Knowledge-based errors in anesthesia: a paired, controlled trial of learning and retention

Les Erreurs Fondées Sur Les Connaissances en Anesthésie : Une Étude Couplée Contrôlée de l'apprentissage et de la Rétention Des Connaissances

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Abstract

Purpose Optimizing patient safety by improving the training of physicians is a major challenge of medical education. In this pilot study, we hypothesized that a brief lecture, targeted to rare but potentially dangerous situations, could improve anesthesia practitioners' knowledge levels with significant retention of learning at six months.

Methods In this paired controlled trial, anesthesia residents and attending physicians at Massachusetts General Hospital took the same 14-question multiple choice examination three times: at baseline, immediately after a brief lecture, and six months later. The lecture covered material on seven "intervention" questions; the remaining seven were "control" questions. The authors measured

immediate knowledge acquisition, defined as the change in percentage of correct answers on intervention questions between baseline and post-lecture, and measured learning retention as the difference between baseline and six months. Both measurements were corrected for change in performance on control questions.

Results Fifty of the 89 subjects completed all three examinations. The post-lecture increase in percentage of questions answered correctly, adjusted for control, was 22.2% [95% confidence interval (CI) 16.0–28.4%; $P < 0.01$], while the adjusted increase at six months was 7.9% (95% CI 1.1–14.7%; $P = 0.024$).

Conclusion A brief lecture improved knowledge, and the subjects retained a significant amount of this learning at six months. Exposing residents or other practitioners to this type of inexpensive teaching intervention may help them to avoid preventable uncommon errors that are rooted in unfamiliarity with the situation or the equipment. The methods used for this study may also be applied to compare the effect of various other teaching modalities while, at the same time, preserving participant anonymity and making adjustments for ongoing learning.

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Résumé

Objectif Un des défis majeurs de l'éducation médicale est l'optimisation de la sécurité des patients par l'amélioration de la formation des médecins. Dans cette étude pilote, nous avons émis l'hypothèse qu'un cours bref décrivant des situations rares mais potentiellement dangereuses pourrait améliorer les niveaux de connaissances des anesthésistes, qui présenteraient une rétention considérable de l'apprentissage six mois plus tard.

Méthode Dans cette étude couplée contrôlée, les résidents en anesthésie et médecins traitants au Massachusetts General Hospital ont passé le même examen de 14 questions à choix de réponses à trois reprises : à la base de référence, immédiatement après un bref cours, et six mois plus tard. Le cours portait sur sept questions « d'intervention » ; les sept autres questions étaient des questions « témoins ». Les auteurs ont mesuré l'acquisition des connaissances immédiate, définie comme le changement du pourcentage de réponses correctes aux questions d'intervention entre la base de référence et juste après le cours, et la rétention d'apprentissage comme la différence entre la base de référence et les réponses données six mois plus tard. Les deux mesures ont été corrigées selon le changement des performances sur les questions témoins.

Résultats Cinquante des 89 sujets ont complété les trois examens. L'augmentation dans le pourcentage de bonnes réponses aux questions après le cours, ajustée pour le témoin, était de 22 % [intervalle de confiance 95 % (IC) 16,0–28,4 %; $P < 0,01$], alors que l'augmentation ajustée à six mois était de 7,9 % (95 % IC 1,1–14,7 %; $P = 0,024$).

Conclusion Un bref cours a amélioré les connaissances, et les sujets ont retenu une quantité significative des connaissances à six mois. Le fait d'exposer les résidents et autres médecins praticiens à ce style d'intervention d'enseignement peu dispendieux pourrait les aider à éviter des erreurs rares mais évitables qui sont dues au manque de connaissances de la situation ou de l'équipement. Les méthodes utilisées dans cette étude peuvent également être appliquées pour comparer l'impact de diverses autres modalités d'enseignement tout en préservant l'anonymat des participants et en procédant à des ajustements pour un apprentissage constant.

Numerous studies show that medical errors can lead to significant patient harm.^{1,2} Applying lessons from other high stakes industries, researchers have examined the significant role of systems factors in allowing or preventing patient harm.^{3–5} In anesthesiology, increased attention is being paid to adverse events that are due to specific systems issues, such as fatigue, medication mislabelling, lack of situational awareness, lack of familiarity with equipment, and poor team communication.^{6–8}

In an effort to learn from prior errors, quality assurance committees at many hospitals have developed critical incident reporting systems.⁹ Morbidity and mortality rounds also represent efforts for clinicians to share experiences, analyze the involved factors, and derive lessons. The ultimate goal is to improve systems and thereby prevent future errors. However, both of these processes rely on learning from errors that have already occurred.

