



ORIGINAL ARTICLE

Waveform capnography in a South African prehospital service: Knowledge assessment of paramedics

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ABSTRACT

Background: Waveform capnography has proven to be of great value in the provision of safe patient care especially in the intubated patient. Although seldom available, or used in African contexts, capnography has become standard practice in well-resourced out-of-hospital services for confirmation of intubation, and optimization of resuscitation and ventilation. To date there has been little research into the knowledge of out-of-hospital staff, both local and internationally, utilising capnography. This study describes the knowledge of paramedics who use waveform capnography in the out-of-hospital environment.

Methods: A cohort of advanced life support qualified paramedics in a private ambulance service in South Africa undertook a web-based survey around their background, training and use of capnography. Participants' knowledge was assessed by exploring their interpretation of waveform capnography and establishing attitudes pertaining to training and constraints of availability of capnography.

Results: Seventy eight paramedics responded, and most (91%) indicated they were likely to use capnography when the tool was available. The majority of training in capnography had been during their primary qualification (85%). Most participants indicated that they would like further training (91%). Use of capnography for confirmation of endotracheal tube placement and quality of compressions during cardiopulmonary resuscitation was well understood (correct in 94% and 84% respectively), while more complicated knowledge such as waveform changes during ventilation (66%) and the effect of hypovolaemia (48%) on capnography were lacking.

Conclusion: Paramedics report using waveform capnography extensively when it is available in the South African out-of-hospital environment. Although the knowledge around capnography and its usage was found to be good in most areas, more complicated scenarios exposed flaws in the knowledge of many paramedics and suggest the need for improved and ongoing training, as well as incorporation into curricula as the field develops across the continent.

African relevance

- Describes the current knowledge of paramedics as it relates to waveform capnography.
- Describes the willingness of paramedics to use waveform capnography in the South African Setting.
- Points out key areas to improve knowledge of paramedics in South Africa as it relates to Waveform Capnography.

Introduction

Capnography, also known as end-tidal carbon dioxide (ETCO₂) monitoring, was developed in the late 1950s, and has become an

essential tool for the provision of emergency care [1–3]. Since 2010, and with added impetus in 2015, the guidelines of the International Liaison Committee on Resuscitation (ILCOR) [4] advocate the use of waveform capnography for confirmation and continuous monitoring of endotracheal tube (ETT) placement. Capnography has also proven to be of value in monitoring physiological processes including the effectiveness of cardiac compressions, return (or loss) of spontaneous circulation, ventilation, and haemodynamic status [5]. These indications have subsequently all been endorsed by the recently developed Clinical Practice Guidelines for South African (SA) prehospital providers, which are currently being implemented and leave no doubt as to the role of capnography in patient care, particularly in the critical care transfer [6–8].

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Despite the widespread international acceptance, and use of capnography, there is little published research on its use in Africa outside of SA, even in national referral hospital anaesthetic practice, capnography is apparently rarely available or used in East and West Africa [9–11]. Prehospital services are in their infancy in much of Africa, and looking to other develop their systems currently [12–14]. Rational use of this important, although still expensive resource, and including it in training programs is important yet understudied.

In SA, emergency medical services (EMS) are provided by public EMS services, operated by provincial government and mandated to provide care to the general public, and the private EMS industry serving predominantly the insured and middle- and high-income population. SA EMS has three broad levels of practice, namely basic, intermediate, and advanced. Advanced life support (ALS) paramedics are able to intubate and ventilate patients, and the usage of capnography is within their scope and training. ALS paramedics qualify either via university diploma/degree (N.Dip, B.Tech and B.EMC) or a series of short courses (CCA) and their scope of practice is regulated by the Health Professions Council of South Africa. For the purposes of this research, ALS paramedics will be referred to as paramedics.

Research into prehospital standard of care and systems is lacking. Previous studies in SA have examined the use, knowledge and availability of capnography in emergency centres [15,16]. The current study was undertaken to establish the knowledge and utilization of waveform capnography of a cohort of paramedics in their clinical practice, to allow a better understanding of the current practice, limitations, and training implications.

