2016 Update of the Intensive Care Society standards for Capnography in Critical Care.

Introduction

The standards for capnography were last reviewed in 2011 after the publication of the UK national audit report four (airway misadventure) (NAP4)[1]. In this review for 2016 we have updated the 2011 standards to take account of new developments and evidence around the use of capnography in critical care.

The aims of this review were to determine:

1. Does there need to be any change to the existing standards based on additional evidence?

We reviewed the published evidence, repeating the search criteria as described in the original review and described in appendix one but we limited the initial search to papers published after 2010 .

In this current literature review, we identified one controlled trial where capnography, associated with a bundle of other interventions, was shown to improve the safety of endotracheal intubation in critical care [2].

We have assumed that the use of capnography during endotracheal intubation and mechanical ventilation has increased in the UK since the publication of the NAP4 audit in 2011. We found an audit as evidence for this change [3] and it is considered that capnography is used in over 90% of NHS critical care units [4], however we were unable to find a national review of the use of capnography in UK critical care units since 2014. In the original standards for capnography, we suggested that there are potential risks associated with capnography in terms of miss-interpretation of the end tidal CO_2 value, technical problems causing a flat trace that would be interpreted as a misplaced endotracheal tube, and problems with capnography being an additional device that would increase the chances of endotracheal extubation.

We found one review of the use of capnography during pre-hospital transfer where the users had assumed that the end tidal CO_2 value would be similar to the arterial value. This had resulted in some patients with traumatic brain injuries being rendered hyper-carbic [5]. We also found one case report of an unplanned endotracheal extubation resulting in bilateral pneumothoraces that the authors felt had been caused by traction on a capnography cable [6].

We reviewed all the patient safety incidents reported to the UK National Reporting and Learning Service between 2004 and 2014 where the incident had been described as 'responsible for the patient's death or major' [7]. In this review, we identified one report that had multiple similarities to the case report of unplanned extubation [6] but we did not find any other reports suggesting significant harm as a result of capnography. In addition to this national review we also studied 23,817 patient safety incidents submitted from 36 critical care units in the North West of England where these incidents represented all the submitted patient safety incidents, in these 36 units we were unable to find any incidents were the use of capnography had harmed a patient. In this more complete, but more geographically isolated, review of patient safety incidents we found the number of patient safety incidents where patients were harmed as a result of airway misadventure decreased from 10 in 2011 to 5 in 2014 [7]. Audit data suggested that capnography was in use in over 90% of ventilated patients in one of the 3 clinical

networks that had reported these patient safety incidents [2]; we had no information concerning the other networks.

Based on this evidence review we conclude that there is no need to change the standards around the use of capnography during endotracheal intubation or during mechanical ventilation.

2. Are there any additional indications for the use of capnography not described in the 2011 review?

1. Use of capnography during the management of cardiac arrest.

The Resuscitation Council (UK) has reviewed the evidence around the use of capnography during the management of patients in cardiac arrest [8]. They have recommended its use both as a guide to initial and continued endotracheal tube placement and a marker of the return of cardiac output [8]. They also noted the use of capnography as a guide to prognosis, although they felt that absolute values could not be used to make decisions about individual patients. This guidance is similar to that of other international societies. *Waveform capnography should be used during resuscitation of patients in cardiac arrest where the trachea is intubated.*

2. Use in patients breathing via continuous positive airway (CPAP) circuits and artificial airways.

We did not find this issue addressed in the literature review, however, the reasons why capnography would be useful as a disconnection or tube misplacement or occlusion alarm in patients during mechanical ventilation would also apply to patients breathing through CPAP circuits and artificial airways. Patients breathing via CPAP circuits could be regarded as safer as they can breathe spontaneously, however these patients are not connected to ventilator alarms that provide an additional safety feature in patients connected to mechanical ventilators. *For these reasons, we now recommend that patients on CPAP circuits breathing via artificial airway devices are monitored with end tidal capnography as a disconnection and occlusion alarm.*

3. For use as a respiratory monitor of patients breathing spontaneously without an artificial airway.

The use of capnography for patients breathing spontaneously has been reviewed in several situations:

i. To monitor the adequacy of respiration during sedation for procedures, for example in the emergency department [9] or during sedation for radiological, endoscopy or cardiac procedures [10,11]. The Academy of Medical Colleges has recommended the use of capnography during moderate or deep sedation [12]

ii. To monitor respiratory rate, rhythm and depth of respiration as a guide to developing critical illness or deterioration in post anaesthetic recovery [13].

