REVIEW ARTICLE

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Anesthesia for cardiac catheterization procedures

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ABSTRACT

Anesthesiologist's involvement for the purpose of diagnostic and interventional procedures in cardiac catheterization laboratory has been evolving particularly since last two decades. Catheterization laboratory environment poses certain challenges for the anesthesiologist including unfamiliar remote location, exposure to radiation, limited help from colleagues and communication with cardiologists. Anesthesiologists working in catheterization laboratory are required to have adequate knowledge of the environment, personnel, fluoroscope, echocardiography and type of radio contrast dye during the procedure. Anyone who is exposed to radiation environment is expected to protect himself from the exposure and must also wear a dosimeter for cumulative exposure tracing. There is no ideal anesthetic technique and the decision about sedation, general anesthesia or regional anesthesia for the procedure has to be made by attending anesthesiologists in consultation with cardiologists. Anesthesiologists should always try to minimize the effects of anesthesia on cardiovascular system. In addition, oxygenation and ventilatory management should be done according to the diagnostic procedure as it can also influence the diagnosis particularly in pediatric cath procedures. Since more complex procedures are being done in cardiac catheterization laboratory, it is the responsibility of anesthesia department to train and assign dedicated anesthesioloists for new challenges. Role of anesthetist should be well defined so that there is no confrontation during patient management. Sedation in cardiac catheterization laboratory by non-anesthetists is also an issue, which can be sorted out by making policies and protocol in consultation with cardiologists.

Keywords: *anesthesia, catheterization laboratory, cardiac.*

INTRODUCTION

Cardiac catheterization laboratory (CCL) procedures especially interventional procedures have increased exponentially over the last decade. First cardiac catheterization on human was introduced by Werner Forssmann (1) in 1929 who inserted a catheter through his own antecubital vein to the right heart. Nowadays extremely complex procedures are being performed in the cath. lab, sometimes entailing several hours.

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The catheterization laboratory environment is claustrophobic for anesthesiologists who are more comfortable working in the familiar environment that is the operating room. It is very important for anesthesiologist to become familiar (2) with the cath lab environment and communicate with cardiologist regarding patient management. Anesthesiologists face several challenges (3) while working in a remote location like the cath lab. These challenges include unfamiliarity with the surroundings, limited help from colleagues, insufficiency of drugs, radiation exposure and limited equipment.

General anesthesia considerations

CCL consists of a procedure room and a much smaller control station. The pro-

cedure room includes a procedure table, Fluoroscope, anesthesia machine, dye injecting equipment and different catheters and equipment necessary for the procedure. Control station has a glass window to provide a shield against radiation through which a technician can witness the whole procedure and also communicate through a mike speaker with cardiologist and other team members. There is also a computer workstation to record the findings of the procedure.

Communication with the cath. lab personnel (4) (nursing staff, technicians and cardiologist) and familiarity with anesthesia equipment is an essential component of the management. Cardiologist uses different routes of arterial and venous access (5) for the procedure. Furthermore, anesthetists need to be well aware of access point and related complications. Gas outlet, anesthesia machine, available medications and equipment all require particular attention. Some of the equipment may be different from main operating room. Every effort must be made to have the same standard equipment as in the main operating room for uniformity. Moreover drugs for intubation and resuscitation should always be prepared. Patients are mostly far away during the procedure therefore long intravenous tubings, long breathing circuits and long monitoring lines including end tidal carbon dioxide tubing are recommended. American Society of Anesthesiologist (ASA) has revised its standards for ventilation monitoring for moderate and deep sedation in 2011 and they have added end tidal carbon dioxide monitoring along with qualitative clinical signs.

During induction and intubation one must ensure that the cath. lab technician moves the fluoroscope from patient's head (6) so that airway can be secured. There are standard compact anesthesia machines also available for remote areas. Anesthesia technician must always be there to help. For prolonged cases a Foley catheter should be inserted. Naloxone and flumazenil should also be available to rescue the effects of narcotics and benzodiazepines.

