



# Anesthesia management for cardiac catheter ablation: what anesthesiologists should know

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## Abstract

Catheter ablation has become a central part of the non-pharmacological treatment of cardiac arrhythmias. It can be performed under conscious sedation, deep sedation, or general anesthesia, but it is getting clear that the incidence of complications during the procedure and the success rate of treatment (with no recurrence of arrhythmia) may be strongly influenced by sedation or anesthesia method. In particular, in sedated patients, ablation procedure may frequently cause severe pain, and the most common adverse events are related to sedation methods. Therefore, anesthesiologists will increasingly be asked to take care of the patients undergoing catheter ablation. In this article, we describe what anesthesiologists should know about ablation procedure and its associated problems, to provide appropriate anesthesia care to patients undergoing catheter ablation.

**Keywords** Catheter ablation · Sedation · General anesthesia

## Introduction

Catheter ablation has increasingly been used as non-pharmaceutical treatment of various cardiac arrhythmias, as this has been shown to be more effective than antiarrhythmic drugs in maintaining sinus rhythm [1–3]. Catheter ablation can be performed under conscious sedation, deep sedation, or general anesthesia [1, 4, 5], but it is getting clear that the incidence of complications during the procedure and the success rate of treatment (with no recurrence of arrhythmia) may be strongly influenced by sedation or anesthesia method [6, 7]. In particular, in sedated patients, ablation procedure may frequently cause severe pain [8–12], and the most common adverse events are related to sedation methods [13]. Therefore, anesthesiologists will increasingly be asked to take care of the patients undergoing catheter ablation.

Recently, practice guidelines for safe sedation [14] and new insights in cardiovascular anesthesia [15] have been published in this journal, but these have not covered anesthesia management of patients undergoing cardiac ablation procedure. Therefore, in this article, we describe what

anesthesiologists should know about ablation procedure and its associated problems, to provide appropriate anesthesia care to patients undergoing catheter ablation.

## Ablation methods

We anesthesiologists should first know that there are several different methods of catheter ablation, and that appropriate anesthesia care is different for different ablation methods. We should also know what operators are doing for what purpose during the procedure, and at what timing are serious complications likely to occur, so that we can provide adequate anesthesia management at each step of procedure to facilitate effective ablation and to prevent complications.

Arrhythmias are often caused by problems with the electrical signals in the heart [1–3]. Catheter ablation is a technique applying energy to targeted heart tissues to ablate abnormal electrical signals, to treat arrhythmias. Several different ablation methods have been developed: radiofrequency, balloon (cryo, hot, or laser), and pulsed field ablation [3, 4]. Radiofrequency ablation is the most commonly used method, and radiofrequency thermal energy is delivered through the tip of the catheter to destroy targeted heart tissues. Balloon ablation is carried out by positioning a catheter balloon (which is filled either hot or cold liquid) to destroy targeted tissues by heat or freezing. With a

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laser-balloon ablation catheter, laser is applied from inside the balloon to ablate targeted tissues. Pulsed field ablation is a non-thermal ablation method, which delivers a strong electric field to increase permeabilization of the cell membranes of targeted tissues, to disrupt the cell function [1–3].

Atrial fibrillation is the most common type of cardiac arrhythmia, and is usually initiated by ectopic beats originating from the pulmonary veins, and those ectopic beats propagate toward the atrium, where they are sustained by substrate [1–3]. Therefore, “isolating the pulmonary veins” by destroying the electrical conduction between the pulmonary veins and the left atrium is effective in terminating atrial fibrillation [3].

An ablation catheter is usually inserted through the femoral vein, the inferior vena cava, and the right atrium, from where it is advanced to the left atrium, by puncturing the inter-atrial septum (trans-septal puncture). With a radiofrequency ablation catheter, ablation is performed around the ostium of the pulmonary vein (or more effectively, around superior and inferior pulmonary veins in the left atrium [16]). The area of lesion produced by each ablation is the size of the tip of a ablation catheter, so that a multiple point-by-point ablations are required (Fig. 1). In contrast, with a balloon ablation catheter, the catheter is inserted to each pulmonary vein, so that the catheter balloon can achieve circumferential contact with the ostium of the pulmonary vein, to perform ablation. Similarly, with a pulsed field ablation catheter, the distal part of the catheter is in a shape of circular, flower, basket, or global configuration, so that this distal part is positioned at the ostium of each pulmonary vein.

