The Comparative Study of Optimal Fresh Gas Flow Rate of the Parallel Pediatric ADE Breathing System in Mode a and Jackson-Rees Breathing System in Spontaneously Breathing Anaesthetized Pediatric Patients

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Background and Objective : The Mapleson A breathing system is the most efficient breathing system in spontaneous breathing anesthetized pediatric patients with economical use of gases and inhalation agents, less operating room pollution, less respiratory complication but many anesthesiologists still use the Mapleson F or Jackson- Rees breathing system which is less efficient instead. The parallel pediatric ADE breathing system in mode Acan be functioned as the Mapleson A breathing system. In this study, we would like to compare efficiency of the parallel pediatric ADE breathing system in mode A with Jackson-Rees breathing system on fresh gas flow consumption.

Material and Method : This study was a randomized cross-over study. Twenty four patients,weighing 5 to 20 kg, ASA physical status I-II and planned to undergo surgery under combined caudal anesthesia with general anesthesia were enrolled. They were allocated into group I(ADE/A-JR) starting with the parallel pediatric ADE breathing system in mode A then switching to Jackson-Rees breathing system or group II (JR-ADE/A) in reversed order. After induction and intubation, anesthesia was maintained with 50% N_2O/O_2 and Sevoflurane 1-3vol%. Fentanyl infusion (1mcg/ml) was titrated for proper respiratory rate. Starting with the first breathing system,all patients were spontaneously ventilated with lowest fresh gas flow that no rebreathing($ImCO_2$=0) occurred for 5 minutes and then fresh gas flow was gradually decreased by 0.5 LPM every five minutes. End-tidal CO_2($EtCO_2$), inspired minimum CO_2($ImCO_2$) , oxygen saturation(SpO_2) and vital signs (SBP/DBP, HR, RR, BT) were recorded until rebreathing occurred($ImCO_2$ > 0 mmHg) and continued until rebreathing was out of clinically acceptable range($ImCO_2$ > 6 mmHg) then anesthesia breathing system was switched to the second breathing system and the study of the fresh gas flow was done in the same pattern.

Results : At no rebreathing, minimum fresh gas flow of the parallel pediatric ADE breathing system in mode A and Jackson-Rees breathing system were 296.95 ± 36.76 and 442.18 ± 47.05 ml/kg/min; p<0.001respectively. At clinically acceptable rebreathing, the value were142.81 ± 24.49 and 287.8 ± 49.12 ml/kg/min; p<0.001 respectively.

Conclusion: The parallel pediatric ADE breathing system in mode A can be applied in anesthetic practice safely, economically and efficiently in spontaneous breathing anesthetized pediatric patients weighing 5 – 20 kg.

Keywords :Mapleson A breathing system, Jackson-Rees breathing system(JR), ADE, breathing System, fresh gas flow, spontaneousy breathing, pediatric patients.

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Introduction

The Mapleson breathing systems are non-absorber system which are commonly used in pediatric anesthesia all over the world with simple construction and easily portability. They can be classified into 6 different breathing systems(Mapleson A, B, C, D, E and F) according to their configurations. Mapleson A is the most efficient system for spontaneous ventilation and Mapleson D is the most efficient system for controlled ventilation.[1]

As mentioned, Mapleson A breathing system is the most efficient breathing system for spontaneous ventilation because of lowest fresh gas flow requirement, operating room pollution and cost.[2] Saving apart from that, it produces less hypothermia and respiratory complication due to reduced dry gas exposure.[2] Also with Mapleson D breathing system, it possesses the same property if it was used in controlled ventilation.

According to sustainable economy principle, the parallel pediatric ADE breathing system was invented from simple equipments found in operating room to be a compact, light weight and multi-function breathing system. It can be used as Mapleson A,D, and E on which configuration it is. It provides the most efficient breathing system for both of spontaneous ventilation and controlled ventilation patients.

Anyway, in anesthe practice today, Jackson-Rees breathing system or modified Mapleson F breathing system is the standard breathing system for performing anesthesia in pediatric patients. Moreover, most anesthesiologists still prefer to use Jackson-Rees breathing system or modified Mapleson F breathing system which is less suitable in spontaneous ventilation anaesthetized patient instead. In this study, we want to compare efficiency of the parallel pediatric ADE breathing system in mode A with Jackson-Rees breathing system on fresh gas flow consumption for both without rebreathing and within clinically acceptable rebreathing.

