The Impact of Capnography Based Education on Knowledge Modification Amongst Dental Staff: A Process Improvement Project

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Abstract

Mild to moderate sedation during dental procedures provide many benefits to the patient and the dentist. However, the depth of sedation occurs along a continuum, and it is impossible to predict how an individual receiving treatment will respond. Many routine monitoring advances have become universally adopted by the dental field including the use of capnography for procedural sedation. The literature and supporting data currently recognize the use of capnography as a valid and reliable monitoring tool for the early detection of oxygen desaturation to prevent adverse outcomes when patients are receiving moderate to deep levels of sedation. Dental providers as well as the assisting staff must be able to diagnose and manage the physiologic consequences that can occur in patients whose level of sedation becomes deeper than intended. This scholarly project aims to examine whether a 30-minute educational session on capnography influences the knowledge retention of the clinical staff employed at a local dental office and to highlight the areas of process improvement. The participants will partake in a quantitative pretest questionnaire designed to establish a baseline level of knowledge regarding the topic, followed by a posttest questionnaire immediately after the presentation, and again after a period of 30 days to assess knowledge retention. Dental practices are utilizing methods to increase patient convenience and satisfaction, and it is the duty of the facility as a whole to ensure that staff have a basic understanding of monitoring equipment, such as capnography, in order to ensure patient safety.

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Airway management during sedation dentistry is essential to maintaining patient safety. A number of different individuals with multiple comorbidities from all age groups require anesthesia and sedation in outpatient dental settings for reasons such as fear, anxiety, and pain management (Brady et al., 2016; Tomeva & Deliverska, 2020). Patient safety in this aspect is dependent upon provider vigilance and monitoring equipment that is capable of early detection of potential airway problems that can significantly affect the patients' respiratory status (Brady et al., 2016; Tomeva & Deliverska, 2020). Dentists and oral surgeons are faced with a huge responsibility when it comes to multitasking both patient care and airway management, especially when procedural sedation is involved (Brady et al., 2016; Matin et al., 2015). Current evidence supports the use of capnography in monitoring patients receiving any form of dental sedation for the early detection of adverse respiratory events (Askar et al., 2020; Dodson et al., 2015; Farish & Garcia, 2013).

Significance and Background of the Clinical Problem

The use of procedural sedation and analgesia (PSA) is steadily increasing, and clinicians with minimal or no training in the administration of moderate to deep levels of sedation are performing and monitoring these activities (Saunders et al., 2017; Waugh et al., 2011). Ambulatory procedures requiring sedation are growing in numbers and performed more than ever at remote locations outside of the operating room. Often, the value of capnography as an effective and reliable monitoring tool does not spread beyond the confines of the anesthesia provider; however, the duty of being an advocate for patients falls upon any assisting staff

member within a healthcare facility. Basic training and knowledge on non-invasive equipment such as capnography can help maintain patient safety.

Advances in airway monitoring have greatly improved the safety and efficacy of anesthesia; however, hypoxia continues to be the leading cause of morbidity and mortality in dental sedation (Anderson et al., 1987; Mortazavi et al., 2017; Parker et al., 2018). Although rare, death following procedural sedation is the most detrimental side effect of dental anesthesia (Mortazavi et al.,2017; Reuter et al., 2016). In 2017, a 2-year-old child died in an Arizona dental clinic while recovering from an extensive procedure involving the placement of multiple root canals and crowns after receiving dental sedation (Hein, 2019). In 2018, a 17-year-old boy in Kissimmee, Florida, died after being placed under dental sedation for a routine procedure involving tooth extractions when he stopped breathing unbeknownst to the dental provider (Rankin, 2018). These examples highlight the need for the proper education and training in the use of capnography during procedural sedation.

The consistency of data seen across multiple high-quality literature reviews, most of which report a reduction in adverse respiratory events with the addition of capnography monitoring, is of clinical importance. In 1991, the dental profession published its own guidelines regarding monitoring during the administration of moderate and deep sedation, and included protocols for the continuous assessment of airway management which includes the use of capnography (American Dental Association, 2016; Becker & Casabianca, 2008).

PICOT Evidence Review Questions

The systematic review of literature was aided by two questions posed in PICOT format. The first addresses the clinical problem: Amongst the staff in a dental setting (P), what is the

effect of facility-based education on the use of capnography as a standard monitor (I) for the early recognition of oxygen desaturation (O) over a 30-day period (T)? The second question addresses the clinical innovation: Amongst the clinical staff at Simmonds Dental Center located in Orlando, Florida (P), does the implementation of an educational session on the use of end-tidal capnography in patients undergoing dental sedation (I) influence the knowledge level and retention on the early recognition of oxygen desaturation (O) after a period of 30 days (T)?

Search Strategy Results

The electronic literature searches incorporated a combination of databases, governmental agencies, and professional practice organizations including the following: PubMed, Google Scholar, Cumulative Index to Nursing and Allied Health Literature (CINAHL), American Association of Nurse Anesthetists, American Society of Anesthesiologists, and the American Dental Association. Key search terms consisted of a combination of MeSH terms and free-text searches within the articles' abstracts and included: *capnography* AND *education,* AND *dental surgery* OR *oral surgery* OR *dental procedures* AND *standard monitoring* AND *hypoxia*, AND *hypoxemia* AND *$ETCO_2$,* AND *sedation dentistry*. MeSH terms included: *dentistry, training, sedation, capnography, hypoxemia, and hypoxic events.* A total of 153 articles were identified and after all duplicates were removed, the titles and abstracts of the remaining articles were scanned for relevance. A total of 86 studies were excluded for not involving capnography as a monitoring tool, and 38 single case studies were eliminated due to the lack of a comparison group. A total of 29 studies met the inclusion criteria. The search was limited to the English language and human subjects.

GRADE Criteria

The quality of evidence was evaluated using the Gradings of Recommendations Assessment, Development, and Evaluation (GRADE) criteria. The initial rating was determined to be a high -4 since the literature was heavily obtained from randomized control trials, meta-analysis, and systematic reviews. The quality of evidence was downgraded to a low -2 due to limitations such as imprecision in the sample sizes, wide confidence intervals, heterogeneity within the samples, recruitment bias, and a lack of blinding within some of the studies. A single study showed publication bias by receiving research funding from the university where the trial took place; however, this did not warrant any further decrease in the GRADE. The quality of evidence was graded up due to the positive effect of capnography on patient safety. The final GRADE was determined to be a moderate -3. Based on the quality of evidence, a recommendation can be made on the implementation of capnography to monitor patients undergoing dental sedation for the early detection of adverse respiratory events.

