Continuing Education for Your Success

It’s official. On August 1, 2016, the National Board of Certification and Recertification for Nurse Anesthetists (NBCRNA) launched its Continued Professional Certification (CPC) Program, ushering in a new era of recertification for Certified Registered Nurse Anesthetists (CRNAs). Details about the program, including Class A and Class B requirements, timelines, Core Modules, the examination, and more information, can be found at the American Association of Nurse Anesthetists (AANA) website (http://cpc-facts.aana.com) and the NBCRNA website (www.nbcrna.com).

AANA Journal Course, Free CEs, AANA Learn
To support CRNAs in attaining 100 continuing education (CE) credits (60 Class A and 40 Class B) over the 4-year period required by the new CPC Program, the AANA provides a wide range of administrative services and CE offerings, including the highly regarded AANA Journal course. Published in the print version of the Journal (6 times per year) and available to members for Class A CE credit through AANA Learn, the association’s online learning center, each Journal course provides leading-edge information that enhances the knowledge and abilities of CRNAs. In addition to the current Journal course, previously published courses are also available at www.AANALearn.com.

Starting this fall, as a benefit of AANA membership, CRNAs will receive a coupon with an exclusive code that can be used for up to 6 free online courses worth 1 Class A CE credit each at www.AANALearn.com.* Members can use this exclusive code up to 6 times during the membership year for courses such as the AANA Journal course. In other words, members can fulfill nearly one-fourth of their 4-year, 100-credit requirement free of charge through AANA Learn.

Core Modules
An integral part of the CPC Program is the Core Modules requirement, which members will be able to fulfill through the AANA’s NBCRNA-recognized modules, now available on AANA Learn. Core Modules are CE activities that meet Class A requirements and provide a consistent structure for CRNAs to stay abreast of evolving, evidence-based knowledge. The modules use a standard set of learning objectives to address the 4 domains of anesthesia care: (1) airway management, (2) applied clinical pharmacology, (3) human physiology and pathophysiology, and (4) anesthesia equipment and technology. The AANA’s 4-part series delivers an innovative, interactive, self-paced Class A CE activity to help CRNAs stay current in today’s anesthesia essentials. Each module is linked with the content outline of the future CPC examination and includes a posttest. Completion of the modules is optional in the first 4-year CPC cycle.

Members of the AANA receive special members-only pricing for the AANA’s CPC Core Modules through AANA Learn. Check the NBCRNA website for other vendors that offer CPC Core Modules.

AANA Annual Congress CE Offerings, CPC Track
Each year the AANA Nurse Anesthesia Annual Congress offers CRNAs the opportunity to attain more than 20 Class A CE credits toward recertification through keynote speakers, general sessions, and educational tracks. During the 2016 Congress in Washington, DC, September 9 to 13, CRNAs will be able to take advantage of a timely new educational track, titled “Continued Professional Certification (CPC) Program Review,” covering the fundamentals of nurse anesthesia principles and practice related to topics covered in the CPC Program. The track also includes educational topics mapped to the future CPC examination.

Along with the traditional lecture format, the track will feature

*Coupon use is limited to courses that are 1 Class A credit on www.AANALearn.com. This offer excludes the AANA Continued Professional Certification (CPC) Core Modules and courses worth more than 1 Class A credit.
“case management” sessions for Class A CE credits that will provide attendees an opportunity to bring personal cases (must meet the health information privacy requirements of the Health Insurance Portability and Accountability Act, or HIPAA) to discuss with experts in areas of interest.

**Class B Credits, AANA Tracking Service**

CPC Class B requirements recognize learning alternatives that enhance anesthesia knowledge, support patient safety, or foster understanding of the broader healthcare environment. Examples of Class B credits include Class A CE credits (which can be used to fulfill Class B requirements), presentations, teaching, publication, research, and more. To help CRNAs adapt to the new Class B requirements, the AANA’s CE tracking service, a highly regarded benefit of AANA membership, is available at no charge to AANA members to conveniently and accurately account for all Class B credits earned. Members can track their Class B credits in real time on AANA Learn. Once submitted, the Class B credits will automatically appear on the member’s AANA transcript.

**Meeting Requirements, Meeting Member Needs**

Throughout the development of the CPC Program, the AANA has worked with the NBCRNA to meet the requirements of the new program while ensuring that AANA members’ CE concerns were addressed and their needs met. A recent example was attaining reassurance from the NBCRNA that facility in-services and educational activities with relevance to nurse anesthesia offered by other accredited providers will still meet Class A requirements for CE credit.

As CRNAs become more familiar with the CPC, the AANA will continue to be there to provide updated information and advice to help members successfully navigate the new recertification process.

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RESEARCH NEWS

Lorraine Jordan, PhD, CRNA, CAE, FAAN
Helen Tselentis, MEd
Jihan Quraishi, MS, RN, AE-CC, CCRC

Developing a Health Services Research Agenda in Nurse Anesthesia Using a Modified Delphi Method

The authors sought to formalize a process and ascertain research priorities for nurse anesthesia, which resulted in a new Health Services Research (HSR) Agenda. After formation of an 8-member ad hoc committee (representing different stakeholders from the American Association of Nurse Anesthetists [AANA]), a modified Delphi technique was used to determine the top 3 HSR research priorities for the 2016 fiscal year. The committee identified 24 high-priority HSR questions/topics specific to policy, education, or practice. An anonymous, web-based survey was distributed to the committee to rank and prioritize the 24 identified research questions using a 5-point Likert scale. Two consensus meetings and a second anonymous, web-based survey were conducted to prioritize the top 3 HSR questions. Through this systematic method, an HSR agenda was created based on the research questions initially submitted by the committee. The method used ensured that the new research agenda is relevant and reflects the priorities of Certified Registered Nurse Anesthetists. This agenda was incorporated into the updated AANA and AANA Foundation Joint Research Program as suggested areas of research. This agenda is intended to focus investigators and funding organizations on highest priority areas in nurse anesthesia research.

The mission of the American Association of Nurse Anesthetists (AANA) Foundation is to advance the science of anesthesia through education and research. One of the goals of the AANA Foundation is to support novice and seasoned investigators in nurse anesthesia through grants, fellowships, and postdoctoral fellowships. These programs are designed to develop researchers across a broad spectrum of research initiatives, which includes healthcare policy, anesthesia science, education, clinical practice, and leadership.

The generation of research has continued to evolve with innovations occurring in a variety of areas, such as instrument development, patient management, and policy related to anesthesia workforce and delivery models. The introduction of these events generates new research questions about value, effectiveness, cost-effectiveness, and other outcome metrics, which require scientifically valid answers. Given the constant changes in our environment, an updated focused research agenda in the context of health services research (HSR) for nurse anesthesia was warranted. To guide investigators and funding agencies, the AANA and the AANA Foundation approved broad research objectives in 2016 that inform the research community of the top research priorities in the field of nurse anesthesia.1

In September 2015, the AANA Foundation and key stakeholders were tasked with exploring and making recommendations regarding 1 to 3 HSR questions for the 2016 fiscal year, which would be supported by an AANA Foundation grant through a generous contribution from the National Board of Certification and Recertification for Nurse Anesthetists (NBCRNA). The purpose of the grant was to provide funding for selective critical research questions to further the nurse anesthesia profession. According to the action, the agenda had to include research questions that fell under one of the following domains:

1. **Policy**—replicating studies similar to the 2010 studies that support nurse anesthesia practice and policy
2. **Education**—exploring the value of credentialing and life-long learning in advancing patient safety through enhancing provider quality
3. **Practice**—examining critical initiatives to secure the future of
The Delphi technique is generally described as a method used to solicit opinion by experts through the use of structured questionnaires and open feedback mechanisms to “arrive at an agreed-upon group position.” An introductory meeting was held via teleconference to review roles and responsibilities and to outline the method used to develop the HSR agenda.

In stage 1, one HSR-AHC member was tasked with identifying 2 to 3 research questions based on a set of criteria that addressed at least one of the policy, education, or practice HSR Agenda domains (described in the Introduction section). The following criteria were provided as a guide for formulating the research questions:

- Is the question scientifically well posed (ie, is it stated in a hypothetical form that leads to a research design and analysis with scientific credibility)?
- Does the research question require data that are accessible or attainable at a reasonable cost or effort?
- Is the research question posed in a way that can explain variability—different outcomes under different conditions?
- Are the units of analysis (observation) clearly identified?
- Does the research extend our understanding of the phenomena being investigated; does it elaborate, extend, or fill in gaps in our present knowledge?

In stage 2, the question submitters were deidentified, and the questions were collated by research domain and redistributed to the entire HSR-AHC in the round 1 survey (Table 1). The purpose of deidentifying the questions was to reduce bias during the question prioritization phase. For distribution of the questions to the HSR-AHC, an electronic survey tool (SurveyMonkey.com) was used so the HSR-AHC would anonymously evaluate each research question based on the level of agreement.

The level of agreement was identified regarding 3 separate statements: addresses gaps in knowledge, potential research design feasibility, and overall impact (Figure 1). A mean composite score of the 3 statements was calculated using a 5-point Likert scale (1 indicated disagree; 2, somewhat disagree; 3, neutral; 4, somewhat agree; and 5, agree). The research questions, along with their respective priority rankings and scores, were sent back to the entire HSR-AHC for review.

As part of stage 3, the HSR-AHC was then asked to select 1 of the top 8 ranked research questions and provide rationale, justification, and evidence using a prepared template and the S.M.A.R.T. research criteria (specific, measurable, achievable, relevant, and time-bound; Figure 2). A consensus meeting was then scheduled for the HSR-AHC to discuss and defend the research questions that each member selected as a top agenda priority. A second-round survey (via SurveyMonkey.com) was conducted to rank the importance of the 8 questions followed by a final consensus meeting to confirm the prioritization of HSR questions for 2016 (computed according to mean scores). The top research questions were collectively analyzed during the final consensus meeting to eliminate redundancy and establish clarity of topics. There were 2 questions posed that were similar in nature of which the HSR-AHC agreed to combine. The 2 separate consensus meetings were conducted virtually via video-conferencing (GoToMeeting) and a teleconference.

Results

Twenty-four research questions and/or topics (Table 1) were initially identified by the 8 HSR-AHC members. Each topic was assigned to one of the following specialty domains with some questions overlapping 2 categories: Education (n = 3); Education/Practice (n = 2); Education/Policy (n = 1); Policy (n = 7); Policy/Practice (n = 4);
<table>
<thead>
<tr>
<th>Rank</th>
<th>Question/topic</th>
<th>Domain</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Has patient access to care (surgical, obstetrical, endoscopy, dental services, and pain) improved in states that have opted out of physician supervision?</td>
<td>Policy</td>
<td>12.26</td>
</tr>
<tr>
<td>2</td>
<td>Does legislative adoption of the Advanced Practice Registered Nurse (APRN) consensus model result in an increased scope of practice for APRNs?</td>
<td>Policy</td>
<td>12.01</td>
</tr>
<tr>
<td>3</td>
<td>What are hospital administrators’ (CEOs, CFOs, CMOs, CNOs) perceptions of CRNA anesthesia services in their institutional settings? (variations by type of hospital, location by state, location by rural vs city)</td>
<td>Policy/Practice</td>
<td>11.88</td>
</tr>
<tr>
<td>4</td>
<td>How do legislators and other key decision makers perceive the influence of CRNAs (or APRNs)? What can be done in the policy arena to be more effective/influential?</td>
<td>Policy</td>
<td>11.64</td>
</tr>
<tr>
<td>5</td>
<td>What are the outcomes of patients cared for in exclusively CRNA-staffed Veterans Affairs (VA) healthcare facilities compared with VA facilities using other anesthesia staffing models?</td>
<td>Practice</td>
<td>11.63</td>
</tr>
<tr>
<td>6</td>
<td>What is the most efficient and cost-effective model of various patient, provider, and payer mixes?</td>
<td>Policy</td>
<td>11.51</td>
</tr>
<tr>
<td>7</td>
<td>What are the workforce needs for anesthesia providers in the US healthcare system in the next 10 years?</td>
<td>Policy</td>
<td>11.39</td>
</tr>
<tr>
<td>8</td>
<td>Does the recent nonsurgical pain management specialty in nursing anesthesia increase access to underserved populations?</td>
<td>Education/Practice</td>
<td>11.39</td>
</tr>
<tr>
<td>9</td>
<td>What are the value-added services hospital administrators and stakeholders value most from an anesthesia practice group?</td>
<td>Practice</td>
<td>11.26</td>
</tr>
<tr>
<td>10</td>
<td>How will the VA adoption of full scope of practice potentially affect access and economic burden in the VA healthcare system for primary care services (including anesthesia)?</td>
<td>Policy/Practice</td>
<td>11.26</td>
</tr>
<tr>
<td>11</td>
<td>Do outcomes in the military model of independent CRNA practice support the expanded use of this model in the nonmilitary anesthesia care setting?</td>
<td>Practice</td>
<td>10.89</td>
</tr>
<tr>
<td>12</td>
<td>What impact would the triple aim framework (access, quality, and affordability) have on CRNA-provided chronic pain management services in rural hospitals?</td>
<td>Policy</td>
<td>10.76</td>
</tr>
<tr>
<td>13</td>
<td>Can the application of Geographic Information Systems (GIS) demonstrate both an economic as well as access expansion and savings by allowing all anesthesia providers to practice at full scope of practice?</td>
<td>Policy/Practice</td>
<td>10.63</td>
</tr>
<tr>
<td>14</td>
<td>Outcomes in a medical direction model vs a medical supervision model of anesthesia delivery: a quality and cost analysis</td>
<td>Policy/Practice</td>
<td>10.13</td>
</tr>
<tr>
<td>15</td>
<td>What dimensions of anesthesia practice are going to be critical in determining a CRNAs readiness for rural anesthesia practice? What are the dimensions of rural anesthesia practice?</td>
<td>Practice</td>
<td>10.13</td>
</tr>
<tr>
<td>16</td>
<td>What antecedent knowledge and skills do students of nurse anesthesia require to practice independently in a small rural hospital setting?</td>
<td>Education</td>
<td>10.01</td>
</tr>
<tr>
<td>17</td>
<td>Does implementation of a Preanesthesia Evaluation Clinic reduce costs and improve patient satisfaction?</td>
<td>Practice</td>
<td>9.88</td>
</tr>
<tr>
<td>18</td>
<td>What are the outcomes of trauma patients cared for in exclusively CRNA-staffed American College of Surgeons Level I trauma centers compared with Level I trauma centers using other anesthesia staffing models?</td>
<td>Practice</td>
<td>9.76</td>
</tr>
<tr>
<td>19</td>
<td>What are the most common procedures being performed throughout the United States in various types of facilities, by various types of providers?</td>
<td>Education/Practice</td>
<td>9.76</td>
</tr>
<tr>
<td>20</td>
<td>What are the effects of a structured and ongoing CRNA preceptor faculty development program on SRNA attrition in graduate nurse anesthesia programs?</td>
<td>Education</td>
<td>9.63</td>
</tr>
<tr>
<td>21</td>
<td>What is the projected vacancy rate of CRNAs in hospitals and surgery centers?</td>
<td>Policy</td>
<td>9.38</td>
</tr>
<tr>
<td>22</td>
<td>What is the personal and societal rate of return to educating various healthcare providers (can include multiple types of ARNP, PAS, AA, MD, etc)?</td>
<td>Education/Policy</td>
<td>9.26</td>
</tr>
<tr>
<td>23</td>
<td>What are the effects of emotional intelligence testing and education on minority SRNA attrition in graduate nurse anesthesia programs prior to matriculation and during the didactic and clinical phase of the program?</td>
<td>Education</td>
<td>9.25</td>
</tr>
<tr>
<td>24</td>
<td>What are the morbidity and mortality rates for the 50 or 100 most common surgical procedures performed in the United States?</td>
<td>Practice</td>
<td>8.76</td>
</tr>
</tbody>
</table>

**Table 1. Questions Submitted by Health Services Research Ad Hoc Committee and Round 1 Survey Results**

Abbreviations: AA, anesthesiologist assistant; CEO, chief executive officer; CFO, chief financial officer; CMO, chief medical officer; CNO, chief nurse officer; CRNA, Certified Registered Nurse Anesthetist; MD, physician; PA, physician assistant; SRNA, student registered nurse anesthetist.

*The mean composite score of the 3 statements was calculated using a 5-point Likert scale (1 indicated disagree; 2, somewhat disagree; 3, neutral; 4, somewhat agree; and 5, agree).*

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and Practice (n = 7). To reduce individual biases, the project staff did not alter any of the 24 original questions that were submitted by the HSR-AHC, nor was the identity of the submitters revealed to the committee. Using an electronic survey tool, the HSR-AHC members anonymously evaluated each of the 24 research questions using a 5-point Likert scale. After the mean composite scores were compiled, 8 unique research questions with a ranking score above 11.0 underwent further evaluation. The highest ranking research questions revealed that committee members gravitated more toward questions under the policy domain relative to the other domains.

- **Consensus Meeting 1 Proceedings.** Each HSR-AHC member was asked to choose, justify, and defend 1 of the top 8 ranked questions during the first consensus meeting. All the HSR-AHC committee members were present and represented their respective affiliates (see Acknowledgments section). The meeting was moderated by Lorraine Jordan, PhD, CRNA, CAE, FAAN, chief executive officer of the AANA Foundation and the executive sponsor for this project. Six of the 8 top-ranked questions were defended and discussed; based on the proceedings, it was decided that 2 of the 6 questions would be eliminated from priority consideration due to issues regarding feasibility (eg, lack of accessibility to the necessary data) and/or because of the impact (eg, pain management).

- **Round 2 Survey Results and Consensus Meeting 2 Proceedings.** A second anonymous survey was conducted to prioritize the top 3 research questions followed by a second consensus meeting to finalize the proposed HSR questions for the 2016 fiscal year. In this second survey, the members were asked to rank the 4 remaining research questions by priority (first, second, third). The final top 3 questions were prioritized as follows (Table 2):

1. How do healthcare administrators (practice and payer) value the cost and care that CRNAs provide in their facilities?
2. Has patient access to care (surgical, obstetrical, endoscopy, dental services, and pain management) improved in states that have opted out of physician supervision?
3. Does legislative adoption of the Advanced Practice Registered Nurse (APRN) consensus model result in an increased scope of practice for APRNs?

**Discussion**

The HSR Agenda for nurse anesthesia was developed using a systematic method. The modified Delphi process used to establish this agenda is optimal because the opinions of each participant representing different affiliates are weighted equally compared with a consensus in-person process in which a few influential participants may prevail and control the outcomes. In brief, the Delphi method involves a formal group process originally developed by the RAND Corporation in Santa Monica, California, to assess long-term trends in science and technology, and their anticipated effects on society.8 9 Over the last decade, researchers have increasingly used the Delphi tech-
nique to identify research priorities in nursing and other specialties.2-7,11 Key components to a Delphi process include anonymity, iteration, controlled acquisition of feedback, and analytic aggregation of responses.9 In addition, the process is structured and transparent and adds validity to the results.

The 24 research questions submitted and ranked by the HSR-AHC members are presented in this article and encompass various HSR topics under the research domains of policy, education, and practice. Compared with the initial AANA and AANA Foundation Research Agenda published in 2014, which spanned a broad range of topics, the updated HSR Agenda offers investigators questions with greater detail that can be considered and further delineated. For example, the top-rated healthcare policy question “How do healthcare administrators (practice and payer) value the cost and care that CRNAs provide in their facilities?” replaced the previous top-rated question from 2014: “What is the impact of nurse anesthesia care?”

This focused HSR agenda systematically highlights important gaps in knowledge about nurse anesthesia as identified. The questions posed in the HSR Agenda were assessed for potential feasibility and are believed to exert a sustained powerful influence in the nurse anesthesia profession. Seasoned CRNA researchers and nurse anesthesia students interested in pursuing high-impact HSR research may choose to concentrate their efforts by focusing or modifying the questions posed in the HSR agenda. Furthermore, the key stakeholder organizations can continue to strengthen HSR efforts by strategically establishing their research programs in the areas of highest need. Finally, this HSR agenda may help funding organizations in allocating limited grant resources to the areas of most need and interest. Through all of these mechanisms, such a research agenda may advance the field of nurse anesthesia forward by promoting change, enhancing practice, or informing policy.

REFERENCES

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Jihan Quraishi, MS, RN, AE-CC, CCRC, is the assistant director of research and quality in the AANA Research and Quality Division.

DISCLOSURES
The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.

ACKNOWLEDGMENTS
The authors acknowledge the enthusiasm and ownership on the part of the Health Services Research Ad Hoc Committee members who participated in this project and hope this project will encourage them and other colleagues to support ongoing research efforts. The AANA Foundation was represented by Ron Castaldo, PhD, MBA, MS, CRNA, CCRN, and Maria (Sallie) Poepsel, PhD, CRNA, APRN. The AANA was represented by Maribeth Massie, CRNA, and Kathryn Waud White, DNP, MA, CRNA. The Council on Accreditation of Nurse Anesthesia Educational Programs was represented by Paul Austin, PhD, MSN, CRNA, and Cormac O’Sullivan, PhD, CRNA, ARNP. The National Board of Certification and Recertification for Nurse Anesthetists was represented by Kevin Driscoll, MS, CRNA, and Charles Vacciano, PhD, CRNA, FAAN.

