DEVICES

Anesthesia for subcutaneous implantable cardioverter-defibrillator implantation: Perspectives from the clinical experience of a U.S. panel of physicians

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Abstract

Background and objective: Worldwide adoption of the subcutaneous implantable cardioverter-defibrillator (S-ICD) for preventing sudden cardiac death continues to increase, as longer-term evidence demonstrating the safety and efficacy of the S-ICD expands. As a relatively new technology, comprehensive anesthesia guidance for the management of patients undergoing S-ICD placement is lacking. This article presents advantages and disadvantages of different periprocedural sedation and anesthesia options for S-ICD implants including general anesthesia, monitored anesthesia care, regional anesthesia, and nonanesthesiologist administered sedation and analgesia.

Methods: Guidance, for approaches to anesthesia care during S-ICD implantation, is presented based upon literature review and consensus of a panel of high-volume S-ICD implanters, a regional anesthesiologist, and a cardiothoracic anesthesiologist with significant S-ICD experience. The panel developed suggested actions for perioperative sedation, anesthesia, surgical practices, and a decision algorithm for S-ICD implantation.

Conclusions: While S-ICD implantation currently requires higher sedation than transvenous ICD systems, the panel consensus is that general anesthesia is not required or is obligatory for the majority of patients for the experienced S-ICD implanter. The focus of the implanting physician and the anesthesia services should be to maximize patient comfort and take into consideration patient-specific comorbidities, with a low threshold to consult the anesthesiology team.

KEYWORDS
Defibrillation testing, general anesthesia, monitored anesthesia care, regional anesthesia, nonanesthesiologist administered sedation and analgesia, subcutaneous implantable cardioverter-defibrillator, transvenous implantable cardioverter-defibrillator

1 | INTRODUCTION

The subcutaneous implantable cardioverter-defibrillator (S-ICD; Boston Scientific, Marlborough, MA, USA) was developed as an alternative to transvenous (TV) ICDs among patients without the need for pacing. It has been shown to be safe and effective and global adoption is increasing. Much focus has been on the appropriate populations for this device. However, there are also significant differences...
between the perioperative management of the S-ICD and the TV-ICD. The S-ICD requires more extensive tissue dissection, tunneling of a lead, and defibrillation testing (DT) remains routine. The most recent and largest prospective registry of S-ICD patients reported that 64% of patients in the United States received general anesthesia (GA) and 87% underwent attempted DT at implant, which may reflect the high incidence of comorbidities now being implanted with this device.7

Despite the increase in implants and sicker cohorts receiving the S-ICD, there are currently no guidelines or recommendations for anesthetic management. Reports have supported a wide spectrum of care including conscious sedation and/or local analgesia, GA, monitored anesthesia care (MAC), and regional anesthesia techniques.8–11 Accordingly, a task force of high-volume S-ICD physicians (1,057 of 22,000 U.S. S-ICD implants) was convened with the objective to provide a guide for addressing the anesthetic needs of patients undergoing implantation of a S-ICD based on literature review and consensus recommendations.

2 METHODS

A panel of experienced cardiac electrophysiologists and two anesthesiologists was convened to develop this consensus document on the perioperative care of the S-ICD patient. The panel members all had significant experience with the implantation of S-ICDs using a variety of anesthesia, sedation, and analgesia protocols that each has developed over the past 3–5 years.

A process mapping methodology based on Continuous Quality Management methodologies12 was facilitated by Timothy Mc Clernon, Ph.D., People Architects Inc., who has experience mapping multiple other medical procedures. Process mapping documents detailed behavioral workflow steps along with cognitive decision-making steps.13 A panel of high-performing participants met face-to-face for 11 hours over two consecutive days to document in detail how they managed patients undergoing S-ICD implantation. The mapping methodology was chosen, in part, because visualizing detailed procedural steps allows participants to quickly identify areas of agreement and disagreement. Dialogue around differences is debated to sort out if or how differences impact procedural outcomes. The resulting process map documents areas of consensus along with alternatives to performing procedural task steps and decision making when consensus is not reached or there is little difference in outcomes based on alternative approaches to performing a specific task.14

Creating a shared characterization of the procedure allows for more focused study and testing. Capturing knowledge work as a series of steps makes it easier to study.15 Process mapping (performance characterization) is an established foundation for further task analysis of the procedure, specifying skills to determine metrics and levels of proficiency, and improving procedural protocols and guidelines.16 Once the complete procedural workflow was mapped from beginning to end, the panel developed anesthesia, sedation, and analgesia recommendations for new or less experienced S-ICD implanters incorporating steps from the map.

