New Therapeutic Agents for Diabetes Mellitus: Implications for Anesthetic Management

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Multiple hormones and transmitter systems contribute to glucose homeostasis and the control of metabolism. Recently, the gastrointestinal peptide hormones glucagon-like peptide 1 and amylin have been shown to significantly contribute to this complex physiology. These advances provide the foundation for new treatments for diabetes mellitus. Therapies based on glucagon-like peptide 1 and amylin have now been introduced into clinical practice. Rimonabant, the selective endocannabinoid receptor antagonist, had been used in European countries for the treatment of obesity; it has recently been withdrawn for this indication. This drug exhibited therapeutic benefits for metabolic variables and for type 2 diabetes mellitus. Anesthesia providers caring for patients with diabetes mellitus will need to understand the implications of these new therapies in perioperative settings, particularly with respect to side effects and interactions.

(Diabetes mellitus (DM) is a condition with an absolute (Type 1) or relative (Type 2) deficiency of insulin. Significant end-organ consequences of both types of diabetes include renal, neurological, cardiovascular, and peripheral vascular pathology that may have an impact on the perioperative course. Multiple hormones and neural systems control glucose homeostasis. The principle regulator of plasma glucose levels is insulin, a polypeptide secreted by pancreatic β cells. The plasma glucose decreasing action of insulin has long been recognized and its effect is counter-regulated by epinephrine, growth hormone, cortisol and glucagon, a polypeptide secreted by pancreatic α cells. Conventional therapies for DM have recently been reviewed.1–4 Table 1 presents a summary of the major classes of medications used in the treatment of DM.

Contemporary studies revealed that two new families of gastrointestinal (GI) hormones, represented by the incretins and amylin, have significant effects on glucose homeostasis. In addition, antagonists of the endocannabinoid system acting at the CB1 receptor, represented by rimonabant, were found to exert multiple effects on food intake and metabolic variables, including glucose homeostasis. These advances provide new opportunities for therapeutic approaches to patients with DM. Anesthesia providers will increasingly encounter patients treated with novel drugs based on the enhanced understanding of glucose homeostasis and the physiological control of metabolism. We aim to provide anesthesia clinicians with an introduction to the rapidly evolving pharmacology of medical treatment for DM.

BIOLOGY OF INCRETINS

Identification of the members of the incretin family of endogenous gut hormones was based on the observation that the insulin response to oral glucose loads is more vigorous than from IV glucose loads producing the same blood glucose levels. In human studies, when subjects achieve identical plasma glucose increases, oral glucose administration resulted in more insulin secretion than IV glucose administration (Fig. 1).5–9 This indicated that previously unidentified factors produced by the GI system influence blood glucose levels in combination with the known hormones, insulin and glucagon. The consequence of these gut factors is called the “incretin” effect.

The incretin effect is mediated via GI hormones that stimulate insulin secretion in response to glucose increase from an enteral carbohydrate load. GIP (glucose-dependent insulinotropic polypeptide) and glucagon-like peptide 1 (GLP-1, Fig. 2) are the first two incretin hormones identified. Because much of GIP’s insulinotropic effect is lost in diabetic patients due to resistance to its actions, its potential utility in diabetic therapy is low7,10 and therefore will not be discussed further. Unlike GIP, GLP-1’s insulinotropic
action persists in patients with DM.\textsuperscript{10} This makes it a potential target for diabetic therapy. Initial studies identified enteroendocrine L cells located in the distal ileum and large intestine as the source of GLP-1. One study also found enteroendocrine L cells located more proximally in the duodenum and jejunum.\textsuperscript{11} The fasting blood GLP-1 level is approximately 5–10 pmol/L. Within minutes of food intake, the level increases to 15–50 pmol/L.\textsuperscript{11} The rapid increase in blood levels of GLP-1 suggests that the secretion of GLP-1 is not simply due to detection of nutrients by the L cells in the digestive tract; a faster endocrine/neural signaling system must also be involved.\textsuperscript{11}

The peptide hormone GLP-1 reduces appetite, slows gastric emptying, reduces glucagon levels, enhances glucose-stimulated insulin secretion, and increases insulin biosynthesis (Table 1).\textsuperscript{9,11,12} In animal models, GLP-1 has trophic actions to increase the numbers of pancreatic β cells.\textsuperscript{13} GLP-1 works through a G protein-coupled signal transduction system, and its receptors are found in pancreatic β and α cells, the central nervous system, and the GI tract. Through its receptors on β cells, GLP-1 enhances insulin exocytosis, but only in a glucose-dependent manner.\textsuperscript{7} GLP-1 induces gene transcription in pancreatic β cells to promote insulin biosynthesis. \textit{In vitro} studies demonstrate that GLP-1 influences β cell survival by promoting

### Table 1. Classes of Agents Regulating Glucose Levels

<table>
<thead>
<tr>
<th>Class</th>
<th>Route</th>
<th>Mechanism of action</th>
<th>Side effects</th>
<th>Clinical agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin</td>
<td>SQ, IV</td>
<td>↑ Glucose uptake</td>
<td>Hypoglycemia</td>
<td>Many preparations</td>
</tr>
<tr>
<td>GLP-1</td>
<td>SQ</td>
<td>↑ Insulin secretion (if hyperglycemia) ↓ Glucagon secretion ↓ Appetite ↓ Gastric emptying</td>
<td>Nausea</td>
<td>Exenatide</td>
</tr>
<tr>
<td>Amylin</td>
<td>SQ</td>
<td>↓ Postprandial glucagon secretion ↑ Satiety ↓ Gastric emptying</td>
<td>Hypoglycemia (with insulin)</td>
<td>Pramlintide</td>
</tr>
<tr>
<td>DPP-IV inhibitor antagonist</td>
<td>Oral</td>
<td>↓ Weight loss</td>
<td>Infection ↓ Glucose Depression ↓ Appetite</td>
<td>Sitagliptin, Rimonaptin</td>
</tr>
<tr>
<td>Sulfonlurea</td>
<td>Oral</td>
<td>↑ Insulin secretion via binding to specific receptor on β cells</td>
<td>Hypoglycemia</td>
<td>Chlorpropamide, Glipepride, Glipizide, Glyburide, Tolazamide, Tolbutamide, Nateglinide, Repaglinide</td>
</tr>
<tr>
<td>Meglitinide</td>
<td>Oral</td>
<td>↑ Insulin secretion by binding to ATP dependent K\textsuperscript{+} channels on β cells</td>
<td>Hypoglycemia</td>
<td></td>
</tr>
<tr>
<td>Thiazolidinedione</td>
<td>Oral</td>
<td>Insulin sensitizer by binding to PPAR γ receptor</td>
<td>Edema, anemia, obesity, CHF, hepatotoxicity</td>
<td>Rosiglitazone, Pioglitazone, Metformin</td>
</tr>
<tr>
<td>Biguanide</td>
<td>Oral</td>
<td>↓ Hepatic glucose output Insulin sensitizer</td>
<td>Lactic acidosis Diarrhea</td>
<td></td>
</tr>
<tr>
<td>Alpha-glucosidase inhibitor</td>
<td>Oral</td>
<td>↓ GI glucose absorption by inhibiting enzyme that metabolizes complex carbohydrates</td>
<td>Malabsorption Flatulence Diarrhea</td>
<td>Acarbose, Miglitol</td>
</tr>
<tr>
<td>Sulfonylurea</td>
<td>Oral</td>
<td>↓ Hepatic glucose output Insulin sensitizer</td>
<td>Lactic acidosis Diarrhea</td>
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Incretin-mimetics (GLP-1, DPP-IV inhibitors) and insulin sensitizers (thiazolidinediones, biguanides) in single agent therapy do not predispose to hypoglycemia even in the fasting state.

**The Incretin Effect:**

**Beta-Cell Response to Oral vs. IV Glucose**

![Figure 1. Insulin secretion after IV or oral glucose load. Subjects received oral glucose (50 g glucose/400 mL) or an IV infusion of glucose to produce the same blood glucose levels. As measured by plasma levels of C-peptide (a fragment of the insulin prohormone), oral glucose loading (solid circles) resulted in a greater secretion of insulin compared with IV glucose loading (open circles) designed to achieve identical plasma glucose concentrations. The difference between insulin secretion profiles after oral versus IV loading is defined as the incretin effect. Left, plasma glucose after oral or isoglycemic IV loading of glucose. Right, C-peptide levels in response to oral or IV glucose loading. Modified from Ref 5, with publisher’s permission from the Endocrine Society.**
proliferation and resistance to apoptosis. Through its receptors on α cells, GLP-1 inhibits glucagon secretion in a glucose-dependent manner and consequently reduces hepatic glucose production. The counter regulatory release of glucagon in response to hypoglycemia remains active. Through actions on the central nervous system, GLP-1 decreases appetite and food intake with a resulting contribution to weight loss. GLP-1 also slows gastric emptying, thereby blunting the postprandial increase in blood glucose levels.

A feature of the biology of GLP-1 is its rapid degradation by the peptidase dipeptidyl peptidase IV (DPP-IV) (Fig. 2a). DPP-IV cleaves peptides at their amino terminal where the penultimate amino acid residue is proline or alanine. The presence of DPP-IV in the capillary bed of the gut mucosa facilitates rapid inactivation of GLP-1. DPP-IV is a ubiquitous, membrane-spanning, cell surface aminopeptidase. Its extracellular domain can be cleaved and circulate in the plasma, retaining full enzymatic strength. DPP-IV is also found in liver, lung, kidney, the intestinal brush border, lymphocytes and endocrine cells. In addition to GLP-1, DPP-IV has numerous substrates, including vasoactive intestinal polypeptide, gastrin-releasing peptide, neuropeptide Y and growth hormone-releasing hormone. DPP-IV also has a role in the immune system. It is found on lymphocytes as CD26, which has been implicated in cellular uptake of the Human Immunodeficiency Virus. Other biological effects of DPP-IV include actions on T cell activation, chemotaxis and possibly tumor transformation and invasion.

Compared with healthy individuals, patients with DM exhibit a blunted increase in blood GLP-1 levels after food intake. Consequently, experimental treatment for DM has evaluated treatment with the native GLP-1 peptide. However, since DPP-IV rapidly degrades GLP-1, only a constant IV infusion of the peptide is effective in sustaining therapeutic plasma levels. Two pharmacological strategies are now clinically used to counter the effects of the DPP-IV peptidase (Table 2). One strategy uses injection of a GLP-1 analog resistant to DPP-IV. A second pharmacological strategy targeting DPP-IV uses an inhibitor of this peptidase in order to increase levels of endogenous GLP-1.

### Specific Agents

The naturally occurring peptide homolog of GLP-1, exendin-4, resists degradation by DPP-IV. The synthetic form is known as exenatide; its commercial name is Byetta. Exendin-4 is derived from salivary secretions of the lizard Heloderma suspectum (the Gila monster) and shares roughly 50% of its amino acid sequence with mammalian

| Table 2. Pharmacologic Agents Acting via the Incretin and Amylin Pathways |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-----------------|-----------------|
| **Agent** | **Mechanism of action** | **Major side effects** | **Time to onset (h)** | **Duration of action (h)** |
| Exenatide (Byetta®) | Incretin-mimetic, increases insulin secretion only with hyperglycemia | Risk of hypoglycemia when given with a sulfonylurea; delay in gastric emptying, nausea, anorexia | <0.25 | 6–12 |
| Sitagliptin (Januvia®) | Inhibitor of DPP-IV | Upper respiratory infections, headache | Peak at 1–4 h | Half life approximately 12 |
| Pramlintide (Symlin®) | Amylin analog, suppresses postprandial glucagon secretion | Hypoglycemia when given with insulin, delay in gastric emptying, nausea | <0.25 | 2–4 |

DPP-IV = dipeptidyl peptidase IV.
GLP-1. However, a substitution of glycine for alanine in its amino terminal protects exenatide from degradation by DPP-IV (Fig. 2b). Exenatide has a circulating half-life variously reported between 60 and 90 min to 2.5 h, with plasma concentrations lasting 4 to 6 h or more after a single subcutaneous dose. Elimination is primarily through the renal system, although patients with mild to moderate renal impairment do not exhibit significantly altered clearance.

Exenatide is currently approved for the treatment of type 2 DM patients receiving concurrent metformin or sulfonylurea therapy. It has no role in therapy of patients with DM type 1. Exenatide is given as a subcutaneous injection of 5 to 10 µg twice daily. Clinical trials show a significant reduction in hemoglobin A1c levels over 30 wk (absolute reduction of approximately 0.6%–0.9% from baseline hemoglobin A1c of 8.2%–8.7%) and a modest amount of weight loss (2 kg over 30 wk).

The most common adverse events were GI symptoms, including nausea and, rarely, vomiting or diarrhea. Patients receiving both exenatide and a sulfonylurea exhibit an increased risk for mild to moderate hypoglycemic events. However, the risk was not increased in patients receiving concurrent treatment with exenatide and metformin. Approximately, 40% to 50% of patients receiving exenatide develop low titers of a weak affinity antibody. However, the antibody formation has not been associated with decreased effectiveness of exenatide or other adverse reactions.

A long-acting exenatide preparation is currently under development, a polylactide-glycolide microsphere suspension containing 3% exenatide peptide. In diabetic rats, this preparation produced dose-dependent control of serum glucose for up to 28 days after a single injection.

Liraglutide is another GLP-1 analog. With amino acid substitutions at positions 34 and 26, and a covalently linked C16 fatty-acid group, liraglutide forms noncovalent bonds with albumin, which confers resistance to DPP-IV-mediated degradation (Fig. 2c). It is not yet released in the United States for clinical use. Like exenatide, liraglutide is given as a subcutaneous injection. It has a half-life of 10–14 h and consequently can be given as a once-daily injection. Clinical trials with liraglutide demonstrated significant reductions in postprandial glucose levels. Reduced hemoglobin A1c levels (absolute reduction of approximately 0.8% from baseline hemoglobin A1c) suggest improved long-term glucose control. Liraglutide also prevents weight gain or induces modest weight loss. The most common adverse event is nausea, which is generally mild and decreases over time.

Sitagliptin is a DPP-IV inhibitor, now commercially available in the United States. The trade name is Januvia. Other DPP-IV inhibitors, including vildagliptin, are in clinical trials and may soon be approved for routine use. Sitagliptin enhances insulin secretion and decreases glucagon secretion in a glucose-dependent manner. However, unlike exenatide and liraglutide, sitagliptin does not affect gastric emptying. It has a half-life of 12 h and is taken orally as a once or twice daily medication. Clinical trials have shown a significant reduction in hemoglobin A1c levels associated with sitagliptin therapy (absolute reduction of 0.8% from baseline hemoglobin A1c of 5.8%–10.4% over 3 mo). Unlike therapy with exenatide, there was no significant weight change associated with sitagliptin. In early clinical trials, sitagliptin seemed to be well tolerated, without significant GI symptoms or hypoglycemic events. Given widespread expression of DPP-IV in many cell types, and multiple potential substrates for this peptidase, additional clinical studies are needed to assess the long-term safety of DPP-IV inhibitors.

BIOLOGY OF AMYLIN

Amylin, another GI hormone, has been identified as a potential therapeutic target in DM (Fig. 3a). Pancreatic β cells, the same cells that manufacture and secrete insulin, produce the amylin peptide hormone. Consequently, patients lacking functional pancreatic β cells (individuals with type 1 DM or advanced type 2 DM) are deficient in both insulin and amylin. Similar to GLP-1, food intake stimulates amylin secretion. Its 24-h profile resembles that of insulin, with low fasting blood levels and a robust increase in response to meals. The glucose-decreasing effect of amylin seems
to be independent of, and additive to, the effects of insulin.28

Like GLP-1, the actions of amylin include suppression of glucagon secretion in a glucose-dependent manner and delayed gastric emptying (Table 1); however, the mechanism(s) of action remain incompletely defined. Amylin is also a satiety agent, with receptors in the area postrema of the hindbrain.28 By suppressing glucagon secretion and delaying gastric emptying, amylin slows the inflow of glucose into the circulation. At the same time, insulin stimulates cellular uptake of glucose to reduce postprandial blood glucose levels. Effort has been made to treat patients with diabetes using the native amylin peptide. However, endogenous amylin aggregates and forms insoluble masses of amyloid. Consequently, synthetic modifications are necessary to produce a soluble amylin analog suitable for clinical use.

**Specific Agent**

Pramlintide is a synthetic amylin analog with proline substitutions at amino acid positions 25, 28, and 29 (Fig. 3b).27 These structural changes improve solubility. Pramlintide is used as an adjunct to insulin for both type 1 and type 2 DM patients. It is given as a subcutaneous injection two or three times daily. Pramlintide has an onset of approximately 20 min and duration of action of about 2 to 4 h. Clinical trials demonstrated significant improvement of postprandial glucose levels and hemoglobin A1c levels (absolute reduction of 0.67% at 13 wk and 0.39% at 52 wk) associated with pramlintide treatment.24 Pramlintide seems to decrease postprandial triglyceride excursions.29 The most common adverse reaction associated with pramlintide therapy is nausea, which improves over the course of treatment. By itself, pramlintide has not been shown to cause an increased risk of hypoglycemia; however, any concurrent insulin dose needs to be adjusted to prevent hypoglycemia.27

**THE ENDOCANNABINOID SYSTEM**

A comprehensive overview of the astonishingly complex endocannabinoid signaling system is beyond the scope of this article. Detailed reviews are available.30 Briefly, the identification of specific binding sites for plant products led to the identification of two G protein-coupled receptors, labeled CB1 and CB2. The CB1 receptor is widespread throughout the brain and peripheral tissues, whereas the CB2 receptor has a more restricted distribution. These receptors seem to use several different signal transduction pathways, depending on how the receptor is activated and the tissue where it is expressed. The diverse distribution of the CB1 receptor, in particular, explains the extensive array of biological activities associated with its activation or blockade which include effects on appetite and ingestive behavior, addictive behaviors, sleep/awake cycles, peripheral energy metabolism, pain and inflammation.

The isolation of specific receptors for exogenous agonists suggested the existence of endogenous ligands for the two cannabinoid receptors. Several candidate ligands have been identified. These include anandamide, derived by enzymatic hydrolysis from the membrane lipid precursor N-arachidonoyl phosphatidylethanolamide, and 2-arachidonoylglycerol derived from diacylglycerol. Of compelling interest for the administration of anesthesia, there is evidence that propofol acts, at least in part, via activation of CB1 receptors.31 This effect may be mediated by the inhibition of anandamide breakdown.32 Schelling et al.33 however, provided evidence that the inhaled general anesthetic sevoflurane has different effects on anandamide levels than does propofol, suggesting agent-specific interactions with the endocannabinoid system.

**Specific Drug**

Rimonabant was available until recently in many countries (trade name: Acomplia), primarily as a treatment for obesity, with an added benefit of improving glucose homeostasis beyond what might be expected from weight loss alone.34,35 Clinical trials with rimonabant (such as the Rimonabant in Obesity trial) demonstrated sustained weight loss and a reduction in waist circumference. In addition, metabolic profiles improved for triglyceride levels, lipoprotein cholesterol levels, and insulin resistance. Consequently, considerable interest developed in this drug for the management of metabolic syndrome.34,36 This drug has multiple pharmacologic effects37 and a long terminal elimination half-life in animals (approximately 7 h). A prominent finding is that treatment with rimonabant is associated with neuropsychiatric side effects.38 Out of concern for an enhanced risk of depression and suicide,39 rimonabant was not approved in the United States40 and it has recently been withdrawn in Europe for the original indication of obesity.

**ANESTHETIC CONSIDERATIONS**

A literature search via the National Library of Medicine tool PubMed does not produce published examples of adverse effects, drug-drug interactions or clinical conundrums attributable to exenatide, pramlintide, a DPP IV inhibitor, or rimonabant in patients undergoing anesthesia or surgery. These drugs have only recently appeared in clinical practice, and only a subset of all treated patients may have required an anesthetic since the drugs were approved and released. Consequently, the number of clinical situations in which a potential adverse effect emerges may be too few for the manifestation of an uncommon reaction.

Alternatively, adverse effects may have occurred, but went undetected in complex clinical scenarios in which patients suffering from multiple co-morbid conditions received several medications concurrently.
Moreover, untoward effects in anesthetized or surgical patients attributable to one of these newly released drugs simply may not have been reported. As clinical experience with these new drugs increases, it is possible that recognizable patterns will develop. Therefore, at this time it is only possible to suggest potential anesthesia concerns based on the known physiology and pharmacology of the novel therapies.

Nausea is the most common adverse reaction associated with medications active along the incretin and amylin pathways. Clinical trials have shown nausea occurring in as many as 57% of patients treated with exenatide. The incidence of vomiting is less frequent. However, vomiting still occurs in approximately 17% of the patients receiving exenatide. Nausea is generally mild to moderate, and most prevalent in the first 8 wk of treatment. The frequency and intensity of nausea generally declines thereafter. The risk of nausea is dose-dependent and can be decreased by gradual dose titration. However, adverse GI effects associated with exenatide are still the most common causes for patients to withdraw from clinical trials.

Clinical studies with DPP-IV inhibitors, such as sitagliptin, have reported no increased GI adverse reactions. They are overall well tolerated with low absolute rates of adverse effects. This lack of GI adverse reactions may be secondary to the fact that DPP-IV inhibitors only moderately increase the levels of endogenous incretin hormones. In contrast, administration of incretin analogs, such as exenatide, increases incretin hormone activity to a much greater extent. Similar reasoning explains the finding that, while incretin analogs cause significant weight loss in patients, DPP-IV inhibitors usually do not produce significant weight changes.

Nausea is the most common adverse effect of pramlintide, the amylin analog. Nausea occurs more frequently in the type 1 DM patient than in the type 2 DM patient. It is usually mild to moderate in intensity, occurring most frequently in the early stage of treatment, and commonly attenuates over time. The incidence of nausea is approximately 47% in type 1 diabetics and 27% in type 2 diabetics. The risk of nausea depends on the dose of pramlintide and can be decreased by gradual dose titration.

Prominent antinausea effects of cannabinoids may be mediated, at least in part, by CB1 receptors. This has led to occasional use of cannabinoids for patients receiving cancer chemotherapy. In a meta-analysis of studies on the use of rimonabant in smoking cessation, nausea was one of the adverse effects emerging from the pooled data from the early trials.

Although there are no published reports of unusual postoperative nausea and vomiting (PONV) attributed to rimonabant or to drugs active along the incretin and amylin pathways, it seems reasonable to expect that patients treated with these medications may experience more frequent, or more severe, PONV than the average patient. Consequently, for elective surgery requiring anesthesia, at this time it seems logical to withhold these medications in the immediate perioperative period to reduce the likelihood or intensity of PONV. In situations of urgent or emergency surgery, without an opportunity to halt the administration of these novel drugs, it is possible that patients will exhibit exaggerated or refractory postoperative nausea. Future clinical studies may eventually provide evidence-based recommendations.

Delaying gastric emptying is one of the mechanisms by which incretin peptides and amylin decrease postprandial glucose levels. By impeding gastric emptying, glucose inflow into the circulation slows. Consequently, the incretins and amylin allow insulin more time to stimulate glucose uptake and regulate serum glucose levels. Both exenatide and pramlintide cause delayed gastric emptying. DPP-IV inhibitors, such as sitagliptin, however, have little or no effect on gastric emptying, probably attributable to the modest increases in GLP-1 levels caused by this class of drugs. Gastroparesis is a feature of advanced diabetes, and medications that slow gastric emptying may exacerbate this problem. Although no published reports document an increased risk of aspiration associated with the new diabetes therapies, patients receiving these medications are theoretically at a greater risk for this complication during the perioperative period, especially those patients with peripheral neuropathy and gastroparesis as manifestations of their diabetes. In urgent or emergent situations where there has been no opportunity to withhold the medications, clinicians may find unexpectedly large volumes of gastric contents removed by gastric suction. The administration of drugs promoting gut motility, such as metoclopramide, might factor more prominently in overall management of the patient unless there are specific contraindications.

Hypoglycemia is a potential adverse effect of medications active along the incretin and amylin pathways, particularly if used in conjunction with an insulin preparation or a sulfonylurea. Because incretin analogs only promote insulin secretion in a “glucose-dependent” manner and because the counter-regulatory release of glucagon secondary to hypoglycemia is preserved with incretins, the risk of hypoglycemia should be low. Clinical trials show that severe hypoglycemia requiring medical intervention is rare with incretin analogs, such as exenatide. In 1 trial, only 5 of 2781 patients treated with exenatide had hypoglycemia requiring medical assistance. All five patients also received an insulin secretagogue, such as a sulfonylurea. No patients receiving both exenatide and an insulin sensitizer, such as metformin, developed hypoglycemia requiring medical assistance.

When clinical trials are combined and reviewed under meta-analysis, the overall incidence of hypoglycemia associated with exenatide is approximately
Hypoglycemia occurs especially when exenatide is co-administered with a sulfonylurea. This risk is comparable with the risk of hypoglycemia for patients receiving insulin for treatment of diabetes. The likelihood of hypoglycemia is greatest during the initial treatment period and declines over time. When compared with incretin analogs, DPP-IV inhibitors carry less risk of hypoglycemia. In meta-analysis, only approximately 1.6% of patients had episodes of mild to moderate hypoglycemia, which was not statistically different from the control group.41

Clinical trials with the amylin analog pramlintide showed no increase in the overall event rates for severe hypoglycemia.46 However, in patients also receiving insulin for their diabetes, the rate of hypoglycemia increased during the initial 4 wk of therapy with pramlintide.46 The enhanced risk of hypoglycemia was transient and diminished with appropriate blood glucose monitoring and adjustments of insulin dose.

The half-lives and clinical effects of sitagliptin, exenatide, and pramlintide are relatively short. Furthermore, no clinical reports suggest that medications active along the incretin or amylin pathways cause hypoglycemia in the perioperative period. However, in the absence of definitive evidence, the theoretical risk of hypoglycemia is another reason to withhold these medications in advance of elective surgery. This would be a particularly pertinent consideration for patients receiving both a sulfonylurea or an insulin preparation and exenatide. Suppression of glucagon release by exenatide would be a mechanism contributing to hypoglycemia. Should longer-acting GLP-1 analogs, such as liraglutide, enter into clinical use, the glucose-decreasing effects might extend into the surgical or anesthesia interval. Anesthesia providers routinely monitor the blood glucose levels of their patients. Perhaps, however, particular vigilance for the possibility of hypoglycemia is warranted, especially in urgent/emergent surgical situations in which there is no opportunity to withhold the medications. In theory, patients treated with long-acting insulin preparations or sulfonylureas along with exenatide would be most vulnerable. Clinicians might consider more frequent monitoring in urgent or emergent situations.

Hypoglycemia does not seem to be a likely consequence of rimonabant therapy.35

OTHER EFFECTS

DPP-IV is a ubiquitous aminopeptidase with multiple natural substrates and it plays a role in the immune system. Consequently, it seems plausible that inhibiting DPP-IV can potentially cause adverse reactions. Clinical trials have shown that DPP-IV inhibitors were very well tolerated with low rates of adverse effects. In meta-analysis, there is a small increased risk of nasopharyngitis and urinary tract infection associated with DPP-IV inhibitors.41 Clinical experience in anesthetized patients receiving DPP-IV inhibitors is limited. Because multiple peptides are potential substrates for this enzyme,18 clinicians should be alert for unusual reactions, especially in urgent procedures in which the drug may not have been withheld.

The endocannabinoid system is involved in many complex behaviors and physiologic responses, including pain and sleep/awake cycles. In preclinical studies, as cited above, there appear to be interactions between the endocannabinoid system and anesthetics. Given the “pleiotropic” effects of rimonabant,37 the exact consequences of clinical interactions between drugs acting on cannabinoid receptors in the brain and periphery with sedatives, narcotics, and inhaled or injected general anesthetics remain to be determined.

SUMMARY AND RECOMMENDATIONS

Food ingestion increases secretion of insulin, amylin, and the incretin peptides. Insulin and amylin regulate postprandial hyperglycemia, while amylin also suppresses glucagon secretion and slows food intake and gastric emptying. GLP-1 amplifies glucose-stimulated insulin release, in addition to suppressing glucagon secretion, food intake, and gastric emptying. The new treatment options for DM acting along the incretin pathway and the amylin analog offer some potential advantages for chronic treatment of DM by targeting these physiologic mechanisms. However, the biological activities of these drugs may present challenges in the perioperative period. This is especially true in the urgent or emergent clinical circumstances in which there are no opportunities to withhold these medications.

As clinical experience accumulates with novel drugs in anesthetized patients, it may become possible to develop more definitive warnings and recommendations. However, until this information becomes available, we suggest withholding GLP-1 analogs, DPP-IV inhibitors, and pramlintide on the day of surgery. Patients can probably continue to take these drugs the day before surgery without an enhanced risk of hypoglycemia while fasting. With these drugs, there are potentially enhanced risks of nausea, aspiration of gastric contents, and hypoglycemia.

As the newer treatments for DM become increasingly prevalent in clinical practice, anesthesia providers should maintain particular vigilance for unusual or exaggerated effects and responses during the perioperative period.

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**Practice Advisory for the Perioperative Management of Patients with Cardiac Rhythm Management Devices: Pacemakers and Implantable Cardioverter–Defibrillators**

A Report by the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Cardiac Rhythm Management Devices

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The use of practice advisories cannot guarantee any specific outcome. Practice advisories summarize the state of the literature and report opinions derived from a synthesis of task force members, expert consultants, open forums, and public commentary. Practice advisories are not supported by scientific literature to the same degree as standards or guidelines because of the lack of sufficient numbers of adequately controlled studies. Practice advisories are subject to periodic revision as warranted by the evolution of medical knowledge, technology, and practice.

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**Methodology**

**A. Definition of Cardiac Rhythm Management Devices**

For this Advisory, a cardiac rhythm management device (CRMD) refers to any permanently implanted cardiac pacemaker or any implantable cardioverter–defibrillator (ICD). The term CRMD also refers to any cardiac resynchronization device. The term CRT refers to a CRMD that provides cardiac resynchronization therapy using biventricular pacing techniques. Generic pacemaker and defibrillator codes are provided in appendix 1. Note that every ICD includes both pacing and shock therapies for the management of bradyarrhythmias and tachyarrhythmias.

**B. Purposes of the Advisory**

The purposes of this Advisory are to (1) facilitate safe and effective perioperative management of the patient with a CRMD and (2) reduce the incidence of adverse outcomes. Perioperative management refers to the preoperative, intraoperative, postoperative or recovery period in any setting where an anesthesia provider delivers anesthesia care. Adverse outcomes associated with a CRMD include (but are not limited to) damage to the device, inability of the device to deliver pacing or shocks, lead–tissue interface damage, changes in pacing behavior, electrical reset to the backup pacing mode, or inappropriate ICD therapies.* Adverse clinical outcomes include (but are not limited to) hypotension, tachyarrhythmia or bradyarrhythmia, myocardial tissue damage, and myocardial ischemia or infarction. Other related outcomes may include extended hospital stay, delay or cancellation of surgery, readmission to manage device malfunction, or additional hospital resource utilization and cost.

**C. Focus**

This Advisory focuses on the perioperative management of patients who have a preexisting, permanently implanted CRMD for treatment of bradyarrhythmia, tachyarrhythmia, or heart failure. Both inpatient and outpatient procedures are addressed by this Advisory. This Advisory does not address the perioperative management of any patient undergoing CRMD implantation or revision. It is not applicable to any patient (1) without

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*Inappropriate ICD therapy refers to the delivery of antitachycardia therapy (pacing or shock) in the absence of a clinically indicated tachyarrhythmia. Inappropriate ICD therapy can harm a patient by inducing ischemia, worsening the arrhythmia, or causing the patient to move during a delicate procedure.
a permanently implanted pacemaker or ICD, (2) with a temporary CRMD, (3) with a noncardiac implantable device (e.g., neurologic or spinal cord stimulator), or (4) with an implantable mechanical cardiac assist device (e.g., ventricular assist device). This Advisory does not address any procedure where there are no known perioperative CRMD concerns, such as diagnostic radiation (e.g., x-ray studies, fluoroscopy, or mammograms), computed tomography scans, or ultrasound.

D. Application
This Advisory is intended for use by anesthesiologists and all other individuals who deliver or who are responsible for anesthesia care. The Advisory may also serve as a resource for other physicians and healthcare professionals who treat patients with CRMDs.