Table 2. Round 2 Survey Results and Health Services Research Project Prioritization

<table>
<thead>
<tr>
<th>Rank</th>
<th>Mean score</th>
<th>Domain</th>
<th>Research question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.38</td>
<td>Policy/Practice</td>
<td>Root question: What are hospital administrators’ (CEOs, CFOs, CMOs, CNOs) perceptions of CRNA anesthesia services in their institutional settings? (variations by type of hospital, location by state, location by rural vs city)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Revised question: How do healthcare administrators (practice and payer) value the cost of the care provided by CRNAs in their facility?</td>
</tr>
<tr>
<td>2</td>
<td>2.63</td>
<td>Policy</td>
<td>Has patient access to care (surgical, obstetrical, endoscopy, dental services, and pain management) improved in states that have opted out of physician supervision?</td>
</tr>
<tr>
<td>3</td>
<td>2.25</td>
<td>Policy</td>
<td>Does legislative adoption of the Advanced Practice Registered Nurse (APRN) consensus model result in an increased scope of practice for APRNs?</td>
</tr>
</tbody>
</table>

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Evaluation of Testing as a Method to Assess Continued Competency in Nurse Anesthesia Practice: A Systematic Review

Dru Riddle, PhD, DNP, CRNA
Kathy Baker, PhD, RN, ACNS-BC, FAAN
Alysha Sapp, MLIS

Competency in healthcare practice has become a priority for sustaining the goals of quality and safety in patient care delivery. Evaluating maintenance of competency for practitioners beyond their initial licensure and credentialing has become a topic of focus in recent years. A systematic review was conducted to evaluate testing as a method of assessing continued competency in nurse anesthesia practice. Using the Joanna Briggs Institute method for a comprehensive systematic review, a literature search followed by critical appraisal of included manuscripts was performed. Sixty-three published and unpublished manuscripts were included in this systematic review. Testing should be used solely for the purpose of assessing knowledge necessary for current practice unique to the individual test taker. Testing should reflect real life and should allow the test taker access to materials and resources normally available in the provision of patient care.

Keywords: Assessment, competency, recertification, systematic review testing.

Competency in healthcare practice has become a priority for sustaining the goals of quality and safety in patient care delivery. Evaluating maintenance of competency for practitioners beyond their initial licensure and credentialing has become a topic of focus recently. Traditionally, recertification in a healthcare practitioner's specialty area has been accepted as a reflection of maintenance of competency. Testing, as a component of recertification activities in healthcare specialties, has become widely used internationally.

Questions have surfaced regarding the appropriateness of recertification by testing as a method of competency assessment. A systematic review was therefore initiated to determine the effectiveness of testing as a method of assessing continued competence in nurse anesthesia practice. A literature synthesis has allowed us to develop working definitions of competency and competence to guide the systematic review. For the purposes of this systematic review, the following working definitions were used as they most accurately capture the literature at large:

**Competency:** "An observable ability of a health professional, integrating multiple components such as knowledge, skills, values, and attitudes. Since competencies are observable, they can be measured and assessed to ensure their acquisition."

**Competence:** "The array of abilities (knowledge, skills, and attitudes) across multiple domains or aspects of performance in a certain context. Statements about competence require descriptive qualifiers to define the relevant abilities, context, and stage of training. Competence is multi-dimensional and dynamic. It changes with time, experience, and setting."

Additionally, this systematic review is based on 3 assumptions underpinning formulation of the review question, search of the literature, and synthesis of all findings:

1. Recertification is not optional. (The merits of the value of recertification were not explored.)
2. Testing as a method of assessing continued competence was examined only as it related to healthcare professions.
3. Testing was conceptualized as a traditional examination (paper and pencil or computer testing).

Reported in this article are the results of a complete systematic review evaluating testing as a means of assessing continued competency in practice.

**Methods**

A 3-step search strategy aimed to find both published and unpublished studies. An initial limited search of PubMed/MEDLINE and Cumulative Index to Nursing & Allied Health Literature (CINAHL) was undertaken followed by analysis of keywords contained in the title and abstract and the index terms used to describe the article (Table 1). A second search using all identified keywords and index terms was undertaken across all included databases. Finally, the reference list of all identified manuscripts was hand searched for additional studies. Studies published in English language were included and no limits were placed on dates. The databases, websites, and gray literature search engines searched were as follows:

American Association of Nurse Anesthetists (AANA), Cumulative Index to Nursing & Allied Health Literature (CINAHL), Education Resources Information Center (ERIC), HealthSTAR, HealthWeb, Hospital Literature, Internet Search Engines, Knowledge Management System (KMS), LILACS, Medline, Medical Health Literature (MEDLINE), Medormen, MENTRIS, National Library of Medicine (NLM), online databases, PubMed, and the Virtual Health Library (VHL).
CINAHL, MEDLINE Complete, Web of Science, Embase, Academic Search Complete, Eric, Education Source, ProQuest Nursing and Allied Health Source, ProQuest Dissertations & Theses, National Board of Certification and Recertification for Nurse Anesthetists (NBCRNA), Castle Worldwide, MedNar, and Cochrane Central Register of Controlled Trials. Complete results of the literature review are available from the authors.

Inclusion criteria included any published manuscript in the English language that discussed testing as a method of assessing competence in nurse anesthesia practice, advanced nursing practice, medicine, and other advanced healthcare practice (pharmacy, physician assistant). To be included, manuscripts must have directly addressed the relationship between testing and assessment of continued competency. Manuscripts were excluded if they did not address testing as a means of assessing continued competency in some form of advanced healthcare practice (advanced decision making, prescriptive decision making, diagnostic testing, etc). No limits were placed on publication date to ensure a robust review of all available evidence.

All manuscripts selected for retrieval were assessed by 2 independent reviewers for methodologic quality using the Joanna Briggs Institute critical appraisal instruments appropriate for the article type. Based on this assessment, manuscripts were assigned a grade of A (critical analysis), B (substantiated expert opinion), or C (expert opinion). Grade A manuscripts were based on a formal process of literature review or research methods. Grade B manuscripts were expert opinions that were substantiated with scientific references. Grade C manuscripts were expert opinion only and not based on scientific references.

Data were extracted using the standardized data extraction tool JBI-NOTARI. Extracted data were then pooled using aggregation and synthesis of findings to generate a set of statements. These findings were then categorized based on similarity in meanings and accounting for their quality. These categories were then subjected to a meta-synthesis in order to produce a single set of comprehensive findings that can inform decisions about testing as a means of assessing continued competence.

Results
Manuscripts selected for inclusion are summarized in Table 2. A total of 63 manuscripts were included in this review (Figure). Manuscripts included critical analyses, correlational studies, white papers and position statements, substantiated expert opinions, and expert opinions.

Two synthesized findings emerged:
1. Testing is a valid, reliable, and proven method of assessing the knowledge component of competency, but not competency in total.
2. Testing is not a means by which the concept of competence is directly measured.

Table 1. Initial Keywords and Index Terms

<table>
<thead>
<tr>
<th>Initial Keywords and Index Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-certification OR revalidation</td>
</tr>
<tr>
<td>Recertification</td>
</tr>
<tr>
<td>&quot;re-certification&quot;</td>
</tr>
<tr>
<td>&quot;simulation test*&quot;</td>
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<tr>
<td>Test*</td>
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<tr>
<td>Exam*</td>
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<tr>
<td>Competence* (clinical) OR (continued)</td>
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<tr>
<td>Knowledge</td>
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<tr>
<td>Health</td>
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<td>Medicine</td>
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<tr>
<td>Nurse*</td>
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<tr>
<td>CRNA</td>
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<tr>
<td>Anesthesia</td>
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<tr>
<td>&quot;quality improvement&quot;</td>
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<tr>
<td>&quot;evaluation method&quot;</td>
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This review synthesizes the entirety of available literature evaluating testing as a means of assessing continued competency in practice. Manuscripts included in these findings represent the current body of knowledge addressing testing as a means of assessing continued competency across nurse anesthesia, advanced practice nursing, pharmacy/allied health, and medicine. The findings of 43 manuscripts (68%) were used to formulate the first synthesized finding above, and the findings of 32 manuscripts (51%) were used for formulating the second synthesized finding. Twelve (19%) of the 63 manuscripts had findings that informed both findings.

Testing has been well established as a valid and reliable method of assessing knowledge across a variety of disciplines and contexts. As a method of assessing knowledge, testing should not be used in isolation to assess competency because knowledge is only one component of competency in anesthesia practice. Competency is complex and difficult to adequately assess using a single method. Current literature suggests the best method of assessing continued competency is through a comprehensive program of evaluation, including testing, along with peer evaluation of practice.

Recommendations
Based on this review, several recommendations can be made to direct future decisions:

1. Testing, if used as part of a recertification process, should be used solely for the purpose of assessing knowledge.
2. Testing, if used as part of a recertification process, should be used to assess knowledge necessary for current practice unique to the individual test taker.
3. Testing, if used as part of a recertification process, should reflect “real life” and should therefore allow the examinee access to materials and resources normally available in the provision of patient care.
<table>
<thead>
<tr>
<th>Author*</th>
<th>Manuscript type</th>
<th>Assessment of quality</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nurse anesthesia</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Haag,12 1992</td>
<td>Editorial</td>
<td>B</td>
<td>Testing ensures public CRNAs have knowledge to be safe.</td>
</tr>
<tr>
<td><strong>Advanced practice nursing</strong></td>
<td></td>
<td></td>
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<tr>
<td>Meadows et al,14 2014</td>
<td>Editorial</td>
<td>B</td>
<td>Examinations provide evidence of knowledge.</td>
</tr>
<tr>
<td>Fullerton &amp; Thompson, 1985</td>
<td>Critical analysis</td>
<td>A</td>
<td>Entry-level examination can be used to recertify candidates in nurse midwifery.</td>
</tr>
<tr>
<td>Hsia,15 1981</td>
<td>Editorial</td>
<td>C</td>
<td>Competence is not defined by a single measure; testing is an assessment of knowledge.</td>
</tr>
<tr>
<td><strong>Pharmacy/allied health</strong></td>
<td></td>
<td></td>
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<tr>
<td>Harries,19 2006</td>
<td>Editorial</td>
<td>B</td>
<td>Testing for recertification only assesses knowledge.</td>
</tr>
<tr>
<td>Maslanka et al,32 1991</td>
<td>Editorial</td>
<td>C</td>
<td>Testing is a poor tool to measure competence.</td>
</tr>
<tr>
<td>Huntington,10 1990</td>
<td>Editorial</td>
<td>C</td>
<td>Testing does not assess competence.</td>
</tr>
<tr>
<td>Jarski &amp; Heinrich,31 1986</td>
<td>Literature review</td>
<td>A</td>
<td>No valid method of assessing competency.</td>
</tr>
<tr>
<td>Campbell &amp; Glazer,16 1984</td>
<td>Quantitative correlation</td>
<td>A</td>
<td>Positive correlation between certification and recertification performance as it relates to physician assistant knowledge.</td>
</tr>
<tr>
<td>Zappacosta,17 1982</td>
<td>Editorial</td>
<td>C</td>
<td>Testing should be required to measure core knowledge related to recertification.</td>
</tr>
<tr>
<td><strong>Medicine</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>McDonnell,33 2015</td>
<td>Editorial</td>
<td>C</td>
<td>Small, focused tests over time are better than 1 large test to assess knowledge.</td>
</tr>
<tr>
<td>Kesavan et al,24 2015</td>
<td>Process analysis</td>
<td>B</td>
<td>Testing assesses knowledge of newer studies, not whether the newer studies are useful in practice.</td>
</tr>
<tr>
<td>Teirstein,40 2015</td>
<td>Translational science</td>
<td>B</td>
<td>Tests for recertification are not tailored for an individual practice; problems with testing might limit their usefulness.</td>
</tr>
<tr>
<td>Ting et al, 2014 (J Am Coll Cardiol; 63(1):92-100)</td>
<td>White paper update</td>
<td>B</td>
<td>Tests determine if the provider has core knowledge.</td>
</tr>
<tr>
<td>Gabb,39 2014</td>
<td>Editorial</td>
<td>B</td>
<td>Testing determines what providers are capable of doing, not what they can actually do.</td>
</tr>
<tr>
<td>Culley et al,34, 2013</td>
<td>Survey</td>
<td>A</td>
<td>Cognitive examination is not related to clinical practice.</td>
</tr>
<tr>
<td>Statman et al,27 2013</td>
<td>CME activity</td>
<td>A</td>
<td>Relationship between MOC examinations and quality; examination should apply to personal practice.</td>
</tr>
<tr>
<td>Iglehart &amp; Baron,25 2012</td>
<td>Health policy brief</td>
<td>A</td>
<td>Testing is contradictory to teaching and practice; examinees should be able to use resources to find missing knowledge.</td>
</tr>
<tr>
<td>Buscemi et al,36 2012</td>
<td>Literature review</td>
<td>A</td>
<td>Test scores do not predict complex practice behaviors.</td>
</tr>
<tr>
<td>Kelly, 2012 (Educ Prim Care; 18(6):697-703)</td>
<td>Survey</td>
<td>A</td>
<td>Testing for knowledge as a component of recertification is supported by 49% of physicians in Scotland.</td>
</tr>
<tr>
<td>Strasburger,29 2011</td>
<td>Editorial</td>
<td>C</td>
<td>Testing should be a component of recertification but should allow access to resources to reflect modern clinical practice.</td>
</tr>
<tr>
<td>Cragno,7 2011</td>
<td>Editorial</td>
<td>C</td>
<td>Multiple-choice tests are designed to measure what is known, not what could be done in every clinical situation.</td>
</tr>
<tr>
<td>Author</td>
<td>Manuscript type</td>
<td>Assessment of quality</td>
<td>Findings</td>
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<tr>
<td>Mahmood, 2010 (Best Pract Res Clin Obstet Gynaecol; 24(6):807-818)</td>
<td>White paper</td>
<td>A</td>
<td>Testing for recertification should be only 1 component of practice evaluation; competency is more than knowledge.</td>
</tr>
<tr>
<td>Weissman,23 2010</td>
<td>Editorial</td>
<td>C</td>
<td>Testing assesses knowledge of the particular subject matter at 1 point in time.</td>
</tr>
<tr>
<td>Mahmood, 2009 (CMAJ;179:979-980)</td>
<td>Editorial</td>
<td>B</td>
<td>Public demands testing for recertification; test scores correlated with patient outcomes in internal medicine.</td>
</tr>
<tr>
<td>McKinley, 2008 (Gynecol Oncol;111(3):389-390)</td>
<td>Editorial</td>
<td>B</td>
<td>Tests for recertification only assess only knowledge necessary to provide high-quality care.</td>
</tr>
<tr>
<td>Burge, 2007</td>
<td>Issue paper</td>
<td>B</td>
<td>Tests should be used to assess knowledge and should allow access to resources.</td>
</tr>
<tr>
<td>Rhodes,20 2007</td>
<td>Correlational study</td>
<td>A</td>
<td>Strong correlation between CME activity, recertification test scores; knowledge is assessed by the recertification exam.</td>
</tr>
<tr>
<td>Pulse, 28 2006</td>
<td>Editorial</td>
<td>C</td>
<td>Impossible to test all knowledge necessary for practice; knowledge does not equate to competency.</td>
</tr>
<tr>
<td>Cassel et al, 2005</td>
<td>Editorial</td>
<td>B</td>
<td>Knowledge does not always translate to proper practice; may know test answers only.</td>
</tr>
<tr>
<td>Steinbrook,22 2005</td>
<td>Editorial</td>
<td>B</td>
<td>Testing is a measurement of cognitive functions as it relates to recertification.</td>
</tr>
<tr>
<td>Norcini, 2005 (Br Med J;330(7506):1458-1459)</td>
<td>Editorial</td>
<td>B</td>
<td>If testing occurs, must provide specific feedback and solutions to improve.</td>
</tr>
<tr>
<td>Batmangelich et al, 2004 (U Contin Educ Health Prof;24(3):134-138).</td>
<td>Progress report</td>
<td>B</td>
<td>Knowledge is the foundation of the Miller pyramid and is best assessed by a test.</td>
</tr>
<tr>
<td>College of Certification Canada, 2004 (CMAJ;171:301-301)</td>
<td>Editorial</td>
<td>B</td>
<td>Complexity of practice means a test is not practical to assess what knowledge is really needed for practice.</td>
</tr>
<tr>
<td>Melnick, 18 2004</td>
<td>Literature review</td>
<td>A</td>
<td>Testing assesses knowledge but is better in small time intervals as a continuous process.</td>
</tr>
<tr>
<td>Madewell et al, 35 2004</td>
<td>White paper</td>
<td>C</td>
<td>Cognitive expertise is evaluated by a test.</td>
</tr>
<tr>
<td>Kiodas, 41 2002</td>
<td>Editorial</td>
<td>C</td>
<td>Passing a test does not mean competence.</td>
</tr>
<tr>
<td>Source</td>
<td>Type</td>
<td>Grade</td>
<td>Summary of Findings and Quality</td>
</tr>
<tr>
<td>------------------------</td>
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<tr>
<td>Scerra, 2001</td>
<td>Presentation</td>
<td>C</td>
<td>Recertification examination should be open book so participants can demonstrate how they can find information; tests do not measure competence.</td>
</tr>
<tr>
<td>Moss, 2001</td>
<td>Review</td>
<td>A</td>
<td>Tests assess knowledge, but this is only 1 component of competence.</td>
</tr>
<tr>
<td>Cunningham, 2000</td>
<td>Editorial</td>
<td>B</td>
<td>Test must start from the premise that the clinician is already competent.</td>
</tr>
<tr>
<td>Siker, 1999</td>
<td>Review</td>
<td>B</td>
<td>Testing measures knowledge but not competence.</td>
</tr>
<tr>
<td>Bashook et al, 1998</td>
<td>Practice analysis</td>
<td>A</td>
<td>Tests are a snapshot of knowledge at 1 point in time.</td>
</tr>
<tr>
<td>Cavanaugh, 1995</td>
<td>Editorial</td>
<td>C</td>
<td>Tests for recertification are highly influenced by individual test-taking skills; tests do not reflect competence.</td>
</tr>
<tr>
<td>McClennan &amp; Herlihy, 1995</td>
<td>Survey</td>
<td>A</td>
<td>As practice years increase, recertification test scores decrease, reflecting a more focused practice not represented by a test.</td>
</tr>
<tr>
<td>Johanson, 1995</td>
<td>Editorial</td>
<td>C</td>
<td>Testing assesses knowledge; competence is determined at local level by peers.</td>
</tr>
<tr>
<td>Norcini, 1994</td>
<td>Review piece</td>
<td>B</td>
<td>Tests do not measure competence but do measure knowledge; should be a component of recertification.</td>
</tr>
<tr>
<td>ABA, 1990</td>
<td>White paper</td>
<td>C</td>
<td>Knowledge is measured by testing.</td>
</tr>
<tr>
<td>Slavin et al, 1995</td>
<td>Retrospective analysis</td>
<td>A</td>
<td>Tests assess knowledge and should be specific to individuals’ practice.</td>
</tr>
<tr>
<td>Trobe et al, 1980</td>
<td>Editorial</td>
<td>C</td>
<td>Tests can assess for only certain types of information and cannot examine clinical skills.</td>
</tr>
<tr>
<td>Chase &amp; Burg, 1977</td>
<td>Review</td>
<td>A</td>
<td>Tests are 1 component to evaluate competence.</td>
</tr>
<tr>
<td>Siker, 1976</td>
<td>Review</td>
<td>B</td>
<td>Knowledge is one component of competence and is best measured by tests.</td>
</tr>
</tbody>
</table>

**Table 2. Summary of Findings and Quality**

Abbreviations: CME, continuing medical education; CRNA, Certified Registered Nurse Anesthetist; MOC, maintenance of certification.

*a* List of reference sources is available upon request.

*b* Grade A was assigned to a critical analysis, such as a literature review or research study; B, substantiated expert opinion (with scientific references); and C, expert opinion (without scientific references).
4. Rigorous, controlled trials to examine the relationship between testing and patient outcomes are needed.

Many manuscripts speak to the notion of testing being used in recertification for the sole purpose of assessing knowledge.10-24 Iglehart and Baron25 state related to physician Maintenance of Certification (MOC) requirements, “Another concern is a requirement that a secure examination be completed without access to outside sources of information. This condition contradicts what medical students and residents are currently taught: They should take advantage of the best sources of information rather than rely entirely on their memory”. If testing is to be part of nurse anesthesia recertification, examinees should be granted access to resource material that would be readily available in the practice setting.

In our search, we were not able to locate a study linking testing and patient outcomes. Many manuscripts identified the need for determining the relationship between testing, patient outcomes, and best methods for assessing competency.25,31-44 It is recommended that rigorous, controlled trials are conducted to evaluate the relationship between testing and patient outcomes. This is important in nurse anesthesia practice as well as healthcare as a whole. Until these data are available, it is impossible to validate that performance on a test is linked to improved patient outcomes.

Limitations

This systematic review only evaluated and included manuscripts published in the English language. It is possible that manuscripts are available in other languages that are not included in this analysis. Bias is always a potential problem when conducting a systematic review, and bias could have influenced the process during this project. Steps were carefully taken to minimize bias; however, when synthesizing qualitative data, it is impossible to eliminate all sources of bias. Also, despite rigorous effort to include all published manuscripts related to the topic, it is possible that manuscripts were missed and were not included in this review. There is a clear lack of rigorous, controlled studies that evaluate the role of examinations in assessing continued competence. Findings in this review are based on the best available literature to date, which included low-level evidence.

Conclusion

Testing, if used as a component of a recertification process for nurse anesthesia, should be used to evaluate knowledge. Testing does not evaluate competency completely; rather, it assesses knowledge that may be necessary for competence. Peers in the practice setting best evaluate competence. It is recommended, based on the synthesis of literature, that testing be included as a component of knowledge evaluation in the bigger context of assessing competence for nurse anesthesia practice.21,25,29,30

If testing is to be used, it should not be used exclusively
to evaluate the test taker but should include a learning and reflection component to promote lifelong learning. Additional rigorously designed studies are needed to evaluate the relationship between testing and patient outcomes. These studies would further support the role of testing as part of practice recertification of nurse anesthetists.

REFERENCES


AUTHORS

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DISCLOSURES

The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.

ACKNOWLEDGMENTS

The authors wish to thank the AANA Continuing Education Committee for serving as a technical advisory group for this work. Funding for this work was provided by the AANA.
Laundering Methods for Reusable Surgical Scrubs: A Literature Review

Christina M. Vera, DNP, CRNA
Tony Umadhay, PhD, CRNA
Marquessa Fisher, DNP, CRNA

Surgical site infection is one of the most frequent and serious postoperative complications. Surgical site infections may be precipitated by high bacterial loads introduced into the operating room setting. The most common microorganisms contributing to infections are Staphylococcus, Streptococcus, and Pseudomonas. The potential for scrub uniforms to carry bacteria has been shown in several studies. Recommendations for surgical scrubs worn by operating room personnel and specific laundering techniques remain debated in evidenced-based research. There exists a variance in perception and a lack of consensus among providers regarding the concept of where and how to launder surgical scrubs. The purpose of this literature review is to determine if facility-laundered surgical scrubs are superior in the prevention of surgical site infections for patients undergoing surgery over home-laundering methods, to evaluate the appropriateness and safety of surgical staff laundering scrub uniforms at home, and to provide recommendations for the laundering of reusable surgical scrubs.