2.1 Search strategy

For the core topic of our literature review, a comprehensive search strategy was developed using a combination of keywords and medical subject headings for the following concepts: subcutaneous implantable cardiac-defibrillator, TV implantable cardiac-defibrillator, analgesia or anesthesia or sedation, nonanesthesiologist-administered sedation and analgesia (NASA), MAC, truncal plane nerve blocks, and perioperative period. A specific search strategy was developed for the U.S. National Library of Medicine Database (MEDLINE), Excerpta Medica Database (EMBASE), and the Cochrane Central Register of Controlled Trials from inception to February 12, 2018. The full search strategy can be viewed in the Appendix. In addition, the bibliographies and citations of all included articles were hand searched to further identify relevant articles for this literature review. Finally, full text articles were also retrieved through consultation with an expert in the field (M.E.).

3 S-ICD SYSTEM IMPLANTATION AND DT

The S-ICD system consists of a pulse generator that provides an 80-Joule (J) defibrillation shock and a single subcutaneous electrode, to sense and defibrillate malignant ventricular arrhythmias. An electrode insertion-tunneling tool, which is a solid metal tunneling rod, is used to create a subcutaneous track to position the subcutaneous electrode. The S-ICD system is implanted in about 70 minutes (average procedure time 65 ± 23 to 75 ± 34 minutes); however, the location, creation, and size of the pocket as well as tunneling require different surgical skills in comparison to conventional TV-ICD systems.11,17 As a result, electrophysiologists must learn to implant this new technology in a safe and controlled environment in order to optimize patient care delivery.

S-ICD system implantation procedure has been described in previous publications.18–20 To summarize, a pulse generator is inserted into a subcutaneous pocket created at the level of the fifth and sixth intercostal spaces in the mid-axillary line. The electrode is tunneled subcutaneously from the pulse generator pocket to an incision approximately 1 cm above and 1 cm lateral to the inferior edge of the xiphoid process, and then subsequently tunneled cephalad (1–2 cm parallel to the left sternal border) to the level of the second intercostal space (manubriosternal junction). In some cases, a third incision is made at the level of the second intercostal space to guide parasternal tunneling. The electrode is then attached to the pulse generator header and the generator is secured in the pocket and closed before DT.

Although DT for TV-ICD systems has declined in recent years, testing the S-ICD system, at a minimum of one ventricular fibrillation (VF) induction, is recommended to ensure adequate VF sensing and defibrillation.1–3,6,21 DT entails delivery of a short duration (2–4 seconds) of extra-thoracic direct current, followed by the delivery of a high-energy shock (65–80 J) and the possibility of required external rescue defibrillation. The total time from VF induction to device therapy, 13–15 seconds, exceeds that associated with TV-ICD testing. Since the majority of failed defibrillation is due to poor device position (too anterior or inferior) and/or the electrode not placed on the fascia (excessive fat under the electrode),22 performing DT at a later date,
does not allow for immediate repositioning of the pulse generator or electrode.

## 4 | ANESTHESIA FOR S-ICD IMPLANTATION AND DT

The best anesthetic for S-ICD implantation and DT is unknown, as a paucity of randomized data exists; however, a review of the literature demonstrates efficacy and safety for S-ICD implantation using several modalities: GA, MAC, regional anesthesia, and local anesthesia supplemented with sedation/analgesia techniques.\(^7\)\(^-\)\(^{11}\),\(^{23}\)\(^-\)\(^{25}\) These data suggest that a successful procedure can be accomplished with a variety of anesthetic modalities and thus selection of an anesthetic is often based upon multiple features including patient comorbidities, physician preference, and hospital policy.

### 4.1 | General endotracheal anesthesia

General endotracheal anesthesia has been reported as a safe and effective anesthetic for S-ICD implantation.\(^7\),\(^{25}\) The use of GA furnishes an operative environment for S-ICD placement where the electrophysiologist focuses predominantly on device implantation and DT.\(^{25}\) Anesthesia care and hemodynamic monitoring is the focus of the anesthesiologist. By unburdening the electrophysiologist of anesthetic care, implanters can focus on the technical aspects of inserting and testing the S-ICD.