Literature Review and Synthesis of Evidence

Adverse events associated with procedural sedation and analgesia in the dental setting primarily result from respiratory depression and airway obstruction (Brady et al., 2016; Parker et al., 2018). Patient monitoring during dental procedures involving sedation has been mostly limited to continuous pulse oximetry readings and standard clinical observation of respiratory rate and electrocardiographic monitoring by dental providers (Anderson et al., 1987; Askar et al., 2020; Brady et al., 2016; Burton et al., 2006). The incidence of arterial oxygen desaturations after receiving procedural sedation is reduced by more than 30%-33% with the use of capnography (Burton et al., 2006; Saunders et al., 2017). Currently, there is a paucity of research regarding the knowledge of ambulatory and office-based clinical staff on the use of capnography,

which warrants the need for this scholarly project. For the purposes of this scholarly project, clinical staff refers to individuals who have been certified as dental hygienists and dental assistants. The following three topics are discussed in the literature review: basic knowledge on the topic of capnography, confidence on the use of capnography, and the relevance of capnography to dental practice.

Basic Knowledge on Capnography

As modern equipment gains value and becomes more accessible to out-of-hospital facilities, the clinical staff may be expected to adopt new methods of airway monitoring. Surveys administered to a group of paramedics in South Africa demonstrated that approximately 94% of the participants who responded displayed sufficient knowledge of basic waveform capnography; however, more complicated waveforms revealed gaps in the knowledge which indicated a need for further training (Wylie et al., 2019). A study conducted on a group of registered nurses on a subacute care unit demonstrated that those with previous experience in capnography were more comfortable with the use of capnography monitoring compared to those without previous experience (Clark et al., 2018).

Confidence on the Use of Capnography

Patients recovering postoperatively are just as vulnerable to the risks associated with procedural sedation such as respiratory depression and apnea. A study conducted by Zito et al. (2019), involving a group of post anesthesia care unit nurses previously trained and educated on capnography monitoring, demonstrated an increased level of confidence in the patients' readiness for discharge. Proper education and training are necessary to strengthen the reliability of capnography when monitoring is done by non-anesthetists. A survey conducted by Wylie et

al. (2019) revealed that 91% of respondents were likely to use capnography monitoring whenever available and expressed interest in further training and use of equipment.

Relevance to the Dental Practice

Both oxygenation and ventilation work together to maintain a homeostatic balance in respiration. Ventilation refers to the exchange of oxygen and carbon dioxide between the environment and the alveoli and measures the partial pressure of carbon dioxide in arterial blood ($PaCO_2$); whereas oxygenation refers to the uptake of oxygen from the lungs and its distribution to the tissues and organs throughout the body and measures the partial pressure of oxygen in arterial blood (PaO_2) (Becker & Casabianca, 2008; Farish & Garcia, 2013). An imbalance between oxygenation and ventilation can lead to a process called hypoxemia which is defined as a hemoglobin oxygen saturation (SpO2) between 85%-95% (Becker & Casabianca, 2008; Saunders et al., 2017). While the use of pulse oximetry during procedural sedation is a non-invasive way of monitoring the status of oxygenation, it does not provide a real-time, continuous measurement of ventilation. End tidal carbon dioxide ($ETCO_2$) is defined as the partial pressure of waste gas that is released at the end of each exhaled breath and represents a more accurate reflection of ventilation (Askar et al., 2020; Farish & Garcia, 2013; Waugh et al., 2011).

The use of capnography during dental surgery can provide an instantaneous representation of the quality and frequency of the patient's air flow and displays a waveform trend which can detect hypoventilation prior to any changes in oxygenation (Anderson et al., 1987; Askar et al., 2020). Respiratory adverse events in the dental setting are a patient safety issue which can be prevented if dental providers incorporated capnography with routine monitoring to patients receiving procedural sedation (Goodchild & Donaldson, 2017; Richardson et al., 2016). Respiratory depression during procedural sedation is 17 times more likely to be

detected when airway monitoring via capnography is implemented (Kodali, 2013; Waugh et al., 2011).

From the various research studies, it is imperative that capnography be utilized in the dental setting to decrease the incidence of adverse respiratory events and improve patient safety and outcomes. An educational session engaging the clinical staff of Simmonds Dental Center in Orlando, Florida, would help shed light on the safe use of capnography equipment and provide advocacy for its incorporation into their practice.

Applicability to Practice

The use of sedation in dentistry has created an avenue for even the most painful oral procedures to become tolerable. Sedation dentistry has seen several adverse respiratory events which could have been prevented with the implementation of capnography in addition to standard monitoring procedures. The growing acceptance and availability of outpatient procedures using dental sedation requires that anesthesia providers as well as non-anesthetists be knowledgeable and trained in the latest patient safety equipment and committed to ongoing education to ensure a level of competency that is appropriate for practice.

In the operating room, the addition of capnography has become a standard of practice for its ability to detect respiratory depression and significantly improve patient safety. Certified Registered Nurse Anesthetists (CRNAs) are highly skilled airway specialists who are trained to detect and prevent the onset of adverse respiratory events via the use of capnography in addition to other monitoring devices. CRNAs operate in various practice locations including dental and oral surgery settings and are valuable components to maintaining patient safety.

This scholarly project seeks to provide evidence-based recommendations on the use of capnography in dental office procedures that require patients to be sedated. Ambulatory surgery centers are rapidly expanding, and the use of appropriate monitoring systems is imperative to help decrease morbidity and mortality. The lack of education and training amongst dental providers and the cost of monitoring equipment are just a few of the limitations to implementing the use of $ETCO_2$ monitoring in many dental practices. This study hopes to provide insight on the issue of respiratory depression that frequently accompanies sedation and anesthesia. The consistency of data from many high-quality sources, reporting the early detection of adverse respiratory events when capnography monitoring is utilized during procedural sedation is of clinical importance.

The results of this scholarly project will provide a knowledge base for the clinical staff of Simmonds Dental Center regarding the importance of $ETCO_2$ monitoring as an effective way to decrease the incidence of adverse respiratory events and improve patient safety and satisfaction. Education is important for clinicians and their staff to be able to interpret the different alarms and waveforms associated with airway equipment as it pertains to patient safety.

Project Aims

The primary aim of this project is to examine whether an educational session on capnography influences the knowledge retention and application of the clinical staff located at Simmonds Dental Center of Orlando, Florida. The specific objectives are as follows:

- Assess the baseline knowledge level of the clinical staff of Simmonds Dental Center regarding capnography via the use of a pretest by Spring 2022.