E. Task Force Members and Consultants
The American Society of Anesthesiologists (ASA) appointed a Task Force of 12 members to (1) review and assess currently available scientific literature, (2) obtain expert consensus and public opinion, and (3) develop a practice advisory. The Task Force members consisted of anesthesiologists and cardiologists in private and academic practices from various geographic areas of the United States and two methodologists from the ASA Committee on Practice Parameters.

The Task Force used a six-step process. First, they reached consensus on the criteria for evidence of effective perioperative management of cardiac rhythm management devices. Second, original published articles from peer-reviewed journals relevant to these issues were evaluated. Third, consultants who had expertise or interest in CRMDs and who practiced or worked in various settings (e.g., academic and private practice) were asked to (1) participate in opinion surveys on the effectiveness of various perioperative management strategies and (2) review and comment on a draft of the Advisory developed by the Task Force. Fourth, additional opinions were solicited from random samples of active members of both the ASA and the Heart Rhythm Society (HRS). Fifth, the Task Force held an open forum at a national anesthesia meeting and at a major cardiology meeting to solicit input on the key concepts of this Advisory. Sixth, all available information was used to build consensus within the Task Force on the Advisory.

The draft document was made available for review on the ASA Web site, and input was invited via e-mail announcement to all ASA members. All submitted comments were considered by the Task Force in preparing the final draft.

F. Availability and Strength of Evidence
Practice advisories are developed by a protocol similar to that of an ASA evidence-based practice guideline, including a systematic search and evaluation of the literature. However, practice advisories lack the support of a sufficient number of adequately controlled studies to permit aggregate analyses of data with rigorous statistical techniques such as meta-analysis. Nonetheless, literature-based evidence from case reports and other descriptive studies is reported. This literature often permits the identification of recurring patterns of clinical practice.

As with a practice guideline, formal survey information was collected from Consultants and members of the ASA. For this Advisory, surveys were also sent to members of the HRS. Additional information was obtained from open forum presentations and other invited and public sources. The advisory statements contained in this document represent a consensus of the current spectrum of clinical opinion and literature-based findings.

Advisories

I. Preoperative Evaluation
Perioperative treatment of CRMD patients is a common occurrence. It has been reported that more than 500,000 individuals in the United States have permanently implanted pacemakers or ICDs with 115,000 new devices implanted each year.1 Perioperative management of CRMD patients typically begins with a focused preoperative evaluation consisting of (1) establishing whether a patient has a CRMD, (2) defining the type of device, (3) determining whether a patient is CRMD dependent for antibradycardia pacing function, and (4) determining device function.

Although no controlled trials of the clinical impact of performing a focused preoperative evaluation for CRMD patients were found, case reports suggest that incomplete preoperative examination of patients with CRMDs may lead to adverse outcomes (e.g., inhibited CRMD function, asystole).2-4 The majority of Consultants and random samples from the ASA and HRS memberships agree that the above four preoperative evaluation activities should be conducted.

Advisory. The consensus of the Task Force is that a focused preoperative evaluation should include establishing whether a patient has a CRMD, defining the type of device, determining whether a patient is CRMD dependent for pacemaking function, and determining CRMD function.

Determining whether a patient has a CRMD should be based on (1) a focused history including but not limited to the patient interview, medical records review, review of available chest x-ray films, electrocardiogram, or any available monitor or rhythm strip information and (2) a focused physical examination (checking for scars, palating for device).

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† Formerly North American Society of Pacing and Electrophysiology (NASPE).
‡ Refer to appendix 2 for a summary of the advisories.
§ Refer to appendix 3 for results of the Consultant, ASA membership, and HRS membership surveys.

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Defining the type of device is accomplished by (1) obtaining the manufacturer’s identification card from the patient or other source, (2) ordering chest x-ray studies if no other data are available, or (3) referring to supplemental resources (e.g., manufacturer’s databases, pacemaker clinic records, consultation with a cardiologist).

Cardiac rhythm management device dependency for pacemaking function may be determined by one or more of the following: (1) a verbal history or an indication in the medical record that the patient has experienced a bradyarrhythmia that has caused syncope or other symptoms requiring CRMD implantation, (2) a history of successful atioventricular nodal ablation that resulted in CRMD placement, or (3) a CRMD evaluation that shows no evidence of spontaneous ventricular activity when the pacemaking function of the CRMD is programmed to VVI pacing mode at the lowest programmable rate.

Cardiac rhythm management device function is ideally assessed by a comprehensive evaluation of the device. If a comprehensive evaluation is not possible, then, at a minimum, confirm whether pacing impulses are present and create a paced beat. Consultation with a cardiologist or CRMD service may be necessary. Contacting the manufacturer for perioperative recommendations may be a consideration.

II. Preoperative Preparation
Preparation for patient safety and proper maintenance of the device during a procedure includes (1) determining whether electromagnetic interference (EMI) is likely to occur during the planned procedure; (2) determining whether reprogramming the CRMD pacemaking function to an asynchronous pacing mode for a procedure were found. Although some case reports suggest that such reprogramming is beneficial during electroconvulsive therapy,†† other reports indicate that EMI may continue to affect reprogrammed pacemakers. The literature lacks sufficient guidance regarding the potential perioperative impact of anesthetic techniques on CRMD function. The majority of Consultants as well as the samples of ASA and HRS members agree that it should be determined whether EMI is likely to occur before a planned procedure. The majority of Consultants agree that a CRMD’s rate-adaptive therapy should be turned off before a procedure, whereas the ASA and HRS members are equivocal.

Advisory. The Task Force agrees that planned procedures should include a determination as to whether EMI is likely to occur for either conventional pacemakers or ICDs.

If EMI is likely to occur, the conventional pacing function of a CRMD should be altered by changing to an asynchronous pacing mode# in pacemaker-dependent patients and suspending special algorithms, including rate-adaptive functions. These alterations may be accomplished by programming or applying a magnet when applicable.** However, the Task Force cautions against the use of the magnet over an ICD.†† In addition, an

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** Most current CRMDs have an x-ray code that can be used to identify the manufacturer of the device.

† The VVT mode (with attention to the upper rate limit) might also be considered for a patient with ventricular ectopy where concern exists regarding R-on-T pacing during an asynchronous pacing mode. However, the upper pacing rate during VVT mode is manufacturer- and possibly generator-specific and can approach 200 beats/min for many devices. Generally, VVT mode pacing would not be a consideration except in very rare circumstances. Before using the VVT mode, a cardiologist and the generator manufacturer should be consulted to determine the suitability of the upper pacing rate for any patient.

# A magnet correctly applied to a pacemaker often results in asynchronous pacemaker function at a predetermined rate without rate responsiveness. The magnet rate and response varies by manufacturer. Magnet response can be affected by programming and remaining battery life. The magnet rate may be excessive for some patients. Some pacemakers may have no magnet response.

†† Magnet application to an ICD rarely alters bradycardia pacing rate and function. A magnet correctly applied to an ICD often results in suspension of tachyarrhythmia therapy. For most ICDs, there is no reliable means to detect appropriate magnet placement. Some ICDs may have no magnet response. Some ICDs can be permanently disabled by magnet application.
ICD’s antitachyarrhythmia functions should be suspended, if present. For ICD patients who depend on pacing function for control of bradyarrhythmia, these functions should be altered by programming as noted above. Consultation with a cardiologist or pacemaker-ICD service may be necessary.

For all CRMDs, consider advising the individual performing the procedure to use a bipolar electrocautery system or an ultrasonic scalpel when applicable. Temporary pacing and defibrillation equipment should be immediately available before, during, and after a procedure.

Finally, the Task Force believes that anesthetic techniques do not influence CRMD function. However, anesthetic-induced physiologic changes (i.e., cardiac rate, rhythm, or ischemia) in the patient may induce unexpected CRMD responses or adversely affect the CRMD-patient interaction.

III. Intraoperative Management

The primary activities associated with intraoperative management of a CRMD include (1) monitoring the operation of the device; (2) preventing potential CRMD dysfunction; and (3) performing emergency defibrillation, cardioversion, or heart rate support.

1. Monitoring. Intraoperative monitoring includes continuous electrocardiography as well as monitoring of the peripheral pulse (e.g., palpation of the pulse, auscultation of heart sounds, monitoring of a tracing of intrarterial pressure, ultrasound peripheral pulse monitoring, or pulse plethysmography or oximetry). Although no controlled trials were found that examined the clinical impact of electrocardiography or peripheral pulse monitoring for CRMD patients, case reports note the importance of intraoperative electrocardiographic monitoring in the detection of pacemaker or cardiac dysfunction for these patients. The majority of Consultants and ASA and HRS members agree that (1) continuous electrocardiographic monitoring should be conducted for all CRMD patients and (2) continuous peripheral pulse monitoring should be conducted.

Advisory. Electrocardiography and peripheral pulse monitoring are important components of perioperative treatment of patients with CRMDs. The Task Force agrees that a patient’s electrocardiogram should be continuously displayed, as required by ASA standards, from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional electrocardiographic monitoring in the postoperative period as indicated by the patient’s medical condition. The Task Force believes that these standards should apply to all CRMD patients receiving general or regional anesthesia, sedation, or monitored anesthesia care. Continuous peripheral pulse monitoring should be performed for all CRMD patients receiving general or regional anesthesia, sedation, or monitored anesthesia care. If unanticipated device interactions are found, consider discontinuation of the procedure until the source of interference can be eliminated or managed.

2. Managing Potential Sources of EMI. Procedures using electrocautery, radiofrequency ablation, lithotripsy, MRI, or radiation therapy may damage CRMDs or interfere with CRMD function, potentially resulting in severe adverse outcomes. Sources of EMI are often unique to specific procedures, and the management of each of these potential EMI sources is reported separately below.

A. Electrocautery. Management of potential sources of EMI associated with electrocautery includes (1) assuring that the cautery tool and current return pad are positioned so that the current pathway does not pass through or near the CRMD pulse generator and leads; (2) avoiding proximity of the cautery’s electrical field to the pulse generator or leads; (3) using short, intermittent, and irregular bursts at the lowest feasible energy levels; and (4) using a bipolar electrocautery system or an ultrasonic (harmonic) scalpel, if possible.

Two case reports and one observational study suggest that EMI may occur despite positioning the current return pad as far as possible away from the generator and leads. However, the majority of Consultants and ASA and HRS members agree that the current return pad should be positioned so that the electrosurgical current pathway does not pass through or near the CRMD pulse generator or leads.

One case report suggested that application of unipolar electrocautery on the sternum resulted in complete pacemaker inhibition. Although some manufacturers suggest substituting bipolar for monopolar electrocautery to minimize CRMD interactions, no clinical literature was found to support this recommendation. The majority of Consultants and ASA and HRS members agree that direct contact between the electrocautery system and the CRMD pulse generator or its leads should be avoided.

Although no recent studies were found examining the benefit of using short, intermittent bursts at the lowest feasible energy levels, earlier literature suggests that short, intermittent bursts may be useful in completing procedures without notable EMI interference. The majority of Consultants and ASA and HRS members agree that short, intermittent bursts should be performed.

Finally, case reports suggest that surgery for pacemaker patients may proceed uneventfully when bipolar electrocautery systems or harmonic scalpels are used. The majority of Consultants and ASA and HRS members agree that bipolar electrocautery systems should be
used when possible. The majority of Consultants and ASA members agree that harmonic scalpels should be used when possible, and HRS members are equivocal.

B. Radiofrequency Ablation. Management of potential sources of EMI associated with radiofrequency ablation primarily involves keeping the radiofrequency current path (electrode tip to current return pad) as far away from the pulse generator and lead system as possible. One observational study reports 3 of 12 cases that resulted in a significant increase in resistance on the pacemaker leads when radiofrequency ablation was used in proximity to the leads.\textsuperscript{65} One case report suggests that positioning of the radiofrequency ablation cluster electrode no closer than 5 cm from the pacer leads allowed the procedure to continue uneventfully.\textsuperscript{40} The majority of Consultants and ASA and HRS members agree that the individual performing the procedure should avoid direct contact between the ablation catheter and the CRMD and leads and should keep the radiofrequency ablation current path as far away from the pulse generator and lead system as possible.

C. Lithotripsy. Management of potential sources of EMI associated with lithotripsy includes (1) avoiding focus of the lithotripsy beam near the pulse generator and (2) disabling atrial pacing if the lithotripsy system triggers on the R wave. The literature is silent regarding the benefits of focusing the lithotripsy beam away from the pulse generator as well as the benefits of disabling atrial pacing during lithotripsy. The majority of Consultants and ASA and HRS members agree that focusing the lithotripsy beam near the pulse generator should be avoided, and all three groups are equivocal regarding whether atrial pacing should be disabled before a procedure if the lithotripsy system triggers on the R wave.

D. Magnetic Resonance Imaging. The literature is not sufficiently rigorous to examine the effects of specific management activities related to CRMD patients receiving MRI. Some descriptive studies and case reports suggest that MRI may be completed without notable EMI under specific circumstances and with appropriate patient qualification and monitoring.\textsuperscript{30,31,64–71} However, other literature generally suggests that MRI is contraindicated.\textsuperscript{21–29} The majority of Consultants and ASA and HRS members generally agree that MRI is contraindicated for all CRMD patients.

E. Radiation Therapy. The literature does not provide sufficient guidance regarding specific management activities related to CRMD patients undergoing radiation therapy. However, none of the Consultants or HRS members and only 10% of the ASA members agree that radiation therapy is contraindicated for all CRMD patients. Fifty-seven percent of the Consultants, 59% of the HRS members, and 37% of the ASA members agree that radiation therapy is contraindicated for some but not all CRMD patients, whereas 43% of the Consultants, 41% of the HRS members, and 53% of the ASA members agree that radiation therapy is not contraindicated for any CRMD patient.

F. Electroconvulsive Therapy. No clinical studies were found that report EMI effects or permanent CRMD malfunction associated with ECT. One study reports two cases where patients’ ICDs were turned off before ECT but does not report the effect of the therapy on ICD function.\textsuperscript{72} However, the author indicates that treatment with ECT might be associated with significant cardiac risks. Transient electrocardiographic changes (e.g., increased P-wave amplitude, altered QRS shape, T-wave and ST-T abnormalities) may result from ECT, and additional cardiac complications (e.g., arrhythmia or ischemia) may occur in patients with preexisting cardiac disease. Finally, physiologic stresses after ECT, such as a period of bradycardia and reduced blood pressure, followed by tachycardia and an increase in blood pressure, may account for cardiac failure in the extended postoperative period (i.e., several hours or days after ECT) among patients with marginal cardiac function.

Advisory. The Task Force believes that EMI could be minimized during certain procedures using a variety of intraoperative management techniques.

The Task Force agrees that the risk of intraoperative interference from electrocautery systems may be minimized by (1) positioning the cautery tool and current return pad so that the current pathway does not pass through or near the CRMD system; (2) avoiding proximity of the cautery’s electrical field to the pulse generator and leads, including avoidance of waving the activated electrode over the generator; (3) using short, intermittent, and irregular bursts at the lowest feasible energy levels; and (4) using bipolar electrocautery systems or ultrasonic (harmonic) scalpels if possible. Advising or reminding the individual performing the procedure to implement these management techniques should be considered.

Risk of interference from radiofrequency ablation may be reduced by avoiding direct contact between the ablation catheter and the pulse generator and leads and by keeping the radiofrequency’s current path (electrode tip to current return pad) as far away from the pulse generator and leads as possible. During all radiofrequency ablative procedures, consider discussing with the individual performing the procedure any concerns regarding the proximity of the ablation catheter to the CRMD leads.

During lithotripsy, the lithotripsy beam should not be focused near the pulse generator. If the lithotripsy system triggers on the R wave, atrial pacing might need to be disabled before the procedure.

\textsuperscript{1}/// For some cases, the electrosurgical receiving plate will need to be placed on a site different from the thigh. For example, in head and neck cases, the receiving plate can be placed on the posterior superior aspect of the shoulder contralateral to the generator position.

\textsuperscript{2} An inhibitory effect could occur even when the active electrode of the electrocautery is not touching the patient.
The Task Force believes that MRI is generally contraindicated for CRMD patients. If MRI must be performed, consult with the ordering physician, the patient’s pacemaker specialist or cardiologist, the diagnostic radiologist, and the CRMD manufacturer.

The Task Force believes that radiation therapy can be safely performed for CRMD patients. The device must be outside the field of radiation. Therefore, some pulse generators will require surgical relocation before commencing radiation. Most manufacturers recommend verification of pulse generator function during and at the completion of radiation. Problems may include pacemaker failure and runaway pacemaker.

Although transient or long-term myocardial and nervous system effects may be associated with ECT, the Task Force believes that such therapies may be administered to CRMD patients without significant damage to a disabled CRMD. If ECT must be performed, consult with the ordering physician and the patient’s cardiologist to plan for the first and subsequent ECTs. All CRMDs should undergo a comprehensive interrogation before the procedure(s). ICD functions should be disabled for shock therapy during ECT; however, be prepared to treat ventricular arrhythmias that occur secondary to the hemodynamic effects of ECT. CRMD-dependent patients may require a temporary pacing system to preserve cardiac rate and rhythm during shock therapy. Also, the CRMD may require programming to asynchronous activity to avoid myopotential inhibition of the device in pacemaker-dependent patients.

3. Emergency Defibrillation or Cardioversion.

During the perioperative period, emergency defibrillation or cardioversion may become necessary for a CRMD patient. In this case, the primary concern is to minimize the current flowing through the pulse generator and lead system. Recent and earlier case reports suggest that optimal positioning of the defibrillation or cardioversion pads or paddles may be an important factor in the prevention of adverse CRMD-related outcomes. The majority of Consultants and ASA and HRS members agree that the defibrillation or cardioversion pads should be positioned as far as possible from the pulse generator. The majority of Consultants and ASA and HRS members also agree that the anterior–posterior position should be used and that a clinically appropriate energy output should be used regardless of the type of CRMD.

Advisory. The Task Force believes that before attempting emergency defibrillation or cardioversion of a patient with an ICD and magnet-disabled therapies, all sources of EMI should be terminated, and the magnet should be removed to reenable antitachycardia therapies. The patient should then be observed for appropriate CRMD therapy. For patients with an ICD and antiarrhythmic therapies that have been disabled by programming, consider reenabling therapies through programming. If the above activities do not restore ICD function, proceed with emergency external defibrillation or cardioversion.

Overriding the above discussion is the need to follow existing Advanced Cardiac Life Support and emergency guidelines to provide rapid cardioversion or defibrillation, and attention should be turned to providing this therapy as quickly as possible.

If a life-threatening arrhythmia occurs, follow Advanced Cardiac Life Support guidelines for energy level and for paddle placement. If possible, attempt to minimize the current flowing through the pulse generator and lead system by (1) positioning the defibrillation or cardioversion paddles as far as possible from the pulse generator and (2) positioning defibrillation or cardioversion paddles perpendicular to the major axis of the CRMD pulse generator and leads to the extent possible by placing them in an anterior–posterior location. A clinically appropriate energy output should always be used regardless of the presence of a CRMD, and the paddles should be positioned as best as can be done in an emergency.

IV. Postoperative Management

Postoperative treatment of CRMD patients primarily consists of interrogating and restoring CRMD function. Although no recent studies were found examining outcomes associated with interrogating or restoring CRMD function, an earlier case report indicates that postoperative evaluation resulted in the discovery and correction of a pacemaker problem. The majority of Consultants and ASA and HRS members agree that postoperative patient treatment should include interrogating and restoring CRMD function in the postanesthesia care unit or intensive care unit.

Advisory. The Task Force believes that cardiac rate and rhythm should be continuously monitored throughout the immediate postoperative period. Backup pacing capability and cardioversion–defibrillation equipment should be immediately available at all times.

Postoperative interrogation and restoration of CRMD function are basic elements of postoperative management. The CRMD first should be interrogated to assess postoperative device functions. If interrogation determines that CRMD settings are inappropriate, the device should be reprogrammed to appropriate settings. For an ICD, all antitachycardia therapies should be restored. Consultation with a cardiologist or pacemaker–ICD service may be necessary.
Appendix 1: Generic Pacemaker and Defibrillator Codes

The generic pacemaker and defibrillator codes were developed as joint projects by the North American Society of Pacing and Electrophysiology (NASPE) and the British Pacing and Electrophysiology Group (BPEG). The five positions refer to the order of the programmed settings on the CRMD (tables 1 and 2).

### Table 1. Generic Pacemaker Code (NBG*: NASPE/BPEG Revised (2002))

<table>
<thead>
<tr>
<th>Position I, Pacing Chamber(s)</th>
<th>Position II, Sensing Chamber(s)</th>
<th>Position III, Response(s) to Sensing</th>
<th>Position IV, Programmability</th>
<th>Position V, Multisite Pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>O = none</td>
<td>O = none</td>
<td>O = none</td>
<td>O = none</td>
<td>O = none</td>
</tr>
<tr>
<td>A = atrium</td>
<td>A = atrium</td>
<td>I = inhibited</td>
<td>R = rate modulation</td>
<td>A = atrium</td>
</tr>
<tr>
<td>V = ventricle</td>
<td>V = ventricle</td>
<td>T = triggered</td>
<td>V = ventricle</td>
<td>D = dual (A + V)</td>
</tr>
<tr>
<td>D = dual (A + V)</td>
<td>D = dual (A + V)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Examples:

AAI = Atrial-only antibradycardia pacing. In the AAI mode, any failure of the atrium to produce an intrinsic event within the appropriate time window (determined by the lower rate limit) results in atrial pacing pulse emission. There is no ventricular sensing; thus, a premature ventricular event will not likely reset the pacing timer.

AOO = Asynchronous atrial-only pacing. In this mode, the pacing device emits a pacing pulse regardless of the underlying cardiac rhythm.

DDD = Dual-chamber antibradycardia pacing function in which every atrial event, within programmed limits, is followed by a ventricular event. The DDD mode implies dual-chamber pacing with atrial tracking. In the absence of intrinsic activity in the atrium, it will be paced, and, after any sensed or paced atrial event, an intrinsic ventricular event must occur before the expiration of the ativoventricular timer or the ventricle will be paced.

DDI = Dual-chamber behavior in which the atrial activity is tracked into the ventricle only when the atrial event is created by the antibradycardia pacing function of the generator. In the DDI mode, the ventricle is paced only when no intrinsic ventricular activity is present.

DOO = Asynchronous atrioventricular sequential pacing without regard to the underlying cardiac rhythm.

VOO = Asynchronous ventricular-only pacing without regard to the underlying cardiac rhythm.

VVI = Ventricular-only antibradycardia pacing. In the VVI mode, any failure of the ventricle to produce an intrinsic event within the appropriate time window (determined by the lower rate limit) results in a ventricular pacing pulse emission. There is no atrial sensing; thus, there can be no atrioventricular synchrony in a patient with a VVI pacemaker and any intrinsic atrial activity.

* NBG: N refers to NASPE, B refers to BPEG, and G refers to generic.

### Table 2. Generic Defibrillator Code (NBD): NASPE/BPEG

<table>
<thead>
<tr>
<th>Position I, Shock Chamber(s)</th>
<th>Position II, Antitachycardia Pacing Chamber(s)</th>
<th>Position III, Tachycardia Detection</th>
<th>Position IV,* Antibradyocardia Pacing Chamber(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O = none</td>
<td>O = none</td>
<td>E = electrogram</td>
<td>O = none</td>
</tr>
<tr>
<td>A = atrium</td>
<td>A = atrium</td>
<td>H = hemodynamic</td>
<td>A = atrium</td>
</tr>
<tr>
<td>V = ventricle</td>
<td>V = ventricle</td>
<td></td>
<td>V = ventricle</td>
</tr>
<tr>
<td>D = dual (A + V)</td>
<td>D = dual (A + V)</td>
<td></td>
<td>D = dual (A + V)</td>
</tr>
</tbody>
</table>

* For robust identification, position IV is expanded into its complete NBG code. For example, a biventricular pacing–defibrillator with ventricular shock and antitachycardia pacing functionality would be identified as VVE-DDDRV, assuming that the pacing section was programmed DDDRV. Currently, no hemodynamic sensors have been approved for tachycardia detection (position III).
Appendix 2: Summary of Practice Advisory

Preoperative Evaluation
- Establish whether a patient has a CRMD.
  - Conduct a focused history (patient interview, medical records review, review of available chest x-ray films, electrocardiogram, or any available monitor or rhythm strip information).
  - Conduct a focused physical examination (check for scars, palpate for device).
- Define the type of CRMD.
  - Obtain manufacturer’s identification card from patient or other source.
  - Order chest x-ray studies if no other data are available.
- Refer to supplemental resources (e.g., manufacturer’s databases).
- Determine dependency on pacing function of the CRMD.
  - History of symptomatic bradyarrhythmia resulting in CRMD implantation.
  - History of successful atrioventricular nodal ablation.
  - Inadequate escape rhythm at lowest programmable pacing rate.
- Determine CRMD function.
  - Interrogate device (consultation with a cardiologist or pacemaker–ICD service may be necessary).
  - Determine whether the device will capture when it paces (i.e., produce a mechanical systole with a pacemaker impulse).
  - Consider contacting the manufacturer for perioperative recommendations.

Preoperative Preparation
- Determine whether EMI is likely to occur during the planned procedure.
- Determine whether reprogramming pacing function to asynchronous mode or disabling rate responsive function is advantageous.
- Suspend antiarrhythmic functions if present.
- Advise individual performing the procedure to consider use of a bipolar electrocautery system or ultrasonic (harmonic) scalpel.
- Temporary pacing and defibrillation equipment should be immediately available.
- Evaluate the possible effects of anesthetic techniques and of the procedure on CRMD function and patient CRMD interactions.

Intraoperative Management
- Monitor operation of the CRMD.
  - Conduct electrocardiographic monitoring per ASA standard.
  - Monitor peripheral pulse (e.g., manual pulse palpation, pulse oximeter plethysmogram, arterial line).
- Manage potential CRMD dysfunction due to EMI.
  - Electrautery.
    - Assure that the electrosurgical receiving plate is positioned so that the current pathway does not pass through or near the CRMD system. For some cases, the receiving plate might need to be placed on a site different from the thigh (e.g., the superior posterior aspect of the shoulder contralateral to the generator position for a head and neck case).
    - Avoid use of monopolar electrocautery system, if possible.
    - Advise individual performing the procedure to avoid proximity of the cautery’s electrical field to the pulse generator or leads.
    - Advise individual performing the procedure to use short, intermittent, and irregular bursts at the lowest feasible energy levels.
    - Advise individual performing the procedure to reconsider the use of a bipolar electrocautery system or ultrasonic (harmonic) scalpel.
- Determine whether EMI is likely to occur during the planned procedure.
  - Electrosurgery.
    - Advise individual performing the procedure to avoid direct contact between the ablation catheter and the pulse generator and leads.
    - Advise individual performing the procedure to keep the radiofrequency’s current path as far away from the pulse generator and lead system as possible.
    - Advise individual performing the procedure to avoid focusing the radiofrequency beam near the pulse generator.
    - If the lithotripsy system triggers on the R wave, consider preoperative disabling of atrial pacing.
    - MRI.
      - MRI is generally contraindicated in patients with CRMDs.
      - If MRI must be performed, consult with the ordering physician, the patient’s cardiologist, the diagnostic radiologist, and the CRMD manufacturer.
    - Radiation therapy.
      - Radiation therapy can be safely performed in patients who have CRMDs.
      - Surgically relocate the CRMD if the device will be in the field of radiation.
    - Electroconvulsive therapy.
      - Consult with the ordering physician, the patient’s cardiologist, a CRMD service, or the CRMD manufacturer.
- Emergency defibrillation or cardioversion.
  - For a patient with an ICD and magnet-disabled therapies:
    - Advise individual performing the procedure to terminate all sources of EMI while magnet is removed.
    - Remove the magnet to reenable antiarrhythmic therapies.
    - Observe the patient and the monitors for appropriate CRMD therapy.
    - If the above activities do not restore ICD function, proceed with emergency external defibrillation or cardioversion.
  - For a patient with an ICD and programming-disabled therapies:
    - Advise individual performing the procedure to terminate all sources of EMI while magnet is removed.
    - Reenable therapies through programming if the programmer is immediately available and ready to be used.
    - Observe the patient and the monitors for appropriate CRMD therapy.
    - If the above activities do not restore ICD function, proceed with emergency external defibrillation or cardioversion.
- For external defibrillation.
  - Position defibrillation/cardioversion pads or paddles as far as possible from the pulse generator.
  - Position defibrillation/cardioversion pads or paddles perpendicular to the major axis of the CRMD to the extent possible by placing them in an anterior–posterior location.
  - If it is technically impossible to place the pads or paddles in locations that help to protect the CRMD, defibrillate/cardiovert the patient in the quickest possible way and be prepared to provide pacing through other routes.
  - Use a clinically appropriate energy output.

Postoperative Management
- Continuously monitor cardiac rate and rhythm and have backup pacing and defibrillation equipment immediately available throughout the immediate postoperative period.
- Interrogate and restore CRMD function in the immediate postoperative period.
  - Interrogate CRMD; consultation with a cardiologist or pacemaker–ICD service may be necessary.
  - Restore all antiarrhythmic therapies in ICDs.
  - Assure that all other settings of the CRMD are appropriate.

Refer to Table 3 for an example of a stepwise approach to the perioperative treatment of the patient with a CRMD.

ASA = American Society of Anesthesiologists; CRMD = cardiac rhythm management device; EMI = electromagnetic interference; ICD = implantable cardioverter–defibrillator; MRI = magnetic resonance imaging.
Table 3. Example of a Stepwise Approach to the Perioperative Treatment of the Patient with a CRMD

<table>
<thead>
<tr>
<th>Perioperative Period</th>
<th>Patient/CRMD Condition</th>
<th>Intervention</th>
</tr>
</thead>
</table>
| Preoperative evaluation | Patient has CRMD | ● Focused history  
  ● Focused physical examination  |
| Determine CRMD type (pacemaker, ICD, CRT) |  | ● Manufacturer’s CRMD identification card  
  ● Chest x-ray studies (no data available)  
  ● Supplemental resources*  |
| Determine whether patient is CRMD-dependent for pacing function |  | ● Verbal history  
  ● Bradycardia symptoms  
  ● Atrioventricular node ablation  
  ● No spontaneous ventricular activity†  |
| Determine CRMD function |  | ● Comprehensive CRMD evaluation;  
  ● Determine whether pacing pulses are present and create paced beats  |
| Preoperative preparation | EMI unlikely during procedure | ● If EMI unlikely, special precautions are not needed  |
| EMI likely: CRMD is pacemaker |  | ● Reprogram to asynchronous mode when indicated  
  ● Suspend rate-adaptive functions§  |
| EMI likely: CRMD is ICD |  | ● Suspend antitachycardia functions  
  ● If patient is dependent on pacing function, alter pacing functions as above  |
| EMI likely: all CRMD |  | ● Use bipolar cautery; ultrasonic scalpel  
  ● Temporary pacing and external cardioversion–defibrillation available  |
| Intraoperative physiologic changes likely (e.g., bradycardia, ischemia) |  | Plan for possible adverse CRMD–patient interaction  |
| Intraoperative management | Monitoring | ● Electrocardiographic monitoring per ASA standard  
  ● Peripheral pulse monitoring  |
| Electrocautery interference |  | ● CT/CRP—no current through PG/leads  
  ● Avoid proximity of CT to PG/leads  
  ● Short bursts at lowest possible energy  
  ● Use bipolar cautery; ultrasonic scalpel  |
| Radiofrequency catheter ablation |  | ● Avoid contact of radiofrequency catheter with PG/leads  
  ● Radiofrequency current path far away from PG/leads  
  ● Discuss these concerns with operator  |
| Lithotripsy |  | ● Do not focus lithotripsy beam near PG  
  ● R wave triggers lithotripsy? Disable atrial pacing|  |
| MRI |  | ● Generally contraindicated  
  ● If required, consult ordering physician, cardiologist, radiologist, and manufacturer  |
| RT |  | ● PG/leads must be outside of RT field  
  ● Possible surgical relocation of PG  
  ● Verify PG function during/after RT course  |
| ECT |  | ● Consult with ordering physician, patient’s cardiologist, a CRMD service, or CRMD manufacturer  |
| Emergency defibrillation–cardioversion | ICD: magnet disabled | ● Terminate all EMI sources  
  ● Remove magnet to reenable therapies  
  ● Observe for appropriate therapies  |
| ICD: programming disabled |  | ● Programming to reenable therapies or proceed directly with external cardioversion–defibrillation  |
| ICD: either of above |  | ● Minimize current flow through PG/leads  
  ● PP as far as possible from PG  
  ● PP perpendicular to major axis PG/leads  
  ● To extent possible, PP in anterior–posterior location  |
| Regardless of CRMD type |  | ● Use clinically appropriate cardioversion/defibrillation energy  |
| Postoperative management | Immediate postoperative period |  | ● Monitor cardiac R&R continuously  
  ● Backup pacing and cardioversion/defibrillation capability  |
| Postoperative interrogation and restoration of CRMD function |  | ● Introguration to assess function  
  ● Settings appropriate?#  
  ● Is CRMD an ICD??  
  ● Use cardiology/pacemaker–ICD service if needed  |

* Manufacturer’s databases, pacemaker clinic records, cardiology consultation. † With cardiac rhythm management device (CRMD) programmed VVI at lowest programmable rate. ‡ Ideally CRMD function assessed by interrogation, with function altered by reprogramming if required. § Most times this will be necessary; when in doubt, assume so. || Atrial pacing spikes may be interpreted by the lithotriptor as R waves, possibly inciting the lithotriptor to deliver a shock during a vulnerable period in the heart. # If necessary, reprogram appropriate settings. ** Restore all antitachycardia therapies.  