An important challenge of medical education in ensuring patient safety is anticipating the knowledge required to prevent errors which may actively or passively lead to patient harm. How do we effectively teach about circumstances so rare that a trainee may never see them clinically, yet when exposed to an uncommon situation for the first time, major patient morbidity or mortality may result? Surprisingly, there are no published studies measuring a lecture's effectiveness (or ineffectiveness) for this type of unusual information. However, much of the current interest in "active" learning (e.g., simulation) is based on the assumption that traditional teaching methods such as lectures are not very effective. We must provide a forum for teaching this critical information and develop methods to measure the success of knowledge acquisition and retention.

Inadequate practitioner knowledge is a contributing factor to a significant proportion of anesthesia errors.¹⁰ Intelligent, vigilant anesthesiologists may commit errors leading to significant patient morbidity or mortality, particularly when confronted with unfamiliar technology or rare clinical situations. Although this has never been proven clinically, presenting the needed information in didactic sessions, such as lectures, simulations, and other formats, should decrease the risk for such errors and lessen the potential ensuing morbidity and mortality. There are only a few anesthesia studies using a controlled design to measure learning and retention of clinically important knowledge following a specific educational intervention.^{11–13}

In this study, we evaluate the effectiveness of a brief lecture on the acquisition and retention of clinical knowledge. The lecture used in this study is designed to increase knowledge about multiple uncommon clinical scenarios and unfamiliar technologies that might be associated with patient morbidity or mortality. Case-based written examinations are used to analyze the immediate impact of this teaching and the retention of learning at six months.

Methods

Selection and description of participants

All anesthesia practitioners in attendance at the departmental conference on June 9th, 2005 and all new residents (within the first six months of their anesthesia training) in attendance at a November 7th, 2005 lecture were invited to participate. The only exclusion criterion was involvement in the development of the examination or the design of the study. After a group explanation of the study and the consent process, answering the examination questions constituted informed consent. Participation in the study was voluntary, confidential, and anonymous. The only

demographic information collected was level of training (resident, attending physician, other). Each subject created a “unique identifier” code consisting of letters and numbers denoting several facts known only to the subject. These codes linked the three examinations and facilitated the comparison of each subject’s scores on intervention and control questions at baseline, directly post-intervention, and six months post-intervention.

Technical information

This prospective controlled paired study was conducted with anesthesia residents and attending physicians serving as anonymous volunteer subjects from June 2005 to May 2006. The Human Investigations Committee at the Massachusetts General Hospital approved the study protocol and waived the requirement for written informed consent. The subjects were informed as a group about the structure of the study, including pre-, post, and follow-up examination. At baseline, each subject filled out a 14 question multiple choice examination. Afterwards, there was a brief teaching presentation addressing the topics of the seven “intervention” questions that were randomly selected. There was no teaching presentation for the remaining seven “control questions”. Immediately after the lecture, we asked the subjects to fill out a copy of the same examination in order to measure their immediate learning and to ascertain their continued attendance at the conference throughout the teaching intervention. Six months later, we asked the subjects to fill out a third copy of the same examination in order to assess their knowledge retention. The subjects served as their own controls, with each of them receiving seven intervention questions and seven control questions. This paired design also controls for the effects of ongoing non-study-based learning attributable to other training or clinical experience during the intervening six months.

Examination

Fourteen questions (Appendix 1) were developed specifically to address uncommon clinical situations to which an anesthesia practitioner could be exposed, for example, unfamiliar technology, procedural complications, or medication interactions. At least three senior faculty members reviewed each question. We derived the question topics from two sources: 1) a departmental database containing hundreds of internal anesthesia quality assurance analyses, with all identifying data removed; and 2) a list of adverse events or “near misses” that were reported by senior faculty. A single clinical scenario was the basis for each question. At six months, we distributed the follow-up examinations to departmental mailboxes. In addition, we

reminded clinicians, via electronic mail and announcements at departmental conferences, to return follow-up examinations.

