A Prospective Study of Various Anesthetic Techniques in Patients with Acyanotic Congenital Heart Diseases Undergoing Device Closure

Nidhi Sultania, Tejaswini C. Jambotkar¹, Shakuntala N. Basantwani

Consultant Anesthesiologist, Jai Hind Healthcare Hospital, Haryana, ¹Department of Anaesthesiology, LTMMC and LTMGH, Sion, Mumbai, Maharashtra, India

ABSTRACT

Background and Aims: Transcatheter device closure of congenital heart defects (CHD) has recently gained popularity. As limited literature exists regarding the ideal anesthetic technique for these procedures, we studied the perioperative anesthetic management and its effects on hemodynamics and complication rate in patients undergoing device closure.

Methods: In this prospective observational study, all patients of 1 month to 50 years of age with acyanotic congenital heart diseases undergoing device closure were included. The anesthesia technique, i.e., general anesthesia with endotracheal tube (GETA)/supraglottic airway device (SGD) or conscious sedation with face mask (S-FM), and intravenous induction agent used was noted. Intraoperatively vital parameters, use of transesophageal echocardiography (TEE), and perioperative complications if any, were noted. Descriptive statistical analysis was done using a statistical package for the social sciences (SPSS) version 15.

Results: GETA was used in the atrial septal defect (ASD) (62.8%), patent ductus arteriosus (PDA) (66.7%), ventricular septal defect (VSD) (65%) patients, SGD in ASD (6.3%), PDA (16.7%), and VSD (13.3%) patients. S-FM in ASD (31.3%), PDA (16.7%) and VSD (21.7%) patients. Etomidate was used as an induction agent in 30.61% of the patients and propofol in 69.39% of the patients. The mean arterial pressure (MAP) in the etomidate and propofol groups was statistically insignificant while decreased heart rate was noted in both groups. Complications like SGD dislodgement, supraventricular tachycardia, and device dislodgements were seen.

Conclusion: In PDA device closure patients, GETA should be preferred. Patients for VSD device closure should receive general anesthesia as complications are common. In ASD device closure, patients without TEE use can be done under general anesthesia with SGD.

Keywords: Anesthesia, congenital heart disease, supraglottic device, transcatheter device closure

INTRODUCTION

In recent years, device closure of defects by percutaneous transcatheter therapy is becoming increasingly recognized as an alternative to surgery for a wide range of patients with congenital heart diseases such as atrial septal defect (ASD), ventricular septal defect (VSD), and patent ductus arteriosus (PDA). The transcatheter closure has advantages of decreased operative risks, it is devoid of sternotomy so there are better cosmetic results and morbidity, lesser postoperative pain, hospital stay, and cost.¹⁻³
Anesthesia for procedures in patients with congenital heart disease poses a challenge for the anesthesiologist due to a wide spectrum of anatomic and physiological abnormalities and complications like arrhythmias, hemodynamic instability, embolization of devices, bleeding, and perforation of the major heart vessels. Right heart dysfunction and pulmonary hypertension due to the left to right (L-R) shunt may worsen after the closure of the defect. Profound knowledge of individual heart disease is necessary. [4,5]

There is no ideal anesthetic technique and the decision about sedation or general anesthesia for the procedure has to be made by the attending anesthesiologists in consultation with the cardiologists. There is limited published data regarding the ideal anesthetic technique and drug for different types of device closure. The available studies are retrospective and conducted on a particular type of defect. [6,7] Hence, we have undertaken this prospective observational study auditing the perioperative anesthetic management of patients with acyanotic congenital heart diseases undergoing device closure in our hospital setting. The primary objectives were to study the effects of different anesthesia induction agents and techniques on hemodynamics. Also, to find out the relationship between the choice of anesthesia technique with the type of defect and to formulate a plan regarding the anesthesia technique most suitable for the different types of defects. The secondary objective was to study the complication rate.

