Clinical Anesthesiology II

Lessons from Morbidity and Mortality Conferences

Jonathan L. Benumof
Gerard R. Manecke
Editors

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Preface

In 2014, we published a unique book, *Clinical Anesthesiology: Lessons Learned from Morbidity and Mortality Conferences*. We now present a logical companion to that book: Volume II, *Clinical Anesthesiology: Lessons Learned from Morbidity and Mortality Conferences*. An extension of its predecessor, this volume is a compilation of new selected cases presented at the weekly University of California San Diego (UC San Diego) Department of Anesthesiology Morbidity and Mortality (M + M)/Quality Improvement (QI) conferences. Case descriptions, relevant physiological and medical issues, and "lessons learned" have been written up in the form of chapters to create an easily accessible, clinically relevant compendium. Two main factors prompted us to create this new book. The first is that Volume I is very popular, with electronic access exceeding 111,000 "look-ups" since its publication. The publisher informs us that, for clinical medicine texts, this performance is excellent. Evidently, readers find the format of the book and teaching points valuable. Secondly, the "lessons" just keep coming! Our weekly conferences continue to be very high-quality case descriptions and discussions presented by a resident and moderated by a senior, learned faculty (often ourselves ☺). Each conference has teaching points brought forth by the moderator, other faculty during discussion, the presenting resident, and other attendees. Being a tertiary/quaternary care health system, UC San Diego has many critically ill patients, as well as numerous healthy patients undergoing "bread and butter" procedures. Thus, at UC San Diego, there is a virtually limitless supply of challenging anesthetics, complex surgeries, emergency calls, and unexpected events in the operating rooms, ICUs, and floor units – all with take-home lessons galore. Immediately upon the completion of Volume I, we recognized that we were rapidly accumulating important new clinical and teaching material for a Volume II.

These new case chapters are presented in the same format as in the first volume, with each consisting of a case description and "lessons learned," gleaned from either the case or the subsequent conference discussion. We believe this format is unique and informative, since it incorporates the case experience of the provider, the "clinical pearls" from the discussion of the group, the lessons provided by the moderator, and the important source information from the medical literature.

There are two significant differences between this volume and Volume I, however. The first is that in this text, we have asked the authors of each chapter to go into significant depth – there are very few superficial discussions in this book. The intent is for the reader to be able to obtain detailed, up-to-date information on a clinical problem, condition, or case scenario, without having to consult other sources. Source references are, of course, provided, should the reader desire to delve even deeper or understand the background and data supporting each chapter. The second difference involves the grouping and ordering of the chapters. In the first volume, the chapters were grouped according to general physiologic systems or areas of anesthetic practice (e.g., respiratory, circulatory, obstetric, pain, and regional). In this volume, the chapters seemed to be organized according to the impact or potential impact on the patient (e.g., death, major morbidity, minor morbidity, no morbidity but clinically challenging). We have thus grouped them by those categories.

Although all the cases in this volume are new, there is necessarily some overlap in the material provided in this volume and the previous one. Items such as hypoxemia, ventilation problems, hypotension, dysrhythmias, obstructive sleep apnea, coagulopathies, and potential for airway fire are recurring themes in our practice and discussions. Thus, they are found in both volumes, in one form or another. There are other chapters in Volume II that cover new and difficult subjects such as death during monitored anesthesia care, drug administration error, massive pulmonary hemorrhage, and abdominal compartment syndrome.

We have both learned a great deal in compiling this text and believe that the reader will likewise learn and benefit from it. We are even so bold as to suggest that the reader's patients will benefit as well. In the preface to Volume I, we pointed out the unique nature of the approach, saying "Try it, you'll like it." You *did* try it, and you *did* like it. With this volume, we say "Try it again, you'll like it again!"

San Diego, CA, USA

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Part I
Cases Resulting in Perioperative Death

Chapter 1
Death During Monitored Anesthesia Care

Kevin D. Marcus and Jonathan L. Benumof

The patient was a 69-year-old, 155 cm, 68 kg female with a calculated BMI of 28.3 kg/m^2, who presented with significant right-upper-quadrant pain. Work-up on the patient revealed choledocholithiasis with evidence of cholecystitis. The patient was subsequently scheduled for endoscopic retrograde cholangiopancreatography (ERCP) **(L-1)** in the endoscopy suite.