Catheter ablation is also used to treat ventricular arrhythmia, by ablation of foci of ectopic beats (which can be distributed in a large area of the myocardium) [17]. To access the left ventricle, the catheter is inserted either by a trans-septal approach from the right atrium, or by retrograde approach from the femoral or radial artery. If the foci of ectopic beats are in the sub-epicardium, percutaneous access to the pericardial space may be chosen [17].

Successful ablation is achieved by accurately locating the foci of ectopic beats, by placing the catheter in contact with the target tissues, and by confirming successful disruption of abnormal electrical conduction. To achieve these, cardiac electrophysiology test is performed before catheter ablation, by inserting a diagnostic multipolar electrode catheter to the desired cavity of the heart, by recording the electrical activities of the tissues of multiple sites, and by identifying arrhythmia induced by electrical stimulation or intravenously injected isoproterenol. From these data, a virtual color-coded 3-dimensional (3D) electroanatomical map of the heart cavities is created so that it is possible to determine the cause of cardiac arrhythmia, and to identify the optimal sites of ablation (Fig. 1) [3, 7, 18]. In addition, newer ablation catheters provide real-time contact force between the catheter tip and

target tissues, so that operator can confirm that the catheter tip is stabilized to the target tissues for a sufficient duration, with an appropriate contact force (usually 10–30 g). After ablation, the mapping system can confirm an effective isolation of the pulmonary veins (Fig. 1).

## Complications and preventive measures

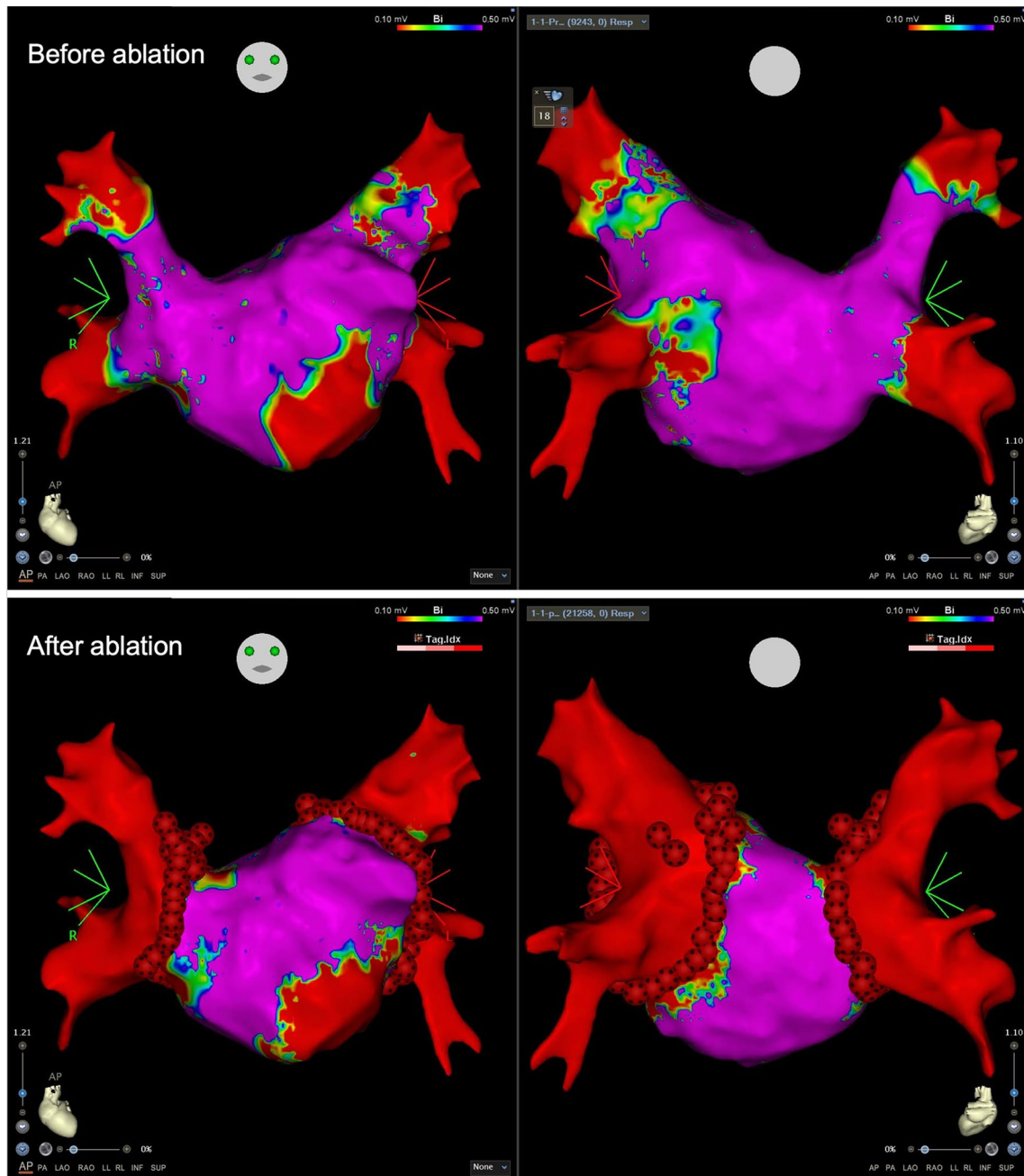
The incidence of complications of catheter ablation ranges from 3 to 8%, and the incidence of death in hospital is 0.1 to 0.5% [1].