**METHODOLOGY**

This prospective observational study was carried out in all American Society of Anaesthesiology (ASA) Grades 2 and 3 patients of 1 month to 50 years with acyanotic congenital heart diseases posted for device closure in the cardiac catheterization laboratory of a tertiary hospital over 2 years. The study was approved by the institutional medical ethics committee and was registered prospectively with the Clinical Trials Registry, India. Written informed consent was obtained from all patients and parents of pediatric patients included in the study. Patients who were hemodynamically unstable due to right heart failure or eisenmengerised were excluded from the study.

In the preoperative holding area, patients were re-evaluated and nil by mouth status was confirmed. Preoperative medications were continued and baseline hemodynamic parameters, i.e., heart rate, blood pressure, and oxygen saturation on air were noted. In the operation theater (OT), monitors like the cardioscope, pulse oximeter, noninvasive blood pressure (NIBP) were attached and intravenous fluid was started. At the discretion of the concerned OT anesthesiologist, the patient was premedicated and anesthesia technique, i.e., general anesthesia with an endotracheal tube (GETA)/general anesthesia with supraglottic airway device (SGD)/conscious sedation with face mask (S-FM) was noted. The intravenous induction agent and neuromuscular blocker, used if any, were noted. Intraoperatively, heart rate, blood pressure, oxygen saturation, any particular event like hypertension, hypotension, tachyarrhythmias, or bradycardias, and treatment given was noted. The change in the heart rate or blood pressure 20% from the baseline, i.e., pre-sedation values were considered significant. Age, size of the defect, duration of anesthesia, and use of transesophageal echocardiography (TEE) if done, was noted. Perioperative complications in the form of laryngospasm, desaturation, and dislodgement of supraglottic airway device were noted. Also, surgical complications like arrhythmias and device dislodgement were noted.

Data collection for the study was carried out over 2 years. During the period of data collection, 62 patients underwent procedures in the cardiac cath lab. The average number of patients undergoing procedures in the last 3 years was 60–65 as per medical records, hence, by complete enumeration technique all the patients who fulfilled the inclusion and exclusion criteria were enrolled in the study. Among the 62 patients, 2 patients were hemodynamically unstable secondary to right heart failure and so were excluded from the study. Hence, the total sample size of the study was 60.

Data analysis was done with the international business machines corporation (IBM) statistical package for social sciences (SPSS) software version 15 and sigma plot version 12 statistics for Windows, Armonk, NY. Quantitative data were presented as mean and standard deviation. Comparison between the study groups was done with an unpaired t-test. Comparison within the study group was done with one-way repeated measures analysis of variance test. Qualitative data were expressed as frequency and percentage table. A P value less than 0.05 was taken as significant.

**RESULTS**

A total of 62 patients were assessed for eligibility and 60 patients undergoing device closure were analyzed further [Figure 1]. The demographic details were divided according to the type and size of defects, age, and duration of anesthesia [Table 1]. Among 60 device closure patients, 32 (53.33%) patients came for ASD device closure, 18 (30%)...
patients for PDA device closure, and 10 (16.67%) patients underwent VSD device closure. The mean age of the patients undergoing ASD closure was 28.38 ± 14.48 years, PDA closure was 4.94 ± 3.69 years and VSD closure was 8.45 ± 4.44 years. In the study population, 35 (58.33%) patients were females and 25 (41.67%) patients were males.

General anesthesia with endotracheal intubation was used in 65% of the patients, 13.33% of the patients received general anesthesia with a supraglottic airway device whereas, sedation with a face mask was used in 21.67% of the patients [Table 2].

Etomidate was used in 30.61% of the patients and propofol in 69.39% of the patients. Following injection of induction agents, a fall in heart rate was noted in both the groups but was statistically insignificant using the unpaired t-test [Figure 2]. There was no significant difference in the mean MAP in the etomidate and propofol groups (P = 0.328) [Figure 3]. Comparing MAP within the propofol group, 6% fall from the baseline was found at 3 and 10 min and was statistically significant (P = 0.009) using one-way repeated measures analysis of variance test. There was no significant difference in the mean MAP in the etomidate group by the same test.