Prior medical history was significant for obesity, now several years status-post laparoscopic gastric band surgery. There was otherwise no significant past medical, surgical, or medication history. A preoperative chest X-ray and EKG were unremarkable. Blood work showed mildly elevated liver enzymes and a hemoglobin and hematocrit of 10.8 gms/dl and 33%. Vital signs were as follows: BP = 135/73 mmHg, HR = 81 bpm, and S_pO_2 = 97% on room air. The patient was deemed to be ASA class II, with mild systemic disease, and taken to surgery with plans for a MAC anesthetic **(L-2)** with propofol sedation **(L-3).**

The patient was positioned prone with O_2 via nasal cannula at 5 L/min. A noninvasive blood pressure cuff, EKG/HR, and S_pO_2 were used to monitor the patient. Continuous CO_2 monitoring was not employed, and an anesthesia machine was not in the endoscopy suite **(L-4, 5)**. However, an American Heart Association (AHA) ACLS "crash" cart was located 50 ft down a hallway.

Anesthesia was induced with an initial propofol bolus of 70 mg, and over the next 40 min, an additional 310 mg was given in intermittent, divided doses ranging

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from 30 to 70 mg. A total of 380 mg of propofol was given during the course of the 40-min ERCP **(L-6)**.

Minutes after the final dose of propofol was given, the anesthesia provider noticed an approximately 50% decrease in the patient's blood pressure, heart rate, and pulse oximeter values. A code was called. The patient was then turned supine and bag mask ventilation was instituted. The decision was made to intubate the patient, and direct laryngoscopy by the anesthesiologist revealed what was thought to be a grade I view of the larynx, and an endotracheal tube (ETT) was passed. One to 2 min after the tracheal intubation attempt, an emergency department (ED) physician arrived on the scene with a portable colorimetric CO_2 monitor (Easy Cap detector), but this monitor was not utilized at this time. There was no CO_2 confirmation of correct ETT placement **(L-7)**.

Several minutes after the ETT was placed, the patient's peripheral pulses were lost to continuous palpation by the ED physician, and there were no audible breath sounds on auscultation or color change on the colorimetric CO_2 detector. The ETT was removed, and a repeat laryngoscopy was performed with placement of a second ETT. This time, there was portable exhaled CO_2 colorimetric confirmation of correct ETT position within the trachea **(L-8)**. However, the patient was unable to be resuscitated despite administration of ACLS during the code blue.

Lessons Learned

L-1: What Is an ERCP?

ERCP stands for endoscopic retrograde cholangiopancreatography and is an invasive procedure performed primarily by gastroenterologists for both diagnostic and therapeutic purposes related to the biliary and pancreatic ductal systems. An endoscope is passed through the mouth and past the stomach into the duodenum where the opening to the biliary and pancreatic ducts, the ampulla of Vater, is located (Fig. 1.1a). A catheter is then advanced through this ampulla and into the biliary and pancreatic ducts, at which point the ductal anatomy can be explored, usually by way of injection of radiopaque dye, which is seen on fluoroscopy.

Therapeutic interventions are also possible, such as removal of stones. The sphincter of Oddi, a circular band of muscle that surrounds the ampulla of Vater, can sometimes present a barrier to access. This is solved with a sphincterotomy (Fig. 1.1b), which can be stimulating and painful to the patient. Removal of stones by deployment of a distal basket or balloon (Fig. 1.1c) can also prove to be painful as the stones are swept out of the ducts. Careful attention must be paid to these portions of the procedure as they may require adjustment in the level of sedation.

Common indications for ERCP include obstructive jaundice, choledocholithiasis, pancreatic tumors, dilation of strictures, and insertion of stents.