CRP = current return pad; CRT = cardiac resynchronization therapy; CT = cautery tool; ECT = electroconvulsive therapy; EMI = electromagnetic interference; ICD = internal cardioverter–defibrillator; MRI = magnetic resonance imaging; PG = pulse generator; PP = external cardioversion–defibrillation pads or paddles; R&R = rhythm and rate; RT = radiation therapy.
Appendix 3: Literature Review and Consensus-based Evidence

A. State of the Literature

For this Advisory, a literature review was used in combination with opinions obtained from experts and other sources (e.g., professional society members, open forums, Web-based postings) to provide guidance to practitioners regarding the perioperative treatment of patients with CRMDs. Both the literature review and opinion data were based on evidence linkages, consisting of directional statements about relations between specific perioperative management activities and CRMD function or clinical outcomes.

A study or report that appears in the published literature is included in the development of an advisory if the study (1) is related to one of the specified linkage statements, (2) reports a finding or set of findings that can be tallied or measured (e.g., articles that contain only opinion are not included), and (3) is the product of an original investigation or report (i.e., review articles or follow-up studies that summarize previous findings are not included). Because CRMDs represent a rapidly changing technology, earlier literature (i.e., literature published before 1990) was rarely included in the evaluation of evidence for this Practice Advisory.

Although evidence linkages are designed to assess causality, few of the reviewed studies exhibited sufficiently acceptable quantitative methods and analyses to provide a clear indication of causality. Therefore, the published literature could not be used as a source of quantitative support (required for the development of practice guidelines). However, many published studies were evaluated that provided evidence linkages would change their clinical practices if the Advisory were published and in table 4.

Interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a $\kappa$ statistic for two-rater agreement pairs were as follows: (1) type of study design, $\kappa = 0.72–0.90$; (2) type of analysis, $\kappa = 0.80–0.90$; (3) evidence linkage assignment, $\kappa = 0.84–1.00$; and (4) literature inclusion for database, $\kappa = 0.70–1.00$. Three-rater chance-corrected agreement values were (1) study design, $Sav = 0.81$, Var $(Sav) = 0.010$; (2) type of analysis, $Sav = 0.86$, Var $(Sav) = 0.009$; (3) linkage assignment, $Sav = 0.82$, Var $(Sav) = 0.005$; and (4) literature database inclusion, $Sav = 0.78$, Var $(Sav) = 0.031$. These values represent moderate to high levels of agreement.

Future studies should focus on prospective methodologies, when possible, that use traditional hypothesis testing techniques. Use of the following methodologic procedures for assessing the impact of perioperative management of CRMDs is recommended: (1) comparison studies (i.e., one technique vs. another) when clinically feasible; (2) randomization; and (3) full reporting of sample size, effect size estimates, test scores, measures of variability, and $P$ values.

B. Consensus-based Evidence

Consensus was obtained from multiple sources, including (1) survey opinion from Consultants who were selected based on their knowledge or expertise in perioperative management of CRMDs, (2) survey opinions from randomly selected samples of active members of the American Society of Anesthesiologists and active members of the HRS, (3) testimony from attendees of two publically held open forums at a national anesthesiology meeting and at a major cardiology meeting, (4) Internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 56% ($n = 23$ of 41) for Consultants, 15% ($n = 89$ of 600) for the ASA membership, and 15% ($n = 44$ of 300) for the HRS membership. Survey results are presented in the text of the document and in table 4.

The ASA Consultants were also asked to indicate which, if any, of the evidence linkages would change their clinical practices if the Advisory was instituted. The rate of return was 59% ($n = 16$ of 41). The percent of responding Consultants expecting no change associated with each linkage were as follows: preoperative evaluation—67%; preoperative patient preparation—67%; intraoperative monitoring of CRMDs—67%; emergency defibrillation or cardioversion—87%; postoperative monitoring of CRMDs—73%; postoperative interrogation and restoration of CRMD function—60%; intraoperative management of EMI during electrosurgery—73%, radiofrequency ablation—73%, lithotripsy—80%, MRI—80%, radiation therapy—80%, and electroconvulsive therapy—73%. Forty percent of the respondents indicated that the Advisory would have no effect on the amount of time spent on a typical case. Nine respondents (60%) indicated that there would be an increase in the amount of time they would spend on a typical case with the implementation of this Advisory. The amount of increased time anticipated by these respondents ranged from 5 to 30 min.

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Consultants</th>
<th>ASA Members</th>
<th>HRS Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To perform a preoperative evaluation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Establish whether a patient has a CRMD.</td>
<td>23 100/0</td>
<td>89 100/0</td>
<td>44 100/0</td>
</tr>
<tr>
<td>Define the type of device.</td>
<td>23 100/0</td>
<td>87 95/0</td>
<td>44 100/0</td>
</tr>
<tr>
<td>Determine whether a patient is CRMD dependent for pacemaking function.</td>
<td>23 96/0</td>
<td>89 96/0</td>
<td>44 96/4</td>
</tr>
<tr>
<td>Determine CRMD function.</td>
<td>23 96/0</td>
<td>89 88/3</td>
<td>44 71/11</td>
</tr>
<tr>
<td>2. To prepare a CRMD patient for a procedure:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determine whether EMI is likely to occur.</td>
<td>23 96/4</td>
<td>89 91/2</td>
<td>44 96/2</td>
</tr>
<tr>
<td>Turn pacemaking rate-adaptive therapy off.</td>
<td>23 52/35</td>
<td>89 35/35</td>
<td>44 34/34</td>
</tr>
<tr>
<td>Program pacemaking function to asynchronous mode:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All CRMD patients.</td>
<td>22 0/82</td>
<td>88 21/48</td>
<td>43 9/84</td>
</tr>
<tr>
<td>Pacemaker-dependent patients only.</td>
<td>22 73/23</td>
<td>83 47/27</td>
<td>43 54/28</td>
</tr>
<tr>
<td>Suspend antiarrhythmic functions.</td>
<td>21 86/5</td>
<td>87 54/21</td>
<td>43 63/21</td>
</tr>
<tr>
<td>Consider using a bipolar electrocautery system (when applicable).</td>
<td>22 91/0</td>
<td>86 90/2</td>
<td>44 77/14</td>
</tr>
<tr>
<td>Consider using an ultrasonic (harmonic) scalpel (when applicable).</td>
<td>22 68/18</td>
<td>88 63/3</td>
<td>44 34/9</td>
</tr>
<tr>
<td>Assure the availability of temporary pacing and defibrillation equipment.</td>
<td>22 100/0</td>
<td>87 95/1</td>
<td>44 89/7</td>
</tr>
<tr>
<td>Consider the possible effects of anesthetic agents or techniques on CRMD function.</td>
<td>22 64/18</td>
<td>86 77/9</td>
<td>44 66/21</td>
</tr>
<tr>
<td>3. Intraoperative monitoring should include:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous electrocardiography.</td>
<td>23 100/0</td>
<td>88 100/0</td>
<td>44 100/0</td>
</tr>
<tr>
<td>Continuous peripheral pulse monitoring.</td>
<td>23 96/0</td>
<td>88 86/11</td>
<td>44 61/18</td>
</tr>
<tr>
<td>4. For procedures using electrocautery:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position the electrosurgical receiving plate so current pathway does not pass through or near the generator or leads.</td>
<td>23 100/0</td>
<td>88 97/0</td>
<td>44 96/0</td>
</tr>
<tr>
<td>Avoid proximity of the cautery’s electrical field to the pulse generator or leads.</td>
<td>23 100/0</td>
<td>87 100/0</td>
<td>44 96/2</td>
</tr>
<tr>
<td>Use short, intermittent, and irregular bursts at the lowest feasible energy levels.</td>
<td>23 96/0</td>
<td>87 83/2</td>
<td>44 91/7</td>
</tr>
<tr>
<td>Use a bipolar electrocautery system (when applicable).</td>
<td>23 91/0</td>
<td>88 94/1</td>
<td>44 84/2</td>
</tr>
<tr>
<td>Use an ultrasonic (harmonic) scalpel (when applicable).</td>
<td>23 57/13</td>
<td>88 65/1</td>
<td>44 41/9</td>
</tr>
<tr>
<td>5. For radiofrequency ablation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoid direct contact between the ablation catheter and the CRMD and leads.</td>
<td>23 83/0</td>
<td>87 76/0</td>
<td>44 91/2</td>
</tr>
<tr>
<td>Keep the current path (electrode tip to return plate) as far away from the pulse generator and lead system as possible.</td>
<td>23 87/0</td>
<td>87 78/0</td>
<td>44 89/5</td>
</tr>
<tr>
<td>6. For lithotripsy:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoid focusing the lithotripsy beam near the pulse generator.</td>
<td>23 91/0</td>
<td>86 78/1</td>
<td>44 86/0</td>
</tr>
<tr>
<td>If the lithotripsy system triggers on the R wave, disable atrial pacing before procedure.</td>
<td>23 39/26</td>
<td>86 38/13</td>
<td>44 39/9</td>
</tr>
<tr>
<td>7. For MRI:†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRI is contraindicated for all CRMD patients.</td>
<td>21 81</td>
<td>79 80</td>
<td>44 55</td>
</tr>
<tr>
<td>MRI is contraindicated for some but not all CRMD patients.</td>
<td>21 19</td>
<td>79 18</td>
<td>44 39</td>
</tr>
<tr>
<td>MRI is not contraindicated for any CRMD patient.</td>
<td>21 0</td>
<td>79 2</td>
<td>44 6</td>
</tr>
<tr>
<td>8. For RT:†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT is contraindicated for all CRMD patients.</td>
<td>21 0</td>
<td>73 10</td>
<td>44 0</td>
</tr>
<tr>
<td>RT is contraindicated for some but not all CRMD patients.</td>
<td>21 57</td>
<td>73 37</td>
<td>44 59</td>
</tr>
<tr>
<td>RT is not contraindicated for any CRMD patient.</td>
<td>21 43</td>
<td>73 53</td>
<td>44 41</td>
</tr>
<tr>
<td>9. For emergency defibrillation or cardioversion:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position the defibrillation or cardioversion pads as far as possible from the pulse generator.</td>
<td>23 83/0</td>
<td>87 69/13</td>
<td>44 91/7</td>
</tr>
<tr>
<td>Use an anterior–posterior position.</td>
<td>23 74/9</td>
<td>84 61/6</td>
<td>44 68/25</td>
</tr>
<tr>
<td>Use a clinically appropriate energy output regardless of the device.</td>
<td>23 100/0</td>
<td>87 87/0</td>
<td>44 100/0</td>
</tr>
<tr>
<td>10. To treat CRMD patients postoperatively:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interrogate and restore CRMD function in the PACU or ICU.</td>
<td>23 96/4</td>
<td>88 98/1</td>
<td>44 77/21</td>
</tr>
</tbody>
</table>

* The percentages of respondents who agreed/disagreed with each item are presented. The percentages of respondents who were uncertain are not presented. † Respondents were asked to select one of the three choices. Therefore, the numbers represent percent agreement only.

ASA = American Society of Anesthesiologists; CRMD = cardiac rhythm management device; EMI = electromagnetic interference; HRS = Heart Rhythm Society; ICU = intensive care unit; MRI = magnetic resonance imaging; PACU = postanesthesia care unit; RT = radiation therapy.

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A Report by the American Society of Anesthesiologists Task Force on Operating Room Fires

This report is a practice advisory developed by the American Society of Anesthesiologists (ASA) Task Force on Operating Room Fires. It outlines the prevention and management strategies for operating room fires, emphasizing the importance of understanding the fire triad: oxidizer, ignition source, and fuel. The advisory highlights the use of scientific literature and expert opinion to guide decision-making in the care of patients during surgery. The report includes sections on the definition of OR fires, high-risk procedures, and the methodology for assessing and managing these incidents. Key concepts such as oxidizer-enriched atmosphere and the role of ignition and fuel sources are discussed in detail. The advisory is supported by the American Society of Anesthesiologists and aims to provide a comprehensive guide for healthcare providers to ensure patient safety during surgical procedures.

Key Concepts:
- **Oxidizers**: Used in the OR are oxygen and nitrous oxide.
- **Ignition Sources**: Include electrocautery devices, lasers, heated surgical or electrocautery devices, lasers, heated tubes, sponges, and other oxidizers.
- **Fuel Sources**: Include oxygen masks, nasal cannulae, the patient's hair, dressings, and packaging materials.

Methodology

A. **Definition of OR Fires, High-risk Procedures, and OR Fire Drills**

For this Advisory, operating room fires are defined as incidents where there is any increase in oxygen concentration above room air level, and/or the presence of any concentration of nitrous oxide. Specific types of surgical fires occurring in patients' airways are also defined.

Methodology includes qualitative and quantitative data analysis, risk assessment, and review of scientific literature to develop practice advisories. The report is endorsed by the American Academy of Otolaryngology–Head and Neck Surgery and supported by the American Society of Anesthesiologists.
Airway fires may or may not include fire in the attached breathing circuit. A high-risk procedure is defined as one in which an ignition source (e.g., electrosurgery) may come in proximity to an oxidizer-enriched atmosphere (e.g., supplemental oxygen and/or nitrous oxide), thereby increasing the risk of fire. Examples of high-risk procedures include, but are not limited to, tonsillectomy, tracheotomy, removal of laryngeal papillomas, cataract or other eye surgery, burr hole surgery, or removal of lesions on the head, neck, or face.

An OR fire drill is defined as a formal and periodic rehearsal of the OR team’s planned response to a fire. In this Advisory, the OR fire drill is characterized as a "formal and periodic rehearsal" to indicate that it takes place during dedicated education time, not during patient care. In other words, an OR fire drill is not the same as a discussion or plan about fire management that takes place during direct patient care.

B. Purpose

The purposes of this Advisory are to (1) identify situations conducive to fire, (2) prevent the occurrence of OR fires, (3) reduce adverse outcomes associated with OR fires, and (4) identify the elements of a fire response protocol. Adverse outcomes associated with OR fires may include major or minor burns, inhalation injuries, infection, disfigurement, and death. Related adverse outcomes may include psychological trauma, prolonged hospitalization, delay or cancellation of surgery, additional hospital resource utilization, and liability.

C. Focus

This Advisory focuses on a specific care setting and subset of fires. The specific care setting is any OR or procedure area where anesthesia care is provided. The specific subset is fires that occur on the patient, in the airway, or in the breathing circuit. This Advisory does not address fires away from the patient (e.g., in a trash can), institutional preplanning for fire, or the responses of fire personnel.

D. Application

This Advisory is intended for use by anesthesiologists or other individuals working under the supervision of an anesthesiologist. Because prevention of OR fires requires close collaboration and prompt coordination between anesthesiologists, surgeons, and nurses, some responsibilities are shared among the disciplines. When shared responsibilities are described in this Advisory, the intent is to give the anesthesiologist a starting point for participating in the allocation and understanding of shared responsibilities. The Advisory may also serve as a resource for other physicians and healthcare professionals (e.g., technicians, safety officers, hospital administrators, biomedical engineers, industry representatives).

E. Task Force Members and Consultants

The ASA appointed a Task Force of nine members. These individuals included four anesthesiologists in private and academic practice from various geographic areas of the United States, an otolaryngologist, a perioperative registered nurse, a professional engineer/fire investigator, and two consulting methodologists from the ASA Committee on Standards and Practice Parameters. Two Task Force members are former firefighters.

The Task Force developed the Advisory by means of a seven-step process. First, they reached consensus on the criteria for evidence. Second, a systematic review and evaluation was performed on original, published, peer-reviewed and other research studies related to OR fires. Third, a panel of expert consultants was asked to (1) participate in opinion surveys on the effectiveness of various strategies for fire prevention, detection, and management and (2) review and comment on a draft of the Advisory developed by the Task Force. Fourth, opinions about the Advisory were solicited from a random sample of active members of the ASA. Fifth, the Task Force held an open forum at a major national meeting to solicit input on its draft recommendations. Sixth, the consultants were surveyed to assess their opinions on the feasibility of implementing this Advisory. Seventh, all available information was used to build consensus within the Task Force to formulate the advisory statements (appendix 1).

F. Availability and Strength of Evidence

Preparation of this Advisory followed a rigorous methodological process (appendix 2). Evidence was obtained from two principal sources: scientific evidence and opinion-based evidence.

Scientific Evidence. Study findings from published scientific literature were aggregated and are reported in summary form by evidence category, as described below. All literature (e.g., randomized controlled trials, observational studies, case reports) relevant to each topic was considered when evaluating the findings. However, for reporting purposes in this document, only the highest level of evidence (i.e., level 1, 2, or 3) within each category is included in the summary.

Category A: Supportive Literature. Randomized controlled trials report statistically significant ($P < 0.01$) differences between clinical interventions for a specified clinical outcome.

Level 1: The literature contains multiple randomized controlled trials, and the aggregated findings are supported by meta-analysis.

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Notes:


§ All meta-analyses are conducted by the ASA methodology group. Meta-analyses from other sources are reviewed but not included.
Level 2: The literature contains multiple randomized controlled trials, but there is an insufficient number of studies to conduct a viable meta-analysis for the purpose of this Advisory.

Level 3: The literature contains a single randomized controlled trial.

**Category B: Suggestive Literature.** Information from observational studies permits inference of beneficial or harmful relationships among clinical interventions and clinical outcomes.

**Level 1:** The literature contains observational comparisons (e.g., cohort, case-control research designs) of two or more clinical interventions or conditions and indicates statistically significant differences between clinical interventions for a specified clinical outcome.

**Level 2:** The literature contains noncomparative observational studies with associative (e.g., relative risk, correlation) or descriptive statistics.

**Level 3:** The literature contains case reports.

**Category C: Equivocal Literature.** The literature cannot determine whether there are beneficial or harmful relationships among clinical interventions and clinical outcomes.

**Level 1:** Meta-analysis did not find significant differences among groups or conditions.

**Level 2:** There is an insufficient number of studies to conduct meta-analysis and (1) randomized controlled trials have not found significant differences among groups or conditions or (2) randomized controlled trials report inconsistent findings.

**Level 3:** Observational studies report inconsistent findings or do not permit inference of beneficial or harmful relationships.

**Category D: Insufficient Evidence from Literature.** The lack of scientific evidence in the literature is described by the following terms.

**Silent:** No identified studies address the specified relationships among interventions and outcomes.

**Inadequate:** The available literature cannot be used to assess relationships among clinical interventions and clinical outcomes. The literature either does not meet the criteria for content as defined in the “Focus” of the Advisory or it does not permit a clear interpretation of findings due to methodologic concerns (e.g., confounding in study design or implementation).

**Opinion-based Evidence.** All opinion-based evidence relevant to each topic (e.g., survey data, open-forum testimony, Web-based comments, letters, editorials) is considered in the development of this Advisory. However, only the findings obtained from formal surveys are reported.

Opinion surveys were developed by the Task Force to address each clinical intervention identified in the document. Identical surveys were distributed to two groups of respondents: expert consultants and ASA members.

**Category A: Expert Opinion.** Survey responses from Task Force-appointed expert consultants are reported in summary form in the text. A complete listing of consultant survey responses is reported in appendix 2.

**Category B: Membership Opinion.** Survey responses from a random sample of members of the ASA and, when appropriate, responses from members of other organizations with expertise in the selected topics of interest are reported in summary form in the text. A complete listing of ASA member survey responses is reported in appendix 2.

Survey responses are recorded using a five-point scale and summarized based on median values.

- **Strongly Agree:** Median score of 5 (at least 50% of the responses are 5)
- **Agree:** Median score of 4 (at least 50% of the responses are 4 or 4 and 5)
- **Equivocal:** Median score of 3 (at least 50% of the responses are 3, or no other response category or combination of similar categories contains at least 50% of the responses)
- **Disagree:** Median score of 2 (at least 50% of responses are 2 or 1 and 2)
- **Strongly Disagree:** Median score of 1 (at least 50% of responses are 1)

**Category C: Informal Opinion.** Open-forum testimony, Web-based comments, letters, and editorials are all informally evaluated and discussed during the development of the Advisory. When warranted, the Task Force may add educational information or cautionary notes based on this information.

### Advisories

#### I. Education

Operating room fire safety education includes, but is not limited to, knowledge of institutional fire safety protocols and participation in institutional fire safety education. Case reports indicate that lack of education can result in severe injury and death from uncontrolled OR fires.\[6,7\] [Category B3 evidence.]

The consultants and ASA members strongly agree that every anesthesiologist should have knowledge of institutional fire safety protocols for the OR, and should participate in OR fire safety education. The consultants and ASA members strongly agree that OR fire safety education for the anesthesiologist should emphasize the risk created by an oxidizer-enriched atmosphere.
Advisory Statements. All anesthesiologists should have fire safety education, specifically for OR fires, with emphasis on the risk created by an oxidizer-enriched atmosphere.

II. OR Fire Drills

A case report indicates that OR fire drills and simulation training can result in improved staff response to a fire.8 [Category B3 evidence.]

The consultants strongly agree and ASA members agree that all anesthesiologists should periodically participate in OR fire drills with the entire OR team. The consultants and ASA members strongly agree that participation should take place during dedicated educational time, not during patient care.

Advisory Statements. Anesthesiologists should periodically participate in OR fire drills with the entire OR team. This formal rehearsal should take place during dedicated educational time, not during patient care.

III. Preparation

Preparation for OR fires includes (1) determining whether or not a high-risk situation exists and (2) a team discussion of the strategy for the prevention and management of an OR fire in a high-risk situation. The literature is silent regarding whether a preoperative determination of a high-risk situation or a team discussion of OR fire strategy reduces the incidence or severity of an OR fire. [Category D evidence.]

The consultants strongly agree and ASA members agree that anesthesiologists should participate with the entire OR team in assessing the risk of an OR fire for each case and determining whether a high-risk situation exists. The consultants strongly agree and ASA members agree that all team members should jointly agree on how a fire will be prevented and managed for each particular procedure. The consultants and ASA members strongly agree that a protocol for the prevention and management of fires should be posted in each location where a procedure is performed.

Advisory Statements. For every case, the anesthesiologist should participate with the entire OR team (e.g., during the surgical pause) in determining whether a high-risk situation exists. If a high-risk situation exists, all team members—including the anesthesiologist—should take a joint and active role in agreeing on how a fire will be prevented and managed. Each team member should be assigned a specific fire management task to perform in the event of a fire (e.g., removing the tracheal tube, stopping the flow of airway gases). Each team member should understand that his or her preassigned task should be performed immediately if a fire occurs, without waiting for another team member to take action. When a team member has completed a preassigned task, he or she should help other team members perform tasks that are not yet complete.

In every OR and procedure area where a fire triad can exist (i.e., an oxidizer-enriched atmosphere, an ignition source, and fuel), an easily visible protocol for the prevention and management of fires should be displayed (fig. 1).

Equipment for managing a fire should be readily available in every procedural area where a fire triad may exist. Table 1 provides an example of fire management equipment that should be in or near the OR or procedural area.

IV. Prevention

Prevention of OR fires includes (1) minimizing or avoiding an oxidizer-enriched atmosphere near the surgical site, (2) safely managing ignition sources, and (3) safely managing fuels.

Comparative studies indicate that a wide range of material ignites more readily in an oxygen-enriched atmosphere than in room air.9–13 [Category B1 evidence.] One comparative study with awake volunteer subjects showed that the configuration of surgical drapes can result in oxygen buildup, increasing the risk of fire.14 [Category B1 evidence.] This study also indicated that replacing oxygen with compressed air or discontinuing supplemental oxygen for a period of time reduces oxygen buildup without significantly reducing oxygen saturation levels. Similarly, a randomized controlled trial comparing supplemental oxygen and compressed air in sedated patients undergoing cataract surgery found no differences in oxygen saturation.15 [Category C2 evidence.]

Observational studies and case reports indicate that electrocautery or electrosurgical devices and lasers are common sources of ignition for many OR fires, particularly when used in an oxidizer-enriched atmosphere.16–68 [Category B2–3 evidence.]

Case reports indicate that alcohol-based skin-prepping agents generate volatile vapors that ignite easily. These reports suggest that insufficient drying time after application of alcohol-based skin-prepping agents is a cause of fires on patients.23,69–75 [Category B3 evidence.] Comparative studies show that conventional tracheal tubes, when exposed to a laser beam, are more likely to ignite or melt than laser-resistant tracheal tubes.74–84 [Category B1 evidence.] Case reports indicate that dry sponges and gauze are common sources of fuel.7,19,55,43–45,55,64,83–87

Comparative studies demonstrate that the flammability of sponges, cottonoids, or packing material is reduced when wet rather than dry or partially dry.88–91 [Category B1 evidence.]

For all procedures, the consultants and ASA members strongly agree that flammable skin prepping solutions should be dry before draping. They strongly agree that surgical drapes should be configured to prevent oxygen from accumulating under the drapes or from flowing into the surgical site. They strongly agree that sponges
Fig. 1. Operating room fires algorithm. CO$_2$ = carbon dioxide; OR = operating room.

1 Ignition sources include but are not limited to electrosurgery or electrocautery units and lasers.
2 An oxidizer-enriched atmosphere occurs when there is any increase in oxygen concentration above room air level, and/or the presence of any concentration of nitrous oxide.
3 After minimizing delivered oxygen, wait a period of time (e.g., 1-3 min) before using an ignition source. For oxygen-dependent patients, reduce supplemental oxygen delivery to the minimum required to avoid hypoxia. Monitor oxygenation with pulse oximetry, and if feasible, inspired, exhaled, and/or delivered oxygen concentration.
4 After stopping the delivery of nitrous oxide, wait a period of time (e.g., 1-3 min) before using an ignition source.
5 Unexpected flash, flame, smoke or heat, unusual sounds (e.g., a “pop,” “snap” or “foomp”) or odors, unexpected movement of drapes, discoloration of drapes or breathing circuit, unexpected patient movement or complaint.
6 In this algorithm, airway fire refers to a fire in the airway or breathing circuit.
7 A CO$_2$ fire extinguisher may be used on the patient if necessary.
Table 1. Operating Room Fire Equipment and Supplies That Should Be Immediately Available*

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Several containers of sterile saline</td>
</tr>
<tr>
<td>A CO₂ fire extinguisher</td>
</tr>
<tr>
<td>Replacement tracheal tubes, guides, facemasks</td>
</tr>
<tr>
<td>Rigid laryngoscope blades; this may include a rigid fiberoptic laryngoscope</td>
</tr>
<tr>
<td>Replacement airway breathing circuits and lines</td>
</tr>
<tr>
<td>Replacement drapes, sponges</td>
</tr>
</tbody>
</table>

* Some facilities or locations may benefit from assembling a portable cart containing equipment and supplies that expedite the immediate response to an operating room fire. The contents of such a cart will vary depending on local conditions and resources. If the items needed for an immediate response to an operating room fire are already available, there may be no added benefit to assembling a portable cart.

should be moistened when used near an ignition source, particularly when used in or near the airway.

For high-risk procedures (i.e., proximity of an ignition source and an oxidizer-enriched atmosphere), the consultants and ASA members strongly agree that anesthesiologists should collaborate with the procedure team for the purpose of preventing and managing a fire. They strongly agree that the surgeon should be notified whenever an ignition source is in proximity to an oxidizer-enriched atmosphere or when the concentration of oxidizer has increased. They strongly agree that the fraction of inspired oxygen (FIO₂) delivered to the patient should be kept as low as clinically feasible when an ignition source is in proximity to an oxygen-enriched atmosphere. They strongly agree that the reduction of FIO₂ delivered to the patient should be guided by monitoring patient oxygenation (e.g., pulse oximetry). Task Force members agree that the reduction of FIO₂ should be monitored, if feasible, by measuring inspired, expired, and/or delivered oxygen concentration. They strongly agree that the use of nitrous oxide should be avoided in settings that are considered high risk for fire. The consultants strongly agree and ASA members agree that oxygen or nitrous oxide buildup may be minimized by either insufflating with medical air or scavenging the operating field with suction.

For laser surgery, consultants and ASA members strongly agree that laser resistant tracheal tubes should be used, and that the tube choice should be appropriate for the procedure and laser. They both strongly agree that the tracheal cuff of the laser tube should be filled with saline rather than air, when feasible. The consultants strongly agree and the ASA members agree that saline in tracheal tube cuff should be tinted with methylene blue to act as a marker for cuff puncture by a laser.

Surgery inside the airway can bring an ignition source into proximity with an oxidizer-enriched atmosphere, thereby creating a high-risk situation. For cases involving surgery inside the airway, consultants and ASA members both agree that a cuffed tracheal tube should be used instead of an uncuffed tracheal tube when medically appropriate. Because an elevated FIO₂ is often necessary during tracheostomy, the Task Force strongly agrees that surgeons should be advised not to enter the trachea with an ignition source such as an electrosurgical device. If an electrosurgical device must be used, the anesthesiologist should request that the surgeon provide adequate warning to allow the concentration of oxidizer to be minimized before the trachea is entered. Consultants and ASA members were asked to report the time that they believe is needed to reduce oxygen or nitrous oxide concentration to a safe level before using an ignition source. For patients being ventilated with a tracheal tube, consultants report a range of time of less than 1 min to 5 min (mean = 1.8 min), and ASA members report a range of time of less than 1 min to 10 min (mean = 2.9 min). For patients wearing a facemask or nasal cannula, both the consultants and ASA members report a range of time of less than 1 min to 5 min (mean = 1.7 min for consultants, and mean = 2.3 min for ASA members). The consultants and ASA members both agree that the oropharynx should be scavenged with suction during oral procedures.

Surgery around the face, head, or neck can bring an ignition source into proximity with an oxidizer-enriched atmosphere, thereby creating a high-risk situation. When monitored anesthesia care is considered for surgery around the face, head, or neck, the Task Force strongly agrees that two specific factors should be considered: (1) the required depth of sedation and (2) oxygen dependence. The Task Force agrees that a sealed gas delivery device (e.g., cuffed tracheal tube or laryngeal mask) should be considered if moderate or deep sedation is required or used, or if the patient exhibits oxygen dependence. If neither factor is present, an open gas delivery device (e.g., facemask or nasal cannula) may be considered. If an open gas delivery system is used, the Task Force agrees that before an ignition source is activated around the face, head, or neck, the surgeon should give the adequate notice that the ignition source will be activated. The anesthesiologist should (1) stop the delivery of supplemental oxygen or reduce the delivery to the minimum required to avoid hypoxia, and (2) wait a few minutes between decreasing the flow of supplemental oxygen and approving the activation of the ignition source. In the unlikely event of nitrous oxide delivery with an open system (e.g., facemask or nasal cannula), the Task Force agrees that the anesthesiologist should (1) stop the delivery of nitrous oxide, and (2) wait a few minutes between stopping the nitrous oxide and approving the activation of the ignition source.

Advisory Statements. To the extent that is medically appropriate, the following basic principles should be applied to the management of oxidizers, ignition sources, and fuels:

- The anesthesiologist should collaborate with all members of the procedure team throughout the procedure.

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to minimize the presence of an oxidizer-enriched atmosphere in proximity to an ignition source.

- Surgical drapes should be configured to minimize the accumulation of oxidizers (oxygen and nitrous oxide) under the drapes and from flowing into the surgical site.
- Flammable skin prepping solutions should be dry before draping.
- Gauze and sponges should be moistened when used in proximity to an ignition source.

For high-risk procedures, the anesthesiologist should notify the surgeon whenever there is a potential for an ignition source to be in proximity to an oxidizer-enriched atmosphere or when there is an increase in oxidizer concentration at the surgical site. Any reduction in supplied oxygen to the patient should be assessed by monitoring (1) pulse oximetry and, if feasible, (2) inspired, exhaled, and/or delivered oxygen concentration.