In 37 patients with GETA, the anesthesia was maintained with oxygen-air (50%-50%). Sevoflurane was used in 48.33% of the patients, whereas in 16.67% of the patients, propofol was used along with muscle relaxant atracurium. In the SGD group, anesthesia was maintained with oxygen-air (50%-50%), propofol was used in 8.33% of the patients whereas sevoflurane was used in 5% of the patients. Dexmedetomidine 0.5 mcg/kg/h infusion was used for maintenance in 21.6% of the patients who received sedation.

Table 1: Mean age distribution, size of defect, and duration of anesthesia among the study groups

| Type of defect | Number of patients (%) | Age (in years) Mean±SD | Size of defect (millimeters) Mean±SD | Duration of anesthesia (minutes) Mean±SD |
|---------------|------------------------|------------------------|--------------------------------------|----------------------------------------|
| ASD           | 32 (16.67%)            | 28.38±14.48            | 18.16±5.23                           | 38±10                                  |
| PDA           | 18 (30%)               | 4.94±3.69              | 3.83±1.08                            | 39±12                                  |
| VSD           | 10 (53.33%)            | 8.45±4.44              | 5.10±1.10                            | 41±14                                  |
| Total         | 60                     |                        |                                      | 39±11                                  |

ASD - Atrial septal defect, VSD - Ventricular septal defect, PDA - Patent ductus arteriosus, SD - Standard deviation. Data are mentioned as mean±SD or numbers (%)

Table 2: Percentage distribution of technique of anesthesia in different defects

| Anesthesia Technique | Type of defect | Number of patients (%) | Total |
|----------------------|----------------|------------------------|-------|
|                      | ASD            | PDA                    | VSD   |
| GETA                 | 20 (62.5%)     | 12 (66.7%)             | 7 (70.0%) | 39 (65.0%) |
| SGD                  | 2 (6.3%)       | 3 (16.7%)              | 3 (30.0%) | 8 (13.3%) |
| S-FM                 | 10 (31.3%)     | 3 (16.7%)              | 0      | 13 (21.7%) |
| Total                | 32             | 18                     | 10     | 60       |

ASD - Atrial septal defect, VSD - Ventricular septal defect, PDA - Patent ductus arteriosus, GETA - general anesthesia with endotracheal tube, SGD - supraglottic airway device, S-FM - Conscious sedation with face mask. Data are presented as numbers (%)

Figure 1: Flow diagram explaining the patient recruitment

Figure 2: Mean heart rate in the etomidate and propofol study groups (using unpaired t-test). HR – Heart rate, SED – Post-sedation, PRE-IND – Pre-induction of anesthesia

Figure 3: Mean map in the etomidate and propofol study group (using unpaired t-test). MAP – Mean arterial pressure, SED – Post-sedation, PRE-IND – Pre-induction of anesthesia
In two patients with SGD insertion, desaturation ($\text{SpO}_2 \approx 80\%$) was observed due to SGD dislodgement and needed intubation. Laryngospasm was not encountered in any case. None of the patients had coughing postoperatively. One patient for VSD device closure under GETA had supraventricular tachycardia during device placement. Device dislodgements were seen in two patients. In VSD patient device dislodged in systemic circulation while in ASD patient, the device dislodged to the right atrium and needed surgical exploration [Table 3].

**DISCUSSION**

Congenital heart defects (CHD) lead to abnormal ventricular volume and pressure load, abnormal atrial emptying, mixing of deoxygenated and oxygenated blood, inadequate systemic cardiac output, and excessive blood flow in the pulmonary vasculature. These abnormalities lead to cardiac enlargement, pulmonary hypertension, rhythm disturbances, stroke, and many more adverse consequences.\[8\]

Anesthesia for percutaneous transcatheter closure of ASD/VSD requires general anesthesia or sedation because of the need for a completely immobile patient and need for hemodynamic stability.\[9\] The available data are either on a single heart defect or studies a particular anesthesia technique for transcatheter device closures. Hence, on a broader note, we undertook this prospective observational study auditing the perioperative anesthetic management of patients with different acyanotic congenital heart diseases undergoing device closure in our hospital setting.