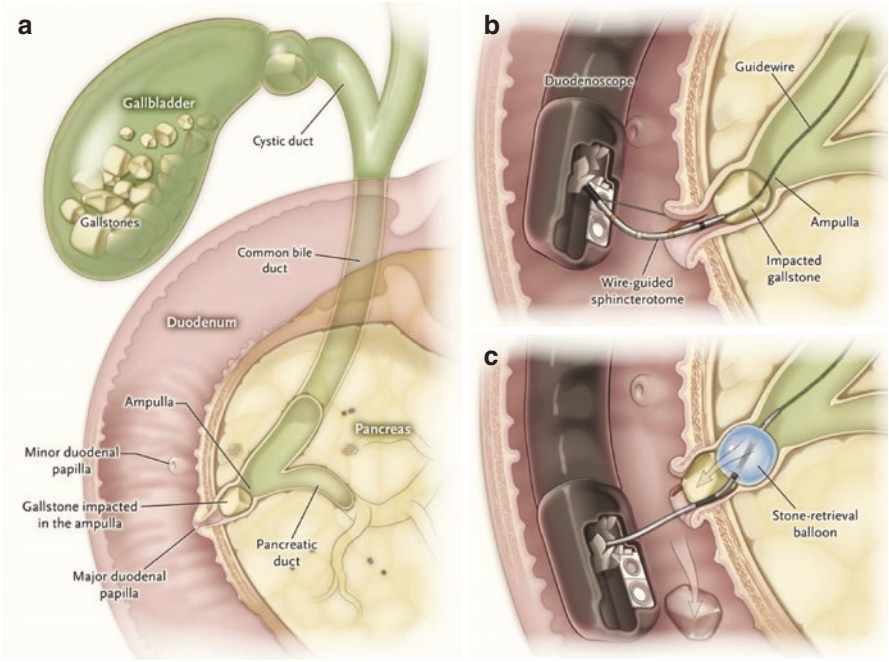

Fig. 1.1 Anatomy of the biliary and pancreatic ductal systems, during ERCP. (**a**) Biliary system anatomy depicting impacted common bile duct gallstone. (**b**) Sphincterotomy for passage of catheter into common bile duct. (**c**) Inflation of distal balloon for gallstone removal. (Reprinted from Fogel and Sherman [18]. With permission from Massachusetts Medical Society)

L-2: What Is a "MAC" Anesthetic? (Fig. 1.2)

Monitored anesthesia care, or MAC, is a "specific anesthesia service in which an anesthesia provider has been requested to participate in the care of a patient undergoing a diagnostic or therapeutic procedure" [1]. The MAC service includes all aspects of anesthesia care, including a pre-procedure visit, intra-procedure care, and post-procedure anesthesia management [2]. Relief of pain, treatment of complications, or diagnosis and treatment of coexisting medical problems are just a few examples of what the MAC service might entail.

According to the ASA position statement on MAC, "monitored anesthesia care may include varying levels of sedation, analgesia and anxiolysis as necessary" [2]. This means that the anesthetic during a MAC may range from local anesthesia without sedation to deep sedation and even general anesthesia. Even if a patient is thought to require only minimal sedation for a procedure, they may need a MAC service because there is the potential for adverse effects, either secondary to the sedation given or the procedure itself, which would require intervention from an anesthesia provider ranging from resuscitation to general anesthesia [3].

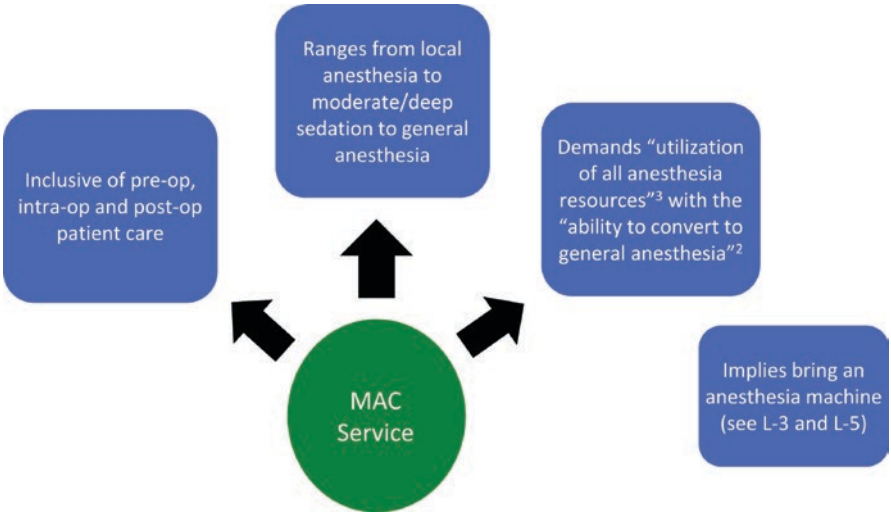

Fig. 1.2 Components of MAC anesthesia service

Therefore, MAC is an anesthesia service and does not imply a specific type of anesthesia being administered.

It should be apparent from the above that a central tenant from the ASA regarding MAC is that the anesthetic provider "must be prepared and qualified to convert to a general anesthetic when necessary" [2]. This fact is key to differentiating MAC from "moderate sedation," as non-anesthesia personnel can often provide moderate sedation (see L-3). MAC service allows for safe administration of a maximal depth of sedation in excess of what can be provided during moderate sedation, by personnel equipped to provide general anesthesia. There is also an ASA expectation that a provider of a MAC service must be able to "utilize all anesthesia resources to support life" [3]. This directive further differentiates "moderate sedation" from a MAC service.

The statements "utilize all anesthesia resources to support life" [3] and "be prepared and qualified to convert to general anesthesia" [2] strongly imply that an anesthesia machine, or the component parts of the anesthesia machine, be immediately available to anyone who provides a MAC service (Fig. 1.2).

L-3: What Are the Different Levels of Sedation?