- Describe the clinical indications for the use of capnography during dental sedation to the clinical staff of Simmonds Dental Center, including basic waveform identification, by Spring 2022.
- Determine whether a correlation exists between a pretest and posttest after the administration of a 30-minute educational session on capnography to the clinical staff of Simmonds Dental Center, following a period of 30 days by Spring 2022.
- Utilize data analysis to provide recommendations regarding the use of capnography and dental sedation to the clinical staff of Simmonds Dental Center by Spring 2022.

Methods

This scholarly project utilized a quantitative descriptive research design which was chosen to help provide insight on the use of capnography during dental sedation and to identify areas of process improvement. The Wilcoxon Signed Rank Test was used to analyze the data. This test compares two related or matched samples, as well as repeated measurements on a single sample, to assess whether there are differences within the ranks of each mean (Durango & Refugio, 2018). A comparison of the participant responses was utilized to examine where the differences occurred between each set of matched pairs pertaining to the pretest and first posttest, the pretest and second posttest, and the first and second posttests.

The G*Power was used to conduct a priori power analysis to calculate the sample size. The effect size was set to 1.0, the alpha error probability was set to 0.05, and the power probability was set to 0.8 which determined that a minimum sample size of 9 subjects would be needed. The inclusion criteria were clinical staff of Simmonds Dental Center, at least 18 years of age. The exclusion criteria were anyone for whom English is not the primary language, and

anyone with prior professional training on capnography use. The independent variable was the 30-minute educational session that was presented to the subjects during the first encounter. The dependent variable was the change in knowledge for the participants involved, which was analyzed from the results of the three questionnaires. Rigor was ensured via honest and ongoing communication between the co-investigators and participants. The objectives and eligibility requirements were clear and concise to ensure adequate understanding regarding the purpose of the scholarly project.

Execution of the proposed project took place at the study site and began with an initial pretest on the topic of capnography. A demographic profile was obtained on each participant to gather insight and background characteristics about the target population (Appendix C). The profile consisted of four questions presented in person via paper format and was presented to each participant after agreeing to participate in the study. The participants were then instructed to scan a quick response (QR) code that was linked to an electronic copy of the Agreement to Participate which was located on a secure Microsoft Forms online tool. A checkbox at the bottom of the page granted access into the pretest where the participants were first asked to create an identification profile consisting of their high school mascot and favorite color. This allowed the participants to remain anonymous and also enabled the co-investigators to track and link the results of the pretest and posttests.

A multiple choice questionnaire was used to assess the responses of the participants (Appendix B). The assessment consisted of a total of ten questions within the following three categories: Basic knowledge, Confidence, and Relevance to dental practice. A 30-minute face-to-face PowerPoint presentation was conducted after the pretest along with a 10-page handout (Appendix A). The first posttest on the presented topic immediately followed the presentation.

After a period of 30 days, a second posttest was administered, and the data collected. The study consisted of a purposive, deliberate sample, and participation was completely voluntary. The email address of each participant was requested from the office manager and a reminder email was sent after a period of three days for completion of the pretest and posttests.

The pretest/posttest questionnaire was developed to incorporate the specifics relating to the basics of capnography. Prior to distribution, the questionnaire was reviewed by three students in the Doctor of Nurse Anesthesia Practice (DNAP) program, a dental hygienist, two DNAP faculty members, and the Associate Vice President for Faculty Development in Teaching and Learning at AdventHealth University. These individuals were chosen to ensure the development and collection of high quality data, and are valuable in determining the appropriateness of the assessment tool and establishing validity. Feedback and recommendations were received and incorporated into the questionnaire prior to administration.

Ethical Considerations

The Institutional Review Board (IRB) determined that an approval was not required on the basis that the study was a quality improvement project, and no human subjects were involved. The project implementation required no funding and there were no conflicts of interest. There were no physical, psychological, or emotional risks involved in this study. Participants were repeatedly reminded both verbally and via written format that participation was completely voluntary and without repercussion.

Planning and Procedures/Limitations

Planning

Three key players, the dentist Dr. Sonia Simmonds, office manager Cherish McCraw, and a dental hygienist, Wayne Brown, were interviewed in order to identify potential barriers,

challenges, and overall feasibility of the project. Dr. Simmonds was chosen for her knowledge and expertise in carrying out dental procedures and managing complications that may arise from airway monitoring. Cherish McCraw was selected for her experience with dental staff scheduling and assistance with facilitation of the online questionnaires. Wayne Brown was selected to provide further insight into the value of staff education as it relates to patient safety.

Budget/Grant

A grant was not requested for the proposed scholarly project. Lunch was provided to all participating staff. Participants were each given a 10-page handout. The handout explained the indications and benefits for capnography use and showed a list of common capnography waveforms including normal and abnormal depictions, with a reference page listing the publication sources used to support the information in the handout. The co-investigators agreed to bear the cost of implementation of the proposed scholarly project.

Implementation

This scholarly project was implemented in Spring of 2022. An anonymous online pretest was administered prior to the educational session. A posttest immediately followed the presentation and again after a period of 30 days. A total of two exchanges took place with the clinical staff where the letters of invitation, pretests, and both posttests were administered. All the data were managed and stored on a password protected file located on a secure Microsoft Forms platform which was created using an AdventHealth University (AHU) Outlook email address. The data was accessible only to direct contributors such as the principal investigator / project chair, consulted statistician, and co-investigators. After the data was analyzed, it was de-identified prior to being exported to a secure internal server within the AHU Research

department. The data will be retained for up to seven years per the AHU Institutional Review Board requirements, then auto deleted.

Barriers/Limitations and Facilitators

The study was conducted at a single clinical setting which was that of Simmonds Dental Center. Therefore, findings may not be representative of all dental practices. Although the data showed statistical significance, the smaller sample size may prevent the results of the study from being generalized outside of the sample group and inferenced to the general population. Additional barriers included the use of a self-validated questionnaire as well as time constraints, as the participants were only available during normal business hours of the dental facility. Accommodations had to be made to ensure adequate time for the educational session and maximal participation. The dental office manager was the facilitator and assisted with coordinating refreshments for participants during the educational session.

Procedures to Sustain

The results of this scholarly project may be utilized to improve patient safety via the use of capnography at the Simmonds Dental Center in Orlando and their future branches, as the practice is currently exploring avenues to expand their reach in the Central Florida area.