In our study, among 78.33% of the patients receiving general anesthesia, endotracheal intubation was done in 65% while SGD was inserted in 13.33% of the patients. While in the other studies, intubation was done in all the patients as hemodynamic instability and airway obstruction under sedation was observed.\[10,11\] Patki et al\[12\] found SGD advantageous over the tracheal tube with statistically lower incidence of coughing during emergence, postoperative sore throat, and postoperative vomiting ($P < 0.05$). Though advantageous, 18 critical incidents (regurgitation, vomiting, laryngospasm, and bronchospasm) related to the airway were reported by Verghese et al\[13\] in a survey on laryngeal mask airway usage in 11,910 patients. We used SGD in eight (13.33%) patients with different defects and desaturation to 80% was observed in two patients at 10 and 20 min due to dislodgement and needed intubation. No other complications related to SGD were seen. To the best of our knowledge, there is no study in the literature of the use of a supraglottic airway device in transcatheter device closure.

Local anesthesia (LA) with sedation is beneficial in the early detection of neurological signs and symptoms of complications like stroke during the procedure. However, deep sedation is needed for immobility during device deployment which has a risk of hypoxia, hypercarbia due to hypoventilation, and aspiration due to the loss of protective airway reflexes.\[14\] Dexmedetomidine provides a state of “cooperative sedation” without attenuating respiratory drive and is preferred over benzodiazepines and propofol which can induce significant respiratory depression and loss of protective airway reflexes.\[15\] In the present study, LA with sedation was used in 13 (21.67%) patients with Inj. Dexmedetomidine and two patients also received propofol as an induction agent. Similarly, Park et al\[16\] retrospectively compared monitored anesthesia care (MAC) using dexmedetomidine + remifentanil and general anesthesia (GA) with propofol + remifentanil in 311 ASD device closure patients and observed no significant difference in the complication rate or hospital stay in either group but a significant longer turnover time in the GA group ($P = 0.004$). Also, Tewari et al.\[17\] compared dexmedetomidine-propofol versus ketamine-propofol anesthesia for patients undergoing device closure procedures and concluded a significantly faster recovery of consciousness ($P < 0.001$) and motor recovery ($P < 0.001$) in the dexmedetomidine-propofol group.

Anesthesia-induction agents like thiopentone, propofol, and ketamine are used in children with CHD. Ketamine and propofol cause changes in the pulmonary vascular resistance (PVR) and systemic vascular resistance (SVR) and may lead to deterioration or alteration in the cardiac function in the already decompensated and diseased heart.\[18\] Lebovic et al.\[19\] in the pediatric patients undergoing elective cardiac catheterization, concluded propofol as a practical alternative and preferable to ketamine due to a significantly shorter recovery time. Etomidate though has a stable cardiac profile but alone does not blunt the hyperdynamic responses (tachycardia and hypertension) associated with laryngoscopy and intubation.\[20\] In our study, the maximum patients received propofol (69.39%) and a few patients (30.61%) received etomidate. There

| Table 3: Complications |
|------------------------|
| Complication       | Frequency (%) |
| Anesthesia related  |               |
| Dislodgement of SGD | 2 (25%)       |
| Procedure related   |               |
| Supraventricular tachycardia | 1 (1.67%) |
| Device dislodgement | 2 (3.33%)     |
| SGD - supraglottic airway device. Data are presented as numbers (%) |
was no significant difference in the mean heart rate and mean MAP in etomidate and propofol group. However, in the propofol group, a fall in MAP started from the 3rd min post-induction and persisted till the 10th min. The fall in the MAP was statistically significant ($P = 0.009$) but clinically insignificant as no patient required vasopressor or inotrope. There was no significant difference in the mean MAP in the etomidate group. None of our patients developed myoclonus with propofol or etomidate due to premedication with midazolam and fentanyl. However, Karagoz et al.\cite{14} did not find any hemodynamic instability after the use of propofol (2–3 mg/kg IV) in 80.3%, thiopental in 2.2% (3–5 mg/kg IV), and ketamine in 7.2% (1–2 mg/kg IV) of the patients for induction. In our study of 39 patients with endotracheal intubation, anesthesia was maintained with oxygen-air (50%–50%) and sevoflurane (48.33%), propofol (16.67%) of the patients along with muscle relaxant atracurium. None of the patients in the present study had a general anesthesia-related complication or postoperative mechanical ventilation was required.