Drawbacks associated with GA usage for S-ICD implantation may include the following: limited availability of anesthesia services, hemodynamic instability, airway injury, postintubation pneumonia, longer procedure room utilization time, additional time for patient evaluation by the anesthesiologist, longer post-GA recovery time, the need for skilled postanesthesia care nurses for recovery, and increased overall cost.\(^{11}\),\(^{25}\),\(^{26}\)\(^-\)\(^{27}\) Although many anesthesiologists may deem it safer to have a secured airway for S-ICD implantation and DT, the myocardial depressant and vasoaddutory properties of volatile anesthetics coupled with adverse hemodynamics associated with DT should be considered when deciding upon anesthetic type.\(^{11}\),\(^{28}\) While GA is commonly used for S-ICD implants, early data suggest that GA may promote the hemodynamic changes trying to be avoided, specifically hypotension and bradycardia, and should be used with caution.\(^{11}\),\(^{25}\),\(^{29}\),\(^{30}\) As centers and implanters are developing their experience with S-ICD, GA may be preferred to unburden the implanting physician from managing cardiovascular hemodynamics and may be the best anesthetic for the learning curve phase.

### 4.2 | MAC

MAC is an anesthesia service where an anesthesiologist is consulted to provide anesthesia care, and the continuum of MAC anesthesia may range from “no sedation” to potentially “GA.” MAC therefore encompasses preoperative patient evaluation, intraoperative anesthetic care, and postoperative patient management, and may be ideal for S-ICD implantation among patients considered “MAC” candidates by the anesthesiologist.\(^{11}\) In the procedure room, with continuous cardiovascular monitoring (pulse oximetry, noninvasive blood pressure monitoring, electrocardiography), capnography, and supplemental oxygen, sedation/analgesia (predominantly a propofol-based regimen) can be initiated prior to surgical preparation of the patient.\(^{11}\) Propofol is an attractive MAC agent since it is easily titrated and has rapid onset and offset of action. Hemodynamic variables (blood pressure, heart rate, heart rhythm [continuous electrocardiography]), respiratory rate, and oxygen saturations are documented at least every 5 minutes, and safety alarms of monitoring devices must be enabled at all times to alert anesthesia personnel of vital changes in the clinical state of a patient. Periodic assessment of depth of sedation (level of consciousness) should also be performed and recorded in 5-minute intervals to guide titration of sedation/analgesia.

The implanting electrophysiologist administers local anesthesia at the pulse generator site and, in some cases, at the xiphoid incision and along the parasternal electrode-tunneling sites. Considering the invasiveness of the dissection required for pulse generator placement, mild-to-moderate sedation may be suboptimal in the absence of adequate local anesthesia. The brief tunneling period as well as DT are also stimulating, and require moderate-to-deep sedation for a brief period of time. Therefore, the need for moderate-to-deep sedation occurs at three or four points in the procedure for less than 1 minute, thus making MAC appealing. This concept of only requiring moderate-to-deep sedation briefly may not be recognized by the anesthesiologist with limited S-ICD experience, and will likely require detailed input from the electrophysiologist.

With MAC, there is the possibility of oversedation and transition to GA without a secured airway, which in turn may lead to increased morbidity and mortality.\(^{11}\),\(^{27}\),\(^{29}\),\(^{31}\)\(^-\)\(^{35}\) Common MAC sedatives/analgesics, and anesthetics such as benzodiazepines, opioids, and propofol, have been shown to increase respiratory complications and may also cause hypotension.\(^{26}\),\(^{36}\) Therefore, the use of MAC may be associated with unanticipated airway obstruction and the need for airway support maneuvers, such as the jaw thrust maneuver and/or airway intervention (nasopharyngeal airway, oropharyngeal airway, bag-mask ventilation, laryngeal mask airway insertion, and/or endotracheal intubation).\(^{26}\),\(^{27}\),\(^{30}\)

A recent report by Essandoh et al. demonstrated the safety and efficacy of MAC for S-ICD placement.\(^{11}\) MAC (propofol-based anesthesia supplemented with local anesthesia) was associated with patient comfort during device implantation and DT. Further, there was no hemodynamic instability during S-ICD implantation and DT, likely due to the maintenance of sympathetic tone and less cardiovascular depression. Although retrospective in nature, the MAC patients enrolled in this study were selected based upon the American Society of Anesthesiologists (ASA) criteria. It is also important to note that MAC was instituted after significant institutional S-ICD implantation experience was gained with GA.\(^{11}\),\(^{25}\)