Intervention

The teaching session addressed the topics of the seven intervention questions with no discussion of the seven control questions. The intervention consisted of a 30-minute PowerPoint presentation that utilized diagrams and photos to explain mechanistic details. The presentation provided information about potential morbidity from an incorrect action, and it offered suggestions for avoiding such complications. The PowerPoint slides used for the intervention are available as Additional Material online (at cja-jca.org).

Statistical analyses

We used a difference-in-difference analytic approach. First, we calculated knowledge acquisition for each subject as the difference in percentage between correct answers before the lecture and those immediately after the lecture. Then, we adjusted the mean change on intervention questions for secular trends in learning by subtracting the change in performance on control questions. We measured learning retention similarly by comparing performance at baseline and at six months. We calculated 95% confidence intervals (CI) for the change in correctly answered questions from baseline for both knowledge acquisition and learning retention. We also calculated 95% CI for change from baseline on intervention questions adjusted for change from baseline in control questions (i.e., difference-in-difference). All comparisons were planned in advance and were made using a two-tailed, paired *t* test. As two comparisons to baseline were made, one immediately post-intervention and the other at the six-month follow-up, we calculated a required significance level of 0.0253, based on the statistically conservative Bonferroni adjustment necessary to retain an overall alpha of 0.05. All *P* values reported in the results are unadjusted and should be compared to the critical *P* value of 0.0253 for determination of significance.

A sample size calculation determined that 34 subjects would be needed to detect a 10% improvement ($\alpha = 0.05$; $\beta = 0.20$; $SD = 20\%$). We aimed to enroll a substantially larger number at baseline, since we anticipated that some participants would need to leave in the middle of the conference in order to attend to clinical responsibilities. We prospectively defined a completed examination as one with 11 or more of the 14 questions answered. Main analyses were confined to those subjects who completed all three examinations. We analyzed all data using Stata/SE 9.2 for Windows (StataCorp LP, College Station, TX, USA).

Results

Study endpoints

Immediate acquisition of knowledge

As shown in Fig. 1a, the correctly answered intervention questions increased by 1.69 questions [24.2% (95% CI 18.5–29.9%)] from baseline to immediately following the lecture. The increase in control questions answered correctly was 0.14 questions [2.0% (95% CI 0.0–4.0%)] post-lecture. The difference in intervention questions adjusted for control (Fig. 1b) was 1.55 questions [22.2% (95% CI 16.0–28.4%); $P < 0.01$].

Fig. 1 Questions answered correctly. Panel **a**: Percentage of intervention vs control questions answered correctly at baseline, directly post-intervention, and at six-month follow-up. White bars indicate control questions and black bars indicate intervention questions answered correctly. Panel **b**: Improvement from baseline on intervention questions above that on control questions. Gray diamonds represent the increase in the number of intervention questions answered correctly above the respective increase in control questions, for baseline to post-intervention and six-month follow-up. Vertical bars represent 95% confidence intervals

Retention of knowledge

Also shown in Fig. 1a, the increase from baseline to six months in correctly answered intervention questions was 0.91 questions [13.0% (95% CI 7.3–18.8%)]. Over the same time period, the performance on control questions increased by 0.36 questions [5.2% (95% CI 1.5–10.6%)]. The difference adjusted for control (Fig. 1b) was 0.55 questions [7.9% (95% CI 1.1–14.7%); $P = 0.024$].

The analysis described above identifies improvements in the overall number of questions answered correctly attributable to the teaching intervention. However, it does not capture random changes in the specific questions participants answered correctly on each examination. Therefore, we show further analysis by performance for each question in Fig. 2a, b. Amongst subjects who answered a particular question incorrectly at baseline, for intervention questions only, there was a significantly higher likelihood of answering it correctly both post-intervention and at six months, i.e., demonstrating learning and retention. Amongst subjects who answered a particular question correctly at baseline, there was a high likelihood of continuing to answer it correctly both post-intervention and at six months, regardless of whether the question was an intervention or control question.

Study sample and follow-up

Ninety-four clinicians were present at the initial conference, but five were excluded because they had participated in developing the test questions. The 89 remaining subjects returned a baseline examination, 83 of which were completed. We collected completed examinations from 79 subjects directly post-intervention. As for the ten subjects with incomplete examinations at either baseline or directly post-intervention, the missing answers were always consecutive at the end of the examination, as opposed to being skipped intermittently, leaving the impression that the subjects needed to leave the conference early. Fifty subjects returned the six-month follow-up examination, and all of these were completed (Fig. 3). Of these 50 participants, 38 were residents and 12 were attending anesthesiologists. Table 1 shows a breakdown of study participant characteristics and examination completion data.

