International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Comparison of Limb-O™ Circuit with Conventional Dual Limb Circuit in Controlled Ventilation

Sanjay Kalani[1], Vijeta Khandelwal[2], Somank Gupta[3]

[1]Professor, Department of Anaesthesiology, New Hospital Medical College, Government Medical College Kota
[2]Assistant Professor, Department of Anaesthesiology, New Hospital Medical College, Government Medical College Kota
[3]Senior Registrar, Department of Anaesthesiology, New Hospital Medical College, Government Medical College Kota

Abstract: ***Background and Aims:** The study aimed to compare the functional characteristics of a newly introduced breathing circuit the Limb-O™ anesthesia breathing circuit with conventional dual limb circuit in controlled mechanical ventilation. **Materials and Methods:** Sixty American Society of Anesthesiologists Grades I and II patients scheduled for various orthopedic surgeries of the upper limb under general anesthesia were divided into two equal groups.. Patients were assigned randomly using computer generated sequence of random numbers to one of the two groups, group Limb-o™ and group conventional. During general anesthesia readings of noninvasive blood pressure (NIBP), heart rate, oxygen saturation (SpO_2), temp. of gases, end tidal CO_2 and inspiratory CO_2 were recorded from monitor. Peak airway pressure, mean airway pressure and static compliance were recorded from ventilator screen in a timely manner using flow sensor at the patient end of the circuit. **Results:** Group Limb-O™ maintained low compliance and retained high temperature of gases in comparison to group conventional. There were no statistically significant difference noted in hemodynamic parameters and airway pressure in both the groups. **Conclusion:** We found that Limb-O™ circuit is capable of delivering a gas mixture to patient retaining more heat as compared to conventional two limb circle system. This Limb-O™ circuit in our view is more convenient and of multiuse, because of its less weight, less compliance and its adaptability to be used as Mapleson D or as a ventilator circuit.*

Keywords: Limb-O™ circuit, conventional dual limb circuit, controlled ventilation.

1. Introduction

The breathing system (respiratory circuit or patient circuit) is a gas pathway connected to the patient, through which gaseous flow occurs at respiratory pressures, and into which a controlled composition of a gas mixture is dispensed.[1] It allows controlled composition and volume of anesthetic gases to be delivered in spontaneous, assisted and controlled ventilation. Various types of breathing circuits have been evolved since the introduction of general anesthesia. When breathing circuit is used in circle configuration with CO_2 absorbers, few choices are available.

The aim of our study was to check and compare the functional characteristics of a newly introduced breathing circuit, the Limb-O anesthesia breathing circuit with the dual limb traditional circuit in the controlled ventilation. The traditional circle breathing circuit incorporates two separate limbs connected by a Y piece. The Limb-O circuit comprises one corrugated tube, 22 mm in diameter, with a septum or a wall extruded down its middle, dividing the inspiratory passage from the expiratory passage. It is different from coaxial circle circuit like MERA-F[2] which has a tube in a tube, where the outer tube functions as an expiratory passage and the inner tube functions as an inspiratory passage

2. Materials and methods

Following approval from the Institutional Ethics & Research Committee and written informed consent from the participants in the study, we selected 60 patients of American Society of Anesthesiologists (ASA) grade I and II of ages between 20 to 60 years of either sex scheduled for elective orthopedic upper limb surgeries under general anesthesia with an anticipated time of two hours or less. The patients with a history of hypertension, diabetes mellitus, cardiovascular, respiratory or cerebrovascular diseases were excluded.

Based on available data for various study parameters from previous studies[3,9] a sample size of 30 patients per group was calculated to show a statistically significant difference between groups taking probability of Type I error of 0.05 and a probability of Type II error of 0.2 as acceptable. A randomization list was prepared using a random number function on a computer spreadsheet. Patients were assigned to one of the two groups, group Limb-O [Figure 1] and group Conventional [Figure 2].

