DECLARATION

I hereby declare that this thesis entitled, "Sevoflurane versus Desflurane for Anesthesia in patients undergoing Transcatheter Device Closure of Atrial Septal Defects: A Randomized, Prospective, Observational study", is a bonafide work undertaken by me during the period 2011 – 2013 under the supervision and guidance of my guide and co-guides and submitted to the Sree Chitra Tirunal Institute for Medical Sciences & Technology, Trivandrum in partial fulfilment of the rules and regulations for the award of degree of Doctorate in Medicine (Cardiothoracic & Vascular Anaesthesiology). This thesis has not been presented fully or in part earlier for the award of any degree, diploma, fellowship or similar titles of recognition.

Date:

Place: Thiruvananthapuram

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CERTIFICATE

This is to certify that this thesis entitled, "Sevoflurane versus Desflurane for Anesthesia in patients undergoing Transcatheter Device Closure of Atrial Septal Defects: A Randomized, Prospective, Observational study", herewith submitted by Dr. Poornima Kasthuri to the Sree Chitra Tirunal Institute for Medical Sciences & Technology, Trivandrum for the award of degree of Doctorate in Medicine (Cardiothoracic & Vascular Anaesthesiology), is a record of the bonafide work done by her under our direct supervision and guidance. The work done in connection with this thesis has been carried out by the candidate herself and checked by us periodically.

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CERTIFICATE

I certify that Dr. Poornima Kasthuri has been a D.M trainee in Cardiothoracic & Vascular Anaesthesiology during the period 2011 - 2013. This thesis entitled, "Sevoflurane versus Desflurane for Anesthesia in patients undergoing Transcatheter Device Closure of Atrial Septal Defects: A Randomized, Prospective, Observational study", herewith submitted by Dr. Poornima Kasthuri to the Sree Chitra Tirunal Institute for Medical Sciences & Technology, Trivandrum for the award of degree of Doctorate in Medicine (Cardiothoracic & Vascular Anaesthesiology), is a record of the bonafide work done by her during the period of study. The work done in connection with this thesis has been carried out by the candidate herself with only technical assistance whenever required, under my guidance and to my satisfaction.

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Dr. Poornima Kasthuri

CONTENTS

INTRODUCTION

INTRODUCTION

In most centres in the developed world, transcatheter device closure done under fluoroscopic guidance and supported by transesophageal echocardiography, has become the treatment of choice for Ostium secundum Atrial Septal Defects (ASD).[1,2] In comparison to standard surgical closure, transcatheter device closure is a much shorter procedure that spares patients all the morbidity linked to open cardiac surgery and extracorporeal circulation. These patients consequently enjoy the benefit of short anaesthetic times, early recovery, and reduced duration of hospitalization.[1]

Volatile anaesthetics are indispensable components of a balanced anaesthesia technique. Sevoflurane and Desflurane are relatively new inhalational agents that are widely used in both paediatric and adult anaesthesia, by virtue of their superior recovery profiles. They both afford smooth and rapid recovery from general anaesthesia which has to be instituted in this population, during therapeutic catheterization.

The lesser soluble Desflurane has yielded faster times to early awakening and extubation after many noncardiac surgical interventions in all age groups. Desflurane may be associated with rapid intermediate recovery (in terms of achieving Intensive Care Unit discharge criteria) when compared to Sevoflurane. However, results from different studies have been conflicting.

Though Desflurane and Sevoflurane have been extensively investigated and directly compared during a wide range of surgical procedures in different

age groups, they have not been evaluated or compared in the context of therapeutic interventional cardiac catheterization laboratory (cath-lab) procedures.

This study is designed to evaluate and compare hemodynamic and recovery characteristics after the use of Sevoflurane (Sevoflurane group) or Desflurane (Desflurane group) for maintenance of anaesthesia in patients undergoing transcatheter ASD device closures in the cardiac catheterization laboratory.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Atrial Septal Defects (ASD) account for 7% of all congenital heart defects.[1,2] The most common ASD is an ostium secundum defect. If left untreated, these defects may result in right-sided heart failure, arrhythmia, and pulmonary hypertension.[1,2] Although surgical closure of ASD is safe, effective, and time-tested, it still requires open heart surgery and hospitalization.[3.4]

Transcatheter closure of secundum ASD was first described in 1976 by Mills and King.[5] All currently existing transcatheter ASD closure devices are designed for use only for secundum ASDs, and all other anatomic subtypes of ASD continue to require surgical repair.[2]

Device closure of secundum ASD is associated with low complication rates, short anaesthetic times, and short hospitalizations. When conditions are favourable, Transcatheter secundum ASD closure has become the treatment of choice rather than surgery in many institutions.[2] The American Heart Association has recommended that Transcatheter secundum ASD closure is indicated in patients with hemodynamically significant ASD with suitable anatomic features (Class I recommendation and Level of Evidence: B).[2]

Sevoflurane, a volatile anaesthetic agent, is a halogenated ether. It has rapid induction due to low blood: gas partition coefficient of 0.65. Desflurane is also a halogenated ether. Due to low blood: gas partition coefficient (0.42),

Desflurane also leads to rapid induction and recovery.[6,7,8] These newer inhalational agents offer the advantage of precise control over depth of anaesthesia along with a rapid, predictable and clear-headed recovery with minimal postoperative sequelae, making it a valuable anaesthetic agent for maintenance in adults and pediatric patients in surgeries of all durations.

Emergence agitation (EA) is a common problem after anaesthesia with either Sevoflurane or Desflurane. EA has been described as a mental disturbance during the recovery from general anaesthesia consisting of hallucinations, delusions, inconsolable crying and confusion manifested by moaning, restlessness, paranoid ideation, involuntary physical activity, and thrashing about in bed.[9,10,11] It is a self-limiting phenomenon lasting 5–25 minutes present in between 20 to 30% of children receiving general anaesthesia. Despite its spontaneous resolution, EA is still considered as a potentially serious complication because of the risk of self-injury, and because of the stress caused to both caregivers and families.

Jindal et al studied 100 patients who underwent short day care gynaecological procedures. The study showed no statistical difference in the intraoperative HR and MAP between the groups which received Desflurane and Sevoflurane. The emergence and early recovery time were shorter after maintenance of anaesthesia with Desflurane. Desflurane group achieved Modified Aldrete Score of 9 significantly faster than patients given Sevoflurane. The incidence of postoperative complications including nausea, vomiting,

drowsiness, sore-throat, headache and respiratory complications were similar in both the groups.[6]

White PF et al randomized 130 outpatients who underwent superficial surgical procedures requiring general anaesthesia. The intraoperative hemodynamic variables did not differ between the two groups, which received either Desflurane or Sevoflurane. The average end-tidal concentrations of Desflurane and Sevoflurane were 4.8% ± 1.9% and 1.3% ± 0.4% respectively. Maintenance of anesthesia with both agents allowed for a fast-track recovery. The Desflurane group experienced a higher overall incidence of coughing during the entire perioperative period.[12]

Nathanson MH et al studied 42 outpatients scheduled for laparoscopic tubal ligation procedures who received either Sevoflurane or Desflurane. HR and MAP were similar during the maintenance and recovery periods. Use of Sevoflurane was associated with a slower emergence from anaesthesia. The end-tidal Sevoflurane and Desflurane concentrations were 1.3% ± 0.35% and 4.07% ± 1.03%, respectively from incision to the end of the procedure. There was no difference in the incidence of postoperative nausea and/or emesis between the two study groups.[13]

Bedforth NM et al in his study on 20 patients who underwent non-neurological procedures concluded that the hemodynamic characteristics of Sevoflurane group were similar to that of Desflurane group at 1 MAC concentration.[14]

Kim JM et al studied the effect of Desflurane and Sevoflurane on children with an average age of 5 years who underwent minor surgeries in the Ear, Nose and Throat region. Emergence and recovery from anaesthesia were significantly faster in the Desflurane group. Although Desflurane enabled more rapid wake-up than Sevoflurane, Desflurane was shown to be associated with a higher incidence of emergence agitation. Compared to Sevoflurane, Desflurane did not result in any difference in respiratory adverse events during recovery.[15]

Song et al studied 80 patients who underwent laparoscopic gynaecological procedures and found no significant differences between Desflurane and Sevoflurane with regard to emergence from anaesthesia. The incidence of nausea and vomiting after surgery was noted to be greater in the Desflurane group, although not statistically significant.[16]

Gupta et al in their meta-analysis found no significant differences between Desflurane and Sevoflurane groups in recovery indices.[17,16,18,19,21]

Larsen et al[18], Coloma et al[19], Karlsen[20] and Tarazi EM et al[21] from their respective studies, found out that the emergence and recovery profiles were similar between the two groups that used Desflurane and Sevoflurane for maintenance.

Naidu-Sjosvard K et al studied 50 patients who underwent arthroscopy procedures using Desflurane or Sevoflurane and found out that the time to open eyes and the time to obey commands was better with Desflurane.[22]

Mahmoud et al from their study on 60 gynaecological day-case patients reported that the use of Desflurane for minor outpatient gynaecological surgery resulted in a faster emergence from anaesthesia.[23]

Cohen et al studied 100 patients, aged 2-7 years of age who underwent adenoidectomy. The authors demonstrated more rapid emergence times and time to discharge readiness in children who received maintenance anaesthesia with Desflurane compared to those who received Sevoflurane.[24]

Mckay et al studied 64 patients, aged 18 to 70 years who were scheduled for surgical procedures under general anaesthesia using laryngeal mask airway (LMA) and reported that Desflurane allowed for an earlier return of protective airway reflexes.[25]

Heavner et al from their study on 50 patients, found that early but not intermediate recovery from Desflurane was faster than from Sevoflurane in elderly patients who underwent prolonged general anaesthesia.[26]

Isik Y et al from their study on 80 patients aged 5 to 15 years, concluded that Desflurane may be preferred over Sevoflurane when early recovery from anaesthesia was warranted.[27]

Using Anaesthesia Information Management System (AIMS) data, Dexter et al conducted a meta-analysis including 29 randomized controlled trials comparing extubation times with Desflurane and Sevoflurane. The authors found out that Desflurane reduced the average extubation time and the variability of extubation time by 20%–25% relative to Sevoflurane.[28]

Welborn et al from their analysis on 80 patients who underwent adenoidectomy, concluded that the faster emergence from Desflurane (compared to Sevoflurane) anaesthesia failed to lead to an earlier discharge from hospital after both outpatient and inpatient surgical procedures. They also reported that Desflurane group of patients had a significantly greater incidence of postoperative agitation and excitement compared with Sevoflurane group of patients.[9]

Bruno Locatelli BG et al studied the effect of Desflurane and Sevoflurane in preschool children who underwent sub-umbilical surgery. Sevoflurane and Desflurane were associated with similar incidence of Emergence Agitation (EA) in these children.[29]

Valley RD et al from their study on 48 children, who underwent elective surgical procedures below the umbilicus, found out that the early arousal scores were significantly higher in the Desflurane group. Emergence agitation and coughing episodes occurred to a greater extent in the Desflurane group.[30]

Saros GB et al[31] and Eshima RW et al[32] in their studies compared Desflurane and Sevoflurane for minor outpatient surgical procedures using LMA. They reported a low incidence of respiratory complications in all patients and no significant differences between the Desflurane and Sevoflurane groups of patients.