In a study by Desai et al.\cite{20} 43 ASD patients for transcatheter closure of age (12–56 years) received lignocaine topical oropharyngeal anesthesia followed by dexmedetomidine bolus 1 mcg/kg IV over 10 min and maintenance dose 0.2–0.7 mcg/kg/h as TEE was inserted. Whereas in our study, all the patients who required TEE (30% of the cases) received GA, therefore, there was no need for topical airway preparation.

The embolization of the device may occur in unexpected sites of the circulatory system and is a serious complication.\cite{21} The embolization of the PDA device more commonly occurs in the pulmonary circulation than the systemic circulation because of the pressure gradient. In a study done by Gokaslan et al.\cite{22} in embolized devices, a majority of the patients had ASD as a primary defect and the embolization rate was 2.2% while 1.5% with muscular VSD and 0.5% for PDA devices. We encountered embolization of 1 ASD device (1.67%), which dislodged to the right atrium and was surgically retrieved and 1 VSD device (1.67%) embolized which was retrieved from systemic circulation. No PDA device was embolized in our study.

In our study, out of the 18 (100%) patients with PDA, 66.67% of the patients were intubated. In 16.67% of the patients, I Gel (SGD) was inserted and 16.67% of the cases were done under conscious sedation. But intubation is preferred as it aids in device deployment. In VSD, all the 10 patients (100%) were done under GA (70% of the patients were intubated and I gel (SGD) was inserted in 30% of the patients). Only one patient in which endotracheal intubation was carried out developed intraoperative supraventricular tachycardia while a device was introduced which reverted without treatment and the steroid was continued for 48 h. However, Laussen et al.\cite{30} and Kapoor et al.\cite{31} in their studies observed major hemodynamic instability, arrhythmias, and blood loss during the device closure. These arrhythmias were associated with hypotension and some arrhythmias required treatment. The technique necessary for the device placement was the suggested reason for hemodynamic instability.

Adding on to the available literature, this present study observed different anesthesia techniques for different defects and complications. Thus, to summarize in the patients undergoing PDA device closure, GA with endotracheal intubation should be used in all the patients as the endotracheal tube acts as a guide for the site of device deployment. The patients for VSD device closure should receive GA either GETA or SGD as hemodynamic instability and arrhythmias are common in them. The patients for ASD device closure can present at any age and in patients where TEE is not used can be done under

### Table 1: Mean heart rate in etomidate and propofol study groups

| Study | Parameter | Etomidate | Propofol | Unpaired t-test | P |
|-------|-----------|-----------|----------|-----------------|---|
|       | Mean      | Std. Dev  | Mean     | Std. Dev        |    |
| HR BL | 104.87    | 11.288    | 97.75    | 23.24           | 1.127 | 0.265 |
| POST‑SED | 102.20    | 10.611    | 95.50    | 20.66           | 1.188 | 0.241 |
| PRE‑IND | 101.07    | 10.053    | 95.44    | 20.43           | 1.011 | 0.317 |
| 1 min | 101.60    | 10.769    | 97.47    | 21.80           | 0.696 | 0.490 |
| 2 min | 102.27    | 10.734    | 95.00    | 21.73           | 1.229 | 0.225 |
| 3 min | 100.07    | 10.925    | 95.08    | 21.40           | 0.853 | 0.398 |
| 4 min | 100.47    | 10.155    | 93.94    | 21.95           | 1.098 | 0.278 |
| 5 min | 97.67     | 9.715     | 94.58    | 18.76           | 0.601 | 0.550 |
| 10 min | 101.13    | 13.190    | 94.72    | 18.37           | 1.223 | 0.227 |
| 20 min | 100.20    | 13.723    | 95.92    | 19.05           | 0.788 | 0.435 |
| 30 min | 101.60    | 12.489    | 95.25    | 20.69           | 1.104 | 0.275 |
| 40 min | 98.38     | 14.870    | 91.69    | 21.55           | 0.785 | 0.441 |
| 50 min | 94.800    | 4.147     | 108.00   | 10.71           | -2.562 | 0.037 |
| 60 min | 93.50     | 0.707     | 108.50   | 12.37           | -1.616 | 0.181 |