Type of anesthesia

All types of anesthesia including monitored anesthesia care (MAC), general anesthesia and regional are provided in cath lab depending on the type of procedure. A discussion with cardiologist regarding the procedure and types of anesthesia is highly recommended. General anesthesia is the best option for new techniques and prolonged interventional procedures particularly those procedures in which the cessation of ventilation is required. Epidural anesthesia is beneficial in lower extremity stents procedures for vascular patency (7).

Most of the procedures in the cath lab can be performed under sedation. Mild sedation is commonly used by cardiologists with the help of nursing staff. A nurse or a physician must also assess and document patient's condition after each bolus of sedation according to the institutional guidelines (8). Unintentional progression from mild or moderate sedation to deep sedation is a possibility, particularly during propofol sedation in debilitated patients. Medical personnel using sedation, particularly deep sedation, should be well versed with the medications they use. Medical personnel must also be aware of the side effects and be able to manage the airway and haemodynamics. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) recommends that sedation practice, in an institution, should be supervised by anesthesia department (http://www.jointcommission.org/).

American Society of Anesthesiologists (ASA) statement in 2012 about granting privileges to non-anesthesiologist physicians for personally administering or su-

pervising deep sedation was that only qualified and trained non-anesthesiologists physicians can be given privileges for deep sedation. They should also be able to recognize and manage the complications. In our hospital, only Basic Life Support (BLS) certified medical staff can give mild sedation while for moderate to deep sedation the staff is necessitated to be Advanced cardiac life support (ACLS) certified. ASA standards for sedation are necessary to be implemented for all such procedures.

Percutaneous intervention (PCI)

PCI is usually performed under mild sedation under the supervision of a cardiologist. Anesthesiologists are usually required when patient is in respiratory distress or haemodynamically is unstable due to acute MI. In addition, cardiologist may decide to call anesthetist for rescue in conditions where cardiologist and team fail to sedate the patient, over-sedate the patient or in case of decompensated heart failure.

Proper intravenous access and airway management is the key for managing these patients. Intubation is always preferred over laryngeal mask airway (LMA). Invasive monitoring may be needed in certain situations. Close communication with the cardiologists is always helpful. Thrombosis is an acute complication during PCI.

Percutaneous closure of septal defect

Transesophageal echocardiography and general anesthesia with endotracheal intubation is commonly needed for atrial septal defect (ASD) and ventricular septal defect (VSD) closure. One has to be careful with transesophageal echocardiography probe manipulation because accidental extubation is a possibility. Arrhythmias, Atrioventricular (AV) conduction defect and device (Amplatzer) embolization are common complications. Post infarct VSD closure has also been tried with device.

Right heart dysfunction and pulmonary hypertension due to L-R shunt may worsen after closure of the defect. Echocardiography may help in early diagnosis and management.

Transcatheter cardiac valve stents

This percutaneous technique was introduced in 2002 for those valvular heart disease patients in whom surgical repair or replacement cannot be performed due to advanced age, comorbidities or technical difficulties. Retrograde transfemoral approach is commonly used for transcatheter aortic valve implantation (TAVI) but transapical and transaxillary (9) approaches have also been tried. Although general anesthesia is commonly used, noninvasive positive pressure ventilation (10) and deep sedation have also been tried successfully. Patients need to be adequately hydrated to prevent renal dysfunction due to intravenous contrast. Preparation for the procedure includes availability of blood, large bore intravenous lines, arterial line, central venous pressure and transesophageal probe insertion. Transventricular pacing wires are also placed for rapid ventricular pacing which helps in reducing the chances of valve migration. Hemodynamic goals during the TAVI procedure include: adequate preload and afterload, maintenance of sinus rhythm and avoidance of tachycardia. Norepinephrine infusion can be used for persistent hypotension (11) and regional anesthetic technique can be also an option for patients who require mini thoracotomy (12). Nitrous oxide is usually avoided during the procedure and patients can be extubated at the end of procedure. Furthermore it can be noted that anesthesiologists role is not only to manage haemodynamics during the procedure as they can also provide assistance during transesophageal echocardiography, which is an essential component of all aortic and mitral valve (13) procedures.