Cardiac tamponade is the most frequent life-threatening complication, with the incidence of 0.5–1.5% [1]. It may occur most frequently during trans-septal puncture performed under fluoroscopic guidance [19], because there is technical difficulty in detecting the puncture needle being deviated from the membranous fossa ovalis. To minimize this complication, an intracardiac echocardiographic catheter is inserted to the right atrium, to confirm the needle direction [6].

Cardiac tamponade may also occur, if a radiofrequency catheter contacts the target tissues too strongly, and perforates the myocardium. Perforation occurs most frequently, at the roof of the left atrium, particularly when the patient takes a deep breath, or makes a body movement due to pain or agitation [20]. Therefore, this complication can be reduced by minimizing movement of the body and the lungs, and by immediately reducing the contact force of the ablation catheter, if the 3D mapping system indicates excessive contact force [7, 16].

Inadvertent formation of a fistula between the left atrium and the esophagus (atrio-esophageal fistula) is another life-threatening complication, with a mortality rate of 50–100% [3, 21]. Atrio-esophageal fistula occurs more frequently during radiofrequency ablation than during cryo-ballon ablation [21], and is usually caused by thermal injury to the esophagus which is close to the posterior left atrial wall. This complication may be minimized by routinely monitoring the esophageal temperature, and by immediately interrupting ablation procedure if esophageal temperature is increased (which is frequently associated with chest pain) [11, 21].

Air embolism may also occur during catheter ablation for atrial fibrillation [3, 22]. The most common cause is introduction of air through a trans-septal sheath, particularly when the pressure in the left atrium becomes low. A sedated patient with sleep apnea syndrome is at an increased risk, because the pressure in the left atrium during inspiration may become negative, and the pressure becomes much lower when the patient takes a deep breath (or snoring) after apnea [22]. This complication may be avoided by preventing upper airway obstruction by inserting an oral or a nasal airway in sedated patients, or inserting a tracheal tube or



**Fig. 1** Three-dimensional electroanatomic map of the left atrium and pulmonary veins, before (upper figures) and after (lower figures) ablation (left (with a face's mark): anterior view; right: posterior view). Voltage signals recorded from individual electrodes are converted to colour-coded voltage maps, providing a static representation of time-dependent electrical activation of the atrium and the pulmonary veins (voltage from 0.10 mV (red) to 0.5 mV (purple)). Before ablation (upper figures), the electrical activation of the proximal segments of the pulmonary veins is as high as the electrical activation of the left atrium (as colour-coded as purple), indicating that electrical activation of the proximal segment of the pulmonary veins is high

enough to produce ectopic beats, and those ectopic beats propagate toward the left atrium. After ablation (lower figures), each small red circle indicates the radiofrequency ablation tag, and the darker the red, the higher the efficacy (based on the duration, power, contact force, and the temperature of a catheter tip) of ablation. In this figure, all the tags are in dark red, making two circles around the superior and inferior pulmonary veins in the left atrium, and the voltage of proximal pulmonary veins (color-coded as red) are now low (0.1 mV), indicating a successful isolation of the pulmonary veins from the left atrium

supraglottic airway in anesthetized patients. High-flow nasal oxygen therapy increases the airway pressure and may prevent upper airway obstruction [23, 24], and thus this would theoretically reduce the risk of air embolism.