The use of capnography during moderate or deep sedation has been shown to reduce the number of hypoxic episodes [10,11], hence the recommendation for its use by the Academy of Royal Colleges [12].

These indications for Capnography fall outside what we would consider to be normal critical care practice. We have therefore not made any recommendations around the use of capnography for these indications.

4. As a monitor of respiratory dead space or similar respiratory variables.

There have been further publications describing the use of the arterial end tidal carbon dioxide difference to calculate variables that estimate physiological dead space [14,15]. High physiological dead space estimated in this way has been shown to predict outcome in adult respiratory distress syndrome [16] and has been used as predictor for pulmonary embolus, [17] and as a guide to fluid resuscitation [18] and for the titration of positive end expiratory pressure (PEEP) [19]. Where used in the identification of pulmonary embolus the relatively flat phase three of the wave form differentiates this from other causes of significant arterial end tidal CO_2 gradients [20].

These techniques show potential promise but have been described mostly in clinical research settings and for this reason we have not yet able to make recommendations for their wider use.

3. Can we recommend any processes that have been used to increase the effective adoption of capnography in critical care?

1.The national audit project of major complications of airway management recommendations around the use of capnography [1] would seem to have had a dramatic effect on the use of capnography in critical care, although there has not been a formal evaluation process of the implementation of these recommendations.

2.We identified studies recommending the use of check lists for use prior to endotracheal intubation [21], and we would recommend that these are used in line with the National Safety Standards for Invasive Procedures recommendations [22] and NAP4 [1]. These check lists should include a check on the provision of working capnography.

3.We have also identified studies describing the use of structured notes and registry forms to record capnography. In one of these studies there was a positive association with structured recording and patient outcome [23], Another study described the entering of structured notes into a registry and associated improvements in airway management [24]. The improvement process in this study used the airway registry as a guide to the success of other quality improvement measures.

We would recommend the use of check lists that include the use of capnography prior to endotracheal intubation and the use of structured recording of intubations in critical care that includes the recording of the use of capnography. These recordings should allow the development of airway registries.

4.Specific educational interventions to increase the use and safety of capnography are outside the scope of this review however we note the following points:

i. The core standards for intensive care units [25] require that all newly appointed nursing staff have a supernumerary induction period where they develop basic competencies in critical care. The standards also require at least half of the staff working in a critical care unit to have had an additional qualification in critical care.

ii. There has correctly been considerable emphasis on the teaching of basic airway drills for tube misplacements and occlusion [26] and these drills should include the use of capnography.

iii. We note some useful on-line training in the use of capnography [27,] and descriptions of basic capnography wave forms [28] which are both useful learning resources.

vi. The ease with which capnography can be used will depend on the ergonomic design of the equipment and the quality of display of the capnography wave form. There has been some work reviewing these issues for one manufacturer's ventilator [29].

As the use of capnography is an essential part of critical care practice we recommend training in capnography use as part of supernumerary induction and critical care skills courses. This training should include: the use of capnography equipment including transport and monitor capnographs, risks of disconnections around the equipment and misconnections resulting in absent wave forms, basic interpretation of common capnography wave forms and the reasons why end tidal capnography may underestimate arterial CO_2.

When purchasing capnography equipment, the robustness and ease of use should be part of the selection criteria.

5. Airway misadventure that causes significant patient harm is an event that is unusual enough to make it difficult to study in randomised clinical trials. The success of programs to reduce airway misadventure can therefore only be judged by reviewing episodes of misadventure to see if there are opportunities to improve patient care revealed by individual episodes. Trends in care can then be estimated by the classification and recording of episodes. This process should happen across critical care networks as the rates in individual trusts would not be large enough to identify significant trends. A process for this review has previously been described [30].

Critical care networks should collect and analyse all episodes of airway misadventure recorded as patient safety incidents in their units and should review trends in these incidents.

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