Arain SR et al demonstrated that when airway responses to Desflurane and Sevoflurane were compared in elective surgical patients breathing through

an LMA, there were significant adverse responses with Desflurane when higher concentrations of volatiles were used. Compared with equipotent concentrations of Desflurane, Sevoflurane was associated with substantially fewer adverse movements and airway effects.[33]

Desflurane and Sevoflurane are associated with increased cost compared with older inhaled anesthetics. [17]

AIMS & OBJECTIVES

AIMS AND OBJECTIVES

1. To evaluate and compare hemodynamic parameters including heart rate (HR) and mean arterial pressure (MAP) during maintenance of anesthesia in the Sevoflurane and Desflurane groups.

2. To evaluate and compare emergence and recovery profiles (specifically time to eye opening, time to obeying commands, time to tracheal extubation, and time to achieving ICU discharge criteria) in the two groups.

3. To find out the mean end tidal concentrations of Sevoflurane or Desflurane required for maintenance of anesthesia in the two groups.

4. To compare the incidence of emergence agitation amongst the two groups.

5. To compare the incidence of complications including bronchospasm, excessive secretions, nausea, vomiting, desaturation, coughing, laryngospasm, and shivering during the period of study in these two groups.

6. To estimate the average quantity and cost of total volatile agent consumed in the two different groups.

MATERIALS & METHODS

MATERIAL AND METHODS

Participants

60 patients having Ostium secundum ASD with significant left to right shunt scheduled for elective Ostium secundum ASD device closure in cardiac catheterization laboratory were enrolled in the study after approval of the Institutional Ethics Committee and obtaining informed written consent.

Randomization

A computer generated randomization protocol was used to allocate patients into 2 groups.

Desflurane group: 30 patients

Sevoflurane group: 30 patients

Inclusion Criteria:

Patients of either gender belonging to the age group of 4 -18 years were included in the study.

Exclusion Criteria:

1. Small ostium secundum ASDs that are hemodynamically insignificant, or are not anatomically suited for device placement as detected by Trans-Thoracic Echocardiography (TTE).
2. Coexisting cardiac lesions
3. Congestive heart failure, severe pulmonary hypertension.
4. Active airway disease, including recent respiratory infection

5. Sleep apnea
6. Developmental delay
7. Neurological, psychological disorders
8. Hepato-renal dysfunction
9. Metabolic or endocrine disorders
10. Morbid obesity (BMI>40)
11. Known allergy to Sevoflurane or Desflurane
12. Family history or personal history of neuromuscular dystrophy (in view of risk of Malignant Hyperthermia)
13. Esophageal pathologies including stricture, previous surgery, and varices that may preclude use of TEE (Trans-Esophageal Echocardiography).
14. Participation in any other drug study in the last one month.
15. Lack of consent for inclusion in the study.

Conduct of the Study:

All patients underwent a thorough pre-anaesthetic evaluation comprising of history taking, general examination, and systemic examination. Complete blood count, Erythrocyte Sedimentation Rate, Random Blood Sugar, Renal Function Tests, Liver Function Tests, Coagulation profile, Electrocardiogram (ECG) and Chest X Ray were done for all as per institutional protocol.

All patients were kept fasting prior to procedure as per the American Society of Anaesthesiologists (ASA) fasting guidelines (Nil per oral for solids-6 hours/ for milk -4 hours/ for clear fluids-2 hours before elective procedures).

Premedication included oral Diazepam at a dose of 0.1mg/kg, given 90 minutes prior to induction. Before shifting to cath- lab, a peripheral intravenous (IV) access, preferably in the upper limb, was procured in the ward and preoperative antibiotics administered.

In the cath-lab, pre-induction monitoring including ECG, non-invasive blood pressure, pulse oximetry, and Bispectral index (BIS) were used. Baseline heart rate (HR) and mean arterial pressure (MAP) were recorded.

All patients were preoxygenated with 100% oxygen at 6 litres/minute. General anesthesia was induced with IV Midazolam 0.05 mg/kg, IV Fentanyl 2-3 μg/kg, and Propofol 2mg/kg. After loss of consciousness (judged by BIS), ventilation of lungs was manually assisted. Neuromuscular blockade was achieved with 0.5mg/kg Atracurium and airway secured with endotracheal tube. IV Dexamethasone 0.15mg/kg was administered as a prophylactic antiemetic. Post-induction monitoring included nasopharyngeal temperature, end-tidal carbon-dioxide ($ETCO_2$), end tidal concentrations as well as minimum alveolar concentration (MAC) of Sevoflurane and Desflurane, airway pressure (AWP), and Trans-Esophageal Echocardiography (TEE).

Following endotracheal intubation, patients were randomized to receive either Sevoflurane 2% - 3% or Desflurane 6% - 8% in an air oxygen mixture, for maintenance of anaesthesia, starting initially at a flow rate of 6 litres per minute

for 10 minutes, after which fresh gas flow was reduced to 2 litres per minute in both the groups. Air oxygen mixture was delivered in proportions adequate to attain a fractional inspired oxygen concentration [FiO_2] of 0.25 - 0.30. Low FiO_2 was used lest oxygen affect quantification of the left to right intra-cardiac shunt. The inspired concentrations of Sevoflurane or Desflurane were adjusted to maintain a BIS value of 40-50, thus ensuring a clinically acceptable depth of anaesthesia. Sevoflurane was delivered using a Sevotec 7 vaporizer (Ohmeda) and Desflurane with a Drager D-Vapor vaporizer. Ventilation was controlled to maintain $ETCO_2$ in a range of 35-40 mmHg using a semi-closed circle system with soda lime absorber.

A multiplane TEE probe (iE33, Philips medical systems) was inserted. TEE examination was done before actually commencing catheterization. Patients aged less than 10 years had rectal Paracetamol suppository (20mg/kg) placed before skin puncture and patients aged above 10 years received intravenous Paracetamol infusion (15mg/kg). The patients received dextrose normal saline as maintenance fluid at a rate of 4ml/kg/hr during the intervention. MAP and HR were recorded before induction, before endotracheal intubation, immediately after intubation, then every minute for 5 minutes, at 10 minutes after intubation, and thereafter every 10 minutes until tracheal extubation. Once shifted to Intensive care unit (ICU), the MAP and HR were recorded every 10 minutes for the first one-hour.

In both groups of patients, if hypotension (a decrease of more than 20% of baseline values) had occurred, it was to be managed by administering IV boluses

of phenyleprine 0.5 – 1 mcg/kg. Bradycardia (decrease of more than 20% of baseline value) would be corrected with IV atropine 0.02 mg per kg. If hypertension and tachycardia (increases exceeding 20% of baseline values) had occured, IV esmolol 0.5 mg per kg followed by infusion of 50 – 300 mcg per kg would have been administered.

The end tidal concentrations of volatile anesthetic, minimum alveolar concentration (MAC), BIS, and airway pressures were recorded immediately after endotracheal intubation (baseline) and then every minute for 5 minutes, at 10 minutes after intubation, and thereafter every 10 minutes till tracheal extubation.

The quantity of total volatile agent consumed and its mean cost was observed. The cost of the volatile anesthetic agent was calculated using the Dion's formula: [anesthetic vaporizer concentration (%) x fresh gas flow (liters per minute) x duration of anesthesia (minutes) x molecular weight of anesthetic (g) x cost (Rupees per mL)] / 2,412 x density (g per mL). The software for easy calculation is freely available.

Once the device was successfully deployed (as judged by fluoroscopy and TEE), the TEE probe was removed. All patients received local infiltration with 0.5% Bupivacine (total 1.5mg/kg) just before sheath removal. The femoral sheath was removed and local dressing applied. The inhalational agent was then abruptly discontinued and the residual neuromuscular block was reversed with

IV Neostigmine 0.05 mg/kg and Glycopyrrolate 0.01mg/kg. The lungs were then ventilated with 100% O_2 at a fresh gas flow of 6 litres per minute.

When patients started demonstrating regular spontaneous breathing pattern and adequate awakening (as indicated by eye opening, facial grimace, or showing purposeful movements) with stable hemodynamics, they were tracheally extubated and transferred to the ICU.

The following were noted:

1. Total procedure time (defined as femoral skin puncture to sheath removal)
2. Total duration of anesthesia (time from induction to discontinuation of volatile agent)
3. Time to eye opening (time from discontinuation of anaesthetic to eye opening)
4. Time to respond to verbal commands (time from discontinuation of anaesthetic to obeying verbal commands)
5. Time to tracheal extubation (defined as time to extubation after discontinuation of anaesthetic)

In the ICU, the patient was nursed in a slightly propped up or in the recovery position (whichever was comfortable for the patient), with O_2 by mask (at flow of 1-2 litres/minute). The patient was kept warm with blankets. HR, MAP

and oxygen saturation (SpO_2) were continuously monitored and charted every 10 minutes for the 1st hour.

Emergence and recovery characteristics were observed and evaluated every 10 minutes by a trained nurse observer. Recovery characteristics were rated by the modified Aldrete score and time to reach discharge criteria which is defined as an Aldrete Score ≥ 9 was observed.

By institutional protocol, the patients were observed in the ICU till next day morning, when they were discharged after procuring a Trans-Thoracic Echocardiogram (TTE) and ECG.

Incidence of adverse events including bronchospasm, desaturation, coughing, laryngospasm, nausea, vomiting, and shivering were noted. Bronchospasm was managed by nebulising with salbutamol and steroid. Laryngospasm was managed with adrenaline nebulisation. Nausea and vomiting was to be treated with IV ondansetron 0.1mg/kg. The need for rescue analgesia was observed and managed with IV Tramadol 1 – 1.5 mg per kg.

Incidence of emergence agitation (EA) among the groups was also compared. Emergence agitation was scored using the Paediatric Anaesthesia Emergence Delirium (PAED) scale. PAED score of 16 or greater is used to define emergence agitation. For patients in whom simple comfort measures (presence of parent, physically holding the child) did not ameliorate EA, 0.5μg/kg IV Fentanyl was administered.

Data Collection

Observations were manually entered in the study chart.