Thrombosis is a major complication of cardiac arrhythmia, and the presence of a thrombus in the heart is a contraindication for catheter ablation due to associated risk of procedural thromboembolic complications [3]. Patients with increased risk of thrombus should receive oral anticoagulants for at least 3 weeks before catheter ablation [3]. During catheter ablation, heparin should be injected intravenously before transseptal puncture, to maintain activated coagulation time (ACT) to be  $> 300$  s [3, 17].

One of the most common adverse events is fluid overload [13]. With radiofrequency ablation, catheter is continuously irrigated with saline (up to 30 ml/min) to cool the tissue interface to minimize formation of thrombus, and to produce deeper lesions to target tissues for a longer duration. Irrigation volume during the procedure can be 1000–2000 ml with a conventional catheter, and 600–1200 ml (or even less) with an improved catheter [25, 26]. Particular care should be taken to avoid fluid overload to reduce the risk of cardiac failure [26].

Phrenic nerve paralysis may occur mainly during cryo-balloon ablation to the superior vena cava or the right pulmonary vein, because the phrenic nerve is located in close proximity to the ablation site [3]. Avoiding ablation distally within the right pulmonary vein and monitoring diaphragmatic movement during phrenic nerve pacing can reduce the incidence of this complication [3].

Anesthesiologists should be aware that almost all the sedated patients would perceive pain during catheter ablation [8, 12], and ablation procedure may frequently need to be interrupted because of body movement caused by pain [10]. Pain would be most frequently perceived during ablation to posterior wall of the left atrium or the left superior pulmonary vein ostium [8, 11]. In addition, severe pain may be perceived if an ablation catheter becomes too close to the esophagus and increases the esophageal temperature [11]. Additional doses of sedatives and analgesics need to be administered during the period when the patient would perceive pain, but these additional doses would frequently increase the risk of apnea.

## Anesthetic management

There are considerable differences between continents, countries, and even between institutions in anesthesia or sedation method in patients undergoing catheter ablation [5]. The choice of anesthesia or sedation should be made based on several factors, such as characteristics of each patient and procedure, physician experience, anesthesia availability,

and institutional protocols [3]. When general anesthesia is chosen, it is necessary to discuss with physician as to if spontaneous breathing can be maintained during ablation or mechanical ventilation after injection of a neuromuscular blocking agent is preferred.

During electrophysiology test, it is desirable to use anesthetics or sedatives which have relatively small effect on electrical conduction system of the heart (*e.g.* sevoflurane, a sedative dose of propofol, midazolam, remimazolam, fentanyl, remifentanyl, and rocuronium).

For cryo-balloon ablation for atrial fibrillation, conscious or deep sedation may be sufficient, because, compared with radiofrequency ablation, cryo-balloon ablation is associated with shorter procedure time and significantly less pain [8–10, 27]. In fact, studies have indicated that the efficacy of ablation and the incidence of complications would be similar between patients receiving conscious sedation and those receiving general anesthesia [27].

For radiofrequency ablation, there has been accumulating evidence that, compared with sedation, general anesthesia is associated with a shorter procedure time, a lower incidence of complications, and a higher success rate of ablation, mainly because of no unexpected body movement and no sudden deep breath (which would improve catheter stability) [6, 7].

When general anesthesia is chosen, the airway should be secured either by a supraglottic airway or by a tracheal tube. The use of a facemask during ablation procedure is not desirable, because irregular breathing by upper airway obstruction or body movement by holding the jaw forward would lower the efficacy of catheter ablation.

The movement of the lungs should be minimized during mapping and during ablation of the heart tissues. In this respect, controlled ventilation after injection of a neuromuscular blocking agent is preferable. The anesthesiologist should first ask a physician in advance, as to if the physician prefers intermittent positive pressure ventilation during ablation, or if the physician does not mind keeping spontaneous breathing via a supraglottic airway. The anesthesiologist should also judge if he or she has a sufficient expertise in maintaining spontaneous breathing without body movement, and in preventing spontaneous breathing whenever the physician asks for minimizing movement of the lungs.