Timeline

The project timeline involved Institutional Review Board (IRB) approval, project implementation, postimplementation data analysis, and information dissemination. The scholarly project was submitted to the Scientific Review Committee (SRC) in November 2021, after which the necessary changes were made and resubmitted. IRB approval was received in February 2022, followed by implementation and data collection in March and April 2022.

Results

The scholarly project was implemented from late March through the end of April 2022. The educational session included a final sample of six participants. Demographic characteristics of the participants including their years of experience pertaining to the topic of capnography are shown in Table 1. All of the participants were 18 years of age and older. Sixty-seven percent (67%) of the participants were female and represented the majority of the participants, and the remaining 33% were male. All of the participants met the inclusion criteria; therefore, no participants were excluded from the study. Participants were asked about their knowledge regarding the topic of capnography through use of a questionnaire which was administered at three different time intervals.

A total of 6 participants started the study. However, it appeared that one of the participants used a different identifier from what was previously chosen, which impacted the results of our study. After comparing the variables from the first and second posttest, it was determined with certainty that it was the same participant. Due to the minor discrepancy, the results reflected an exclusion of that participant, bringing the number of participants down to 5 for comparison of the first and second posttest.

Study Findings

Descriptive and statistical analysis was conducted utilizing the Wilcoxon Signed Rank Test. As a result of the smaller sample size, a larger significance level of alpha ($\alpha = 0.1$) was utilized for each test. A brief description of the Wilcoxon Signed Rank Test is as follows: we started by finding the difference and absolute value for each pair and applied a positive or negative sign to the value. If the scores increased from pretest to posttest or from the first and

second posttest, a negative sign was used. The pairs were then assigned a rank from smallest to largest absolute differences. We ignored any pair that had an absolute difference of "0" and utilized a mean rank for any values that were tied. The sums of the positive and negative ranks were calculated and the smaller of the absolute values was determined to be our test statistic (W=0). A critical value was determined for each questionnaire.

The results of the Wilcoxon Signed Rank Test showed a significant difference between the pretest and first posttest (N=6, W=0 < Critical value V=2, $\alpha = 0.10$), the first and second posttests (N=5, W=0 < Critical value V=2, $\alpha = 0.10$), and between the pretest and second posttest (N=6, W=0 < Critical value V=2, $\alpha = 0.10$). Therefore, there is statistically significant evidence of a difference in participant scores after the implementation of the educational seminar compared to before. The results of the Wilcoxon Signed Rank Test are listed in Table 2. Overall, the results of this study showed a positive correlation between the implementation of an educational session on capnography and knowledge retention of the dental clinical staff.

Table 1
Demographic Profile of Participants

Characteristics	**Number (%) of Participants**
Age	
Over 18 years	6 (100)
Under 18 years	0 (0)
Gender	
Male	2 (33)
Female	4 (67)
English as a first language	
Yes	6 (100)
No	0 (0)
Years of experience with capnography	
0	6 (100)
1-5 years	0 (0)
5-10 years	0 (0)
10-15 years	0 (0)
>15 years	0 (0)

Table 2.
Wilcoxon Signed Rank Test at 10% level of Significance (α = 0.10)

		N	Mean Rank	Sum of Ranks	Test Statistic	Critical Value
Pretest-First Posttest	Negative Rank Positive Rank Ties	6 0 3	3.50 0.00	-21.00 0.00	0*	2
First-Second Posttest	Negative Rank Positive Rank Ties	5 0 2	4.00 0.00	-20.00 0.00	0*	1
Pretest-Second Posttest	Negative Rank Positive Rank Ties	6 0 2	3.50 0.00	-21.00 0.00	0*	2

**Result shows statistical significance if the test statistic is less than the critical value*

Discussion and implications

Capnography monitoring during dental sedation is necessary for the prevention of adverse events that are associated with the lack of it. This will not only ensure the safety and comfort of patients of all ages, but it will also help absolve many dental practitioners from the legal implications of life-threatening events that may occur with sedation dentistry.

The results obtained from the initial and final posttests exhibited an increase in the knowledge base of the dental staff, compared to the pretest prior to the educational session (N=6, W=0 < Critical value V=2, α = 0.10), (N=5, W=0 < Critical value V=2, α = 0.10), (N=6, W=0 < Critical value V=2, α = 0.10). (See Table 2). It can be inferred from these results that the educational session conducted on capnography monitoring for the dental staff at Simmonds Dental Center led to an increase in their knowledge base and will subsequently yield an increase in patient safety and satisfaction rates. This scholarly project demonstrated that educating dental staff on the importance of capnography monitoring is a viable proposition for the prevention of adverse events during procedural sedation in the dental setting. However, due to the small sample size of 6 participants and the use of only one dental practice setting, there is not enough

statistical evidence to contribute to existing literature and to healthcare in general. Even though the participants demonstrated a significant amount of knowledge retention from the results of the two posttests conducted, the co-investigators were unable to generalize the findings to the practice of sedation dentistry.

The 30-minute educational session on capnography definitely reflected a positive change in the knowledge base of the dental staff. This was seen in the comparison of their scores on the pretest and the first posttest (Table 2). The second posttest which was conducted after 30 days also yielded higher scores from the participants, compared to the results obtained from the pretest.

During the implementation phase of the project, the co-investigators noted that the participants had little understanding of the words “capnography” and “ventilation” in the context of the test questions. The use of these medical terminologies might have posed a barrier that influenced the low scores associated with the pretest. Therefore, it is recommended that for future studies, co-investigators utilize familiar words or more lay terminology that dental staff can easily comprehend like “carbon dioxide monitoring” and “breathing” respectively.

The innovation PICOT for this project sought to determine if a 30-minute educational session held for the staff of Simmonds Dental Center in Orlando on the use of end-tidal capnography monitoring in patients undergoing dental sedation would influence their knowledge level and retention on the early recognition of oxygen desaturation in their patients after a period of 30 days. The co-investigators adopted the Plan-Do-Study-Act (PDSA) cycle of process improvement for the implementation of this project. Throughout the process, all barriers and

limitations identified by the co-investigators were addressed systematically and necessary alterations were made to ensure maximum efficacy.

Although the results of the study did not prove statistically significant enough to draw absolute conclusions, the co-investigators acknowledge that the trend of the test scores depicted an increase in the participants' knowledge base following the 30-minute educational PowerPoint presentation on the importance of capnography monitoring in the dental setting.