A. Demographic Data:

- Age
- Sex
- Weight
- Height

B. Intra Operative Variables:

- Heart Rate
- Mean Arterial Pressure
- Airway Pressures
- End Tidal Gas Concentration
- BIS
- MAC value
- Duration of procedure
- Duration of anesthesia

C. Recovery Characteristics:

- Response to verbal commands
- Spontaneous eye opening
- Time to tracheal extubation

- Modified Aldrete Score
    - On arrival in ICU
    - After 10 minutes of arrival in ICU
- Time to achieve Aldrete Score of 9

D. Adverse Events:

- Emergence Agitation
- Bronchospasm/ excessive secretions
- Nausea, Vomiting
- Desaturation
- Coughing/Laryngospasm
- Shivering
- Need for rescue analgesia

STATISTICAL ANALYSIS

STATISTICAL ANALYSIS

Statistical analysis was performed by two-way repeated measures ANOVA to minimize variance within subjects. Pair-wise comparisons were performed using Sidak post-hoc test with $P \leq 0.05$ considered significant.

OBSERVATIONS & RESULTS

OBSERVATIONS AND RESULTS

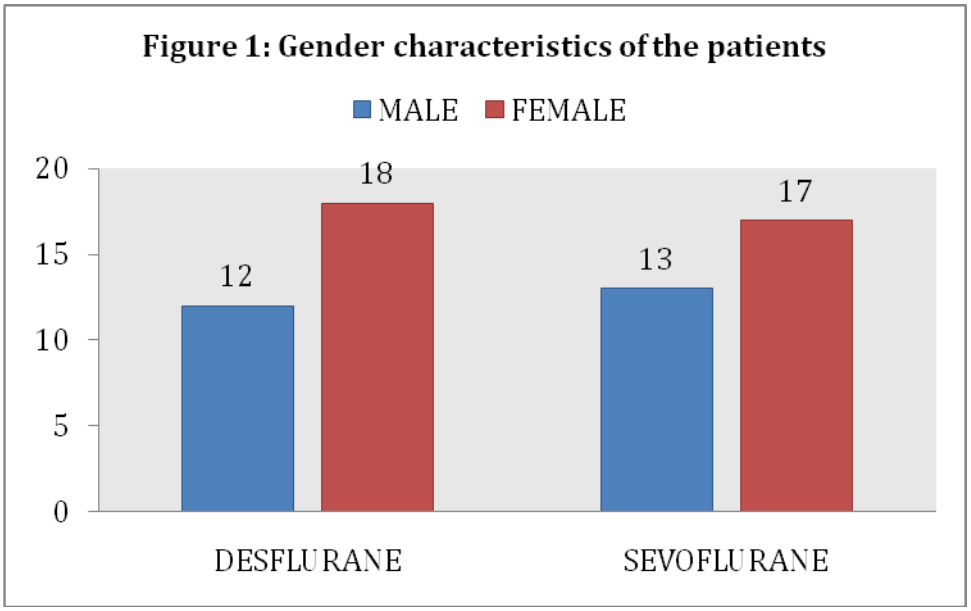
This study was conducted in a prospective and randomized manner. The following observations were recorded and results were statistically analyzed.

Demographic Profile:

Table 1: Gender characteristics of the patients

DEMOGRAPHY		DESFLURANE (n=30)		SEVOFLURANE (n=30)		p Value
		Mean	%	Mean	%	
Gender	Male	12	40	13	43.3	NS
	Female	18	60	17	56.7	

NS – Non-significant

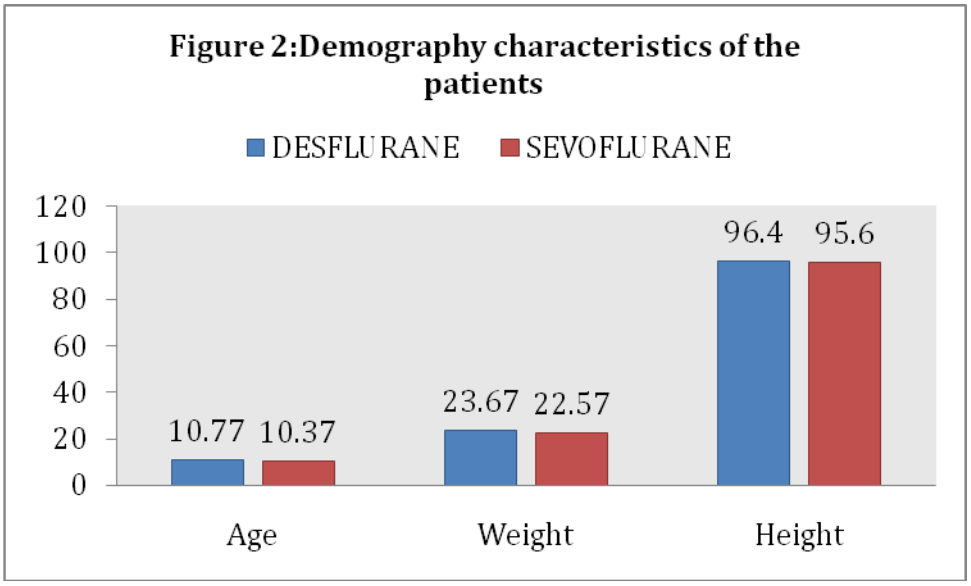


The number of male patients who received Desflurane and Sevoflurane was 12 and 13 respectively. The number of female patients who received Desflurane and Sevoflurane was 18 and 17 respectively (Figure 1). The percentage of male patients who received Desflurane and Sevoflurane was 40 and 43.3 respectively. The percentage of female patients who received Desflurane and Sevoflurane was 60 and 56.7 respectively (Table 1). There was no statistical difference between the two groups with regard to the gender distribution.

Table 2: Demography characteristics of the patients

DEMOGRAPHY	DESFLURANE (n=30)		SEVOFLURANE (n=30)		p Value
	Mean	SD	Mean	SD	
Age (yrs)	10.77	3.81	10.37	3.78	NS
Weight (kgs)	23.67	10.32	22.57	9.72	
Height (cms)	96.4	26.88	95.6	27.08	

NS – Non-significant

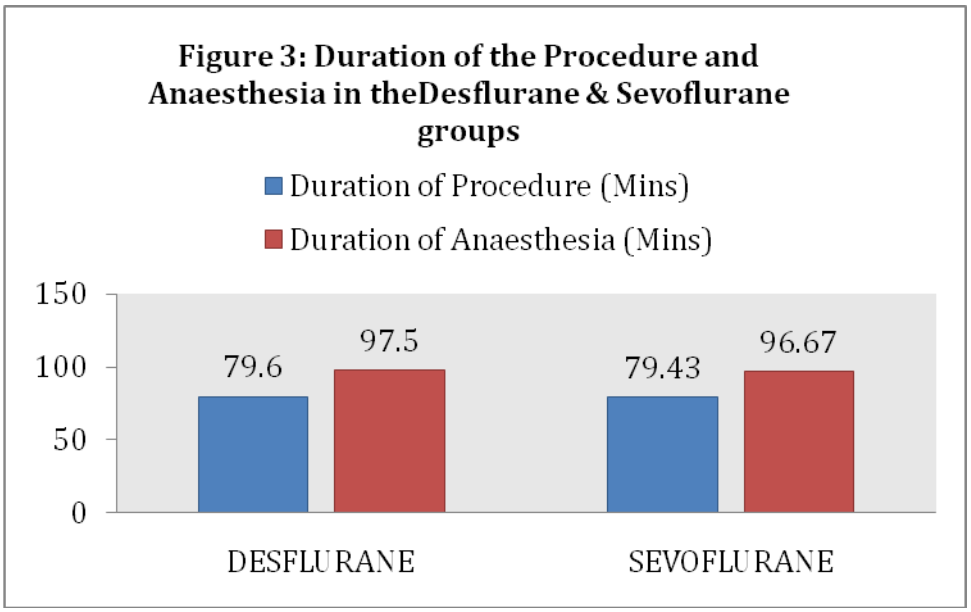


The mean age of the patients who underwent the device closure using Desflurane and Sevoflurane was 10.77 years and 10.37 years respectively. The mean weight of the patients who underwent the device closure using Desflurane and Sevoflurane was 23.67 kgs and 22.57 kgs respectively (Table 2). The mean height of the patients who underwent the procedure of closure of ASD using Desflurane and Sevoflurane was 96.4 cms and 95.6 cms respectively (Figure 2). There was no statistically significant difference between the groups with regard to age (p value - 0.068), weight (p value = 0.672) and height (p value =0.909).

Table 3: Duration of the Procedure and Anaesthesia in the Desflurane & Sevoflurane groups

DURATION (minutes)	DESFLURANE (n=30)		SEVOFLURANE (n=30)		p Value
	Mean	SD	Mean	SD	
Duration of Procedure	79.6	14.47	79.43	13.33	NS
Duration of Anaesthesia	97.5	15.41	96.67	13.35	

NS – Non-significant



The duration of procedure in the Desflurane and Sevoflurane groups was 79.6 ± 14.47 and and 79.43 ± 13.33 minutes respectively (Table 3). The total duration of anaesthesia in the Desflurane and Sevoflurane groups was 95.5 ± 15.41 and 96.67 ± 13.35 minutes respectively (Figure 3). The difference in duration taken to complete the closure of ASD (procedure time) using Desflurane and Sevoflurane was not significant (p value = 0.963). Similarly, the difference in total duration of anaesthesia using either Desflurane and Sevoflurane was not significant (p value = 0.824)

Table 4: Heart rate characteristics in the Desflurane & Sevoflurane groups

HEART RATE (beats / min)		DESFLURANE (n=30)	SEVOFLURANE (n=30)	Mean difference	95% CI of difference	p value
		Mean	Mean			
Before induction		99.90	98.13	1.767	-2.179 to 5.712	NS
Before intubation		95.80	95.27	0.5333	-3.412 to 4.479	NS
Immediately after intubation		104.6	105.9	-1.333	-5.279 to 2.612	NS
FOLLOWING INTUBATION	2 minutes	99.63	98.77	0.8667	-3.079 to 4.812	NS
	3 minutes	97.53	97.6	-0.06667	-4.012 to 3.879	NS
	4 minutes	89.57	89.23	0.3333	-3.612 to 4.279	NS
	5 minutes	86.47	86.37	0.1000	-3.845 to 4.045	NS
	10 minutes	81.87	80.03	1.833	-2.112 to 5.779	NS
	20 minutes	81.87	80.00	1.867	-2.079 to 5.812	NS
	30 minutes	80.63	83.07	-2.433	-6.379 to 1.512	NS
	40 minutes	80.63	80.00	0.6333	-3.312 to 4.579	NS
	50 minutes	80.63	80.03	0.6000	-3.345 to 4.545	NS
	60 minutes	81.87	83.07	-1.200	-5.145 to 2.745	NS
	70 minutes	81.87	83.07	-1.200	-5.145 to 2.745	NS
	80 minutes	86.10	89.53	-3.433	-7.379 to 0.5121	NS
	90 minutes	86.10	89.23	-3.133	-7.079 to 0.8121	NS
	100 minutes	86.10	89.23	-3.133	-7.079 to 0.8121	NS
	110 minutes	86.10	89.23	-3.133	-7.079 to 0.8121	NS