There were no significant differences in performance on the baseline examination between subjects who did and those who did not meet completion criteria, nor were there significant differences between those who did and those who did not complete subsequent examinations (data not shown). Sensitivity analyses to assess how non-response may have influenced study results were performed for the 26 residents and attending physicians who completed baseline examinations but did not complete post-

Fig. 2 Subjects retaining knowledge at six-month follow-up, stratified by correct response on baseline examination. White bars indicate percentage of subjects answering a given question correctly immediately post-intervention and at six months of follow-up. Gray vertical lines represent 95% confidence intervals. Panel **a** shows results for subjects who answered questions incorrectly at baseline. Panel **b** shows results for subjects who answered questions correctly at baseline

intervention and follow-up examinations. For unanswered questions, we assumed two alternative scenarios: 1) Answers were the same as at baseline. 2) Answers were more likely to be wrong for intervention than for control questions. Neither scenario for which we included responders and non-responders ($n = 76$; data not shown) substantively altered findings from the main analysis confined to responders ($n = 50$). We show all subsequent analyses and results for the 50 participants who met completion criteria for all three examinations.

We found that all but two of the questions on the baseline examination were answered correctly by 46–84% of participants, as shown in Table 2. This indicates that most questions had an appropriate level of difficulty for this audience and discriminated participant knowledge. Question six was answered correctly by 98% of participants at baseline, and question eight was answered correctly by only 16% of participants. In retrospect, it appears that question eight had two plausible correct answers. Analysis of the data, excluding these two

Fig. 3 Subject enrollment and drop-out **Table 1** Subjects who completed each examination

Title	All participants (<i>n</i> = 89)		Completion of baseline ^a (<i>n</i> = 83)		Completion of baseline and post-intervention ^a (<i>n</i> = 79)		Completion of baseline, post-intervention, and six-month follow-up ^a (<i>n</i> = 50)	
	<i>N</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Resident	51	57.30	50	60.24	48	60.76	38	76.00
Year								
0	21		20		20		19	
1	15		15		14		9	
2	10		10		9		7	
3	5		5		5		3	
Attending	30	33.71	26	31.32	25	31.65	12	24.00
Other	8	8.99	7	8.43	6	7.60	0	0.00

^a In each case, completion is defined as answering at least 11 of the 14 questions on all of the specified examinations

questions, did not significantly alter any results (data not shown). Results of all reported analyses include all questions.

In an exploratory analysis, we considered the performance of residents and attending physicians separately. As the study was neither prospectively designed nor powered to detect differences within subgroups, no tests of

significance were performed. For residents (*n* = 38), baseline average number of intervention and control questions answered correctly were 4.6 and 4.2, respectively. For attending physicians (*n* = 12), both quantities were 5.1 questions. On intervention questions, the residents improved 2.0 questions post-intervention and 1.1 questions at six months, compared to baseline. On control questions,

Table 2 Performance of individual questions on baseline, post-intervention, and six-month follow-up examinations^a

Question	Baseline Number of participants answering correctly (%)	Post-intervention Number of participants answering correctly (%)	6-Month follow-up Number of participants answering correctly (%)
<i>Control questions</i>			
Q2	35 (70%)	34 (68%)	42 (84%)
Q4	36 (72%)	37 (74%)	36 (72%)
Q6	49 (98%)	49 (98%)	48 (96%)
Q8	8 (16%)	10 (20%)	5 (10%)
Q10	27 (54%)	29 (58%)	32 (64%)
Q12	36 (72%)	41 (82%)	42 (84%)
Q14	28 (56%)	31 (62%)	36 (72%)
<i>Intervention questions</i>			
Q1	42 (84%)	49 (98%)	48 (96%)
Q3	24 (48%)	48 (96%)	40 (80%)
Q5	42 (84%)	47 (94%)	44 (88%)
Q7	23 (46%)	47 (94%)	45 (90%)
Q9	40 (80%)	43 (86%)	38 (76%)
Q11	36 (72%)	44 (88%)	37 (74%)
Q13	30 (60%)	48 (96%)	35 (70%)

^a Only data for the 50 subjects who completed all three examinations are included

the residents improved 0.2 and 0.6 questions, respectively. On intervention questions, attending physicians improved 1.0 questions post-intervention and 0.6 questions at six months, compared to baseline. On control questions, attending physicians improved 0.4 and −0.2 questions, respectively.

