Baby EAR Circuit: A Clinical Determination of Optimal Fresh Gas Flow in Spontaneous Breathing Anesthesia

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Background: *Baby EAR circuit is a new modified enclosed afferent reservoir anesthetic breathing system invented to use in pediatric patients. By following His Majesty the King of Thailand's self-sufficiency philosophy, the circuit is simply made of low-cost and easy-to-find materials in the operating room.*
Objective: *Investigate clinical use of the circuit and to find the optimal fresh gas flow in spontaneous breathing anesthesia.*
Material and Method: *A prospective descriptive study was conducted in pediatric patients, who weighed 5-20 kg, anesthetized for surgery and divided into three groups of body weight: groups I (5-<10 kg), groups II (10-<15 kg), groups III (15-20 kg). The Baby EAR circuit was used for general anesthesia with endotracheal tube and spontaneous breathing. Different fresh gas flow of 4, 3.5, 3, 2.5, 2, and 1.5 liter per minute (LPM) was used consecutively. The authors recorded end-tidal carbon dioxide (*$EtCO_2$*) and mean inspiratory carbon dioxide (*$ImCO_2$*) while using fresh gas flow at 4, 3.5, 3, 2.5, 2, and 1.5 LPM.* $EtCO_2$ *of 35-60 mmHg and* $ImCO_2$ *of < 6 mmHg were considered clinically acceptable.*
Results: *Thirty-five patients were enrolled in the present study. Mean value (95% CI) of* $EtCO_2$*,* $ImCO_2$ *and fresh gas flow rate in group I were 42* $\pm$ *3.2 (39.8, 44.2), 3* $\pm$ *1.2 (2.2, 3.8) mmHg, and 1.7* $\pm$ *0.6 (1.2, 2.1) LPM respectively. Mean value (95% CI) of* $EtCO_2$ $ImCO_2$ *and fresh gas flow rate in group II were 50* $\pm$ *5.6 (47.2, 52.8), 3* $\pm$ *0.9 (2.6, 3.4) mmHg, 2* $\pm$ *0.4 (1.8, 2.2) LPM respectively. Mean value (95% CI)* $EtCO_2$ $ImCO_2$ *and fresh gas flow rate in group III were 51* $\pm$ *7.2 (46.7, 55.3), 2* $\pm$ *1 (1.4, 2.6) mmHg, and 2* $\pm$ *0.3 (1.8, 2.2) LPM respectively. No patients had serious complications in the present study.*
Conclusion: *Baby EAR circuit can be made economically and used safely for general anesthesia with spontaneous breathing in pediatric patients who weighed 5-20 kg at optimal fresh gas flow rate of* $\geq$ *2.5 LPM.*

Keywords: *Enclosed afferent reservoir (EAR), Breathing system, Pediatric anesthesia, Fresh gas flow, Spontaneous breathing*

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Enclosed Afferent Reservoir (EAR) is an anesthetic breathing circuit invented in 1988[1] by Miller&Miller. It is a modification of Mapleson A system that is a type of breathing circuit without carbon dioxide (CO_2) absorber. The advantage over Mapleson A system is that it can be used in both control ventilation and spontaneous breathing. It has been widely investigated for its safety and effectiveness for use in adult and pediatric patients[2-7].

Baby EAR circuit[8] (Fig. 1, 2) is a modification of EAR circuit invented by the Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Thailand for clinical use in patients who weighed less than 20 kg. By applying His Majesty the King of Thailand's self-sufficiency philosophy, the circuit is made of low-cost and easy-to-find materials

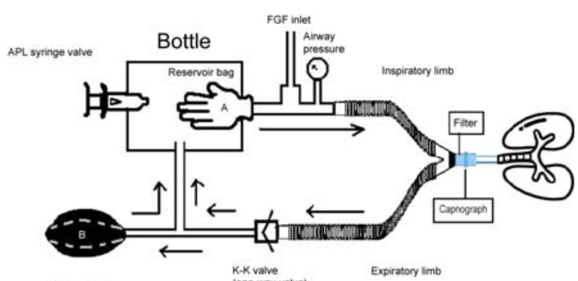

Fig. 1 Diagram of Baby EAR circuit (→ shows direction of gas flow)
FGF = fresh gas flow; APL = adjustable pressure limiting