NS – Non-significant

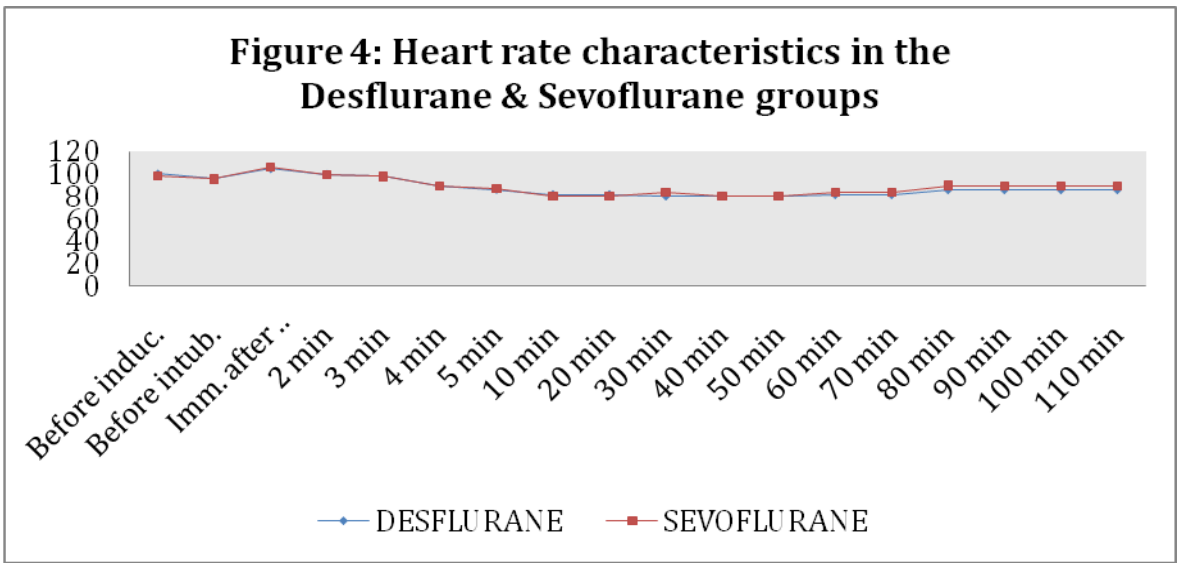
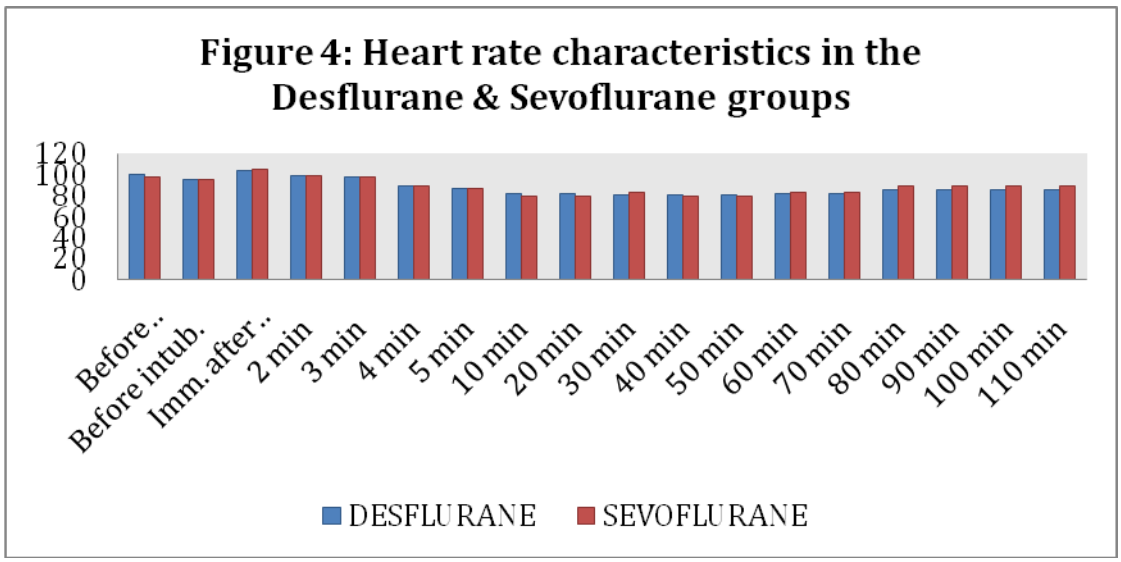


Figure 4: Heart rate characteristics in the Desflurane & Sevoflurane groups

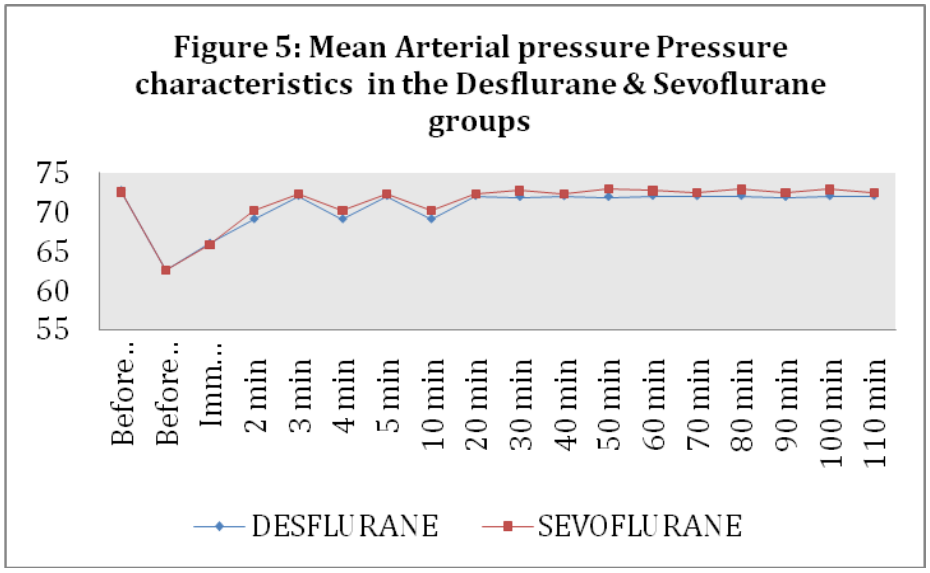


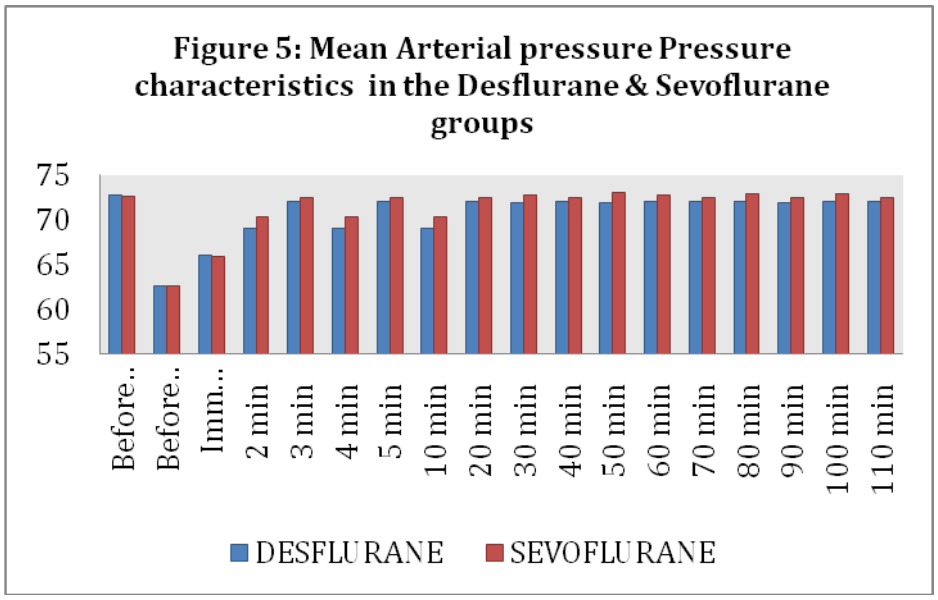
The mean heart rate of patients during the anaesthetic in the two groups is listed in Table 4. The mean heart rate varied from 80 to 104 beats / minute in the group which received Desflurane and from 80 to 105 beats / minute in the group which received Sevoflurane (Table 4). There was no statistical difference in the mean heart rate between the two groups (Table 4). The mean heart rate in the patients when they were administered the two volatile agents (Desflurane and Sevoflurane) is depicted in the Figure 4.

Table 5: Mean Arterial pressure characteristics in the Desflurane & Sevoflurane groups

MEAN ARTERIAL PRESSURE (mm/Hg)		DESFLURANE (n=30)	SEVOFLURANE (n=30)	Mean difference	95% CI of difference	p value
		Mean	Mean			
Before induction		72.67	72.57	0.1000	-1.394 to 1.594	NS
Before intubation		62.53	62.50	0.03333	-1.461 to 1.528	NS
Immediately after intubation		65.97	65.80	0.1667	-1.328 to 1.661	NS
FOLLOWING INTUBATION	2 minutes	69.07	70.23	-1.167	-2.661 to 0.3277	NS
	3 minutes	72.03	72.37	-0.3333	-1.828 to 1.161	NS
	4 minutes	69.07	70.23	-1.167	-2.661 to 0.3277	NS
	5 minutes	72.03	72.37	-0.3333	-1.828 to 1.161	NS
	10 minutes	69.07	70.23	-1.167	-2.661 to 0.3277	NS
	20 minutes	72.03	72.37	-0.3333	-1.828 to 1.161	NS
	30 minutes	71.90	72.73	-0.8333	-2.328 to 0.6610	NS
	40 minutes	72.00	72.37	-0.3667	-1.861 to 1.128	NS
	50 minutes	71.90	72.97	-1.067	-2.561 to 0.4277	NS
	60 minutes	72.03	72.73	-0.7000	-2.194 to 0.7943	NS
	70 minutes	72.00	72.47	-0.4667	-1.961 to 1.028	NS
	80 minutes	72.03	72.90	-0.8667	-2.361 to 0.6277	NS
	90 minutes	71.90	72.47	-0.5667	-2.061 to 0.9277	NS
	100 minutes	72.00	72.90	-0.9000	-2.394 to 0.5943	NS
	110 minutes	72.03	72.47	-0.4333	-1.928 to 1.061	NS

NS – Non-significant





The mean arterial pressure in the two groups using Desflurane and Sevoflurane is listed in the Table 5. The mean arterial pressure varied from 62.53 to 72.67 mmHg in the group which received Desflurane and from 62.50 to 72.97 mmHg in the group which received Sevoflurane (Table 5). There was no statistical difference in the mean arterial pressure between the two groups (Table 5). The mean arterial pressure in the patients when they were administered the two volatile agents (Desflurane and Sevoflurane) is depicted in Figure 5.