### 4.3 | Regional anesthesia

Regional anesthesia techniques have been described for subpectoral TV-ICD device placement.\(^{37}\) In contrast to the relatively small
infraclavicular region—requiring anesthesia for TV-ICD, S-ICD placement requires regional coverage of the left anterolateral chest wall for creation of the pocket, and the left parasternal region for tunneling of the electrode. Regional techniques, which provide coverage to these areas, include thoracic epidural and thoracic paravertebral block. A combination of more recently described truncal plane nerve block techniques including the PECS I&II, the transversus thoracic muscle plane, and the serratus anterior plane blocks also provide coverage of these areas. While thoracic epidural block provides dense coverage of the chest wall, it may be of limited utility in this patient population. In theory, a thoracic epidural block can be used to provide anesthesia during S-ICD implantation, but it may not be useful for postoperative pain management in ambulatory patients. Moreover, the sympathectomy that occurs with epidural anesthesia may not be well tolerated by patients with significant cardiovascular disease. Patients presenting for S-ICD placement are frequently anticoagulated or may take dual antiplatelet therapy precluding the possibility of epidural placement.

Thoracic paravertebral block also provides dense coverage to the chest wall and is useful for postoperative pain management. Similar to the thoracic epidural, however, utilization may be limited by anticoagulation or the risk of hypotension due to segmental sympathetic nervous system blockade.

The PECS block is a more recently described technique which provides anesthesia to the chest wall while avoiding issues associated with the thoracic epidural and paravertebral blocks. The original PECS block, now commonly referred to as the PECS I block, anesthetizes the medial and lateral pectoral nerves and provides coverage of the anterior chest wall including the pectoralis major and minor muscles. The PECS II block anesthetizes the intercostobrachial nerve, intercostal nerves three through six, and the long thoracic nerve and was developed for breast surgery. The serratus anterior plane and the transversus thoracic muscle plane blocks anesthetize the long thoracic and thoracodorsal nerves, lateral cutaneous and anterior cutaneous branches of the thoracic intercostal nerves, and provide analgesia to the anterolateral chest wall and the parasternal area, respectively, and have been reported to provide significant postprocedure analgesia after S-ICD implantation. Even with adequate regional block, patients undergoing S-ICD may still require GA or MAC but perhaps to a lesser extent. To date, however, there are only a few case reports and a retrospective study describing the usefulness of regional anesthesia use for S-ICD implantation and/or postprocedure pain control, and this technique may not be the best initial anesthetic approach, but an analgesic adjunct to GA or MAC.

4.4 NASA

NASA involves sedation administered by an electrophysiologist or a nurse under the supervision of an electrophysiologist, and is routinely supplemented with local anesthesia. This approach was used successfully for over half of the initial S-ICD implants at the Amsterdam Medical Center and is being reported by implanters in the United States and Europe. The main concern for NASA is patient safety, due to the risk of respiratory and cardiovascular complications associated with sedation. This risk is especially high when nonanesthesia personnel administer potent sedatives/analgesics, and anesthetics with narrow therapeutic windows, i.e., unintentional rapid transition from sedation to GA. Propofol especially causes hypotension, bradycardia, central and peripheral apnea, and blunts airway reflexes, and should be administered with extra caution if at all. Moreover, unlike benzodiazepines and opioids, propofol sedation cannot be reversed pharmacologically and requires heightened vigilance. The safe administration of propofol by nonanesthesia personnel, however, has been reported in numerous studies when used in endoscopy and electrophysiology procedures.

The NASA approach is particularly appealing at centers where there is limited availability of anesthesia services and it is worth noting that NASA has been employed successfully for transfemoral transcatheter aortic valve replacement (TF-TAVR) with excellent outcomes. Despite the NASA technique’s adoption in some European centers for S-ICD placement, the types of sedatives, local anesthetics, and approaches to patient management were not described in detail in most of the studies. A recent study by Peyrol and colleagues reported successful S-ICD placement and DT in 16 patients in France using midazolam, nalbuphine, and local anesthesia without any complications, demonstrating that NASA for S-ICD implantation may be safe, feasible, and effective.