Dissemination Plan

After careful analysis of the collected data from the study, the information was disseminated via a PowerPoint and poster presentation. The PowerPoint presentation and poster board were made available in Spring 2023. This scholarly project was presented during the AdventHealth University Doctor of Nurse Anesthesia Practice (DNAP) Scholarship and Poster Presentation week via the canvas course DNAP 2023 Scholarly Project Dissemination.

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Purpose	Variables	Setting/Subjects	Measurement and Instruments	Results	Evidence Quality
Study One: Investigate if the use of capnometry is more sensitive at detecting oxygen desaturations in oral surgery cases using midazolam for sedation **Study Two:** Determine if the addition of capnography in reduces the incidence of hypoxia in the emergency department (ED).	**Study One:** **Primary outcome:** Early detection of oxygen desaturation with capnometry **Secondary Outcome:** None of the patients experienced respiratory depression **Study Two:** **Primary outcome:** Early detection of hypoxia **Secondary Outcome:** More physician interventions	**Study One:** **Setting:** Oral surgery department of a university-affiliated dental school and hospital **Subjects:** 33 adults under age 65 with an ASA class of 1 or 2, and a BMI less than 35 **Study Two:** **Setting:** Albert Einstein Medical Center in Philadelphia, PA **Subjects:** 132 adults undergoing sedation with propofol	**Study One:** McNemar's test **Study Two:** Statistical Package for the Social Sciences (SPSS). Patient's level of alertness was assessed using a Ramsay Scale	**Study One:** Changes in capnometry were detected after changes in pulse oximetry **Study Two:** Hypoxia was detected more frequently in the capnography group leading to more physician intervention.	**Study One:** **Methodological flaws:** Recruitment bias, lost data from equipment failure **Inconsistency:** None **Indirectness:** None **Imprecision:** Small sample size **Publication bias:** None **Study Two:** **Methodological flaws:** Recruitment bias **Inconsistency:** None **Indirectness:** None **Imprecision:** None **Publication bias** None
Design				**Implications**	
Study One: Prospective observational study **Study Two:** Randomized control trial				**Study One:** Pulse oximetry is useful in oral surgery **Study Two:** Capnography can aid ED physicians in the early detection of hypoxia	

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Purpose	Variables	Setting/Subjects	Measurement and Instruments	Results	Evidence Quality
Study One: Evaluate the use of capnography as a method of detecting hypoventilation and apnea **Study Two:** Determine if the addition of microstream capnography reduces the incidence of oxygen desaturations during conscious sedation with midazolam for oral surgery. **Design** **Study One:** The design was not stated but appears to be a cross-sectional study **Study Two:** Randomized control trial	**Study One:** **Primary Outcome:** Accuracy of $PetCO_2$ in the early detection of alveolar hypoventilation **Secondary Outcome:** Early detection of apnea and airway obstruction **Study Two:** **Primary Outcome:** Patients with any hypoxemia **Secondary Outcome:** Patients with moderate to severe hypoxemia, and patients receiving verbal stimulation or supplemental oxygen	**Study One:** **Setting**: University of North Carolina School of Dentistry **Subjects**: Ten ASA class I patients requiring removal of at least one third molar and who desired outpatient general anesthesia **Study Two:** **Setting:** Cork University Dental School and Hospital in Ireland **Subjects:** 190 patients ranging from ages 14-62 years old. (93 patients in the capnography group, 97 patients in the control group).	**Study One:** Quantitative measurements **Study Two:** Control group with blinded capnography and an intervention group who received capnography.	**Study One:** Capnography immediately detected periods of hypoventilation. The transcutaneous oxygen monitor was inadequate in detecting rapid changes in PaO2 **Study Two:** Results were inconclusive as to whether or not capnography plays a role in preventing hypoxemia **Implications** **Study One:** Hypoxia is a leading cause of morbidity and mortality during dental anesthesia. **Study Two:** Further research is needed to evaluate the use of capnography in oral surgery.	**Study One:** **Methodological flaws:** Lack of a control group **Inconsistency:** None **Indirectness:** None **Imprecision:** None Sample size was small **Publication bias**: None **Study Two:** **Methodological flaws:** Recruitment bias, technical difficulties resulting in the loss of data, no scale was used to record the depth of sedation (ex. Ramsey) **Inconsistency:** None **Indirectness:** None **Imprecision:** Small sample size **Publication bias:** Study received research funding

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Dodson, T. B., Gonzalez, M.S., & Matin, M.B. (2015). What Factors Influence Community Oral Surgeons' Choice to use Capnography in the Office-Based Ambulatory Anesthesia Setting? American Association of Oral and Maxillofacial Surgeons. http://dx.doi.org/10.1016/j.joms.2015.03.062

Purpose	Variables	Setting/Subjects	Measurement and Instruments	Results	Evidence Quality
Study One: Determine if end-tidal carbon dioxide ($ETCO_2$) monitoring would detect an acute respiratory event earlier than other than current monitoring practices **Study Two:** Determine how often capnography is used and the factors that influence a surgeon's choice for use.	**Study One:** **Primary Outcome:** $ETCO_2$ abnormalities preceded oxygen desaturation or witnessed hypoventilation. **Secondary Outcome:** Acute respiratory events occurred that warranted ventilatory assistance. **Study Two:** **Primary Outcome:** Capnography was not used on every patient **Secondary Outcome:** Several factors influenced a physician's decision to use capnography.	**Study One:** **Setting:** Emergency Department of a Tertiary level hospital. **Subjects:** 60 patients who visited the facility for procedural sedation and analgesia within five-month period. **Study Two:** **Setting:** Office-based ambulatory care setting **Subjects:** 124 oral and maxillofacial surgeons registered with the American Association of Oral and Maxillofacial Surgeons and 3,495 patients seen during a 12-month study period.	**Study One:** Ramsay score clinical assessment and data from patient monitoring. **Study Two:** Secure, web-based, Health Insurance Portability and Accountability Act-compliant data collection instrument and Statistical Package for the Social Sciences (SPSS).	**Study One:** $ETCO_2$ monitoring provided early detection of clinically significant acute respiratory events compared to standard monitoring. **Study Two:** Approximately 1 out of 7 surgeons used capnography to monitor their sedated patients and only 1 out of 18 patients received $ETCO_2$ monitoring.	**Study One:** **Methodological flaws:** Sampling bias, unreliable data capture technology. **Inconsistency:** None **Indirectness:** None Use of patients who were high risk for acute respiratory events. **Imprecision:** None **Publication bias:** None **Study Two:** **Methodological flaws:** None **Inconsistency:** None **Indirectness:** None **Imprecision:** Large number of patient and surgeon variables **Publication bias:** None
Design **Study One:** Prospective observational study. **Study Two:** Benchmark study				**Implications** **Study One:** $ETCO_2$ monitoring is a more reliable tool in detecting acute respiratory events **Study Two:** Capnography can be used for a multitude of patient comorbidities.	