The ASA defines four distinct levels of sedation or anesthesia, namely, minimal sedation, moderate sedation, deep sedation, and general anesthesia [1] (Table 1.1). The commonly used term "conscious sedation" is synonymous with a moderate sedation level.

Table 1.1 ASA definition of levels of sedation and general anesthesia in terms of various clinical parameters

Clinical parameter	Minimal sedation	Moderate sedation	Deep sedation[a]	General anesthesia
Responsiveness	Normal response to verbal stimuli	Purposeful response to verbal or tactile stimuli	Purposeful response following repeated painful stimuli	Unarousable even with painful stimulus
Airway patency	Unaffected	No intervention required	Intervention may be required	Intervention often required
Spontaneous ventilation	Unaffected	Adequate	May be inadequate	Frequently inadequate
Cardiovascular function	Unaffected	Usually maintained	Usually maintained	May be impaired

Based on data from Ref. [1]

[a]If a provider is planning deep sedation, they must be prepared to provide a general anesthetic according to the ASA position statement. This may include the probability of needing an anesthesia machine

As depicted in the above table, the various levels of sedation and anesthesia are largely defined by the patient's response to various stimuli during the course of their sedation.

Minimal sedation is defined as a "drug-induced state during which patients respond normally to verbal commands" [1]. Cognitive function and physical coordination may be slightly impaired.

Moderate sedation, or "conscious sedation," is defined as "drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation" [1]. Purposeful responses do not include reflex withdrawal. Non-anesthesia providers can give moderate sedation to patients but must be trained to also recognize deep sedation, manage its consequences, and adjust the level of sedation to a moderate or lesser level.

Deep sedation is defined as a "drug-induced depression of consciousness during which patients cannot be easily aroused, but respond purposefully following repeated or painful stimulation" [1]. It is during deep sedation that spontaneous ventilation may become compromised, requiring an airway intervention by the provider. It is for this reason that in cases where deep sedation may be required, a MAC service is essential for the reasons discussed in the previous lesson (see L-2).

General anesthesia is defined as a "drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation" [1]. It is at this point that spontaneous ventilation is often inadequate and airway intervention is frequently required, although general anesthesia does not mandate use of an advanced airway.

The ASA's position statement on the various levels of sedation comments that the level of sedation is fluid and can rapidly fluctuate from one level to another and that it is often not possible to predict an individual's response to sedative or hypnotic medications. For this reason, it is recommended that a provider of sedation be able to rescue and treat a patient who becomes one level deeper than expected [1]. For instance, if a provider is planning "deep sedation," they must be prepared to provide

a general anesthetic and all that accompanies this service, which may include the probability of needing an anesthesia machine.

L-4: What Are the Standard ASA Monitors?

The ASA last published practice guidelines on the standards for basic anesthetic monitoring in 2010, with an effective date of July 1, 2011. These standards were meant to apply to all anesthesia care, including general anesthesia, regional anesthesia, and monitored anesthesia care. The overall standard is that "the patient's oxygenation, ventilation, circulation and temperature be continually evaluated" [4].

Oxygenation

To adequately ensure blood oxygenation, it is required that a quantitative method of assessing oxygenation, such as pulse oximetry, be used for all anesthetics. It is not enough just to use a pulse oximeter; a variable pitch pulse tone, which changes with specific O_2 saturation levels, and low threshold alarm must also be audible to the anesthesiologist. For general anesthetics utilizing an anesthesia machine, it is also required that an oxygen analyzer with a low O_2 concentration alarm be used to assess the oxygen concentration in the breathing circuit (Table 1.2).

Table 1.2 Monitoring requirements for each clinical parameter listed in the ASA practice guideline for basic anesthetic monitoring during moderate/deep sedation and general anesthesia

Clinical parameter to be monitored	Mandatory monitors	Additional/supplementary monitors
Oxygenation	Pulse oximeter with audible alarms	None, all monitoring mandatory
	Oxygen analyzer with low [O_2] alarm	
Ventilation (also see Table 1.3)	Continual exhaled CO_2 detection	Quantitative monitoring of volume of expired gas[b]
	Audible alarm for detecting circuit leaks[a]	
Circulation	Continuous ECG tracing	Palpation of pulse
	BP and HR every 5 min	Auscultation of heart sounds
		Arterial line pressure tracing
		Ultrasound peripheral pulse monitoring
		Pulse plethysmography[c]
Body temperature	Must be monitored when clinically significant changes are intended, anticipated, or suspected	

[a]Only when ventilation is controlled by mechanical ventilator
[b]Strongly encouraged by ASA during general anesthesia
[c]At least one of the listed additional circulation monitors must be used in addition to the mandatory monitors