Appropriate anesthesia to the left hemithorax will facilitate S-ICD implantation and reduce sedation requirements, and this makes the NASA approach to S-ICD implantation appealing. The experience with sedatives and analgesics by the consensus panel was very variable so no consensus could be reached. Whereas NASA has demonstrable efficiencies and benefits such as less resource utilization, cost effectiveness, and shorter hospital length of stay, it is critical to note that this may not be appropriate for the novice S-ICD implanter. NASA was embraced for TV-ICD implantation and TF-TAVR only after implantation mastery was achieved using GA. Furthermore, in addition to the skill set of the implanting physician, equally important is appropriate staffing. The nurse responsible for patient sedation and monitoring should be exempt from additional duties, in order to enable rapid recognition and treatment of sedation-related complications. In the event of an airway complication, personnel with significant training and experience in advanced airway management should be readily available to provide care and prevent adverse outcomes.

Monitoring the cardiovascular and respiratory systems should be performed continuously to prevent poor outcomes. As recommended by the ASA, the following monitors should be used in all NASA cases: continuous audible pulse oximetry, continuous capnography, noninvasive blood pressure measurement (5-minute intervals, at minimum), and continuous electrocardiography. Oxygen supplementation should be performed in all patients to minimize the potential for hypoxemia from oversedation. However, it is important to recognize that the use of supplemental oxygen may delay the diagnosis of airway obstruction, hence the need to monitor and to interpret capnography to determine airway patency. Considering patients will be fully draped for S-ICD implantation, it is important to avoid covering the patient’s face to prevent rebreathing of carbon dioxide. The assessment of respiratory efforts with impedance bands over the thorax and abdomen may...
be useful as well; however, its use has not been investigated for S-ICD implantation. Visual inspection of chest wall respiratory excursion and periodic auscultation of the lungs may also not be feasible due to the application of sterile drapes over the entire chest wall. To minimize sedation-related complications, depth of sedation should be assessed periodically and documented in 5-minute intervals to guide titration of sedation/analgesia. The sedation team members should be certified in advanced cardiac life support.

For moderate-to-deep sedation using the NASA approach, we suggest the use of small bolus doses of etomidate 0.1 mg/kg and to avoid use of propofol due to the potential for cardiovascular and respiratory depression. Since some S-ICD patients may have a normal ejection fraction, propofol may be utilized, with administration being in small increments, at a dose of 0.1–0.2 mg/kg. The dosing of course needs to be titrated based on the patient’s level of sedation and respiratory and hemodynamic parameters. A small dose of etomidate or propofol added to a patient sedated with opioids and benzodiazepines can provide a significant potentiation of sedation and respiratory depression, thus the suggestion of only providing doses as small increments. The rationale for sedation and analgesia for DT is similar. Often times, the level of sedation for DT does not need to be more than moderate since the effects of 15 seconds of VF often results in minimal perception of pain and no awareness of shock delivery.

Lastly, implanters considering NASA and the use of propofol, methohexital, or etomidate should review institutional and state regulations that may prevent nonanesthesia personnel from administering these drugs. In the United States between 2009 and 2011, the Centers for Medicare and Medicaid Services made a number of revisions to the anesthesiology interpretive guidelines, transferring the interpretation of these guidelines to the local hospital and Director of Anesthesia. We advocate that S-ICD system implantation using the NASA approach may be adopted in a similar fashion to TV-ICD, only after mastering the S-ICD implantation learning curve. The S-ICD system implant learning curve warrants electrophysiologists to develop the surgical skills for reproducible successful S-ICD implantation under GA or MAC operative environment before proceeding to NASA. Although the exact number of S-ICDs implants needed to achieve proficiency is unknown, Knops et al. recently demonstrated that the majority of learning with S-ICD implantation occurs after four implants.

Based upon clinical experience and prior reports, we developed a Decision Tree for the S-ICD implanter who is considering using the NASA approach (Figure 1). This algorithm incorporates the following criteria: (1) hospital policy permits the implanter to administer moderate-to-deep sedation; (2) staff are trained to monitor patients receiving moderate-to-deep sedation and respond to protect the airway; (3) there is room with adequate monitoring facilities and equipment to support GA if intubation is required; (4) the implanter considering NASA should have performed at least five S-ICD implants with GA or MAC and has achieved confidence with device implantation techniques; (5) the implanter has developed an anesthesia and sedation plan in conjunction with the hospital anesthesiology staff; and (6) the implanter evaluates the suitability of NASA for each patient and have developed alternative anesthetic plans.