Figure 1: Limb-O™ Circuit

Figure 2: Conventional dual limb Circuit

After obtaining a venous access by adequate size venous cannula in the operating room, standard monitoring as per ASA guidelines non-invasive blood pressure (NIBP), pulse oximetry (SpO_2) by finger probe and heart rate using electrocardiogram (ECG) were applied. All patients were premedicated with midazolam 0.05 mg / kg, glycopyrrolate 0.005mg/kg and pentazocine 0.5mg/kg 15 minutes before surgery. Before starting the study, fresh soda lime was used and the system was flushed with oxygen to make sure denitrogenation. A Spacelab Blease focus anesthesia workstation with monitor and Blease 900 series ventilator was used in all patients. The compliance and leak test for the workstation and the ventilator was performed as per the manufacturer's instructions. The operating room temperature was kept constant at 25^{o} C through central cooling.

Following preoxygenation with either of the circuit, induction of anesthesia was done with propofol 2-3 mg/kg body weight followed by succinylcholine 2 mg/kg intravenously (IV). After IPPV and at the time when patient became apneic, a quiet and gentle laryngoscopy done. The trachea was intubated with 7.5-8.5 mm internal diameter cuffed endotracheal tube. Neuromuscular relaxation was obtained with adequate doses of vecuronium bromide. Anesthesia was maintained with isoflurane. A flow sensor was placed at the patient end of the circuit to monitor airway pressure and compliance. BIS monitoring was done to maintain adequate depth of anesthesia (BIS score 40-50). Controlled mechanical ventilation was given keeping the settings of tidal volume at 6-8 ml/kg, ventilator rate 12 breaths/min. and I:E ratio of 1:2. Temperature probe was inserted on the patient side of the circuit at a side port in angle piece and tip was manipulated to lie in the inspiratory side of the circuit to note the temperature of gases. A blinded observer, first-year anesthesia resident recorded readings of NIBP, HR, SpO_2, temp. of gases, end tidal CO_2 ($EtCO_2$) and inspiratory CO_2 (ICO_2) from the monitor and peak airway pressure, mean airway pressure and compliance from the ventilator screen in a timely manner. Arterial blood gas analysis was done immediately after induction, at 30 minutes and at the end of anesthesia. At the end of surgery, all anesthetic drugs were discontinued and residual muscle paralysis was antagonized using IV glycopyrrolate and neostigmine. Ventilation was controlled with 6l/min. oxygen until extubation.

The endotracheal tube was removed when adequate spontaneous ventilation (tidal volume >4ml/kg) and the patient's response to verbal commands were established. All the qualitative data (sex distribution and ASA grading) were analyzed by using the Chi- square test. In each group, the change in clinical parameters from preinduction to other time points of observation were computed in terms of mean and standard deviation. Statistical significance of these parameters was tested by applying independent student t test. 'P' value < 0.05 was considered as statistically significant. IBM Statistical Package for Social Sciences (SPSS) version 21 for Windows and MS Excel was used for statistical analysis.

3. Results

There were no statistically significant differences in the demographic data. [Table 1] Also no significant difference was noted in SBP, DBP, HR, $EtCO_2$, SpO2 and arterial blood gases analysis between the two groups during the procedure and during recovery. [Figure 3, 4]

Table 1: Distribution of subjects according to baseline demographic profile

Parameter	Group Limb-O	Group Conv	Significance
Age (mean±SD) years	41.9±10.4	42.6±9.7	not significant
Weight (mean±SD) kg	58.6±7.8	57.5±8.7	not significant
Sex distribution (Male; Female)	14:6	15:5	not significant
ASA grading (Grade I: II)	16:04	15:05	not significant
Duration of anesthesia (Mean±SD) min	92±8.9	96±9.1	not significant