Table 6: SpO_2 characteristics in the Desflurane & Sevoflurane groups

SpO_2 (% Saturation)		DESFLURANE (n=30)	SEVOFLURANE (n=30)	Mean difference	95% CI of difference	p value
		Mean	Mean			
Before induction		99.23	98.90	0.3333	-0.4353 to 1.102	NS
Before intubation		100.0	100.0	0.0	-0.7687 to 0.7687	NS
Immediately after intubation		99.63	99.47	0.1667	-0.6020 to 0.9353	NS
FOLLOWING INTUBATION	2 minutes	100.0	100.0	0.0	-0.7687 to 0.7687	NS
	3 minutes	99.23	98.93	0.3000	-0.4687 to 1.069	NS
	4 minutes	97.67	98.03	-0.3667	-1.135 to 0.4020	NS
	5 minutes	97.60	97.80	-0.2000	-0.9687 to 0.5687	NS
	10 minutes	97.60	97.60	0.0	-0.7687 to 0.7687	NS
	20 minutes	97.60	97.67	-0.06667	-0.8353 to 0.7020	NS
	30 minutes	97.60	97.60	0.0	-0.7687 to 0.7687	NS
	40 minutes	97.60	98.00	-0.4000	-1.169 to 0.3687	NS
	50 minutes	97.60	97.67	-0.06667	-0.8353 to 0.7020	NS
	60 minutes	97.60	97.60	0.0	-0.7687 to 0.7687	NS
	70 minutes	97.60	97.60	0.0	-0.7687 to 0.7687	NS
	80 minutes	97.60	97.67	-0.06667	-0.8353 to 0.7020	NS
	90 minutes	97.60	97.97	-0.3667	-1.135 to 0.4020	NS
	100 minutes	97.60	97.60	0.0	-0.7687 to 0.7687	NS
	110 minutes	97.60	97.67	-0.06667	-0.8353 to 0.7020	NS

NS – Non-significant

The mean SpO_2 ranged from 99 to 100% in both groups from the time prior to intubation to upto 3 minutes following intubation. Following endotracheal intubation, the FiO_2 was 0.25 to 0.3 and the mean SpO_2 ranged from 97.6 to 98.03 from 4 minutes after intubation upto the end of the procedure as is evident in Table 6. There was no statistical difference in SpO_2 between the groups which received Desflurane and Sevoflurane at any point of time.

Table 7: Airway Pressure characteristics in the Desflurane & Sevoflurane groups

AIRWAY PRESSURE (cm/H_2O)		DESFLURANE (n=30)	SEVOFLURANE (n=30)	Mean difference	95% CI of difference	p value
		Mean	Mean			
Before induction		0.0	0.0	0.0	-0.7847 to 0.7847	NS
Before intubation		0.0	0.0	0.0	-0.7847 to 0.7847	NS
Immediately after intubation		16.30	15.70	0.6000	-0.1847 to 1.385	NS
FOLLOWING INTUBATION	2 minutes	14.47	14.57	-0.1000	-0.8847 to 0.6847	NS
	3 minutes	14.43	14.57	-0.1333	-0.9180 to 0.6513	NS
	4 minutes	14.47	14.40	0.06667	-0.7180 to 0.8513	NS
	5 minutes	14.50	14.43	0.06667	-0.7180 to 0.8513	NS
	10 minutes	14.43	14.57	-0.1333	-0.9180 to 0.6513	NS
	20 minutes	14.47	14.40	0.06667	-0.7180 to 0.8513	NS
	30 minutes	14.50	14.43	0.06667	-0.7180 to 0.8513	NS
	40 minutes	14.47	14.57	-0.1000	-0.8847 to 0.6847	NS
	50 minutes	14.43	14.40	0.03333	-0.7513 to 0.8180	NS
	60 minutes	14.50	14.43	0.06667	-0.7180 to 0.8513	NS
	70 minutes	14.47	14.57	-0.1000	-0.8847 to 0.6847	NS
	80 minutes	14.43	14.40	0.03333	-0.7513 to 0.8180	NS
	90 minutes	14.47	14.43	0.03333	-0.7513 to 0.8180	NS
	100 minutes	14.43	14.57	-0.1333	-0.9180 to 0.6513	NS
	110 minutes	14.43	14.40	0.03333	-0.7513 to 0.8180	NS

NS – Non-significant

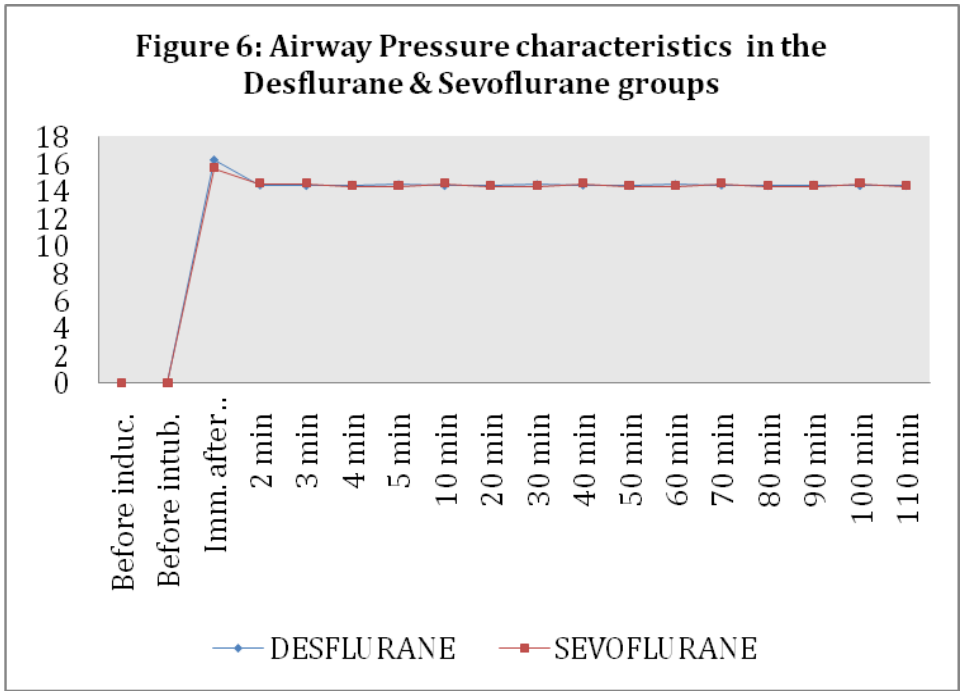


Figure 6: Airway Pressure characteristics in the Desflurane & Sevoflurane groups

The mean airway pressure ranged from 14.43 to 16.30 cmH_2O in the patients who received Desflurane and from 14.40 to 15.7 cmH_2O in the patients who received Sevoflurane (Figure 6). Regarding airway pressure, there was no statistical difference between the two groups at any point of time (Table 7).

Minimum Alveolar Concentration (MAC) in the two groups

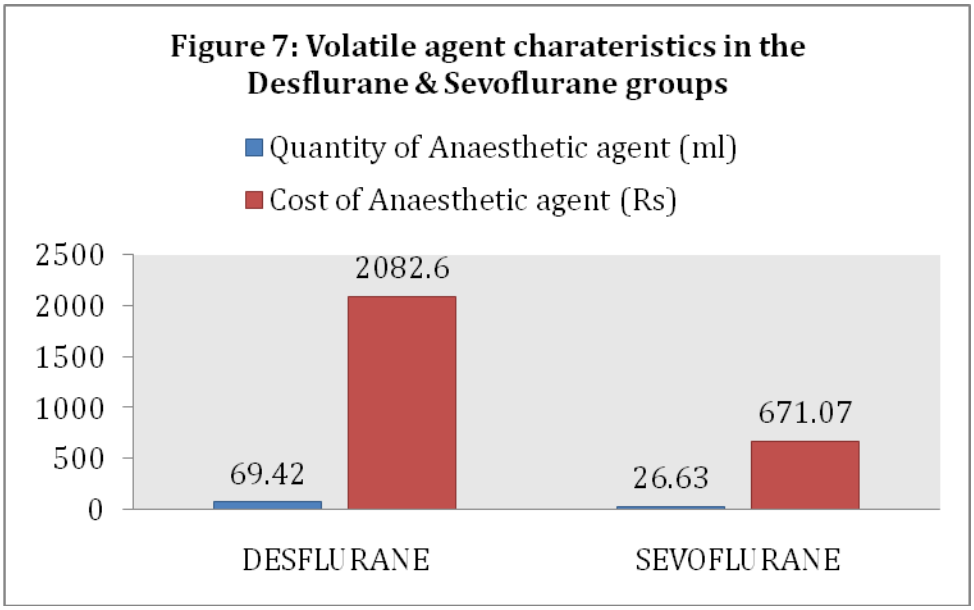
The mean value of minimum alveolar concentration (MAC) ranged from 0.960 to 0.967 in the patients who received both Desflurane and Sevoflurane. The statistical analysis revealed no significant difference between the two groups.

End Tidal Anaesthetic Concentration in the 2 groups

The mean end tidal anaesthetic concentration to keep a Bispectral index (BIS) value of 40-50 ranged from 5.83% to 6.27% in the group which received Desflurane and from 1.86% to 2.07% in the group which received Sevoflurane.

Table 8: Quantity and cost of volatile agent used in the two groups

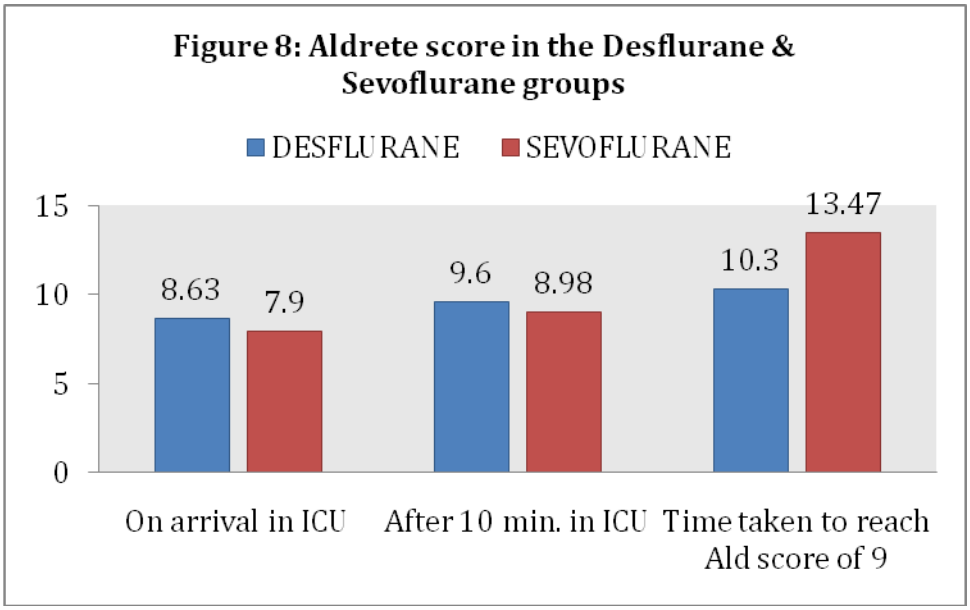
Anaesthetic agent	DESFLURANE (n=30)		SEVOFLURANE (n=30)		p Value
	Mean	SD	Mean	SD	
Quantity of Volatile agent (ml)	69.422	9.92	26.63	3.06	--
Cost of Volatile agent (Rs)	2082.6	315.07	671.07	78.32	0.0001



The mean quantity of the volatile agent used for each patient was 69.42 ml and 26.63 ml in Desflurane and Sevoflurane groups respectively (Figure 7 & Table 8). The mean cost of the volatile agent used for each patient was Rs. 2082.6 and Rs. 671.07 in the Desflurane and Sevoflurane groups respectively. The difference in the cost of the volatile agents between the two groups was statistically highly significant (p value – 0.0001).