Before activating a laser, the surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated. The anesthesiologist should (1) reduce the delivered oxygen concentration to the minimum required to avoid hypoxia, (2) stop the use of nitrous oxide, and (3) wait a few minutes after reducing the oxidizer-enriched atmosphere before approving activation of the laser.

For cases involving an ignition source and surgery inside the airway, cuffed tracheal tubes should be used when clinically appropriate. The anesthesiologist should advise the surgeon on entering the trachea with an ignition source (e.g., electrosurgery unit). Before activating an ignition source inside the airway, the surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated. The anesthesiologist should (1) reduce the delivered oxygen concentration to the minimum required to avoid hypoxia, (2) stop the use of nitrous oxide, and (3) wait a few minutes after reducing the oxidizer-enriched atmosphere before approving activation of the laser.

For cases involving moderate or deep sedation, an ignition source, and surgery around the face, head, or neck, the anesthesiologist and surgeon should develop a plan that accounts for the level of sedation and the patient’s need for supplemental oxygen.

- If moderate or deep sedation is required or used, or if the patient exhibits oxygen dependence, the anesthesiologist and surgeon should consider a sealed gas delivery device (e.g., cuffed tracheal tube or laryngeal mask).
- If moderate or deep sedation is not required, and the patient does not exhibit oxygen dependence, an open gas delivery device (e.g., facemask or nasal cannula) may be considered. Before activating an ignition source around the face, head, or neck, the surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated. The anesthesiologist should (1) stop the delivery of supplemental oxygen or reduce the delivered oxygen concentration to the minimum required to avoid hypoxia, and (2) wait a few minutes after reducing the oxidizer-enriched atmosphere before approving the activation of the ignition source.

V. Management of OR Fires

Management of OR fires includes (1) recognizing the early signs of fire, (2) halting the procedure, (3) making appropriate attempts to extinguish the fire, (4) following an evacuation protocol when medically appropriate, and (5) delivering postfire care to the patient.

Case reports indicate that early signs of a fire may include a flame or flash, unusual sounds, odors, smoke, or heat.\textsuperscript{22–24,41,42,46,53,62,73,92} [Category B3 evidence.] One case report indicates that removing the tracheal tube and stopping the flow of oxygen can minimize patient injury.\textsuperscript{53} [Category B3 evidence.] One case report demonstrated that pouring saline into the patient’s tracheal tube was effective in extinguishing the fire.\textsuperscript{93} [Category B3 evidence.] One case report indicated that fire extinguishers were available but not used by the OR staff on the patient.\textsuperscript{7}

When early warning signs of a fire are noted, the consultants and ASA members strongly agree that there should be an immediate halt to the procedure. When a fire is definitely present, the consultants and ASA members agree that the delivery of all airway gases should stop, and they both agree that saline should be poured into the patient’s airway to extinguish any residual embers and cool the tissues.

For a fire in the airway or breathing circuit, the consultants and ASA members strongly agree that, as quickly as possible, the tracheal tube should be removed and all flammable and burning materials should be removed from the airway. The consultants strongly agree and ASA members agree that the delivery of all airway gases should stop, and they both agree that saline should be poured into the patient’s airway to extinguish any residual embers and cool the tissues.

For a fire elsewhere on or in the patient, the consultants agree and ASA members are equivocal regarding whether the delivery of all airway gases should stop. They both strongly agree that all burning and flammable materials (including all drapes) should be removed from the patient, and that all burning materials in, on, or
around the patient should be extinguished (e.g., with saline, water, or a fire extinguisher).

Seventy-one percent of the consultants and 77% of the ASA members indicated that the preferred means for safely responding to an OR fire is for each team member to immediately perform a fire management task in a predetermined sequence. Twenty-nine percent of the consultants and 23% of the ASA members indicated that the preferred means of safely responding to an OR fire is for each team member to immediately perform a preassigned task, without waiting for others to act. The Task Force believes that a predetermined sequence of tasks can be attempted when a fire occurs, but that team members should not wait for each other if there are impediments to following the predetermined sequence of tasks in a rapid manner. The Task Force agrees that a team member who has completed a preassigned task may assist another team member whose task is not yet complete.

If the first attempt to extinguish the fire in, on, or around the patient is not successful, the consultants and ASA members both agree that a CO₂ fire extinguisher should be used. If fire persists after use of a CO₂ fire extinguisher, consultants and ASA members both strongly agree that the fire alarm should be activated and the patient should be evacuated, if feasible. The consultants and ASA members both agree that the door to the room should be closed and not reopened. The consultants strongly agree and the ASA members agree that the medical gas supply to the room should be turned off after evacuation.

The consultants and ASA members strongly agree that after a fire has been extinguished, the patient’s status should be assessed and a plan should be devised for ongoing care of the patient. When an airway or breathing circuit fire has been extinguished, consultants and ASA members both agree that ventilation should be re-established, avoiding supplemental oxygen and nitrous oxide, if possible. Both the consultants and ASA members strongly agree that the tracheal tube should be examined to assess whether fragments have been left behind in the airway. The consultants strongly agree and the ASA members agree that rigid bronchoscopy should be considered to assess thermal injury, look for tracheal tube fragments, and aid in the removal of residual materials. If the fire did not involve the airway and the patient was not intubated before the fire, the consultants and ASA members both strongly agree that the patient should be assessed for injury related to smoke inhalation.

Advisory Statements. When an early warning sign is noted, halt the procedure and call for an evaluation of fire. Early signs of a fire may include unusual sounds (e.g., a “pop,” “snap,” or “foomp”), unusual odors, unexpected smoke, unexpected heat, unexpected movement of drapes, discoloration of drapes or breathing circuit, unexpected patient movement or complaint, and unexpected flash or flame.

When a fire is definitely present, immediately announce the fire, halt the procedure, and initiate fire management tasks.

Team members should perform their preassigned fire management tasks as quickly as possible. Before the procedure, the team may identify a predetermined order for performing the tasks. If a team member cannot rapidly perform his or her task in the predetermined order, other team members should perform their tasks without waiting. When a team member has completed a preassigned task, he or she should help other members perform tasks that are not yet complete.

The following lists are shown in an order that the team may wish to consider in its discussion of a predetermined sequence.

For a fire in the airway or breathing circuit, as fast as possible:

- Remove the tracheal tube.
- Stop the flow of all airway gases.
- Remove all flammable and burning materials from the airway.
- Pour saline or water into the patient’s airway.

For a fire elsewhere on or in the patient, as fast as possible:

- Stop the flow of all airway gases.
- Remove all drapes, flammable, and burning materials from the patient.
- Extinguish all burning materials in, on and around the patient (e.g., with saline, water, or smothering).

If the airway or breathing circuit fire is extinguished:

- Reestablish ventilation by mask, avoiding supplemental oxygen and nitrous oxide, if possible.
- Extinguish and examine the tracheal tube to assess whether fragments were left in the airway. Consider bronchoscopy (preferably rigid) to look for tracheal tube fragments, assess injury, and remove residual debris.
- Assess the patient’s status and devise a plan for ongoing care.

If the fire elsewhere on or in the patient is extinguished:

* Some experts and educators recommend an initial step that involves two simultaneous actions: removal of the tracheal tube and stopping the flow of medical gases (e.g., by disconnecting the breathing circuit at the Y-piece or the inspiratory gas limb). The intent is to prevent a "blowtorch" effect caused by continued gas flow through a burning tracheal tube. This "blowtorch" effect can spread fire to other locations on or near the patient, and may cause additional burns on the patient or other members of the OR team. The Task Force has carefully considered this concern and agrees that these simultaneous actions represent an ideal response. However, the Task Force is concerned that, in actual practice, the simultaneous actions may be difficult to accomplish or may result in delay when one team member waits for another. Therefore, the Task Force recommends that the actions take place as fast as possible.

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• Assess the patient’s status and devise a plan for ongoing care of the patient.
• Assess for smoke inhalation injury if the patient was not intubated.

If the fire is not extinguished after the first attempt (e.g., after performing the preassigned tasks):
• Use a CO₂ fire extinguisher, on, or around the patient.
• If the fire persists after use of the CO₂ fire extinguisher:
  • Activate the fire alarm.
  • Evacuate the patient if feasible, following institutional protocols.
  • Close the door to the room to contain the fire, and do not reopen it or attempt to reenter the room.
  • Turn off the medical gas supply to the room.

Follow local regulatory reporting requirements (e.g., report fires to your local fire department and state department of health). Treat every fire as an adverse event, following your institutional protocol.

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Appendix 1: Primary Findings of the Advisory Task Force

I. Education

- All anesthesiologists should have fire safety education, specifically for OR fires, with an emphasis on the risk created by an oxidizer-enriched atmosphere.

II. OR Fire Drills

- Anesthesiologists should periodically participate in OR fire drills, with the entire OR team. This formal rehearsal should take place during dedicated educational time, not during patient care.

III. Preparation

- For every case, the anesthesiologist should participate with the entire OR team (e.g., during the surgical pause) in assessing and determining whether a high-risk situation exists.

- If a high-risk situation exists, all team members—including the anesthesiologist—should take a joint and active role in agreeing on how a fire will be prevented and managed.

- Each team member should be assigned a specific fire management task to perform in the event of a fire (e.g., removing the tracheal tube, turning off the airway gases).

- Each team member should understand that his or her preassigned task should be performed immediately if a fire occurs, without waiting for another team member to take action.

- When a team member has completed a preassigned task, he or she should help other team members perform tasks that are not yet complete.

- In every OR and procedure area where a fire triad can exist (i.e., an oxidizer-enriched atmosphere, an ignition source, and fuel), an easily visible protocol for the prevention and management of fires should be displayed.

- Equipment for managing a fire should be readily available in every procedural location where a fire triad may exist.

IV. Prevention

- The anesthesiologist should collaborate with all members of the procedure team throughout the procedure to minimize the presence of an oxidizer-enriched atmosphere in proximity to an ignition source.

- For all procedures:
  - Surgical drapes should be configured to minimize the accumulation of oxidizers (oxygen and nitrous oxide) under the drapes and from flowing into the surgical site.
  - Flammable skin prepping solutions should be dry before draping.
  - Gauze and sponges should be moistened before use in proximity to an ignition source.

- For high-risk procedures:
  - The anesthesiologist should notify the surgeon whenever there is a potential for an ignition source to be in proximity to an oxidizer-enriched atmosphere or when there is an increase in oxidizer concentration at the surgical site.
  - Any reduction in supplied oxygen to the patient should be assessed by monitoring (1) pulse oximetry and, if feasible, (2) inspired, exhaled, and/or delivered oxygen concentration.

- For laser procedures:
  - A laser-resistant tracheal tube should be used.
  - The laser-resistant tracheal tube used should be chosen to be resistant to the laser used for the procedure (e.g., CO₂, Nd:YAG, Ar, Er:YAG, KTP).
  - The tracheal cuff of the laser tube should be filled with saline and colored with an indicator dye such as methylene blue.
  - Before activating a laser:
    - The surgeon should give the anesthesiologist adequate notice that the laser is about to be activated.
    - The anesthesiologist should:
      - Reduce the delivered oxygen concentration to the minimum required to avoid hypoxia.
      - Stop the use of nitrous oxide.
      - Wait a few minutes after reducing the oxidizer-enriched atmosphere before approving activation of the laser.

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- The surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated.
- The anesthesiologist should:
  - Reduce the delivered oxygen concentration to the minimum required to avoid hypoxia.
  - Stop the use of nitrous oxide.
  - Wait a few minutes after reducing the oxidizer-enriched atmosphere before approving the ignition of the ignition source.
- In some cases (e.g., surgery in the oropharynx), scavenging with suction may be used to reduce oxidizer enrichment in the operative field.
- For cases involving moderate or deep sedation, an ignition source, and surgery around the face, head, or neck:
  - The anesthesiologist and surgeon should develop a plan that accounts for the level of sedation and the patient’s need for supplemental oxygen.
  - If moderate or deep sedation is required or used, or if the patient exhibits oxygen dependence, the anesthesiologist and surgeon should consider a sealed gas delivery device (e.g., cuffed tracheal tube or laryngeal mask).
  - If moderate or deep sedation is not required, and the patient does not exhibit oxygen dependence, an open gas delivery device (e.g., facemask or nasal cannula) may be considered.
- Before activating an ignition source around the face, head, or neck:
  - The surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated.
  - The anesthesiologist should:
    - Stop the delivery of supplemental oxygen or reduce the delivered oxygen concentration to the minimum required to avoid hypoxia.
    - Wait a few minutes after reducing the oxidizer-enriched atmosphere before approving the activation of the ignition source.

V. Management of OR Fires

- When an early warning sign is noted, halt the procedure and call for an evaluation of fire.
- When a fire is definitely present, immediately announce the fire, halt the procedure, and initiate fire management tasks.
- Team members should perform their preassigned fire management tasks as quickly as possible.
  - Before the procedure, the team may identify a predetermined order for performing the tasks.
  - If a team member cannot rapidly perform his or her task in the predetermined order, other team members should perform their tasks without waiting.
  - When a team member has completed a preassigned task, he or she should help other members perform tasks that are not yet complete.
- For a fire in the airway or breathing circuit, as fast as possible:
  - Remove the tracheal tube.
  - Stop the flow of all airway gases.
  - Remove all flammable and burning materials from the airway.
  - Pour saline or water into the patient’s airway.
- For a fire elsewhere on or in the patient, as fast as possible:
  - Stop the flow of all airway gases.
  - Remove all drapes, flammable, and burning materials from the patient.
  - Extinguish all burning materials in, on, and around the patient (e.g., with saline, water, or smothering).
- If the airway or breathing circuit fire is extinguished:
  - Reestablish ventilation by mask, avoiding supplemental oxygen and nitrous oxide, if possible.
  - Extinguish and examine the tracheal tube to assess whether fragments were left in the airway.
  - Consider bronchoscopy (preferably rigid) to look for tracheal tube fragments, assess injury, and remove residual debris.
  - Assess the patient’s status and devise a plan for ongoing care.
- If the fire elsewhere on or in the patient is extinguished:
  - Assess the patient’s status and devise a plan for ongoing care of the patient.
  - Assess for smoke inhalation injury if the patient was not intubated.
- If the fire is not extinguished after the first attempt (e.g., after performing the preassigned tasks):
  - Use a CO₂ fire extinguisher in, on, or around the patient.
  - If the fire persists after use of the CO₂ fire extinguisher:
    - Activate the fire alarm.
    - Evacuate the patient if feasible, following institutional protocols.
    - Close the door to the room to contain the fire and do not reopen it or attempt to reenter the room.
    - Turn off the medical gas supply to the room.
- Follow local regulatory reporting requirements (e.g., report fires to your local fire department and state department of health).
- Treat every fire as an adverse event, following your institutional protocol.

Appendix 2: Methods and Analyses

A. State of the Literature
For this Advisory, a literature review was used in combination with opinions obtained from experts and other sources (e.g., professional society members, open forums, Web-based postings) to provide guidance to practitioners regarding OR fire prevention and management. Both the literature review and opinion data were based on evidence linkages, or statements regarding potential relationships between fire prevention and management interventions and OR fire outcomes.**

The evidence linkage interventions are listed below.

I. Education
1. Fire safety education, with an emphasis on an oxidizer-enriched atmosphere

II. OR Fire Drills
2. Periodic participation in OR fire drills

III. Preparation
3. Display of an easily visible protocol for the prevention and management of fires
4. Preoperative determination of a high-risk situation
5. OR team discussion of OR fire strategy

IV. Prevention
6. Surgical drape configuration to minimize the accumulation of oxidizers
7. Drying of flammable skin prepping solutions
8. Moistening of sponges and gauze when used in proximity to an ignition source
9. Reducing the concentration of supplied oxygen for high-risk procedures
10. Avoidance of nitrous oxide for high-risk procedures

** Unless otherwise specified, outcomes for the listed interventions refer to the occurrence of fire or adverse sequelae.

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11. Cuffed versus uncuffed tracheal tubes for cases in or around the airway.
12. Insufflating with medical air during cases in or around the airway.
13. Scavenging with suction during cases in or around the airway.
15. Filling the tracheal cuff of the laser tube with saline colored with an indicator dye.

V. Management

16. Early signs of a fire include a flame or flash, unusual sounds, odors, smoke, or heat (observational).
17. Removing the tracheal tube and stopping the flow of oxygen to minimize patient injury after an airway or breathing circuit fire.
18. Pouring saline into the patient’s tracheal tube to extinguish an airway fire.

For the literature review, potentially relevant studies were identified via electronic and manual searches of the literature. The literature search covered a 56-yr period from 1952 through 2007. More than 400 citations were initially identified, yielding a total of 340 articles that addressed topics related to the evidence linkages and met our criteria for inclusion. After review of the articles, 240 studies did not provide direct evidence and were subsequently eliminated. A total of 100 articles contained direct linkage-related evidence.†† No evidence linkage contained enough studies with well-defined experimental designs and statistical information to conduct a quantitative analysis (i.e., meta-analysis).

Interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a κ statistic for two-rater agreement pairs were as follows:

†† A complete list of references used to develop this Advisory is available on the ANESTHESIOLOGY Web site, www.anesthesiology.org, or by writing to the American Society of Anesthesiologists.

B. Consensus-based Evidence

Consensus was obtained from multiple sources, including (1) survey opinion from consultants who were selected based on their knowledge or expertise in OR fire prevention and management, (2) survey opinions solicited from active members of the ASA, (3) testimony from attendees of a publicly held open forum at a national anesthesia meeting, (4) Internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 52% (n = 38 of 73) for the consultants, and 64 surveys were received from active ASA members. Results of the surveys are reported in tables 2 and 3 and in the text of the Advisory.

The consultants were asked to indicate which, if any, of the evidence linkages would change their clinical practices if the Advisory was instituted. The rate of return was 18% (n = 13 of 73). The percent of responding consultants expecting a change in their practice associated with each linkage topic was as follows: (1) education, 77%; (2) OR fire drills, 69%; (3) team discussion of fire strategy, 69%; (4) minimizing or avoiding an oxidizer-enriched atmosphere near the surgical site, 38%; (5) managing ignition sources, 38%; (6) managing fuels, 31%; (7) identification of a high-risk procedure, 31%; and (9) OR fire management, 77%. Eighty-five percent of the respondents indicated that the Advisory would have no effect on the amount of time spent on a typical case, and 15% indicated that there would be an increase of 1–5 min in the amount of time spent on a typical case with the implementation of this Advisory.
Table 2. Consultant Survey Responses

<table>
<thead>
<tr>
<th>Item</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
<tbody>
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<td><strong>Education</strong></td>
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<tr>
<td>1a. Every anesthesiologist should have knowledge of institutional</td>
<td>38</td>
<td>92.1*</td>
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<tr>
<td>1b. Every anesthesiologist should participate in OR fire safety</td>
<td>38</td>
<td>81.6*</td>
<td>15.8</td>
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<td>0.0</td>
<td>0.0</td>
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<tr>
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<td>emphasize the risk of an oxidizer-enriched atmosphere</td>
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<tr>
<td>2a. All anesthesiologists should periodically participate in OR fire</td>
<td>38</td>
<td>60.5*</td>
<td>31.6</td>
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<td>drills with the entire OR team</td>
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<tr>
<td>2b. Participation in an OR fire drill should take place during</td>
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<td>50.0*</td>
<td>34.2</td>
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<td>10.5</td>
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<td>dedicated educational time, not during patient care</td>
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<td><strong>Preparation</strong></td>
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<td>3. Anesthesiologists should participate with the entire OR team in</td>
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<td>29.0</td>
<td>2.6</td>
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<tr>
<td>assessing the risk of an OR fire for each case, and determining</td>
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<td>whether a high-risk situation exists</td>
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<td>4. All team members should agree on how an OR fire will be</td>
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<td>29.0</td>
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<td>prevented and managed for each particular procedure</td>
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<td>5. Hospitals and procedure units should post a protocol for the</td>
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<td>procedure is performed</td>
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<td>6. Flammable skin prepping solutions should be dry before draping</td>
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<td>7. Surgical drapes should be configured to prevent oxygen from</td>
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<td>accumulating under the drapes or from flowing into the surgical site</td>
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<td>8. Sponges should be moistened, particularly when used in or</td>
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<td>near the airway</td>
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<td><strong>Prevention for high-risk† procedures</strong></td>
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<td>9. Anesthesiologists should collaborate with the procedure team for</td>
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<td>the purpose of preventing and managing a fire</td>
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<td>10. The surgeon should be notified of an increase in or the</td>
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<td>presence of an oxidizer-enriched atmosphere in which an ignition</td>
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<td>source will be used</td>
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<td>11a. Oxygen levels should be kept as low as clinically feasible while</td>
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<td>12. The use of nitrous oxide should be avoided in settings that are</td>
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<td>52.6*</td>
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<td>13. Oxygen or nitrous oxide buildup may be minimized by either</td>
<td>38</td>
<td>50.0*</td>
<td>36.8</td>
<td>10.5</td>
<td>2.6</td>
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<td>insufflating with room air or scavenging the operating field with</td>
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<td>suction</td>
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<td><strong>Prevention during cases in or around the airway</strong></td>
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<td>14. Cuffed tracheal tubes should be used instead of uncuffed tracheal</td>
<td>38</td>
<td>39.5</td>
<td>31.6*</td>
<td>23.7</td>
<td>5.2</td>
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<td>15. The oropharynx should be scavenged with suction during oral</td>
<td>38</td>
<td>42.1</td>
<td>23.7*</td>
<td>28.9</td>
<td>5.3</td>
<td>0.0</td>
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<td>16. The sufficient amount of time needed to reduce oxygen or nitrous</td>
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<td>oxide concentrations to a safe level before using an ignition</td>
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<td>source in the airway: Mean = 1.76 min,</td>
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<td>Range = 0.25–5 min</td>
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<td>17. The sufficient amount of time needed to reduce oxygen or nitrous</td>
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<td>oxide concentrations to a safe level before using an ignition</td>
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<tr>
<td>source for patients wearing a facemask or nasal cannula: Mean =</td>
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<tr>
<td>18. Laser-resistant tracheal tubes appropriate to the procedure and</td>
<td>38</td>
<td>68.4*</td>
<td>29.0</td>
<td>2.6</td>
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<td>0.0</td>
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<td>laser should be used</td>
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<tr>
<td>19a. Tracheal tube cuffs should be filled with saline rather than</td>
<td>38</td>
<td>71.1*</td>
<td>26.3</td>
<td>2.6</td>
<td>0.0</td>
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<td>air, when feasible</td>
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(continued)
### Table 2. Continued

<table>
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<tr>
<th></th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
<tbody>
<tr>
<td>19b. Saline in tracheal tube cuffs should be tinted with methylene blue to act as a marker for cuff puncture by a laser</td>
<td>38</td>
<td>50.0*</td>
<td>39.5</td>
<td>10.5</td>
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</tr>
</tbody>
</table>

**Management of OR fires**

20. When early warning signs of a fire are noted, the procedure should be halted immediately  
21. When a fire is definitely present, the fire should be immediately announced and the procedure should halt  
22. For a fire in the airway or breathing circuit:
   a. The tracheal tube should be removed as quickly as possible  
   b. All flammable and burning materials should be removed from the airway as quickly as possible  
   c. The delivery of all airway gases should stop  
   d. Saline should be poured into the patient’s airway to extinguish any residual embers and cool the tissues  
   
23. For a fire elsewhere on or in the patient:
   a. The delivery of all airway gases should stop  
   b. All burning and flammable materials (including all drapes) should be removed from the patient  
   c. All burning materials in, on and around the patient should be extinguished (e.g., with saline, water, or a fire extinguisher)  

24. The preferred means of safely responding to an OR fire is:
   a. For each team member to immediately respond without waiting for others to act  
   b. To immediately initiate a predetermined sequence of responses  

25. If the first attempt to extinguish the fire is not successful, a CO₂ fire extinguisher should be used  
26. If the fire persists after use of a CO₂ fire extinguisher:
   a. The fire alarm should be activated  
   b. The patient should be evacuated, if feasible  
   c. The door to the room should be closed and not reopened  
   d. The medical gas supply to the room should be turned off  

27. After a fire has been extinguished, the patient’s status should be assessed and a plan devised for ongoing care of the patient

28. When the airway or breathing circuit fire has been extinguished:
   a. Ventilation should be reestablished, avoiding supplemental oxygen and nitrous oxide, if possible  
   b. The tracheal tube should be examined to assess whether fragments may be left behind in the airway  
   c. Rigid bronchoscopy should be considered to assess thermal injury and look for tracheal tube fragments and other residual materials  

29. If the fire did not involve the airway and the patient was not intubated before the fire, the patient should be assessed for injury related to smoke inhalation

* Median response falls within this designated response category.  † A high-risk procedure is defined as one in which an ignition source may be in proximity to an oxidizer-enriched atmosphere.  ‡ n is the number of consultants who responded to each item. All other numbers in the table represent the percentage of consultants who selected the designated response category.

CO₂ = carbon dioxide; FIO₂ = fraction of inspired oxygen; OR = operating room.
Table 3. ASA Member Survey Responses

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Education</strong></td>
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</tr>
<tr>
<td>1a. Every anesthesiologist should have knowledge of institutional fire safety protocols for the OR</td>
<td>142</td>
<td>74.6*</td>
<td>24.7</td>
<td>0.7</td>
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<tr>
<td>1b. Every anesthesiologist should participate in OR fire safety education</td>
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<td>55.6*</td>
<td>38.7</td>
<td>5.6</td>
<td>0.0</td>
</tr>
<tr>
<td>1c. OR fire safety education for the anesthesiologist should emphasize the risk of an oxidizer-enriched atmosphere</td>
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<td>73.9*</td>
<td>22.5</td>
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<td><strong>OR fire drills</strong></td>
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<tr>
<td>2a. All anesthesiologists should periodically participate in OR fire drills with the entire OR team</td>
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<td>42.3</td>
<td>40.1*</td>
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<tr>
<td>2b. Participation in an OR fire drill should take place during dedicated educational time, not during patient care</td>
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<td>54.9*</td>
<td>31.0</td>
<td>10.6</td>
<td>2.1</td>
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<td><strong>Preparation</strong></td>
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</tr>
<tr>
<td>3. Anesthesiologists should participate with the entire OR team in assessing the risk of an OR fire for each case, and determining whether a high-risk situation exists</td>
<td>142</td>
<td>38.7</td>
<td>45.8*</td>
<td>8.5</td>
<td>3.5</td>
</tr>
<tr>
<td>4. All team members should agree on how an OR fire will be prevented and managed for each particular procedure</td>
<td>142</td>
<td>39.4</td>
<td>38.0*</td>
<td>13.4</td>
<td>7.8</td>
</tr>
<tr>
<td>5. Hospitals and procedure units should post a protocol for the prevention and management of fires in each location where a procedure is performed</td>
<td>142</td>
<td>51.4*</td>
<td>36.6</td>
<td>8.5</td>
<td>2.8</td>
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<tr>
<td><strong>Prevention for all procedures</strong></td>
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<tr>
<td>6. Flammable skin prepping solutions should be dry before draping</td>
<td>142</td>
<td>68.3*</td>
<td>21.8</td>
<td>9.2</td>
<td>0.7</td>
</tr>
<tr>
<td>7. Surgical drapes should be configured to prevent oxygen from accumulating under the drapes or from flowing into the surgical site</td>
<td>142</td>
<td>64.8*</td>
<td>28.2</td>
<td>6.3</td>
<td>0.7</td>
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<tr>
<td>8. Sponges should be moistened, particularly when used in or near the airway</td>
<td>142</td>
<td>63.4*</td>
<td>30.3</td>
<td>5.6</td>
<td>0.7</td>
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<tr>
<td><strong>Prevention for high-risk† procedures</strong></td>
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<td>9. Anesthesiologists should collaborate with the procedure team for the purpose of preventing and managing a fire</td>
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<td>67.6*</td>
<td>31.0</td>
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<tr>
<td>10. The surgeon should be notified of an increase in or the presence of an oxidizer-enriched atmosphere in which an ignition source will be used</td>
<td>142</td>
<td>66.2*</td>
<td>29.6</td>
<td>3.5</td>
<td>0.7</td>
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<td>11a. Oxygen levels should be kept as low as clinically feasible while the ignition source is in proximity to the oxygen-enriched atmosphere</td>
<td>142</td>
<td>70.4*</td>
<td>26.1</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>11b. The reduction of Fio₂ should be guided by monitoring patient oxygenation</td>
<td>142</td>
<td>71.8*</td>
<td>24.7</td>
<td>2.8</td>
<td>0.7</td>
</tr>
<tr>
<td>12. The use of nitrous oxide should be avoided in settings that are considered high risk for OR fire</td>
<td>142</td>
<td>50.0*</td>
<td>36.6</td>
<td>9.2</td>
<td>3.5</td>
</tr>
<tr>
<td>13. Oxygen or nitrous oxide buildup may be minimized by either insufflating with room air or scavenging the operating field with suction</td>
<td>142</td>
<td>32.4</td>
<td>43.0*</td>
<td>21.8</td>
<td>2.8</td>
</tr>
<tr>
<td><strong>Prevention during cases in or around the airway</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Cuffed tracheal tubes should be used instead of uncuffed tracheal tubes</td>
<td>142</td>
<td>35.9</td>
<td>43.0*</td>
<td>16.2</td>
<td>4.9</td>
</tr>
<tr>
<td>15. The oropharynx should be scavenged with suction during oral procedures</td>
<td>142</td>
<td>22.5</td>
<td>27.5*</td>
<td>44.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Mean = 3.3 min, Range = 0.0°–10 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. The sufficient amount of time needed to reduce oxygen or nitrous oxide concentrations to a safe level before using an ignition source in the airway:</td>
<td>142</td>
<td>22.5</td>
<td>27.5*</td>
<td>44.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Mean = 2.8 min, Range = 0.0–10 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. The sufficient amount of time needed to reduce oxygen or nitrous oxide concentrations to a safe level before using an ignition source for patients wearing a facemask or nasal cannula:</td>
<td>142</td>
<td>22.5</td>
<td>27.5*</td>
<td>44.4</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>Prevention during laser surgery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Laser-resistant tracheal tubes appropriate to the procedure and laser should be used</td>
<td>142</td>
<td>61.3*</td>
<td>35.9</td>
<td>2.8</td>
<td>0.0</td>
</tr>
<tr>
<td>19a. Tracheal tube cuffs should be filled with saline rather than air, when feasible</td>
<td>142</td>
<td>61.3*</td>
<td>33.1</td>
<td>4.9</td>
<td>0.7</td>
</tr>
</tbody>
</table>

(continued)
**Table 3. Continued**

<table>
<thead>
<tr>
<th>19b. Saline in tracheal tube cuffs should be tinted with methylene blue to act as a marker for cuff puncture by a laser</th>
<th>n†</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>142</td>
<td>44.4</td>
<td>37.3*</td>
<td>14.1</td>
<td>3.5</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Management of OR fires**

20. When early warning signs of a fire are noted, the procedure should be halted immediately

21. When a fire is definitely present, the fire should be immediately announced and the procedure should halt

22. For a fire in the *airway or breathing circuit*:
   a. The tracheal tube should be removed as quickly as possible
   b. All flammable and burning materials should be removed from the airway as quickly as possible
   c. The delivery of all airway gases should stop
   d. Saline should be poured into the patient’s airway to extinguish any residual embers and cool the tissues

23. For a fire *elsewhere on or in the patient*:
   a. The delivery of all airway gases should stop
   b. All burning and flammable materials (including all drapes) should be removed from the patient
   c. All burning materials in, on and around the patient should be extinguished (e.g., with saline, water, or a fire extinguisher)

24. The preferred means of safely responding to an OR fire is:
   a. For each team member to immediately respond without waiting for others to act
   b. To immediately initiate a predetermined sequence of responses

25. If the first attempt to extinguish the fire is not successful, a CO₂ fire extinguisher should be used

26. If the fire persists after use of a CO₂ fire extinguisher:
   a. The fire alarm should be activated
   b. The patient should be evacuated, if feasible
   c. The door to the room should be closed and not reopened
   d. The medical gas supply to the room should be turned off

27. After a fire has been extinguished, the patient’s status should be assessed and a plan devised for ongoing care of the patient

28. When the *airway or breathing circuit fire* has been extinguished:
   a. Ventilation should be reestablished, avoiding supplemental oxygen and nitrous oxide, if possible
   b. The tracheal tube should be examined to assess whether fragments may be left behind in the airway
   c. Rigid bronchoscopy should be considered to assess thermal injury and look for tracheal tube fragments and other residual materials

29. If the fire did not involve the airway and the patient was not intubated before the fire, the patient should be assessed for injury related to smoke inhalation

* Median response falls within this designated response category. † A high-risk procedure is defined as one in which an ignition source may be in proximity to an oxidizer-enriched atmosphere. ‡ n is the number of ASA members who responded to each item. All other numbers in the table represent the percentage of ASA members who selected the designated response category.