Electrophysiological studies

A discussion with cardiologist regarding the type of anesthesia is needed as most of the procedures can be done under moderate sedation. Haemodynamically significant tachyarrhythmias present before mapping are treated with cardioversion whereas antiarrhythmics are avoided. Deep sedation may be needed at the time of electrical cardioversion in certain procedures. Droperidol can depress accessory pathways conduction while opioids and barbiturates have been safely used in WPW syndrome (14). AV conduction through normal and accessory pathway can be depressed by volatile anesthetics halothane, isoflurane and enflurane (15). Sympathomimetic drugs should be avoided during ectopic foci mapping. Coughing, snoring and patients movements should be avoided during intra cardiac mapping. Dexmedetomidine may also interfere with elctrophysiological studies as it has shown to suppress supraventricular arrhythmias after congenital heart surgery (16).

High frequency jet ventilation (HFJV) has been used for atrial fibrillation ablation to reduce chest wall and lung movements, along with reduction in left atrial volume changes. HFJV not only reduces procedure time, but also leads to improved outcomes (17, 18). Total intravenous anesthesia should be used for maintenance with this technique.

Patients coming for catheter-based procedure for ventricular arrhythmias usually have underlying coronary artery disease (CAD), severe LV dysfunction and are on multiple drugs, which can interact with anesthetics. Particularly, caution is needed with amiodarone and its potential side effects of hypothyroidism, hypotension and bradycardia. Temporary pacemakers should be available as these patients may not respond to atropine (19, 20). General anesthesia with endotracheal tube is usually chosen due to prolong cases and patient's condition. Volatile anesthetics have variable effect (21) while opioids have no effect on inducing ventricular tachycardia (VT) (22).

Implantable cardioverter defibrillator (ICD)

These patients are usually very sick, have multiple comorbidities and have history of myocardial infarction, ventricular tachycardia and ventricular fibrillation. They may not be able to remain in supine position for a long period of time. Device can be placed percutaneously under mild to moderate sedation (23) but device testing by delivering shocks requires deep sedation or general anesthesia. Nurse based deep sedation has also been tried to reduce the cost of the procedure but it increases the use of narcotic reversals agents (24).

External defibrillator adhesive pads must always be placed on the patient's chest. These are used for inducing ventricular fibrillation and at the same time as back up for defibrillation in case of ICD failure. Pacing may be also required as bradycardia may follow defibrillation. Testing is not always needed at the time of insertion and can be omitted in high risk patients. Arterial line is usually not required except in unstable patients.

Complications related to procedure include cardiac perforation, myocardial injury(25), stroke and pneumothorax due to subclavian venous access. Furthermore, refractory hypotension is a possibility after repeated shocks (26).

Radiation exposure

Healthcare workers are exposed to radiation during fluoroscopy (27) which can cause damaging effects such as dermal necrosis, cellular mutation, cancer and birth defects. It has carcinogenic effect on brain, skin and thyroid. Prolonged exposures can

lead to infertility. Exposure to radiation is measured by roentgen equivalent man (rem). Normal chest X-ray delivers 40 milirem (mrem) per examination. Anyone who is exposed to radiation environment should wear a dosimeter for cumulative exposure tracing. Two monitoring badges are mainly recommended by International commission on radiation protection, one under the lead apron and second on the collar. A fetal monitor is recommended for pregnant health care worker (28). Centre of Disease Control (CDC) supports the principle of ALARA (As low as reasonably possible) for radiation exposure and several centres are using protocols (29). Occupational limit of radiation exposure must not exceed 5 rem per calendar year (30).

Anesthesiologists and other healthcare personnel should minimize radiation exposure by adhering to three basic principles: firstly, keeping a maximum possible distance from radiation source; secondly, minimizing the exposure time; thirdly, shielding by wearing the lead aprons, thyroid collar ad shielded gloves. Acrylic stands and leaded glasses can also be used for protection. Anesthesiologist should depend more on infusion techniques for sedation and general anesthesia so that they can stay away from the radiation source. Intermittent intravenous boluses during the procedure increases the chances of radiation dose (31). 18% of the active bone marrow is still exposed to the effects of radiation even with proper lead apparel.