In a patient in whom a neuromuscular blocking agent has been injected, one method to minimize lung movement is interruption of intermittent positive pressure ventilation for several minutes [18, 28]. High-frequency jet ventilation may also improve catheter stability, reduces procedure time, and increases the success rate of ablation [29]. Nevertheless, jet ventilation may be associated with serious complications such as barotrauma, a longer length of stay in the post-anesthesia care unit, and a higher risk of intra-procedural hypocarbia and hypotension [29]. High-frequency

low-tidal-volume positive pressure ventilation (with tidal volume 3.0–3.5 ml/kg, respiratory rate 25–30 breaths/min) would be a better choice than jet ventilation [30].

In a patient in whom spontaneous breathing via a supraglottic airway has been maintained, sufficient dose of either an intravenous anesthetic (such as propofol) or an opioid (such as remifentanyl or fentanyl) should be injected shortly before each ablation procedure, to prevent body movement evoked by ablation-induced pain, and to minimize lung movement by inhibiting spontaneous breathing.

When the phrenic nerve is to be stimulated to confirm the absence of phrenic nerve palsy, neuromuscular blockade should be reversed and appropriate reversal should be confirmed using a quantitative neuromuscular monitoring device.

When sedation is chosen, unexpected body movement due to pain and irregular breathing should be avoided, as they would be associated with a lower efficacy of ablation and an increased risk of serious complications, such as cardiac tamponade and air embolism. Therefore, sufficient analgesia and sedation should be provided, particularly when radiofrequency ablation is being performed to posterior wall of the left atrium or the left superior pulmonary vein ostium.

The use of sedatives and analgesics for deep sedation often causes upper airway obstruction, respiratory depression or apnea, and thus may frequently require airway management. One study [31] has reported that, in patients undergoing catheter ablation, to whom monitored anesthesia care was provided, insertion of an oral or a nasal airway was required in 40% of patients, and conversion to general anesthesia (with insertion of a supraglottic airway or a tracheal tube) was required in 10% of patients. Therefore, even when monitored anesthesia care is planned, necessary airway devices and anesthetic drugs should be readily available. High-flow nasal oxygen therapy may prevent hypoxemia and upper airway obstruction in sedated patients undergoing catheter ablation, as in patients undergoing gastrointestinal endoscopy under deep sedation [32].

Appropriate analgesia should also be provided postoperatively, as more than 50% of patients underwent catheter ablation may feel moderate or severe pain within the first 24 h after the procedure [33].

The circumstances of airway and respiratory management outside the operating rooms are quite different from those inside the operating rooms [34]. In an electrophysiological lab, the patient is frequently hemodynamically unstable, access to the patient is frequently restricted, necessary drugs and airway devices may not be at hand, and medical staff who has expertise with airway management may not be present. Therefore, electrophysiological labs should be equipped with necessary drugs, monitors (including wave capnography), airway device (such as a tracheal tube and a “rescue” supraglottic airway), and anesthetic machines.

Before ablation procedure, we should make a clear plan for emergency situations (such as failed oxygenation, cardiac arrest, or requiring emergency surgery for cardiac tamponade), as to how an emergency management team is quickly assembled, who will be the leader of the rescue team and who will organize emergency surgery in an operating room. For example, if cardiac tamponade occurs during ablation and emergency surgical treatment becomes required, the anesthesiologist in charge should instruct the medical staff to contact cardiac surgeons, anesthesiologists and operating nurses to carry out emergency cardiac surgery, while inducing general anesthesia, securing the airway, maintaining hemodynamics, and transferring the patient to an operating room.

## Conclusions

Catheter ablation has become much more effective in treating various cardiac arrhythmias over the decade or two. Nevertheless, even now, the success rate of treatment and the incidence of complications is strongly influenced by sedation or anesthesia method. Therefore, we anesthesiologists should make further efforts to find the ideal respiratory management and analgesic method to each patient, to provide appropriate anesthesia care to patients undergoing catheter ablation.

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## Declarations

**Conflict of interests** TA is an Associate Editor-in-Chief of the *Journal of Anesthesia*. TS has no conflicts to declare.

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