4.5 S-ICD implant sedation and analgesia suggested actions

The section below summarizes the management of perioperative sedation and analgesia.

5 GENERAL SUGGESTIONS

- Anesthesia and sedation plan need to be customized to the patient.
- Use of a dedicated anesthesia team during the S-ICD implant-learning curve phase (initial 5–10 implants).
- GA can be utilized, but is not required for S-ICD implants. The preferred technique for cases with anesthesia support may be MAC.
- If an implanter plans to use the NASA approach for S-ICD implants, it is suggested to work with an anesthesiologist for several cases before performing NASA without anesthesia involvement.
- Know your hospital guidelines regarding: (1) NASA, (2) use of nonanesthesia professionals to monitor patients under moderate-to-deep sedation, and (3) requirements for deep sedation privileges.
- Excellent local anesthesia is critical to patient comfort.
- Establish a NASA protocol for S-ICD procedures using dedicated meetings involving electrophysiologists and anesthesiologists as well as electrophysiology laboratory staff to help clarify and assure proper workflow and equipment and adequate training for all team members.

6 PRIOR TO IMPLANT

- Determine a perioperative sedation and anesthesia plan and discuss with the patient.
- As with a TV-ICD implant, consider GA or MAC versus NASA when the patient:
  - Is morbidly obese and/or has a challenging airway.
  - Has psychiatric illness for which psychoactive drugs are prescribed or opiates for chronic pain, as both scenarios may lead to increased sedation and analgesia requirements.
  - Consider the use of multimodal analgesia by administering pre-operative oral analgesics such as narcotics (e.g., oxycodone), and acetaminophen for postoperative pain control.

7 CREATION OF POCKET

- Apply continuous cardiovascular monitors (pulse oximetry, noninvasive blood pressure monitoring, electrocardiography), capnography, and supplemental oxygen after the patient is positioned on the procedure table.
Nonanesthesiologist Administered Sedation and Analgesia

- Administer mild-to-moderate sedation/analgesia during surgical preparation of the patient and prior to administering local anesthesia to minimize response to discomfort upon injection.
- Adequate and appropriate use of local anesthesia is important to ensure patient comfort during and after the implant. Most commonly used local anesthetics for device implantation are lidocaine and bupivacaine. Lidocaine has a rapid onset but short duration of action, provides minimal postprocedure analgesia, and may not be the best choice. Although bupivacaine has a slower onset, it has a longer duration of action (4–8 hours), and may be the best local anesthetic for S-ICD implantation. A field block at the pulse generator and the parasternal lead tunneling sites using 0.25% bupivacaine would provide an ideal surgical environment and optimal postprocedure pain control. Considering that the maximum allowable dose of bupivacaine is 2.5–3 mg/kg (or maximum 175 mg/dose), a maximum infiltration dose of 2 mg/kg will provide a safety margin of 0.5 mg/kg. Intralipid 20% should be available for intravenous infusion in the event of local anesthetic systemic toxicity.
- Local anesthetic mixtures such as a mixture of lidocaine and bupivacaine present dosing issues; and further, their toxicities are additive and this practice is not encouraged.
- A useful formula for calculating the maximum allowable volume (in mL) of a local anesthetic is: maximum allowable dose (mg/kg) × (weight in kg/10) × (1/concentration of local anesthetic) = mL local anesthetic.\(^{51}\)

8 | TUNNELING

Tunneling from the pocket to the xiphoid incision and parasternally are fairly quick steps in the implant, but can be painful, and requires the patient to be sedated adequately. Some of the implanters infiltrate local anesthesia in the parasternal tunnel tract to minimize operative and postoperative pain and suggest delivering the local anesthetic directly into the tunnel versus delivering it through the skin.

9 | DT

At least moderate sedation should be used for DT following the implantation of an S-ICD given the pain associated with transthoracic pacing for induction of VF and defibrillation shocks. Etomidate is preferred by some since it causes minimal respiratory depression and provides greater cardiovascular stability in comparison to propofol. However, studies on cardioversion using propofol or etomidate do not indicate superiority of one drug.\(^{28}\)

10 | DISCHARGE

Most panel implanters report that the majority of their S-ICD patients are discharged the same day of the procedure and are prescribed several days of pain medication. Patients receiving MAC and NASA recover faster (1–2 hours) compared with GA. While all physicians
advocate that patients limit postoperative activity to minimize discomfort, the panel physicians believe there is less need for activity restrictions after S-ICD implantation in comparison to after TV-ICD.