Discussion

The knowledge level of anesthesia practitioners improved substantially immediately following a brief lecture targeted to rare situations involving potentially life-threatening iatrogenic harm. More importantly, the subjects retained a significant amount of their learning six months later. The 13% retention of intervention question learning, 7.9% when corrected for control question learning, may not appear to be substantial. However, this difference, representing more than half of a question on average is an impressive improvement from baseline when one considers that the participants are mostly residents in the midst of intensive training. These same participants improved from baseline to six months—one-sixth of the duration of an anesthesia residency—by only 5.2% or less than half of a question on control questions while, at the same time, being exposed to many lectures, morbidity and mortality rounds, clinical experiences, discussions, and their own reading. The non-residents were anesthesia attending physicians in an academic environment who also engage in significant ongoing learning, albeit likely at a slower rate on average than during residency.

The motivation for this study came from several senior attending physicians who made an anecdotal observation that certain rare situations, with a frequency of approximately three years or the duration of a residency, led to serious, perhaps preventable, morbidity. The inference was made that perhaps, after publicizing a critical issue of iatrogenic harm at morbidity and mortality rounds, a similar event was much less likely to be repeated by others, until the institutional memory lapsed with the entrance of a new generation of residents. A discussion followed as to whether these events could be prevented before they occurred. These events were fundamentally different from other morbidity and mortality presentations where poor communication, fatigue, insufficient equipment, or other factors were considered to be the main causes of a suboptimal outcome. While such factors certainly could contribute, the proximal cause in these events was the lack of specific technical knowledge or the failure to apply such knowledge, resulting in a serious outcome for the patient.

The *raison d'être* for morbidity and mortality rounds is to ask ourselves and our colleagues, “What can we learn from this case to prevent similar events from occurring in the future?” This question can be separated into two components: 1) What systems changes can we implement to prevent a similar event from occurring in the future? and 2) How can we adapt our individual knowledge, thinking, and actions to prevent a similar event from occurring in the future? In the language of James Reason’s Swiss cheese model of accident prevention, both of these efforts are building in-depth defenses.¹⁴ At a systems level, we strive to add more slices, i.e., layers of protection, while

minimizing the number of holes, i.e., weak points, in order to decrease the risk that the holes in each slice of Swiss cheese may line up exactly allowing an accident to occur. As we examine the effects of other systems changes to improve patient safety, we must also bridge these two components by testing the effect of targeted educational interventions to prevent patient harm. While morbidity and mortality rounds are an Accreditation Council for Graduate Medical Education requirement for all medical training programs, and there is a strong belief that such presentations are helpful, multiple PubMed searches found very few studies that examine their effect on increased knowledge and found none that examine improved clinical outcomes. The closest category we found included studies that either asked the residents to rate the learning value of morbidity and mortality conferences or that correlated conference attendance with In-Training Examination scores.^{15–17}

In our introduction, we posed the following question: How do we effectively teach about circumstances so rare that a trainee may never see them clinically, yet when exposed to an uncommon situation for the first time, major patient morbidity or mortality may result? This pilot study begins to answer the question by providing a working model for teaching this critical information and by developing methods to measure the success of knowledge acquisition and retention. As such, this study recruited relatively few subjects (50 participants who completed all three examinations); it tested a modest number of questions and evaluated knowledge retention after six months. If indeed the promising results of this small study are replicated in larger and longer studies, it may well be worth designing brief engaging lecture-based interventions that could be presented at the early stage of many residency programs in order to address the serious pitfalls to avoid in that particular field. Both the ideal time to present such material to new trainees and the number of repetitions required for them to retain the information remain to be seen. Exposing anesthesia residents to this kind of brief teaching presentation is a small investment to pay in both time and resources in order to potentially avoid preventable but serious errors that are rooted in a lack of familiarity with the situation or the equipment.