CO₂ = carbon dioxide; FIO₂ = fraction of inspired oxygen; OR = operating room.
Multiple hormones and transmitter systems contribute to glucose homeostasis and the control of metabolism. Recently, the gastrointestinal peptide hormones glucagon-like peptide 1 and amylin have been shown to significantly contribute to this complex physiology. These advances provide the foundation for new treatments for diabetes mellitus. Therapies based on glucagon-like peptide 1 and amylin have now been introduced into clinical practice. Rimonabant, the selective endocannabinoid receptor antagonist, had been used in European countries for the treatment of obesity; it has recently been withdrawn for this indication. This drug exhibited therapeutic benefits for metabolic variables and for type 2 diabetes mellitus. Anesthesia providers caring for patients with diabetes mellitus will need to understand the implications of these new therapies in perioperative settings, particularly with respect to side effects and interactions.

Diabetes mellitus (DM) is a condition with an absolute (Type 1) or relative (Type 2) deficiency of insulin. Significant end-organ consequences of both types of diabetes include renal, neurological, cardiovascular, and peripheral vascular pathology that may have an impact on the perioperative course. Multiple hormones and neural systems control glucose homeostasis. The principle regulator of plasma glucose levels is insulin, a polypeptide secreted by pancreatic \( \beta \) cells. The plasma glucose decreasing action of insulin has long been recognized and its effect is counter-regulated by epinephrine, growth hormone, cortisol and glucagon, a polypeptide secreted by pancreatic \( \alpha \) cells. Conventional therapies for DM have recently been reviewed.\(^1\)\-\(^4\) Table 1 presents a summary of the major classes of medications used in the treatment of DM.

Contemporary studies revealed that two new families of gastrointestinal (GI) hormones, represented by the incretins and amylin, have significant effects on glucose homeostasis. In addition, antagonists of the endocannabinoid system acting at the CB1 receptor, represented by rimonabant, were found to exert multiple effects on food intake and metabolic variables, including glucose homeostasis. These advances provide new opportunities for therapeutic approaches to patients with DM. Anesthesia providers will increasingly encounter patients treated with novel drugs based on the enhanced understanding of glucose homeostasis and the physiological control of metabolism. We aim to provide anesthesia clinicians with an introduction to the rapidly evolving pharmacology of medical treatment for DM.

**BIOLOGY OF INCRETINS**

Identification of the members of the incretin family of endogenous gut hormones was based on the observation that the insulin response to oral glucose loads is more vigorous than from IV glucose loads producing the same blood glucose levels. In human studies, when subjects achieve identical plasma glucose increases, oral glucose administration resulted in more insulin secretion than IV glucose administration (Fig. 1).\(^5\)\-\(^9\) This indicated that previously unidentified factors produced by the GI system influence blood glucose levels in combination with the known hormones, insulin and glucagon. The consequence of these gut factors is called the “incretin” effect.

The incretin effect is mediated via GI hormones that stimulate insulin secretion in response to glucose increase from an enteral carbohydrate load. GIP (glucose-dependent insulinotropic polypeptide) and glucagon-like peptide 1 (GLP-1, Fig. 2) are the first two incretin hormones identified. Because much of GIP’s insulinotropic effect is lost in diabetic patients due to resistance to its actions, its potential utility in diabetic therapy is low\(^7\)\(^,\)\(^10\) and therefore will not be discussed further. Unlike GIP, GLP-1’s insulinotropic
action persists in patients with DM.\textsuperscript{10} This makes it a potential target for diabetic therapy. Initial studies identified enteroendocrine L cells located in the distal ileum and large intestine as the source of GLP-1. One study also found enteroendocrine L cells located more proximally in the duodenum and jejunum.\textsuperscript{11} The fasting blood GLP-1 level is approximately 5–10 pmol/L. Within minutes of food intake, the level increases to 15–50 pmol/L.\textsuperscript{11} The rapid increase in blood levels of GLP-1 suggests that the secretion of GLP-1 is not simply due to detection of nutrients by the L cells in the digestive tract; a faster endocrine/neural signaling system must also be involved.\textsuperscript{11}

The peptide hormone GLP-1 reduces appetite, slows gastric emptying, reduces glucagon levels, enhances glucose-stimulated insulin secretion, and increases insulin biosynthesis (Table 1).\textsuperscript{9,11,12} In animal models, GLP-1 has trophic actions to increase the numbers of pancreatic $\beta$ cells.\textsuperscript{13} GLP-1 works through a G protein coupled signal transduction system, and its receptors are found in pancreatic $\beta$ cells, the central nervous system, and the GI tract. Through its receptors on $\beta$ cells, GLP-1 enhances insulin exocytosis, but only in a glucose-dependent manner.\textsuperscript{7} GLP-1 induces gene transcription in pancreatic $\beta$ cells to promote insulin biosynthesis. In vitro studies demonstrate that GLP-1 influences $\beta$ cell survival by promoting

<table>
<thead>
<tr>
<th>Class</th>
<th>Route</th>
<th>Mechanism of action</th>
<th>Side effects</th>
<th>Clinical agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin</td>
<td>SQ, IV</td>
<td>↑ Glucose uptake</td>
<td>Hypoglycemia</td>
<td>Many preparations</td>
</tr>
<tr>
<td>GLP-1</td>
<td>SQ</td>
<td>↑ Glucose secretion (if hyperglycemia)</td>
<td>Nausea</td>
<td>Exenatide</td>
</tr>
<tr>
<td>Amylin</td>
<td>SQ</td>
<td>↑ Postprandial glucagon secretion</td>
<td>Hypoglycemia (with insulin)</td>
<td>Pramlintide</td>
</tr>
<tr>
<td>DPP-IV inhibitor</td>
<td>Oral</td>
<td>↑ Satiety</td>
<td>Infection</td>
<td>Sitagliptin</td>
</tr>
<tr>
<td>Cannabinoid receptor antagonist</td>
<td>Oral</td>
<td>↑ Gastric emptying</td>
<td>↓ Glucose</td>
<td>Rimonabant</td>
</tr>
<tr>
<td>Sulfonylurea</td>
<td>Oral</td>
<td>↑ Insulin secretion via binding to specific receptor on $\beta$ cells</td>
<td>Hypoglycemia, Hypernatremia, Drug-drug interactions</td>
<td>Chlorpropamide, Glimepiride, Glipizide, Glyburide, Tolazamide, Tolbutamide, Repaglinide, Nateglinide</td>
</tr>
<tr>
<td>Meglitinide</td>
<td>Oral</td>
<td>↑ Insulin secretion by binding to ATP dependent $K^+$ channels on $\beta$ cells</td>
<td>Hypoglycemia</td>
<td></td>
</tr>
<tr>
<td>Thiazolidinedione</td>
<td>Oral</td>
<td>Insulin sensitizer by binding to PPAR $\gamma$ receptor</td>
<td>Edema, anemia, obesity, CHF, hepatoxotoxicity</td>
<td>Rosiglitazone, Pioglitazone</td>
</tr>
<tr>
<td>Biguanide</td>
<td>Oral</td>
<td>↓ Hepatic glucose output</td>
<td>Lactic acidosis, Diarrhea</td>
<td>Metformin</td>
</tr>
<tr>
<td>Alpha-glucosidase inhibitor</td>
<td>Oral</td>
<td>↓ Glucose absorption by inhibiting enzyme that metabolizes complex carbohydrates</td>
<td>Malabsorption, Flatulence, Diarrhea</td>
<td>Acarbose, Miglitol</td>
</tr>
</tbody>
</table>

Incretin-mimetics (GLP-1, DPP-IV inhibitors) and insulin sensitizers (thiazolidinediones, biguanides) in single agent therapy do not predispose to hypoglycemia even in the fasting state.

CHF = congestive heart failure; SQ = subcutaneous; DPP-IV = dipeptidyl peptidase IV; GLP-1 = glucagon-like peptide 1.

The Incretin Effect: Beta-Cell Response to Oral vs. IV Glucose

Figure 1. Insulin secretion after IV or oral glucose load. Subjects received oral glucose (50 g glucose/400 mL) or an IV infusion of glucose to produce the same blood glucose levels. As measured by plasma levels of C-peptide (a fragment of the insulin prohormone), oral glucose loading (solid circles) resulted in a greater secretion of insulin compared with IV glucose loading (open circles) designed to achieve identical plasma glucose concentrations. The difference between insulin secretion profiles after oral versus IV loading is defined as the incretin effect. Left, plasma glucose after oral or isoglycemic IV loading of glucose. Right, C-peptide levels in response to oral or IV glucose loading. Modified from Ref 5, with publisher’s permission from the Endocrine Society.
proliferation and resistance to apoptosis. Through its receptors on α cells, GLP-1 inhibits glucagon secretion in a glucose-dependent manner and consequently reduces hepatic glucose production. The counter regulatory release of glucagon in response to hypoglycemia remains active. Through actions on the central nervous system, GLP-1 decreases appetite and food intake with a resulting contribution to weight loss. GLP-1 also slows gastric emptying, thereby blunting the postprandial increase in blood glucose levels.

A feature of the biology of GLP-1 is its rapid degradation by the peptidase dipeptidyl peptidase IV (DPP-IV) (Fig. 2a). DPP-IV cleaves peptides at their amino terminal where the penultimate amino acid residue is proline or alanine. The presence of DPP-IV in the capillary bed of the gut mucosa facilitates rapid inactivation of GLP-1. DPP-IV is a ubiquitous, membrane-spanning, cell surface aminopeptidase. Its extracellular domain can be cleaved and circulate in the plasma, retaining full enzymatic strength. DPP-IV is also found in liver, lung, kidney, the intestinal brush border, lymphocytes and endocrine cells. In addition to GLP-1, DPP-IV has numerous substrates, including vasoactive intestinal polypeptide, gastrin-releasing peptide, neuropeptide Y and growth hormone-releasing hormone. DPP-IV also has a role in the immune system. It is found on lymphocytes as CD26, which has been implicated in cellular uptake of the Human Immunodeficiency Virus. Other biological effects of DPP-IV include actions on T cell activation, chemotaxis and possibly tumor transformation and invasion.

Compared with healthy individuals, patients with DM exhibit a blunted increase in blood GLP-1 levels after food intake. Consequently, experimental treatment for DM has evaluated treatment with the native GLP-1 peptide. However, since DPP-IV rapidly degrades GLP-1, only a constant IV infusion of the peptide is effective in sustaining therapeutic plasma levels. Two pharmacological strategies are now clinically used to counter the effects of the DPP-IV peptidase (Table 2). One strategy uses injection of a GLP-1 analog resistant to DPP-IV. A second pharmacological strategy targeting DPP-IV uses an inhibitor of this peptidase in order to increase levels of endogenous GLP-1.

### Specific Agents

The naturally occurring peptide homolog of GLP-1, exendin-4, resists degradation by DPP-IV. The synthetic form is known as exenatide; its commercial name is Byetta®. Exendin-4/exenatide is originally derived from salivary secretions of the lizard Heloderma suspectum (the Gila monster) and shares roughly 50% of its amino acid sequence with mammalian

![Figure 2. Structure of the peptide glucagon-like peptide 1 (GLP-1) and analogs.](image)

<table>
<thead>
<tr>
<th>Agent</th>
<th>Mechanism of action</th>
<th>Major side effects</th>
<th>Time to onset (h)</th>
<th>Duration of action (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exenatide (Byetta®)</td>
<td>Incretin-mimetic, increases insulin secretion only with hyperglycemia</td>
<td>Risk of hypoglycemia when given with a sulfonylurea; delay in gastric emptying, nausea, anorexia</td>
<td>&lt;0.25</td>
<td>6–12</td>
</tr>
<tr>
<td>Sitagliptin (Januvia®)</td>
<td>Inhibitor of DPP-IV</td>
<td>Upper respiratory infections, headache</td>
<td>Peak at 1–4 h</td>
<td>Half life approximately 12</td>
</tr>
<tr>
<td>Pramlintide (Symlin®)</td>
<td>Amylin analog, suppresses postprandial glucagon secretion</td>
<td>Hypoglycemia when given with insulin, delay in gastric emptying, nausea</td>
<td>&lt;0.25</td>
<td>2–4</td>
</tr>
</tbody>
</table>

DPP-IV = dipeptidyl peptidase IV.
GLP-1. However, a substitution of glycine for alanine in its amino terminal protects exenatide from degradation by DPP-IV (Fig. 2b). Exenatide has a circulating half-life variously reported between 60 and 90 min to 2.5 h, with plasma concentrations lasting 4 to 6 h or more after a single subcutaneous dose. Elimination is primarily through the renal system, although patients with mild to moderate renal impairment do not exhibit significantly altered clearance.

Exenatide is currently approved for the treatment of type 2 DM patients receiving concurrent metformin or sulfonylurea therapy. It has no role in therapy of patients with DM type 1. Exenatide is given as a subcutaneous injection of 5 to 10 μg twice daily. Clinical trials show a significant reduction in hemoglobin A1c levels over 30 wk (absolute reduction of approximately 0.6%–0.9% from baseline hemoglobin A1c of 8.2%–8.7%) and a modest amount of weight loss (2 kg over 30 wk).

The most common adverse events were GI symptoms, including nausea and, rarely, vomiting or diarrhea. Patients receiving both exenatide and a sulfonylurea exhibit an increased risk for mild to moderate hypoglycemic events. However, the risk was not increased in patients receiving concurrent treatment with exenatide and metformin. Approximately, 40% to 50% of patients receiving exenatide develop low titers of a weak affinity antibody. However, the antibody formation has not been associated with decreased effectiveness of exenatide or other adverse reactions.

A long-acting exenatide preparation is currently under development, a polylactide-glycolide microsphere suspension containing 3% exenatide peptide. In diabetic rats, this preparation produced dose-dependent control of serum glucose for up to 28 days after a single injection.

Liraglutide is another GLP-1 analog. With amino acid substitutions at positions 34 and 26, and a covalently linked C16 fatty-acid group, liraglutide forms noncovalent bonds with albumin, which confers resistance to DPP-IV-mediated degradation (Fig. 2c). It is not yet released in the United States for clinical use. Like exenatide, liraglutide is given as a subcutaneous injection. It has a half-life of 10–14 h and consequently can be given as a once-daily injection. Clinical trials with liraglutide demonstrated significant reductions in postprandial glucose levels. Reduced hemoglobin A1c levels (absolute reduction of approximately 0.8% from baseline hemoglobin A1c) suggest improved long-term glucose control. Liraglutide also prevents weight gain or induces modest weight loss. The most common adverse event is nausea, which is generally mild and unclear over time.

Sitagliptin is a DPP-IV inhibitor, now commercially available in the United States. The trade name is Januvia. Other DPP-IV inhibitors, including vildagliptin, are in clinical trials and may soon be approved for routine use. Sitagliptin enhances insulin secretion and decreases glucagon secretion in a glucose-dependent matter. However, unlike exenatide and liraglutide, sitagliptin does not affect gastric emptying. It has a half-life of 12 h and is taken orally as a once or twice daily medication. Clinical trials have shown a significant reduction in hemoglobin A1c levels associated with sitagliptin therapy (absolute reduction of 0.8% from baseline hemoglobin A1c of 5.8%–10.4% over 3 mo). Unlike therapy with exenatide, there was no significant weight change associated with sitagliptin. In early clinical trials, sitagliptin seemed to be well tolerated, without significant GI symptoms or hypoglycemic events. However, given widespread expression of DPP-IV in many cell types, and multiple potential substrates for this peptidase, additional clinical studies are needed to assess the long-term safety of DPP-IV inhibitors.

BIOLOGY OF AMYLIN

Amylin, another GI hormone, has been identified as a potential therapeutic target in DM (Fig. 3a). Pancreatic β cells, the same cells that manufacture and secrete insulin, produce the amylin peptide hormone. Consequently, patients lacking functional pancreatic β cells (individuals with type 1 DM or advanced type 2 DM) are deficient in both insulin and amylin. Similar to GLP-1, food intake stimulates amylin secretion. Its 24-h profile resembles that of insulin, with low fasting blood levels and a robust increase in response to meals. The glucose-decreasing effect of amylin seems...
to be independent of, and additive to, the effects of insulin.28

Like GLP-1, the actions of amylin include suppression of glucagon secretion in a glucose-dependent manner and delayed gastric emptying (Table 1); however, the mechanism(s) of action remain incompletely defined. Amylin is also a satiety agent, with receptors in the area postrema of the hindbrain.28 By suppressing glucagon secretion and delaying gastric emptying, amylin slows the inflow of glucose into the circulation. At the same time, insulin stimulates cellular uptake of glucose to reduce postprandial blood glucose levels. Effort has been made to treat patients with diabetes using the native amylin peptide. However, endogenous amylin aggregates and forms insoluble masses of amyloid. Consequently, synthetic modifications are necessary to produce a soluble amylin analog suitable for clinical use.

**Specific Agent**

Pramlintide is a synthetic amylin analog with proline substitutions at amino acid positions 25, 28, and 29 (Fig. 3b).27 These structural changes improve solubility. Pramlintide is used as an adjunct to insulin for both type 1 and type 2 DM patients. It is given as a subcutaneous injection two or three times daily. Pramlintide has an onset of approximately 20 min and duration of action of about 2 to 4 h. Clinical trials demonstrated significant improvement of postprandial glucose levels and hemoglobin A1c levels (absolute reduction of 0.67% at 13 wk and 0.39% at 52 wk) associated with pramlintide treatment.24 Pramlintide seems to decrease postprandial triglyceride excursions.29 The most common adverse reaction associated with pramlintide therapy is nausea, which improves over the course of treatment. By itself, pramlintide has not been shown to cause an increased risk of hypoglycemia; however, any concurrent insulin dose needs to be adjusted to prevent hypoglycemia.27

**THE ENDOCANNABINOID SYSTEM**

A comprehensive overview of the astonishingly complex endocannabinoid signaling system is beyond the scope of this article. Detailed reviews are available.30 Briefly, the identification of specific binding sites for plant products led to the identification of two G protein-coupled receptors, labeled CB1 and CB2. The CB1 receptor is widespread throughout the brain and peripheral tissues, whereas the CB2 receptor has a more restricted distribution. These receptors seem to use several different signal transduction pathways, depending on how the receptor is activated and the tissue where it is expressed. The diverse distribution of the CB1 receptor, in particular, explains the extensive array of biological activities associated with its activation or blockade which include effects on appetite and ingestive behavior, addictive behaviors, sleep/awake cycles, peripheral energy metabolism, pain and inflammation.

The isolation of specific receptors for exogenous agonists suggested the existence of endogenous ligands for the two cannabinoid receptors. Several candidate ligands have been identified. These include anandamide, derived by enzymatic hydrolysis from the membrane lipid precursor N-arachidonoyl phosphatidylethanolamide, and 2-arachidonoylglycerol derived from diacylglycerol. Of compelling interest for the administration of anesthesia, there is evidence that propofol acts, at least in part, via activation of CB1 receptors.31 This effect may be mediated by the inhibition of anandamide breakdown.32 Schelling et al.33 however, provided evidence that the inhaled general anesthetic sevoflurane has different effects on anandamide levels than does propofol, suggesting agent-specific interactions with the endocannabinoid system.

**Specific Drug**

Rimonabrant was available until recently in many countries (trade name: Acomplia), primarily as a treatment for obesity, with an added benefit of improving glucose homeostasis beyond what might be expected from weight loss alone.34,35 Clinical trials with rimonabant (such as the Rimonabant in Obesity trial) demonstrated sustained weight loss and a reduction in waist circumference. In addition, metabolic profiles improved for triglyceride levels, lipoprotein cholesterol levels, and insulin resistance. Consequently, considerable interest developed in this drug for the management of metabolic syndrome.34,36 This drug has multiple pharmacologic effects37 and a long terminal elimination half-life in animals (approximately 7 h). A prominent finding is that treatment with rimonabant is associated with neuropsychiatric side effects.38 Out of concern for an enhanced risk of depression and suicide,39 rimonabant was not approved in the United States40 and it has recently been withdrawn in Europe for the original indication of obesity.

**ANESTHETIC CONSIDERATIONS**

A literature search via the National Library of Medicine tool PubMed does not produce published examples of adverse effects, drug-drug interactions or clinical conundrums attributable to exenatide, pramlintide, a DPP IV inhibitor, or rimonabant in patients undergoing anesthesia or surgery. These drugs have only recently appeared in clinical practice, and only a subset of all treated patients may have required an anesthetic since the drugs were approved and released. Consequently, the number of clinical situations in which a potential adverse effect emerges may be too few for the manifestation of an uncommon reaction. Alternatively, adverse effects may have occurred, but went undetected in complex clinical scenarios in which patients suffering from multiple co-morbid conditions received several medications concurrently.
Moreover, untoward effects in anesthetized or surgical patients attributable to one of these newly released drugs simply may not have been reported. As clinical experience with these new drugs increases, it is possible that recognizable patterns will develop. Therefore, at this time it is only possible to suggest potential anesthesia concerns based on the known physiology and pharmacology of the novel therapies.

Nausea is the most common adverse reaction associated with medications active along the incretin and amylin pathways. Clinical trials have shown nausea occurring in as many as 57% of patients treated with exenatide. The incidence of vomiting is less frequent. However, vomiting still occurs in approximately 17% of the patients receiving exenatide. Nausea is generally mild to moderate, and most prevalent in the first 8 wk of treatment. The frequency and intensity of nausea generally declines thereafter. The risk of nausea is dose-dependent and can be decreased by gradual dose titration. However, adverse GI effects associated with exenatide are still the most common causes for patients to withdraw from clinical trials.

Clinical studies with DPP-IV inhibitors, such as sitagliptin, have reported no increased GI adverse reactions. They are overall well tolerated with low absolute rates of adverse effects. This lack of GI adverse reactions may be secondary to the fact that DPP-IV inhibitors only moderately increase the levels of endogenous incretin hormones. In contrast, administration of incretin analogs, such as exenatide, increases incretin hormone activity to a much greater extent. Similar reasoning explains the finding that, while incretin analogs cause significant weight loss in patients, DPP-IV inhibitors usually do not produce significant weight changes.

Nausea is the most common adverse effect of pramlintide, the amylin analog. Nausea occurs more frequently in the type 1 DM patient than in the type 2 DM patient. It is usually mild to moderate in intensity, occurring most frequently in the early stage of treatment, and commonly attenuates over time. The incidence of nausea is approximately 47% in type 1 diabetics and 27% in type 2 diabetics. The risk of nausea depends on the dose of pramlintide and can be decreased by gradual dose titration.

Prominent antinausea effects of cannabinoids may be mediated, at least in part, by CB1 receptors. This has led to occasional use of cannabinoids for patients receiving cancer chemotherapy. In a meta-analysis of studies on the use of rimonabant in smoking cessation, nausea was one of the adverse effects emerging from the pooled data from the early trials.

Although there are no published reports of unusual postoperative nausea and vomiting (PONV) attributed to rimonabant or to drugs active along the incretin and amylin pathways, it seems reasonable to expect that patients treated with these medications may experience more frequent, or more severe, PONV than the average patient. Consequently, for elective surgery requiring anesthesia, at this time it seems logical to withhold these medications in the immediate perioperative period to reduce the likelihood or intensity of PONV. In situations of urgent or emergency surgery, without an opportunity to halt the administration of these novel drugs, it is possible that patients will exhibit exaggerated or refractory postoperative nausea. Future clinical studies may eventually provide evidence-based recommendations.

Delaying gastric emptying is one of the mechanisms by which incretin peptides and amylin decrease postprandial glucose levels. By impeding gastric emptying, glucose inflow into the circulation slows. Consequently, the incretins and amylin allow insulin more time to stimulate glucose uptake and regulate serum glucose levels. Both exenatide and pramlintide cause delayed gastric emptying. DPP-IV inhibitors, such as sitagliptin, however, have little or no effect on gastric emptying, probably attributable to the modest increases in GLP-1 levels caused by this class of drugs. Gastroparesis is a feature of advanced diabetes, and medications that slow gastric emptying may exacerbate this problem. Although no published reports document an increased risk of aspiration associated with the new diabetes therapies, patients receiving these medications are theoretically at a greater risk for this complication during the perioperative period, especially those patients with peripheral neuropathy and gastroparesis as manifestations of their diabetes. In urgent or emergent situations where there has been no opportunity to withhold the medications, clinicians may find unexpectedly large volumes of gastric contents removed by gastric suction. The administration of drugs promoting gut motility, such as metoclopramide, might factor more prominently in overall management of the patient unless there are specific contraindications.

Hypoglycemia is a potential adverse effect of medications active along the incretin and amylin pathways, particularly if used in conjunction with an insulin preparation or a sulfonylurea. Because incretin analogs only promote insulin secretion in a “glucose-dependent” manner and because the counter-regulatory release of glucagon secondary to hypoglycemia is preserved with incretins, the risk of hypoglycemia should be low. Clinical trials show that severe hypoglycemia requiring medical intervention is rare with incretin analogs, such as exenatide. In 1 trial, only 5 of 2781 patients treated with exenatide had hypoglycemia requiring medical assistance. All five patients also received an insulin secretagogue, such as a sulfonylurea. No patients receiving both exenatide and an insulin sensitizer, such as metformin, developed hypoglycemia requiring medical assistance.

When clinical trials are combined and reviewed under meta-analysis, the overall incidence of hypoglycemia associated with exenatide is approximately
Hypoglycemia occurs especially when exenatide is co-administered with a sulfonylurea. This risk is comparable with the risk of hypoglycemia for patients receiving insulin for treatment of diabetes. The likelihood of hypoglycemia is greatest during the initial treatment period and declines over time. When compared with incretin analogs, DPP-IV inhibitors carry less risk of hypoglycemia. In meta-analysis, only approximately 1.6% of patients had episodes of mild to moderate hypoglycemia, which was not statistically different from the control group.41

Clinical trials with the amylin analog pramlintide showed no increase in the overall event rates for severe hypoglycemia.46 However, in patients also receiving insulin for their diabetes, the rate of hypoglycemia increased during the initial 4 wk of therapy with pramlintide.46 The enhanced risk of hypoglycemia was transient and diminished with appropriate blood glucose monitoring and adjustments of insulin dose.

The half-lives and clinical effects of sitagliptin, exenatide, and pramlintide are relatively short. Furthermore, no clinical reports suggest that medications active along the incretin or amylin pathways cause hypoglycemia in the perioperative period. However, in the absence of definitive evidence, the theoretical risk of hypoglycemia is another reason to withhold these medications in advance of elective surgery. This would be a particularly pertinent consideration for patients receiving both a sulfonylurea or an insulin preparation and exenatide. Suppression of glucagon release by exenatide would be a mechanism contributing to hypoglycemia. Should longer-acting GLP-1 analogs, such as liraglutide, enter into clinical use, the glucose-decreasing effects might extend into the surgical or anesthesia interval. Anesthesia providers routinely monitor the blood glucose levels of their patients. Perhaps, however, particular vigilance for the possibility of hypoglycemia is warranted, especially in urgent/emergent surgical situations in which there is no opportunity to withhold the medications. In theory, patients treated with long-acting insulin preparations or sulfonylureas along with exenatide would be most vulnerable. Clinicians might consider more frequent monitoring in urgent or emergent situations.

Hypoglycemia does not seem to be a likely consequence of rimonabant therapy.35

OTHER EFFECTS

DPP-IV is a ubiquitous aminopeptidase with multiple natural substrates and it plays a role in the immune system. Consequently, it seems plausible that inhibiting DPP-IV can potentially cause adverse reactions. Clinical trials have shown that DPP-IV inhibitors were very well tolerated with low rates of adverse effects. In meta-analysis, there is a small increased risk of nasopharyngitis and urinary tract infection associated with DPP-IV inhibitors.41 Clinical experience in anesthetized patients receiving DPP-IV inhibitors is limited. Because multiple peptides are potential substrates for this enzyme,18 clinicians should be alert for unusual reactions, especially in urgent procedures in which the drug may not have been withheld.

The endocannabinoid system is involved in many complex behaviors and physiologic responses, including pain and sleep/awake cycles. In preclinical studies, as cited above, there appear to be interactions between the endocannabinoid system and anesthetics. Given the “pleiotropic” effects of rimonabant,37 the exact consequences of clinical interactions between drugs acting on cannabinoid receptors in the brain and periphery with sedatives, narcotics, and inhaled or injected general anesthetics remain to be determined.

SUMMARY AND RECOMMENDATIONS

Food ingestion increases secretion of insulin, amylin, and the incretin peptides. Insulin and amylin regulate postprandial hyperglycemia, while amylin also suppresses glucagon secretion and slows food intake and gastric emptying. GLP-1 amplifies glucose-stimulated insulin release, in addition to suppressing glucagon secretion, food intake, and gastric emptying. The new treatment options for DM acting along the incretin pathway and the amylin analog offer some potential advantages for chronic treatment of DM by targeting these physiologic mechanisms. However, the biological activities of these drugs may present challenges in the perioperative period. This is especially true in the urgent or emergent clinical circumstances in which there are no opportunities to withhold these medications.

As clinical experience accumulates with novel drugs in anesthetized patients, it may become possible to develop more definitive warnings and recommendations. However, until this information becomes available, we suggest withholding GLP-1 analogs, DPP-IV inhibitors, and pramlintide on the day of surgery. Patients can probably continue to take these drugs the day before surgery without an enhanced risk of hypoglycemia while fasting. With these drugs, there are potentially enhanced risks of nausea, aspiration of gastric contents, and hypoglycemia.

As the newer treatments for DM become increasingly prevalent in clinical practice, anesthesia providers should maintain particular vigilance for unusual or exaggerated effects and responses during the perioperative period.

ACKNOWLEDGMENTS

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Practice Advisory for the Perioperative Management of
Patients with Cardiac Rhythm Management Devices:
Pacemakers and Implantable Cardioverter–Defibrillators

A Report by the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Cardiac Rhythm Management Devices

PRACTICE advisories are systematically developed reports that are intended to assist decision making in areas of patient care. Advisories provide a synthesis and analysis of expert opinion, clinical feasibility data, open forum commentary, and consensus surveys. Advisories are not intended as standards, guidelines, or absolute requirements. They may be adopted, modified, or rejected according to clinical needs and constraints.

The use of practice advisories cannot guarantee any specific outcome. Practice advisories summarize the state of the literature and report opinions derived from a synthesis of task force members, expert consultants, open forums, and public commentary. Practice advisories are not supported by scientific literature to the same degree as standards or guidelines because of the lack of sufficient numbers of adequately controlled studies. Practice advisories are subject to periodic revision as warranted by the evolution of medical knowledge, technology, and practice.

Methodology

A. Definition of Cardiac Rhythm Management Devices

For this Advisory, a cardiac rhythm management device (CRMD) refers to any permanently implanted cardiac pacemaker or any implantable cardioverter–defibrillator (ICD). The term CRT also refers to any cardiac resynchronization device. The term CRT refers to a CRMD that provides cardiac resynchronization therapy using biventricular pacing techniques. Generic pacemaker and defibrillator codes are provided in appendix 1. Note that every ICD includes both pacing and shock therapies for the management of bradyarrhythmias and tachyarrhythmias.

B. Purposes of the Advisory

The purposes of this Advisory are to (1) facilitate safe and effective perioperative management of the patient with a CRMD and (2) reduce the incidence of adverse outcomes. Perioperative management refers to the preoperative, intraoperative, postoperative or recovery period in any setting where an anesthesia provider delivers anesthesia care. Adverse outcomes associated with a CRMD include (but are not limited to) damage to the device, inability of the device to deliver pacing or shocks, lead–tissue interface damage, changes in pacing behavior, electrical reset to the backup pacing mode, or inappropriate ICD therapies.* Adverse clinical outcomes include (but are not limited to) hypotension, tachyarrhythmia or bradycardia, myocardial tissue damage, and myocardial ischemia or infarction. Other related outcomes may include extended hospital stay, delay or cancellation of surgery, readmission to manage device malfunction, or additional hospital resource utilization and cost.