11 | TRAINING

Institutions considering the NASA approach for S-ICD implants should educate and train the implant sedation team (electrophysiologists and nurses) monitoring the patient. This training should include policies and procedures to guide the administration of sedation, patient monitoring, and airway management as has been done for NASA used in the endoscopy suite and for other procedures in the cardiac catheterization laboratory.26,36,42–44,49 It is important to develop a multidisciplinary planning team comprising anesthesiologists, electrophysiologists, laboratory nurses, and postanesthesia care unit nurses to help develop and implement NASA. Anesthesiologists should provide structured training and education. This should consist of airway management, as well as education on the pharmacokinetic and pharmacodynamic properties of common sedative, analgesic, and anesthetic agents.26 The electrophysiology sedation team may also undergo supervision by anesthesiologists during clinical care, following completion of training. It is strongly suggested that competency and credentialing requirements for NASA be completed under anesthesiologists’ supervision.42

The following factors should be considered for such training and education, as well as protocol development:

1. Sedation Team Selection
   
   It is essential to structure the sedation team with electrophysiologists and nurses with extensive sedation experience. Such requirement would shorten the NASA learning curve and improve patient care.

2. Patient Selection
   
   The optimal patient profile for NASA has not been determined; however, the associated risks for NASA sedation-related complications should be considered during patient selection. All S-ICD candidates being considered for NASA require a detailed preoperative assessment by the electrophysiology team to ensure optimal candidacy, with special attention paid to the cardiovascular and respiratory systems. The presence of comorbidities, like left ventricular systolic dysfunction, valvular heart disease, significant coronary artery disease, pulmonary hypertension, morbid obesity, obstructive sleep apnea, poorly controlled gastroesophageal reflux disease, severe pulmonary disease, gastroparesis, and a nonassuring airway examination (short neck, abnormalities of the oropharynx, limited oral opening, limited neck mobility) warrant the consultation of anesthesia services for NASA candidacy.28 Furthermore, patients with orthopnea, high ASA scores (ASA score ≥ 3), or history of difficult intubation may also be poor NASA candidates. These patients require a comprehensive preoperative assessment to determine the best anesthetic approach, and whether or not anesthesia services are needed.

3. Pharmacology of Anesthetic Drugs
   
   Didactics on the pharmacodynamics and pharmacokinetics of common sedatives and analgesics is suggested for the sedation team. In centers where electrophysiologists have privileges to administer propofol for deep sedation, specialized training is required with emphasis on the variable effects of propofol boluses versus propofol infusion, as well as the associated risks of respiratory and cardiovascular depression. Also, the impact of comorbidities and age on the clinical effects of propofol should be emphasized.36 Propofol infusion (vs bolus), however, should be implemented only by anesthesia providers and can be dangerous if administered by nonanesthesia personnel.

4. Airway Education and Training
   
   The electrophysiology sedation team should be able to perform comprehensive anatomical airway assessments to help identify patients at risk for airway compromise during NASA. Didactic and hands-on training inclusive of the Mallampati classification score (size of the tongue relative to the oropharynx) and additional predictors of airway obstruction, such as a short thick neck, macroglossia, abnormalities of the oropharynx, redundant oropharyngeal tissue, microglossia, goiter, etc., are necessary. Furthermore, the electrophysiology sedation team should be able to expediently recognize impending airway compromise, provide noninvasive rescue therapy, and activate the emergency response system. Specific training in noninvasive airway interventions, like the chin lift maneuver, jaw-thrust maneuver, nasopharyngeal airway and oropharyngeal airway insertion, and bag-mask ventilation, should be taught to minimize the risk of airway-associated complications related to oversedation, including airway obstruction, hypoxemia, hypercarbia, and aspiration.30

