnography has been used extensively for cardiac arrest and procedural sedation[15].

This technique is easily transferable to the pre-hospital context, being particularly important with regard to environments where there are high rates of intubation failures, with the introduction of the tube into the esophagus, therefore, capnography is used to monitor and verify whether intubation is being performed correctly[16]. In fact, capnography is very relevant in pre-hospital resuscitation situations, being the technique most frequently used to confirm the correct position of the endotracheal tube[17]. In addition to this important advantage, capnography is also used to monitor the quality of chest compressions, to monitor ventilation and to predict the prognosis[17]. Also in a study carried out in Japan, capnography was evaluated as very useful and important to work in a pre-hospital context, especially in environments that are not conducive to performing endotracheal intubation, thus allowing to understand whether this procedure is, effectively performed and if the patient is properly ventilated[18].

Capnography also showed advantages about the prevention of severe forms of septicemia. It is suggested that the measurement of $ETCO_2$, performed through capnography, can be a predictor of simple and clinically useful results in a pre-hospital context, and can be performed immediately and non-invasively[18]. It has been shown that $ETCO_2$ values are able to predict mortality, being inversely proportional to serum lactate levels in pre-hospital patients with suspected septicemia. Thus, the presence of capnography equipment should be considered mandatory in advanced life support units[19].

Another great advantage of capnography in the pre-hospital setting is that $ETCO_2$ monitoring is a very useful measure to assess the quality of resuscitation in cases of cardiac arrest[20]. The same study also identifies the previously mentioned advantage, which is the continuous evaluation of the placement of the endotracheal tube, of extreme relevance with regard to the orientation of efforts at the level of resuscitation[20].

The recommendation for the use of capnography is present in the main international guidelines for resuscitation, with emphasis on its role in monitoring the quality of resuscitation in situations of cardiac arrest, due to the early recognition of recovery of circulation, thus being a potential indicator of the patient's diagnosis[21]. The recognition and prediction of recovery of spontaneous circulation is also confirmed by other studies[22], namely in the context of monitoring cardiac arrests occurring in a pre-hospital environment. The importance of capnography in the diagnosis and prognosis of the patient is also mentioned[22].

CONCLUSION

Capnography is an important tool for informing the patient's status in situations such as cardiac arrest, anesthesia, mechanical ventilation, among others, with numerous advantages regarding its use in a pre-hospital context, constituting an effective means of diagnosis and prognosis, while continuously and non-invasively evaluating the patient's $ETCO_2$, allowing the prevention of more serious conditions through a quick intervention.

The development of knowledge acquired through evidence-based practice, systematized through the present literature review, intends to be a tool for all nurses, with regard to the development of skills for the continuous monitoring of respiratory function in a pre-hospital context using the capnography.

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Authors

Tiago Nobre Dias

https://orcid.org/0000-0001-8408-5555

Carla Alexandra de Sousa Boura Santos Cristino

https://orcid.org/0000-00022434-2895

Tiago de Oliveira Almeida Augusto

https://orcid.org/0000-0002-8876-5715

Nuno Miguel da Silva Rente

https://orcid.org/0000-0003-4553-1510

Susana Manageiro Pereira

https://orcid.org/0000-0001-8177-2931

Rui Miguel Lopes Alves

https://orcid.org/0000-0001-5468-0935

Corresponding Author/Autor Correspondente:

Tiago Dias – Instituto Nacional de Emergência Médica, Delegação Regional do Sul, Lisboa, Portugal. tiago.dias@inem.pt

Authors' contributions

TD: Study coordination, study design, data collection, storage and analysis, review and discussion of results.
CC: Study design, data analysis, review and discussion of results.
TA: Study design, data analysis, review and discussion of results.
NR: Study design, data analysis, review and discussion of results.
SP: Study design, data analysis, review and discussion of results.
RA: Study design, data analysis, review and discussion of results.
All authors read and agreed with the published version of the manuscript.

Chart 1 – Criteria for formulating the ILR research question.↖

Population	Who is studied?	People in need of respiratory monitoring
Concept	What is studied?	Advantages of capnography
Context	In what context is it studied?	Pre-hospital context

Chart 2 – Inclusion and exclusion criteria for articles analyzed in the ILR.↖

Inclusion criteria for articles	Exclusion criteria for articles
a) Access to the full text; b) Articles in Portuguese and English; c) Studies on capnography in a pre-hospital context; d) Articles published between 2012 and 2022.	a) Duplicate articles; b) Articles in languages other than those considered in the inclusion criteria; c) Studies on other methods of respiratory monitoring; d) Studies in contexts other than pre-hospital; e) Studies published before 2012.