Mean map in the etomidate and propofol study groups

### Table 2: Mean map in the etomidate and propofol study groups

| Study | Parameter | Etomidate | Propofol | Unpaired t-test | P |
|-------|-----------|-----------|----------|-----------------|---|
|       | Mean      | Std. Dev  | Mean     | Std. Dev        |    |
| Map BL | 86.36     | 14.30     | 83.19    | 12.82           | 0.776 | 0.442 |
| POST‑SED | 83.04    | 12.17     | 80.59    | 15.24           | 0.553 | 0.583 |
| PRE‑IND | 83.47    | 15.13     | 78.90    | 14.03           | 1.036 | 0.305 |
| 1 min | 83.98     | 13.76     | 82.46    | 15.79           | 0.324 | 0.748 |
| 2 min | 81.51     | 12.93     | 80.72    | 14.64           | 0.181 | 0.857 |
| 4 min | 82.87     | 14.23     | 78.47    | 12.75           | 1.084 | 0.284 |
| 6 min | 81.56     | 11.99     | 79.80    | 14.61           | 0.411 | 0.683 |
| 8 min | 82.58     | 10.66     | 79.79    | 15.22           | 0.645 | 0.522 |
| 10 min | 80.42    | 14.70     | 78.81    | 15.10           | 0.351 | 0.727 |
| 20 min | 80.27    | 14.09     | 80.40    | 14.03           | -0.031 | 0.976 |
| 30 min | 81.87    | 13.13     | 80.60    | 14.66           | 0.287 | 0.775 |
| 40 min | 85.74    | 12.86     | 80.71    | 14.00           | 0.887 | 0.384 |
| 50 min | 83.67      | 15.78     | 73.25    | 16.92           | 0.900 | 0.403 |
| Map 60 min | 73.00   | 0.47      | 73.50    | 21.54           | -0.031 | 0.977 |
GA with SGD. However, when TEE is used, GA with endotracheal intubation is preferable. The supraglottic airway device can be used as an alternative to endotracheal intubation in patients undergoing ASD/VSD device closure, however, a deeper plane of anesthesia should be maintained to prevent laryngospasm and supraglottic airway device dislodgement. Though both etomidate and propofol can be used as anesthesia induction agents for device closure, the present study in addition to the available literature suggests propofol a safer alternative when used in graded doses without clinically significant hemodynamic instability and faster postoperative recovery.

The limitations of the study are that it was a single-center observational study and with a small sample size in each group. The author recommends further studies in a larger population to validate these results.