12 | CONCLUSIONS

The use of the S-ICD system continues to increase globally for prevention of sudden cardiac death. This growth of S-ICD implantation and implanter experience may influence a shift toward less GA and more MAC or NASA techniques to anesthesia, sedation, and analgesia. It is likely that there is no single best anesthetic approach for S-ICD implantation, but rather, the choice of anesthesia is best determined on a case-by-case basis taking into account patient preferences and clinical comorbidities, operator experiences, local hospital policies, and credentials, as well as availability of anesthesia services. While S-ICD system implantation currently requires higher sedation than TV-ICD systems, the authors do not believe GA is required, or obligatory for the majority of patients for the experienced S-ICD implanter. The NASA approach may be most confidently adopted after the first 5–10 anesthesia-supported S-ICD implants and completion of an appropriate training program (Figure 1). Practitioners trained by electrophysiologists, and specific protocols, are required for patient selection and monitoring during S-ICD implantation in order to manage sedation, analgesia, and anesthesia safely and effectively. Moreover, anesthesiologists should be part of the team to provide guidance.
whenever anesthetic challenges arise. Prospective trials are required to determine the best way to provide a safe, efficient, affordable, and effective anesthetic for S-ICD system implantation: GA, MAC, or NASA.

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CONFLICT OF INTEREST

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APPENDIX

MEDLINE

1. Defibrillators, Implantable/ (14183)
2. (implantable adj2 defibril?ator*).mp. (18335)
3. 1 or 2 (18335)
4. anesthesia/ or anesthesia, cardiac procedures/ (59869)
5. anesthesia*.mp. (238247)
6. analgesia*.mp. (56275)
7. “anesthesia and analgesia”/ or analgesia/ (18649)
8. analgesia*.mp. (68186)
9. sedation.mp. (36905)
10. or/4-9 (329857)
11. 3 and 10 (310)
12. remove duplicates from 11 (310)
13. exp Perioperative Care/ (138238)
14. perioperative.mp. (85706)
15. preop*.mp. (292288)
16. operative.mp. (288129)
17. pre-op*.mp. (29317)
18. postop*.mp. (747388)
19. postop*.mp. (747388)
20. pre-surg*.mp. (3277)
21. presurg*.mp. (8419)
22. post-surg*.mp. (13885)
23. postsurg*.mp. (16509)
24. surg*.mp. (1962213)
25. or/13-24 (2402533)
26. 12 and 25 (136)
EMBASE

1. implantable cardioverter defibrillators/ (33088)
2. (implantable adj2 defibrillator*).mp. (44516)
3. 1 or 2 (44531)
4. anesthesiological procedure/ or anesthesia/ (100939)
5. anesthesia*.mp. (352061)
6. anaesthesia*.mp. (80032)
7. analgesia/ (106096)
8. analgesia*.mp. (158339)
9. sedation.mp. (81959)
10. or/4-9 (534575)
11. 3 and 10 (1099)
12. remove duplicates from 11 (1093)
13. Perioperative period/ (39430)
14. perioperative.mp. (124782)
15. preop*.mp. (423006)
16. operative.mp. (358032)
17. pre-op*.mp. (54602)
18. postop*.mp. (943718)
19. postop*.mp. (943718)
20. pre-surg*.mp. (6743)
21. presurg*.mp. (11638)
22. post-surg*.mp. (26500)
23. postsurg*.mp. (20753)
24. surg*.mp. (3679150)
25. perioperative monitoring/ (125)
26. postoperative period/ (177216)
27. postoperative care/ (80908)
28. preoperative care/ or preoperative period/ (80315)
29. or/13-28 (3966652)
30. 12 and 29 (560)
31. remove duplicates from 30 (560)

COCHRANE

1. Defibrillators, Implantable/ (896)
2. (implantable adj2 defibrillator*).mp. (2397)
3. 1 or 2 (2397)
4. anesthesia/ or anesthesia, cardiac procedures/ (1434)
5. anesthesia*.mp. (37425)
6. anaesthesia*.mp. (13290)
7. "anesthesia and analgesia"/ or analgesia/ (1752)
8. analgesia*.mp. (24937)
9. sedation.mp. (11429)
10. or/4-9 (62183)
11. 3 and 10 (81)
12. remove duplicates from 11 (78)
13. exp Perioperative Care/ (11069)
14. perioperative.mp. (10525)
15. preop*.mp. (25999)
16. operative.mp. (22941)
17. pre-op*.mp. (3557)
18. postop*.mp. (78228)
19. postop*.mp. (78228)
20. pre-surg*.mp. (387)
21. presurg*.mp. (651)
22. post-surg*.mp. (1975)
23. postsurg*.mp. (1832)
24. surg*.mp. (136104)
25. or/13-24 (164144)
26. 12 and 25 (34)