Radio contrast dye

Two types of contrast dyes are used in cardiovascular imaging studies. Classification of these dyes depends on their dissociation (ionic) and non dissociation (Nonionic) in a solution. Incidence of adverse reaction with ionic dye is 5.65% (32) while nonionic agents are relatively less toxic. Electrocardiography (ECG) changes and vasodilation is more pronounced with ionic agents. Nonionic dyes can be safely given to the patients who developed anaphylactoid reaction to ionic contrast in previous studies. Commonly used nonionic contrasts are Iohexol (Omnipaque), Iopamidol (Isovue) and Ioxilan (Oxilan).

Pre-procedure orders should clearly mention six hours fasting after light meal and two hours of clear liquid so that patient is adequately hydrated. Contrast administration in a patient with impaired renal function can lead to further impairment (33). Nephrotoxicity depends on the amount of contrast reaching the renal arteries so cardiologist should try to limit the dose. Prolonged and multiple studies can be performed in stages by giving a gap of 72 hrs. For the prevention of contrast induced nephropathy, avoidance of high osmolar contrast media and administration of adequate hydration (34) before and after the procedure is recommended. Acetylcysteine is not recommended by ACC/AHA for contrast induced nephropathy (8).

Pediatric cardiac procedures

Pediatric cath procedures are different from adults in several ways including different types of disease pattern in the patient, different requirements for the procedure, mandatory sedation or GA in almost all patients and a need of complete evaluation of structurally abnormal heart. Commonly performed procedures are angioplasty, valvuloplasty, coil embolization, atrial septostomy, device closure and electrophysiological studies. Right heart catheterization is commonly done in CHD patients for evaluation of shunting, oxygenation and pressures in different chambers and pulmonary vascular resistance. Bennett (35) et al. have reported the incidence of cardiac arrest and death during the procedure 0.49% and 0.08% respectively. These complications are much higher in those patients who

have supra systemic pulmonary hypertension (36, 37). There is no ideal anesthetic technique and the decision about sedation or general anesthesia for the procedure has to be made by attending anesthesiologists in consultation with cardiologists. General anesthesia is mainly chosen in critically ill patients, prolonged procedures, uncooperative patients and in procedures which require transesophageal echocardiography.

Midazolam is commonly used for premedication and during the procedure. Cardiologist and nursing staff feel comfortable with the use of midazolam and fentanyl for mild to moderate sedation. Advantages of midazolam include short duration, minimal effects on haemodynamics and respiration and reversibility with flumazenil. Over sedation with premedication and during the procedure may lead to hypercarbia, hypoxemia, airway obstruction and exaggerated pulmonary hypertension (HTN).

Ketamine has several advantages over other anesthetics as it maintains respiration and hemodynamics, provides analgesia and at the same time it keeps the patient sedated and motionless for the procedure. There is however some controversy regarding its effect on pulmonary vascular resistance. Williams et al. (38) used ketamine safely with sevoflurane in pulmonary HTN patients. It has also been used in combination with midazolam and propofol to counteract its side effects of cardiovascular stimulation and emergence reaction (39).

Generally, FiO2 is reduced to around 25 % or below when checking SaO2 in different chambers of the heart. Higher FiO2 during the procedure may change the pulmonary vascular resistance measurements. Blood should be cross-matched and available in those interventional procedures where there is a possibility of uncontrolled bleeding. Anesthesiologists should be particularly careful in removing air from all the intravenous tubings.

CONCLUSION

It is quite clear that the number of procedures and their complexities have increased in the cardiac catheterization laboratory. Furthermore, an increase in interventional procedures performed on very sick patient can be foreseen. The role of anesthesiologist has become more challenging in this changing environment. Anesthesia departments should plan ahead to cope with this growing population by allocating the trained staff and by developing policies according to the procedure and type of anesthesia. Furthermore, communication and planning in consultation with the cardiology department can facilitate patient care in this remote location.

Although cardiologist and nursing staff in certain cases can provide sedation in the catheterization laboratory, policies for sedation should be made and should be strictly implemented by both departments.

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