Ventilation

The practice guidelines to ensure adequate ventilation depend on the type of anesthesia that is being provided. The anesthesia provider need only assess the qualitative clinical signs of adequate ventilation during regional or local anesthesia performed without sedation (Table 1.3). These qualitative clinical signs may include chest excursion, observation of the reservoir breathing bag, or auscultation of breath sounds [4]. However, during moderate, deep sedation and general anesthesia, the "adequacy of ventilation *SHALL* be evaluated by the presence of exhaled CO_2 unless precluded or invalidated by the nature of the patient, procedure or equipment" [4]. These preclusions might include cardiopulmonary bypass, operations on the nose and mouth, or machine malfunctions mid-operation, all of which may affect the ability to accurately interpret exhaled CO_2.

For general anesthesia with an endotracheal tube (ETT) or laryngeal mask airway (LMA), correct positioning must be verified by clinical assessment and exhaled CO_2. Additionally, continuous end-tidal CO_2 using capnometry, capnography, or mass spectroscopy must be in use from the time of placement of the airway device to the time of removal.

Table 1.3 ASA statement on the requirements for adequate monitoring of ventilation

Depth of anesthesia +/− airway	Regional or local anesthesia without sedation	Moderate or deep sedation	General anesthesia without airway	General anesthesia with ETT or LMA
Quote from the ASA on the type of monitoring required for ventilation based upon the depth of anesthesia	"The adequacy of ventilation shall be evaluated by continual observation of qualitative clinical signs[a]" [4]	"The adequacy of ventilation shall be evaluated by continual observation of qualitative clinical signs[a] and monitoring for the presence of exhaled carbon dioxide" [4]	"Every patient receiving general anesthesia shall have the adequacy of ventilation continually evaluated… continual monitoring for the presence of exhaled CO_2 shall be performed" [4]	"Continual end-tidal CO_2 analysis, in use from the time of ETT/LMA placement until extubation/removal… shall be performed using a quantitative method such as capnography, capnometry or mass spectroscopy" [4]
Qualitative clinical signs	YES	YES	YES	YES
Qualitative CO_2 monitoring[b]	NO	YES	YES	NO
Quantitative CO_2 monitoring	NO	NO	NO	YES

[a]Qualitative clinical signs may include chest excursion, assessment of the reservoir breathing bag movement, or auscultation of breath sounds

[b]For example, colorimetric CO_2 detection devices

Note that the essential difference between regional and/or local anesthesia without any sedation given and moderate or deep sedation is that with no sedation given, a provider need only monitor qualitative signs of adequate ventilation; however, if *any* sedation is given, one must also utilize, at a minimum, qualitative exhaled CO_2 monitoring.

Circulation

To ensure adequate circulation during all anesthetics, multiple monitoring components must be satisfied. First, every patient must have a continuously displayed electrocardiogram from the beginning to the end of the anesthetic. Secondly, arterial blood pressure and heart rate must be assessed at least every 5 min. Lastly, circulation must also be assessed by at least one of the following in addition to the mandates above: palpation of pulse, auscultation of heart sounds, intra-arterial pressure tracing, ultrasound peripheral pulse monitoring, or pulse plethysmography or oximetry [4].

Body Temperature

In order to enable the anesthesia provider to maintain appropriate patient body temperature during anesthesia, every patient must have their temperature monitored when clinically significant changes are intended, anticipated, or suspected [4].

The ASA has issued a separate statement on standards for appropriate respiratory monitoring that has specific implications to the case presented in this chapter. It states that "exhaled CO_2 *should* be conducted during endoscopic procedures in which propofol alone or in combination with opioids and/or benzodiazepines" are utilized for sedation [5]. The statement clearly emphasizes that special attention needs to be paid to ERCP procedures performed in the prone position.

In summary, the basic monitors required for all anesthetics are pulse oximetry, exhaled CO_2 (except when no sedation given), continuous electrocardiography, arterial blood pressure monitoring (usually via noninvasive cuff pressures), heart rate display (usually via ECG, pulse oximetry, or noninvasive blood pressure), and temperature. In this case, the provider failed to adequately assess ventilation by not having a means of monitoring exhaled CO_2. They also failed to appropriately confirm placement of their ETT with exhaled CO_2 (see L-7).

L-5: What Are the Advantages of Having an Anesthesia Machine at Out-of-the-OR Locations?

Many times, anesthesia providers are asked to administer sedation and/or general anesthesia in locations other than the operating rooms. These out-of-OR locations may include endoscopy suites, interventional radiology, interventional cardiology,

MRI or CT scanners, or even ICU beds. Providing anesthesia in these remote locations can be an unfamiliar and even dangerous experience, if not properly prepared.