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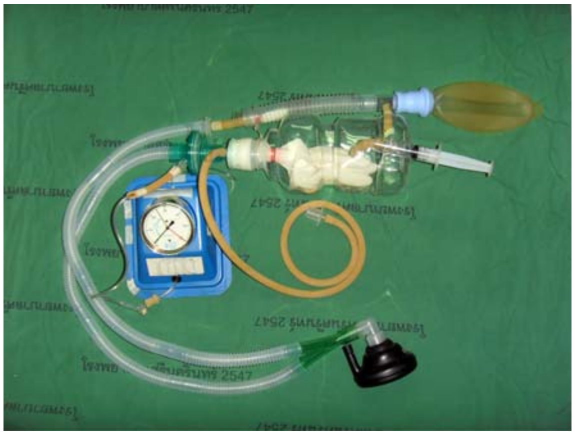

Fig. 2 Baby EAR circuit

in the operating room. The present study was to investigate clinical use of the circuit and to find the optimal fresh gas flow in spontaneous breathing anesthesia.

Material and Method

The present study is a prospective descriptive study, conducted at Srinagarind Hospital, Faculty of Medicine, Khon Kaen University, Thailand. After approval from the institutional Ethics Committee, 35 ASA I-II (American Society of Anesthesiologists physical status I-II) pediatric patients who weighed 5-20 kg scheduled for elective surgery and general anesthesia with endotracheal intubation between September 2007 and April 2008 were recruited. Patients with cardiovascular and respiratory disease were excluded. Informed consent was obtained from the parents.

All patients received standard care for general anesthesia. The Baby EAR circuit was used for general anesthesia with endotracheal tube and spontaneous breathing. After premedication with fentanyl 0.5-1mcg/kg intravenously, anesthesia was then induced with sodium thiopental 3-5 mg/kg succinylcholine 1 mg/kg was used for intubation and end of action was verified by nerve stimulator. Anesthesia was maintained by N_2O: O_2: Sevoflurane at the ratio of 2:1:2-3%. Ventilation was controlled to achieve peak airway pressure of 15-20 cmH_2O and respiratory rate 20-24 breath per minute (bpm) until spontaneous breathing returned regularly. Different fresh gas flow rate of 4, 3.5, 3, 2.5, 2, and 1.5 liter per minute (LPM) was used consecutively. The authors recorded end-tidal carbon dioxide ($EtCO_2$) and mean inspiratory carbon dioxide ($ImCO_2$) while using fresh gas flow rate at 4, 3.5, 3, 2.5, 2, and 1.5 LPM for at least 5 minutes for each flow rate. $EtCO_2$ of 35-60 mmHg and $ImCO_2$ of < 6 mmHg were considered clinically acceptable. In case of $ImCO_2$ > 6 mmHg the fresh gas flow was adjusted back to 4 LPM until $ImCO_2$ decreased to < 6 mmHg and the protocol was repeated. Body temperature was controlled within 36-37°C. Vital signs and respiratory parameters were also recorded. Data was presented and analyzed using descriptive vstatistics, namely percentage, mean $\pm$ SD, and 95% CI (95% confidence interval).

Results

Thirty-five patients were enrolled in the present study; their demographic data are shown in Table 1. The value of $EtCO_2$ $ImCO_2$ and FGF when patients are divided into three groups according to their weight (5-< 10, 10-< 15, and 15-20 kg) is shown in Table 2. Graphic presentation of $ImCO_2$and $EtCO_2$ is shown in Fig. 3, and 4 respectively. No patients had serious complications during the present study.

Discussion

Miller & Miller[1] (1988) introduced the enclosed afferent reservoir (EAR) breathing systems, which is a modification of Mapleson A system and evaluated its use in a clinical setting. Droppert et al[7](1991) has suggested that fresh gas flow of 70 ml/kg should be used for control ventilation in adult patients. For pediatric use in control ventilation and spontaneous breathing mode, Meakin et al[6] (1992) concluded in their study that the formula for optimal fresh gas flow rate is 0.6 x weight$^{0.5}$ (kg). This fresh gas flow rate will produce normocapnia to mild hypocapnia in control ventilation and normocapnia to mild or

Table 1. Demographic data of the 35 pediatric patients

Data	Number (%)	95% CI
Mal/female	19 (54.3)/16 (45.7)	
Age (yr)		
0-2	13 (37.1)	
2.1-4	15 (42.9)	
4.1-6	6 (7.1)	
6.1-8	0	
8.1-10	1 (2.9)	
Weight $\pm$ SD (kg)	12.6 $\pm$ 4.2	11.2, 14.0
Height $\pm$ SD (cm)	88.7 $\pm$ 18.2	82.7, 94.7
ASA class I/II	22 (62.9)/13 (37.1)	