This study does not measure the effect of the intervention on actual errors in the clinical management of patients or the effect of the intervention on serious patient outcomes, both of which are rare and difficult to study prospectively. Therefore, we cannot know the direct effect of this teaching intervention on morbidity and mortality. However, in prior analyses, insufficient knowledge or training has clearly been shown to contribute significantly to adverse events.^{3,18} A significant and sustainable improvement in clinical knowledge about rare and

potentially dangerous situations is worth pursuing, especially when the teaching intervention requires a relatively small investment of time and resources. The medical lecture is one of the least expensive and easiest ways to present clinical information to a large group of people. It is very possible that newer methods that involve active learning (e.g., virtual patients, high fidelity simulations, or computer-based teaching) may provide a more effective learning experience and offer more memory cues to aid in the retention of learning.

Our pilot study suggests that an initial evaluation, with adequate sensitivity to measure the acquisition and retention of clinical anesthesia information, is possible using a prospective paired controlled trial of relatively modest size. Confirmation should be carried out with larger studies, because a small study, such as this, is vulnerable to the confounding influence of a random “learning” event. For example, the occurrence of a well-publicized clinical incident could have a large effect on apparent study “learning” for either a control or an intervention question. After confirmation with larger studies, this paired design, with subjects serving as their own controls and questions being divided into intervention and control groups, could be utilized to compare learning and retention after a lecture vs other teaching methods.

There are several other limitations to this study. The questions were derived from a database specific to a single academic department, and all of the tests were taken by residents and attending physicians within that department. There were 14 questions; therefore, only a limited number of clinical scenarios were tested. Our decisions about what constituted “uncommon” problems were admittedly arbitrary, though all questions were reviewed by multiple senior anesthesiologists. Although our results indicate that we achieved an appropriate level of difficulty to assess our department, this might not have been true in another department. Since it was known that follow-up testing would occur in this learning environment, there was the potential for observer effects and for bias, in that subjects may have remembered information better than usual when informed there would be a post-intervention examination and a follow-up examination. However, the anonymity of their results likely mitigates this bias to some extent. We were able to measure an effect at six months, but this does not guarantee longer term retention. In the future, it would be valuable to assess knowledge retention at multiple time points in order to determine at what interval a teaching intervention should be repeated.

In summary, we found that anesthesia residents and attending physicians showed statistically significant evidence of retained learning six months after a brief lecture addressing the knowledge necessary to avoid preventable

serious errors that are rooted in a lack of familiarity with uncommon situations or equipment.

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Appendix 1: Examination questions, with answers at the end

1. The most likely consequence of running Phenytoin/Normal Saline and Phenylephrine/D5W together is:

- A Bleeding
- B Drug Inactivation
- C Precipitation
- D Hemolysis
- E Hypotension

2. You have an unexpected difficult airway in a 69yo M smoker with GERD and COPD having finger surgery. You can't intubate and can't ventilate with mask or LMA. His SpO₂ is dropping quickly, so you call for surgical assistance and perform jet ventilation through a 16 ga needle in the cricothyroid membrane. After 10 breaths, his SpO₂ improves to 85%, but his BP drops rapidly, and you can't feel a pulse. His EKG shows sinus tachycardia. Your next action (surgeons have not yet arrived) should be:

- A Remove the needle
- B Detach jet ventilator
- C Connect anesthesia circuit and hand-ventilate
- D Begin chest compressions
- E Administer phenylephrine

3. Your pt becomes severely hypotensive during a bowel resection and has insufficient iv access. You realize he has a hemodialysis catheter in his L subclavian vein. If you use a pressure bag to infuse crystalloid rapidly through this catheter, it is most likely to cause:

- A Bleeding
- B Pneumothorax
- C Subcutaneous emphysema
- D Catheter fracture
- E Catheter dislodgement

4. Your SICU pt has known CAD and is recovering well from his Whipple three days ago. He is breathing spontaneously with SpO₂ 98%, HR 67, BP 124/68. You are at his bedside when he suddenly develops VF and stops breathing. A code cart and all equipment is immediately available. What would you do first?