In a review of the ASA Closed Claims database, it was determined that overall, patients receiving anesthesia in remote locations were older, had higher ASA classifications, and more often underwent emergent procedures than those patients in the OR [6]. The most common anesthetic technique at remote locations was MAC, whereas general anesthesia was the most common anesthetic technique in the OR. Although adverse respiratory events were the most common mechanism of injury at both locations, they occurred roughly twice as commonly in remote locations [6]. Furthermore, the proportion of deaths in outlying locations was nearly twice as what occurred in the OR [6] (Fig. 1.3). In-depth analysis of these closed claims cases revealed that injuries at these remote locations were more often judged to be preventable by better monitoring of patients.

Based upon the prior data, it would stand to reason that having all available supplies to administer general anesthesia, despite whatever the initial plan for anesthesia was, would be a prudent decision. Having a fully stocked anesthesia machine with attached monitors, drawers, and ventilators is of great value, especially when considering that an unanticipated anesthetic urgency or emergency might occur.

Some of the advantages of a fully stocked anesthesia machine include:

1. Continuous CO_2 waveform: usually in the form of a capnograph, continuous CO_2 is important for breath-to-breath confirmation of adequate ventilation. It is also useful for confirmation of appropriate ETT placement and adequacy of chest compressions and return of spontaneous circulation during cardiac arrest (see L-8).
2. Additional airway supplies: drawers in the anesthesia machine will typically have multiple additional laryngoscopes in various sizes and shapes. There is also

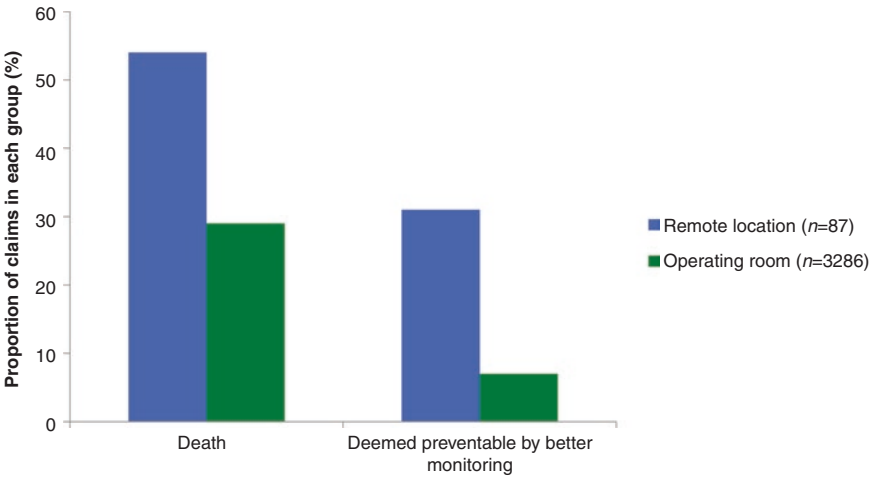

Fig. 1.3 Proportion of claims in remote locations vs. operating rooms including death and total proportion of claims that were thought to be preventable by better monitoring. (Based on data from Ref. [6])

typically a bougie, as well as LMAs, oral/nasal airways, and other devices necessary to complete the difficult airway algorithm.
3. Mechanical ventilator: various modes of ventilation can be helpful in situations where sedation is rapidly converted to general anesthesia with the need for mechanical ventilation. There is also the added benefit of known minute ventilation and the ability to set tidal volumes, respiratory rates, and respiratory modes.
4. Additional O_2 source: all anesthesia machines will have an extra E-cylinder of oxygen attached. This can prove invaluable in the event of loss of wall pressure or other malfunction. Having a backup O_2 source is one of the absolute requirements for providing out-of-OR anesthesia [8].
5. Touch-sensitive reservoir bag: provides tactile feedback when providing positive pressure ventilation and/or assisting spontaneous ventilation. The bag is also useful for determining changes in lung compliance/resistance and can even help in detecting early esophageal intubation in the hands of a skilled provider.
6. Volatile anesthetics: in the event of conversion to a general anesthetic, having the option of providing volatile anesthesia is an advantage.
7. N_2O tank: readily available on most anesthesia machines is an E-cylinder of nitrous oxide, which can be used to provide additional inspired analgesia with minimal decrement in respiratory drive and minute ventilation.
8. Suction: provides life-saving capability should the need arise for intubation in a patient with copious secretions, active vomiting, or a bloody airway. This is another mandatory item for providing anesthesia in out-of-the-OR locations according to the ASA [8].
9. O_2 flush valve: allows rapid filling of the anesthesia machine bellows and reservoir bag.

