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Development and psychometric evaluation of an instrument for the assessment of nurses' knowledge on capnography

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Capnography;
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Summary
Background: Despite the expansion of capnography use, instruments for evaluating healthcare professionals' knowledge about capnography are missing from international literature.
Objectives: To develop and validate an instrument for evaluating nurses' knowledge about capnography, named the ''Nurses' Knowledge about Capnography Test'' (NKCT).
Method: A literature review was performed to formulate instrument items. Thirty-six items were initially developed, which covered principles of capnography function, conditions affecting end-tidal CO_2 pressure and capnography waveform, and indications for capnography use. Six items were deleted after content validity and intra-rater reliability evaluation. The final 30-item instrument was completed by 103 anesthesiology department nurses employed in six hospitals of Greece, to test its internal consistency, item difficulty and discrimination, and construct validity.
Results: Kuder—Richardson 20 coefficient was 0.79. Ten items were found to be of high difficulty, while item discrimination was low for two of them. Instrument scores were found significantly higher among participants with higher educational level and longer experience in capnography use.
Conclusion: NKCT is a psychometrically comprehensive instrument for evaluating nurses' knowledge about capnography, which is recommended to be re-validated beyond the anesthesiology department and be used for the assessment of educational programs on capnography.

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1. Introduction and background

1.1. Capnography: definition and conditions affecting its measurements

Capnography refers to ventilatory function monitoring based on the continuous measurement of exhaled CO_2 partial pressure (Zwerneman, 2006). Quantification of this pressure is displayed as a waveform on the monitoring screen along with a numeric value, which corresponds to the maximum CO_2 pressure at the end of expiration, or end-tidal CO_2 pressure ($etCO_2$) (Krauss & Hess, 2007; Zwerneman, 2006).

Exhaled CO_2 pressure can be affected by a number of respiratory, circulatory, metabolic or technical conditions, thus information provided by its measurement needs to be correctly interpreted by clinicians (Kodali, 2013). Lower than normal (35—45 mmHg) values of $etCO_2$ may indicate hyperventilation, hypothermia, hypovolemia or decreased cardiac output, while values above normal are common during hypoventilation, hyperthermia, onset of sepsis, shivering, partial airway obstruction or ventilator leak (Fox, Flegal, & Kuhlman, 2009; Godden, 2011). Evaluating the arterial to end-tidal CO_2 pressure gradient is also important, considering that values above normal (1—5 mmHg) are expected in patients with chronic obstructive pulmonary disease or raise suspicion of pulmonary embolism (Park, Bendjelid, & Bonvini, 2013).

A capnography waveform normally consists of four phases: inspiratory baseline, expiratory upstroke, expiratory plateau and inspiratory downstroke (Benumof, 1998). The quality of this waveform should be determined before accepting $etCO_2$ values, while its shape should be analyzed to identify abnormalities (St. John, 2003; Welliver, 2013).

1.2. Clinical indications of capnography

The need for promoting safety of surgical patients against the risk of life-threatening adverse events, such as respiratory depression, airway obstruction and pulmonary embolism, has led to the inclusion of capnography among standard monitoring within the Operating Room (OR) (Odom-Forren, 2011). Capnography use is also warranted in the Postanesthesia Care Unit (PACU) for patients with obesity, obstructive sleep apnea, chronic pulmonary diseases, difficult airway management and major thoracic/abdominal operations (Clifford, 2012; Godden, 2011). Considering the respiratory-depressive effect of sedative or opioid drugs, capnography can be further recommended during patient-controlled analgesia or the performance of minimally invasive procedures in endoscopy, radiology or cardiology suites under sedation (Clifford, 2012; Kodali, 2013; Sandlin, 2002). A recent meta-analysis of studies on adverse respiratory events during procedural sedation revealed that respiratory depression was 17 times more likely to be detected when capnography was used (Waugh, Epps, & Khodneva, 2011). It is also worth noticing that, compared with pulse oximetry, capnography allowed significantly more effective and earlier detection of respiratory depression in studies conducted on both postoperative orthopedic patients and those undergoing upper endoscopy (Hutchison & Rodriguez, 2008; Vargo et al., 2002).

Historically, capnography has been used in the Intensive Care Unit (ICU) and the Emergency Department (ED), primarily for the assessment of endotracheal, gastric and small bowel tube placement, along with prompt identification of endotracheal tube dislodgement or circuit disconnection (Ahrens, 2004; Ahrens & Sona, 2003; Kindopp, Drover, & Heyland, 2001). Capnography use has also been suggested during inter-hospital or intra-hospital patient transfers for timely detection of adverse events (Kodali, 2013; Odom-Forren, 2011). Finally, there is evidence to support capnography use during cardiopulmonary resuscitation, for evaluating the efficacy of chest compressions, identifying the return of spontaneous circulation and predicting patient outcomes (Grmec & Klemen, 2001; Scarth & Cook, 2012; Whitaker, 2011).

1.3. Importance of personnel's knowledge about capnography

Despite the undoubted benefits of capnography, monitoring technologies are only as good as the user who interprets the information provided (McConnell, 1998). In this context, appropriate capnography application depends on the knowledge and clinical skills of healthcare professionals. Nurses should be capable of understanding how capnography functions and what it measures, as well as of correctly interpreting its readings and waveforms. It seems thus plausible that limited personnel's knowledge about capnography can be detrimental for patient care, since this is expected to hinder personnel from identifying pathologic conditions or adverse events that affect patient ventilation or circulation, or even result in false safety sense, which could prevent timely interventions and negatively affect patient outcomes. Studies have reported unfamiliarity with or incorrect use of monitoring equipment to be among the leading causes of equipment-related patient safety incidents in ICU settings (Thomas & Galvin, 2008; Welters, Gibson, Mogk, & Wenstone, 2011). In this context, patient harm could have been prevented by identifying personnel's knowledge deficits about monitoring equipment use and by providing adequate education and training.

The concept of knowledge is commonly operationalized through the measurement by appropriately developed instruments, which allow the evaluation of individual knowledge levels, along with the identification of specific knowledge gaps and needs for education (Ismail et al., 2013). Considering that capnography has long been used in clinical settings and its use has been expanding (Kodali, 2013), there is a remarkable lack of studies and instruments for evaluating healthcare professionals' knowledge about capnography from the literature. Thus, the objectives of this study were to develop and evaluate the psychometric properties of an instrument for the assessment of nurses' knowledge about capnography, which was named ''Nurses' Knowledge about Capnography Test'' (NKCT).