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Purpose/Objectives	Search Strategy	Number and Type of Studies in the Review Including Sample Sizes	Results	Conclusions/ Implications	Evidence Quality
Study One: Explore the importance of capnography monitoring in determining the incidence of arterial oxygen desaturations during the use of dental procedures requiring sedation. **Study Two:** Understand whether the use of capnography in addition to pulse oximetry and visual monitoring reduces the incidence of adverse events during procedural sedation and analgesia (PSA).	**Study One:** **Data Bases:** PRISMA, PubMed, Embase, the Cochrane Library **Search Terms:** Conscious sedation, capnography, sedation, oximetry, capnometry, randomized control trials **Limits:** None **Reviewers:** Two independent reviewers conducted electronic and manual searches **Study Two:** **Data Bases:** PubMed, Embase, the Cochrane Library **Search Terms:** combination of MeSH terms and free text **Limits:** Only articles published after January 1st, 1995 were included **Reviewers:** Two independent reviewers conducted searches using Sourcerer. A modified Jadad Scale was used to assess the risk of bias	**Study One:** This review included 14 randomized control trials with a total of 5,687 participants. All of the subjects were adults with the exception of one pediatric patient **Study Two:** This review included 13 randomized control trials based on a modified Jadad Scale which assessed the studies based on their design and reporting. A score of 0 = low quality, and a score of 5 = high quality. The total number of participants was not stated.	**Study One:** There was a total of 302 articles that resulted with the initial search but only 14 studies were found to be eligible for the analysis **Study Two:** Incidence of mild desaturations (SpO2 <90-95%) was reduced by more than 30% with the addition of capnography and showed a 95% CI 0.67-0.89 Incidence of severe desaturations (SpO2 <85%) showed a 95% CI 0.43-0.81	**Study One:** This review found that capnography reduced the incidence of hypoxemia and oxygen desaturations compared to pulse oximetry monitoring **Implications:** Capnography allows dental clinicians the advantage of early detection and intervention of respiratory depression **Study Two:** This review found that the addition of capnography reduces the odds of oxygen desaturations compared to pulse oximetry and visual inspection alone. **Implications:** The addition of capnography in addition to standard patient monitoring during PSA can increase patient safety.	**Study One:** **Methodological flaws:** Recruitment bias, lack of dental setting, heterogeneity of samples **Inconsistency:** Variability in the ASA statuses **Indirectness:** Patients had different diagnoses **Imprecision:** None **Publication bias:** None **Methodological flaws:** Heterogeneity of samples **Inconsistency:** None **Indirectness:** None **Imprecision:** The level of sedation used in each study was not uniformly reported **Publication bias:** None

Systematic Review Articles

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Parker, W., Estrich, C. G., Abt, E., Carrasco-Labra, A., Waugh, J. B., Conway, A., Lipman, R. D., & Araujo, M. (2018). Benefits and harms of capnography during procedures involving moderate sedation: A rapid review and meta-analysis. *Journal of the American Dental Association (1939)*, *149*(1), 38–50.e2. https://doi.org/10.1016/j.adaj.2017.08.030

Waugh, J. B., Epps, C. A., & Khodneva, Y. A. (2011). Capnography enhances surveillance of respiratory events during procedural sedation: a meta-analysis. *Journal of clinical anesthesia*, *23*(3), 189–196. https://doi.org/10.1016/j.jclinane.2010.08.012

Purpose/Objectives	Search Strategy	Number and Type of Studies in the Review Including Sample Sizes	Results	Conclusions/ Implications	Evidence Quality
Study One: Determine whether the use of capnography in dental procedures requiring sedation influences the risk of adverse respiratory events such as hypoxemia. **Study Two:** Determine if the use of standard monitoring alone compared to the addition of capnography influences detection of respiratory complications.	**Study One:** **Data Bases:** PubMed, Google Scholar **Search Terms:** Capnography**,** systemic review, procedural sedation, analgesia **Limits:** English language **Reviewers:** Three staff members independently extracted data. The authors used the GRADE approach **Study Two:** **Data Bases:** PRISMA, PubMed, CINAHL, the Cochrane Library **Search Terms:** capnography, conscious sedation, procedural sedation, analgesia **Limits:** English language **Reviewers:** Three independent reviewers determined the inclusion criteria	**Study One:** This review included 16 random control trials and included 3866 adult participants **Study Two:** This review included five selected studies of random control trials and included 332 participants	**Study One:** Capnography was more sensitive in detecting adverse respiratory events compared to standard monitoring alone and showed a 95% CI 0.65-0.99. There was a 31% reduction in hypoxemia for adults receiving capnography. **Study Two:** The pooled statistical analysis of the five studies showed a 95% CI of 4.55-13.84	**Study One:** The use of capnography reduces the risk of developing hypoxemia during dental procedures requiring moderate sedation **Implications:** Early detection of adverse respiratory events in patients undergoing procedural sedation can decrease the probability of hypoxemia and increase patient safety. **Study Two:** The incidence of respiratory depression was 17.6 times more likely to be detected by capnography than standard monitoring alone during procedural sedation **Implications:** Capnography is an essential element in detecting adverse respiratory events	**Study One:** **Methodological flaws:** Recruitment bias, heterogeneity of samples, lack of blinding **Inconsistency:** None **Indirectness:** None **Imprecision:** None **Publication bias:** None **Study Two:** **Methodological flaws:** Recruitment bias, heterogeneity of samples **Inconsistency:** None **Indirectness:** None **Imprecision:** Small sample size, wide confidence intervals **Publication bias:** None

Systematic Review Articles

Bibliography

Parker, W., Estrich, C. G., Abt, E., Carrasco-Labra, A., Waugh, J. B., Conway, A., Lipman, R. D., & Araujo, M. (2018). Benefits and harms of capnography during procedures involving moderate sedation: A rapid review and meta-analysis. *Journal of the American Dental Association (1939)*, *149*(1), 38–50.e2. https://doi.org/10.1016/j.adaj.2017.08.030

Waugh, J. B., Epps, C. A., & Khodneva, Y. A. (2011). Capnography enhances surveillance of respiratory events during procedural sedation: a meta-analysis. *Journal of clinical anesthesia*, *23*(3), 189–196. https://doi.org/10.1016/j.jclinane.2010.08.012