Although most of these supplies may also be found in anesthesia work rooms and collected prior to providing anesthesia in an out-of-OR location, having the complete anesthesia machine saves time and also prevents possible oversight that can happen when trying to assemble all of the necessary components listed above. Especially in an emergency situation, familiarity with your workstation and knowing you have all of the necessary equipment can mean the difference between a close call and a disaster.

L-6: What Are the Guidelines for the Use of Propofol During MAC Anesthesia?

Propofol is an alkylphenol compound that is formulated as an egg lecithin emulsion commonly used for intravenous induction and maintenance of anesthesia. Once injected, propofol produces rapid hypnosis, usually within 40 s, and has a blood-brain equilibration half-time of 1–3 min [7]. Because propofol is a rapid-acting sedative-hypnotic, it is a very popular medication to administer for both general anesthesia and sedation cases (Table 1.4).

Table 1.4 Propofol dosing recommendations for sedation cases based upon intermittent bolus dosing or continuous infusion

Method of administration	Induction of sedation	Maintenance of sedation
Intermittent bolus dosing	0.5 mg/kg over 3–5 min	10–20 mg individual doses titrated to clinical effect
Continuous infusion	100–150 μg/kg/min for period of 3–5 min	25–75 μg/kg/min and adjusted to clinical response

Current recommendations for the dosing of propofol for sedation cases can be found in the above table [7]. However, no patient or procedure is exactly the same. Therefore, as with any other anesthetic agent, propofol must be carefully titrated by the anesthesia provider to achieve the desired sedative effects while minimizing the undesired side effects, such as cardiorespiratory depression. During sedation with propofol, side effects such as hypotension, hypopnea, apnea, and oxyhemoglobin desaturation are more common with intermittent bolus dosing [7]. For this reason, it is recommended by the manufacturers that a variable rate infusion method be used for maintenance of sedation instead of intermittent boluses [7]. If intermittent bolusing of propofol is to take place, it is recommended that the anesthesia provider wait a period of 3–5 min to allow for the peak drug effect of the previous dose to be observed clinically before administering another dose so as to minimize the risk of overdosing [7].

Like nearly all anesthetic agents, propofol requires special consideration when being administered to the elderly (age >55 years) and debilitated patient populations. Due to decreased clearance rates and a decreased volume of distribution, the elderly population can be expected to have increased blood concentrations of propofol after equivalent doses in the younger population. This contributes to increased sedative and cardiorespiratory depressant effects in the elderly. Therefore, the manufacturers of propofol have stated that, in the elderly (age >55 years), "repeat bolus administration should not be used for MAC sedation" and that the dosage "should be reduced to approximately 80% of the usual adult dosage" [7].

In the case presented herein, it is clear that the anesthesiologist did not follow several of the package insert recommendations for the administration of propofol for MAC sedation in an elderly patient (Fig. 1.4).

L-7: Use of Exhaled CO_2 to Confirm Placement of Endotracheal Tubes

Confirmation of correct placement of an endotracheal tube (ETT) within the trachea by presence of exhaled CO_2 is mandated by several guidelines for the safe practice of anesthesia [4, 9, 10]. Visualization of the ETT passing through the vocal cords, although helpful, does not take the place of objective confirmation by exhaled CO_2. Multiple methods exist for accurate confirmation of the exhaled CO_2 after instrumentation of the airway.

- Intermittent bolus dosing was used in an elderly patient despite recommendation for continuous infusion
- The dose of propofol was not reduced to the recommended 80% of maximum for an elderly patient
- 30-70 mg bolus doses were used instead of the recommended 10-20 mg doses for maintenance of sedation
- 70 mg (~1 mg/kg) induction dose was administered instead of the recommended 0.5 mg/kg induction of sedation dose
- The 68 kg patient received a total of 380 mg over 40 min, which calculates out to 140 μg/kg/min continuous infusion rate. The package insert for propofol states that a range between 150 – 200 μg/kg/min should be used for 10–15 min after induction of general anesthesia, followed by a 30–50% reduction in dose. At a calculated total dose of 140 μg/kg/min given for 40 min, it is clear that the provider in this case administered a general anesthetic dose of propofol for a planned sedation case

Fig. 1.4 Deviations from propofol package insert recommendations found in the case presented in this chapter

One method for determination of exhaled CO_2 is a colorimetric device that changes color depending on the presence of CO_2. These devices are relatively inexpensive, portable, and qualitative in nature, allowing for fast and efficient confirmation of CO_2, even in remote locations where anesthesia is performed. The detector houses a pH-sensitive paper that changes color from purple to yellow with the presence of exhaled CO_2, allowing for easy visual confirmation. Studies have shown that these detectors are reliable indicators of properly positioned ETTs, with sensitivity approaching 100% [11, 12] (Fig. 1.5).