C. Focus

This Advisory focuses on the perioperative management of patients who have a preexisting, permanently implanted CRMD for treatment of bradyarrhythmia, tachyarrhythmia, or heart failure. Both inpatient and outpatient procedures are addressed by this Advisory. This Advisory does not address the perioperative management of any patient undergoing CRMD implantation or revision. It is not applicable to any patient (1) without
a permanently implanted pacemaker or ICD, (2) with a temporary CRMD, (3) with a noncardiac implantable device (e.g., neurologic or spinal cord stimulator), or (4) with an implantable mechanical cardiac assist device (e.g., ventricular assist device). This Advisory does not address any procedure where there are no known perioperative CRMD concerns, such as diagnostic radiation (e.g., x-ray studies, fluoroscopy, or mammograms), computed tomography scans, or ultrasound.

D. Application

This Advisory is intended for use by anesthesiologists and all other individuals who deliver or who are responsible for anesthesia care. The Advisory may also serve as a resource for other physicians and healthcare professionals who treat patients with CRMDs.

E. Task Force Members and Consultants

The American Society of Anesthesiologists (ASA) appointed a Task Force of 12 members to (1) review and assess currently available scientific literature, (2) obtain expert consensus and public opinion, and (3) develop a practice advisory. The Task Force members consisted of anesthesiologists and cardiologists in private and academic practices from various geographic areas of the United States and two methodologists from the ASA Committee on Practice Parameters.

The Task Force used a six-step process. First, they reached consensus on the criteria for evidence of effective perioperative management of cardiac rhythm management devices. Second, original published articles from peer-reviewed journals relevant to these issues were evaluated. Third, consultants who had expertise or interest in CRMDs and who practiced or worked in various settings (e.g., academic and private practice) were asked to (1) participate in opinion surveys on the effectiveness of various perioperative management strategies and (2) review and comment on a draft of the Advisory developed by the Task Force. Fourth, additional opinions were solicited from random samples of active members of both the ASA and the Heart Rhythm Society (HRS).† Fifth, the Task Force held an open forum at a national anesthesia meeting and at a major cardiology meeting to solicit input on the key concepts of this Advisory. Sixth, all available information was used to build consensus within the Task Force on the Advisory.

The draft document was made available for review on the ASA Web site, and input was invited via e-mail announcement to all ASA members. All submitted comments were considered by the Task Force in preparing the final draft.

F. Availability and Strength of Evidence

Practice advisories are developed by a protocol similar to that of an ASA evidence-based practice guideline, including a systematic search and evaluation of the literature. However, practice advisories lack the support of a sufficient number of adequately controlled studies to permit aggregate analyses of data with rigorous statistical techniques such as meta-analysis. Nonetheless, literature-based evidence from case reports and other descriptive studies is reported. This literature often permits the identification of recurring patterns of clinical practice.

As with a practice guideline, formal survey information was collected from Consultants and members of the ASA. For this Advisory, surveys were also sent to members of the HRS. Additional information was obtained from open forum presentations and other invited and public sources. The advisory statements contained in this document represent a consensus of the current spectrum of clinical opinion and literature-based findings.§

Advisories

I. Preoperative Evaluation

Perioperative treatment of CRMD patients is a common occurrence. It has been reported that more than 500,000 individuals in the United States have permanently implanted pacemakers or ICDs with 115,000 new devices implanted each year.1 Perioperative management of CRMD patients typically begins with a focused preoperative evaluation consisting of (1) establishing whether a patient has a CRMD, (2) defining the type of device, (3) determining whether a patient is CRMD dependent for antibradycardia pacing function, and (4) determining device function.

Although no controlled trials of the clinical impact of performing a focused preoperative evaluation for CRMD patients were found, case reports suggest that incomplete preoperative examination of patients with CRMDs may lead to adverse outcomes (e.g., inhibited CRMD function, asystole).2–4 The majority of Consultants and random samples from the ASA and HRS memberships agree that the above four preoperative evaluation activities should be conducted.§

Advisory. The consensus of the Task Force is that a focused preoperative evaluation should include establishing whether a patient has a CRMD, defining the type of device, determining whether a patient is CRMD dependent for pacemaking function, and determining CRMD function.

Determining whether a patient has a CRMD should be based on (1) a focused history including but not limited to the patient interview, medical records review, review of available chest x-ray films, electrocardiogram, or any available monitor or rhythm strip information and (2) a focused physical examination (checking for scars, palpating for device).

† Formerly North American Society of Pacing and Electrophysiology (NASPE).
‡ Refer to appendix 2 for a summary of the advisories.
§ Refer to appendix 3 for results of the Consultant, ASA membership, and HRS membership surveys.
Defining the type of device is accomplished by (1) obtaining the manufacturer’s identification card from the patient or other source, (2) ordering chest X-ray studies if no other data are available, or (3) referring to supplemental resources (e.g., manufacturer’s databases, pacemaker clinic records, consultation with a cardiologist).

Cardiac rhythm management device dependency for pacemaking function may be determined by one or more of the following: (1) a verbal history or an indication in the medical record that the patient has experienced a bradyarrhythmia that has caused syncope or other symptoms requiring CRMD implantation, (2) a history of successful atioventricular nodal ablation that resulted in CRMD placement, or (3) a CRMD evaluation that shows no evidence of spontaneous ventricular activity when the pacemaking function of the CRMD is programmed to VVI pacing mode at the lowest programmable rate.

Cardiac rhythm management device function is ideally assessed by a comprehensive evaluation of the device. If a comprehensive evaluation is not possible, then, at a minimum, confirm whether pacing impulses are present and create a paced beat. Consultation with a cardiologist or CRMD service may be necessary. Contacting the manufacturer for perioperative recommendations may be a consideration.

II. Preoperative Preparation

Preparation for patient safety and proper maintenance of the device during a procedure includes (1) determining whether electromagnetic interference (EMI) is likely to occur during the planned procedure; (2) determining whether reprogramming the CRMD pacemaking function to an asynchronous mode for a procedure were found. Although some case reports suggest such reprogramming is beneficial during electrocautery, other reports indicate that EMI may continue to affect reprogrammed pacemakers. The literature lacks sufficient guidance regarding the potential perioperative impact of anesthetic techniques on CRMD function and patient–CRMD interactions. For most ICDs, there is no reliable means to detect the use of the magnet over an ICD. A magnet correctly applied to a pacemaker often results in asynchronous pacing function at a predetermined rate without rate responsiveness. The magnet rate and response vary by manufacturer. Magnet response can be affected by programming and remaining battery life. The magnet rate may be excessive for some patients. Some pacemakers may have no magnet response.

†† Magnet application to an ICD rarely alters bradycardia pacing rate and function. A magnet correctly applied to an ICD often results in suspension of tachyarrhythmia therapy. For most ICDs, there is no reliable means to detect appropriate magnet placement. Some ICDs may have no magnet response. Some ICDs can be permanently disabled by magnet application.

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Advisory. The Task Force agrees that planned procedures should include a determination as to whether EMI is likely to occur for either conventional pacemakers or ICDs. If EMI is likely to occur, the conventional pacing function of a CRMD should be altered by changing to an asynchronous pacing mode in pacemaker-dependent patients and suspending special algorithms, including rate-adaptive functions. These alterations may be accomplished by programming or applying a magnet when applicable. However, the Task Force cautions against the use of the magnet over an ICD. In addition, an

Numerous descriptive studies and case reports suggest that the following procedures are likely to be associated with EMI: (1) electrocautery, (2) radio frequency ablation, (3) magnetic resonance imaging (MRI), and (4) radiation therapy. No studies were found that reported EMI during electrosurgical therapy (ECT). Some descriptive studies report the occurrence of EMI during lithotripsy, whereas other descriptive studies and case reports indicate no apparent EMI effects. No controlled trials of the clinical impact of programming the pacemaking function to an asynchronous mode for a procedure were found. Although some case reports suggest that such reprogramming is beneficial during electrocautery, other reports indicate that EMI may continue to affect reprogrammed pacemakers. The literature lacks sufficient guidance regarding the potential perioperative impact of anesthetic techniques on CRMD function and patient–CRMD interactions.

†† Most current CRMDs have an x-ray code that can be used to identify the manufacturer of the device.

† The VVT mode (with attention to the upper rate limit) might also be considered for a patient with ventricular ectopy where concern exists regarding R-on-T pacing during an asynchronous pacing mode. However, the upper pacing rate during VVT mode is manufacturer- and possibly generatorspecific and can approach 200 beats/min for many devices. Generally, VVT mode pacing would not be a consideration except in very rare circumstances. Before using the VVT mode, a cardiologist and the generator manufacturer should be consulted to determine the suitability of the upper pacing rate for any patient.

** A magnet correctly applied to a pacemaker often results in asynchronous pacing function at a predetermined rate without rate responsiveness. The magnet rate and response vary by manufacturer. Magnet response can be affected by programming and remaining battery life. The magnet rate may be excessive for some patients. Some pacemakers may have no magnet response.

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III. Intraoperative Management

The primary activities associated with intraoperative management of a CRMD include (1) monitoring the operation of the device; (2) preventing potential CRMD dysfunction; and (3) performing emergency defibrillation, cardioversion, or heart rate support.

1. Monitoring. Intraoperative monitoring includes continuous electrocardiography as well as monitoring of the peripheral pulse (e.g., palpation of the pulse, auscultation of heart sounds, monitoring of a tracing of intraarterial pressure, ultrasound peripheral pulse monitoring, or pulse plethysmography or oximetry). Although no controlled trials were found that examine the clinical impact of electrocardiography or peripheral pulse monitoring for CRMD patients, case reports note the importance of intraoperative electrocardiographic monitoring in the detection of pacemaker or cardiac dysfunction for these patients. The majority of Consultants and ASA and HRS members agree that (1) continuous electrocardiographic monitoring should be done for all CRMD patients and (2) continuous peripheral pulse monitoring should be conducted.

Advisory. Electrocardiography and peripheral pulse monitoring are important components of perioperative treatment of patients with CRMDs. The Task Force agrees that a patient’s electrocardiogram should be continuously displayed, as required by ASA standards, from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional electrocardiographic monitoring in the postoperative period as indicated by the patient’s medical condition.

2. Managing Potential Sources of EMI. Procedures using electrocautery, radiofrequency ablation, lithotripsy, MRI, or radiation therapy may damage CRMDs or interfere with CRMD function, potentially resulting in severe adverse outcomes. Sources of EMI are often unique to specific procedures, and the management of each of these potential EMI sources is reported separately below.

A. Electrocautery. Management of potential sources of EMI associated with electrocautery includes (1) assuring that the cautery tool and current return pad are positioned so that the current pathway does not pass through or near the CRMD pulse generator and leads; (2) avoiding proximity of the cautery’s electrical field to the pulse generator or leads; (3) using short, intermittent, and irregular bursts at the lowest feasible energy levels; and (4) using a bipolar electrocautery system or an ultrasonic (harmonic) scalpel, if possible.

Two case reports and one observational study suggest that EMI may occur despite positioning the current return pad as far as possible away from the generator and leads. However, the majority of Consultants and ASA and HRS members agree that the current return pad should be positioned so that the electrosurgical current pathway does not pass through or near the CRMD pulse generator or leads.

One case report suggested that application of unipolar electrocautery on the sternum resulted in complete pacemaker inhibition. Although some manufacturers suggest substituting bipolar for monopolar electrocautery to minimize CRMD interactions, no clinical literature was found to support this recommendation. The majority of Consultants and ASA and HRS members agree that direct contact between the electrocautery system and the CRMD pulse generator or its leads should be avoided.

Although no recent studies were found examining the benefit of using short, intermittent bursts at the lowest feasible energy levels, earlier literature suggests that short, intermittent bursts may be useful in completing procedures without no ttable EMI interference. The majority of Consultants and ASA and HRS members agree that short, intermittent bursts should be performed.

Finally, case reports suggest that surgery for pacemaker patients may proceed uneventfully when bipolar electrocautery systems or harmonic scalpels are used. The majority of Consultants and ASA and HRS members agree that bipolar electrocautery systems should be

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‡‡ Although commonly referred to as the “grounding pad,” most operating room power supplies in the United States are ungrounded.
§§ See appendix 3 for an explanation of the term earlier literature.

ICD’s antitachyarrhythmia functions should be suspended, if present. For ICD patients who depend on pacing function for control of bradyarrhythmia, these functions should be altered by programming as noted above. Consultation with a cardiologist or pacemaker-ICD service may be necessary.

For all CRMDs, consider advising the individual performing the procedure to use a bipolar electrocautery system or an ultrasonic scalpel when applicable. Temporary pacing and defibrillation equipment should be immediately available before, during, and after a procedure.

Finally, the Task Force believes that anesthetic techniques do not influence CRMD function. However, anesthetic-induced physiologic changes (i.e., cardiac rate, rhythm, or ischemia) in the patient may induce unexpected CRMD responses or adversely affect the CRMD-patient interaction.
used when possible. The majority of Consultants and ASA members agree that harmonic scalpels should be used when possible, and HRS members are equivocal.

**B. Radiofrequency Ablation.** Management of potential sources of EMI associated with radiofrequency ablation primarily involves keeping the radiofrequency current path (electrode tip to current return pad) as far away from the pulse generator and lead system as possible. One observational study reports 3 of 12 cases that resulted in a significant decrease in resistance on the pacemaker leads when radiofrequency ablation was used in proximity to the leads.65 One case report suggests that positioning of the radiofrequency ablation cluster electrode no closer than 5 cm from the pacemaker leads allowed the procedure to continue uneventfully.40 The majority of Consultants and ASA and HRS members agree that the individual performing the procedure should avoid direct contact between the ablation catheter and the CRMD and leads and should keep the radiofrequency ablation current path as far away from the pulse generator and lead system as possible.

**C. Lithotripsy.** Management of potential sources of EMI associated with lithotripsy includes (1) avoiding focus of the lithotripsy beam near the pulse generator and (2) disabling atrial pacing if the lithotripsy system triggers on the R wave. The literature is silent regarding the benefits of focusing the lithotripsy beam away from the pulse generator as well as the benefits of disabling atrial pacing during lithotripsy. The majority of Consultants and ASA and HRS members agree that focusing the lithotripsy beam near the pulse generator should be avoided, and all three groups are equivocal regarding whether atrial pacing should be disabled before a procedure if the lithotripsy system triggers on the R wave.

**D. Magnetic Resonance Imaging.** The literature is not sufficiently rigorous to examine the effects of specific management activities related to CRMD patients receiving MRI. Some descriptive studies and case reports suggest that MRI may be completed without notable EMI under specific circumstances and with appropriate patient qualification and monitoring.30,31,64–71 However, other literature generally suggests that MRI is contraindicated.21–29 The majority of Consultants and ASA and HRS members generally agree that MRI is contraindicated for all CRMD patients.

**E. Radiation Therapy.** The literature does not provide sufficient guidance regarding specific management activities related to CRMD patients undergoing radiation therapy. However, none of the Consultants or HRS members and only 10% of the ASA members agree that radiation therapy is contraindicated for all CRMD patients. Fifty-seven percent of the Consultants, 59% of the HRS members, and 37% of the ASA members agree that radiation therapy is contraindicated for some but not all CRMD patients, whereas 43% of the Consultants, 41% of the HRS members, and 53% of the ASA members agree that radiation therapy is not contraindicated for any CRMD patient.

**F. Electroconvulsive Therapy.** No clinical studies were found that report EMI effects or permanent CRMD malfunction associated with ECT. One study reports two cases where patients’ ICDs were turned off before ECT but does not report the effect of the therapy on ICD function.72 However, the author indicates that treatment with ECT might be associated with significant cardiac risks. Transient electrocardiographic changes (e.g., increased P-wave amplitude, altered QRS shape, T-wave and ST-T abnormalities) may result from ECT, and additional cardiac complications (e.g., arrhythmia or ischemia) may occur in patients with preexisting cardiac disease. Finally, physiologic stresses after ECT, such as a period of bradycardia and reduced blood pressure, followed by tachycardia and an increase in blood pressure, may account for cardiac failure in the extended postoperative period (i.e., several hours or days after ECT) among patients with marginal cardiac function.

**Advisory.** The Task Force believes that EMI could be minimized during certain procedures using a variety of intraoperative management techniques.

The Task Force agrees that the risk of intraoperative interference from radiofrequency ablation or electrocautery systems may be minimized by (1) positioning the cautery tool and current return pad so that the current pathway does not pass through or near the CRMD system; (2) avoiding proximity of the cautery’s electrical field to the pulse generator and leads, including avoidance of waving the activated electrode over the generator; (3) using short, intermittent, and irregular bursts at the lowest feasible energy levels; and (4) using bipolar electrocautery systems or ultrasonic (harmonic) scalpels if possible. Advising or reminding the individual performing the procedure to implement these management techniques should be considered.

Risk of interference from radiofrequency ablation may be reduced by avoiding direct contact between the ablation catheter and the pulse generator and leads and by keeping the radiofrequency’s current path (electrode tip to current return pad) as far away from the pulse generator and leads as possible. During all radiofrequency ablative procedures, consider discussing with the individual performing the procedure any concerns regarding the proximity of the ablation catheter to the CRMD leads.

During lithotripsy, the lithotripsy beam should not be focused near the pulse generator. If the lithotripsy system triggers on the R wave, atrial pacing might need to be disabled before the procedure.
The Task Force believes that MRI is generally contra-indicated for CRMD patients. If MRI must be performed, consult with the ordering physician, the patient’s pacemaker specialist or cardiologist, the diagnostic radiologist, and the CRMD manufacturer.

The Task Force believes that radiation therapy can be safely performed for CRMD patients. The device must be outside the field of radiation. Therefore, some pulse generators will require surgical relocation before commencing radiation. Most manufacturers recommend verification of pulse generator function during and at the completion of radiation. Problems may include pacemaker failure and runaway pacemaker.

Although transient or long-term myocardial and nervous system effects may be associated with ECT, the Task Force believes that such therapies may be administered to CRMD patients without significant damage to a disabled CRMD. If ECT must be performed, consult with the ordering physician and the patient’s cardiologist to plan for the first and subsequent ECTs. All CRMDs should undergo a comprehensive interrogation before the procedure(s). ICD functions should be disabled for shock therapy during ECT; however, be prepared to treat ventricular arrhythmias that occur secondary to the hemodynamic effects of ECT. CRMD-dependent patients may require a temporary pacing system to preserve cardiac rate and rhythm during shock therapy. Also, the CRMD may require programming to asynchronous activity to avoid myopotential inhibition of the device in pacemaker-dependent patients.

3. Emergency Defibrillation or Cardioversion.

During the perioperative period, emergency defibrillation or cardioversion may become necessary for a CRMD patient. In this case, the primary concern is to minimize the current flowing through the pulse generator and lead system. Recent and earlier case reports suggest that optimal positioning of the defibrillation or cardioversion pads or paddles may be an important factor in the prevention of adverse CRMD-related outcomes. The majority of Consultants and ASA and HRS members agree that the defibrillation or cardioversion paddles should be as far as possible from the pulse generator. The majority of Consultants and ASA and HRS members also agree that the anterior–posterior position should be used and that a clinically appropriate energy output should be used regardless of the type of CRMD.

Advisory. The Task Force believes that before attempting emergency defibrillation or cardioversion of a patient with an ICD and magnet-disabled therapies, all sources of EMI should be terminated, and the magnet should be removed to reenable antitachycardia therapies. The patient should then be observed for appropriate CRMD therapy. For patients with an ICD and antiarrhythmic therapies that have been disabled by programming, consider reenabling therapies through programming. If the above activities do not restore ICD function, proceed with emergency external defibrillation or cardioversion.

Overriding the above discussion is the need to follow existing Advanced Cardiac Life Support and emergency guidelines to provide rapid cardioversion or defibrillation, and attention should be turned to providing this therapy as quickly as possible.

If a life-threatening arrhythmia occurs, follow Advanced Cardiac Life Support guidelines for energy level and for paddle placement. If possible, attempt to minimize the current flowing through the pulse generator and lead system by (1) positioning the defibrillation or cardioversion pads or paddles as far as possible from the pulse generator and (2) positioning defibrillation or cardioversion paddles perpendicular to the major axis of the CRMD pulse generator and leads to the extent possible by placing them in an anterior–posterior location. A clinically appropriate energy output should always be used regardless of the presence of a CRMD, and the paddles should be positioned as best as can be done in an emergency.

IV. Postoperative Management

Postoperative treatment of CRMD patients primarily consists of interrogating and restoring CRMD function. Although no recent studies were found examining outcomes associated with interrogating or restoring CRMD function, an earlier case report indicates that postoperative evaluation resulted in the discovery and correction of a pacemaker problem. The majority of Consultants and ASA and HRS members agree that postoperative patient treatment should include interrogating and re-storing CRMD function in the postanesthesia care unit or intensive care unit.

Advisory. The Task Force believes that cardiac rate and rhythm should be continuously monitored throughout the immediate postoperative period. Backup pacing capability and cardioversion–defibrillation equipment should be immediately available at all times.

Postoperative interrogation and restoration of CRMD function are basic elements of postoperative management. The CRMD first should be interrogated to assess postoperative device functions. If interrogation determines that CRMD settings are inappropriate, the device should be reprogrammed to appropriate settings. For an ICD, all antitachycardia therapies should be restored. Consultation with a cardiologist or pacemaker–ICD service may be necessary.
Appendix 1: Generic Pacemaker and Defibrillator Codes

The generic pacemaker and defibrillator codes were developed as joint projects by the North American Society of Pacing and Electro-physiology (NASPE)‡‡‡ and the British Pacing and Electrophysiology Group (BPEG).80,81 The five positions refer to the order of the programmed settings on the CRMD (tables 1 and 2).

Table 1. Generic Pacemaker Code (NBG*): NASPE/BPEG Revised (2002)

<table>
<thead>
<tr>
<th>Position I, Pacing Chamber(s)</th>
<th>Position II, Sensing Chamber(s)</th>
<th>Position III, Response(s) to Sensing</th>
<th>Position IV, Programmability</th>
<th>Position V, Multisite Pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>O = none</td>
<td>O = none</td>
<td>O = none</td>
<td>O = none</td>
<td>O = none</td>
</tr>
<tr>
<td>A = atrium</td>
<td>A = atrium</td>
<td>I = inhibited</td>
<td>R = rate modulation</td>
<td>A = atrium</td>
</tr>
<tr>
<td>V = ventricle</td>
<td>V = ventricle</td>
<td>T = triggered</td>
<td>V = ventricle</td>
<td>D = dual (A + V)</td>
</tr>
<tr>
<td>D = dual (A + V)</td>
<td>D = dual (A + V)</td>
<td>D = dual (T + I)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Examples:

AAI = Atrial-only antibradycardia pacing. In the AAI mode, any failure of the atrium to produce an intrinsic event within the appropriate time window (determined by the lower rate limit) results in an atrial pacing pulse emission. There is no ventricular sensing; thus, a premature ventricular event will not likely reset the pacing timer.

AOO = Asynchronous atrial-only pacing. In this mode, the pacing device emits a pacing pulse regardless of the underlying cardiac rhythm.

DDD = Dual-chamber antibradycardia pacing function in which every atrial event, within programmed limits, is followed by a ventricular event. The DDD mode implies dual-chamber pacing with atrial tracking. In the absence of intrinsic activity in the atrium, it will be paced, and, after any sensed or paced atrial event, an intrinsic ventricular event must occur before the expiration of the atrioventricular timer or the ventricle will be paced.

DDI = Dual-chamber behavior in which the atrial activity is tracked into the ventricle only when the atrial event is created by the antibradycardia pacing function of the generator. In the DDI mode, the ventricle is paced only when no intrinsic ventricular activity is present.

DOO = Asynchronous atrioventricular sequential pacing without regard to the underlying cardiac rhythm.

VOO = Asynchronous ventricular-only pacing without regard to the underlying cardiac rhythm.

VVI = Ventricular-only antibradycardia pacing. In the VVI mode, any failure of the ventricle to produce an intrinsic event within the appropriate time window (determined by the lower rate limit) results in a ventricular pacing pulse emission. There is no atrial sensing; thus, there can be no atrioventricular synchrony in a patient with a VVI pacemaker and any intrinsic atrial activity.

* NBG: N refers to NASPE, B refers to BPEG, and G refers to generic.

Table 2. Generic Defibrillator Code (NBD): NASPE/BPEG

<table>
<thead>
<tr>
<th>Position I, Shock Chamber(s)</th>
<th>Position II, Antitachycardia Pacing Chamber(s)</th>
<th>Position III, Tachycardia Detection</th>
<th>Position IV,* Antibradycardia Pacing Chamber(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O = none</td>
<td>O = none</td>
<td>E = electrogram</td>
<td>O = none</td>
</tr>
<tr>
<td>A = atrium</td>
<td>A = atrium</td>
<td>H = hemodynamic</td>
<td>A = atrium</td>
</tr>
<tr>
<td>V = ventricle</td>
<td>V = ventricle</td>
<td></td>
<td>V = ventricle</td>
</tr>
<tr>
<td>D = dual (A + V)</td>
<td>D = dual (A + V)</td>
<td></td>
<td>D = dual (A + V)</td>
</tr>
</tbody>
</table>

* For robust identification, position IV is expanded into its complete NBG code. For example, a biventricular pacing–defibrillator with ventricular shock and antitachycardia pacing functionality would be identified as VWE-DDDRV, assuming that the pacing section was programmed DDDRV. Currently, no hemodynamic sensors have been approved for tachycardia detection (position III).

‡‡‡ Now called the Heart Rhythm Society (HRS).

Anesthesiology, V 103, No 1, Jul 2005.
Appendix 2: Summary of Practice Advisory

Preoperative Evaluation
- Establish whether a patient has a CRMD.
- Conduct a focused history (patient interview, medical records review, review of available chest x-ray films, electrocardiogram, or any available monitor or rhythm strip information).
- Conduct a focused physical examination (check for scars, palpate for device).

Preoperative Preparation
- Define the type of CRMD.
- Obtain manufacturer’s identification card from patient or other source.
- Order chest x-ray studies if no other data are available.
- Refer to supplemental resources (e.g., manufacturer’s databases).

Intraoperative Management
- Monitor operation of the CRMD.
- Conduct electrocardiographic monitoring per ASA standard.
- Monitor peripheral pulse (e.g., manual pulse palpation, pulse oximeter plethysmograph, arterial line).
- Manage potential CRMD dysfunction due to EMI.
- Electrocautery.
  - Assure that the electrosurgical receiving plate is positioned so that the current pathway does not pass through or near the CRMD system. For some cases, the receiving plate might need to be placed on a site different from the thigh (e.g., the superior posterior aspect of the shoulder contralateral to the generator position for a head and neck case).
  - Advise individual performing the procedure to avoid proximity of the cautery’s electrical field to the pulse generator or leads.
  - Advise individual performing the procedure to use short, intermittent, and irregular bursts at the lowest feasible energy levels.
  - Advise individual performing the procedure to reconsider the use of a bipolar electrocautery system or ultrasonic (harmonic) scalpel.
- Temporary pacing and defibrillation equipment should be immediately available.
- Evaluate the possible effects of anesthetic techniques and of the procedure on CRMD function and patient CRMD interactions.

Postoperative Management
- Evaluate whether a patient was successfully restored to normal cardiac rhythm and rhythm.
- Identify any residual CRMD dysfunction.
- Consider contacting the manufacturer for perioperative recommendations.

Refer to Table 3 for an example of a stepwise approach to the perioperative treatment of the patient with a CRMD.

ASA = American Society of Anesthesiologists; CRMD = cardiac rhythm management device; EMI = electromagnetic interference; ICD = implantable cardioverter–defibrillator; MRI = magnetic resonance imaging.
Table 3. Example of a Stepwise Approach to the Perioperative Treatment of the Patient with a CRMD

<table>
<thead>
<tr>
<th>Perioperative Period</th>
<th>Patient/CRMD Condition</th>
<th>Intervention</th>
</tr>
</thead>
</table>
| **Preoperative evaluation** | Patient has CRMD | ● Focused history  
● Focused physical examination |
| Determine CRMD type (pacemaker, ICD, CRT) | | ● Manufacturer’s CRMD identification card  
● Chest x-ray studies (no data available)  
● Supplemental resources* |
| Determine whether patient is CRMD-dependent for pacing function | | ● Verbal history  
● Bradycardia symptoms  
● Atrioventricular node ablation  
● No spontaneous ventricular activity† |
| Determine CRMD function | | ● Comprehensive CRMD evaluation‡ |
| **Preoperative preparation** | EMI unlikely during procedure | ● If EMI unlikely, special precautions are not needed |
| EMI likely: CRMD is pacemaker | | ● Reprogram to asynchronous mode when indicated  
● Suspend rate-adaptive functions§ |
| EMI likely: CRMD is ICD | | ● Suspend antitachyarrhythmia functions  
● If patient is dependent on pacing function, alter pacing functions as above |
| EMI likely: all CRMD | | ● Use bipolar cautery; ultrasonic scalpel  
● Temporary pacing and external cardioversion–defibrillation available |
| **Intraoperative physiologic changes** | Intraoperative management | ● Plan for possible adverse CRMD–patient interaction |
| **likely (e.g., bradycardia, ischemia)** | Monitoring | ● Electrocardiographic monitoring per ASA standard  
● Peripheral pulse monitoring |
| Electrocautery interference | | ● CT/CRP—no current through PG/leads  
● Avoid proximity of CT to PG/leads  
● Short bursts at lowest possible energy  
● Use bipolar cautery; ultrasonic scalpel |
| Radiofrequency catheter ablation | | ● Avoid contact of radiofrequency catheter with PG/leads  
● Radiofrequency current path far away from PG/leads  
● Discuss these concerns with operator |
| Lithotripsy | | ● Do not focus lithotripsy beam near PG  
● R wave triggers lithotripsy? Disable atrial pacing† |
| MRI | | ● Generally contraindicated  
● If required, consult ordering physician, cardiologist, radiologist, and manufacturer |
| RT | | ● PG/leads must be outside of RT field  
● Possible surgical relocation of PG  
● Verify PG function during/after RT course |
| ECT | | ● Consult with ordering physician, patient’s cardiologist, a CRMD service, or CRMD manufacturer |
| **Emergency defibrillation–cardioversion** | ICD: magnet disabled | ● Terminate all EMI sources  
● Remove magnet to reenable therapies  
● Observe for appropriate therapies |
| ICD: programming disabled | | ● Programming to reenable therapies or proceed directly with external cardioversion–defibrillation |
| ICD: either of above | | ● Minimize current flow through PG/leads  
● PP as far as possible from PG  
● PP perpendicular to major axis PG/leads  
● To extent possible, PP in anterior–posterior location |
| **Postoperative management** | Regardless of CRMD type | ● Use clinically appropriate cardioversion/defibrillation energy |
| Immediate postoperative period | | Monitor cardiac R&R continuously  
● Backup pacing and cardioversion/defibrillation capability |
| Postoperative interrogation and restoration of CRMD function | | ● Interrogation to assess function  
● Settings appropriate?#  
● Is CRMD an ICD??  
● Use cardio/pacemaker–ICD service if needed |

* Manufacturer’s databases, pacemaker clinic records, cardiology consultation. † With cardiac rhythm management device (CRMD) programmed VVI at lowest programmable rate. ‡ Ideally CRMD function assessed by interrogation, with function altered by reprogramming if required. § Most times this will be necessary; when in doubt, assume so. † Atrial pacing spikes may be interpreted by the lithotriptor as R waves, possibly inciting the lithotriptor to deliver a shock during a vulnerable period in the heart. # If necessary, reprogram appropriate settings. ** Restore all antitachycardia therapies.

CRP — current return pad; CRT — cardiac resynchronization therapy; CT — cautery tool; ECT — electroconvulsive therapy; EMI — electromagnetic interference; ICD — internal cardioverter-defibrillator; MRI — magnetic resonance imaging; PG — pulse generator; PP — external cardioversion–defibrillation pads or paddles; R&R — rhythm and rate; RT — radiation therapy.
Appendix 3: Literature Review and Consensus-based Evidence

A. State of the Literature

For this Advisory, a literature review was used in combination with opinions obtained from experts and other sources (e.g., professional society members, open forums, Web-based postings) to provide guidance to practitioners regarding the perioperative treatment of patients with CRMDs. Both the literature review and opinion data were based on evidence linkages, consisting of directional statements about relations between specific perioperative management activities and CRMD function or clinical outcomes.

A study or report that appears in the published literature is included in the development of an advisory if the study (1) is related to one of the specified linkage statements, (2) reports a finding or set of findings that can be tallied or measured (e.g., articles that contain only opinion are not included), and (3) is the product of an original investigation or report (i.e., review articles or follow-up studies that summarize previous findings are not included). Because CRMDs represent a rapidly changing technology, earlier literature (i.e., literature published before 1990) was rarely included in the evaluation of evidence for this Practice Advisory.