Table 2. FGF, $ImCO_2$ and $EtCO_2$ in each weight group

Body weight (kg)	FGF (LPM) mean ± SD (95%CI)	$ImCO_2$ (mmHg) mean ± SD (95%CI)	$EtCO_2$ (mmHg) mean ± SD (95%CI)
5-<10	1.7 ± 0.6 (1.2, 2.1)	3.0 ± 1.2 (2.2, 3.8)	42 ± 3.2 (39.8, 44.2)
10-<15	2.0 ± 0.4 (1.8, 2.2)	3.0 ± 0.9 (2.6, 3.4)	50 ± 5.6 (47.2, 52.8)
15-20	2.0 ± 0.3 (1.8, 2.2)	2.0 ± 1.0 (1.4, 2.6)	51 ± 7.2 (46.7, 55.3)

FGF = fresh gas flow rate; $ImCO_2$ = inspiratory carbon dioxide; $EtCO_2$ = end-tidal carbon dioxide

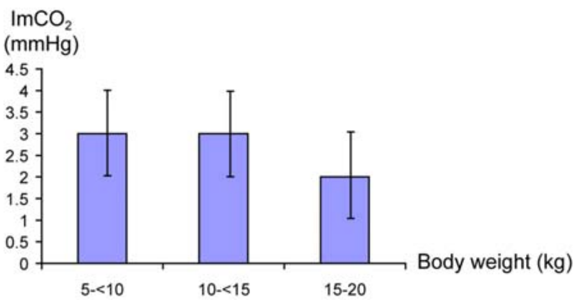

Fig. 3 $ImCO_2$ (mean ± SD) in each weight group

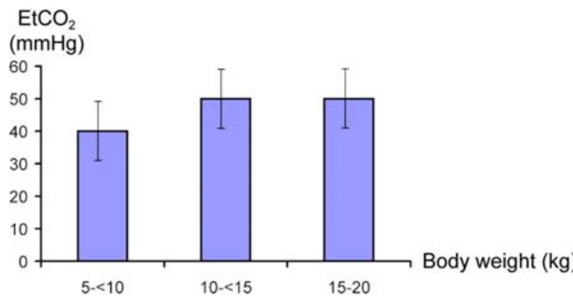

Fig. 4 $EtCO_2$ (mean ± SD) in each weight group

moderate hypercapnia in spontaneous breathing anesthesia in children who weighed 10-70 kg.

Baby EAR pediatric breathing system is an innovation on the non-absorber breathing system with character of Mapleson A system in pediatric anesthesia. It was developed by a team of anesthesiologists at Srinagarind Hospital, Faculty of Medicine, Khon Kaen University to use in small children. It was simply made of disposable materials in the operating room such as 1-liter plastic bottle of intravenous fluid, surgical gloves, bacterial filter, endotracheal tube, 10-ml and 20-ml disposable plastic syringes, plastic corrugated hoses (15-mm internal diameter), yellow latex rubber tube, and pediatric Y connector (Fig. 1). The difference of this new breathing system from others is that after installing a one-way valve (KK one-way valve) in the expiratory hose before pouring the expired gas into the enclosed plastic bottle, it can be used both in controlled ventilation and spontaneous breathing mode with fresh gas flow rate as low as 2-3 LPM in pediatric patients weighing less than 20 kg.

The present study has shown that the Baby EAR circuit can be used safely in all patients with fresh gas flow rate of 2.5 LPM in spontaneous breathing anesthesia (Table 2). By categorizing patients into three groups by body weight (Table 2), $EtCO_2$ and $ImCO_2$ tended to be lower when using the same fresh gas flow in smaller than larger children, corresponding with alveolar ventilation that varies depending on their body weight. Therefore, the authors suggest the fresh gas flow rate of 2.5 LPM in pediatric patients who weighed 5-20 kg. However, the use of capnography will increase safety of patients if the lower fresh gas flow is to be used. Thorough understanding of the structure and function of the system is essential for the safe use of this system.

Conclusion

Baby EAR circuit is a new non-absorber pediatric anesthetic breathing system that can simply be made of disposable materials in the operating room. It can be used safely for general anesthesia with spontaneous breathing in pediatric patients who weighed 5-20 kg at optimal fresh gas flow rate of 2.5 LPM.