- A Intubate
- B Epinephrine 1 mg iv
- C Chest compressions
- D Defibrillate
- E Amiodarone 300 mg iv

5. The pt you pick up from the Neuro ICU has a ventriculostomy drain in place. You connect your A-line transducer set to the drain with a stopcock in order to measure her ICP. The most likely consequence of this action is:

- A Increasing Intracranial Blood Flow
- B Intracranial Infection
- C Increasing ICP
- D Hypoxia
- E Air Embolism

6. Glycopyrrolate 0.8 mg and neostigmine 4 mg are given to reverse the neuromuscular blockade of a 66yo patient following radical prostatectomy. Following awakening and extubation, he suddenly goes into laryngospasm and SpO₂ falls. He is given 100 mg propofol, 100 mg succinylcholine and reintubated. Twenty minutes later, he is well-oxygenated but has no evidence of twitches on train of four. The most appropriate course of action is:

- A Give more neostigmine
- B Switch to physostigmine
- C Give sedation and place patient on ventilator in PACU
- D Let CO₂ build up to check whether the patient will breathe on his own.
- E Arrange for emergency CT scan

7. You are examining a 78 yo SICU patient who needs emergency abdominal exploration. She had ARDS, but now is alert, breathing through her tracheostomy, and vocalizing with her Passy-Muir valve. Suddenly, she becomes unresponsive and stops breathing. You connect an ambu bag, inflate the tracheostomy cuff, and begin ventilating. The most likely adverse consequence of your actions would be:

- A Hypotension
- B Laryngeal Fracture
- C Venous Air Embolus
- D Tracheal Bleeding
- E Tracheal Foreign Body

8. You perform a rapid sequence intubation for upper endoscopy in a 12 year old boy with acid reflux. After you

give him succinylcholine, you are unable to open his mouth due to masseter spasm. You continue mask ventilation with cricoid pressure. Your next step should be:

- A Do a nasal fiberoptic intubation
- B Cancel the case
- C Tracheostomy
- D Administer cisatracurium
- E Give more succinylcholine

9. You have just placed a left interscalene block in a 70 yo male patient with an elbow fracture. Afterwards, he complains of shortness of breath. His SpO₂ is 92% on 5L face-mask oxygen, and you aren't sure that you hear breath sounds on the left. BP 110/60 HR 102 RR 28. The most appropriate action to take next is:

- A Intubate
- B Insert a needle in the left 2nd intercostal space
- C Start a nitroglycerin infusion
- D Administer metoprolol
- E Obtain a STAT chest X-ray

10. You are paged on RICU [respiratory ICU] consult to see a 21 yo male with Ebstein's anomaly who has a suspected pulmonary embolus following a minor procedure. When you arrive, his SpO₂ is 84% on 5L O₂ by face mask. BP 96/48, HR 120, RR 26, vitals unchanged over past five minutes. He is talking to you in full sentences, but when asked says he does feel short of breath. While working up his pulmonary embolus, the most appropriate supportive treatment is

- A Nebulized albuterol
- B Metoprolol
- C Continue face-mask oxygen
- D Intubate using local anesthesia
- E Intubate using etomidate and succinylcholine

11. A 72 yr old trauma patient is brought to the OR for a probable ruptured spleen. BP is 80/50, HR is 110. A pacemaker bulge is seen on her chest, but no spikes are seen on the ECG. Which of the following is most important to do before inducing general anesthesia?

- A Administer atropine
- B Obtain a stat CXR
- C Insert a ventricular pacing wire
- D Obtain a pacer magnet
- E Interrogate the pacer

12. Asking an awake patient to "hum" during an internal jugular vein cannulation is most helpful in order to avoid:

- A Movement
- B Air Embolus
- C Pneumothorax

- D Hypertension
- E Arterial Cannulation

13. You decide to place an epidural for a three year old having thoracic surgery. Saline is preferable to air for loss of resistance primarily because it decreases the risk of:

- A Epidural hematoma
- B Epidural abscess
- C Venous embolus
- D Accidental dural puncture
- E Patchy block

14. You are pacing your patient via a PA catheter pacing port. The amount of surgical blood loss increases, so you plug in a 2nd fluid warmer. Just after that, as the surgeons are using the bovie, the LIM (Line Isolation Monitor) goes from 2 mA to 9 mA and alarms. The most important first step is:

- A Unplug the 2nd fluid warmer
- B Put a pacer magnet on your patient's chest
- C Ask the surgeons to stop using the Bovie
- D Attach an external pacing device
- E Ask somebody to flip the circuit breaker

Answers

- 1 C
- 2 B
- 3 A
- 4 D
- 5 C
- 6 C
- 7 A
- 8 D (Multiple correct answers in retrospect)
- 9 E
- 10 C
- 11 D
- 12 B
- 13 C
- 14 A

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