Keywords: Facility laundering of hospital garments, home laundering of hospital uniforms, hospital uniform laundering guidelines, laundering of surgical scrub uniforms.

Despite advances in modern-day medicine, surgical site infection (SSI) remains one of the most prevalent and costly postoperative complications. Surgical site infections contribute to an array of undesirable patient outcomes, including increased mortality, prolonged hospital stays, excess antibiotic use, and escalating indirect costs to patients from surmounting loss of productivity. It is reported that 300,000 to 500,000 cases of SSIs occur annually in the United States. The overall incidence varies from 0.2% for abdominal laparoscopic surgery to 3.7% for open sternal procedures. The global sequelae are a heightened annual cost and resource burden to the healthcare system, ranging from $28.4 billion to $45 billion.

Several factors influence SSI acquisition. Intrinsic elements, which cannot be modified, include patient age, type of surgery, coexisting diseases, and health state. Consequently, the paradigm shift is focused on extrinsic contributors to SSI, including adherence to best practices to decrease the incidence of SSI. Methods of extrinsic prevention, such as the administration of appropriately dosed and timed antibiotics and proper hand washing, are supported throughout the literature and adopted as the standard of care. Anesthesia providers and other surgical staff play a major role in the prevention of SSIs through proper laundering of surgical scrub uniforms worn in the operating room (OR). However, specific recommendations for the well-cited potential extrinsic influence of surgical scrubs and laundering techniques remain controversial, leaving providers with a deficit of recommendations for the laundering of scrubs in the home setting.

Establishing a relationship between contaminated scrubs and SSI incidence is difficult because of the vast causes of SSI. Moreover, the risk is dependent on the number and type of microbes, as well as resistance of the host. It is acknowledged that uniforms worn by healthcare workers become contaminated with microorganisms during patient care, notably during surgical procedures. It is logical to infer that SSIs may result from microbes present on scrubs worn by OR personnel. Given the importance of establishing the cleanest surgical conditions for the prevention of SSI, the proper laundering of scrubs is a major issue for staff.

This literature review will appraise evidence concerning the relationship between hospital uniforms and SSIs, primarily any differences noted between facility-laundered surgical scrubs (FLSS) and home-laundered surgical scrubs (HLSS). An analysis of infection control practices suggested by hospitals and infection control governing bodies will be presented along with evidence-based recommendations for the practice of laundering surgical scrub uniforms.

Literature Review Methods
An independently performed electronic search included the Cumulative Index to Nursing & Allied Health Literature (CINAHL), PubMed, MEDLINE, and Scopus databases. The search was limited to the English language, and the following search terms were applied in the
Table 1. Levels of Evidence by Melnyk and Fineout-Overholt

<table>
<thead>
<tr>
<th>Level</th>
<th>Type of design</th>
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<tbody>
<tr>
<td>I</td>
<td>Review/meta-analysis; randomized controlled trial</td>
</tr>
<tr>
<td>II</td>
<td>One or more randomized controlled trials</td>
</tr>
<tr>
<td>III</td>
<td>Controlled trial (no randomization)</td>
</tr>
<tr>
<td>IV</td>
<td>Case-control, cohort, or cross-sectional study</td>
</tr>
<tr>
<td>V</td>
<td>Systematic review; descriptive/qualitative study</td>
</tr>
<tr>
<td>VI</td>
<td>Descriptive or qualitative study</td>
</tr>
<tr>
<td>VII</td>
<td>Expert opinion</td>
</tr>
</tbody>
</table>

database searches: surgical scrubs, home laundering, bacteria prevention, hospital laundry, and surgical site infection prevention. A review was conducted electronically on infection control guidelines, including recommendations from the websites of the Centers for Disease Control and Prevention (CDC), Occupational Safety and Health Administration (OSHA), and Association of periOperative Registered Nurses (AORN).

Duplicate articles and titles with abstracts not deemed relevant were eliminated from review. Inclusion criteria for research articles were based on whether the article provided answers to the following questions:

- Can scrubs act as a vehicle for transferring bacteria?
- Is there a relationship between microbes found on scrub uniforms and SSI?
- What are the differences between facility laundering or home laundering in microbial decontamination?
- What are the current or suggested recommendations for the decontamination of surgical scrubs?

The search resulted in 75 articles related to the previously mentioned criteria. The research was classified using the Melnyk and Fineout-Overholt Evidence Appraisal classification tool (Table 1). Of the 75 articles, 30 met the criteria; 2 were randomized controlled trials, 10 were literature reviews, 18 were experimental studies, 4 were case reports, 1 was a cross-sectional survey, and 3 pieces of data were expert opinions (Table 2).

### Surgical Scrubs as a Vehicle for Microbial Transfer

Bacteria may be introduced into the OR despite stringent infection control protocols. Potential routes of transmission during surgery are multifactorial and include airborne, droplet, skin desquamation, direct contact with surgical personnel’s skin, and fomites, which are items placed near the surgical field that carry bacteria capable of transmission. Common fomites are clothing, hospital badges, personal bags, and pens. Limiting the number of fomites during surgery decreases the amount of bacteria transferred to the surgical site. However, this has not been correlated with decreased SSIs.

It has been identified that up to 60% of healthcare personnel’s uniforms may be contaminated with microorganisms. A myriad of publications emphasize the bacteria-carrying ability of hospital uniforms throughout workday activities. Research conducted on nursing and physician uniforms noted that bacterial counts on uniforms are higher at the end of the work shift, suggesting bacteria are spread through patient contact. Most bacteria found on uniforms consist of normal flora from the wearer and are found in highest concentrations on the scrub pants. This finding is the theoretical concern for anesthesia providers who routinely engage in close contact with patients lying in the supine position, thus exposing them to the higher-colonized level on the providers’ uniform while standing at the patient’s bedside.

The presence of pathogens and potential for vehicular transmission via scrub uniforms has been identified in both small-scale studies and randomized controlled trials. Whether this is clinically significant depends on whether scrubs are found to be pathogenic in environments where extreme cleanliness is imperative, such as the OR.

### Operating Room Scrub Uniforms and Surgical Site Infection

It has been estimated that an SSI will develop in as many as 5% of patients following surgery. The CDC details that the infection must manifest within 30 days after a surgical procedure to be cataloged as an SSI. The most common microorganisms contributing to SSI are Staphylococcus, Streptococcus, and Pseudomonas. The most influential factor associated with SSI is the quantity of bacteria transferred to the incision site, although there are no true human studies examining the exact amount of bacteria necessary to cause SSI. The quota of microbes requisite for infection is extremely fickle due to intrinsic factors such as varying bacterial species, type and length of surgical procedure, and age and immune status of the host.

Many successful extrinsic measures of infection control, such as proper hand washing and appropriate dosing and timing of perioperative antibiotics, have been shown to decrease SSI incidence, making them the standard of care. However, standards addressing the extrinsic influence of laundering hospital attire, particularly surgical scrubs, are lacking. Studies examining the bacterial contamination of hospital uniforms are evident, but identifying a definitive correlation between contaminated surgical scrubs and SSI is challenging. This may be attributed to the fact that assuming a 1.5% to 2.0% rate of SSI, establishing a statistical power greater than 80% would require a sample of nearly 10,000 patients to determine effects of 1 independent variable.

There is some evidence that ineffective washing of...
FLSS is linked with SSIs. One case report describes a microbial link between scrubs contaminated with large amounts of *Bacillus cereus* during prolonged neurologic surgery time, resulting in meningitis for 2 postoperative patients. It was later discovered that the infection was the result of improperly washed, contaminated facility laundry rather than surgical time and exposure of scrubs to the wound site.21

Additionally, the literature notes that scrubs improperly decontaminated in the home setting may be linked to SSI.22,23 A polymicrobial outbreak in patients who had undergone cardiac surgery is affirmed in 1 report, which cited microbial contamination in 14 of 22 postsurgical patients. Involved staff members’ wearing of scrubs and uniform jackets that had been home-laundered was reported as a strong correlate.22 A similar case study found 3 instances of *Gordonia bronchialis* sternal wound infection transmitted to patients by a healthcare worker.23 The findings determined that a nurse anesthetist, involved in all 3 surgeries, tested positive for *G bronchialis* isolated from scrubs and personal belongings.23 It was also noted that the nurse anesthetist’s home washing machine was harboring the bacteria, and it was a suspected vector causing subsequent cross-contamination in the home.23

Reports indicate that bacteria introduced to patients by healthcare providers’ uniforms may lead to SSI. However, few possible correlations between SSIs and the presence of OR staff wearing contaminated FLSS during surgery have been identified.22,23 Interestingly, research also shows that FLSS are linked to SSIs.21 There is minimal small-scale evidence currently available that bacteria harbored on scrub uniforms plays a major role in acquisition of SSIs, but the noted case reports imply that scrubs may retain some potential to cause infection.

**Facility Laundering Versus Home Laundering**

Cleaning uniforms serves the nonmicrobiologic function of restoring the wearer’s appearance and the microbiologic function of ridding the garment of microbes.38 According to OSHA, decontamination is the physical means to remove, inactivate, or destroy bloodborne pathogens from an item to the point at which it is no

<table>
<thead>
<tr>
<th>Source</th>
<th>Subjects/sample</th>
<th>Design</th>
<th>Purpose</th>
<th>Evidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burden et al,34 2011</td>
<td>100 residents and hospitalists</td>
<td>Randomized controlled trial</td>
<td>Compared bacteria on laundered scrubs after 8 hours</td>
<td>II</td>
</tr>
<tr>
<td>Burden et al,35 2013</td>
<td>105 hospitalists, nurses, physician assistants</td>
<td>Randomized controlled trial</td>
<td>Examined contamination with antimicrobial scrubs</td>
<td>II</td>
</tr>
<tr>
<td>McHugh et al,4 2014</td>
<td>Review of 50 articles on surgical attire and perception in SSI</td>
<td>Literature review</td>
<td>Identified current evidence, provided data for future studies</td>
<td>V</td>
</tr>
<tr>
<td>Fijan &amp; Turk,16 2012</td>
<td>Review of 57 articles on textiles and infection</td>
<td>Literature review</td>
<td>Identified current evidence, provided data for future studies</td>
<td>V</td>
</tr>
<tr>
<td>Loveday et al,33 2007</td>
<td>Review of 24 articles on importance of uniforms in prevention of infection</td>
<td>Literature review</td>
<td>Identified current evidence, provided data for future studies</td>
<td>V</td>
</tr>
<tr>
<td>Ibrahim et al,5 2011</td>
<td>Review of 107 articles on routes of bacterial transfer during cutaneous surgery</td>
<td>Literature review</td>
<td>Identified current evidence, provided data for future studies</td>
<td>V</td>
</tr>
<tr>
<td>Reichman &amp; Greenberg,20 2009</td>
<td>Review of 83 articles on reduction methods for SSI</td>
<td>Literature review</td>
<td>Identified current evidence, provided data for future studies</td>
<td>V</td>
</tr>
<tr>
<td>Al-Benna,6 2010</td>
<td>Review of 49 articles on laundering scrubs at home</td>
<td>Literature review</td>
<td>Identified current evidence, provided data for future studies</td>
<td>V</td>
</tr>
<tr>
<td>Belkin,30 2001</td>
<td>Review of 41 articles on effect of home laundering scrubs on SSI and home</td>
<td>Literature review</td>
<td>Identified current evidence, provided data for future studies</td>
<td>V</td>
</tr>
<tr>
<td>Patel et al,9 2006</td>
<td>6 squares of scrub fabric with <em>Staphylococcus aureus</em> washed in 4 different washing machines</td>
<td>Experimental</td>
<td>Evaluated if staff scrub uniforms could be decontaminated at home</td>
<td>VI</td>
</tr>
<tr>
<td>Speers et al,10 1969</td>
<td>68 nurses and 2 physicians in surgical ward</td>
<td>Experimental</td>
<td>Evaluated sources of uniform contamination</td>
<td>VI</td>
</tr>
<tr>
<td>Wong et al,11 1991</td>
<td>100 physicians in an urban general hospital</td>
<td>Experimental</td>
<td>Evaluated microbes and transmission on coats</td>
<td>VI</td>
</tr>
<tr>
<td>Hambraeus,8 1973</td>
<td>57 scrubs and cover gowns worn by nurses in burn unit</td>
<td>Experimental</td>
<td>Studied transfer of <em>S aureus</em> by nurses’ scrubs</td>
<td>VI</td>
</tr>
<tr>
<td>Twomey et al,12 2010</td>
<td>160 scrub suits; facility-laundered, third-party, and home-laundered, and single-use</td>
<td>Experimental</td>
<td>Assessed bioburden of scrubs and determined efficacy of laundering</td>
<td>VI</td>
</tr>
</tbody>
</table>

Table 2 continues ➔
longer capable of transmitting infectious particles. Decontamination is an act that consists of elements such as water temperature, detergents and chemicals added for cleaning, dilution, and time of the wash cycle. Laundering methods aimed at proper decontamination may decrease transfer of bacteria that have theoretically been associated with infection.

Facility laundering is the decontamination of textiles at accredited facilities following industry standards. The Healthcare Laundry Accreditation Council accredits laundry facilities that decontaminate healthcare textiles by incorporating OSHA and CDC guidelines. This includes quality control monitoring, testing water quality and temperatures, monitoring wash loads and measurements of detergents, and the duration of the washing cycle. Facility laundering typically uses a continuous-batch washing machine that decontaminates the items in the wash load at a minimum of 65°C for a minimum of 10 minutes, but more commonly at a temperature of 71°C for 3 minutes using bleach for grossly contaminated items.

In comparison, home laundering is the process of laundering uniforms in the home setting using a domestic home washing machine and dryer. Domestic washing machines typically operate at temperatures of 60°C for 30- to 40-minute cycles but have the ability to reach higher wash temperatures of 90°C. Newer domestic washing machines using the Energy Star technology consume 37% less energy and 50% less water than their counterparts. The trend toward lower temperature and water consumption and lack of regulation over home laundering has incited theoretical concerns of uniforms being ineffectively decontaminated in the home. Laundering of scrub uniforms at 71°C, per CDC recommendations, is not achievable using most home washing machines.

<table>
<thead>
<tr>
<th>Source</th>
<th>Subjects/sample</th>
<th>Design</th>
<th>Purpose</th>
<th>Evidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huang et al, 2006</td>
<td>Methicillin-resistant <em>S aureus</em> (MRSA) on fomites</td>
<td>Experimental</td>
<td>Examined survival time of MRSA fomites</td>
<td>VI</td>
</tr>
<tr>
<td>Wiener-Well et al, 2011</td>
<td>238 samples from 75 nurses and 60 physicians</td>
<td>Experimental</td>
<td>Examined attire as a source of infection</td>
<td>VI</td>
</tr>
<tr>
<td>Krueger et al, 2012</td>
<td>30 resident scrubs swabbed before and after a call shift</td>
<td>Experimental</td>
<td>Tested bacteria on scrubs before and after call shift</td>
<td>VI</td>
</tr>
<tr>
<td>Lakadavala et al, 2011</td>
<td>Scrubs from nurses in different wards</td>
<td>Experimental</td>
<td>Examined ironing and low-temperature wash</td>
<td>VI</td>
</tr>
<tr>
<td>Smith et al, 1987</td>
<td>20 samples of bacteria after varied temperature washes</td>
<td>Experimental</td>
<td>Tested efficacy of temperature for washing</td>
<td>VI</td>
</tr>
<tr>
<td>Walter &amp; Schillinger, 1975</td>
<td>10 swatches washed in 2 different washing machines</td>
<td>Experiment</td>
<td>Evaluated efficacy of laundering with varying times and temperatures</td>
<td>VI</td>
</tr>
<tr>
<td>Gerba &amp; Kennedy, 2007</td>
<td>Clothing and pillowcases soiled with rotavirus, adenovirus, and hepatitis</td>
<td>Experiment</td>
<td>Evaluated home laundering and bleach use on viral survival</td>
<td>VI</td>
</tr>
<tr>
<td>Orr et al, 2002</td>
<td>9 industrial laundries</td>
<td>Experiment</td>
<td>Assessed facility laundering</td>
<td>VI</td>
</tr>
<tr>
<td>Hammer et al, 2011</td>
<td><em>Trichophyton rubrum</em> and <em>Candida albicans</em> added in home laundry machines</td>
<td>Experimental</td>
<td>Examined dermatophytes seen during storage and after home laundering</td>
<td>VI</td>
</tr>
<tr>
<td>Jurkovich, 2004</td>
<td>Sample of 50 surgical scrubs: 30 home-laundered, 20 facility-laundered</td>
<td>Quasi-experimental pilot study</td>
<td>Determined microbes on facility vs home-laundered scrubs</td>
<td>VI</td>
</tr>
<tr>
<td>Barrie et al, 1994</td>
<td>Samples from hospital’s water supply and linens</td>
<td>Case report</td>
<td>Examined sources of contamination</td>
<td>VI</td>
</tr>
<tr>
<td>Nguyen et al, 2014</td>
<td>Staff present for surgeries interviewed and sampled</td>
<td>Case report</td>
<td>Described outbreak of 22 SSIs following surgery</td>
<td>VI</td>
</tr>
<tr>
<td>Wright et al, 2012</td>
<td>Samples of operating room environment</td>
<td>Case report</td>
<td>Described SSI following cardiac surgery</td>
<td>VI</td>
</tr>
<tr>
<td>Mangram et al, 1999</td>
<td>NA</td>
<td>Expert opinion</td>
<td>Position statement on laundering uniforms</td>
<td>VII</td>
</tr>
<tr>
<td>OSHA, 1991</td>
<td>NA</td>
<td>Expert opinion</td>
<td>Final bloodborne pathogens standard</td>
<td>VII</td>
</tr>
<tr>
<td>AORN (Braswell &amp; Spruce), 2012</td>
<td>NA</td>
<td>Expert opinion</td>
<td>Position statement on surgical attire</td>
<td>VII</td>
</tr>
</tbody>
</table>

**Table 2. Summary of Reviewed Studies**

Abbreviations: AORN, Association of periOperative Registered Nurses; NA, not available; OSHA, Occupational Safety and Health Administration; SSI, surgical site infection.
machine temperatures, and evidence suggests that bacterial eradication from clothing is less effective using lower temperatures. The use of bleach in the wash has also been found to reduce microorganisms found on uniforms that were home-laundered. However, the practice of adding bleach to home-laundered clothing is not a routine practice and cannot be ensured.

Some concern has been expressed regarding home-laundering techniques and the persistence of pathogens in domestic washing machines resulting in cross-contamination. Research shows the transfer of microbes from contaminated garments to other garments. For instance, it is possible for microorganisms to survive current home-laundering procedures and be transferred via wet laundry. However, some studies argue that microorganisms passed on to other clothing via domestic washers can be eradicated by drying or ironing, and evidence supports that washing uniforms at low-temperatures of 60°C to 65°C is effective for decontamination if drying or ironing is implemented after the wash. In fact, hospitals that have implemented HLSS policies have not cited increases in SSI rates and have found great financial reward. Additionally, bacteria found on surgical scrubs as a result of ineffective facility laundering or improper textile storage have led to questions on whether home laundering can provide an effective alternative for uniform decontamination.

Evidence comparing facility and home laundering of surgical scrubs in SSI prevention is lacking. The only study comparing these methods has concluded no difference exists in efficacy. The perceived advantage of regulatory bodies overseeing laundering facilities should be carefully stated because microbial testing is not a standard in facility-laundered textiles; thus, continual levels of contamination are not assessed. Finally, there is no compelling evidence that reveals HLSS are inferior to FLSS in SSI prevention, and unchanged SSI rates at hospitals that have initiated home-laundering programs suggest that home laundering may provide an acceptable choice for decontaminating scrubs.

Recommendations for Laundering of Scrub Uniforms
There is no nationally sanctioned scrub laundering method adopted as the standard of care. Practices for decontaminating scrubs have been largely left to institutional policy. Healthcare facilities often rely on organizational experts in infection control, such as the CDC, OSHA, and the AORN, during policy development. The CDC offers no recommendation on how or where to launder scrubs. Conversely, the AORN opines that after daily use, reusable surgical attire should be laundered in a facility-approved laundry. Furthermore, OSHA states that employers are required to launder employee-owned scrubs that have become visibly contaminated during work and concludes that scrubs not soiled with blood or virulent matter may be laundered at home.

When developing a surgical scrub policy, policymakers would be prudent to use the available evidence to establish a guideline for scrub uniform decontamination. Because of varying perceptions and lack of definitive evidence supporting one laundering method over another, data elicited in these studies would best be regarded in an equitable manner when one is establishing and enforcing a facility uniform policy. It is reasonable to allow for self-laundering of scrub uniforms by staff provided that they follow standard recommendations for employing a proper decontamination process at home (Table 3).