Table 9: Aldrete score in the Desflurane & Sevoflurane groups

Aldrete score	DESFLURANE (n=30)	SEVOFLURANE (n=30)	Mean difference	95% CI of differences	p Value
	Mean	Mean			
On arrival in the ICU	8.63	7.90	0.7333	0.4362 to 1.030	0.0001
After 10 minutes in the ICU	9.60	8.98	0.6167	0.3195 to 0.9138	
Time to reach Aldrete score of 9	10.30	13.47	-3.167	-3.464 to -2.870	



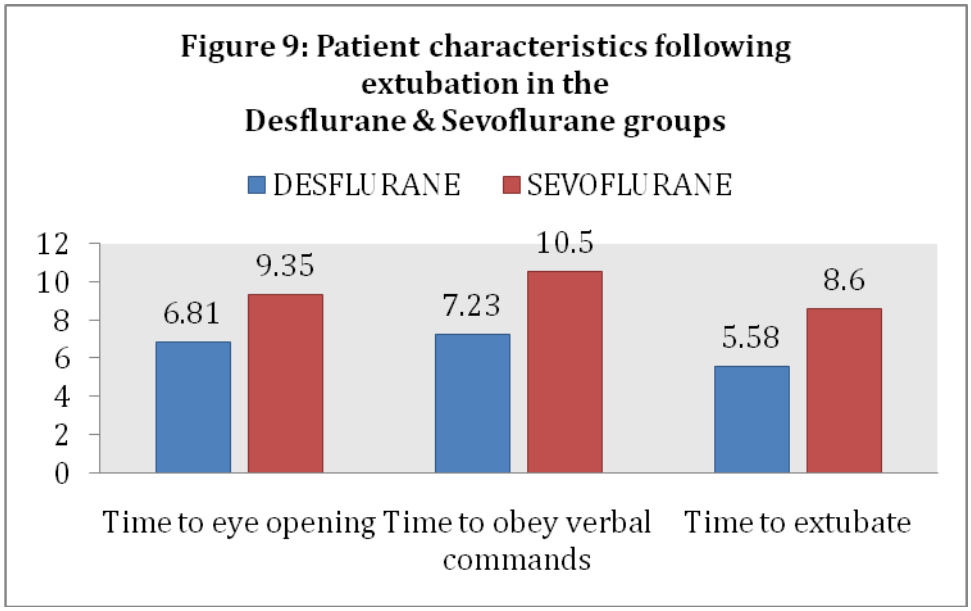
The Aldrete score was calculated in all patients on arrival in the ICU and after 10 minutes of arrival in the ICU. The time taken to reach the Aldrete score of 9 was also calculated. The mean Aldrete score immediately on arrival in the ICU was 8.63 in the Desflurane group and 7.90 in the Sevoflurane group. The mean Aldrete score at 10 minutes following arrival in the ICU was 9.6 and 8.98 respectively in the patients who received Desflurane and Sevoflurane respectively. The mean time taken to reach an Aldrete score of 9 following arrival in the ICU was 10.30 and 13.47

minutes in the Desflurane and Sevoflurane groups respectively (Figure 8 and Table 9).

The mean difference and the confidence interval (CI) of the differences of Aldrete score in the two groups, on arrival in the ICU, after 10 minutes of arrival in the ICU, and the time taken to reach the Aldrete score of 9 is shown in the Table 9. The difference in the Aldrete score in the two groups (on arrival in the ICU and at 10 minutes following arrival in the ICU) was statistically significant (p value – 0.0001). The difference in the time taken to reach Aldrete score of 9 was also statistically significant (p value – 0.0001).

Table 10: Time taken to open eyes, to obey commands and time taken to tracheal extubation following discontinuation of volatile anaesthetic

Following extubation	DESFLURANE (n=30)	SEVOFLURANE (n=30)	Mean Difference	95% CI of difference	p Value
	Mean	Mean			
Time taken to eye opening	6.81	9.350	-2.540	-2.860 to -2.220	0.0001
Time taken to obey verbal commands	7.23	10.50	-3.267	-3.587 to -2.947	
Time taken to extubate	5.58	8.600	-3.017	-3.337 to -2.697	



Following discontinuation of the anesthetic, the time taken to open the eyes, the time taken to obey the verbal commands and the time taken to tracheal extubation was noted in both the groups. The mean time taken to open the eyes was 6.81 minutes in the Desflurane group and 9.35 minutes in the Sevoflurane group. This difference was statistically different (p value – 0.0001). The mean time taken to obey commands was 7.23 minutes in the Desflurane group and 10.50 minutes in the

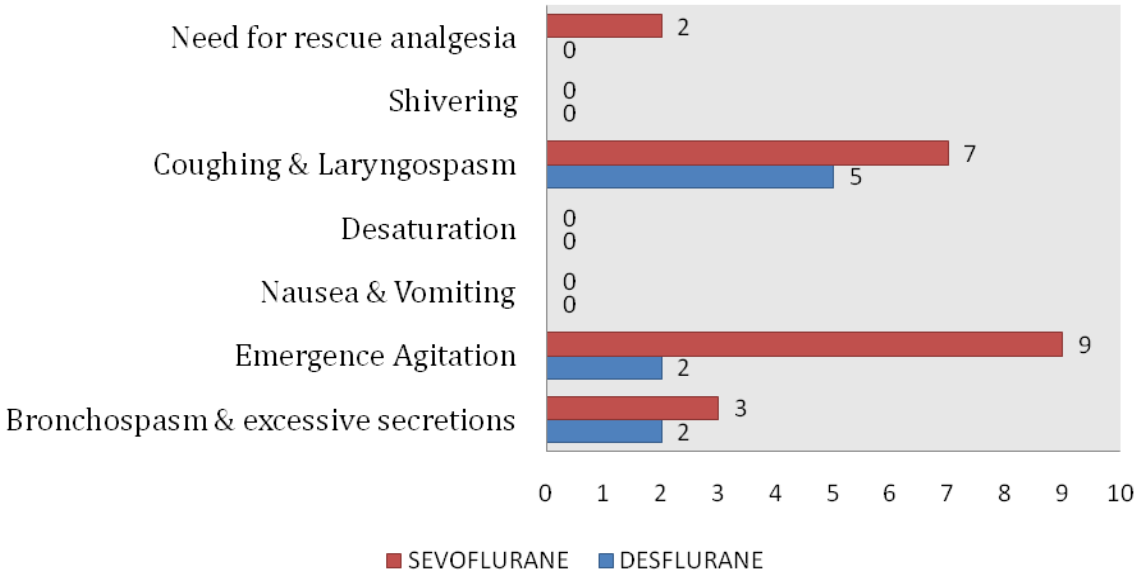
Sevoflurane group. This difference was statistically different (p value – 0.0001). The mean time taken to tracheal extubation was 5.58 minutes in the Desflurane group and 8.6 minutes in the Sevoflurane group. This difference was statistically different (p value – 0.0001) (Figure 9 and Table 10).

Table 11: Postoperative complications in the Desflurane & Sevoflurane groups

POSTOPERATIVE COMPLICATIONS	DESFLURANE (n=30)		SEVOFLURANE (n=30)		p Value
	Patients with complications (n)	%	Patients with complications (n)	%	
Bronchospasm & Excessive secretions	2	6.7	3	10	1.000
Emergence Agitation	2	6.7	9	30	0.042
Nausea & Vomiting	0	0	0	0	0
Desaturation	0	0	0	0	0
Coughing & Laryngospasm	5	16.7	7	23.3	0.748
Shivering	0	0	0	0	0
Need for rescue analgesia	0	0	2	6.9	0.237

SD - Standard Deviation; **p value < 0.05 is statistically significant**

Figure 10: Postoperative complications in the Desflurane & Sevoflurane groups



The postoperative complications noted in the the two groups were bronchospasm & excessive secretions, emergence agitation, nausea and vomiting, desaturation, coughing & laryngospasm, and shivering. The need for rescue analgesia was also noted in the two groups. 2 patients in the Desflurane group and 3 patients in the Sevoflurane group developed bronchospasm with excessive secretions. This difference was not statistically significant. The number of patients who exhibited emergence agitation was 2 and 9 in the Desflurane and Sevoflurane groups respectively. This difference was statistically significant (p value = 0.042). No patient in either group suffered from desaturation, shivering, nausea or vomiting. 5 patients in the Desflurane group and 7 patients in the Sevoflurane group developed coughing and laryngopasm. This difference was not statistically significant. None of the patients needed rescue analgesia in the Desflurane group while 2 patients needed rescue analgesia in the Sevoflurane group. This difference was not statistically significant (Figure 10 and Table 11)

DISCUSSION

DISCUSSION

Device closure of Atrial Septal Defect (ASD) was performed in the two study groups (of 30 patients in each) in whom anaesthesia was administered using either Desflurane or Sevoflurane.

In our study, the mean heart rate and arterial pressure showed no statistically significant difference between the two groups. These findings were consistent with the studies by Jindal et al[6], White PF et al[12], Nathanson et al[13] and Bedforth NM et al.[14]

The time taken to open the eyes, to obey the verbal commands and the time taken to tracheal extubation was shorter in the group which received Desflurane than the group which received Sevoflurane in our study. This was in accordance with the findings from previously published studies by Kim JM et al[15], Naidu-Sjosvard K et al[22], Mahmoud et al[23], Cohen et al[24], and Welborn et al[9]. This finding of ours was different from that of other studies conducted by Song et al[16], Gupta et al[17], Larsen et al[18], Coloma et al[19], Karlsen[20] and Tarazi EM et al.[21]

In our study, the group which received Desflurane had a higher Aldrete score on arrival in the ICU and also after 10 minutes of arrival in the ICU. The time taken to reach an Aldrete score of 9 was lower in the group, which received Desflurane. This finding was similar to that of Jindal et al[6] and Valley RD et al.[30]

In our study, the end tidal anaesthetic concentration to keep a Bispectral index (BIS) value of 40-50 ranged from 5.83% to 6.27% in the group which received Desflurane and from 1.86% to 2.07% in the group which received Sevoflurane. The lower end tidal anaesthetic concentrations of Desflurane and Sevoflurane required in the study done by White PF et al. and in the study done by Nathanson MH et al., may be explained by the fact that they either titrated their anaesthetic to obtain a BIS value of 50-60 (White PF et al) or did not use depth of anaesthesia monitoring (Nathanson MH et al.).