Parametric data expressed as Mean±SD, SD=Standard deviation

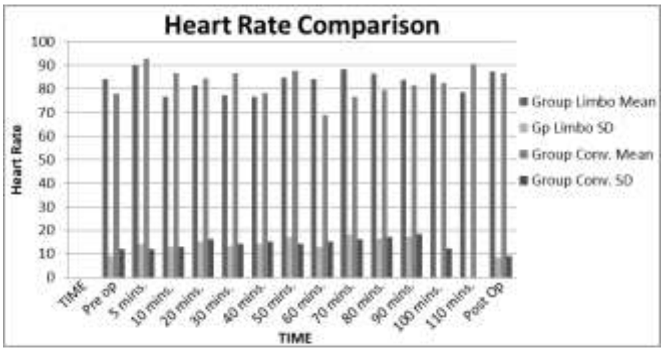

Figure 3: Heart rate comparison

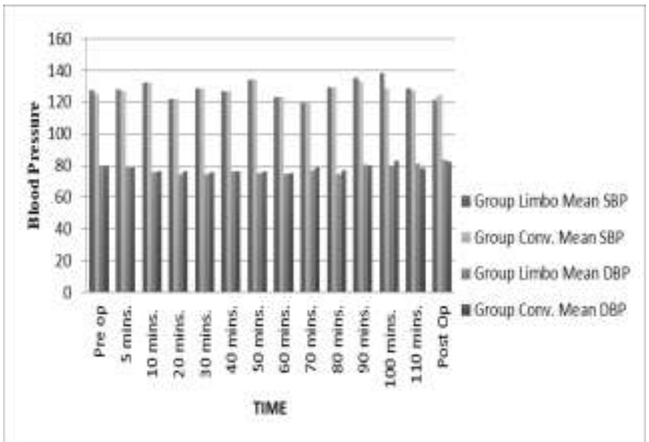

Figure 4: Systolic and Diastolic Blood Pressure comparison

Table 2: Comparison of systemic compliance in both circuits

Time	Group Limb-O	Group Conv.	P value
5 mins.	7.38	8.22	0.01
10 mins.	7.53	8.22	0.02
20 mins.	7.53	8.22	0.02
30 mins.	7.53	8.22	0.02
40 mins.	7.53	8.22	0.02
50 mins.	7.53	8.22	0.02
60 mins.	7.53	8.22	0.02
70 mins.	7.53	8.22	0.02
80 mins.	7.53	8.22	0.02
90 mins.	7.51	8.23	0.03
100 mins.	7.43	8.09	0.23
110 mins.	7.05	8.50	0.12

Table 3: Comparison of temperature increase over room temp. (25°C) in both circuits

Time	Group Limb-OTM	Group Conv.	P value
5 mins.	1.33	0.75	0.04
10 mins.	1.96	0.97	0.00
20 mins.	2.48	1.06	0.00
30 mins.	2.82	1.22	0.00
40 mins.	2.99	1.30	0.00
50 mins.	3.21	1.38	0.00
60 mins.	3.41	1.43	0.05
70 mins.	3.60	1.53	0.00
80 mins.	3.84	1.66	0.60
90 mins.	4.14	1.67	0.10
100 mins.	4.05	1.66	0.31
110 mins.	4.01	1.72	