Future Recommendations for Study
The OR is a semirestrictive environment in terms of sterility and minimizing bacterial contamination. Hospitals are dynamic environments in which providers move from one area to another, leading to apprehension regarding the wearing of surgical uniforms outside designated semirestricted areas. This issue has been poorly examined and is certainly an area in which future research could expand. Likewise, more research is warranted regarding the wear of HLSS to and from the hospital. One recommendation is that clean surgical attire be donned in a designated changing location before entering semirestricted areas from nonrestricted areas, including outside environments such as the home setting. However, this suggestion errs on the side of caution, with awareness that

Table 3. Recommendations for Home Laundering of Scrubs

<table>
<thead>
<tr>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use a washing machine water temperature of at least 60°C for standard wash cycles.</td>
</tr>
<tr>
<td>Use bleach-based detergents when it would not adversely affect the garments’ quality.</td>
</tr>
<tr>
<td>Use the highest dryer settings and suggested to iron scrubs immediately after wash.</td>
</tr>
<tr>
<td>Always launder scrubs in a separate and last load, wash hands after handling laundry, and disinfect washer after removing.</td>
</tr>
<tr>
<td>Protect scrubs from recontamination by securing them in closed bags after laundering and donning them on arrival to the workplace.</td>
</tr>
</tbody>
</table>

*To ensure proper decontamination of scrubs, specific guidance should be provided for a home-laundering program to include recommendations derived from available research. Studies show that home laundering in temperatures between 40°C and 60°C is equally effective at decontaminating garments if proper decontamination measures are undertaken. Washing hospital textiles at less than 40°C has not been well studied. In fact, only one study confirmed the effective decontamination of linens at temperatures of 31°C, but the results are not clinically relevant because the linens were contaminated with bacteria not commonly implicated in SSIs.27*
scrub uniforms act as a vehicle for bacterial transmission and the environment plays a role in bacterial acquisition. Consequently, the current literature does not meet criteria for acceptable studies.42

Conclusion
Evidence shows that hospital uniforms become contaminated during typical patient care activities.8,10,11,17,18 Yet, evidence on the laundering of hospital uniforms is limited, and most of the research has examined only laundering routines for linens that have been artificially inoculated with microbes. Authors of some studies submit the possibility that home laundering is a safe and cost-effective method for decontamination.6,9,14,28,30 Indeed, there is insufficient evidence to conclude that home laundering is inferior to facility laundering in the level of decontamination.

Many hospitals mandate facility laundering of uniforms. Others allow staff to wash uniforms at home, with no new SSI outbreaks cited.30 During the current cost-reduction climate of today’s healthcare system, HLSS offers a financial solution for facilities.26,29,30 If HLSS programs are instituted, proper decontamination should be enforced and recommendations including proper handling of garments, wash temperatures, drying methods, and storage of HLSS should be provided. Ultimately, the decision to mandate specific surgical scrub laundering methods or guidelines will depend on institutional and provider preference.

REFERENCES


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**DISCLOSURES**

The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.
Variables measured in modern pulse oximetry apparatuses include a graphic pulse curve and a specified perfusion value (PV) that could be a sensitive marker for detecting differences in sympathetic activity. We hypothesized that there is a correlation between a reduction of PV and the time to eye opening after anesthesia with propofol-remifentanil. This study includes 29 patients, ASA physical status 1 or 2, scheduled for elective thyroid surgery. Main outcome measures were PV measured by pulse oximetry, heart rate, and noninvasive mean arterial blood pressure recorded before anesthesia, 15 minutes after induction, and at start of surgery, end of surgery, and eye opening at the end of anesthesia. Carbon dioxide ($P_{ET}CO_2$) and oxygen inspiratory ($F_I$-$PO_2$) and expiratory ($F_E$-$PO_2$) concentrations were measured at all times except before anesthesia. Results demonstrated that PVs before anesthesia and at eye opening were lower than 15 minutes after induction and at end of surgery ($P < .05$). The $P_{ET}CO_2$ and difference of $F_I$-$P_{ET}O_2$ increased at eye opening compared with the end of surgery ($P < .05$). We conclude that the pulse oximetry PV and the increased $P_{ET}CO_2$ could be useful variables to predict timing of recovery in terms of eye opening after intravenous anesthesia.

Keywords: Carbon dioxide, inspiratory and expiratory oxygen, intravenous anesthesia, perfusion, plethysmography, pulse oximeter.

Plethysmography is part of the monitoring equipment routinely used for assessment of patients during anesthesia to ensure adequate hemoglobin oxygen saturation ($SpO_2$). Pulse oximetry is a method of using a noninvasive technique to measure $SpO_2$ by the principles of spectrophotometry (eg, that the relative absorption of red and infrared light of the systolic waveform correlates to arterial blood oxygen saturations). Pulse oximetry also provides information about heart rate and changes in arterial blood flow that may occur because of fluctuations in blood pressure during anesthesia.

The plethysmography unit uses 2 light-emitting diodes with different wavelengths: 1 emitting visible red light at 660 nm and 1 infrared light at 940 nm measured by a light-sensitive phototransistor, which records the transmittance of the light in the tissue. Variables measured in modern pulse oximetry apparatuses include $SpO_2$, a graphic pulse curve, and/or a specified perfusion value (PV). Some studies have suggested that the amplitude of the PV may be sensitive to estimate the level of sympathetic activity. However, to the authors' knowledge, there are no standard values described for the awake patient, and the values probably are influenced by real-time changes caused by temperature, pain, and hypovolemia.

Earlier studies had used eye opening and/or orientation to person to verify the recovery time after anesthesia. In our previous study, the PV was found to be larger during deep anesthesia using 1.2 minimum alveolar concentration and to return toward baseline after the end of anesthesia, when the patient regains consciousness and reopens his or her eyes. This study also demonstrates that during induction and maintenance of anesthesia, PV and bispectral index values matched each other well. However, during the recovery phase the PVs returned to baseline levels faster than the bispectral index values.

The aim of the present study was to investigate whether PV is related to depth of anesthesia in terms of eye opening after intravenous anesthesia.

Materials and Methods

- **Ethics.** Ethical approval for this study according to the standards set in the Helsinki Declaration was provided by the Regional Ethics Committee, Lund, Sweden, in December 2013 (Dnr: 2013/780). Patients scheduled for elective thyroid surgery were enrolled by surgery reception nurses. Consent to participate in the study was received from each patient.

- **Patients.** The investigation included 30 patients, ASA physical status 1 or 2, at Skåne University Hospital, Lund, Sweden, from November 2012 to January 2013. Patients were considered for inclusion in the trial if they were more than 18 years of age and scheduled for elective thyroid surgery. Patients with known pulmonary or...
cardiovascular disease or receiving pharmacologic antihypertensive treatment were excluded. The study was prospective and descriptive.

**Experimental Procedure.** Before the start and throughout anesthesia, all patients were monitored as described here. Before induction, the first set of values (heart rate, noninvasive blood pressure, SpO₂, and PV) was recorded (time: preanesthesia). Intravenously, anesthesia was induced with propofol at 1 to 3 mg/kg and remifentanil at 0.8 to 1 μg/kg; suxamethonium (Suxameton), 1 mg/kg, was administered for muscle paralysis. Infusion of propofol at 3 to 4 mg/kg/h and remifentanil at 0.2 to 0.3 μg/kg/min volume was started and was measured with 2 syringe pumps (B Braun Perfusor Space, B Braun Melsungen AG). Ventilation was assisted manually with 0.8 L of oxygen via a semiopen circle system (4.5 L in volume) until tracheal intubation. Then by ventilator, patients were ventilated at a respiratory rate (RR) of 10/min to 12/min, with a fraction of inspired oxygen (FIO₂) at 0.35 in nitrogen by fresh gas flow of 5 L/min. The tidal volume (Vₜ) and RR were adjusted to maintain end-tidal carbon dioxide measured at the end of the endotracheal tube (PₑₜCO₂) at 33.8 mm Hg throughout the study. After 5 minutes, the fresh gas flow was adjusted to 0.5 L/min throughout the anesthesia period.

The second set of values (heart rate, noninvasive blood pressure, SpO₂, carbon dioxide expiratory partial pressure (PₑₜCO₂), inspiratory and expiratory oxygen partial pressure (FIO₂, PₑₜO₂) and PV was recorded 15 minutes after induction (time: anesthesia 15 minutes). Five minutes before surgical skin incision, the anesthesia provider increased the infusions of propofol to 6 mg/kg/h and remifentanil to 0.5 μg/kg/min. The values (heart rate, noninvasive blood pressure, SpO₂, PₑₜCO₂, FIO₂, PₑₜO₂, and PV) were recorded a third time 5 minutes after skin incision (time: start of surgery). After 15 minutes, propofol infusion was reduced to 4 mg/kg/h and remifentanil infusion was adjusted to 0.4 to 0.6 μg/kg/min dependent on the noninvasive mean arterial blood pressure (MAP) of patients. If MAP decreased below 55 mm Hg, patients received ephedrine, 5 to 10 mg intravenously. All patients received 3 to 5 mL/kg/h of 2.5% glucose solution with sodium (70 mmol/L), chloride (45 mmol/L), and acetate (25 mmol/L) intravenously. Thirty minutes before the expected end of the anesthesia, all patients received an opiate agonist, ketobemidone (5 mg) intravenously, to prevent postoperative pain.

At completion of the last skin suture, a third set of values was recorded (time: end of surgery). Intraoperative recovery time was defined as the time from the discontinuation of propofol-remifentanil at the end of surgery to eye opening when a fourth set of values (heart rate, noninvasive blood pressure, SpO₂, PₑₜCO₂, FIO₂, PₑₜO₂, and PV) were recorded (time: eye opening). When the patients opened their eyes, the mechanical ventilation was suspended.

### Table 1. Patient Characteristics (N = 29)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women (n)</td>
<td>21</td>
</tr>
<tr>
<td>Age, y</td>
<td>57 ± 18</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>75 ± 18</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.66 ± 0.1</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>26.7 ± 4.3</td>
</tr>
</tbody>
</table>

### Results

Patient characteristics are presented in Table 1. One patient was excluded from the study because of an atrial fibrillation discovered when the patient was connected to the ECG monitoring at the start of anesthesia. No other intraoperative problems were noted during the study. All patients recovered from anesthesia and left the postoperative unit in accordance with the routines assigned for the surgical procedure.

The values of propofol and remifentanil were significantly lower at preanesthesia compared with start of surgery and end of surgery (P < .05, Table 2). The values of noninvasive MAP were similar at preanesthesia vs the time point of eye opening but significantly higher compared with anesthesia 15 minutes and end of surgery (P < .05, Table 3). Heart rates were significantly higher at preanesthesia compared with all other time points (P < .05, see Table 3).
The values of PETCO2 and difference in FICO2 were larger at the time point eye opening compared with anesthesia 15 minutes and end of surgery (P < .05, Table 4). The values of difference in FICO2 were significantly larger at time point start of surgery compared with anesthesia 15 minutes (15 minutes after induction) and end of surgery. Values of perfusion were lower at preanesthesia and at eye opening compared with the total anesthesia period. Values of perfusion were lower at start of surgery compared with anesthesia 15 minutes.

Discussion
In the present study using propofol and remifentanil, the PVs increased between the periods of anesthesia 15 minutes and end of surgery. The PV thereafter returns

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**Table 2.** Propofol and Remifentanil Doses Administered

<table>
<thead>
<tr>
<th>Drug</th>
<th>Pre anesthesia</th>
<th>Anesthesia 15 min</th>
<th>Start of surgery</th>
<th>End of surgery</th>
<th>Eye opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propofol (mg/kg/h)</td>
<td>N/A</td>
<td>3.4 ± 0.3b</td>
<td>5.7 ± 0.4</td>
<td>4.1 ± 0.3</td>
<td>N/A</td>
</tr>
<tr>
<td>Remifentanil (μg/kg/min)</td>
<td>N/A</td>
<td>0.26 ± 0.04b</td>
<td>0.56 ± 0.06</td>
<td>0.49 ± 0.07</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Values are mean ± SD (N = 29). Values of propofol and remifentanil were statistically significantly lower at anesthesia 15 minutes (15 minutes after induction) compared with start of surgery and end of surgery.
*P* < .05 (1-way analysis of variance followed by Tukey and Scheffé post hoc tests).

**Table 3.** Comparison of Noninvasive Mean Arterial Blood Pressure (MAP) and Heart Rate

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre anesthesia</th>
<th>Anesthesia 15 min</th>
<th>Start of surgery</th>
<th>End of surgery</th>
<th>Eye opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP (mm Hg)</td>
<td>83 ± 18</td>
<td>61 ± 9b</td>
<td>65 ± 12b</td>
<td>65 ± 10b</td>
<td>76 ± 14</td>
</tr>
<tr>
<td>Heart rate (/min)</td>
<td>72 ± 14</td>
<td>62 ± 9b</td>
<td>65 ± 9b</td>
<td>64 ± 11b</td>
<td>64 ± 10b</td>
</tr>
</tbody>
</table>

*Values are mean ± SD (N = 29). Values of MAP and heart rate were statistically significantly larger in preanesthesia compared with anesthesia 15 minutes (15 minutes after induction), start of surgery, and end of surgery. Values of MAP were statistically significantly larger at eye opening.
*P* < .05 (1-way analysis of variance followed by Tukey and Scheffé post hoc tests).

**Table 4.** Comparison of Oximetry and Other Respiratory Values

<table>
<thead>
<tr>
<th>Value</th>
<th>Preanesthesia</th>
<th>Anesthesia 15 min</th>
<th>Start of surgery</th>
<th>End of surgery</th>
<th>Eye opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate (/min)</td>
<td>N/A</td>
<td>11 ± 1.5</td>
<td>11 ± 1.5</td>
<td>10 ± 1.3</td>
<td>10 ± 1.3</td>
</tr>
<tr>
<td>VT (mL)</td>
<td>N/A</td>
<td>498 ± 144</td>
<td>481 ± 148</td>
<td>493 ± 136</td>
<td>492 ± 132</td>
</tr>
<tr>
<td>PETCO2 (mm Hg)</td>
<td>N/A</td>
<td>32.3 ± 2.3</td>
<td>32.3 ± 2.3</td>
<td>33.0 ± 1.5</td>
<td>35.3 ± 1.5b,c</td>
</tr>
<tr>
<td>FICO2 (%)</td>
<td>N/A</td>
<td>34.3 ± 5.1</td>
<td>33.0 ± 3.1</td>
<td>34.9 ± 4.1</td>
<td>35.1 ± 5.8</td>
</tr>
<tr>
<td>PETO2 (%)</td>
<td>N/A</td>
<td>29.2 ± 5.2</td>
<td>275 ± 3.2</td>
<td>29.3 ± 4.4</td>
<td>28.8 ± 6.2</td>
</tr>
<tr>
<td>Difference in FI- PETO2</td>
<td>N/A</td>
<td>5.1 ± 0.7</td>
<td>5.6 ± 0.9b</td>
<td>5.5 ± 0.7b</td>
<td>6.3 ± 1.0b,c</td>
</tr>
<tr>
<td>SpO2 (%)</td>
<td>100 ± 1.3</td>
<td>100 ± 1.2</td>
<td>99 ± 1.8</td>
<td>99 ± 1.3</td>
<td>99 ± 1.1</td>
</tr>
<tr>
<td>Perfusion</td>
<td>1.7 ± 0.7</td>
<td>6.8 ± 3.5d</td>
<td>3.6 ± 2.4bd</td>
<td>5.7 ± 2.7d</td>
<td>1.9 ± 0.9c</td>
</tr>
</tbody>
</table>

*Abbreviations: FI, fraction of inspired oxygen; PETCO2, end-tidal carbon dioxide; PETO2, expiratory oxygen fraction; SpO2, oxygen saturation; VT, tidal volume.
*Values are mean ± SD (N = 29). Values for respiratory rate, VT, and SpO2 were similar at all time points. Values of PETCO2 were larger at time of eye opening compared with during the anesthesia period. Difference between FICO2 and PETO2 was significantly larger at start of surgery and time of eye opening compared with Anesthesia 15 minutes (15 minutes after induction) and end of surgery. Values of perfusion were lower at preanesthesia and at eye opening compared with the total anesthesia period. Values of perfusion were lower at start of surgery compared with anesthesia 15 minutes.
*Anesthesia 15 minutes; *P* < .05 (1-way analysis of variance followed by Tukey and Scheffé post hoc tests).
*End of surgery; *P* < .05 (1-way analysis of variance followed by Tukey and Scheffé post hoc tests).
*Preanesthesia; *P* < .05 (1-way analysis of variance followed by Tukey and Scheffé post hoc tests).
to baseline once the patient regains consciousness and reopens his or her eyes (Figure 3). We also observed after the end of surgery to the time of eye opening, during unchanged ventilations modes, an increase in $P_{ET}CO_2$ as well as an increase in the $F_1-P_{ET}O_2$ differences, which could indicate an increased metabolism. These findings are in line with those of Elizarov and colleagues, who observed a correlation between painful surgery and increased metabolism according to various surgical stimuli. Steinbrook and Concepcion also demonstrated an increased hemodynamic response when epidural local anesthetic with epinephrine was given, which resulted in an increased CO$_2$ production.

The aim of the present study was to investigate whether PV was related to the different time points during the anesthesia period. As mentioned in our results, we observed that at the start of surgery and during eye opening, the patient's PV was decreased, which might indicate an increased sympathetic activity between these time points. Other studies support these findings and demonstrate that the amplitude of the pulse curve may be a sensitive marker for changes in the sympathetic system, such as painful stimuli (eg, skin incision during anesthesia). In the present study, we therefore interpret, together with the increase in the CO$_2$ values and the increase in the oxygen consumption, that the differences in the PVs could mirror an increased adrenergic and/or metabolic response during the awakening phase. Our previous study using sevoflurane anesthesia showed a similar appearance. This earlier study also demonstrated that there was an increase in the PV throughout the anesthesia period and a strong agreement between the PV before induction of anesthesia and eye opening in the recovery phase. However, it is notable that the PVs during the intraoperative period are decreased with use of propofol-remifentanil in the present study (PVs of 6 to 7) vs our earlier study using sevoflurane (PVs of 9 to 10). We interpret this finding to be increased vascular dilation during use of an inhalational agent.

Our results must be interpreted with caution because changes in the plethysmographic waveform and the PV could be caused by a pharmacologic hypotension or...
hypovolemia. Other researchers demonstrate a strong correlation between plethysmographic wave amplitude and the arterial pressure waveform; both the plethysmographic waveform and the arterial waveform reflect the cardiac stroke volume.\(^1\)\(^2\)\(^3\) Other reasons could be that during a pressure ventilation technique, the amplitude of the plethysmographic waveform varies synchronously with the respiratory cycle.\(^2\)\(^3\) Furthermore, administration of adrenergic drugs normally provides a drug-induced vasoconstriction that reduces the pulse amplitude, with a lower PV as a result. However, the present study involved patients with ASA physical status 1 and 2 without any history of circulatory conditions, and no hypothermia or hypovolemia was recorded and no adrenergic drugs were given. It therefore seems reasonable to assume that the observed PVs reflect different depths of anesthesia.

Another limitation in the present study could be the small number of participants. However, considering the design of the study, we believed it was still possible to achieve convincing results since the results are based on adequate statistical power. We also believe that being able to more quickly detect patients’ physiologic changes could benefit patient safety, such as time of recovery phase, and presumably have an impact on patient flow according to the operating schedule. However, further studies are needed to determine if the PV is useful in other forms of anesthesia procedures to better predict recovery times by detecting adrenergic circulatory responses.

In conclusion, in hemodynamically stable patients, pulse oximetry PVs could be a useful variable to predict the timing of recovery in terms of eye opening after intravenous anesthesia.

REFERENCES

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DISCLOSURES
The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.
The purpose of this evidence-based, quality improvement practice project was to increase anesthesia providers’ knowledge and awareness of the taping practice for securing the endotracheal (ET) tube that increases the patient’s exposure to pathogens and the risk of nosocomial infections. A change in the taping practice by anesthesia providers was the desired outcome. Participants completed an anonymous questionnaire about their knowledge and use of a taping practice to secure the ET tube. They then received an in-service on ET tube taping, which included reading an investigator-developed article about the evidence regarding patient safety during securing of the ET tube. The project ran for 4 weeks. Final data collection followed, in which participants completed the same anonymous questionnaire.

After the intervention, there was strong agreement that the tape for securing the ET tube needs to be designated solely for this purpose. A Mann-Whitney U test demonstrated statistical significance (U = 55, P = .003). Additionally, anesthesia providers gave a strong indication that they would not use adhesive tape that had fallen to the floor (U = 78, P = .04, Mann-Whitney U test). This project demonstrated that a change in practice occurred after an intervention regarding securing the ET tube with adhesive tape.

Keywords: Anesthesia, anesthesia equipment, contamination, disinfection, hand hygiene.

Hospital-acquired infections (HAIs) pose a major concern for our patients. Approximately 440,000 patients develop HAIs annually in the United States, with surgical site infections and Clostridium difficile infections reported with the most frequency (36% and 30.3%, respectively). Although all patients with HAIs have an extended hospital stay, patients with methicillin-resistant Staphylococcus aureus (MRSA) stay the longest, with an additional 15.7 to 23.0 days, respectively. Furthermore, Zimlichman et al in their meta-analysis on the costs associated with HAIs, report that as many as 75% of HAIs are preventable.

Before anesthesia delivery, the anesthesia provider prepares the anesthetic location to ensure the functionality and the availability of equipment and supplies. Commonly, nonsterile adhesive tape is cut or torn and adhered to the anesthesia gas machine during this preparation. The tape will be used to secure the endotracheal (ET) tube to the patient’s face on induction of general anesthesia. The current practice for securing the ET tube with adhesive tape appears to be a benign task, yet research reveals that it increases the patient’s exposure to pathogens and pathogen transmission. Anesthesia providers have an important role in preventing pathogen exposure and pathogen transmission. The taping practice for securing the ET tube is a modifiable risk factor related to anesthesia care. With accepted best practices of infection prevention and control incorporated into the taping practice, anesthesia providers can lead in this effort to advance patient safety in this area.