Methods

Paramedics in SA with access to capnography from a single (private) ambulance service were invited to complete a web-based survey that was generated from a structured literature review, piloted and then distributed to a cohort of paramedics, known to all have access to capnography. The service, one of the largest in the country, operates in 8 of the 9 provinces of SA, and manages 280 ambulances and rapid response vehicles, responding to in excess of 260 000 emergency calls a year, with 1177 patients who were either intubated or ventilated, managed in 2015. (*Personal communication B.Johnson CEO ER24 2016*) It has an institutional policy requiring paramedics to use capnography on all intubated patients.

The survey was designed to gather the demographics of participants, as well as to depict their background, training, and willingness to use the tool. The participant's knowledge was assessed using a series of short questions, specifically exploring their interpretation of waveform capnography by presenting a series of case examples to be identified. Open ended questions were used to establish the respondents' attitudes pertaining to training and constraints of availability of capnography.

A pilot study involving five senior paramedics established face validity. Based on employment records, there were 112 paramedics employed in the service, and with an anticipated response rate of at least 60% this would provide adequate data for analysis [17]. Inclusion criteria were permanent employment with the private ambulance service and registration with the Health Professions Council of SA as a paramedic or emergency care practitioner.

Participants were invited by email to the online survey, following consent. Participants who had not started or fully completed the survey were sent three weekly reminders. Data were collected using a web-based form (Survey Monkey®, www.surveymonkey.net) and presented as numbers, means and medians, as appropriate, using IBM SPSS® Statistics Version 22 software. Free text comments underwent thematic analysis.

Ethics approval for the research was obtained from the University of Cape Town's Faculty of Health Sciences' Human Research Ethics Committee (HREC REF: 681/2015). Permission was granted by the research committee of the participating ambulance service.

Table 1
Characteristics of participants.

Age (Years) group	Median = 34 (IQR ^a 27–38)	
	Number	Percentages
20–29	28	35%
30–39	37	47%
40–49	11	14%
50–59	2	2%
Gender		
Male	53	67%
Female	25	32%
Operational Division		
Aeromedical Operations	6	7%
ICU ^b transfer Operations	4	5%
Road Operations	68	87%

^a IQR: Inter-quartile range.

^b ICU: Intensive Care Unit.

Results

One hundred and twelve surveys were distributed and 80 responses were returned between October 2015 and November 2015, yielding a response rate of 80/112 (71%). There were 58 complete responses and 22 were partially completed. Of these 22 partially completed surveys, five participants exited the survey during the knowledge based questions, a further eight during the scenario based waveform questions, and seven in the open-ended questions. Two respondents were excluded from the analysis (one did not grant consent, the other completed demographic information only), giving a total of 78 included responses (incomplete surveys were included for those questions answered).

The majority of respondents were male 54/78 (69%), with a median age of 34 years and an interquartile range (IQR) of 27–38 years. Responses were received from all provinces where the service operates. Characteristics of the respondents are summarised in [Table 1](#).

Participant training and reported usages of capnography

Sixty seven (85%) paramedics indicated they were taught how to utilise capnography during their primary qualification, while 32/78 (41%) indicated that they received training subsequently during a 2-day professional course. Participants had undergone training a median of three years (IQR 2–6 years) prior to the survey.

Nearly all participants (53/58 (91%)) indicated that they would like further training in the use of ETCO₂, with 18 of the 58 respondents indicating that they considered themselves out of date or that their initial training was not sufficient with respect to capnography. When asked how training should be delivered the following key words were identified in the analysis: continuous medical education [14], online training [9], lectures [12], workshops [7], and practical training [6].

Of the 78 respondents, 61 reported that they do use capnography when the tool is available. ([Table 2](#)). Capnography was identified as a necessity in the day-to-day practice by 74/78 (94%) of these respondents.

Fig. 1 – Shows the percentage of participants who correctly answered the waveform capnography interpretations. They were further asked about the usefulness of capnography for various indications as shown in [Table 3](#).

Interpretations of capnography tracings and improving ventilation varied: some 46/68 (67%) of respondents correctly identified that in order to increase the ETCO₂ reading, the minute volume had to be decreased. When asked whether the ETCO₂ has an effect on oxygen saturation 26/73 (35%) answered yes and 17/73 (23%) of the participants reported that an increase in fractional inspired oxygen would decrease the ETCO₂.

Table 2
Qualification, training and usage of capnography.