Identification

Records identified
by searching Pubmed,
Medline and CINAHL
(n=57)

Selection

Records after duplicate elimination
(n=51)

Records selected
(n=27)

Records excluded
after reading the title
and abstract
(n=8)

Eligibility

Full articles evaluated
as eligible
(n=19)

Excluded full articles
They did not meet
the inclusion criteria
of the work
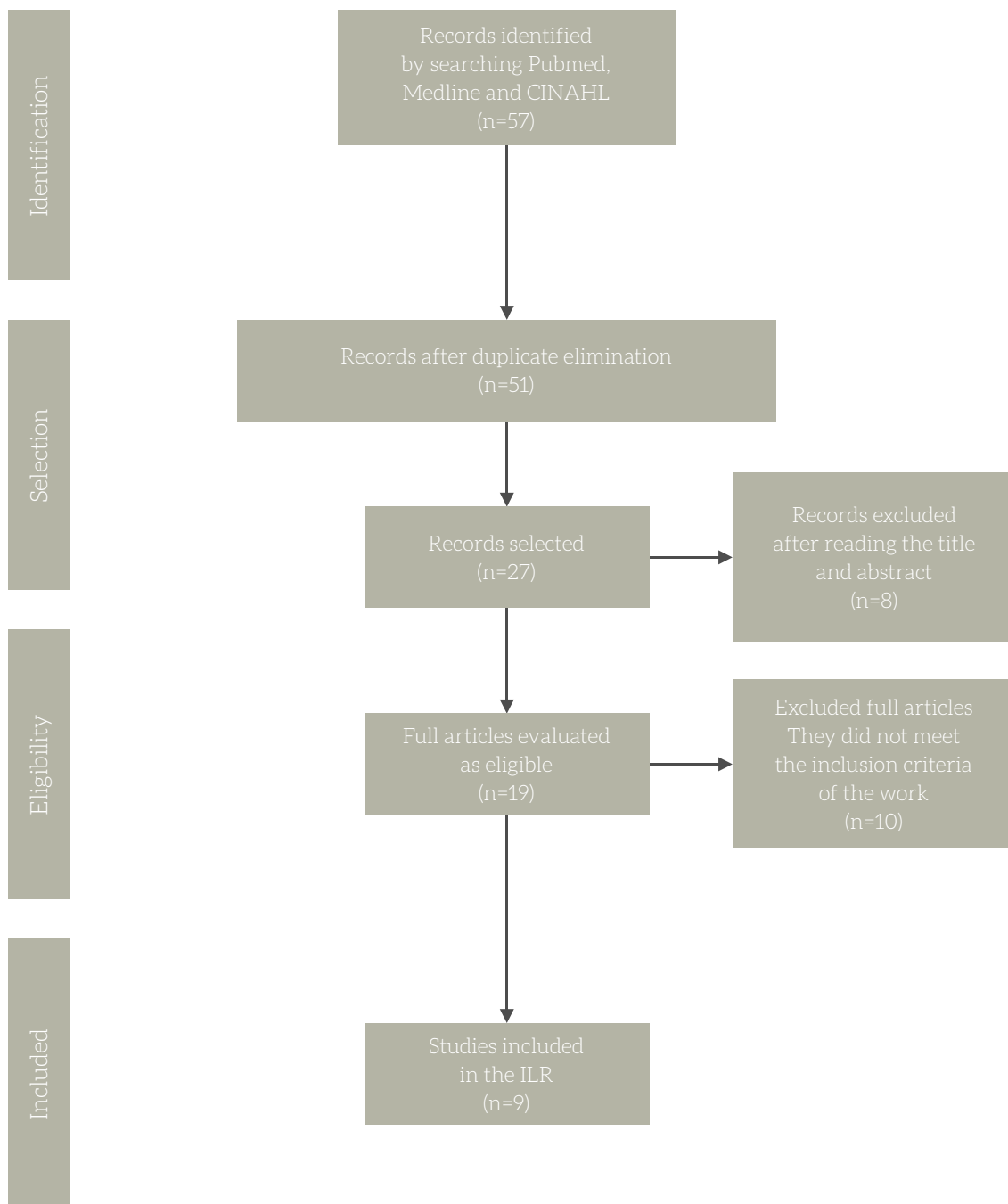(n=10)

Included

Studies included
in the ILR
(n=9)