Method

This prospective randomized cross-over study was approved by Khon Kaen University Ethics Committee in Human Research, Khon Kaen University, Thailand (HE 581185) and informed consent was obtained from all patients' parents.

Twenty four patients weighing 5 to 20 kg, ASA physical status I-II and scheduled for elective surgery under combined caudal anesthesia with general anesthesia at Srinagarind hospital, Khon Kaen University between September 2015 to August 2016 were included in the study. Patients with cardiovascular disease, respiratory disease, neurological disease, musculoskeletal disease, malnutrition, BMI > 30 kg/m^2, upper abdominal surgery, prone position, BT > 37.8 °C, and peri-operative complication were excluded from the study.

After that, the patients were randomly allocated into group I(starting with ADE/A breathing system then switching to JR breathing system) or group II(starting with JR breathing system then switching to ADE/A breathing system). All patients had been given chloral hydrate 50-100 mg/kg orally 30 minutes before being transferred to operating room. Baseline vital signs(blood pressure, respiratory rate, heart rate, body temperature and oxygen saturation) were recorded then anesthesia was induced by intravenous fentanyl 0.5-1 mcg/kg and propofol 1-2 mg/kg or inhaled 8% Sevoflurane with 50% N_2O/O_2. Intubation was facilitated by succinylcholine 1-1.5 mg/kg together with atropine 0.02 mg/kg intravenously. After successful intubation, caudal epidural anesthesia was performed with 0.75-1.0 ml/kg of mixocaine with adrenaline 1:200,000(solution of 1% xylocaine with adrenaline 1:100,000 mixing with 0.5%bupivacaine in equal proportion). Anesthesia was maintained by 50% N_20/O_2 and Sevoflurane 1-3% for achieving adequate depth of anesthesia and fentanyl infusion (1mcg/ml) was gradually titrated for optimal respiratory rate. After the operation was started and stable vital signs were achieved, all patients were spontaneously ventilated by the first breathing system of which they were allocated in group using lowest fresh gas flow rate withno rebreathing ($ImCO_2$=0) for 5 minutes and then gradually decreasing fresh gas flow by 0.5 LPM every five minutes. End-tidal CO_2 ($EtCO_2$), inspired minimum CO_2($ImCO_2$) , oxygen saturation(SpO_2) and vital signs (SBP/DBP, HR, RR, BT) were recorded until rebreathing occurred($ImCO_2$ > 0 mmHg) and continued until rebreathing was out of clinically acceptable range($ImCO_2$ > 6 mmHg) then anesthesia breathing system was

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switching to the second breathing system and the study was done repeatedly in the same pattern.

Pattenty would be excluded from the any of these study it complications occurred; desaturation(SpO_2 < 94%), unacceptable rebreathing($ImCO_2$ >6 mmHg), hypercapnia($EtCO_2$ >60 mmHg). All patients would be promptly and properly treated. When the operation was tinished, all patients were observed for complications in post-anesthetic care nit following standard protocol until they were good enough to return to ward.

Results

Demographic data and relevant factors of the study are presented in Table 1.

According to primary outcome, the lowest fresh gas flow of the parallel pediatric ADE breathing system in mode A was statistically significantly lower than Jackson-Rees breathing system (p < 0.001) (Table 2). Fresh gas flow requirement for the parallel pediatric ADE breathing system in mode A decreased by 32.84% compared to Jackson-Rees breathing system. $EtCO_2$ was also statistically significantly lower in the parallel pediatric ADE breathing system in mode A.

For secondary outcome, by clinically acceptable rebreathing, fresh gas flow requirement in the parallel pediatric ADE breathing system in mode A was statistically significantly lower than Jackson-Rees breathing system(p < 0.001)(Table 2) with reduced flow by 50.38%. There was no statistically significant difference in vital signs between both groups at any time interval. This study was done successfully without any complications.