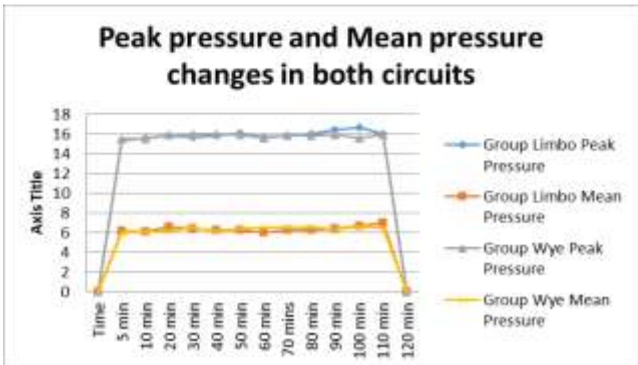

Figure 5: Comparison of peak and mean pressure changes in both circuits

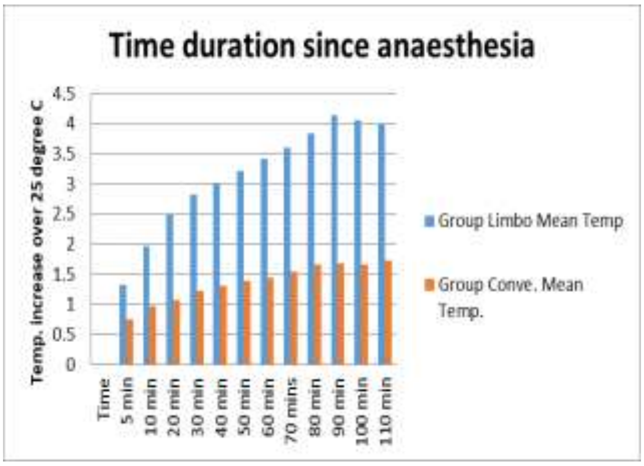

Figure 6: Graph showing difference in temp increase over room temp (25°C)

Comparison of compliance between the two groups shows a significant difference. Group Limb-O has less compliance than group conventional. [Table 2] There was no statistically significant difference between the peak and mean airway pressure in both the groups. [Figure 5] We also found that there was a significant difference in temperatures of gases delivered by two circuits. The group with Limb-O^{TM} circuit retained more heat and had higher values over room temperature (1°C at 5 minutes and 2°C at 70 minutes) as the duration of anesthesia progresses in comparison to the conventional dual lumen circle system. [Table 3 and Figure 6]

4. Discussion

Breathing circuits have been continuously evolving ever since the introduction of general anesthesia. Resistance to gas flow, compliance of the circuit, humidity, and temperature of gases for maintenance of normal respiratory and mucociliary functions are certain concerns which demand development of a better breathing circuit. There is a need for a flexible, light, compact and easy to use an anesthetic circuit that will let the use of low fresh gas flow rates.[3] Over a period of years, several circuits have come into practice to overcome these obstacles. We have investigated a new Limb-O circle circuit which meets most of these criteria.

The use of a coaxial version of Mapleson D system was first described by Bain and Spoerel in 1972.[4] The main features of this Bain system were incorporation of fresh gas inflow tubing inside exhalation limb. This system requires higher fresh gas flow to prevent rebreathing and was unsuitable to use in circle system with CO_2 absorber.[5]

Because of this limitation of Bain circuit, Fukunaga[2] and Tanaka and Umeki[6] introduced the new system called MERA-F circuit in Japan. MERA-F was a coaxial anesthetic breathing circuit, that is, a tube within a tube. The inspiratory gases were delivered to the patient by an inner tube and exhaled gases were carried away by larger outer tube. To use this system as circle system in controlled ventilation, an adaptor was required to divert exhaled gases to the expiratory valve of gas machine.

However, in spite of preserving the convenient features of Bain circuit, the shorter length of MERA-F made it unpopularized.[7] Nakae et al[8] conducted a study comparing the efficacy of three anesthetic circuits, the Jackson-Rees circuit, pediatric circle and the MERA-F in spontaneously breathing children and concluded highest work of breathing in MERA-F circuit.

Use of conventional circle system (having two limbs connected by a Y piece) in controlled ventilation has following advantages:

1) Low flow of anesthesia gases can be used to decrease theatre pollution and cost.
2) It maintains heat and moisture in inspired gases (thereby preserving normal physiological functions of the respiratory system) by retaining both in the system.[9]

Coaxial circle systems provide compactness and moderately increase heat and humidity because of the proximity of inspiratory and expiratory gases in comparison to the conventional circuit but they have the disadvantage of the increased airway resistance.[10] But if the inner tube has a leak or becomes retracted at the patient end, the dead space will be increased which may lead to rebreathing and hypercapnia.[11]