Although evidence linkages are designed to assess causality, few of the reviewed studies exhibited sufficiently acceptable quantitative methods and analyses to provide a clear indication of causality. Therefore, the published literature could not be used as a source of quantitative support (required for the development of practice guidelines). However, many published studies were evaluated that provided the Task Force with important noncausal evidence. For example, descriptive literature (i.e., reports of frequency or incidence) is often useful in providing an indication of the scope of a problem. Information regarding whether a particular adverse outcome is common or rare may have considerable bearing on the practicality of an advisory. Case reports are typically used as a forum for reporting and recognizing unusual or adverse outcomes and may suggest caution when deeming an advisory.

For the literature review, potentially relevant studies were identified via electronic and manual searches of the literature. The electronic search covered a 39-yr period from 1966 through 2004. The manual search covered a 45-yr period from 1961 through 2005. More than 1,500 citations were initially identified, yielding a total of 411 nonoverlapping articles that addressed topics related to the evidence linkages. After review of the articles, 283 studies did not provide direct evidence and were subsequently eliminated. A total of 128 articles (from 39 journals) contained direct linkage-related evidence. No evidence linkage contained enough studies with well-defined experimental designs and statistical information to conduct a quantitative analysis (i.e., meta-analysis).

Interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a κ statistic for two-rater agreement pairs were as follows: (1) type of study design, κ = 0.72–0.90; (2) type of analysis, κ = 0.80–0.90; (3) evidence linkage assignment, κ = 0.84–1.00; and (4) literature inclusion for database, κ = 0.70–1.00. Three-rater chance-corrected agreement values were (1) study design, Sav = 0.81, Var (Sav) = 0.010; (2) type of analysis, Sav = 0.86, Var (Sav) = 0.009; (3) linkage assignment, Sav = 0.82, Var (Sav) = 0.005; and (4) literature database inclusion, Sav = 0.78, Var (Sav) = 0.031. These values represent moderate to high levels of agreement.

Future studies should focus on prospective methodologies, when possible, that use traditional hypothesis testing techniques. Use of the following methodologic procedures for assessing the impact of perioperative management of CRMDs is recommended: (1) comparison studies (i.e., one technique vs. another) when clinically feasible; (2) randomization; and (3) full reporting of sample size, effect size estimates, test scores, measures of variability, and P values.

B. Consensus-based Evidence

Consensus was obtained from multiple sources, including (1) survey opinion from Consultants who were selected based on their knowledge or expertise in perioperative management of CRMDs, (2) survey opinions from randomly selected samples of active members of the American Society of Anesthesiologists and active members of the HRS, (3) testimony from attendees of two publicly held open forums at a national anesthesia meeting and at a major cardiology meeting,§§§ (4) Internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 56% (n = 23 of 41) for Consultants, 15% (n = 89 of 600) for the ASA membership, and 15% (n = 44 of 300) for the HRS membership. Survey results are presented in the text of the document and in table 4.

The ASA Consultants were also asked to indicate which, if any, of the evidence linkages would change their clinical practices if the Advisory was instituted. The rate of return was 39% (n = 16 of 41). The percent of responding Consultants expecting no change associated with each linkage were as follows: preoperative evaluation—67%; preoperative patient preparation—67%; intraoperative monitoring of CRMDs—67%; emergency defibrillation or cardioversion—87%; postoperative monitoring of CRMDs—73%; postoperative interrogation and restoration of CRMD function—60%; intraoperative management of EMI during electrocautery—73%, radiofrequency ablation—73%, lithotripsy—80%, MRI—80%, radiation therapy—80%, and electroconvulsive therapy—73%. Forty percent of the respondents indicated that the Advisory would have no effect on the amount of time spent on a typical case. Nine respondents (60%) indicated that there would be an increase in the amount of time they would spend on a typical case with the implementation of this Advisory. The amount of increased time anticipated by these respondents ranged from 5 to 30 min.

### Table 4. Consultant and Membership Survey Responses: Percent Agreement/Disagreement*

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Consultants</th>
<th>ASA Members</th>
<th>HRS Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To perform a preoperative evaluation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Establish whether a patient has a CRMD.</td>
<td>23</td>
<td>89</td>
<td>44</td>
</tr>
<tr>
<td>Define the type of device.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Determine whether a patient is CRMD dependent for pacemaking function.</td>
<td>23</td>
<td>89</td>
<td>44</td>
</tr>
<tr>
<td>Determine CRMD function.</td>
<td>23</td>
<td>89</td>
<td>44</td>
</tr>
<tr>
<td>2. To prepare a CRMD patient for a procedure:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determine whether EMI is likely to occur.</td>
<td>23</td>
<td>88</td>
<td>44</td>
</tr>
<tr>
<td>Turn pacemaking rate-adaptive therapy off.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Program pacemaking function to asynchronous mode:</td>
<td>22</td>
<td>86</td>
<td>44</td>
</tr>
<tr>
<td>All CRMD patients.</td>
<td>22</td>
<td>86</td>
<td>44</td>
</tr>
<tr>
<td>Pacemaker-dependent patients only.</td>
<td>22</td>
<td>83</td>
<td>44</td>
</tr>
<tr>
<td>Suspend antiarrhythmia functions.</td>
<td>21</td>
<td>87</td>
<td>43</td>
</tr>
<tr>
<td>Consider using a bipolar electrocautery system (when applicable).</td>
<td>22</td>
<td>86</td>
<td>43</td>
</tr>
<tr>
<td>Consider using an ultrasonic (harmonic) scalpel (when applicable).</td>
<td>22</td>
<td>88</td>
<td>44</td>
</tr>
<tr>
<td>Assure the availability of temporary pacing and defibrillation equipment.</td>
<td>22</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Consider the possible effects of anesthetic agents or techniques on CRMD function.</td>
<td>22</td>
<td>86</td>
<td>44</td>
</tr>
<tr>
<td>3. Intraoperative monitoring should include:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous electrocardiography.</td>
<td>23</td>
<td>88</td>
<td>44</td>
</tr>
<tr>
<td>Continuous peripheral pulse monitoring.</td>
<td>23</td>
<td>88</td>
<td>44</td>
</tr>
<tr>
<td>4. For procedures using electrocautery:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position the electrosurgical receiving plate so current pathway does not pass through or near the generator or leads.</td>
<td>23</td>
<td>88</td>
<td>44</td>
</tr>
<tr>
<td>Avoid proximity of the cautery’s electrical field to the pulse generator or leads.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Use short, intermittent, and irregular bursts at the lowest feasible energy levels.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Use a bipolar electrocautery system (when applicable).</td>
<td>22</td>
<td>88</td>
<td>44</td>
</tr>
<tr>
<td>Use an ultrasonic (harmonic) scalpel (when applicable).</td>
<td>22</td>
<td>88</td>
<td>44</td>
</tr>
<tr>
<td>5. For radiofrequency ablation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoid direct contact between the ablation catheter and the CRMD and leads.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Keep the current path (electrode tip to return plate) as far away from the pulse generator and lead system as possible.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>6. For lithotripsy:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoid focusing the lithotripsy beam near the pulse generator.</td>
<td>23</td>
<td>86</td>
<td>44</td>
</tr>
<tr>
<td>If the lithotripsy system triggers on the R wave, disable atrial pacing before procedure.</td>
<td>23</td>
<td>86</td>
<td>44</td>
</tr>
<tr>
<td>7. For MRI:†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRI is contraindicated for all CRMD patients.</td>
<td>21</td>
<td>81</td>
<td>44</td>
</tr>
<tr>
<td>MRI is contraindicated for some but not all CRMD patients.</td>
<td>21</td>
<td>19</td>
<td>44</td>
</tr>
<tr>
<td>MRI is not contraindicated for any CRMD patient.</td>
<td>21</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td>8. For RT:†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT is contraindicated for all CRMD patients.</td>
<td>21</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td>RT is contraindicated for some but not all CRMD patients.</td>
<td>21</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td>RT is not contraindicated for any CRMD patient.</td>
<td>21</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td>9. For emergency defibrillation or cardioversion:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position the defibrillation or cardioversion pads as far as possible from the pulse generator.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>Use an anterior–posterior position.</td>
<td>23</td>
<td>84</td>
<td>44</td>
</tr>
<tr>
<td>Use a clinically appropriate energy output regardless of the device.</td>
<td>23</td>
<td>87</td>
<td>44</td>
</tr>
<tr>
<td>10. To treat CRMD patients postoperatively:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interrogate and restore CRMD function in the PACU or ICU.</td>
<td>23</td>
<td>88</td>
<td>44</td>
</tr>
</tbody>
</table>

* The percentages of respondents who agreed/disagreed with each item are presented. The percentages of respondents who were uncertain are not presented. † Respondents were asked to select one of the three choices. Therefore, the numbers represent percent agreement only.

ASA = American Society of Anesthesiologists; CRMD = cardiac rhythm management device; EMI = electromagnetic interference; HRS = Heart Rhythm Society; ICU = intensive care unit; MRI = magnetic resonance imaging; PACU = postanesthesia care unit; RT = radiation therapy.
72. Goldberg RJ, Badger JM: Major depressive disorder in patients with the implantable cardioverter defibrillator: Two cases treated with ECT. Psychosomatics 1993; 34:273–7
78. ACLS Provider Manual. Edited by Cummins RO. Dallas, American Heart Association, 2003
Practice Advisory for the Prevention and Management of Operating Room Fires

A Report by the American Society of Anesthesiologists Task Force on Operating Room Fires

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PRACTICE advisorys are systematically developed reports that are intended to assist decision making in areas of patient care. Advisories are based on a synthesis of scientific literature and analysis of expert opinion, clinical feasibility data, open forum commentary, and consensus surveys. Advisories developed by the American Society of Anesthesiologists (ASA) are not intended as standards, guidelines, or absolute requirements. They may be adopted, modified, or rejected according to clinical needs and constraints.

The use of practice advisories cannot guarantee any specific outcome. Practice advisories summarize the state of the literature and report opinions obtained from expert consultants and ASA members. Practice advisories are not supported by scientific literature to the same degree as standards or guidelines because of the lack of sufficient numbers of adequately controlled studies. Practice advisories are subject to periodic revision as warranted by the evolution of medical knowledge, technology, and practice.

The incidence of operating room (OR) fires is difficult to determine, due in part to the lack of a mandatory national reporting system for OR fires. Some estimates suggest that between 50 and 200 OR fires occur in the United States every year, with as many as 20% of reported fires resulting in serious injury or death.

Fire requires the presence of three components, known as the “fire triad”: (1) an oxidizer, (2) an ignition source, and (3) fuel.

- **Oxidizers** used in the OR are oxygen and nitrous oxide. An oxidizer-enriched atmosphere increases the likelihood and intensity of combustion. An oxidizer-enriched atmosphere commonly exists within closed or semi-closed breathing systems, including the patient’s airway. It can also be created locally when the configuration of the drapes and open oxygen sources (e.g., masks, nasal cannula) promote the trapping or pooling of oxygen or a mixture of oxygen and nitrous oxide.

- **Ignition** sources include, but are not limited to, electrosurgical or electrocautery devices, lasers, heated probes, drills and burrs, argon beam coagulators, fiberoptic light cables, and defibrillator paddles or pads.

- **Fuel** sources include, but are not limited to, tracheal tubes; sponges; drapes; gauze; alcohol-containing solutions (e.g., certain prepping solutions); solutions containing other volatile compounds, such as ether or acetone; oxygen masks; nasal cannulae; the patient’s hair; dressings; ointments; gowns; gastrointestinal tract gases; blankets; suction catheters; flexible endoscopes; fiberoptic cable coverings; gloves; and packaging materials.

**KEY CONCEPT: An oxidizer-enriched atmosphere occurs when there is any increase in oxygen concentration above room air level, and/or the presence of any concentration of nitrous oxide.**

A Definition of OR Fires, High-risk Procedures, and OR Fire Drills

For this Advisory, operating room fires are defined as fires that occur on or near patients who are under anesthesia care, including surgical fires, airway fires, and fires within the airway circuit. A surgical fire is defined as a fire that occurs on or in a patient. An airway fire is a specific type of surgical fire that occurs in a patient’s airway

Methodology

A. Definition of OR Fires, High-risk Procedures, and OR Fire Drills

For this Advisory, operating room fires are defined as fires that occur on or near patients who are under anesthesia care, including surgical fires, airway fires, and fires within the airway circuit. A surgical fire is defined as a fire that occurs on or in a patient. An airway fire is a specific type of surgical fire that occurs in a patient’s...
airway. Airway fires may or may not include fire in the attached breathing circuit.

A high-risk procedure is defined as one in which an ignition source (e.g., electrosurgery) may come in proximity to an oxidizer-enriched atmosphere (e.g., supplemental oxygen and/or nitrous oxide), thereby increasing the risk of fire. Examples of high-risk procedures include, but are not limited to, tonsillectomy, tracheostomy, removal of laryngeal papillomas, cataract or other eye surgery, burr hole surgery, or removal of lesions on the head, neck, or face.

An OR fire drill is defined as a formal and periodic rehearsal of the OR team’s planned response to a fire. In this Advisory, the OR fire drill is characterized as a "formal and periodic rehearsal" to indicate that it takes place during dedicated education time, not during patient care. In other words, an OR fire drill is not the same as a discussion or plan about fire management that takes place during direct patient care.

B. Purpose

The purposes of this Advisory are to (1) identify situations conducive to fire, (2) prevent the occurrence of OR fires, (3) reduce adverse outcomes associated with OR fires, and (4) identify the elements of a fire response protocol. Adverse outcomes associated with OR fires may include major or minor burns, inhalation injuries, infection, disfigurement, and death. Related adverse outcomes may include psychological trauma, prolonged hospitalization, delay or cancellation of surgery, additional hospital resource utilization, and liability.

C. Focus

This Advisory focuses on a specific care setting and subset of fires. The specific care setting is any OR or procedure area where anesthesia care is provided. The specific subset is fires that occur on the patient, in the airway, or in the breathing circuit. This Advisory does not address fires away from the patient (e.g., in a trash can), institutional preplanning for fire, or the responses of fire personnel.

D. Application

This Advisory is intended for use by anesthesiologists or other individuals working under the supervision of an anesthesiologist. Because prevention of OR fires requires close collaboration and prompt coordination between anesthesiologists, surgeons, and nurses, some responsibilities are shared among the disciplines. When shared responsibilities are described in this Advisory, the intent is to give the anesthesiologist a starting point for participating in the allocation and understanding of shared responsibilities. The Advisory may also serve as a resource for other physicians and healthcare professionals (e.g., technicians, safety officers, hospital administrators, biomedical engineers, industry representatives).

E. Task Force Members and Consultants

The ASA appointed a Task Force of nine members. These individuals included four anesthesiologists in private and academic practice from various geographic areas of the United States, an otolaryngologist, a perioperative registered nurse, a professional engineer/fire investigator, and two consulting methodologists from the ASA Committee on Standards and Practice Parameters. Two Task Force members are former firefighters.

The Task Force developed the Advisory by means of a seven-step process. First, they reached consensus on the criteria for evidence. Second, a systematic review and evaluation was performed on original, published, peer-reviewed and other research studies related to OR fires. Third, a panel of expert consultants was asked to (1) participate in opinion surveys on the effectiveness of various strategies for fire prevention, detection, and management and (2) review and comment on a draft of the Advisory developed by the Task Force. Fourth, opinions about the Advisory were solicited from a random sample of active members of the ASA. Fifth, the Task Force held an open forum at a major national meeting to solicit input on its draft recommendations. Sixth, the consultants were surveyed to assess their opinions on the feasibility of implementing this Advisory. Seventh, all available information was used to build consensus within the Task Force to formulate the advisory statements (appendix 1).

F. Availability and Strength of Evidence

Preparation of this Advisory followed a rigorous methodological process (appendix 2). Evidence was obtained from two principal sources: scientific evidence and opinion-based evidence.

Scientific Evidence. Study findings from published scientific literature were aggregated and are reported in summary form by evidence category, as described below. All literature (e.g., randomized controlled trials, observational studies, case reports) relevant to each topic was considered when evaluating the findings. However, for reporting purposes in this document, only the highest level of evidence (i.e., level 1, 2, or 3) within each category is included in the summary.

Category A: Supportive Literature. Randomized controlled trials report statistically significant ($P < 0.01$) differences between clinical interventions for a specified clinical outcome.

Level 1: The literature contains multiple randomized controlled trials, and the aggregated findings are supported by meta-analysis.\textsuperscript{§}
Level 2: The literature contains multiple randomized controlled trials, but there is an insufficient number of studies to conduct a viable meta-analysis for the purpose of this Advisory.

Level 3: The literature contains a single randomized controlled trial.

Category B: Suggestive Literature. Information from observational studies permits inference of beneficial or harmful relationships among clinical interventions and clinical outcomes.

Level 1: The literature contains observational comparisons (e.g., cohort, case-control research designs) of two or more clinical interventions or conditions and indicates statistically significant differences between clinical interventions for a specified clinical outcome.

Level 2: The literature contains noncomparative observational studies with associative (e.g., relative risk, correlation) or descriptive statistics.

Level 3: The literature contains case reports.

Category C: Equivocal Literature. The literature cannot determine whether there are beneficial or harmful relationships among clinical interventions and clinical outcomes.

Level 1: Meta-analysis did not find significant differences among groups or conditions.

Level 2: There is an insufficient number of studies to conduct meta-analysis and (1) randomized controlled trials have not found significant differences among groups or conditions or (2) randomized controlled trials report inconsistent findings.

Level 3: Observational studies report inconsistent findings or do not permit inference of beneficial or harmful relationships.

Category D: Insufficient Evidence from Literature. The lack of scientific evidence in the literature is described by the following terms.

Silent: No identified studies address the specified relationships among interventions and outcomes.

Inadequate: The available literature cannot be used to assess relationships among clinical interventions and clinical outcomes. The literature either does not meet the criteria for content as defined in the “Focus” of the Advisory or it does not permit a clear interpretation of findings due to methodologic concerns (e.g., confounding in study design or implementation).

Opinion-based Evidence. All opinion-based evidence relevant to each topic (e.g., survey data, open-forum testimony, Web-based comments, letters, editorials) is considered in the development of this Advisory. However, only the findings obtained from formal surveys are reported.

Opinion surveys were developed by the Task Force to address each clinical intervention identified in the document. Identical surveys were distributed to two groups of respondents: expert consultants and ASA members.

Category A: Expert Opinion. Survey responses from Task Force-appointed expert consultants are reported in summary form in the text. A complete listing of consultant survey responses is reported in appendix 2.

Category B: Membership Opinion. Survey responses from a random sample of members of the ASA and, when appropriate, responses from members of other organizations with expertise in the selected topics of interest are reported in summary form in the text. A complete listing of ASA member survey responses is reported in appendix 2.

Survey responses are recorded using a five-point scale and summarized based on median values.

Strongly Agree: Median score of 5 (at least 50% of the responses are 5)
Agree: Median score of 4 (at least 50% of the responses are 4 or 4 and 5)
Equivocal: Median score of 3 (at least 50% of the responses are 3, or no other response category or combination of similar categories contains at least 50% of the responses)
Disagree: Median score of 2 (at least 50% of responses are 2 or 1 and 2)
Strongly Disagree: Median score of 1 (at least 50% of responses are 1)

Category C: Informal Opinion. Open-forum testimony, Web-based comments, letters, and editorials are all informally evaluated and discussed during the development of the Advisory. When warranted, the Task Force may add educational information or cautionary notes based on this information.

Advisories

I. Education

Operating room fire safety education includes, but is not limited to, knowledge of institutional fire safety protocols and participation in institutional fire safety education. Case reports indicate that lack of education can result in severe injury and death from uncontrolled OR fires.6,7 [Category B3 evidence.]

The consultants and ASA members strongly agree that every anesthesiologist should have knowledge of institutional fire safety protocols for the OR, and should participate in OR fire safety education. The consultants and ASA members strongly agree that OR fire safety education for the anesthesiologist should emphasize the risk created by an oxidizer-enriched atmosphere.
Advisory Statements. All anesthesiologists should have fire safety education, specifically for OR fires, with emphasis on the risk created by an oxidizer-enriched atmosphere.

II. OR Fire Drills

A case report indicates that OR fire drills and simulation training can result in improved staff response to a fire.8 [Category B3 evidence.]

The consultants strongly agree and ASA members agree that all anesthesiologists should periodically participate in OR fire drills with the entire OR team. The consultants and ASA members strongly agree that participation should take place during dedicated educational time, not during patient care.

Advisory Statements. Anesthesiologists should periodically participate in OR fire drills with the entire OR team. This formal rehearsal should take place during dedicated educational time, not during patient care.

III. Preparation

Preparation for OR fires includes (1) determining whether or not a high-risk situation exists and (2) a team discussion of the strategy for the prevention and management of an OR fire in a high-risk situation. The literature is silent regarding whether a preoperative determination of a high-risk situation or a team discussion of OR fire strategy reduces the incidence or severity of an OR fire. [Category D evidence.]

The consultants strongly agree and ASA members agree that anesthesiologists should participate with the entire OR team in assessing the risk of an OR fire for each case and determining whether a high-risk situation exists. The consultants strongly agree and ASA members agree that all team members should jointly agree on how a fire will be prevented and managed for each particular procedure. The consultants and ASA members strongly agree that a protocol for the prevention and management of fires should be posted in each location where a procedure is performed.

Advisory Statements. For every case, the anesthesiologist should participate with the entire OR team (e.g., during the surgical pause) in determining whether a high-risk situation exists. If a high-risk situation exists, all team members—including the anesthesiologist—should take a joint and active role in agreeing on how a fire will be prevented and managed. Each team member should be assigned a specific fire management task to perform in the event of a fire (e.g., removing the tracheal tube, stopping the flow of airway gases). Each team member should understand that his or her preassigned task should be performed immediately if a fire occurs, without waiting for another team member to take action. When a team member has completed a preassigned task, he or she should help other team members perform tasks that are not yet complete.

In every OR and procedure area where a fire triad can exist (i.e., an oxidizer-enriched atmosphere, an ignition source, and fuel), an easily visible protocol for the prevention and management of fires should be displayed (fig. 1).

Equipment for managing a fire should be readily available in every procedural area where a fire triad may exist. Table 1 provides an example of fire management equipment that should be in or near the OR or procedural area.

IV. Prevention

Prevention of OR fires includes (1) minimizing or avoiding an oxidizer-enriched atmosphere near the surgical site, (2) safely managing ignition sources, and (3) safely managing fuels.

Comparative studies indicate that a wide range of material ignites more readily in an oxygen-enriched atmosphere than in room air.9–13 [Category B1 evidence.] One comparative study with awake volunteer subjects showed that the configuration of surgical drapes can result in oxygen buildup, increasing the risk of fire.14 [Category B1 evidence.] This study also indicated that replacing oxygen with compressed air or discontinuing supplemental oxygen for a period of time reduces oxygen buildup without significantly reducing oxygen saturation levels. Similarly, a randomized controlled trial comparing supplemental oxygen and compressed air in sedated patients undergoing cataract surgery found no differences in oxygen saturation.15 [Category C2 evidence.]

Observational studies and case reports indicate that electrosurgery or electrosurgical devices and lasers are common sources of ignition for many OR fires, particularly when used in an oxidizer-enriched atmosphere.16–68 [Category B2–3 evidence.]

Case reports indicate that alcohol-based skin-prepping agents generate volatile vapors that ignite easily. These reports suggest that insufficient drying time after application of alcohol-based skin-prepping agents is a cause of fires on patients.23,69–73 [Category B3 evidence.] Comparative studies show that conventional tracheal tubes, when exposed to a laser beam, are more likely to ignite or melt than laser-resistant tracheal tubes.74–84 [Category B1 evidence.] Case reports indicate that dry sponges and gauze are common sources of fuel.7,19,53,43,45,55,64,83–87 Comparative studies demonstrate that the flammability of sponges, cottonoids, or packing material is reduced when wet rather than dry or partially dry.88–91 [Category B1 evidence.]

For all procedures, the consultants and ASA members strongly agree that flammable skin prepping solutions should be dry before draping. They strongly agree that surgical drapes should be configured to prevent oxygen from accumulating under the drapes or from flowing into the surgical site. They strongly agree that sponges
Fig. 1. Operating room fires algorithm. CO2 = carbon dioxide; OR = operating room.
Several containers of sterile saline
A CO₂ fire extinguisher
Replacement tracheal tubes, guides, facemasks
Rigid laryngoscope blades; this may include a rigid fiberoptic laryngoscope
Replacement airway breathing circuits and lines
Replacement drapes, sponges

* Some facilities or locations may benefit from assembling a portable cart containing equipment and supplies that expedite the immediate response to an operating room fire. The contents of such a cart will vary depending on local conditions and resources. If the items needed for an immediate response to an operating room fire are already available, there may be no added benefit to assembling a portable cart.

CO₂ = carbon dioxide

should be moistened when used near an ignition source, particularly when used in or near the airway.

For high-risk procedures (i.e., proximity of an ignition source and an oxidizer-enriched atmosphere), the consultants and ASA members strongly agree that anesthesiologists should collaborate with the procedure team for the purpose of preventing and managing a fire. They strongly agree that the surgeon should be notified whenever an ignition source is in proximity to an oxidizer-enriched atmosphere or when the concentration of oxidizer has increased. They strongly agree that the fraction of inspired oxygen (FiO₂) delivered to the patient should be kept as low as clinically feasible when an ignition source is in proximity to an oxygen-enriched atmosphere. They strongly agree that the reduction of FiO₂ delivered to the patient should be guided by monitoring patient oxygenation (e.g., pulse oximetry). Task Force members agree that the reduction of FiO₂ should be monitored, if feasible, by measuring inspired, expired, and/or delivered oxygen concentration. They strongly agree that the use of nitrous oxide should be avoided in settings that are considered high risk for fire. The consultants strongly agree and ASA members agree that oxygen or nitrous oxide buildup may be minimized by either insufflating with medical air or scavenging the operating field with suction.

For laser surgery, consultants and ASA members strongly agree that laser resistant tracheal tubes should be used, and that the tube choice should be appropriate for the procedure and laser. They both strongly agree that the tracheal cuff of the laser tube should be filled with saline rather than air, when feasible. The consultants strongly agree and the ASA members agree that saline in tracheal tube cuff should be tinted with methylene blue to act as a marker for cuff puncture by a laser.

Surgery inside the airway can bring an ignition source into proximity with an oxidizer-enriched atmosphere, thereby creating a high-risk situation. For cases involving surgery inside the airway, consultants and ASA members both agree that a cuffed tracheal tube should be used instead of an uncuffed tracheal tube when medically appropriate. Because an elevated FiO₂ is often necessary during tracheostomy, the Task Force strongly agrees that surgeons should be advised not to enter the trachea with an ignition source such as an electrosurgical device. If an electrosurgical device must be used, the anesthesiologist should request that the surgeon provide adequate warning to allow the concentration of oxidizer to be minimized before the trachea is entered. Consultants and ASA members were asked to report the time that they believe is needed to reduce oxygen or nitrous oxide concentration to a safe level before using an ignition source. For patients being ventilated with a tracheal tube, consultants report a range of time of less than 1 min to 5 min (mean = 1.8 min), and ASA members report a range of time of less than 1 min to 10 min (mean = 2.9 min). For patients wearing a facemask or nasal cannula, both the consultants and ASA members report a range of time of less than 1 min to 5 min (mean = 1.7 min for consultants, and mean = 2.3 min for ASA members). The consultants and ASA members both agree that the oropharynx should be scavenged with suction during oral procedures.

Surgery around the face, head, or neck can bring an ignition source into proximity with an oxidizer-enriched atmosphere, thereby creating a high-risk situation. When monitored anesthesia care is considered for surgery around the face, head, or neck, the Task Force strongly agrees that two specific factors should be considered: (1) the required depth of sedation and (2) oxygen dependence. The Task Force agrees that a sealed gas delivery device (e.g., cuffed tracheal tube or laryngeal mask) should be considered if moderate or deep sedation is required or used, or if the patient exhibits oxygen dependence. If neither factor is present, an open gas delivery device (e.g., facemask or nasal cannula) may be considered. If an open gas delivery system is used, the Task Force agrees that before an ignition source is activated around the face, head, or neck, the surgeon should give the adequate notice that the ignition source will be activated. The anesthesiologist should (1) stop the delivery of supplemental oxygen or reduce the delivery to the minimum required to avoid hypoxia, and (2) wait a few minutes between decreasing the flow of supplemental oxygen and approving the activation of the ignition source. In the unlikely event of nitrous oxide delivery with an open system (e.g., facemask or nasal cannula), the Task Force agrees that the anesthesiologist should (1) stop the delivery of nitrous oxide, and (2) wait a few minutes between stopping the nitrous oxide and approving the activation of the ignition source.

Advisory Statements. To the extent that is medically appropriate, the following basic principles should be applied to the management of oxidizers, ignition sources, and fuels:

- The anesthesiologist should collaborate with all members of the procedure team throughout the procedure...
to minimize the presence of an oxidizer-enriched atmosphere in proximity to an ignition source.

- Surgical drapes should be configured to minimize the accumulation of oxidizers (oxygen and nitrous oxide) under the drapes and from flowing into the surgical site.
- Flammable skin prepping solutions should be dry before draping.
- Gauze and sponges should be moistened when used in proximity to an ignition source.

For high-risk procedures, the anesthesiologist should notify the surgeon whenever there is a potential for an ignition source to be in proximity to an oxidizer-enriched atmosphere or when there is an increase in oxidizer concentration at the surgical site. Any reduction in supplied oxygen to the patient should be assessed by monitoring (1) pulse oximetry and, if feasible, (2) inspired, exhaled, and/or delivered oxygen concentration.

For laser procedures, a laser-resistant tracheal tube should be used, and the tube should be chosen to be resistant to the laser used for the procedure (e.g., carbon dioxide [CO₂], Nd:YAG, Ar, Er:YAG, KTP). The tracheal cuff of the laser tube should be filled with saline and colored with an indicator dye such as methylene blue. Before activating a laser, the surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated. The anesthesiologist should (1) reduce the delivered oxygen concentration to the minimum required to avoid hypoxia, (2) stop the use of nitrous oxide, and (3) wait a few minutes after reducing the oxidizer-enriched atmosphere before approving activation of the laser.

For cases involving an ignition source and surgery inside the airway, cuffed tracheal tubes should be used when clinically appropriate. The anesthesiologist should advise the surgeon against entering the trachea with an ignition source (e.g., electrosurgery unit). Before activating an ignition source inside the airway, the surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated. The anesthesiologist should (1) reduce the delivered oxygen concentration to the minimum required to avoid hypoxia, (2) stop the use of nitrous oxide, and (3) wait a few minutes after reducing the oxidizer-enriched atmosphere before approving activation of the laser.

For cases involving moderate or deep sedation, an ignition source, and surgery around the face, head, or neck, the anesthesiologist and surgeon should develop a plan that accounts for the level of sedation and the patient’s need for supplemental oxygen.

- If moderate or deep sedation is required or used, or if the patient exhibits oxygen dependence, the anesthesiologist and surgeon should consider a sealed gas delivery device (e.g., cuffed tracheal tube or laryngeal mask).
- If moderate or deep sedation is not required, and the patient does not exhibit oxygen dependence, an open gas delivery device (e.g., facemask or nasal cannula) may be considered. Before activating an ignition source around the face, head, or neck, the surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated. The anesthesiologist should (1) stop the delivery of supplemental oxygen or reduce the delivered oxygen concentration to the minimum required to avoid hypoxia, and (2) wait a few minutes after reducing the oxidizer-enriched atmosphere before approving the activation of the ignition source.

V. Management of OR Fires

Management of OR fires includes (1) recognizing the early signs of fire, (2) halting the procedure, (3) making appropriate attempts to extinguish the fire, (4) following an evacuation protocol when medically appropriate, and (5) delivering postfire care to the patient.

Case reports indicate that early signs of a fire may include a flame or flash, unusual sounds, odors, smoke, or heat.22–24,41,42,46,53,62,73,92 [Category B3 evidence.] One case report indicates that removing the tracheal tube and stopping the flow of oxygen can minimize patient injury.55 [Category B3 evidence.] One case report demonstrated that pouring saline into the patient’s tracheal tube was effective in extinguishing the fire.93 [Category B3 evidence.] One case of a patient death from an OR fire indicated that fire extinguishers were available but not used by the OR staff on the patient.7

When early warning signs of a fire are noted, the consultants and ASA members strongly agree that there should be an immediate halt to the procedure. When a fire is definitely present, the consultants and ASA members strongly agree that there should be an immediate announcement of fire, followed by an immediate halt to the procedure.