In our study, the emergence agitation was lower in the group which received Desflurane rather than the group which received Sevoflurane. This finding was contrary to the findings by Welborn et al[9], Bruno Locatelli BG et al[29] and Valley RD et al.[30]

In our study, the incidence of respiratory complications including coughing, laryngospasm, bronchospasm and excessive secretions were lower in the group which received Desflurane compared to Sevoflurane, though this difference was not statistically significant. This was unlike the findings of Jindal et al[6], McKay et al[25], Saros GB et al[31] and Eshima et al[32] which found no difference in incidence of respiratory complications in the two groups. In the study by Valley RD et al[30] and White PF et al[12], the respiratory complications were more in the Desflurane group than in the Sevoflurane group.

None of the patients in our study suffered from nausea and vomiting. This could be attributed to the pre-emptive administration of IV Dexamethasone. In

the study by Song et al[16], incidence of nausea and vomiting was greater in the Desflurane group (compared to Sevoflurane group) and in the study by White PF et al[12], the incidence of nausea and vomiting was less in patients who received Desflurane than in those who received Sevoflurane. None of the patients in our study suffered from desaturation or shivering.

In our study, the cost of the volatile agent used for each patient was significantly higher in the Desflurane group as compared to the Sevoflurane group when similar flow rates (2 L/min) were used in the two groups. Chernin et al found that at similar flow rates, Sevoflurane was less expensive to administer than Desflurane. They reported that, when comparing lowest allowable flow rates, the cost of administering Desflurane at 0.5 L/min is more cost effective than administering Sevoflurane at 1 L/min or higher.[34] Chemical inertness, minimal metabolism, and low solubility of Desflurane make its use for low-flow anaesthesia easy.[35]

Currently in the United States, the Food and Drug Administration (FDA) recommends fresh gas flow (FGF) no less than 1 L/min for cases less than 2 MAC hours and FGF 2 L/min for cases longer than 2 MAC hours for Sevoflurane.[36] We decided to use FGF of 2 L/min because we were not sure that every case of ours would last less than 2 MAC hours. Desflurane has no restrictions on flow rate and may be administered with FGF as low as 0.5 L/min.[37] Unlike Desflurane, there are limitations to applying low flow anaesthesia to Sevoflurane.[37] Sevoflurane is degraded to Compound A upon contact with carbon dioxide (CO_2) absorbants.

Compound A is vinyl ether that has been known to cause nephrotoxicity in animals. Low flow anaesthesia in closed circuits, warm CO_2 absorbants, and very dry CO_2 absorbants all enhance the production of Compound A.[37] The difference in utilization cost between Desflurane and Sevoflurane depends on the fresh gas flow rate, which can be adjusted by the anaesthesia professional to control the cost of the volatile anaesthetic agent.[37]

CONCLUSIONS

CONCLUSIONS

1. The intraoperative hemodynamic characteristics were comparable with both Desflurane and Sevoflurane.
2. The emergence from anaesthesia was faster following the administration of Desflurane compared to Sevoflurane. In the group which received Desflurane, the Aldrete score was higher on arrival in the ICU, and at 10 minutes of arrival in the ICU. The time taken to reach an Aldrete score of 9 was lower in the group which received Desflurane.
3. The mean end tidal anaesthetic concentration to keep a Bispectral index (BIS) value of 40-50 ranged from 5.83% to 6.27% in the group which received Desflurane and from 1.86% to 2.07% in the group which received Sevoflurane.
4. Sevoflurane appeared to have greater propensity to cause emergence agitation when compared to Desflurane.
5. There was less incidence of bronchospasm, coughing and laryngospasm in the Desflurane group when compared to Sevoflurane group although this difference was not statistically significant. None of the patients in both groups had nausea, vomiting, desaturation, or shivering.
6. The cost of the volatile agent used for each patient was significantly higher in the Desflurane group as compared to the Sevoflurane group when similar fresh gas flow rates were used.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Webb G, Gatzoulis MA. Atrial Septal Defects in the Adult. Recent Progress and Overview. Circulation 2006; 114:1645-1653.
2. Feltes TF, Bacha E, Beekman RH. Indications for Cardiac Catheterization and Intervention in Pediatric Cardiac Disease. A Scientific Statement from the American Heart Association. Circulation 2011; 123:2607-2652.
3. Suchon E, Pieculewicz M, Tracz W, Przewlocki T, Sadowski J, Podolec P. Transcatheter closure as an alternative and equivalent method to the surgical treatment of atrial septal defect in adults: comparison of early and late results. Med Sci Monit. 2009; 15:CR612–CR617.
4. Kaya MG, Baykan A, Dogan A, Inanc T, Gunebakmaz O, Dogdu O, Uzum K, Eryol NK, Narin N. Intermediate-term effects of transcatheter secundum atrial septal defect closure on cardiac remodeling in children and adults. Pediatr Cardiol. 2010; 31:474–482.
5. Mills NL, King TD. Nonoperative closure of left-to-right shunts. J Thorac Cardiovasc Surg. 1976; 72:371–378.
6. Jindal R, Kumra VP, Narani KK, Sood J. Comparison of maintenance and emergence characteristics after desflurane or sevoflurane in outpatient anaesthesia. Indian J Anaesth. 2011; 55(1): 36–42.
7. Eberts TJ, Schmid PG. Inhaled anesthetics. In: Barash PG, Cullen BF, Stoelting RK, Cahalan MK, Stock MC, editors. Clinical Anesthesia. 6th ed. Philadelphia: Lippincott Williams and Wilkins; 2009. pp. 413–43.

8. Morgan GE, Jr, Mikhail MS, Murray MJ. Clinical Anesthesiology. 4th ed. New York: McGraw-Hill; 2006. Inhalational anesthetics; pp. 155–78
9. Welborn LG, Hannallah RS, Norden JM, Ruttimann UE, Callan CM. Comparison of emergence and recovery characteristics of sevoflurane, desflurane and halothane in pediatric ambulatory patients. Anesth Analg. 1996; 83:917–20.
10. Voepel-Lewis T, Malviya S, Tait AR. A prospective cohort study of emergence agitation in the pediatric postanesthesia care unit. Anesth Analg 2003; 96: 1625–30
11. Olympio MA. Postanesthetic delirium: historical perspectives. J Clin Anesth. 1991; 3(1):60-3.
12. White PF, Tang J, Wender RH, Yumul R, Stokes OJ, Sloninsky A, et al. Desflurane versus sevoflurane for maintenance of outpatient anesthesia: the effect on early versus late recovery and perioperative coughing. Anesth Analg. 2009;109(2):387-93
13. Nathanson MH, Fredman B, Smith I, White PF. Sevoflurane versus desflurane for outpatient anesthesia: a comparison of maintenance and recovery profiles. Anesth Analg. 1995; 81(6):1186-90.
14. Bedforth NM, Hardman JG, Nathanson MH. Cerebral hemodynamic response to the introduction of desflurane: A comparison with sevoflurane. Anesth Analg. 2000; 91(1):152-5.
15. Kim JM, Lee JH, Lee HJ, Koo BN. Comparison of Emergence Time in Children Undergoing Minor Surgery According to Anesthetic: Desflurane and Sevoflurane. Yonsei Med J. 2013; 54(3):732-738

16. Song D, Joshi GP, White PF. Fast-track eligibility after ambulatory anesthesia: a comparison of desflurane, sevoflurane, and propofol. Anesth Analg 1998; 86:267–73.
17. Gupta A, Stierer T, Zuckerman R, Sakima N, Parker SD, Fleisher LA. Comparison of Recovery profile after ambulatory anesthesia with propofol, isoflurane, sevoflurane and desflurane: a systematic review. Anesth Analg. 2004; 98(3):632-41
18. Larsen B, Seitz A, Larsen R. Recovery of cognitive function after remifentanil-propofol anesthesia: a comparison with desflurane and sevoflurane anesthesia. Anesth Analg 2000; 90:168–74.
19. Coloma M, Zhou T, White PF, et al. Fast-tracking after outpatient laparoscopy: reasons for failure after propofol, sevoflurane, and desflurane anesthesia. Anesth Analg 2001; 93:112–5.
20. Karlsen KL, Persson E, Wennberg E, Stenqvist O. Anaesthesia, recovery and postoperative nausea and vomiting after breast surgery. A comparison between desflurane, sevoflurane and isoflurane anaesthesia. Acta Anaesthesiol Scand. 2000; 44(4):489-93.
21. Tarazi EM, Philip BK. A comparison of recovery after sevoflurane or desflurane in ambulatory anesthesia. J Clin Anesth 1998; 10:272–7.
22. Naidu-Sjosvard K, Sjoberg F, Gupta A. Anaesthesia for videoarthroscopy of the knee: a comparison between desflurane and sevoflurane. Acta Anaesthesiol Scand 1998; 42:464–71.