The new Limb-~~O~~TM circuit is compact, lightweight, having length of 72 inches with a weight of about 170 grams. It is a single lumen circuit of 22 mm diameter which is divided by smooth wall septum into two lumens of 11 mm diameter each. Its design minimizes the inconvenience of two-limbed circle circuit at the patient end especially, in head and neck surgeries.[12]
It has other favorable features [12] like:-
1) A common smooth wall between inspiratory and expiratory lumen allows better heat transfer to inspired gases and maintains a higher temperature in comparison to conventional two tube circuit so it might have amplified humidification.
2) Smooth common wall of septum reduces turbulent flow resulting in resistance compatible to traditional two tube circuits, in spite of having smaller lumen.
3) The Limb-O circuit has less compliance in comparison to conventional circle system so whatever volume is set, is delivered to patient with minimum loss.
4) Lightweight reduces torque on tracheal tube, preventing unintentional extubation.
5) In addition, this Limb-~~O~~TM circuit can be used during transportation of the patient from operation room to the high dependency units or ICU, by simply attaching a transport system and converting it to Mapleson D, which is safe and convenient alternative to self-inflating manual resuscitator.
6) The same circuit can be used in ICU to attach with the ventilator and thereby eliminating the need to duplicate disposable equipment.

Various tests are described for testing of a coaxial system as for Mapleson D like Pethiks test and another test to check the integrity of inner and outer tubes.[13,14] The important drawback that we found in Limb-~~O~~TM circuit is nonavailability of leak test to check patency of septum between the two inspiratory and expiratory part.

5. Conclusion

We found that Limb-~~O~~TM circuit is capable of delivering a gas mixture to the patient retaining more heat as compared to conventional two limb circle system. We didn't measure the humidity but should be equal or higher to the performance of coaxial or conventional circle system. More clinical investigations are warranted to compare the heat and moisture conservation characteristics.

This Limb-~~O~~TM circuit in our view is more convenient and of multi-use, because of its less weight, less compliance and its adaptability to be used as Mapleson D or ventilator circuit.

6. Acknowledgement

No financial assistance/ funding used. No conflict of interest.

References

[1] American society for testing and materials. Standard specification for minimum performance and safety requirements for anesthesia breathing systems. 1st edition, West Conshohocken, PA. Author 2000;F1208-89.
[2] Fukunaga AF. A compact multipurpose breathing circuit: An application to the anesthetic circle system. Jap J Anesth 1978;27:1113-7.
[3] Shandro J. A coaxial circle circuit: comparison with conventional circle and Bain circuit. Can Anaesth Soc J 1982;29:121-5.
[4] Bain JA, Spoerel WE. A streamlined anaesthetic system. Can Anaesth Soc J 1972;19:426.
[5] Bain JA and Spoerel WE. Flow requirements for a modified Mapleson D system during controlled ventilation. Can Anaesth Soc J 1973;20:629.
[6] Tanaka T, Umeki Y. Clinical validity of Mera F breathing system for anesthesia. Hiroshima J Anesth 1979;15:163-7.
[7] Byrick RJ, Janssen E, Yamashita M. Rebreathing and co-axial circuits: a comparison of the Bain and MERA F. Can Anaesth Soc J 1981;28:321-8.
[8] Nakae Y, Masayuki M, Sonoda H, Tamiya K. Comparison of the Jackson-Rees Circuit, the Pediatric Circle, and the Mera F breathing system for Pediatric Anesthesia. Anesth Analg 1996;83:488-92.
[9] Mizrak A, Bilgi M, Koruk S, Ganidagli S, Karatas E, Oner U,et al. Comparison of the coaxial circle circuit with the conventional circle circuit. Eurasian J Med 2011;43:92-8.
[10] Dorsch J, Dorsch S. The Circle System. In: Dorsch J, Dorsch S, editors. Understanding Anesthesia Equipment, 5th ed. USA: Lippincott Williams & Wilkins 2008.p.236-7.
[11] Jellish WS, Nollan T, Kleinman B. Hypercapnia related to a faulty adult co-axial breathing circuit. Anesth Analg 2001;93:973-4.

[12] Cozard T. Evaluation of the functional characteristics of the Limb-~~O~~™ anesthesia breathing circuit. A White Paper, Teecie Cozad, RN, BSN, Vital Signs Inc., A GE healthcare company USA L2088_Global_v1_february 2012.
[13] Kaul TK, Mittal G. Mapleson's breathing systems. Indian J Anaesth 2013;57:507-15.
[14] Beauprie IG, Clark AG, Keith IC, Spence D. Pre-use testing of coaxial circuits: The perils of Pethik. Can J Anaesth 1990;37:103.