In contrast to the portable and qualitative nature of colorimetric CO_2 detection devices are the more standard and traditional means of exhaled CO_2 quantification via capnometry. This refers to the numerical representation of a CO_2 concentration that can be displayed continuously during both inspiration and exhalation, usually via a capnograph. This technique relies upon either infrared absorption spectrophotometry or mass spectrometry to quantify the concentration of exhaled CO_2. The main advantages of this method are the quantifiable nature of CO_2 concentration and the graphical representation of these numerical values. Analysis of this information allows the anesthesiologist to make judgments on physiologic changes that can arise in a patient under anesthesia, in addition to serving as a method of accurate confirmation of ETT placement within the trachea. Some of the causes of changes in end-tidal CO_2 ($EtCO_2$) can be found in Fig. 1.6 below.

L-8: What Is the Value of Exhaled CO_2 Monitoring During Cardiac Arrest?

As seen in the previous figure, one cause for the precipitous decrease and eventual loss of $EtCO_2$ is cardiac arrest. During arrest, cardiac output goes to zero, and there is no mechanism for the return of CO_2 to the pulmonary circulation to allow for

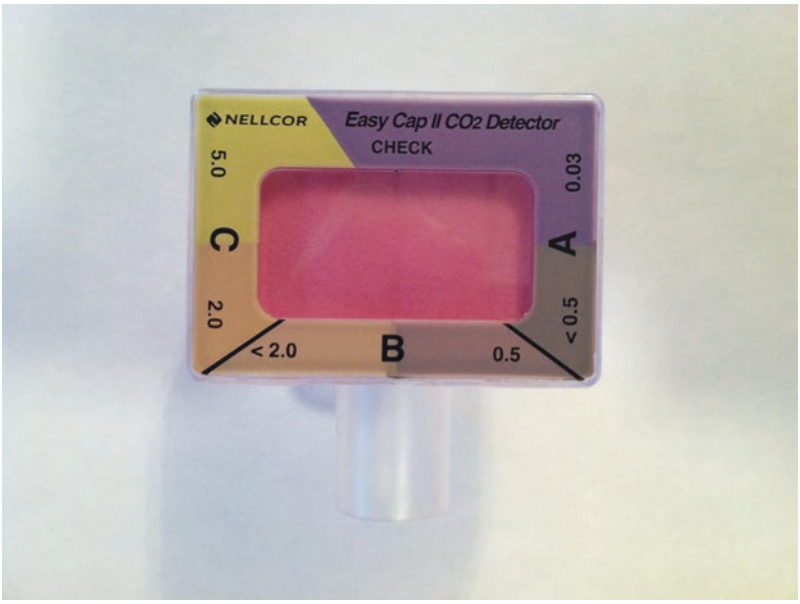

Fig. 1.5 Nellcor Easy Cap II qualitative, colorimetric CO_2 detection device. The purple pH-sensitive paper in the center will change to a yellow/gold color as indicated on the perimeter of the device as increasing levels of CO_2 are detected

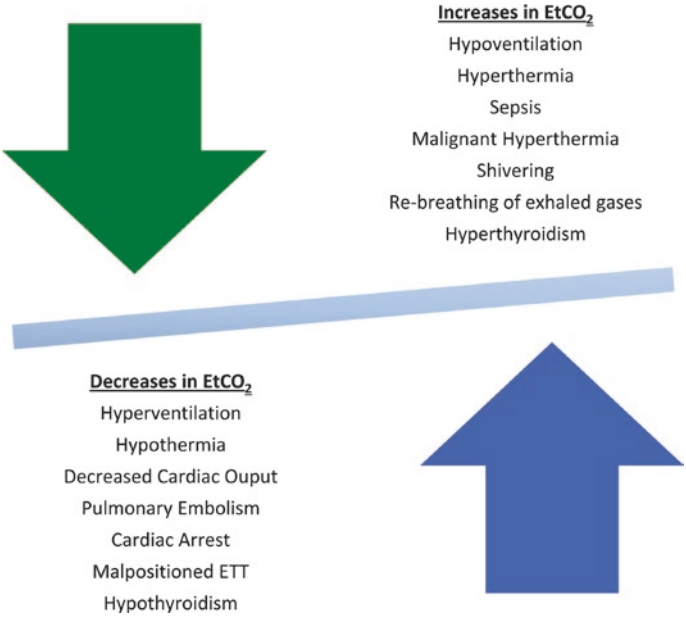

Fig. 1.6 Common causes of changes in quantitative end-tidal CO_2 ($EtCO_2$) concentration during anesthesia. (Based on data from Ref. [13])