• Literature Review. A literature review was conducted to determine whether the adhesive tape that is currently used, Durapore surgical tape (3M), permits the transmission of pathogens to the patient through this vector and, therefore, poses a significant risk to the surgical patient. The identification of the best current evidence involved searches of the following online electronic databases: MEDLINE/PubMed, The Cochrane Library, Cumulative Index to Nursing & Allied Health Literature (CINAHL), and SUMSearch. To capture the largest number of relevant citations available, the authors manually searched the reference lists of all articles obtained from any reports of research not already identified. Guidelines from professional, national, and international organizations were reviewed. The Food and Drug Administration Medical Device Classifications, the Centers for Disease Control and Prevention guidelines, and the US Federal Register were searched as well. The following keywords and word strings were used alone and in combination: anesthesia, anesthesia equipment, contamination, disinfection, hand hygiene, and operating room. The international literature search was limited to English-language articles published between 1974 and 2013. Items were included for review if the literature addressed 1 or all of the common elements of the taping practice, which are the tape, the anesthesia gas machine, and the anesthesia provider. Unpublished reports, research, and findings were not
The search yielded 31 items that met the inclusion criteria, with a minimum of 6 items addressing each of the common elements of the taping practice. The adhesive tape that is typically available in the clinical setting is contaminated. Many researchers have found tape, once outside its original packaging, to be contaminated. The bacteria found on the tape in these studies included *Pseudomonas*, *Escherichia coli*, *Klebsiella*, *Enterobacter*, coagulase-positive staphylococci, methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci, coagulase-negative staphylococci, and *Micrococcus* species. A 7-day bacteriologic survey of adhesive tape being used in a 16-bed intensive care unit of a 560-bed teaching hospital revealed that 8 of 23 rolls of tape yielded pure cultures. Harris et al. in a bacteriologic survey conducted in 3 hospitals in Australia, found 11 of 21 tape batches contained pathogens; specifically, MRSA or MRSA and vancomycin-resistant enterococci were identified. Redelmeier and Livesey, in a bacteriologic survey, found 74% of their tape specimens colonized with pathogenic bacteria. The inner layer of the tape had 2 of 42 specimens, and the outer layer had 59 of 80 specimens (*P* < .001). The evidence consistently found pathogens on the adhesive tape that is currently available.

Anesthesia gas machine and equipment contamination occurs despite disinfection. Munoz-Price et al. found in their environmental study at a 1,500-bed, county teaching facility that despite disinfection, 12.5% of the surfaces continued to have pathogens in their 43 operating rooms (*P* = .998). Research reveals that the likely contaminated items of the anesthesia gas machine included the flow control knobs, vaporizer dials, and the breathing system bags. Loftus et al. reported that stopcock transmission events with contamination occurred in 23% (126 of 548) of the cases, with 14 between-case and 30 within-case transmission events confirmed. Loftus et al. in their prospective observational study in 28 operating rooms, found that bacterial contamination of the operating room environment occurred in 89% (146 of 164) of cases studied. Interestingly, a patient does not need to have direct contact with the anesthesia gas machine, a part of the environment, for pathogen transmission to occur.

Otter et al. report that the presence of pathogens does not indicate the cause of the infection solely. According to their review, it does matter when considering that the environmentally associated nosocomial dose of pathogens to cause an infection can be low. They reported that “less than 15 S. aureus cells were sufficient to cause infection in experimental lesions, less than 1 CFU/cm² was sufficient to cause *C. difficile* in mice, and a single norovirus particle is thought to have the capacity to cause infection.” Furthermore, this adds evidence confirming that contaminated surfaces transmit pathogens that can be detrimental to patients.

Hand hygiene is important but often ineffective, and providers are often noncompliant with this prevention measure. Bacterial contamination during the delivery of anesthesia occurs often and is serious. Loftus et al. found that in 12% of the cases (17 of 146) that had bacterial contamination, the anesthesia providers were the origin of it. Munoz-Price et al. reported that during an 8-hour period, anesthesia providers performed only 13 hand disinfections but touched 1,132 objects. Biddle and Shah, in their observational study of anesthesia providers over a 4-week period, found a hand-hygiene failure rate ranging from 64% to 93%, with a mean aggregate failure rate of 82%. Evidence confirms that hand contamination, the inadvertent transmission of pathogens, and poor hand hygiene are associated with the current taping practice.

The primary purpose of this evidence-based quality improvement practice project was to increase anesthesia providers’ knowledge and awareness of the common elements of the taping practice for securing the ET tube that increase the patient’s exposure to pathogens and the risk of nosocomial infection. The secondary goal was to present taping practice guidelines for securing the ET tube with an education module for the anesthesia providers to improve patient safety. Overall, the desired outcome was a change in the anesthesia providers’ current taping practice for securing the ET tube due to this project to improve patient safety. If there were a change in the anesthesia providers’ perceptions related to pathogen exposure of the current taping practice, they would adopt the taping practice guidelines for securing the ET tube. This would be interpreted as a positive result of the project.

Materials and Methods

- **Project Design.** This evidence-based quality improvement project used a 1-group before-and-after design to measure differences between the groups with an 11-item anonymous questionnaire obtained from the anesthesia providers for data collection. Fixed-alternative and open-ended questions about a variety of issues related to cleanliness and the taping practice were used in the questionnaire developed by the principal investigator (L.K.). The anesthesia providers completed the same 11-item anonymous questionnaire at the end of the project, which ran for 4 weeks.

- **Sample.** A convenience sample was used, consisting of all the anesthesia providers of a 400-bed hospital in South Florida. Eighteen anesthesia providers agreed to participate (78% of 23); the participants included 5 anesthesiologists, 9 nurse anesthetists, and 4 nurse anesthesia residents. The anesthesia providers’ experience varied within their specialty. Both male and female anesthesia providers of different ethnicities participated.

- **Materials.** Criteria were established for the alternative tapes that would be used for this project. These
included a tape length of at least 76.2 cm (30 in), good adhesive quality, hypoallergenic, latex free, durable, and disposable. Most importantly, the tape needed to be a single patient use item, and each roll needed to be individually packaged. For securing the ET tube, it needed to be clean but not sterile. Currently, there are 5 tape products from 4 companies on the market for securing ET tubes, but not all of them met the criteria of this project. Durapore is commonly available in 2.5 cm × 9.14 m (1 in × 10 yd) multiple patient use lengths or in 2.5 cm × 1.37 m (1 in × 1.5 yd) single patient use lengths. Neither tape is individually packaged as a single-use item. Thus, they did not meet the criteria for inclusion in the project. TrioMed Antimicrobial Medical Adhesive Tape (TrioMed Corp) is not yet available for use in the US. It has an antimicrobial agent engineered into the product that is 99.99% effective against pathogens, including resistant organisms. It, too, did not meet the criteria for inclusion in the project. A precut foam adhesive ET tube holder tape (ET Tape, B&B Medical Technologies Inc) is marketed for patients who require a few days of ventilator support and must be wrapped around the patient's neck. It is packaged as a clean, single patient use item. This tape met the criteria for inclusion in the project. Last, a zinc oxide adhesive tape (Hy-Tape, Hy-Tape International Inc) is marketed for short-term use and longer-term ventilator-dependent patients. It can be packaged individually when it is assembled as part of a kit. It, too, met the criteria for the project. Thus, the 2 alternative tapes that met the inclusion criteria for this project were ET Tape and Hy-Tape.

- **Data Collection Procedure.** The institutional review boards of both the university and the hospital granted the project exempt status and determined that the project was a nonresearch activity. At the beginning of the project, the anesthesia providers were given a cover letter that explained the project and were asked to complete an 11-item questionnaire that focused on their knowledge of pathogen transmission related to anesthesia, the taping methods, tape requirements, and the role that anesthesia providers have in preventing pathogen transmission to patients. Immediately following the initial questionnaire, the anesthesia providers had an educational in-service at the hospital, where they read an evidence-based article given to them by the principal investigator. Over the period of the project, the anesthesia providers practiced at least 2 days per week in the facility. All anesthesia providers practiced at least 2 days per week in the facility. All anesthesia providers had been in practice for 11 or more years. All anesthesia providers practiced at least 2 days per week in the facility. All anesthesia providers had been in practice for 11 or more years. All anesthesia providers practiced at least 2 days per week in the facility. All anesthesia providers had been in practice for 11 or more years.

- **Instrumentation.** The data collection instrument was an 11-item investigator-developed questionnaire regarding the anesthesia provider's knowledge and use of a taping practice to secure the ET tube. All questions had multiple-choice answers except the last one, which asked to provide a short answer. Demographic data such as gender, provider type, years in practice, and job status was sought. In addition, the questionnaire asked the following:

1. What features do the anesthesia providers identify as attributes and deterrents of the taping practice before and after an education module?
2. What percentage of anesthesia providers were able to identify situations that increased the patient's exposure to pathogens when performing the taping practice before and after an education module?
3. What is the anesthesia provider's overall evaluation of the taping practice after an education module?
4. What is the rationale that anesthesia providers gave for failing to use the taping practice?
5. What are the recommendations that anesthesia providers give as a result of the taping practice?

The intervention involved the anesthesia providers reading an article given to them by the principal investigator. Over the period of the project, the anesthesia providers were to secure the ET tube for adult patients who required general anesthesia for elective surgery in the supine position using the alternative tapes and the taping practice presented. The anesthesia providers had 5 opportunities to secure the ET tube with the 2 alternative tapes. The intervention tool was an evidence-based article that was written by the principal investigator about the most recent clinical evidence of practices that have an impact on patient safety while securing the ET tube. This article was later published in the AANA Journal.23

**Results**

Of the 18 (78% of 23) anesthesia providers who participated in the evidence-based quality improvement practice project, 11 (61.1%) were women and 7 (38.9%) were men. Five (27.9%) of the anesthesia providers were anesthesiologists, 9 (50%) were nurse anesthetists, and 4 (22.2%) were nurse anesthesia residents. Six (33.3%) of the anesthesia providers had been in practice between 1 and 3 years. Two (11.1%) of the anesthesia providers had been in practice between 4 and 6 years, 1 (5.6%) had been in practice between 7 and 10 years, and 9 (50%) had been in practice for 11 or more years. All anesthesia providers practiced at least 2 days per week in the facility. All the anesthesia providers stated that they currently used adhesive tape from an 11.1-m (10-yd) roll. Four anesthesia providers dropped out of the study after completing...
the preintervention survey: 2 nurse anesthetists and 2 nurse anesthesia residents. Thus, the anesthesia providers who completed the project consisted of 8 women (57.1%) and 6 men (42.8%), for a total of 14 (61% of 23). Five (35.7%) of the anesthesia providers were anesthesiologists, 7 (50%) were nurse anesthetists, and 2 (14.2%) were nurse anesthesia residents. Four (28.5%) of the anesthesia providers had been in practice between 1 and 3 years, 1 (7.1%) had been in practice between 4 and 6 years, 1 (7.1%) had been in practice between 7 and 10 years, and 8 (57.1%) had been in practice for 11 or more years.

- **Statistically Significant Results.** Figure 1 shows the results for the survey question related to the anesthesia provider's level of agreement of having designated tape for securing the ET tube. A Mann-Whitney U test was conducted to evaluate the hypothesis that after the intervention the median level of agreement that “the ET tube needs to be secured with tape designated for anesthesia use” would increase. The difference in ranks between the preintervention and the postintervention responses was significant \((U = 55, P = .003)\). The median level of agreement for designated adhesive tape changed from 2 (agree) at the preintervention to 1 (strongly agree) at the postintervention questionnaire.

Figure 2 shows the results for the survey question related to the likelihood that the anesthesia provider would use the adhesive tape if it dropped to the floor during the taping process and was immediately retrieved. A Mann-Whitney U test was conducted to evaluate the hypothesis that after the intervention anesthesia providers would be less likely to use the adhesive tape if it fell to the floor. The difference in ranks between the preintervention and the postintervention responses was significant \((U = 78, P = .04)\). The median likelihood for using the adhesive tape changed from 4 (probably not) at the preintervention to 5 (definitely not) at the postintervention questionnaire.

Anesthesia providers were asked to rank factors that prevented them from using a clean taping practice for securing the ET tube. A Mann-Whitney U test was conducted to evaluate the hypothesis that after the intervention “I did not realize the importance of the practice” would be ranked as more descriptive of factors that prevent using a clean taping practice. The difference in median responses between the preintervention and the postintervention questionnaire was significant \((U = 27.5, P = .05)\). The median rank for not realizing the importance of the practice changed from 1 (least describes) at the preintervention to 4 (describes) at the postintervention questionnaire. Not realizing the importance of a clean taping practice became more important after the intervention as a reason for not following a clean taping practice.

A Mann-Whitney U test was conducted to evaluate the hypothesis that after the intervention “difficult to incorporate into practice” would be ranked as less descriptive of factors that prevent using a clean taping practice. The difference in median responses between the preintervention and the postintervention questionnaire was significant \((U = 45.8, P = .02)\) (Mann-Whitney U test).
The median rank for difficult to incorporate into practice changed from 4 at the pretest to 2 at the posttest. A Mann-Whitney U test was conducted to evaluate the hypothesis that after the intervention “length and width of the tape” would be ranked as less descriptive of factors that prevent using a clean taping practice. The difference in median responses between the pretest and the posttest was significant ($U = 46.5, P = .02$). The median rank for length and width of the tape changed from 3 before the intervention to 2 after the intervention. The factor, the length and width of the tape, was more descriptive of reasons for not using a clean taping practice before compared with after the intervention.

**Results With No Statistical Significance.** When asked whether the taping practice for securing the ET tube was part of anesthesia care, the anesthesia providers agreed (11%) or strongly agreed (89%) on the pretest that it was part of anesthesia care, and they agreed (14%) or strongly agreed (86%) with the statement on the posttest (not significant; $U = 122, P = .45$, Table 1). The anesthesia providers confirmed their belief that securing the ET tube is part of anesthesia care.

Anesthesia providers did not significantly change their responses when asked whether the taping practice for securing the ET tube needed to maintain cleanliness from pre-intervention to postintervention ($U = 115, P = .35$). All anesthesia providers either agreed or strongly agreed with the statement both before and after the intervention (see Table 1). As well, there was no statistically significant change in the responses of the anesthesia providers from preintervention to postintervention questionnaires when asked about the importance of a clean taping practice to decrease pathogen exposure to the patient ($U = 106, P = .23$). Before the intervention, 89% of anesthesia providers responded that they agreed or strongly agreed. After the intervention, 93% of anesthesia providers responded that they agreed or strongly agreed that a clean taping practice is needed to prevent pathogen exposure to the patient. Regarding the anesthesia provider's re-

<table>
<thead>
<tr>
<th>Question and possible responses</th>
<th>Responses (%)</th>
<th>Preintervention (N = 18)</th>
<th>Postintervention (N = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The taping practice for securing the ET tube is a part of anesthesia care.</td>
<td></td>
<td>Strongly agree</td>
<td>88.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Agree</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neither agree nor disagree</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disagree</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strongly disagree</td>
<td>0.0</td>
</tr>
<tr>
<td>The taping practice for securing the ET tube needs to maintain cleanliness.</td>
<td></td>
<td>Strongly agree</td>
<td>55.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Agree</td>
<td>44.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neither agree nor disagree</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disagree</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strongly disagree</td>
<td>0.0</td>
</tr>
<tr>
<td>A clean taping practice is needed to decrease pathogen exposure to the patient.</td>
<td></td>
<td>Strongly agree</td>
<td>55.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Agree</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neither agree nor disagree</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disagree</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strongly disagree</td>
<td>0.0</td>
</tr>
<tr>
<td>What is the likelihood that you would use visibly soiled adhesive tape for securing the ET tube?</td>
<td></td>
<td>Definitely not</td>
<td>77.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Probably not</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not sure</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Probably</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Definitely</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 1. Preintervention and Postintervention Survey Results

Abbreviation: ET, endotracheal.

*Percentages may not total to 100% because of rounding.
response to using visibly soiled tape to secure the ET tube, nearly 94% of the anesthesia providers responded that they would not use the visibly soiled adhesive tape to secure the ET tube before intervention vs 100% of anesthesia providers after the intervention ($U = 109, P = .27$). Cronbach coefficient $\alpha$ for internal consistency for these 3 survey questions was .78.

The 2-way contingency table analysis found no significant change in the preferences of anesthesia providers regarding the packaging of the adhesive tape as a result of the intervention, $\chi^2 (df = 1) = 1.003, P = .801$ (Table 2). Before the intervention, 14 of 18 (78%) of the anesthesia providers preferred adhesive tape that was packaged clean, a single patient use item. After the intervention, 2 of 18 (11%) indicated that they preferred the tape to be packaged clean as a single-patient-use item. One of 18 (6%) of anesthesia providers responded before the intervention that packaging of the tape did not matter, whereas none of the anesthesia providers gave this response after the intervention, a nonsignificant change.

The tape identification features were ranked (1 = least desirable to 5 = most desirable) based on the anesthesia provider’s preference on both preintervention and postintervention questionnaires (Figure 4). The importance of packaging did not significantly change with a median score of 2.0 on the pretest and a median score of 2.5 on the posttest ($U = 60.5, P = .21$). The importance of the tape color did not significantly change, with a median preintervention score of 2.0 and a median postintervention score of 3.0 ($U = 58.5, P = .25$). The importance of tape location on the anesthesia gas machine also did not significantly change (median scores of 3.0 preintervention vs 3.0 postintervention, $U = 59.5, P = .41$). The median score for importance of the width of the tape did not significantly change either (3.0 for pre- and postintervention, $U = 75, P = .27$).

When asked about the tape features that would most promote a clean taping practice, anesthesia providers responded by ranking the following options: the tape qualities such as breathability, waterproof, and flexibility; the techniques of tape application and removal; the cost of the tape; and its use on all patients (Figure 5). Overall, the anesthesia providers did not significantly change their responses from preintervention to postintervention questionnaires. Tape qualities had a median preintervention score of 4.5 and a median postintervention score of 5.0 ($U = 75, P = .27$). Use on all patients had a median score of 3.5 before the intervention and a median score of 4.0 after the intervention ($U = 71.5, P = .38$). Techniques of tape application and removal had a median score of 3.0 on preintervention and postintervention surveys ($U = 60.5, P = .29$). Lastly, the cost of the tape had a median score of 1.0 on both pretest and posttest ($U = 80, P = .36$).

### Table 2. Packaging Preferences

<table>
<thead>
<tr>
<th>Packaging preference</th>
<th>Preintervention, No. (%)</th>
<th>Postintervention, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean, single-patient use</td>
<td>14 (78)</td>
<td>12 (86)</td>
</tr>
<tr>
<td>Clean, multiple-patient use</td>
<td>2 (11)</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Sterile, single-patient use</td>
<td>1 (6)</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Packaging does not matter</td>
<td>1 (6)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

*Percentages may not total to 100% because of rounding.*
the anesthesia provider. Using individually packaged clean tape for a single patient was the response for 7 of 9 responses (78%). Using adhesive tape that is hypoallergenic and nonabrasive to the skin were recommendations from 2 of 9 anesthesia providers (22%). Availability of a suitable tape for use by the anesthesia provider was a recommendation 2 of 9 times (22%). Two of 9 anesthesia providers (22%) responded that education and support of the anesthesia providers would be needed to implement a clean taping practice.

Discussion
Research demonstrates that the common elements of the ET tube taping practice increase the patient’s exposure to pathogens. Most anesthesia providers fail to relate these findings with anesthesia delivery. This project found that the anesthesia providers began the intervention with awareness and knowledge of the facts and the concepts of infection control practices that relate to a clean taping practice. Furthermore, this project demonstrated that the anesthesia providers gained awareness and received new information about the taping practice. This encouraged the anesthesia providers to apply practical, procedural knowledge to a clean taping practice for securing the ET tube that they had not previously considered. Also, this project illustrated the preferences of anesthesia providers that would facilitate a clean taping practice and those preferences that they would use to identify the tape for securing the ET tube.

• Level of Improvement. Statistical significance was demonstrated in 5 areas (Table 3). First, the anesthesia providers saw a lack of awareness as an unimportant factor in preventing an unclean taping practice before the intervention. After the intervention, the anesthesia providers saw the lack of awareness as second only to the lack of a suitable product as a reason for explaining an unclean taping practice (Figure 6). This change suggests that there was a lack of knowledge among anesthesia providers about a clean taping practice. They perceived the importance of a clean taping practice as a more important reason for not following a clean taping practice. This realization by the anesthesia providers led them to consider the feasibility of a cleaner practice.

Second, the anesthesia providers indicated before the intervention that incorporating a clean taping practice would be difficult. Yet after the intervention, the anesthesia providers saw a clean taping practice as less difficult to incorporate into practice. This suggests that the anesthesia providers had an improved understanding, conceptually, of a clean taping practice. This change in response suggests that they could consider incorporating a clean taping practice and apply it in the clinical setting.

Table 3. Questions and Responses Where Change Occurred

<table>
<thead>
<tr>
<th>Questions and Possible Responses</th>
<th>1 = least describes</th>
<th>5 = best describes</th>
</tr>
</thead>
<tbody>
<tr>
<td>What BEST describes the factor that prevents you from using a clean taping practice?</td>
<td>1 = least describes</td>
<td>5 = best describes</td>
</tr>
<tr>
<td>I did not realize the importance of the practice.</td>
<td>1 = least describes</td>
<td>5 = best describes</td>
</tr>
<tr>
<td>No knowledge of another way. I thought I was using a clean practice.</td>
<td>1 = least describes</td>
<td>5 = best describes</td>
</tr>
<tr>
<td>Difficult to incorporate into practice.</td>
<td>1 = least describes</td>
<td>5 = best describes</td>
</tr>
<tr>
<td>Lack of suitable products</td>
<td>1 = least describes</td>
<td>5 = best describes</td>
</tr>
<tr>
<td>Assumption that a clean taping practice is unattainable.</td>
<td>1 = least describes</td>
<td>5 = best describes</td>
</tr>
</tbody>
</table>

For anesthesia purposes, the adhesive tape used for securing the endotracheal tube needs to be designated solely for securing the endotracheal tube.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If the adhesive tape fell to the floor during the taping process and was immediately returned to you, how likely would you use the tape for securing the endotracheal tube?

<table>
<thead>
<tr>
<th>Definitely</th>
<th>Probably</th>
<th>Not sure</th>
<th>Probably not</th>
<th>Definitely not</th>
</tr>
</thead>
</table>

If another tape product were available, which factor would facilitate your use of a clean taping practice the MOST?

<table>
<thead>
<tr>
<th>The tape qualities such as breathability, waterproof, and flexibility</th>
<th>The techniques of tape application and removal</th>
<th>The cost of the tape</th>
<th>The length and width of the tape</th>
<th>Its use on all patients</th>
</tr>
</thead>
</table>

Figure 6. Factors That Prevent Clean Taping Practice in Clinical Area
Final response indicates that a clean taping practice was assumed to be unattainable.