Figure 1 – PRISMA article selection flowchart.⌐

Chart 3 – Descriptive summary of the included studies.↗↖

Title	Authors/Year/ Country/Publication	Objectives	Methodology and level of evidence	Results	Main conclusions/ implications for practice
Inter- and Intra- -hospital Transport of the Critically Ill.	Blakeman T, Branson R. 2013. USA. Respiratory Care.	To evaluate current practices in inter- and intra-hospital transport, namely ventilation monitoring.	Literature review. Evidence level: 5.	The performance of transport equipment, including ventilators, is improving substantially, allowing caregivers to move closer to the goal of bringing the ICU to the patient throughout the transport process.	Careful planning, monitoring and allocation of resources, including having professionals trained in transport, are of utmost importance to ensure that patients remain as safe as possible in the context.
Pre-hospital anaesthesia: the same but different.	Lockey D, Crewdson K, Lossius H. 2014. The United Kingdom. British Journal of Anaesthesia.	To present a review on airway management during anesthesia in a pre-hospital setting.	Literature review. Evidence level: 5.	Capnography is easily transferable to prehospital care and is mandatory in an environment with high rates of difficulty in intubation and esophageal intubation. A study carried out in Florida demonstrates the importance of prehospital capnography, reducing the displacement of the tracheal tube on arrival at the hospital by 9% to zero, with the introduction of continuous CO_2 monitoring.	Capnography is increasingly the suggested method for monitoring $ETCO_2$ in a pre-hospital setting.

Chart 3 – Descriptive summary of the included studies.↔↗↖

Title	Authors/Year/ Country/Publication	Objectives	Methodology and level of evidence	Results	Main conclusions/ implications for practice
Are prehospital airway management resources compatible with difficult airway algorithms? A nationwide cross-sectional study of helicopter emergency medical services in Japan.	Ono Y, Shinohara K, Goto A, Yano T, Sato L, Miyazaki H, Shimada J, Tase C. 2015. Japan. Journal of Anesthesia.	This study aims to determine whether Japanese Medical Services Helicopters (HEMS) are adequately equipped to comply with the difficult airway algorithms of the Japanese and American Anesthesiology Societies.	Cross-sectional study, nationwide, carried out in May 2015. A questionnaire was sent to the hospitals where questions related to airway management equipment and support staff were asked. Evidence level: 4.	Of the 45 HEMS-based hospitals questioned, 42 (93.3 %) answered the questionnaires. A surgical airway was feasible for all HEMS. However, in the prehospital, supportive care was available in 14.3%, supraglottic devices in 16.7% and capnometry in 66.7%. No HEMS held all four options.	In Japan, health professionals working in a pre-hospital setting should consider the risks and benefits of performing endotracheal intubation in environments that are not conducive to performing this procedure.
A prehospital screening tool utilizing end-tidal carbon dioxide predicts sepsis and severe sepsis.	Hunter C, Silvestri S, Ralls G, Stone A, Walker A, Papa L. 2016. USA. American Journal of Emergency Medicine.	To determine the usefulness of a pre-hospital sepsis screening protocol using SIRS and $ETCO_2$ (capnography).	Prospective cohort study among sepsis alerts triggered by emergency medical services, for a period of 12 months after initiation of a new sepsis screening protocol using the criteria ≥ 2 SIRS and $ETCO_2$ levels of ≤ 25 mmHg in patients with suspected infection. Evidence level: 2b.	Sepsis alerts, following the protocol, had a sensitivity of 90% (95% CI 81-95%), a specificity of 58% (95% CI 52-65%), and a negative sensitivity of 93% predictive value (95% CI 87-97%) for severe sepsis. There were significant associations between prehospital $ETCO_2$ levels and serum bicarbonate (r= 0.415, P b .001), anion gap (r= -0.322, P b .001), and lactate (r= -0.394, P b .001).	A pre-hospital screening protocol using SIRS and $ETCO_2$ criteria predicts sepsis and severe sepsis, which could potentially shorten the duration of therapeutic intervention.

Chart 3 – Descriptive summary of the included studies.↔↗↖

Title	Authors/Year/Country/Publication	Objectives	Methodology and level of evidence	Results	Main conclusions/implications for practice
Capnography in the Emergency Department: A review of uses, waveforms and limitations.	Long B, Koyfman A, Vivirito M. 2017. USA. The Journal of Emergency Medicine.	This review evaluates several indications about capnography beyond cardiac arrest and procedural sedation in the Emergency Department, as well as limitations and specific waveforms.	Literature review. Evidence level: 5.	Capnography includes the non-invasive measurement of CO_2, providing information on ventilation, perfusion, and metabolism in spontaneously breathing intubated patients. Since the 1990s, capnography has been used extensively for cardiac arrest and procedural sedation.	Capnography demonstrates benefits in cardiac arrest, procedural sedation, mechanically ventilated patients, and patients with acidemia. Further study is needed in patients with seizures, trauma and certain respiratory conditions.
Use of Capnography and Cardiopulmonary Resuscitation Feedback Devices Among Prehospital Advanced Life Support Providers.	Sahyoun C, Siliciano C, Kessler D. 2018. USA. Pediatric Emergency Care.	The objectives of this study were to assess the availability of capnography and CPR feedback devices in New York State advanced life support units; describe the use of these devices in prototypes and evaluate the attitudes of professionals in relation to the use of these devices.	Cross-sectional study. The advanced life support units were identified through their registration, and their professionals were contacted via email, who were asked to complete a questionnaire about their unit's experience with capnography and CPR feedback devices. Evidence level: 4.	Of the 710 units identified, 238 (33.5%) completed the survey. 95% of these units declared to have capnography and 24% have CPR feedback devices available on-board ambulances. 97% of the units reported having protocols for clinical capnography, 63% for the return of spontaneous circulation, and 54% to guide CPR. 47% agreed that capnography improves outcomes in pediatric resuscitation, while 51% of professionals were neutral and 2% disagreed.	Capnography is available in most surveyed advanced life support units. Cardiopulmonary resuscitation devices are less common. Protocols for the use of capnography are mainly focused on endotracheal intubation and less for the recognition of the return of spontaneous circulation and to guide CPR. Half of the professionals surveyed were neutral about whether capnography improves outcomes in pediatric resuscitation.