23. Mahmoud NA, Rose DJA, Laurence AS. Desflurane or sevoflurane for gynaecological day-case anaesthesia with spontaneous respiration? Anaesthesia 2001;56:171–4
24. Cohen IT, Finkel JC, Hannallah RS, et al. The effect of fentanyl on the emergence characteristics after desflurane or sevoflurane anesthesia in children. Anesth Analg 2002; 94:1178–81.
25. McKay RE, Large MJ, Balea MC, McKay WR. Airway reflexes return more rapidly after desflurane anesthesia than after sevoflurane anesthesia. Anesth Analg 2005; 100:697-700.
26. Heavner JE, Kaye AD, Lin BK, King T. Recovery of elderly patients from two or more hours of desflurane or sevoflurane anaesthesia. Br J Anaesth 2003;91:502–6
27. Isik Y, Goksu S, Kocoglu H, Oner U. Low flow desflurane and sevoflurane anaesthesia in children. Eur J Anaesthesiol. 2006; 23:60–4.
28. Dexter F, Bayman EO, Epstein RH. Statistical modeling of average and variability of time to extubation for meta-analysis comparing desflurane to sevoflurane. Anesth Analg. 2010; 110:570–80.
29. Bruno Locatelli BG, Ingelmo PM, Emre S, Meroni V, Minardi C et al. Emergence delirium in children: a comparison of sevoflurane and desflurane anesthesia using the Paediatric Anesthesia Emergence Delirium scale. Pediatric Anesthesia. 2013; 23:301–308

30. Valley RD, Freid EB, Bailey AG, Kopp VJ, Georges LS, Fletcher J, et al. Tracheal extubation of deeply anesthetized pediatric patients: a comparison of desflurane and sevoflurane. Anesth Analg. 2003 May;96(5):1320-4
31. Saros GB, Doolke A, Anderson RE, Jakobsson JG. Desflurane vs. sevoflurane as the main inhaled anaesthetic for spontaneous breathing via a laryngeal mask for varicose vein day surgery: a prospective randomized study. Acta Anaesthesiol Scand. 2006 May; 50(5):549-52.
32. Eshima RW, Maurer A, King T, Lin BK, Heavner JE, Bogetz MS, Kaye AD. A comparison of airway responses during desflurane and sevoflurane administration via a laryngeal mask airway for maintenance of anesthesia. Anesth Analg 2003;96:701–5
33. Arain SR, Shankar H, Ebert TJ. Desflurane enhances reactivity during the use of the laryngeal mask airway. Anesthesiology 2005; 103:495–9.
34. Chernin EL. Pharmacoeconomics of inhaled anesthetic agents: considerations for the pharmacist. American Journal of Health- System Pharmacy. 2004; 61(suppl 4):S18-S22.
35. Kapoor MC, Vakamudi M. Desflurane – Revisited. J Anaesthesiol Clin Pharmacol. 2012; 28(1): 92–100.
36. Ultane (sevoflurane) volatile liquid for inhalation. Food and Drug Administration.From http://www.accessdata.fda.gov/drugsatfda_docs/label/2006/020478s016lbl.pdf. Accessed 8/31/2012.

37. John K Varkey. Cost analysis of Desflurane and Sevoflurane. An Integrated Review and Implementation Project (Capstone Project), introducing the Volatile Anaesthetic Cost Calculator. john.varkey@tcu.edu

APPENDIX

Paediatric Anaesthesia Emergence Delirium (PAED) SCALE

Score	0	1	2	3	4
The child makes an eye contact with the caregiver	Extremely	Very much	Quite a bit	Just a little	Not at all
The child's actions are purposeful	Extremely	Very much	Quite a bit	Just a little	Not at all
The child is aware of his/her surroundings.	Extremely	Very much	Quite a bit	Just a little	Not at all
The child is restless.	Not at all	Just a little	Quite a bit	Very much	Extremely
The child is inconsolable	Not at all	Just a little	Quite a bit	Very much	Extremely

MODIFIED ALDRETE SCORE

Criterion	Score
Activity	
Moves 4 extremities voluntarily or on command	2
Moves 2 extremities voluntarily or on command	1
Unable to move extremities voluntarily or on command	0
Respiration	
Able to breathe deeply, cough or cry	2
Dyspnoea or limited breathing	1
Apneic	0
Circulation	
Blood pressure± 20% of preanaesthetic value	2
Blood pressure ±21-49% of preanaesthetic value	1
Blood pressure± 50% of preanaesthetic value	0
Consciousness	
Fully awake	2
Arousable to stimuli	1
Unresponsive	0
O_2 saturation	
Able to maintain O_2 saturation >92% on room air	2
Needs O_2 inhalation to maintain O_2saturation >90%	1
O_2 saturation<90% even with O_2 supplement	0

STUDY PROFORMA

STUDY PROFORMA

Name:
Age/Sex:
Weight (kg):
Height (cm):
Diagnosis:
Procedure:

Duration of procedure	Duration of anesthesia

Parameter / Timing	HR	BP	MAP	SPO2	AWP	MAC	BIS	ET anesthetic Concentration
Baseline (Before Induction)								
Before Intubation								
Immediately after intubation								
2 mins								
3 mins								
4 mins								
5 mins								
10 mins								
20 mins								
30 mins								
40 mins								
50 mins								
60 mins								
70 mins								
80 mins								
90 mins								
100 mins								
110 mins								

Quantity of volatile agent consumed	
Cost of volatile agent consumed	

Recovery Parameters

Time to eye opening	
Time to respond to verbal commands	
Time to extubation	
Modified Aldrete's score-on arrival in CCU	
- at 10 min	
Time to achieve Aldrete's score of 9	

Adverse events:

Bronchospasm & excessive secretions	
Emergence agitation	
Nausea and vomiting	
Desaturation	
Coughing /laryngospasm	
Shivering	
Need for rescue analgesia	

Name and signature of the investigator

CONSENT FORM

CONSENT FORM FOR PARENT/GUARDIAN

Title of the study:

Sevoflurane versus Desflurane for anesthesia in patients undergoing Transcatheter Device Closure of Atrial Septal Defects: A Randomized, Prospective and Observational study.

Study number:

You and your child/ ward are being requested to participate in a study, which evaluates the effects of the anaesthetic agents - desflurane and sevoflurane, on hemodynamic and recovery characteristics of patients during and after anesthesia for transcatheter device closure of atrial septal defects.We will include 120 patients in this study.

What is Transcatheter Device Closure of Atrial Septal Defects?

The patient is going to undergo a non-surgical technique to close the hole (Atrial septal defect or ASD) in the heart. A device (Atrial septal occluder) is delivered at the site of the hole/ASD through a long catheter/tube, which is inserted through the femoral vein in the leg and guided by X-ray (Fluoroscopy) and Transesophageal echocardiography (TEE). The major advantages of this procedure are avoidance of surgical scar, short procedure time, early recovery and short hospital stay. The procedure will be done under general anaesthesia.

Why are desflurane and sevoflurane used for anaesthesia?

Anaesthesia is administered during all surgical procedures so that

- The patient is asleep during the procedure.
- The patient is unaware of the procedure
- The patient remains pain free during the surgery.

Desflurane and Sevoflurane are anaesthetic vapours administered along with oxygen during surgery so that the patient remains asleep, unaware and pain free. After the procedure, these anaesthetic agents are discontinued and the patient will become awake. Use of these agents ensures rapid early recovery from anaesthesia with minimal side effects.

Why are we doing the study?

Both sevoflurane and Desflurane offer rapid recovery and hence are very suitable for day care surgeries. Cardiac catheterization laboratory interventions are also short procedures. Hence, we would like to evaluate their utility in the cardiac catheterization laboratory.

Is Desflurane or sevoflurane safe to be used for these procedures?

The anaesthetic vapours desflurane and sevoflurane are routinely used during anaesthesia for a wide range of surgical procedures in different age groups and are considered safe agents.

Can you withdraw from this study after it starts?

Your participation in this study is entirely voluntary and you are also free to decide to withdraw permission to participate in this study. If you do so, this will not affect your childs' usual treatment at this hospital in any way.

What will happen if you develop any study related injury?

We do not expect any injury to happen to your child / ward but if they do develop any side effects or problems due to the study, these will be treated at no cost to you.

Will you have to pay for the study?

No.

Will your personal details be kept confidential?

The results of this study will be published as thesis and in a medical journal but you or your child/ward will not be identified by name in any publication or presentation of results. However, people associated with the study, without your additional permission, should you decide to participate in this study, may review your child's/wards' medical notes.

If you have any further questions, please ask

Dr. Poornima Kasthuri (Tel: 8281252523), poornima@sctimst.ac.in
Dr. Rupa Sreedhar, Professor of Anesthesiology (Cardiac Anaesthesia Division), SCTIMST (Tel: 9446314043)
Dr. Shrinivas Gadhinglajkar, Professor of Anesthesiology (Cardiac Anaesthesia Division), SCTIMST (Tel: 9446304043)

ASSENT FORM

CHILD PARTICIPANT ASSENT FORM

Title of Study

Sevoflurane versus Desflurane for anaesthesia in patients undergoing Transcatheter Device Closure of Atrial Septal Defects: A Randomized, Prospective and Observational study.

My name is Dr. Poornima Kasthuri. I am doing a study to compare effects of two medicines called Sevoflurane and Desflurane used to give anaesthesia or make you sleep during closure of the hole in your heart. If you like, you can take part in this study.

You are going to undergo a simple procedure to close the hole (ASD or Atrial septal defect) in your heart. Sevoflurane and Desflurane are vapours used with oxygen during the procedure so that you remain asleep, unaware and pain free. After the procedure when these agents are stopped, you will quickly become awake without any side effects and can be with your parents.

Why are we doing the study?

Both Sevoflurane and Desflurane offer rapid recovery and hence are very suitable and safe for short surgical procedures. Hence, we would like to evaluate their utility in the cardiac catheterization laboratory where this procedure will be done. We also hope to learn something that may help other people some day.

Do I have a choice?

Your parents or guardian have to agree for you to participate in the study. After they decide, you will get to choose if you want to do it too. It is alright if you

do not want to take part. It is also fine if you decide to join now but change your mind later on. You can stop any time.

What will happen if I get hurt?

We do not expect any injury to happen to you, but if you do develop any side effects or problems due to the study, these will be treated at no cost to you.

Will anyone know I am in the study?

We will not tell anyone you took part in this study. When we are done with the study, we will write a report about what we found out. We won't use your name in the report.

My telephone number is 8281252523. You can call me if you have questions about the study or if you decide you don't want to be in the study any more. I will give you a copy of this form in case you want to ask questions later.

Agreement

I have decided to be in the study even though I know that I don't have to do it. Dr. Poornima Kasthuri has answered all my questions.

_____	_____	_____
Child's name	**Signature of the child**	**Date**
_____	_____	_____
Person obtaining Assent	**Signature**	**Date**

LIST OF ABBREVIATIONS

ABBREVIATIONS

ASD	Atrial Septal Defect
EA	Emergence Agitation
ASA	American Society of Anaesthesiologists
ICU	Intensive Care Unit
PAED	Paediatric Anaesthesia Emergence Delirium scale
IV	Intravenous
HR	Heart rate
MAP	Mean Arterial pressure
ECG	Electrocardiogram
LMA	Laryngeal Mask Airway
BMI	Body Mass Index
TEE	TransEsophageal Echocardiography
TTE	TransThoracic Echocardiography
SpO_2	Oxygen saturation
BIS	Bispectral index
$ETCO_2$	End-Tidal carbon-dioxide concentration
MAC	Minimum Alveolar Concentration
AWP	Airway Pressure Monitoring
FiO_2	Fractional Inspired Oxygen Concentration
SD	Standard Deviation
CI	Confidence Interval
NS	Non-significant

MASTER CHART

KEY TO MASTER CHART

BI	Before Induction
BT	Before intubation
II	Immediately after intubation
A: Y1 to Y30	Patients (1 to 30) who received Desflurane
B: Y1 to Y30	Patients (1 to 30) who received Sevoflurane
HR	Heart rate
MAP	Mean arterial pressure
SpO_2	Oxygen saturation
AWP	Airway pressure