ET tube taping practice increase the patient’s exposure to pathogens. Most anesthesia providers fail to relate these findings with anesthesia delivery. This project found that the anesthesia providers began the intervention with awareness and knowledge of the facts and the concepts of infection control practices that relate to a clean taping practice. Furthermore, this project demonstrated that the anesthesia providers gained awareness and received new information about the taping practice. This encouraged the anesthesia providers to apply practical, procedural knowledge to a clean taping practice for securing the ET tube that they had not previously considered. Also, this project illustrated the preferences of anesthesia providers that would facilitate a clean taping practice and those preferences that they would use to identify the tape for securing the ET tube.

The anesthesia provider. Using individually packaged clean tape for a single patient was the response for 7 of 9 responses (78%). Using adhesive tape that is hypoallergenic and nonabrasive to the skin were recommendations from 2 of 9 anesthesia providers (22%). Availability of a suitable tape for use by the anesthesia provider was a recommendation 2 of 9 times (22%). Two of 9 anesthesia providers (22%) responded that education and support of the anesthesia providers would be needed to implement a clean taping practice.
Third, there was a change in the median responses of the anesthesia providers, from agree to strongly agree, regarding the designation of adhesive tape for securing the ET tube. After the intervention, there was strong agreement that the tape for securing the ET tube needs to be designated for this use exclusively. Their responses suggest an increased awareness and understanding of the need for this special tape. In addition, their responses suggest that they processed new information beyond factual and conceptual knowledge levels to make practical determinations regarding a clean taping practice.

Contamination of the tape through inadvertent dropping to the floor was addressed indirectly in the research of Munoz-Price et al. Her group observed, “Objects fall onto the operating room floors and are frequently placed back either on the horizontal work surfaces or on patients themselves.” In an observational study of 7,976 hand-hygiene opportunities, Biddle and Shah noted that tape is one of those items that falls to the floor, is picked up, and is used. The anesthesia provider’s responses to the situational question regarding the use of tape that falls to the floor and is retrieved for securing the ET tube demonstrated that they had factual and conceptual knowledge about this possible occurrence. The change in the anesthesia provider’s responses from “probably not” to “definitely not” suggests that they increased their understanding of a clean taping practice and applied practical knowledge to respond to this question. Presenting a scenario as in this question challenged the anesthesia providers to refine their practice. They responded that they would definitely not use tape that had fallen to the floor for securing the ET tube. Thus, the taping practice improved.

When the anesthesia providers were asked to consider another tape product, the length and width of the adhesive tape was a moderately descriptive factor that anesthesia providers initially indicated would facilitate their use of a clean taping practice, but after the intervention the length and width of the tape was seen as less descriptive. With their increase in knowledge and experience gained from this project, the anesthesia providers recognized that length and width of the tape of another tape product may not be an important factor to facilitate a clean taping practice.

There were a number of items where no significant change was demonstrated. The anesthesia providers confirmed that the taping practice for securing the ET tube is part of anesthesia care. There was no lack of understanding that this is a duty of anesthesia providers. Factually and conceptually, the anesthesia providers demonstrated that they had awareness and understanding of the importance of maintaining cleanliness when securing the ET tube. They demonstrated that they had understanding of the factual information regarding the prevention of pathogens and that this was an important component of a clean taping practice. Avoiding the use of visibly soiled tape for securing the ET tube demonstrated that they conceptually understood that the taping practice must be clean. It suggests an increased awareness of the importance of infection control practice even when the tape is not visibly soiled. There was no change in the anesthesia provider’s responses regarding tape preferences for securing the ET tube. The anesthesia providers indicated that the tape needs to be packaged clean as a single-patient-use item. Their not choosing a tape that is packaged sterile suggests that the anesthesia providers had factual and conceptual knowledge about pathogen transmission and of infection control practices.

To facilitate a clean taping practice, anesthesia providers identified tape qualities such as breathable, waterproof, and flexible as needed features. Additionally, the tape needs to be able to be used on all patients, including those that have skin sensitivities, facial hair, and open wounds of the face. It must be easy to apply and remove. The packaging of the tape was unimportant as long as it was clean and for single patient use. As well, the anesthesia provider’s preferences regarding the designation and identification of tape for securing the ET tube was unchanged.

- **Implications for Clinical Practice.** Based on the results of this evidence-based practice project, the researchers recommend that the adhesive tape for securing the ET tube be packaged as a clean, single-patient-use item. To facilitate a clean taping practice, the tape needs to be breathable, waterproof, and flexible. As well, it needs to be suited for all patients, even those with facial wounds, facial hair, and allergies. It should be easy to apply and remove. The best way to designate the tape is by color and packaging. It is less important to designate the tape by location on the anesthesia gas machine or by tape type, width, or length. Anesthesia providers may need education and training to improve their knowledge of and experience with a clean taping practice. Healthcare facilities should provide a suitable tape for use on their surgical patients who require general anesthesia. Anesthesia providers may then decrease pathogen exposure to patients while securing the ET tube.

- **Strengths, Weaknesses, and Limitations of the Project.** Strengths of this project come from the amount, type, and variety of information regarding the taping practice that was gained because of this project and the impact that this information has on patient safety. There were 4 major weaknesses of this project, the small sample size, the duration of the project, the quality of the survey questions, and the preparation of some of the providers. The small sample size of those who participated (N = 18) and the lack of normality limited the type of statistical test that could be applied for this project. The Mann-Whitney U test was selected because of its application for small groups. As well, all test assumptions were met. Thus, results and generalizations could be determined. In the end, the anesthesia providers who did partici-
pate were representative of the population of anesthesia providers at this hospital. The duration of the project, 4 weeks, was too short, as some providers noted that they could not get the required tape practices on patients. The wording of some of the questions on the survey was convoluted, resulting in results that were difficult to interpret. Soliciting information according to importance would have made interpretation easier. There was limited variability in the questions because all participants were well informed about the importance of cleanliness. In addition, the intervention was not administered uniformly to all providers. Three providers were unable to attend the group in-service and had to have individualized sessions. There is a potential that the Hawthorne effect, in which behaviors change because the subjects know they are being watched, may have contributed to the responses of the anesthesia providers. Another consideration for the behavior change of the anesthesia providers is that a suitable alternative tape was part of the intervention, which facilitated their knowledge and experience.

A major limitation of the project was that some anesthesia providers failed to rank all responses in the surveys. Some providers rated all responses with the same rank or only ranked a few, rather than ranking all of the responses as they were instructed to do. This violated the assumption of independence for some of the questions in the survey. The second limitation of this project deals with the response options for a few of the questions on the survey. On one question, the response options were not displayed progressively. The response option “Probably not” and “Not sure” were out of order. Because they were numeric responses, they were reordered to make “Not sure” appear as the middle response without adjusting the numeric value or the anesthesia provider’s selection before data entry.

Last, nurse anesthesia residents were included as participants in this evidence-based quality improvement practice project. Their inclusion was disclosed and approved by all entities related to the project. Some may argue that the nurse anesthesia residents’ questionnaire responses may have been influenced by their preceptor’s bias. Although this may be a consideration, it is important to note that safeguards were in place to protect all participants. In addition, all questionnaires were anonymous and secured after completion as described in the approved project protocol.

**Implications for Future Projects.** This short, evidence-based quality improvement practice project increased the anesthesia provider’s awareness and knowledge of the common elements of the taping practice that increase the patient’s exposure to pathogens and the risk of nosocomial infection. As well, this project presented a clean taping practice with an education module and suitable alternative tapes for anesthesia providers to reduce pathogen transmission, thereby improving patient safety. This project can serve as a pilot project for a larger hospital project. It can be continued and expanded to include multiple facilities to test for consistency of results. Also, it is recommended that this project be broadened to patient populations other than anesthesia. These could include trauma, cancer, and wound care patients. Future research will need to investigate the application of other means to secure the ET tube when they become available.

**Conclusion**

Anesthesia providers have the responsibility of securing the ET tube once the patient is intubated for a general anesthetic. Research concludes that the current taping practice is a high-risk practice. All the common elements independently and collectively involve the tape and its potential to increase the patient’s exposure to pathogens through the taping practice. The anesthesia providers involved in this project changed their perceptions about the taping practice because of an increase in their awareness and knowledge of the taping practice. This evidence-based quality improvement project has demonstrated that a change in practice occurred after an intervention that focused on presenting the best and most current evidence regarding securing the ET tube with adhesive tape.

**REFERENCES**


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**DISCLOSURES**
The authors have declared no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.
A failed subarachnoid block due to prolonged surgical duration continues to be a challenging problem for anesthesia providers. This evidence-based review updates a 2013 systematic review describing the use of intravenous dexmedetomidine as an extrathecal spinal adjunct capable of extending the duration of a subarachnoid block. Eight randomized controlled trials published after the 2013 systematic review met the inclusion criteria. The evidence continues to support the use of intravenous dexmedetomidine as an effective method for prolonging the duration of motor and sensory blockade and postoperative analgesia in a subarachnoid block, with minimal side effects. This updated review reported a more consistent use of assessment tools measuring motor and sensory recovery, expanded the volume of evidence related to postoperative analgesia, and further validated the safe and efficacious use of intravenous dexmedetomidine in extending the duration of a subarachnoid block. Future studies are needed to evaluate the rescue benefit of intravenous dexmedetomidine in failed subarachnoid blocks converted to general anesthesia resulting from prolonged surgical times.

Keywords: Dexmedetomidine, duration, intravenous, spinal, subarachnoid.

Prolongation of Subarachnoid Block With Concomitant Use of Intravenous Dexmedetomidine: An Evidence-based Review

William L. Johnson, DNAP, CRNA
Marilyn A. Pugh, PhD

The subarachnoid block (SAB) is a safe, quick, and effective form of regional anesthesia with predictable and reliable therapeutic benefits. Despite these positive attributes, a major disadvantage of the SAB is the limited methods for extending the duration of the anesthetic intraoperatively to address the needs of prolonged surgical procedures. Anesthesia providers have resorted to using higher local anesthetic doses, combined spinal-epidural block techniques, or intrathecal adjunct medications (epinephrine, phenylephrine, neostigmine, and clonidine) to extend the duration of an SAB. Higher doses of local anesthetics can predispose a patient to a “high spinal” complication, whereas combined spinal-epidural techniques can be technically difficult and time-consuming to perform. Authors of a 2013 systematic review with meta-analysis described the use of intravenous (IV) dexmedetomidine as an extrathecal spinal adjunct capable of extending the duration of an SAB.

Dexmedetomidine is a highly selective α2 agonist with spinal antinoceptive (visceral and somatic) properties that produces a synergistic effect with intraspinal local anesthetics. A supraspinal mechanism of action of IV dexmedetomidine has not been clearly defined. One group postulated that IV α2 agonists inhibit the activity of the locus coeruleus in the brain, leading to the disinhibition of noradrenergic nuclei. The reduced noradrenergic outflow is thought to strengthen the inhibitory nociceptive effect on the spinal cord. This evidence-based review evaluates the efficacy and safety of using IV dexmedetomidine in SAB cases and provides an update to the 2013 systematic review with meta-analysis.

History and Review of the Literature

• History. The overall failure rate for SABs has been reported to be 0.6%, with about one-fourth of all failed SABs attributed to prolonged surgical times. Spinal anesthetic failure resulting in a general anesthetic conversion negates the positive effects of regional anesthesia. The reported benefits of an SAB include decreased incidence of venous thrombosis, reduction in intraoperative blood loss, and decline in postoperative narcotic requirements, leading to lower rates of postoperative nausea and vomiting, postoperative ileus, and constipation. Extending the duration of the SAB could avoid these unnecessary general anesthetic conversions in those cases in which prolonged surgical time is the predominant factor for spinal anesthetic failure.

The IV α2 agonists, clonidine and dexmedetomidine, have been reported to be effective in prolonging the duration of an SAB. Dexmedetomidine has 8 to 10 times higher binding affinity for the α2 receptor than does clonidine. This higher α2 receptor selectivity for IV dexmedetomidine reduces the severity of hemodynamic side effects (bradycardia and hypotension) and is capable of extending the duration of an SAB longer than clonidine. A lower side effect profile combined with improved SAB duration has led to the dissemination of...
research regarding the use of IV dexmedetomidine as an extrathecal adjunct.3

Authors of a systematic review published in 2013 suggested that IV dexmedetomidine could be an effective spinal adjunct for prolonging the duration of regional blockade and postoperative analgesia in patients receiving an SAB (Table 1).3 This systematic review by Abdallah et al contained 7 intermediate to high-quality (Jadad score of 3 or higher) randomized controlled trials (RCTs) examining 364 subjects, equally distributed between placebo and IV dexmedetomidine treatment groups. Primary outcome measures in their review were duration of motor and sensory block, postoperative analgesia, and adverse-related effects (bradycardia, hypotension, respiratory depression, and postoperative sedation). The authors described a comprehensive search strategy and appraisal of articles in their review.3

In the review by Abdallah et al,3 dosing of dexmedetomidine was highly variable between studies and the standardization of assessment measures for sensory and motor block duration lacked consistency. The authors indicated that a high level of heterogeneity (I² > 85%) was also present in all 7 RCTs, which could lessen the generalizability of the results of the systematic review.3 Using the ratio of means11 as the measure, there was an increase in motor and sensory block duration and time to first analgesic request favoring the addition of IV dexmedetomidine to the SAB. Ratio of means is derived by dividing mean differences from the control and intervention groups to calculate a ratio that describes the magnitude of effect in continuous data.11 Bradycardia was the only complication reported in the dexmedetomidine-treated groups.3

• Review of the Literature. This new evidence-based review updates the earlier systematic review with meta-analysis3 examining the safety and efficacy of IV dexmedetomidine on the block characteristics of a spinal anesthetic.

• The PICO Question. The PICO (patient or population, intervention, comparison, outcome) question12 guiding the search for evidence was as follows: “In patients undergoing spinal anesthesia (P), does intravenous dexmedetomidine (I) effectively and safely prolong the motor (O) and sensory (O) blockade duration and postoperative analgesia (O) of a neuroaxial anesthetic?”

• Search Strategy. Evidence included only those studies published subsequent to the sources included in the systematic review with meta-analysis.3 The search for evidence (2012-2015) was conducted using PubMed, The Cochrane Database of Systemic Reviews, and Google Scholar. The ancestry approach and the PubMed-related citations feature were used to locate other sources. Search terms included spinal, subarachnoid block, dexmedetomidine, intravenous, anesthesia, analgesia, pain prevention, and duration. Evidence was limited to full-text, English-language systematic reviews and studies published in peer-reviewed journals examining motor and sensory blockade duration, side effects, and postoperative analgesia benefits.

Studies were included regardless of the local anesthetic used for the SAB. All methods and dosing regimens for IV dexmedetomidine were included in this review. Sources were included based on reviewing the title, abstract, and full text of possible sources. Evidence was appraised using the method offered by Melnyk and Fineout-Overholt.13

• Critical Appraisal of Literature. Eight sources, all RCTs (480 subjects), met the inclusion criteria14-21 (Figure). These RCTs are described in Tables 2 and 3.

Table 1. Summary of Systematic Review With Meta-Analysis3 Examining Characteristics of Spinal Anesthetics With Concomitant Use of Intravenous Dexmedetomidine

<table>
<thead>
<tr>
<th>Type of evidence</th>
<th>Dexmedetomidine method of dosing, number of studies</th>
<th>N</th>
<th>Motor block duration (ROM, 95% CI)a</th>
<th>Sensory block duration (ROM, 95% CI)b</th>
<th>Time to first analgesic requestc (ROM, 95% CI)a</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 RCTs</td>
<td>Bolus, 2 maintenance, 5</td>
<td>364</td>
<td>1.21 (1.17-1.25)</td>
<td>1.38 (1.34-1.42)</td>
<td>1.60 (1.53-1.67)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; RCT, randomized controlled trial; ROM, ratio of means.

aRatio of means was performed according to methods described by Friedrich et al11 at a 95% confidence interval. Final pooled estimates were derived from the 7 randomized controlled trials used in the systematic review. ROM 0 indicates no effect; value > 0 favors dexmedetomidine.
bOnly 3 of the 7 studies evaluated analgesic outcomes.

dFigure. Flow Diagram of Literature Search Examining Spinal Block Characteristics Associated With Intravenous Dexmedetomidine
<table>
<thead>
<tr>
<th>Evidence source and level of evidence,(^{13})</th>
<th>Total number of subjects and groups (subjects per group)</th>
<th>Dexmedetomidine before subarachnoid block</th>
<th>Dose of bupivacaine(^a)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jung et al,(^{16}) 2013 Level II</td>
<td>60; NS (n = 20); dexmedetomidine, 0.25 μg/kg bolus (n = 20); dexmedetomidine, 0.5 μg/kg bolus (n = 20)</td>
<td>No</td>
<td>12 mg(^b)</td>
<td>Desired sample size based on results of power analysis. Recovery to knee flexion used, not MBS. No observer training described. Double blinded.</td>
</tr>
<tr>
<td>Reddy et al,(^{21}) 2013 Level II</td>
<td>75; NS (n = 25); dexmedetomidine, 0.5 μg/kg bolus (n = 25); clonidine, 1 μg/kg bolus (n = 25)</td>
<td>Yes</td>
<td>15 mg 0.5%</td>
<td>Desired sample size based on results of power analysis. Randomization method not described. No statistical difference in motor block from controls. Initial SAB sensory level was 2 dermatomes higher than control. Double blinded.</td>
</tr>
<tr>
<td>Harsoor et al,(^{15}) 2013 Level II</td>
<td>50; NS (n = 25); dexmedetomidine, 0.5 μg/kgbolus, and 0.5 μg/kg/h infusion (n = 25)</td>
<td>Yes</td>
<td>12.5 mg(^b)</td>
<td>Desired sample size based on results of power analysis. Loss of temperature sensation used, but exact method not described. Initial SAB sensory level was 2 dermatomes higher for control subjects. Double blinded.</td>
</tr>
<tr>
<td>Dinesh et al,(^{14}) 2014 Level II</td>
<td>100; NS (n = 50); dexmedetomidine, 1 μg/kg bolus, and 0.5 μg/kg/h infusion (n = 50)</td>
<td>No</td>
<td>15 mg 0.5%</td>
<td>Desired sample size based on results of power analysis. Initial SAB sensory level was 1 dermatome higher than control. Observer training not described. Reported a time for complete sensory S1 regression. Shivering 10% higher in control group. Blinding method not described.</td>
</tr>
<tr>
<td>Lee et al,(^{19}) 2014 Level II</td>
<td>60; NS (n = 20); dexmedetomidine, 0.5 μg/kgbolus (n = 20); dexmedetomidine, 1 μg/kg bolus (n = 20)</td>
<td>Yes</td>
<td>12 mg 0.5%</td>
<td>Desired sample size based on results of power analysis. 5 of 20 subjects did not reach initial MBS of 3 (2 of 20 controls; 1 in dexmedetomidine, 0.5 μg/kg, group; and 2 in dexmedetomidine, 1 μg/kg, group). Observer training not described. Double blinded.</td>
</tr>
<tr>
<td>Kim et al,(^{17}) 2014 Level II</td>
<td>90; NS (n = 30); dexmedetomidine, 1 μg/kg bolus, and 0.5 μg/kg/h infusion (n = 30); ketamine, 0.2 mg/kg bolus, and 0.5 mg/kg/h infusion(^c) (n = 30)</td>
<td>No</td>
<td>10 mg 0.5%</td>
<td>No power analysis conducted. Observer training not described. Used MBS (1-6) rating scale with endpoint of 4. Blinding method not described.</td>
</tr>
<tr>
<td>Park et al,(^{20}) 2014 Level II</td>
<td>45; NS (n = 15); dexmedetomidine, 0.5 μg/kg bolus (n = 15); dexmedetomidine, 1 μg/kg bolus (n = 15)</td>
<td>No</td>
<td>6 mg(^b)</td>
<td>Desired sample size based on results of power analysis. Three patients lost to attrition because of insufficient anesthesia level resulting in less than the desired sample of 15 subjects. No initial MBS set point from SAB recorded. Low-dose (6-mg) bupivacaine given. Observer training not described. Maximum block level not described. No difference in groups for time-to-first request of analgesic. No statistical difference in motor block duration between control and dexmedetomidine groups. Blinding method not described.</td>
</tr>
<tr>
<td>Kumar et al,(^{18}) 2015 Level II</td>
<td>100; NS (n = 50); dexmedetomidine, 1 μg/kg bolus, and 0.5 μg/kg/h infusion (n = 50)</td>
<td>No</td>
<td>15 mg 0.5%</td>
<td>No power analysis conducted. No exclusion/inclusion criteria described. Initial SAB sensory level was 1 dermatome higher than control. Observer training not described.</td>
</tr>
</tbody>
</table>

Table 2. Summary of Randomized Control Trials Describing Spinal Block Characteristics with the Concomitant Use of Intravenous Dexmedetomidine

Abbreviations: MBS, motor Bromage scale; NS, normal saline; RCT, randomized controlled trial; SAB, subarachnoid block; TDR, 2-dermatome regression.

\(^a\) Authors in all studies reported using a hyperbaric solution of bupivacaine.

\(^b\) Bupivacaine concentration not disclosed.

\(^c\) Results from medications examined in the study other than dexmedetomidine were not included in the table.
Primary outcome measures of the RCTs included the duration of motor and sensory blockade,\textsuperscript{14-21} postoperative analgesia,\textsuperscript{14,15,20,21} and side effects (bradycardia and hypotension)\textsuperscript{14-21} when IV dexmedetomidine was administered simultaneously with an SAB. No difference was noted in demographic characteristics between the treatment and control groups, and randomization techniques in each of the RCTs\textsuperscript{14-21} were described in detail with the exception of 1 study.\textsuperscript{21} Three RCTs\textsuperscript{14,17,20} failed to describe details about blinding methods. All the RCTs included in this review were published outside the United States.\textsuperscript{14-21}

Authors of 2 RCTs\textsuperscript{19,21} failed to conduct a power analysis to determine a sample size for outcomes measured. Park et al\textsuperscript{20} performed a power analysis (α = .05, β = 0.2) but had 3 subjects withdraw because of an insufficient anesthetic level, leaving the RCT underpowered based on the author’s calculated sample size, as they did not take into account subject attrition. Authors of 6 RCTs performed a power analysis using a 15% difference in either duration of analgesia\textsuperscript{15} or time to 2-dermatome regression (TDR) of at least 20 minutes as measured outcomes.\textsuperscript{14,16-18,20}

Dosing of dexmedetomidine was either a bolus only\textsuperscript{16,20,21} or a bolus plus a maintenance infusion.\textsuperscript{14,15,17-19} Intravenous dexmedetomidine administration in 4 studies\textsuperscript{14,16,18,20} was commenced after the SAB was placed. Two RCTs omitted the preload IV fluid bolus before SAB placement.\textsuperscript{16,17} In the other 6 RCTs,\textsuperscript{14,15,18-21} a fluid bolus dose, decreased HR at all time intervals. Atropine administered for HR < 50/min in 5 of 20 subjects in dexmedetomidine, 0.5 μg/kg, group.\textsuperscript{b} No IV fluid bolus given before SAB. No statistical difference seen in MAP between groups.