Discussion

Jackson-Rees breathing system was used as a standard breathing system in pediatric anesthesia for a long time. Even though it can be used in patients with spontaneous and controlled ventilation, only controlled ventilation was efficiently and ecomonically used. Fresh gas flow requirement was much more needed for spontaneous ventilation leading to increased cost, operating room pollution, hypothermia and respiratory complication. The Mapleson A breathing system was the most suitable breathing system for patients with spontaneous ventilation because of least fresh gas flow requirement, light-weight, and compact design as previous study.[2-4]

Under His Majesty the King's sustainable economy's principle, "Understanding, Accessibility, Developing", Dr. Sunchai Theerapongpakdee, senior anesthesiology staff of Srinagarind hospital, Khon Kaen university had invented the parallel pediatric ADE breathing system, combining the most efficient breathing systems for

Table 1 Demographic data and relevant factors

Variables Group	ADE/A-JR(n=12)	Group JR-ADE/A(n=12)	p-value
Demographic data			
Age (year-month)	2-2	2-1	0.73
Sex (female/male)	3 / 9	2 / 10	0.61
BW (kg)	11.43 ± 2.94	11.63 ± 2.89	0.86
Height (cm)	86.25 ± 12.89	83.75 ± 12.20	0.63
ASA class (I/II)	9 / 3	8 / 4	0.653
Type of surgery			
Lower abdomen	4	5	0.54
Lower extremities	3	1	
External genitalia	5	6	
Duration of surgery (min)	83.75 ± 21.33	90.00 ± 29.38	0.55
Anesthetic data			
Total fentanyl infusion (mcg/kg/hr)	1.89 ± 0.22	1.97 ± 0.20	0.41
Total caudal block (ml/kg)	0.83 ± 0.12	0.85 ± 0.13	0.68

Mean ± SD , p-value < 0.05 referred to bestatistically significant

Table 2 FGF, $EtCO_2$, $ImCO_2$, Vital signs at point of no rebreathing and clinically acceptable rebreathing($ImCO_2$ < 6 mmHg)

Variables	ADE/A (mean ± SD) n = 24	JR (mean ± SD) n = 24	Mean Differonce + 95% CI	p-value
FGF without rebreathing (ml/kg/min)	296.95 ± 36.76	442.18 ± 47.05	145.23 ± 39.44	<0.001
FGF with acceptable range rebreathing (ml/kg/min)	142.81 ± 24.49	287.8 ± 49.12	144.98 ± 49.62	<0.001
$EtCO_2$ (mmHg) at $ImCO_2$ = 0 mmHg	49.17 ± 4.38	47.79 ± 4.47	1.375 ± 2.24	0.006
$EtCO_2$ (mmHg) at ImCO2 < 6 mmHg	50.45 ± 4.42	49.54 ± 4.19	0.91 ± 2.44	0.08
SpO_2 (%)	99.88 ± 0.44	99.87 ± 0.44	-	-
HR	126.67 ± 18.03	126.21 ± 17.0	0.45 ± 2.78	0.428
RR	28.04 ± 4.39	28.54 ± 4.48	0.5 ± 1.28	0.069
SBP (mmHg)	88.33 ± 7.16	86.83 ± 6.09	1.5 ± 3.17	0.03
DBP (mmHg)	42.55 ± 7.66	41.25 ± 8.07	1.25 ± 3.66	1.08
BT (°C)	35.98 ± 0.6	35.90 ± 0.63	0.08 ± 0.11	0.001

spontaneous and controlled ventilation, from readily available equipments found in operating room. This breathing system can be used interchangeably (A/D/E) depending on which configuration it is. It is also simple, compact, comfortable, and easily-used.

In this study, we found that the parallel pediatric ADE breathing in mode A showed superior performance in spontaneous breathing anesthetized pediatric patients compared to Jackson-Rees breathing system with reduced fresh gas requirement by 32.84% at point of no breathing and 50.38% at point of clinically acceptable rebreathing. There was no difference of vital signs between both groups and no complications also. However, this parallel pediatric breathing system in other modes(D/E) have not yet been studied. Further studies are needed to evaluate efficiency of them and make the parallel pediatric ADE breathing system becomes more practical.

Conclusion

Thus, the parallel pediatric ADE breathing system in mode A can be efficiently, safely, and economically used in anesthesia practice and might be preferred in spontaneously breathing anesthetized pediatric patients weighing 5 – 20 kg instead of Jackson-Rees breathing system.

Acknowledgements

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