CONCLUSION

From our study, we conclude that GA is preferred in most device closure patients. The supraglottic airway device can be safely used in ASD/VSD device closure patients. Vigilance for complications is the utmost need.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Durongpisitkul K, Soongswang J, Laohaprasitiporn D, Nana A, Sriyoschat S, Ponvilawan S, et al. Comparison of atrial septal defect closure using amplatzr septal occluder with surgery. Pediatr Cardiol 2002;23:36-40.
2. Guo J, Lao YK, Chen ZY, Cao H, Yan XP, Chen H, et al. Long-term outcomes of device closure of very large secundum atrial septal defects: A comparison of transcatheter vs intraoperative approaches. Clin Cardiol 2012;35:626-31.
3. Siddiqui WT, Usman T, Aliq M, Amanullah MM. Transcatheter versus surgical closure of atrial septum defect: A debate from a developing country. J Cardiovasc Thorac Res 2014;6:205-10.
4. Vittinghoff M. Deep sedation / procedural sedation for cardiac catheterization in children. Appl Cardiopulmonary Pathophysiol 2009;13:34-40.
5. Hamid A. Anesthesia for cardiac catheterization procedures. Heart Lung Vessel 2014;6:225-31.
6. Karagoz AH, Ankil-Yilbas A, Kaban M, Tuner M, Ozkutlu S, Karagoz T. Anesthesia for percutaneous transcatheter closure of atrial and ventricular septal defects in pediatric patients. Turk J Pediatr 2013;55:628-32.
7. Ince M, Ozkan G, Kilic A, Suat Dodanci, Vedat Y. Anesthesia management for transcatheter atrial septal defect closure in pediatric patients. J Clin Anal Med 2016;7:1-3.
8. Bernstein D. Atracurium: congenital heart disease: Left to right shunt lesions. In: Behrnam RE, editor. Nelson Textbook of Pediatrics. 20th ed. New Delhi: Elsevier; 2016. p. 2189-99.
9. Park YS, Choi DK, Kang J, Park J, Jung KW, Choi IC. Comparison between monitored anesthesia care and general anesthesia in patients undergoing device closure of atrial septal defect. J Thorac Dis 2019;11:1421-7.
10. Laussen PC, Hansen DD, Perry SB, Fox ML, Javorski JJ, Burrows FA, et al. Transcatheter closure of ventricular septal defects: Hemodynamic instability and anesthesia management. Anesth Analg 1995;80:1076-82.
11. Kapoor MC, Sharma S, Sharma VK, Dugal JS, Singh C. Anesthesia for percutaneous transcatheter closure of perimembranous ventricular septal defect. J Cardiothorac Vasc Anesth 2006;20:202-8.
12. Parki A. Laryngeal mask airway vs the endotracheal tube in pediatric airway management: A meta-analysis of prospective randomised controlled trials. Indian J Anaesth 2011;55:537-41.
13. Verghese C, Brimacome JR. Survey of laryngeal mask airway usage in 11,910 patients: Safety and efficacy for conventional and nonconventional usage. Anesth Analg 1996;82:129-33.
14. Gerlach AT, Dasta JF. Dexmedetomidine: An updated review. Ann Pharmacother 2007;41:245-52.
15. Ulgey A, Aksu R, Bicer C, Akin A, Altuntas R, Esmaoglu A, et al. Is the addition of dexmedetomidine to a ketamine–propofol combination in pediatric cardiac catheterization sedation useful? Pediatr Cardiol 2012;33:770-4.
16. Tewari K, Tewari V, Datta S. Dexmedetomidine-propofol vs Ketamine-propofol anesthesia in pediatric and young adult patients undergoing device closure procedures in cardiac catheterization laboratory: An open label randomized trial. Indian J Anaesth 2018;62:531-7.
17. Oklu E, Bulutcu FS, Yalcin Y, Ozbek U, Cakali E, Bayindir O. Which anesthetic agent alters the hemodynamic status during pediatric catheterization? Comparison of propofol versus ketamine. J Cardiothorac Vasc Anesth 2003;17:686-90.
18. Lebovic S, Reich DL, Steinberg LG. Comparison of propofol versus ketamine. J Cardiovasc Thorac Res 1992;5:490-4.
19. Dhwani N, Chauhan S, Kothari SS, Kiran U, Das S, Makhija N. Hemodynamic responses to etomidate in pediatric patients with congenital cardiac shunt lesions. J Cardiothorac Vasc Anesth 2010;24:802-7.
20. Desai PM, Umbarkar SR, Sarkar MS, Lohiya R. Conscious sedation using dexmedetomidine for percutaneous transcatheter closure of atrial septal defects: A single center experience. Ann Card Anaesth 2016;19:463-7.
21. Berdat PA, Chatterjee T, Pfmamatter JP, Windecker S, Meier B, Carrel T. Surgical management of complications after transcatheter closure of an atrial septal defect or patent foramen ovale. J Thorac Cardiovasc Surg 2000;120:1034-9.
22. Gokaslan G, Ustunsoy H, Deniz H, Ozcelikhan O, Yasiim A, Baspinar O, et al. Urgent surgical management for embolized occluder devices in childhood: Single center experience. J Cardiothorac Vasc Surg 2012;7:127.