Lowest HR, instances of bradycardia (< 50/min), lowest SBP (20% decrease from baseline), and DBP intraoperatively were in the dexmedetomidine group.\textsuperscript{b} Treatment with atropine was not disclosed.

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean motor recovery time (min)</th>
<th>Mean sensory block recovery time (min)</th>
<th>Postoperative analgesic benefits</th>
<th>Heart rate/mean arterial pressure effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jung et al,\textsuperscript{16} 2013</td>
<td>DMB</td>
<td>TDR</td>
<td>Not evaluated</td>
<td>Dexmedetomidine, 0.5-μg bolus dose, decreased HR at all time intervals. Atropine administered for HR &lt; 50/min in 5 of 20 subjects in dexmedetomidine, 0.5 μg/kg, group.\textsuperscript{b} No IV fluid bolus given before SAB. No statistical difference seen in MAP between groups. No difference in MAP and HR between groups.</td>
</tr>
<tr>
<td>Reddy et al,\textsuperscript{21} 2013</td>
<td>MBS (3-1)\textsuperscript{c} NS = 139 (SD = 32); dexmedetomidine = 146 (SD = 32)</td>
<td>TDR</td>
<td>Mean time to first analgesic request (min): NS = 41 (SD = 29); dexmedetomidine = 243 (SD = 57)\textsuperscript{d}</td>
<td>Atropine administered for HR &lt; 50/min in 4 of 25 in dexmedetomidine group.\textsuperscript{b} Low MAP was treated in 2 of 25 subjects in dexmedetomidine group.</td>
</tr>
<tr>
<td>Harsoor et al,\textsuperscript{15} 2013</td>
<td>MBS (3-0)\textsuperscript{c} NS = 231 (SD = 32); dexmedetomidine = 256 (SD = 53)\textsuperscript{d}</td>
<td>TDR</td>
<td>Mean paracetamol use (g): NS = 2.7 (SD = 0.6); dexmedetomidine = 1.87 (SD = 0.6)\textsuperscript{e}</td>
<td>Lowest HR, instances of bradycardia (&lt; 50/min), lowest SBP (20% decrease from baseline), and DBP intraoperatively were in the dexmedetomidine group.\textsuperscript{b} Treatment with atropine was not disclosed.</td>
</tr>
<tr>
<td>Dinesh et al,\textsuperscript{14} 2014</td>
<td>MBS (3-0)\textsuperscript{c} NS = 131 (SD = 10); dexmedetomidine = 220 (SD = 17)\textsuperscript{e}</td>
<td>TDR</td>
<td>Mean diclofenac use (mg): NS = 117 (SD = 41); dexmedetomidine = 77 (SD = 56)\textsuperscript{f}</td>
<td>Table 3 continues ➔</td>
</tr>
</tbody>
</table>
with knee flexion. Recorded endpoints for motor recovery had MBS scores that varied from 0 to 114,15,18-21 and 4. Observer training in motor and sensory block assessment was identified in only 2 studies.15,21

Sedation from IV dexmedetomidine using a bolus plus maintenance method14,15,17-19 could have an impact on the validity and reliability of sensory and motor recovery times because subject participation is required. Of these 5 studies,14,15,17-19 2 RCTs14,15 indicated Ramsey sedation scores during the postoperative period that were equal to those of the control group. One RCT19 described 5 of 20 subjects with a Ramsey sedation score above 5 in the dexmedetomidine, 1 μg/kg/h, group with a sedation regression time (< 3) recorded at 90 minutes. Two RCTs did not disclose18 or evaluate17 Ramsey sedation scores during IV dexmedetomidine administration.

Postoperative analgesia assessment was analyzed in 4 studies.14,15,20,21 Assessment tools used in the studies varied widely and included visual analog score (VAS), time to first analgesic request, and 24-hour dosage requirements of postoperative pain medications. The VAS scores in the first 24-hour postoperative period were recorded in 1 study,20 whereas time to a VAS score above 3 was the endpoint in another study.15 Observer training evaluating postoperative analgesia outcomes was detailed in only 2 of these studies.15,21

Discussion of the State of Art
The 8 RCTs14-21 had a considerable amount of variability in the initial maximum sensory level achieved by the SAB.

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean motor recovery time (min)</th>
<th>Mean sensory block recovery time (min)</th>
<th>Postoperative analgesic benefits</th>
<th>Heart rate/mean arterial pressure effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee et al,19 2014</td>
<td>MBS (3-1)c NS = 99 (SD = 34);</td>
<td>TDR NS = 58 (SD = 23); dexmedetomidine, 0.5 μg/kg = 66 (SD = 24)b; dexmedetomidine, 1 μg/kg = 93 (SD = 31)d</td>
<td>Not evaluated</td>
<td>No difference in MAP and HR between groups</td>
</tr>
<tr>
<td></td>
<td>dexmedetomidine, 0.5 μg/kg = 133 (SD = 43)b</td>
<td>dexmedetomidine, 1 μg/kg = 130 (SD = 50)b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kim et al,17 2014</td>
<td>MBS (4)5 NS = 124 (SD = 19);</td>
<td>TDR NS = 99 (SD = 11); dexmedetomidine = 122 (SD = 14)b</td>
<td>Not evaluated</td>
<td>No difference in MAP and HR between groups</td>
</tr>
<tr>
<td></td>
<td>dexmedetomidine = 145 (SD = 22)b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Park et al,20 2014</td>
<td>MBS (3-0)c NS = 80 (SD = 32);</td>
<td>TDR (cold) NS = 94 (SD = 28); dexmedetomidine, 0.5 μg/kg = 97 (SD = 28); dexmedetomidine, 1 μg/kg = 115 (SD = 28)d</td>
<td>VAS 0-1 at 24 h. Same in all groups, no data disclosed.</td>
<td>No difference in MAP and HR between groups</td>
</tr>
<tr>
<td></td>
<td>dexmedetomidine, 0.5 μg/kg = 94 (SD = 51); dexmedetomidine, 1 μg/kg = 80 (SD = 39)</td>
<td>TDR (pinprick) NS = 82 (SD = 21); dexmedetomidine, 0.5 μg/kg = 90 (SD = 23)d; dexmedetomidine, 1 μg/kg = 98 (SD = 29)g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kumar et al,18 2014</td>
<td>MBS (3-0)c NS = 131 (SD = 10);</td>
<td>TDR NS = 169 (SD = 12); dexmedetomidine = 270 (SD = 21)d</td>
<td>Not evaluated</td>
<td>No difference in MAP and HR between groups</td>
</tr>
<tr>
<td></td>
<td>dexmedetomidine = 221 (SD = 17)d</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Findings of Evidence Sources Examining Spinal Block Characteristics With Concomitant Use of Intravenous Dexmedetomidine
Abbreviations: DBP, diastolic blood pressure; DMB, time to recovery of knee flexion; HR, heart rate; IV, intravenous; MAP, mean arterial pressure; MBS, motor Bromage scale; NS, normal saline; SAB, subarachnoid block; SBP, systolic blood pressure; TDR, 2-dermatome sensory regression; VAS, visual analog score.

a Values expressed as a median (range).
b P < .05 (control vs intervention)
c Initial MBS required with endpoint recorded for motor duration. Grade 0 indicates no paralysis; 1, unable to raise extended leg; 2, unable to flex knee; and 3, unable to flex ankle.
d P < .0001 (control vs intervention).
e P < .001 (control vs intervention).
f MBS scale from 1-6 with no initial motor block level reported. Return level of 4 was the endpoint (1 indicated complete block, while 6 was no paralysis).
g P value not reported.
Of the 8 RCTs, only 2 studies\textsuperscript{17,20} reported a TDR of less than 30 minutes was a clinically significant difference. In 2 studies,\textsuperscript{17,19} no difference in the highest sensory block level that was higher in the dexmedetomidine and control groups. In 2 studies,\textsuperscript{17,19} no difference in the highest sensory block level had less influence on this outcome.\textsuperscript{14-21} Maximum sensory level variability between the dexmedetomidine and control groups could have an impact on motor recovery duration times with higher block levels prolonging the duration of motor recovery.\textsuperscript{2} The TDR was recorded from maximum sensory level, so the variability in block level had less influence on this outcome.\textsuperscript{14-21}

\textit{Sensory Block Duration}. Authors of all 8 RCTs\textsuperscript{14-21} used a TDR assessment tool to measure sensory recovery. Each of the 8 RCTs was statistically significant in extending the duration of sensory blockade (see Table 3).\textsuperscript{14-21} Several authors\textsuperscript{16,19} indicated that extending the sensory block by 30 minutes was a clinically significant difference. Of the 8 RCTs, only 2 studies\textsuperscript{17,20} reported a TDR of less than 30 minutes when dexmedetomidine was compared with the normal saline control group. Of these 2 RCTs, Park et al\textsuperscript{20} used a 6-mg dose of bupivacaine in the SAB, with no initial maximum level reported involving cases of less than 2 hours in duration. Considering this dose, assessment of TDR from a sacral-level SAB explains why initial maximum levels were not disclosed in this study. Overall, sensory blockade duration beyond 30 minutes using the TDR tool was not affected by the method (bolus or bolus plus maintenance), timing (before or after SAB placement), or the dexmedetomidine dose.\textsuperscript{14-21}

\textit{Motor Block Duration}. In 6 of the 8 RCTs, the concomitant use of IV dexmedetomidine with SAB produced a statistically significant difference in the duration of motor blockade (see Table 3).\textsuperscript{14-21} In 4 RCTs, motor block duration exceeded control values by more than 30 minutes.\textsuperscript{14,16,18,19} Two authors indicated that a 30 minute prolongation in duration was clinically significant for prolonging motor blockade.\textsuperscript{16,19} Of these 4 studies, 1 study\textsuperscript{16} involved bolus-only dosing of dexmedetomidine, and 3 RCTs used bolus plus maintenance dosing.\textsuperscript{14,18,19} Authors of 1 RCT\textsuperscript{19} reported that an MBS of 3 (complete paralysis) was not achieved in 5 subjects. One RCT\textsuperscript{15} administered dexmedetomidine before the SAB was placed, and this was the only study in which the maximum sensory block level did not exceed the control group. The results of 4 RCTs failed to demonstrate a prolongation in the motor block duration beyond 30 minutes when dexmedetomidine was compared with the control groups.\textsuperscript{15,17,20,21} Recorded block duration times were initiated at the time of the SAB placement.\textsuperscript{14-21} Dosing of dexmedetomidine as a bolus plus maintenance after SAB placement produced the longest duration of motor blockade among the 8 RCTs.\textsuperscript{14-21} Dosing of dexmedetomidine as a bolus with a maintenance infusion had the greatest effect on the duration of motor and sensory blockade.\textsuperscript{14-21} Starting bolus doses of dexmedetomidine of 0.5 to 1 μg/kg, followed by an infusion of dexmedetomidine of 0.5 μg/kg/h, prolonged the motor and sensory characteristics of an SAB the longest.\textsuperscript{14,18,19} Authors of 1 RCT\textsuperscript{19} used a bolus of 1 μg/kg plus maintenance infusion dosing of 0.5 μg/kg/h with motor and sensory block recovery times of less than 30 minutes between the dexmedetomidine and control groups. Bolus-only dosing of dexmedetomidine at 1 μg/kg was also shown to extend the motor and sensory blockade of an SAB but not to the same extent as bolus plus a maintenance infusion.\textsuperscript{16}

\textit{Postoperative Analgesia}. Only 1 RCT\textsuperscript{20} failed to find a statistically significant difference between the dexmedetomidine and control group in VAS in the first 24 hours (see Table 3). Total 24-hour pain medication dosage requirements were reported in 1 RCT\textsuperscript{14} with a significant reduction in the use of paracetamol, diclofenac, and tramadol in a comparison of dexmedetomidine with the control group. Additionally, time for the first analgesic request was prolonged by more than 2 hours in 2 RCTs.\textsuperscript{14,21} The addition of IV dexmedetomidine to spinal anesthesia in patients undergoing surgery improved the duration and intensity of postoperative analgesia when measured by VAS,\textsuperscript{15} pain medication dosage requirements,\textsuperscript{14} or time-to-the-first-analgesic-request assessment tools.\textsuperscript{14-21}

\textit{Adverse Hemodynamic and Respiratory Effects}. Authors of 8 RCTs measured mean arterial pressure and heart rate parameters before, during, and after dexmedetomidine administration.\textsuperscript{14-21} Bradycardia (heart rate < 50/min) requiring treatment with atropine was reported in 2 RCTs.\textsuperscript{15,16} In 1 of these RCTs\textsuperscript{16} reporting atropine treatment, dexmedetomidine was administered before the SAB,\textsuperscript{15} whereas in the other RCT, dexmedetomidine was given after placement of the SAB and without the administration of a preload fluid bolus.\textsuperscript{16} Five RCTs reported no statistical difference in either mean arterial pressure or heart rate data when comparing dexmedetomidine and control groups with each other.\textsuperscript{17-21} In the 8 RCTs,\textsuperscript{14-21} no respiratory-related complications were reported in any of the IV dexmedetomidine groups.

Results from this evidence-based update\textsuperscript{14-21} are similar to the findings published in an earlier systematic review.\textsuperscript{3} Calculated pooled mean differences from evidence sources\textsuperscript{3,14-21} in this updated review confirm this comparative conclusion (Table 4). This updated review of 8 RCTs\textsuperscript{14-21} published subsequent to the systematic review reported a more consistent use of assessment tools measuring motor and sensory recovery, expanded the volume of evidence related to postoperative analgesia, and further validated the safe and efficacious use of IV dexmedetomidine in extending the duration of an SAB.
A major disadvantage of the SAB is the inability to extend the duration of the anesthetic intraoperatively to address the needs of prolonged surgical procedures. Methods to address this problem include using intrathecal adjuncts, combined spinal-epidural techniques, and higher SAB local anesthetic doses. The results of the systematic review with meta-analysis and the 8 subsequently published RCTs indicate that IV dexmedetomidine is probably an effective alternative method for prolonging the duration of motor and sensory blockade and postoperative analgesia with minimal side effects. Intravenous dexmedetomidine has not been studied as a “rescue” method when surgery is unexpectedly prolonged, but future studies should examine this use. Clinicians must weigh the risk and benefits in selecting IV dexmedetomidine as a primary SAB adjunct in cases that may be unexpectedly prolonged and require a conversion to general anesthesia.

Patients receiving an SAB often have a desire to be sedated during the operation. Intravenous dexmedetomidine has the added benefit of providing this intraoperative level of sedation while also extending the duration of an SAB. Intravenous dexmedetomidine does not cause significant respiratory depression and provides a dependable and titratable level of intraoperative sedation with a wide safety margin.

Studies are needed examining postoperative pain reduction outcomes. We found only 4 RCTs and 3 studies in the systematic review examining duration of postoperative analgesia. Additionally, future studies using consistent assessment tools for motor and sensory block recovery, equivalent SAB local anesthetic doses, and similar IV dexmedetomidine dosing regimens across a broad class of patients are needed. Such studies could add to the generalizability and potentially reduce the heterogeneity of research results when IV dexmedetomidine is evaluated for the extension of sensory and postoperative analgesia in an SAB.

### Table 4. Pooled Mean Differences Evaluating Subarachnoid Block Characteristics With Concurrent Use of Intravenous Dexmedetomidine

<table>
<thead>
<tr>
<th>Source</th>
<th>Dexmedetomidine dosing method (No. of studies)</th>
<th>Subjects (N)</th>
<th>Motor recoverya (min)</th>
<th>Sensory recoverya (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdallah et al, 2013</td>
<td>Bolus (n = 2) Bolus + Maintenance (n = 7)</td>
<td>364</td>
<td>35</td>
<td>53</td>
</tr>
<tr>
<td>Updated RCTs</td>
<td>Bolus (n = 3) Bolus + Maintenance (n = 5)</td>
<td>480</td>
<td>40b</td>
<td>46b</td>
</tr>
</tbody>
</table>

Abbreviations: RCT, randomized controlled trial; +, plus.

a Calculated pooled mean differences did not include one study because a median value was reported. Median differences from this study were motor (30 minutes) and sensory (45 minutes).

b Mean differences were calculated using the dexmedetomidine group with the largest difference in motor and sensory times between the control groups.

### Conclusion

A major disadvantage of the SAB is the inability to extend the duration of the anesthetic intraoperatively to address the needs of prolonged surgical procedures. Methods to address this problem include using intrathecal adjuncts, combined spinal-epidural techniques, and higher SAB local anesthetic doses. The results of the systematic review with meta-analysis and the 8 subsequently published RCTs indicate that IV dexmedetomidine is probably an effective alternative method for prolonging the duration of motor and sensory blockade and postoperative analgesia with minimal side effects. Intravenous dexmedetomidine has not been studied as a “rescue” method when surgery is unexpectedly prolonged, but future studies should examine this use. Clinicians must weigh the risk and benefits in selecting IV dexmedetomidine as a primary SAB adjunct in cases that may be unexpectedly prolonged and require a conversion to general anesthesia.

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DISCLOSURES
The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.

ACKNOWLEDGMENTS
The authors would like to sincerely thank Paul Austin, PhD, CRNA; Tito Tubog, DNAP, CRNA; and James Schmidt, PhD, for their support and contribution in publishing this manuscript.
Anesthetic Management of Unstable Cervical Spine: Is Intubating LMA CTrach a Right Choice? A Case Report

Geetanjali T. Chilkoti, MD
Ashok Saxena, MD, FAMS

The LMA (Laryngeal Mask Airway) CTrach (LMA North America Inc) is widely used for airway management in patients undergoing cervical spine immobilization. Three important concerns in these patients are stabilization of the neck, prevention of aspiration of regurgitated gastric contents, and hypoxia. The standard maneuver—down-up down maneuver—applied to the LMA CTrach to improve the glottis view has been reported to cause pulmonary aspiration in cases of regurgitation of gastric contents in predisposed patients. In the present case report, the LMA CTrach was used to facilitate endotracheal intubation in an anesthetized and paralyzed patient. We hypothesize that the factors responsible for the increased risk of pulmonary aspiration with the use of an LMA CTrach in patients with cervical spine trauma are its use in anesthetized patients, use of optimization maneuvers (down-up down maneuver) leading to an unprotected airway, and the underlying risk of regurgitation due to autonomic nervous system dysfunction. We thus advocate the routine use of aspiration prophylaxis and the use of an awake technique whenever the LMA CTrach is used for airway management in patients with cervical spine injuries, to reduce the risk of aspiration.

Keywords: Cervical spine immobilization, laryngeal mask airway, LMA CTrach, prophylaxis

General anesthesia is frequently administered in patients with suspected or known cervical spine instability undergoing cervical spine immobilization. The 3 standard procedures required in these patients are stabilization of the neck, prevention of aspiration of regurgitated gastric contents, and hypoxia. An increased predisposition to regurgitation is seen in patients with cervical spinal cord injury because of autonomic nervous system dysfunction. The LMA (Laryngeal Mask Airway) CTrach (LMA North America Inc) has the advantages of being a difficult airway adjunct that can be inserted in the neutral position and of providing continuous ventilation during intubation. In the present case report, we discuss the various factors causing an increased predisposition to pulmonary aspiration with the use of the LMA CTrach for airway management in patients with cervical spine injuries as well as preventive measures.

Case Summary
A 38-year-old man, weighing 60 kg, with a traumatic cervical spine fracture at the C2 and C3 levels was scheduled for cervical spine stabilization. Findings of all preoperative investigations and airway assessment were within the normal range. The patient was accepted for anesthesia under ASA grade 1. Patient received alprazolam, 0.5 mg, orally on the night before and again on the morning of surgery. Patient was kept fasted for approximately 9 hours. In the operating theater, standard routine monitoring was instituted, which showed noninvasive blood pressure of 126/70 mm Hg, heart rate of 80/min, and 99% oxygen saturation measured by pulse oximetry (SpO2). An intravenous line was secured. After preoxygenation with a face mask with tidal volume breathing of 100% oxygen at 5 L/min for 3 minutes, anesthesia was induced with fentanyl, 2 μg/kg; propofol, 2 mg/kg; and rocuronium, 0.6 mg/kg, intravenously. Manual in-line stabilization of the head and neck was applied. The lungs were ventilated with 100% oxygen, and sevoflurane was administered at concentrations of 1% to 2%. After lubrication with 2% lidocaine jelly, a size 4 LMA CTrach was inserted using a 1-handed rotational movement. The cuff was inflated, and the correct placement was confirmed clinically with chest expansion and the square-wave capnograph on the monitor. After successful ventilation, the display screen was attached to the LMA CTrach, and the glottis was visualized following down-up down maneuver twice. Tracheal intubation was facilitated under direct vision. Immediately after endotracheal intubation, there was regurgitation of the gastric contents into the oral cavity. The endotracheal cuff was inflated immediately and was followed by oral and endotracheal suctioning. Endotracheal suctioning did not reveal any aspiration of regurgitated gastric contents. After thorough suctioning, the LMA CTrach was removed. Chest auscultation did not reveal any conducted sounds. The surgery lasted for...
2 hours, and the perioperative period thereafter remained uneventful.