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การหาปริมาณก๊าซที่เหมาะสมต่อการใช้งานทางคลินิกในการวางยาสลบแบบหายใจเองในวงจร Baby EAR

สรรชัย ธีรพงศ์ภักดี, ปิยะพร บุญแสงเจริญ, เดือนเพ็ญ ห่อรัตนาเรือง, ธัญญารัตน์ พันธ์ภานุสิทธิ์, ชุติมา อัศวอารี, กาญจนา อุปปัญ

ภูมิหลัง*: Baby EAR เป็นวงจรวางยาสลบแบบใหม่ที่ประดิษฐ์เพื่อใช้ในผู้ป่วยเด็ก ทำขึ้นจากวัสดุที่หาง่าย ราคาถูก สอดคล้องกับแนวพระราชดำริเรื่องเศรษฐกิจแบบพอเพียง สามารถช่วยลดงบประมาณในการซื้อวงจรวางยาสลบที่มีราคาแพงจากต่างประเทศได้ คณะผู้นิพนธ์จึงต้องการศึกษาการใช้วงจร Baby EAR ในการวางยาสลบผู้ป่วยเด็กแบบหายใจเองเพื่อดูประสิทธิภาพในการใช้งานทางคลินิก และศึกษาหาปริมาณ fresh gas flow ที่เหมาะสม*

วัสดุและวิธีการ*: เป็นการศึกษาแบบพรรณนา โดยใช้วงจร baby EAR วางยาสลบแบบหายใจเองในผู้ป่วยเด็กน้ำหนักตัว 5-20 กก. โดยแบ่งตามน้ำหนักตัวเป็น 3 กลุ่ม บันทึกค่า end-tidal carbon dioxide ($EtCO_2$) และ mean inspiratory carbon dioxide ($ImCO_2$) ขณะใช้ fresh gas flow rate (FGF) ขนาด 4, 3.5, 3, 2.5, 2, 1.5 ลิตรต่อนาที ค่า $EtCO_2$ และ $ImCO_2$ ที่ยอมรับได้ทางคลินิกคือ 35-60 มม.ปรอท และ < 6 มม.ปรอท ตามลำดับ คำนวณค่าทางสถิติและนำเสนอในรูปค่าเฉลี่ยร้อยละ และ 95% CI (95% confidence interval)*

ผลการศึกษา*: ผู้ป่วยเข้าร่วมการศึกษาจำนวน 35 ราย พบว่ากลุ่มที่หนึ่ง (น้ำหนักตัว 5-<10 กก.) มีค่าเฉลี่ย (95% CI) ของ $EtCO_2$, $ImCO_2$ และ FGF เท่ากับ 42 ± 3.2 (39.8, 44.2), 3 ± 1.2 (2.2, 3.8) มม.ปรอท, 1.7 ± 0.6 (1.2, 2.1) ลิตรต่อนาที ตามลำดับ ในกลุ่มที่สอง (น้ำหนักตัว 10-<15 กก.) มีค่าเฉลี่ย (95% CI) ของ $EtCO_2$, $ImCO_2$ และ FGF เท่ากับ 50 ± 5.6 (47.2, 52.8), 3 ± 0.9 (2.6, 3.4) มม.ปรอท, 2 ± 0.4 (1.8, 2.2) ลิตรต่อนาทีตามลำดับ ในกลุ่มที่สาม (น้ำหนักตัว 15-20 กก.) มีค่าเฉลี่ย (95% CI) ของ $EtCO_2$, $ImCO_2$ และ FGF เท่ากับ 51 ± 7.2 (46.7, 55.3), 2 ± 1 (1.4, 2.6) มม.ปรอท, และ 2 ± 0.3 (1.8, 2.2) ลิตรต่อนาที ตามลำดับ และไม่มีผู้ป่วยรายใดเกิดภาวะแทรกซ้อนจากการใช้วงจรในการศึกษานี้*

สรุป*: วงจร bvaby EAR เป็นนวัตกรรมตามแนวเศรษฐกิจแบบพอเพียง และสามารถใช้ในการวางยาสลบแบบหายใจเอง ในผู้ป่วยเด็กที่มีน้ำหนักตัวระหว่าง 5-20 กก. ได้อย่างปลอดภัยโดยค่า fresh gas flow rate ที่เหมาะสมคือ ≥ 2.5 ลิตรต่อนาที*