Chart 3 – Descriptive summary of the included studies.⟵→↖

Title	Authors/Year/ Country/Publication	Objectives	Methodology and level of evidence	Results	Main conclusions/ implications for practice
Modeling the impact of ventilations on the capnogram in out-of--hospital cardiac arrest.	Gutiérrez J, Ruiz J, Gauna S, Gonáliz-Otero D, Leturiondo M, Russell J, Corcuera C, Urtusagasti F, Daya M. 2020. Spain. Plos One.	To analyze the impact of ventilations on exhaled CO_2, measured from capnograms collected in a pre-hospital context in situations of resuscitation in cardiac arrest.	The defibrillator monitor files collected in out-of-hospital cardiac arrest situations were retrospectively analyzed with simultaneous capnogram, compression depth and ECG monitoring. The variation in exhaled CO_2 concentration with each ventilation was modeled with an exponential decrease of function. Evidence level: 2b.	From the original dataset of 1002 pre-hospital cardiac arrests (one per patient), 377 episodes had the necessary signs and 196 segments of 96 patients met the inclusion criteria. The type of airway was endotracheal tube in 64.8% of segments, supraglottic King LT-D™ in 30.1%, and unknown in 5.1%. Differences in the decrease factor with airway type were not statistically significant (p= 0.17). Based on these results, we propose a model to estimate the contribution of CCs to the level of expired CO_2 between consecutive ventilations and to estimate the variation in expired CO_2 as a function of ventilation rate.	This discovery allowed us to hypothesize a mathematical model to explain the effect of chest compressions on $ETCO_2$ compensating for the influence of ventilation rate during cardiac arrest. However, more work is needed to confirm the validity of this model during continuous chest compressions.

Chart 3 – Descriptive summary of the included studies.↩↖

Title	Authors/Year/ Country/Publication	Objectives	Methodology and level of evidence	Results	Main conclusions/ implications for practice
Pulseless Electrical Activity: Detection of Underlying Causes in a Prehospital Setting.	Bempt S, Wauterss L, Dewolf P. 2020. Belgium. Medical Principles and Pratice.	The aim of this study was to review the diagnostic tools available in the pre-hospital setting and their interpretation during cardiac arrest with pulseless electrical activity as the initial rhythm.	Systematic review of the literature with search of articles in PubMed. Articles were assessed for eligibility by title, abstract, and full text. Evidence level: 3a.	Ultrasonography has become a major advantage in detecting underlying causes and a variety of protocols have been proposed. There are currently no studies comparing these protocols on its viability and its effect on patient survival. Limited evidence suggests that capnography can be used in the diagnosis of asphyxia related to cardiac arrest.	More comparative studies are needed in order to identify the best ultrasound protocol that can be included in prehospital resuscitation guidelines.
Optimizing airway management and ventilation during prehospital advanced life support in out-of- -hospital cardiac arrest: A narrative review.	Schupper H, Boomars R, Kooij F, Koster R, Hollmann M. 2021. The Netherlands. Best Practice & Research Clinical Anaesthesiology.	Presentation of how to optimize airway management during pre-hospital advanced life support in a cardiac arrest situation.	Narrative Literature Review Evidence level: 5.	Waveform capnography plays an important role in several aspects of prehospital resuscitation. Capnography represents the gold standard for confirming correct tube position and can be used to monitor the quality of chest compressions, ROSC detection, ventilation rate monitoring and prognosis. Furthermore, as some causes of cardiac arrest lead to lower or higher than expected CO_2, it can be used for differential diagnosis.	Capnography produces more relevant information than just the position of the tube, and should always be used in a resuscitation situation.