Discussion
Cervical spine injury constitutes 2% to 5% of blunt trauma, and spinal cord injury can be a devastating consequence.1 Cervical spinal cord–injured patients have autonomic nervous system dysfunction causing paralytic ileus and thus are predisposed to regurgitation and pulmonary aspiration.3–5 An important concern during airway management in patients undergoing cervical spine immobilization includes the risk of spinal cord injury mandating the use of neck immobilization during laryngoscopy and intubation; however, simultaneous risks of aspiration and hypoxia are also of paramount concern in these patients.2

Awake fiberoptic intubation is the gold standard method of airway management in cervical spine injuries because it does not require neck mobilization or wide mouth opening,2 and the risk of aspiration is meager.6–7 The LMA CTrach is functionally identical to the intubating laryngeal mask airway (ILMA) but has an integrated fiberoptic bundle with liquid crystal display. It enables ventilation and allows real-time visualization of endotracheal intubation. All the studies evaluating the potential of the LMA CTrach in cervical spine trauma have been carried out by simulation and have shown it to be a useful airway adjunct.8–11

Similar to the ILMA, an important reason for using the LMA CTrach in patients undergoing cervical spine immobilization is that its insertion requires minimal neck movement. However, like ILMA, it can be hypothesized that the LMA CTrach itself may cause posterior displacement of cervical spine, but the evidence in this regard is lacking. The role of the ILMA until now was controversial; some studies have shown posterior displacement of the cervical spine during its insertion, inflation, and in situ,12 whereas other studies have shown no significant difference.13,14

There have been cases of pulmonary aspiration with the use of LMAs in patients at increased risk of aspiration.15 Abdi et al16 reported that standard maneuvers applied to the LMA CTrach to improve the glottis view may lead to pulmonary aspiration in cases of regurgitation of gastric contents in morbidly obese and predisposed patients. It was suggested that in contrast to the Chandy maneuver, which increases the airway seal, the down-up down maneuver dislodges the distal tip of the LMA mask from its protective place at the hypopharynx, thus causing risk of pulmonary aspiration in case of gastric regurgitation.16 In addition, it has been observed that greater numbers of optimization maneuvers are required to facilitate tracheal intubation with the LMA CTrach in patients undergoing cervical spine immobilization.9,11

An important consideration when the LMA CTrach is used in an anesthetized and paralyzed patient undergoing cervical spine immobilization is the increased risk of aspiration due to the patient’s baseline predisposition to regurgitation and the use of optimization maneuvers such as the down-up down maneuver. In our case, the LMA CTrach was used to facilitate endotracheal intubation in anesthetized and paralyzed patient, and the use of optimization maneuvers might have led to an unprotected airway and thus a risk of pulmonary aspiration following regurgitation of gastric contents in the already predisposed patient. In our patient, pulmonary aspiration did not occur because the regurgitation took place soon after endotracheal intubation, and the endotracheal cuff was inflated immediately followed by thorough oral and endotracheal suctioning.

Because of the lack of evidence of the LMA CTrach regarding its effect on cervical spine displacement, suggested risk of aspiration following use of optimization maneuvers, and a known risk of regurgitation in patients with cervical spine injuries, the use of the LMA CTrach for airway management in these patients warrants careful evaluation. We thus advocate the use of routine aspiration prophylaxis and the use of an awake technique in experienced hands whenever the LMA CTrach is used for airway management in patients with cervical spine injuries, to reduce the risk of aspiration.

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**DISCLOSURES**
The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.
AANA Journal Course
Update for Nurse Anesthetists

Awareness With Recall: A Systematic Review

Caitlin Sullivan, DNAP, CRNA

This article provides a systematic review of awareness with recall, also called intraoperative awareness. Major topics of this review include the incidence and causes of this phenomenon, in addition to an examination of current strategies for prevention of intraoperative awareness. Awareness with recall creates substantial physical and/or psychological distress for the patient, representing a continued threat to patient safety. Factors related to cases of awareness include those of the patient, surgical procedure, anesthesia provider, and system in which providers deliver care. Anesthesia providers today consider use of electroencephalographic depth-of-anesthesia monitors such as the bispectral index monitor (BIS, Covidien, now Medtronic), as a potential tool for preventing awareness. This Journal course explores evidence related to the utility and limitations of this monitor in clinical practice. It also reviews evidence-based practices that may decrease the incidence of awareness with recall, including avoidance of muscle relaxants and protocol-driven approaches to awareness prevention.

Keywords: Anesthesia awareness, depth-of-anesthesia monitors, electroencephalogram.

Objectives
At the completion of this course, the reader should be able to:
1. Describe the effects of anesthesia awareness on the patient’s intraoperative and postoperative experience.
2. Describe patient factors that contribute to cases of anesthesia awareness.
3. Identify potential benefits and limitations of bispectral index monitors.
4. Discuss the results of recent studies with regard to outcomes of bispectral index–guided anesthesia compared with anesthesia guided by end-tidal anesthetic concentration on the incidence of anesthesia awareness.
5. Discuss position statements issued by the Joint Commission, the American Association of Nurse Anesthetists, and the American Society of Anesthesiologists regarding awareness with recall.

Introduction
Intraoperative awareness, defined when “a patient becomes conscious during a procedure performed under general anesthesia and subsequently has recall of these events,” has the potential to result in severe psychological distress for those it affects. Although this traumatic phenomenon is rare, up to 70% of patients who experience recall may exhibit posttraumatic stress disorder (PTSD). This Journal course is a systematic review of the literature on the topic of anesthesia awareness, with the goal of exploring patient, surgical, provider, and systems factors that contribute to its incidence.

Literature Review Methods
Search criteria of 2 databases (The Cochrane Collaboration and PubMed) included the following search terms: anesthesia awareness, awareness, recall, and BIS monitor. The review focused on research studies published since 2014 and included case studies and review articles published since the year 1984. One research study authored by a paid consultant to Aspect Medical Systems was excluded because of the potential for bias. Bibliographies of research articles provided additional references for this review.

Incidence and Stages of Awareness With Recall
Awareness under general anesthesia occurs in the United States about 1 to 2 times per 1,000 patients. This incidence may seem relatively small, but it equates to 20,000 to 40,000 cases per year. Reported rates of awareness under anesthesia varies between countries. For example, the 2013 5th National Audit Project (NAP5) in the United Kingdom and Ireland documented a lower incidence, about 1 in 19,000. (Of note, this study relied...
on patients’ self-reporting.7) Awareness during general anesthesia represents a threat to patients’ safety and outcomes, and erodes their overall trust in anesthesia providers. The Joint Commission, the American Association of Nurse Anesthetists (AANA), and the American Society of Anesthesiologists (ASA) have issued statements detailing the importance of preventing and managing the impact of recall during and after general anesthesia.

Authors describe awareness under anesthesia using terms such as intraoperative awareness, accidental awareness during general anesthesia, and awareness with recall (AWR), to name a few.2,8,9 For the purposes of this Journal course, AWR denotes the phenomenon of awareness under anesthesia. Awareness with recall includes 2 major components: (1) the experience of consciousness during a procedure performed under general anesthesia and (2) subsequent recall of these events.2,3 The ASA defines the terms consciousness, general anesthesia, and recall as follows: “Consciousness is a state in which a patient is able to process information from his or her surroundings…. General anesthesia is a drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation…. Recall is the patient’s ability to retrieve stored memories.”1

Amnesia, or the loss of memory formation, is one goal of general anesthesia. In cases of AWR with explicit (conscious) recall, the patient remembers spoken words, experiences, and sensations from the general anesthetic. Patients also may experience implicit (unconscious) recall, which creates almost equally traumatic psychological consequences following surgery. These patients do not remember spoken words or sensations, yet still unconsciously experience vague psychological difficulties in the postoperative period.10 Explicit memory is more sensitive to general anesthesia than is implicit memory. Low or modest depths of anesthesia may abolish explicit memory but may be insufficient to prevent implicit memory formation.

Kaul and Bharti11 described 4 stages of awareness: (1) conscious awareness with explicit recall, (2) conscious awareness with no explicit recall, (3) subconscious awareness with implicit recall, and (4) no awareness or recall. In a 2006 Practice Advisory, the ASA acknowledged that awareness cannot be measured intraoperatively. The recall component is the defining factor for AWR and can be obtained only from the patient in a postoperative interview.1 Administration of benzodiazepines impairs new memory formation, while previously formed memories remain intact. As the dose of benzodiazepines increases, memory impairment increases. Anesthesia providers should consider amnestic drugs such as midazolam or scopolamine in cases where light anesthesia becomes necessary.10

Patients undergoing anesthesia often report that the risk of recall is a substantial cause of worry.8,9 Those who experience AWR recount feelings of helplessness, inability to breathe, pain, panic, anxiety, and impending death. These patients later experience sleep disturbances, flashbacks, depression, fear about future anesthesia, and hospital avoidance. Many such patients report recall after anesthesia to be their “worst hospital experience” and may refuse future surgeries as a result. Up to 70% of patients who have recall after anesthesia experience PTSD.2,4,12 In her book titled, Silenced Screams, Dr Liska13 described her life-changing experience with AWR. “[T]he surgeon’s electric knife… tore into my skin. It felt like a blowtorch. Lightning bolts of pain more intense than any pain I had ever experienced surged and ricocheted through my torso…. But I was the only one who heard my own tortured screams…”

Causes of Awareness under General Anesthesia

In a 2004 Sentinel Event Alert, the Joint Commission indicated that it is difficult for anesthesia providers to detect AWR.4 Autonomic responses (eg, sudden hypertension, tachycardia, lacrimation, sweating, and pupil dilation) are unreliable indicators of the depth of anesthesia. Beta-blockers or calcium-channel blockers may decrease the sympathetic response to surgical stimulation, which can mask hemodynamic changes in response to AWR.3,14 Administration of neuromuscular blocking drugs during general anesthesia prevents the patient from moving, which could otherwise alert the provider of inadequate depth of anesthesia. Movement in a nonparalyzed patient allows the provider to deepen the anesthetic depth, thereby potentially decreasing the risk for AWR. Providers should consider the minimum dose of muscle relaxants required for adequate surgical exposure and should avoid total paralysis.5 Even if muscle relaxants are not used during general anesthesia, providers must maintain vigilance, as many factors can contribute to AWR. A 1997 prospective study by Nordstrom et al15 investigated 1,000 patients anesthetized with total intravenous anesthesia (TIVA). The authors found no difference in the rate of AWR in TIVA-based anesthesia compared with any other type of anesthesia for paralyzed patients.

Inadequate depression of the central nervous system during anesthetic care is the primary culprit of AWR and may be related to both human and systems factors. Medication errors and infusion pump malfunction are examples of specific, identifiable causes of AWR. In the 2013 NAP5 study, human factors contributed to up to 68% of AWR cases; these factors included failure to fill vaporizers, premature discontinuation of anesthesia before the end of surgery, and accidental administration of muscle relaxants to awake patients.16 Although some of these errors depict examples of inadequate provider oversight, they sometimes represent manifestations of latent errors in the systems in which providers operate. The 2013 NAP5 study reported that system factors, such
as staff shortages, production pressure, and distractions during critical moments, contributed to cases of AWR.16

Certain patient populations exhibit higher risk of awareness after general anesthesia, including those undergoing cardiac, obstetric, or major trauma surgery.10 Cardiac surgery often requires cardiopulmonary bypass (CPB); the anesthetic gas concentration emerging from the exhaust gas port of the CPB oxygenator is not routinely monitored. This fact, combined with a lack of heart rate and blood pressure generated by the patient during CPB, creates a challenge for depth-of-anesthesia monitoring during cardiac surgery.17

Pach et al18 found the incidence of AWR after obstetric surgeries to be 0.4%. Parturients have an increased cardiac output, resulting in rapid redistribution of induction agents. Therefore, a potential period of light anesthesia before the volatile agent reaches an adequate partial pressure to prevent AWR may exist shortly after induction. Ensuring adequate administration of the volatile agent to induce adequate central nervous system depression to obstetric patients has the potential to decrease AWR, yet concerns remain for the effect of these agents on uterine tone and neonatal drug exposure.18

Consequences of major trauma include hypotension, acidemia, anemia, and hypothermia. Bogetz and Katz19 found an increased incidence of AWR during trauma surgery when factors characteristic of severe injury necessitated a decrease in the level of anesthesia. Other high-risk patient factors for AWR include a history of addiction, long-term use of analgesics, female gender, young age, high ASA score, or previous experience of awareness.2 Anesthesia providers should consider preoperative discussion of the risk of AWR with patients identified as at high risk.1,10

In the 2015 NAP5 study, authors wrote that “the period from the start of induction of anesthesia to the start of the surgical intervention … is the time when [awareness after general anesthesia] most commonly occurred.”22 This represented a novel finding that is not currently supported by other studies in the literature, including a 2009 review of reported cases of AWR that found awareness occurred most frequently during the maintenance phase of anesthesia.8 Intraoperative hemodynamic instability, in addition to premature discontinuation of appropriate anesthetic dosing toward the end of surgery, also may contribute to the incidence of AWR.1

**Depth-of-Anesthesia Monitoring**

Providers consider many factors when administering general anesthesia. Some of these factors include subjective methods such as observation of clinical signs (including hemodynamic changes, lacrimation, sweating, movement, and pupil size) that may be affected by a wide range of factors unrelated to anesthetic depth.11 Observation of end-tidal anesthetic gas concentration (ETAC) is another consideration when titrating anesthetic delivery. An ETAC alarm set to at least 0.7 age-adjusted minimum alveolar concentration (MAC) represents one potential component of an awareness prevention protocol.3 However, major shortcomings of this approach are its lack of applicability during TIVA-based anesthesia and the unique patient variability in the MAC response.

Anesthesia providers may also use brain function monitoring as an objective guide for depth of anesthesia. These monitors include both electroencephalographic (EEG) monitors (monitoring spontaneous electrical activity) and auditory evoked potential monitors (monitoring evoked electrical activity).1 Although much research focuses on the bispectral index (BIS, Covidien, now Medtronic), other depth-of-anesthesia monitors exist, including E-Entropy (GE Healthcare) and Narcotrend (MT MonitorTechnik GmbH & Co). Electroencephalographic monitors such as BIS include a sensor (placed on the patient’s forehead), a monitor, and a signal converter. Based on electrical signals from the cerebral cortex, BIS technology uses algorithms to create a numeric value between 0 (no detectable brain activity) and 100 (fully awake).5,20 This number correlates with the patient’s depth of anesthesia, or hypnosis, with values between 40 and 60 implying a state of general anesthesia.2,21 These numeric values typically lag behind the current anesthetic state of the brain by 15 to 30 seconds because of processing time for the EEG signal. During times when rapid changes in anesthetic levels occur (eg, induction and intubation), this delay may decrease the utility of these monitors.14 An additional limitation of BIS monitoring includes paradoxical increases in BIS readings when nitrous oxide or ketamine is used.11 A 2014 study by Lee et al22 investigated general anesthesia performed in the beach-chair position and its effects on BIS values. The authors found this position correlated with a time-dependent decrease in BIS values compared with supine positioning.22 Mallick et al23 discovered that a Trendelenburg tilt position greater than 30 degrees showed higher BIS values than the same tilt at less than 30 degrees. Of note in this study, BIS values returned to baseline levels when the patient reassumed the supine position. The authors referenced the potential effect of large shifts in intracranial blood distribution as a source of variation in BIS values.23 Both the potential utility and limitations of this monitor must be considered for safe anesthesia care (Table 1).

With the advent of physiologic depth-of-anesthesia monitors such as the BIS, the question arises: Does BIS-guided anesthesia prevent awareness compared with anesthesia guided by other protocols? A 2011 study titled “BIS or Anesthetic Gas to Reduce Explicit Recall Trial” (BAG-RECALL) failed to demonstrate superiority of the BIS in preventing recall compared with ETAC monitoring in high-risk surgical patients.3 In 2012, Mashour et
controlled trials in 2013 by Shepherd et al.8 found BIS moni-
toring was associated with a statistically significant
decrease in AWR in high-risk patients. However, the
authors of this research advised caution when interpret-
ing the results because of heterogeneity and bias in many
of the trials.12

**Table 1.** Pros and Cons of Bispectral Index Monitoring

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tr>
<td>• May decrease total anesthesia consumption, recovery times, and incidence of postoperative delirium24,28</td>
<td>• 15- to 30-second delay due to EEG processing time14</td>
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<td>• As part of protocol-guided anesthesia, may decrease risk of AWR (especially when used in combination with ETAC monitoring)21</td>
<td>• BIS values may paradoxically increase with ketamine or nitrous oxide use11</td>
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<td>• Offers depth-of-anesthesia monitoring during TIVA (when ETAC cannot be monitored)24</td>
<td>• Beach-chair position may decrease BIS values,22 whereas Trendelenburg position may increase BIS values compared with supine position23</td>
</tr>
<tr>
<td><strong>Note:</strong></td>
<td>• BIS &lt; 60 does not eliminate the risk of AWR3</td>
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al17 examined the use of the BIS in an unselected surgical
population, noting similar results to the BAG-RECALL
trial. Other large studies and meta-analyses reviewed
use of the BIS and found it to be associated with a lower
incidence of awareness compared with anesthesia guided
by clinical signs, but once again did not demonstrate su-
periority in awareness rates compared with ETAC-guided
anesthesia.5,8,12,24 A systematic review of 22 randomized
controlled trials in 2013 by Shepherd et al.12 found BIS
monitoring was associated with a statistically significant
decrease in AWR in high-risk patients. However, the
authors of this research advised caution when interpret-
ing the results because of heterogeneity and bias in many
of the trials.12

**Prevention of Awareness With Recall in Clinical Practice**

Studies reveal that protocol-driven approaches, in ad-
tion to standard clinical monitoring, may be effective
in preventing AWR. Routine setting of audible ETAC
alarms to at least 0.7 MAC is one example of an evidence-
based protocol. Implementing an ETAC-based protocol
requires measurement of exhaled anesthetic gas concen-
trations and the ability to routinely set alarms for ETAC
values.3 For several anesthetic gas monitoring systems,
it is relatively easy to set audible ETAC alarms. Use of
audible ETAC alarms, as part of a systems approach to
preventing AWR, is a cost-effective option in the noisy
and distracting environment of the operating room.25 In
addition to protocol-driven approaches, studies docu-
menced that midazolam premedication (compared with ETAC-guided anesthesia) was superior to use of either ETAC or BIS monitoring alone. In addition, Mashour et al.20 noted in their post hoc analysis that use of a BIS-guided protocol decreased awareness compared with anesthesia delivered with no protocol. Bispectral index monitors may help prevent an excessively deep level of anesthesia (or cumula-
tive deep hypnotic time, BIS < 45), which was a sig-
nificant independent predictor on 1-year mortality.26,27

In a 2013 study that examined 1,277 patients over the
age of 60 years, patients experienced a decreased risk
of postoperative delirium after BIS-guided anesthesia.28

This study found that extremely low BIS values (< 20)
correlated with an increased incidence of postoperative
delirium in elderly patients.28 Several studies suggested
that BIS-guided anesthesia decreased total anesthesia
consumption, in addition to decreased recovery times,
compared with anesthesia administered based on clinical
signs alone.12,24,26 Although these benefits are notewor-
thy, they may not necessarily equate to improved patient
outcomes or cost savings.

The importance of BIS and ETAC-guided protocols is
no substitute for provider vigilance. Careful consideration
of the effect of drugs administered, use of the smallest
dose of muscle relaxants necessary for surgical exposure,
and ensuring the functionality of all equipment are criti-
cal components in the prevention of AWR. Recognition
of contributory systems factors, such as distractions and
miscommunication in the operating room, should guide
protocol development at an institutional level.

**Recommendations of Other Organizations**

Preventing AWR is of paramount importance for any
facility in which providers administer general anesthe-
sia. The AANA recommended that each facility create
and maintain a policy to prevent and manage awareness
under anesthesia. This policy should include clinical
guidelines that address identification of high-risk pa-

tients preoperatively, in addition to intraoperative rec-

ommendations for practice.29 In a Sentinel Event Alert
issued in 2004, the Joint Commission suggested provi-
sion of support services (such as counseling or a referral
to a psychiatrist or psychologist) to patients who experi-
ence AWR.4 The ASA 2006 Practice Advisory endorsed
multiple modalities in clinical practice to prevent AWR:
observation of clinical signs, standard ASA monitoring,
and case-by-case consideration of use of brain function
monitoring.1 Providers may reference these statements
when developing clinical guidelines or protocols to
prevent AWR (Table 2).
Conclusion
The rate of AWR is unacceptably high given the significant risk of PTSD that this phenomenon carries. One of the most important findings of recent studies is that protocol-guided anesthesia (eg, BIS or ETAC-guided protocols) decreased the incidence of AWR compared with anesthesia guided by clinical signs alone. Both BIS monitoring and ETAC-guided protocols are acceptable in the prevention of AWR. When considering use of a protocol, providers should first consider the availability of depth-of-anesthesia monitors in their facility. With the advent of physiologic brain function monitors in recent years, one must recognize both the utility and potential limitations of these monitors in safe anesthesia practice. Bispectral index monitoring can be an appropriate component of an institution’s protocol with careful consideration of both its clinical benefits and shortcomings. Protocol implementation represents one important part of a facility’s policy, which must also address identification of high-risk patients and follow-up for patients who experience AWR. Sufficient evidence exists to suggest that anesthesia providers use the smallest dose of muscle relaxant necessary for surgical exposure, routinely check the functionality of all anesthesia delivery equipment, and consider protocol-guided anesthesia in their practice.

REFERENCES

Table 2. Summary of Recommendations Regarding Awareness With Recall

<table>
<thead>
<tr>
<th>Organization</th>
<th>AANA (^29)</th>
<th>Joint Commission (^4)</th>
<th>ASA (^1)</th>
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<tbody>
<tr>
<td>Type of statement, year issued</td>
<td>Position statement, 2005</td>
<td>Recommendation, 2004(^8)</td>
<td>Practice advisory, 2006</td>
</tr>
</tbody>
</table>

Abbreviations: AANA, American Association of Nurse Anesthetists; ASA, American Society of Anesthesiologists; AWR, awareness with recall; CRNA, Certified Registered Nurse Anesthetist; GA, general anesthesia.

\(^8\) Sentinel event alert has since been retired.