Use of capnography	Total n (%) n = 78
Every patient > 90%	61 (78.2%)
Mostly 60–90%	12 (15.4%)
Usually 50%	3 (3.9%)
Never 10%	2 (2.6%)
Training in capnography received ^a	
Primary qualification	84.10%
2 day professional course	40.50%
In-service training	24.10%

^a Surveyed individuals may have received training from multiple sources.

In a polytrauma scenario 32/66 (48%) of respondents correctly identified the need for fluid replacement when hypocapnia was not improving with ventilation adjustments, while 14/66 (21%) interpreted the graph as indicating a needing to check the ETT for correct placement.

Resource constraints and availability

Respondents were asked why they might not use capnography, to which the majority 51/66 (77%) said that they always use ETCO₂. However 25/66 (37%) indicated that there is a concern regarding the availability of the consumables. Paramedics noted that if the transport time to hospital is short then the respondents would not use CO₂ monitoring. Most respondents indicated that there are no concerns with accessibility to the technology, with one respondent commenting, “*waveform capnography is always available at the base I work*”.

Clinical use

Almost all of the respondents 59/60 (98%) reported that ETCO₂ does make a difference in their clinical practice when used. Most of the comments made, specifically related to the control of ventilation when using ETCO₂ indicated that the use of ETCO₂ should be mandatory practice within the ambulance service. Respondents commented that capnography can improve their clinical practice, “*I believe it should be mandatory as it can instantaneously pick up any adverse issues with the ventilation in real time which helps in the back of a moving ambulance.*”

Discussion

The use of waveform capnography has been established to be of

benefit both for patient safety and the augmentation of treatment modalities [18]. While EMS can procure and deploy new technology, the implementation of this technology is often reliant on several factors, including limited insight into the benefits of a technology, and the required expertise and know-how in applying the technology [19]. In 2011, having conducted a local multi-sectorial study, Botha [16] found that only 19% of SA paramedics used ETCO₂ for the verification of tube placement in the out-of-hospital setting. In stark contrast, we demonstrated a large proportion (90%) of paramedics that utilise capnography in the out-of-hospital environment in 2015. It is likely that this is mainly due to increased availability over the subsequent 4 years, and an institutional policy to implement its use [16].

Continuous waveform capnography is the most reliable way to establish ETT placement [20]. We found that paramedics correctly identified the indication for ETT verification, but only three quarters could identify apnoea. During intubation training it is often emphasized that capnography can be used for the verification of ETT placement, yet practitioners would seem to be less familiar with its use for continuous monitoring.

ETCO₂ has been established to be of value in monitoring the quality of compressions during cardiopulmonary resuscitation and is recommended as standard practice [4]. A consensus statement released in Circulation in 2013 [21] indicates that an ETCO₂ of less than 10 mmHg during CPR, when adequate CPR is being performed, is a strong predictor for unsuccessful resuscitation. A subsequent systematic review concluded that although ETCO₂ values do correlate with ROSC, the cut-off of the predictive values is not fully established [22]. In this study only two thirds indicated that ETCO₂ could be used as a predictor for ROSC. Although current resuscitation training highlights the quality of CPR (“Push Hard, Push Fast” [4]), the predictive value of ETCO₂ may not be emphasized in training, and would seem to be poorly understood by the paramedic.

Capnography is an immediate feedback tool with regards to ventilation and can be used to adjust ventilation when other modalities like arterial blood gas analysis are not available [23]. Only two thirds of the participants were able to identify hyperventilation and how to correct it. Literature regarding the ability of paramedics to adjust ventilation based on ETCO₂ is limited. Davis et al. [24] found that hyperventilation occurred often following paramedic rapid sequence intubation, despite the use of ETCO₂. A recent unpublished university thesis [25] which surveyed 20 SA paramedics, reported that as many as 80% of paramedics could identify hyperventilation. Small numbers and the limited geographical setting may affect the external validity of this study [25]. The findings of our study are thus in keeping with prior studies, although a significant number of participants did indicate that FiO₂ and oxygen saturation had influence on ETCO₂, suggesting room for improvement in the knowledge and use of ETCO₂ during ventilation.