For a fire in the airway or breathing circuit, the consultants and ASA members strongly agree that, as quickly as possible, the tracheal tube should be removed and all flammable and burning materials should be removed from the airway. The consultants strongly agree and ASA members agree that the delivery of all airway gases should stop, and they both agree that saline should be poured into the patient’s airway to extinguish any residual embers and cool the tissues.

For a fire elsewhere on or in the patient, the consultants agree and ASA members are equivocal regarding whether the delivery of all airway gases should stop. They both strongly agree that all burning and flammable materials (including all drapes) should be removed from the patient, and that all burning materials in, on, or
around the patient should be extinguished (e.g., with saline, water, or a fire extinguisher).

Seventy-one percent of the consultants and 77% of the ASA members indicated that the preferred means for safely responding to an OR fire is for each team member to immediately perform a fire management task in a predetermined sequence. Twenty-nine percent of the consultants and 23% of the ASA members indicated that the preferred means of safely responding to an OR fire is for each team member to immediately perform a preassigned task, without waiting for others to act. The Task Force believes that a predetermined sequence of tasks can be attempted when a fire occurs, but that team members should not wait for each other if there are impediments to following the predetermined sequence of tasks in a rapid manner. The Task Force agrees that a team member who has completed a preassigned task may assist another team member whose task is not yet complete.

If the first attempt to extinguish the fire in, on, or around the patient is not successful, the consultants and ASA members both agree that a CO₂ fire extinguisher should be used. If fire persists after use of a CO₂ fire extinguisher, consultants and ASA members both strongly agree that the fire alarm should be activated and the patient should be evacuated, if feasible. The consultants and ASA members both agree that the door to the room should be closed and not reopened. The consultants strongly agree and the ASA members agree that the medical gas supply to the room should be turned off after evacuation.

The consultants and ASA members strongly agree that after a fire has been extinguished, the patient’s status should be assessed and a plan should be devised for ongoing care of the patient. When an airway or breathing circuit fire has been extinguished, consultants and ASA members both agree that ventilation should be re-established, avoiding supplemental oxygen and nitrous oxide, if possible. Both the consultants and ASA members strongly agree that the tracheal tube should be examined to assess whether fragments have been left behind in the airway. The consultants strongly agree and the ASA members agree that rigid bronchoscopy should be considered to assess thermal injury, look for tracheal tube fragments, and aid in the removal of residual materials. If the fire did not involve the airway and the patient was not intubated before the fire, the consultants and ASA members both strongly agree that the patient should be assessed for injury related to smoke inhalation.

Advisory Statements. When an early warning sign is noted, halt the procedure and call for an evaluation of fire. Early signs of a fire may include unusual sounds (e.g., a “pop,” “snap,” or “foomp”), unusual odors, unexpected smoke, unexpected heat, unexpected movement of drapes, discoloration of drapes or breathing circuit, unexpected patient movement or complaint, and unexpected flash or flame.

When a fire is definitely present, immediately announce the fire, halt the procedure, and initiate fire management tasks.

Team members should perform their preassigned fire management tasks as quickly as possible. Before the procedure, the team may identify a predetermined order for performing the tasks. If a team member cannot rapidly perform his or her task in the predetermined order, other team members should perform their tasks without waiting. When a team member has completed a preassigned task, he or she should help other members perform tasks that are not yet complete.

The following lists are shown in an order that the team may wish to consider in its discussion of a predetermined sequence.

For a fire in the airway or breathing circuit, as fast as possible:

- Remove the tracheal tube.
- Stop the flow of all airway gases.
- Remove all flammable and burning materials from the airway.
- Pour saline or water into the patient’s airway.

For a fire elsewhere on or in the patient, as fast as possible:

- Stop the flow of all airway gases.
- Remove all drapes, flammable, and burning materials from the patient.
- Extinguish all burning materials in, on and around the patient (e.g., with saline, water, or smothering).

If the airway or breathing circuit fire is extinguished:

- Reestablish ventilation by mask, avoiding supplemental oxygen and nitrous oxide, if possible.
- Extinguish and examine the tracheal tube to assess whether fragments were left in the airway. Consider bronchoscopy (preferably rigid) to look for tracheal tube fragments, assess injury, and remove residual debris.
- Assess the patient’s status and devise a plan for ongoing care.

If the fire elsewhere on or in the patient is extinguished:

* Some experts and educators recommend an initial step that involves two simultaneous actions: removal of the tracheal tube and stopping the flow of medical gases (e.g., by disconnecting the breathing circuit at the Y-piece or the inspiratory gas limb). The intent is to prevent a "blowtorch" effect caused by continued gas flow through a burning tracheal tube. This "blowtorch" effect can spread fire to other locations on or near the patient, and may cause additional burns on the patient or other members of the OR team. The Task Force has carefully considered this concern and agrees that these simultaneous actions represent an ideal response. However, the Task Force is concerned that, in actual practice, the simultaneous actions may be difficult to accomplish or may result in delay when one team member waits for another. Therefore, the Task Force recommends that the actions take place as fast as possible.
Assess the patient’s status and devise a plan for ongoing care of the patient.

Assess for smoke inhalation injury if the patient was not intubated.

If the fire is not extinguished after the first attempt (e.g., after performing the preassigned tasks):

- Use a CO₂ fire extinguisher, on, or around the patient.
- If the fire persists after use of the CO₂ fire extinguisher:
  - Activate the fire alarm.
  - Evacuate the patient if feasible, following institutional protocols.
  - Close the door to the room to contain the fire, and do not reopen it or attempt to reenter the room.
  - Turn off the medical gas supply to the room.

Follow local regulatory reporting requirements (e.g., report fires to your local fire department and state department of health). Treat every fire as an adverse event, following your institutional protocol.

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Appendix 1: Primary Findings of the Advisory Task Force

I. Education

- All anesthesiologists should have fire safety education, specifically for OR fires, with emphasis on the risk created by an oxidizer-enriched atmosphere.

II. OR Fire Drills

- Anesthesiologists should periodically participate in OR fire drills, with the entire OR team. This formal rehearsal should take place during dedicated educational time, not during patient care.

III. Prevention

- For every case, the anesthesiologist should participate with the entire OR team (e.g., during the surgical pause) in assessing and determining whether a high-risk situation exists.

- If a high-risk situation exists, all team members—including the anesthesiologist—should take a joint and active role in agreeing on how a fire will be prevented and managed.

- Each team member should be assigned a specific fire management task to perform in the event of a fire (e.g., removing the tracheal tube, turning off the airway gases).

- Each team member should understand that his or her preassigned task should be performed immediately if a fire occurs, without waiting for another team member to take action.

- When a team member has completed a preassigned task, he or she should help other team members perform tasks that are not yet complete.

- In every OR and procedure area where a fire triad can exist (i.e., an oxidizer-enriched atmosphere, an ignition source, and fuel), an easily visible protocol for the prevention and management of fires should be displayed.

- Equipment for managing a fire should be readily available in every procedural location where a fire triad may exist.

IV. Prevention

- The anesthesiologist should collaborate with all members of the procedure team throughout the procedure to minimize the presence of an oxidizer-enriched atmosphere in proximity to an ignition source.

- For all procedures:
  - Surgical drapes should be configured to minimize the accumulation of oxidizers (oxygen and nitrous oxide) under the drapes and from flowing into the surgical site.
  - Flammable skin prepping solutions should be dry before draping.
  - Gauze and sponges should be moisturized before use in proximity to an ignition source.

- For high-risk procedures:
  - The anesthesiologist should notify the surgeon whenever there is a potential for an ignition source to be in proximity to an oxidizer-enriched atmosphere or when there is an increase in oxidizer concentration at the surgical site.
  - Any reduction in supplied oxygen to the patient should be assessed by monitoring (1) pulse oximetry and, if feasible, (2) inspired, exhaled, and/or delivered oxygen concentration.

- For laser procedures:
  - A laser-resistant tracheal tube should be used.
    - The laser-resistant tracheal tube used should be chosen to be resistant to the laser used for the procedure (e.g., CO₂, Nd:YAG, Ar, Er:YAG, KTP).
  - The tracheal cuff of the laser tube should be filled with saline and colored with an indicator dye such as methylene blue.
  - Before activating a laser:
    - The surgeon should give the anesthesiologist adequate notice that the laser is about to be activated.
    - The anesthesiologist should:
      - Reduce the delivered oxygen concentration to the minimum required to avoid hypoxia.
      - Stop the use of nitrous oxide.
      - Wait a few minutes after reducing the oxidizer-enriched atmosphere before considering activation of the laser.

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The surgeon should give the anesthesiologist adequate notice that the ignition source is about to be activated.

The anesthesiologist should:
- Reduce the delivered oxygen concentration to the minimum required to avoid hypoxia.
- Stop the use of nitrous oxide.
- Wait a few minutes after reducing the oxidizer-enriched atmosphere before approving the activation of the ignition source.
- Close the door to the room to contain the fire and do not reopen it or attempt to reenter the room.
- Activate the fire alarm.
- Evacuate the patient if feasible, following institutional protocols.
- Assess the patient’s status and devise a plan for ongoing care.
- Reestablish ventilation by mask, avoiding supplemental oxygen and nitrous oxide, if possible.
- Extinguish and examine the tracheal tube to assess whether fragments were left in the airway.
- Consider bronchoscopy (preferably rigid) to look for tracheal tube fragments, assess injury, and remove residual debris.
- Assess the patient’s status and devise a plan for ongoing care.
- Stop the flow of all airway gases.
- Remove the tracheal tube and any other oral, pharyngeal, or nasopharyngeal airway equipment, if present.
- Reestablish ventilation by mask, avoiding supplemental oxygen and nitrous oxide, if possible.
- Consider bronchoscopy (preferably rigid) to look for tracheal tube fragments, assess injury, and remove residual debris.
- Assess the patient’s status and devise a plan for ongoing care.
- Assess for smoke inhalation injury if the patient was not intubated.
- Treat every fire as an adverse event, following your institutional protocol.

If the fire is not extinguished after the first attempt (e.g., after performing the preassigned tasks):
- Use a CO₂ fire extinguisher in, on, or around the patient.
- If the fire persists after use of the CO₂ fire extinguisher:
  - Activate the fire alarm.
  - Evacuate the patient if feasible, following institutional protocols.
  - Close the door to the room to contain the fire and do not reopen it or attempt to reenter the room.
  - Turn off the medical gas supply to the room.
- Follow local regulatory reporting requirements (e.g., report fires to your local fire department and state department of health).
- Circumvent scavenging with suction may be used to reduce oxidizer enrichment in the operative field.
- Pour saline or water into the patient’s airway.
- Stop the flow of all airway gases.
- Remove the tracheal tube.
- Reestablish ventilation by mask, avoiding supplemental oxygen and nitrous oxide, if possible.
- Extinguish and examine the tracheal tube to assess whether fragments were left in the airway.
- Consider bronchoscopy (preferably rigid) to look for tracheal tube fragments, assess injury, and remove residual debris.
- Assess the patient’s status and devise a plan for ongoing care.
- Assess for smoke inhalation injury if the patient was not intubated.
- Treat every fire as an adverse event, following your institutional protocol.

Appendix 2: Methods and Analyses

A. State of the Literature
For this Advisory, a literature review was used in combination with opinions obtained from experts and other sources (e.g., professional society members, open forums, Web-based postings) to provide guidance to practitioners regarding OR fire prevention and management. Both the literature review and opinion data were based on evidence linkage interventions, or statements regarding potential relationships between fire prevention and management interventions and OR fire outcomes.** The evidence linkage interventions are listed below.

I. Education
1. Fire safety education, with an emphasis on an oxidizer-enriched atmosphere

II. OR Fire Drills
2. Periodic participation in OR fire drills

III. Preparation
3. Display of an easily visible protocol for the prevention and management of fires
4. Preoperative determination of a high-risk situation
5. OR team discussion of OR fire strategy

IV. Prevention
6. Surgical drapes configuration to minimize the accumulation of oxidizers
7. Drying of flammable skin prepping solutions
8. Moistening of sponges and gauze when used in proximity to an ignition source
9. Reducing the concentration of supplied oxygen for high-risk procedures
10. Avoidance of nitrous oxide for high-risk procedures

** Unless otherwise specified, outcomes for the listed interventions refer to the occurrence of fire or adverse sequelae.
11. Cuffed versus uncuffed tracheal tubes for cases in or around the airway
12. Insufflating with medical air during cases in or around the airway
13. Scavenging with suction during cases in or around the airway
14. Laser-resistant versus non–laser-resistant tracheal tubes during laser surgery
15. Filling the tracheal cuff of the laser tube with saline colored with an indicator dye

V. Management

16. Early signs of a fire include a flame or flash, unusual sounds, odors, smoke, or heat (observational)
17. Removing the tracheal tube and stopping the flow of oxygen to minimize patient injury after an airway or breathing circuit fire
18. Pouring saline into the patient’s tracheal tube to extinguish an airway fire

For the literature review, potentially relevant studies were identified via electronic and manual searches of the literature. The literature search covered a 56-yr period from 1952 through 2007. More than 400 citations were initially identified, yielding a total of 340 articles that addressed topics related to the evidence linkages and met our criteria for inclusion. After review of the articles, 240 studies did not provide direct evidence and were subsequently eliminated. A total of 100 articles contained direct linkage-related evidence.†† No evidence linkage contained enough studies with well-defined experimental designs and statistical information to conduct a quantitative analysis (i.e., meta-analysis).

Interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a $\kappa$ statistic for two-rater agreement pairs were as follows:

(1) type of study design, $\kappa = 0.63–0.82$; (2) type of analysis, $\kappa = 0.40–0.87$; (3) evidence linkage assignment, $\kappa = 0.84–1.00$; and (4) literature inclusion for database, $\kappa = 0.69–1.00$. Three-rater chance-corrected agreement values were (1) study design, Sav = 0.69, Var (Sav) = 0.013; (2) type of analysis, Sav = 0.57, Var (Sav) = 0.031; (3) linkage assignment, Sav = 0.89, Var (Sav) = 0.004; and (4) literature database inclusion, Sav = 0.79, Var (Sav) = 0.025. These values represent moderate to high levels of agreement.

B. Consensus-based Evidence

Consensus was obtained from multiple sources, including (1) survey opinion from consultants who were selected based on their knowledge or expertise in OR fire prevention and management, (2) survey opinions solicited from active members of the ASA, (3) testimony from attendees of a publicly held open forum at a national anesthesia meeting, (4) Internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 52% (n = 38 of 73) for the consultants, and 64 surveys were received from active ASA members. Results of the surveys are reported in tables 2 and 3 and in the text of the Advisory.

The consultants were asked to indicate which, if any, of the evidence linkages would change their clinical practices if the Advisory was instituted. The rate of return was 18% (n = 13 of 73). The percent of responding consultants expecting a change in their practice associated with each linkage topic was as follows: (1) education, 77%; (2) OR fire drills, 69%; (3) team discussion of fire strategy, 69%; (4) minimizing or avoiding an oxidizer-enriched atmosphere near the surgical site, 38%; (5) managing ignition sources, 38%; (6) managing fuels, 31%; (7) identification of a high-risk procedure, 85%; (8) management of a high-risk procedure, 31%; and (9) OR fire management, 77%. Eighty-five percent of the respondents indicated that the Advisory would have no effect on the amount of time spent on a typical case, and 15% indicated that there would be an increase of 1–5 min in the amount of time spent on a typical case with the implementation of this Advisory.

†† A complete list of references used to develop this Advisory is available on the ANESTHESIOLOGY Web site, www.anesthesiology.org, or by writing to the American Society of Anesthesiologists.
Table 2. Consultant Survey Responses

<table>
<thead>
<tr>
<th>Education</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Every anesthesiologist should have knowledge of institutional fire</td>
<td>38</td>
<td>92.1*</td>
<td>7.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1b. Every anesthesiologist should participate in OR fire safety education</td>
<td>38</td>
<td>81.6*</td>
<td>15.8</td>
<td>2.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1c. OR fire safety education for the anesthesiologist should emphasize</td>
<td>38</td>
<td>81.6*</td>
<td>18.4</td>
<td>0.0</td>
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<td>0.0</td>
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<tr>
<td>OR fire drills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2a. All anesthesiologists should periodically participate in OR fire</td>
<td>38</td>
<td>60.5*</td>
<td>31.6</td>
<td>5.3</td>
<td>2.6</td>
<td>0.0</td>
</tr>
<tr>
<td>2b. Participation in an OR fire drill should take place during dedicated</td>
<td>38</td>
<td>50.0*</td>
<td>34.2</td>
<td>5.3</td>
<td>10.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Anesthesiologists should participate with the entire OR team in</td>
<td>38</td>
<td>57.9*</td>
<td>29.0</td>
<td>2.6</td>
<td>10.5</td>
<td>0.0</td>
</tr>
<tr>
<td>4. All team members should agree on how an OR fire will be prevented and</td>
<td>38</td>
<td>60.5*</td>
<td>29.0</td>
<td>7.9</td>
<td>2.6</td>
<td>0.0</td>
</tr>
<tr>
<td>5. Hospitals and procedure units should post a protocol for the</td>
<td>38</td>
<td>50.0*</td>
<td>26.3</td>
<td>18.4</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Prevention for all procedures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Flammable skin prepping solutions should be dry before draping</td>
<td>38</td>
<td>86.8*</td>
<td>13.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7. Surgical drapes should be configured to prevent oxygen from</td>
<td>38</td>
<td>76.3*</td>
<td>18.4</td>
<td>2.6</td>
<td>2.6</td>
<td>0.0</td>
</tr>
<tr>
<td>8. Sponges should be moistened, particularly when used in or near the</td>
<td>38</td>
<td>63.2*</td>
<td>15.8</td>
<td>21.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Prevention for high-risk† procedures</td>
<td></td>
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<tr>
<td>9. Anesthesiologists should collaborate with the procedure team for the</td>
<td>38</td>
<td>84.2*</td>
<td>15.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>10. The surgeon should be notified of an increase in or the presence of</td>
<td>38</td>
<td>84.2*</td>
<td>15.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>11a. Oxygen levels should be kept as low as clinically feasible while</td>
<td>38</td>
<td>81.6*</td>
<td>13.2</td>
<td>2.6</td>
<td>0.0</td>
<td>2.6</td>
</tr>
<tr>
<td>11b. The reduction of FIO2 should be guided by monitoring patient</td>
<td>38</td>
<td>86.8*</td>
<td>7.9</td>
<td>5.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>12. The use of nitrous oxide should be avoided in settings that are</td>
<td>38</td>
<td>52.6*</td>
<td>26.3</td>
<td>15.8</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>13. Oxygen or nitrous oxide buildup may be minimized by either</td>
<td>38</td>
<td>50.0*</td>
<td>36.8</td>
<td>10.5</td>
<td>2.6</td>
<td>0.0</td>
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<tr>
<td>Prevention during cases in or around the airway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>14. Cuffed tracheal tubes should be used instead of uncuffed</td>
<td>38</td>
<td>39.5</td>
<td>31.6*</td>
<td>23.7</td>
<td>5.2</td>
<td>0.0</td>
</tr>
<tr>
<td>15. The oropharynx should be scavenged with suction during oral</td>
<td>38</td>
<td>42.1</td>
<td>23.7*</td>
<td>28.9</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>16. The sufficient amount of time needed to reduce oxygen or nitrous</td>
<td>Mean = 1.76 min,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. The sufficient amount of time needed to reduce oxygen or nitrous</td>
<td>Range = 0.25–5 min</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Prevention during laser surgery</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>18. Laser-resistant tracheal tubes appropriate to the procedure and</td>
<td>38</td>
<td>68.4*</td>
<td>29.0</td>
<td>2.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>19a. Tracheal tube cuffs should be filled with saline rather than air,</td>
<td>38</td>
<td>71.1*</td>
<td>26.3</td>
<td>2.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

(continued)
Table 2. Continued

<table>
<thead>
<tr>
<th>Management of OR fires</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>19b. Saline in tracheal tube cuffs should be tinted with methylene blue to act as a marker for cuff puncture by a laser</td>
<td>38</td>
<td>50.0*</td>
<td>39.5</td>
<td>10.5</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>20. When early warning signs of a fire are noted, the procedure should be halted immediately</td>
<td>38</td>
<td>78.9*</td>
<td>15.8</td>
<td>5.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>21. When a fire is definitely present, the fire should be immediately announced and the procedure should halt</td>
<td>38</td>
<td>92.1*</td>
<td>7.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>22. For a fire in the airway or breathing circuit:</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>a. The tracheal tube should be removed as quickly as possible</td>
<td>38</td>
<td>78.9*</td>
<td>13.2</td>
<td>7.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>b. All flammable and burning materials should be removed from the airway as quickly as possible</td>
<td>38</td>
<td>94.7*</td>
<td>5.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c. The delivery of all airway gases should stop</td>
<td>38</td>
<td>73.7*</td>
<td>18.4</td>
<td>5.3</td>
<td>2.6</td>
<td>0.0</td>
</tr>
<tr>
<td>d. Saline should be poured into the patient’s airway to extinguish any residual embers and cool the tissues</td>
<td>38</td>
<td>47.4</td>
<td>21.0*</td>
<td>21.0</td>
<td>7.9</td>
<td>2.6</td>
</tr>
<tr>
<td>23. For a fire elsewhere on or in the patient:</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. The delivery of all airway gases should stop</td>
<td>38</td>
<td>47.4</td>
<td>13.1*</td>
<td>23.7</td>
<td>15.8</td>
<td>0.0</td>
</tr>
<tr>
<td>b. All burning and flammable materials (including all drapes) should be removed from the patient</td>
<td>38</td>
<td>89.5*</td>
<td>10.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c. All burning materials in, on and around the patient should be extinguished (e.g., with saline, water, or a fire extinguisher)</td>
<td>38</td>
<td>86.8*</td>
<td>13.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>24. The preferred means of safely responding to an OR fire is:</td>
<td></td>
<td>Agree = 29%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. For each team member to immediately respond without waiting for others to act</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>b. To immediately initiate a predetermined sequence of responses</td>
<td></td>
<td>Agree = 71%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>25. If the first attempt to extinguish the fire is not successful, a CO2 fire extinguisher should be used</td>
<td>38</td>
<td>39.5</td>
<td>39.5*</td>
<td>13.1</td>
<td>7.9</td>
<td>0.0</td>
</tr>
<tr>
<td>26. If the fire persists after use of a CO2 fire extinguisher:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. The fire alarm should be activated</td>
<td>38</td>
<td>79.0*</td>
<td>10.5</td>
<td>10.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>b. The patient should be evacuated, if feasible</td>
<td>38</td>
<td>60.5*</td>
<td>34.2</td>
<td>5.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c. The door to the room should be closed and not reopened</td>
<td>38</td>
<td>47.4</td>
<td>23.7*</td>
<td>26.3</td>
<td>2.6</td>
<td>0.0</td>
</tr>
<tr>
<td>d. The medical gas supply to the room should be turned off</td>
<td>38</td>
<td>60.5*</td>
<td>18.4</td>
<td>21.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>27. After a fire has been extinguished, the patient’s status should be assessed and a plan devised for ongoing care of the patient</td>
<td>38</td>
<td>84.2*</td>
<td>10.5</td>
<td>2.6</td>
<td>0.0</td>
<td>2.6</td>
</tr>
<tr>
<td>28. When the airway or breathing circuit fire has been extinguished:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Ventilation should be reestablished, avoiding supplemental oxygen and nitrous oxide, if possible</td>
<td>38</td>
<td>47.4</td>
<td>31.6*</td>
<td>10.5</td>
<td>10.5</td>
<td>0.0</td>
</tr>
<tr>
<td>b. The tracheal tube should be examined to assess whether fragments may be left behind in the airway</td>
<td>38</td>
<td>81.6*</td>
<td>18.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>c. Rigid bronchoscopy should be considered to assess thermal injury and look for tracheal tube fragments and other residual materials</td>
<td>38</td>
<td>68.4*</td>
<td>23.7</td>
<td>5.3</td>
<td>0.0</td>
<td>2.6</td>
</tr>
<tr>
<td>29. If the fire did not involve the airway and the patient was not intubated before the fire, the patient should be assessed for injury related to smoke inhalation</td>
<td>38</td>
<td>60.5*</td>
<td>36.8</td>
<td>2.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

* Median response falls within this designated response category. † A high-risk procedure is defined as one in which an ignition source may be in proximity to an oxidizer-enriched atmosphere. ‡ n is the number of consultants who responded to each item. All other numbers in the table represent the percentage of consultants who selected the designated response category.

CO2 = carbon dioxide; FIO2 = fraction of inspired oxygen; OR = operating room.
Table 3. ASA Member Survey Responses

<table>
<thead>
<tr>
<th>Education</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Every anesthesiologist should have knowledge of institutional fire safety protocols for the OR</td>
<td>142</td>
<td>74.6*</td>
<td>24.7</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1b. Every anesthesiologist should participate in OR fire safety education</td>
<td>142</td>
<td>55.6*</td>
<td>38.7</td>
<td>5.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1c. OR fire safety education for the anesthesiologist should emphasize the risk of an oxidizer-enriched atmosphere</td>
<td>142</td>
<td>73.9*</td>
<td>22.5</td>
<td>3.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OR fire drills</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a. All anesthesiologists should periodically participate in OR fire drills with the entire OR team</td>
<td>142</td>
<td>42.3</td>
<td>40.1*</td>
<td>12.0</td>
<td>5.6</td>
<td>0.0</td>
</tr>
<tr>
<td>2b. Participation in an OR fire drill should take place during dedicated educational time, not during patient care</td>
<td>142</td>
<td>54.9*</td>
<td>31.0</td>
<td>10.6</td>
<td>2.1</td>
<td>1.4</td>
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</table>

<table>
<thead>
<tr>
<th>Preparation</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Anesthesiologists should participate with the entire OR team in assessing the risk of an OR fire for each case, and determining whether a high-risk situation exists</td>
<td>142</td>
<td>38.7</td>
<td>45.8*</td>
<td>8.5</td>
<td>3.5</td>
<td>3.5</td>
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<tr>
<td>4. All team members should agree on how an OR fire will be prevented and managed for each particular procedure</td>
<td>142</td>
<td>39.4</td>
<td>38.0*</td>
<td>13.4</td>
<td>7.8</td>
<td>1.4</td>
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<tr>
<td>5. Hospitals and procedure units should post a protocol for the prevention and management of fires in each location where a procedure is performed</td>
<td>142</td>
<td>51.4*</td>
<td>36.6</td>
<td>8.5</td>
<td>2.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prevention for all procedures</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Flammable skin prepping solutions should be dry before draping</td>
<td>142</td>
<td>68.3*</td>
<td>21.8</td>
<td>9.2</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>7. Surgical drapes should be configured to prevent oxygen from accumulating under the drapes or from flowing into the surgical site</td>
<td>142</td>
<td>64.8*</td>
<td>28.2</td>
<td>6.3</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>8. Sponges should be moistened, particularly when used in or near the airway</td>
<td>142</td>
<td>63.4*</td>
<td>30.3</td>
<td>5.6</td>
<td>0.7</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prevention for high-risk† procedures</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
<tbody>
<tr>
<td>9. Anesthesiologists should collaborate with the procedure team for the purpose of preventing and managing a fire</td>
<td>142</td>
<td>67.6*</td>
<td>31.0</td>
<td>1.4</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>10. The surgeon should be notified of an increase in or the presence of an oxidizer-enriched atmosphere in which an ignition source will be used</td>
<td>142</td>
<td>66.2*</td>
<td>29.6</td>
<td>3.5</td>
<td>0.7</td>
<td>0.0</td>
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<tr>
<td>11a. Oxygen levels should be kept as low as clinically feasible while the ignition source is in proximity to the oxygen-enriched atmosphere</td>
<td>142</td>
<td>70.4*</td>
<td>26.1</td>
<td>2.1</td>
<td>1.4</td>
<td>0.0</td>
</tr>
<tr>
<td>11b. The reduction of FIO₂ should be guided by monitoring patient oxygenation</td>
<td>142</td>
<td>71.8*</td>
<td>24.7</td>
<td>2.8</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>12. The use of nitrous oxide should be avoided in settings that are considered high risk for OR fire</td>
<td>142</td>
<td>50.0*</td>
<td>36.6</td>
<td>9.2</td>
<td>3.5</td>
<td>0.7</td>
</tr>
<tr>
<td>13. Oxygen or nitrous oxide buildup may be minimized by either insufflating with room air or scavenging the operating field with suction</td>
<td>142</td>
<td>32.4</td>
<td>43.0*</td>
<td>21.8</td>
<td>2.8</td>
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</table>

<table>
<thead>
<tr>
<th>Prevention during cases in or around the airway</th>
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<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. Cuffed tracheal tubes should be used instead of uncuffed tracheal tubes</td>
<td>142</td>
<td>35.9</td>
<td>43.0*</td>
<td>16.2</td>
<td>4.9</td>
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<tr>
<td>15. The oropharynx should be scavenged with suction during oral procedures</td>
<td>142</td>
<td>22.5</td>
<td>27.5*</td>
<td>44.4</td>
<td>5.6</td>
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</tr>
<tr>
<td>16. The sufficient amount of time needed to reduce oxygen or nitrous oxide concentrations to a safe level before using an ignition source in the airway:</td>
<td>142</td>
<td>Mean = 3.3 min, Range = 0.08–10 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. The sufficient amount of time needed to reduce oxygen or nitrous oxide concentrations to a safe level before using an ignition source for patients wearing a facemask or nasal cannula:</td>
<td>142</td>
<td>Mean = 2.8 min, Range = 0.0–10 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prevention during laser surgery</th>
<th>n‡</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Laser-resistant tracheal tubes appropriate to the procedure and laser should be used</td>
<td>142</td>
<td>61.3*</td>
<td>35.9</td>
<td>2.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>19a. Tracheal tube cuffs should be filled with saline rather than air, when feasible</td>
<td>142</td>
<td>61.3*</td>
<td>33.1</td>
<td>4.9</td>
<td>0.7</td>
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</tr>
</tbody>
</table>

(continued)
Table 3. Continued

<table>
<thead>
<tr>
<th>n†</th>
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<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

19b. Saline in tracheal tube cuffs should be tinted with methylene blue to act as a marker for cuff puncture by a laser

Management of OR fires

20. When early warning signs of a fire are noted, the procedure should be halted immediately

21. When a fire is definitely present, the fire should be immediately announced and the procedure should halt

22. For a fire in the airway or breathing circuit:
   a. The tracheal tube should be removed as quickly as possible
   b. All flammable and burning materials should be removed from the airway as quickly as possible
   c. The delivery of all airway gases should stop
   d. Saline should be poured into the patient’s airway to extinguish any residual embers and cool the tissues

23. For a fire elsewhere on or in the patient:
   a. The delivery of all airway gases should stop
   b. All burning and flammable materials (including all drapes) should be removed from the patient
   c. All burning materials in, on and around the patient should be extinguished (e.g., with saline, water, or a fire extinguisher)

24. The preferred means of safely responding to an OR fire is:
   a. For each team member to immediately respond without waiting for others to act
   b. To immediately initiate a predetermined sequence of responses

25. If the first attempt to extinguish the fire is not successful, a CO₂ fire extinguisher should be used

26. If the fire persists after use of a CO₂ fire extinguisher:
   a. The fire alarm should be activated
   b. The patient should be evacuated, if feasible
   c. The door to the room should be closed and not reopened
   d. The medical gas supply to the room should be turned off

27. After a fire has been extinguished, the patient’s status should be assessed and a plan devised for ongoing care of the patient

28. When the airway or breathing circuit fire has been extinguished:
   a. Ventilation should be reestablished, avoiding supplemental oxygen and nitrous oxide, if possible
   b. The tracheal tube should be examined to assess whether fragments may be left behind in the airway
   c. Rigid bronchoscopy should be considered to assess thermal injury and look for tracheal tube fragments and other residual materials

29. If the fire did not involve the airway and the patient was not intubated before the fire, the patient should be assessed for injury related to smoke inhalation

* Median response falls within this designated response category. † A high-risk procedure is defined as one in which an ignition source may be in proximity to an oxidizer-enriched atmosphere. ‡ n is the number of ASA members who responded to each item. All other numbers in the table represent the percentage of ASA members who selected the designated response category.

CO₂ = carbon dioxide; FIO₂ = fraction of inspired oxygen; OR = operating room.