Purpose/Objectives	Search Strategy	Number and Type of Studies in the Review Including Sample Sizes	Results	Conclusions/ Implications	Evidence Quality
Study One: Determine whether the use of capnography in dental procedures requiring sedation influences the risk of adverse respiratory events such as hypoxemia. **Study Two:** Determine if the use of standard monitoring alone compared to the addition of capnography influences detection of respiratory complications.	**Study One:** **Data Bases:** PubMed, Google Scholar **Search Terms:** Capnography**,** systemic review, procedural sedation, analgesia **Limits:** English language **Reviewers:** Three staff members independently extracted data. The authors used the GRADE approach **Study Two:** **Data Bases:** PRISMA, PubMed, CINAHL, the Cochrane Library **Search Terms:** capnography, conscious sedation, procedural sedation, analgesia **Limits:** English language **Reviewers:** Three independent reviewers determined the inclusion criteria	**Study One:** This review included 16 random control trials and included 3866 adult participants **Study Two:** This review included five selected studies of random control trials and included 332 participants	**Study One:** Capnography was more sensitive in detecting adverse respiratory events compared to standard monitoring alone and showed a 95% CI 0.65-0.99. There was a 31% reduction in hypoxemia for adults receiving capnography. **Study Two:** The pooled statistical analysis of the five studies showed a 95% CI of 4.55-13.84	**Study One:** The use of capnography reduces the risk of developing hypoxemia during dental procedures requiring moderate sedation **Implications:** Early detection of adverse respiratory events in patients undergoing procedural sedation can decrease the probability of hypoxemia and increase patient safety. **Study Two:** The incidence of respiratory depression was 17.6 times more likely to be detected by capnography than standard monitoring alone during procedural sedation **Implications:** Capnography is an essential element in detecting adverse respiratory events	**Study One:** **Methodological flaws:** Recruitment bias, heterogeneity of samples, lack of blinding **Inconsistency:** None **Indirectness:** None **Imprecision:** None **Publication bias:** None **Study Two:** **Methodological flaws:** Recruitment bias, heterogeneity of samples **Inconsistency:** None **Indirectness:** None **Imprecision:** Small sample size, wide confidence intervals **Publication bias:** None

Systematic Review Articles

Bibliography Kummer, D. J., & Walden, B. J. (2019). Capnography Monitoring for Patients Undergoing Moderate Sedation: An SGNA Fellowship Project. *Gastroenterology nursing: the official journal of the Society of Gastroenterology Nurses and Associates*, *42*(1), 49–54. https://doi.org/10.1097/SGA.0000000000000426					
Purpose/Objectives	**Search Strategy**	**Number and Type of Studies in the Review Including Sample Sizes**	**Results**	**Conclusions/ Implications**	**Evidence Quality**
Study One: Determine whether the implementation of education on capnography is a useful tool to enable nurses to recognize the signs of oxygen desaturation faster than pulse oximetry.	**Study One:** **Data Bases:** There were no identifying data on the survey utilized for this study. **Search Terms:** Capnography**,** conscious sedation, nursing staff, oximetry, adverse effects, respiratory insufficiency **Limits:** English language **Reviewers:** The survey was collected and transcribed by the principal investigator who is a senior employee of the private ambulance service.	**Study One:** The sample size consisted of a capnography group with 57 adults and a non-capnography group with 102 adults.	**Study One:** Education on the use of capnography was an effective tool to enable nurses in the early and frequent recognition of the signs associated with respiratory depression than that of oximetry alone.	**Study One:** Capnography is more accurate than pulse oximetry in detecting early signs of respiratory depression in adults undergoing procedural sedation. **Implications:** The addition of capnography provides a safer alternative for patients undergoing procedural sedation in detecting the early signs of respiratory depression and preventing the occurrence of adverse events.	**Study One:** **Methodological flaws:** Recruitment bias, heterogeneity of samples **Inconsistency:** None **Indirectness:** None **Imprecision:** None **Publication bias:** Participants received incentives no greater than $10 for their participation in the study

Systematic Review Articles

<table>
<tr><td colspan="6">Bibliography
Wylie, C., Welzel, T., & Hodkinson, P. (2019). Waveform capnography in a South African prehospital service: Knowledge assessment of paramedics. African journal of emergency medicine: Revue africaine de la medecine d'urgence, 9(2), 96–100. https://doi.org/10.1016/j.afjem.2019.01.010</td></tr>
<tr><td>Purpose</td><td>Variables</td><td>Setting/Subjects</td><td>Measurement and Instruments</td><td>Results</td><td>Evidence Quality</td></tr>
<tr><td>Study One:
Evaluate the knowledge of paramedics on the use of waveform capnography outside of a hospital based setting to identify areas of improvement.</td><td rowspan="2">Study One:
Primary Outcome:
Paramedics demonstrated basic knowledge in the use of capnography.

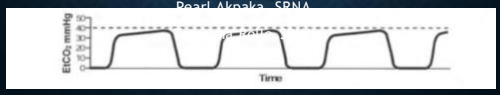
Secondary Outcome:
Paramedics demonstrated a knowledge deficit in more complicated case scenarios involving changes in the capnography waveform.</td><td rowspan="2">Study One:
Setting:
A single private ambulance service based in South Africa

Subjects:
112 paramedics trained in advanced life support and employed by the private ambulance service</td><td rowspan="2">Study One:
A web-based survey was conducted using Survey Monkey and was transcribed by the principal investigator who is a senior employee of the private ambulance service.</td><td>Study One:
66% of participants were able to correctly interpret the $ETCO_2$ waveform change associated with ROSC during CPR, 20-25% were unable to identify and correct apneic events, 66% were unable to identify waveform changes during hypoventilation, and 48% could not identify and correct waveform changes related to hypovolemia.</td><td rowspan="2">Study One:
Methodological flaws:
Sampling bias, small sample size, unreliable data capture technology
Inconsistency: None
Indirectness: None
Imprecision:
None
Publication bias:
The principal investigator was a senior employee of the private ambulance service.</td></tr>
<tr><td>Design</td><td>Implications</td></tr>
<tr><td>Study One:
Pilot study</td><td>Study One:
This study indicates the need for further training of paramedics in South Africa in the interpretation of waveform capnography to improve patient outcomes.</td></tr>
</table>

Appendix A: Powerpoint Presentation

CAPNOGRAPHY 101

Pearl Akpaka, SRNA



1

BASIC TERMINOLOGY

- Respiration is the transfer of oxygen (O_2) TO the body's tissues, and the carbon dioxide CO_2 AWAY from the body's tissues.
- CO_2 is a colorless, odorless gas that is essential forrespiration
- End-tidal carbon dioxide ($ETCO_2$) represents the level of CO_2 that is released from the lungs at the end of an exhaled breath.