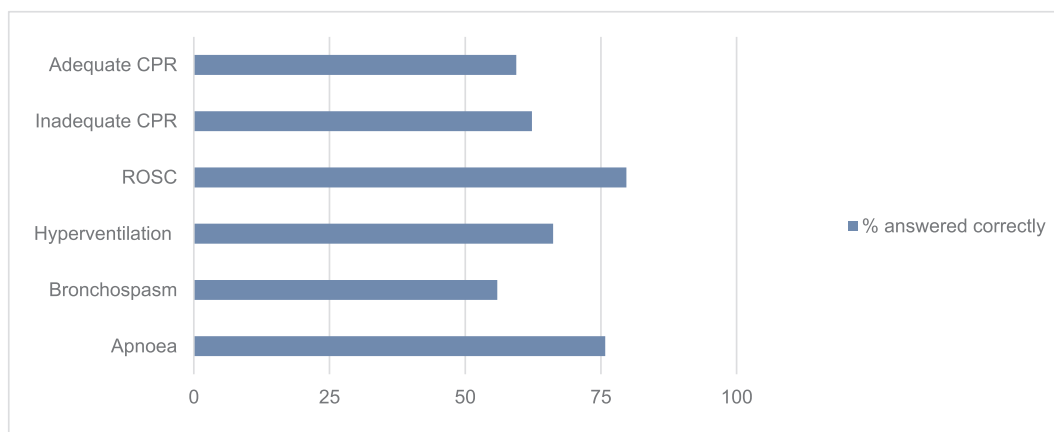


Fig. 1. Participants who correctly answered the waveform capnography scenario.

Table 3
Participant responses as to the potential uses of capnography.

Potential uses of capnography in out-of-hospital practice	Useful	Useful in some circumstances	Not useful/Unsure
Placement of ETT (n = 74)	70 (95%)	4 (5%)	–
Monitoring compression quality during CPR (n = 74)	61 (82%)	7 (10%)	6 (8%)
Return of spontaneous circulation during CPR (n = 73)	51 (69%)	9 (12%)	13 (18%)
Optimizing ventilator settings (n = 74)	73 (98%)	–	1 (2%)

A large number of participants indicated that they would like further training in the use of waveform capnography. It is difficult to establish the exact content of training received by paramedics during their primary qualification as the curricula vary between institutions. Knox et al. [26] established that Irish paramedics prefer practical type learning. This was in keeping with the findings of this study where most participants indicated that they would like training in workshops or practical simulations. Less than half of the participants indicated that they have received ongoing training related to the use of waveform capnography during widely accepted advanced life support short courses or continuous medical education. The impact of such training programs is unclear, and regular updates and refreshers are recommended to maintain competency [27].

An improvement project conducted by a private service helicopter emergency medical service showed that online learning platforms can be implemented in SA, and this could be a cost effective way of achieving further training in capnography [28]. While cost effectiveness should always be taken into consideration in the low-to-middle income countries, training in waveform capnography needs to take all aspects of improvement and change methodology into consideration, understanding what is needed, what the local limitations are and monitoring outcomes to narrow the identified knowledge gaps. We believe that there is undoubtedly a role for capnography even in low resource settings, and as out-of-hospital systems development grows in Africa, and training curricula develop, cognizance needs to be made of including this in training programs.

The study was conducted in a single private emergency medical service, raising the concern of applicability or external validity of these results to all paramedics in SA. Capnography is theoretically available in all vehicles in this service, whilst other services and the public sector have variable but often minimal access to capnography. We believe this cohort provides a useful assessment of early implementation which can guide this service in optimizing use, as well as guiding further nationwide roll-out and use of capnography.

The principal investigator is a senior employee of the private ambulance service. Although the respondents are not directly subordinate, this may have influenced how the questionnaire was answered, and possibly the willingness to take part in the questionnaire. The company subscribes to a non-punitive approach whenever staff report adverse events, and for this reason and anonymity we feel that participants would have felt free to answer the survey honestly.

Conclusion

Capnography is a valued tool in the SA prehospital setting where the tool is available. We have established that in a setting where the tool is readily available, most practitioners report that they will choose to make use of the ETCO₂ monitoring. The capabilities of ETCO₂ seem to be well understood, however the ability to interpret different waveform capnographs is variable. Further education in the interpretation of waveform capnography is needed and may prove of value for the paramedic in understanding and utilising waveform capnography to its optimal potential in the SA setting.

Dissemination of results

Results from this study were shared with the participating ambulance service.

Author contribution

Authors contributed as follows to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: CW contributed 50%, TW 15% and PH 35%. All authors approved the version to be published and agreed to be accountable for all aspects of the work.

Conflict of interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.afjem.2019.01.010>.

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