2

WHAT IS THE DIFFERENCE?

Oxygenation

- Oxygenation refers to an uptake of oxygen (O_2) from the lungsand its distribution to the tissues and organs

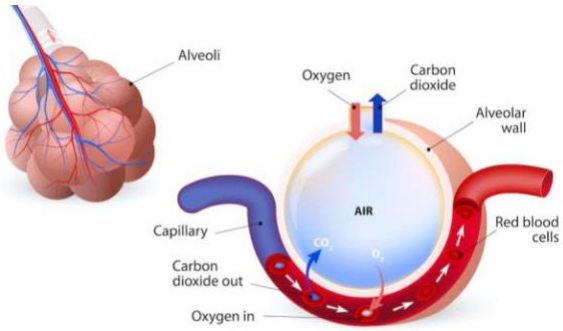
Ventilation

- Ventilation refers to the exchange of oxygen (O) and carbon dioxide (CO2) between the environment and the

Apnea

- Apnea refers to a temporary cessation of breathing. No airflow into or out of the lungs.

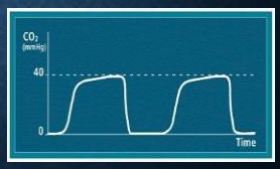
3



4

WHAT IS CAPNOGRAPHY?

- Measurement of exhaled CO2!!
- Consists of a number and a graph
- Normal Range: 35-45 mmHg



5

NASAL CANNULA

- Special device that provides oxygen delivery through one prong, and carbon dioxide monitoring from the other prong
- Provides a sample line for capnography
- Prongs are curved to improve the anatomical fit and for patient comfort
- Tubing is secured proximally around the

6

BASIC CAPNOGRAPHY WAVEFORM

- Pattern: Normal Breathing
- Range: 35-45 mmHg

7

BASIC CAPNOGRAPHY WAVEFORM

Pattern: Hypoventilation	Breathing too shallow or too slow	Range: > 45 mmHg

8

BASICCAPNOGRAPHYWAVEFORM

- Pattern: Hyperventilation
- Rapid or deep breathing
- Range: < 45 mmHg

9

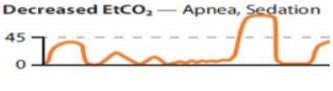
BASICCAPNOGRAPHYWAVEFORM

- Pattern: Sudden loss of the waveform
- Dislodged or kinked sample line

10

BASIC CAPNOGRAPHY WAVEFORM

- Pattern: Decreasing $ETCO_2$
- Apnea or Sedation
- Inadequate ventilation



11

SIGNIFICANCE IN DENTISTRY

Oral & IV Sedation

- Midazolam (Versed) - IV, PO
- Diazepam (Valium) - PO
- Lorazepam (Ativan) - IV, PO

Complications

- Airway obstruction
- Respiratory depression
- Decreased ventilation
- Apnea
- Aspiration

12

ADVERSEEVENTS

- In 2017, a 2-year-old child died in an Arizona dental clinic while recovering from an extensive procedure involving the placement of multiple root canals and crowns after receiving dental sedation.
- In 2018, a 17-year-old boy in Kissimmee, Florida, died after undergoing dental sedation for a routine procedure involving tooth extractions when he stopped breathing. The dental provider was unaware of the patient's respiratory status.

13

IMPORTANCE OF CAPNOGRAPHY EDUCATION

- Hypoxia is the leading cause of morbidity and mortality in dental sedation
- Death following dental sedation is the most detrimental side effect of dental anesthesia
- Capnography provides an early warning regarding subtle changes in ventilation
- Proper education and training on basic airway monitoring for dental providers and their staff can further optimize patient care
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14

LIMITATIONS TO CAPNOGRAPHY

- Alarm fatigue naccurate $ETCO_2$ readings from device alposition
- Inaccurate waveform interpretation
- Nasal cannula can be uncomfortable to wear
- Skin irritation (mainly seen in elderly undergoing longer procedures)

15

CONTRAINDICATIONS

16

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17

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18

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19

Appendix B: Pretest/Posttest Questionnaire

1. During respiration, which of the following gases is transferred from the body's tissues?	a. Oxygen **b. Carbon dioxide** c. Nitrous oxide d. Helium
2. Ventilation refers to the exchange of oxygen and carbon dioxide between the environment and which part of the respiratory anatomy?	a. Nostrils b. Skin pores **c. Alveoli** d. Bronchi
3. Apnea is defined as which of the following?	**a. No airflow in or out of the lungs** b. Little airflow out of the mouth c. Little airflow through the nostrils d. Just enough airflow in and out of the lungs
4. Capnography is a measurement of	a. Inhaled oxygen b. Temperature **c. Exhaled carbon dioxide** d. Respiratory rate
5. The normal range of carbon dioxide is	a. 20-25mmHg b. 25-30mmHg c. 30-35mmHg **d. 35-45mmHg**
6. What is the interpretation of the capnography waveform below? 	a. Shallow breathing b. Deep breathing c. Abnormal breathing **d. Normal breathing**
7. What is the interpretation of the capnography waveform below? 	**a. There is a kink in the CO_2 sampling line** b. This is a normal waveform c. The patient is wide awake d. The patient is in pain
8. Which of the following is NOT a complication of oral and intravenous sedation in dentistry?	a. Aspiration b. Apnea **c. Increased ventilation** d. Decreased ventilation
9. Which of the following devices can detect subtle changes in ventilation?	**a. Capnography** b. Pulse oximetry c. Blood pressure cuff d. Thermometer
10. For which of the following populations receiving dental sedation can capnography be used?	a. Toddlers b. The elderly **c. Anyone** d. Teenagers

Appendix C: Pretest/Posttest Questionnaire

Please provide the following information. All data will be kept anonymous and confidential. Thank you.

1. What is your age?
    a. Under 18
    b. Over 18

2. What is your gender?
    a. Male
    b. Female
    c. Would rather not say

3. Is English your first language?
    a. Yes
    b. No

4. How many years of experience do you have on the topic of capnography?
    a. 0
    b. 1-5 years
    c. 5-10 years
    d. 10-15 years
    e. > 15 years