Cairo University
Faculty of Medicine
Anaesthesia Department

Assessment of The Safety of Low Flow Anaesthesia in Children

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BY

Hatem Saber Mohamed
M.B.B.Ch (Mansoura University)
MSc (Mansoura University)

Supervisors

Prof. Dr. **HANAA EL-SAYED ABOU EL-NOUR**
Professor of Anaesthesiology
Faculty of Medicine – Cairo University

Prof. Dr. **Salwa Mohamed Hefnawy**
Professor of Anaesthesiology
Faculty of Medicine – Cairo University

Prof. Dr. **Ola Abd El-Menaem El-Sisi**
Professor of Clinical Pathology
Faculty of Medicine – Cairo University

Main Supervisor: Prof. Dr. **Hanaa El-Sayed Abou El-Nour**
Professor of Anaesthesiology
Faculty of Medicine – Cairo University

Faculty of Medicine
Cairo University

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جامعة القاهرة
كلية الطـب
قسـم التخـدير

تقييم أمان التخدير ذو معدل السريان القليل فى الأطفال

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الطبيب/ حـاتم صـابر محمـد
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المشرفـون

الأستاذة الدكتورة/ **هناء السيد أبو النور**
أستـاذ التخـدير
كلية الطب – جامعة القاهرة

الأستاذة الدكتورة/ **سلوى محمد حفناوى**
أستـاذ التخـدير
كلية الطب – جامعة القاهرة

الأستاذة الدكتورة/ **علا عبد المنعم السيسى**
أستـاذ الباثولوجيا الإكلينيكية
كلية الطب – جامعة القاهرة

المشرف الرئيسى: الأستاذة الدكتورة/ **هناء السيد أبو النور**
أستـاذ التخـدير
كلية الطب – جامعة القاهرة

كليـة الطـب
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Abstract

Low-flow anaesthesia is a simple method of reducing the fresh gas flow rate for anaesthetic gases during inhalation anaesthesia. Sevoflurane has a lower blood solubility which predicts a rapid uptake and elimination. Minimal degradation of isoflurane is related both to the stability of its molecule and to its rapid elimination from the body after its administration. Forty paediatric patients (2-10 years) were assigned into four groups to inhale one of the two volatile anaesthetics; sevoflurane and isoflurane in high and low flow anaesthesia. A 10ml blood sample and urine sample were collected from each patient pre- and post-operatively for laboratory evaluation. Measurement of serum and urinary inorganic fluoride from the patients at 0, 12, 24 hour post induction of anaesthesia. the efficacy endpoint measures haemodynamic stability and improvement in recovery variables while safety endpoint measures hepatic and renal laboratory parameters, serum and urinary inorganic fluoride. The results of this study demonstrated that neither of sevoflurane or isoflurane has deleterious effects on liver or renal functions despite the transient elevation in serum and urinary inorganic fluoride ions with low flow sevoflurane anaesthesia. However, low-flow sevoflurane proved to be superior to low-flow isoflurane anaesthesia in haemodynamic stability and faster recovery.

Key Words:

Low flow anaesthesia – sevoflurane – isoflurane – Sevo-H – Sevo-L – Iso-H – Iso-L – recovery indices – serum and urinary inorganic fluoride ions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abbreviations

APL	Adjustable pressure limiting
ASA	American Society of Anaesthesiologists
CC	Closing capacity
$CMRO_2$	Cerebral oxygen consumption
DBP	Diastolic blood pressure
F_A	Alveolar concentration of inhaled anaesthetic
FGF	Fresh gas flow
F_I	Inspired concentration of inhaled anaesthetic
FRC	Functional residual capacity
HFIP	Hexafluoroisopropanol
HR	Heart rate
Iso-H	High-flow isoflurane group
Iso-L	Low-flow isoflurane group
LMA	Laryngeal mask airway
MAC	Minimum alveolar concentration
MBP	Mean blood pressure
NS	Not significant
PIFE	Pentafluoroisopropenyl fluoromethyl ethyl ether
PONV	Postoperative nausea and vomiting
Ra	Resistance to reabsorption of C.S.F
S	Significant
SBP	Systolic blood pressure
Sevo-H	High-flow sevoflurane group
Sevo-L	Low-flow sevoflurane group
TFA	Trifluoroacetic acid
TOF	Train of four
V_A/FRC	The relationship of alveolar ventilation to functional residual capacity
VC	Vital capacity
Vd/Vt	The ratio of dead space to tidal volume ventilation
V_F	Rate of C.S.F formation

INTRODUCTION

During the past 10 years, there has been a revival of interest in low flow anaesthesia in adult practice. This appears to reflect a desire to minimize wastage of expensive volatile anaesthetic agents and reduce atmospheric pollution ***(Meakin, 1999).***

Specific reservations of use of low flow anaesthesia in children can be divided into concerns about the use of circle system per se and doubts about the feasibility and effectiveness of low-flow methods ***(Lin and Brock-Utne, 1996).***

The wide spread use of highly developed anaesthesia machines with adopting miniaturized system in order to minimize dead space and resistance, the highly advanced monitors and the introduction of two new fluorinated inhalation anaesthetics with low solubility in human tissues, desflurane and sevoflurane encourage the use of low flow anaesthesia in children ***(Mielkel and Entholazner, 1995).***

Sevoflurance is a widely used inhalational anaesthetic with low blood gas solubility coefficient and non-pungent properties that make it attractive for use in pediatric patients, studies have shown that sevoflurane provides rapid and smooth inhalation induction in children with rapid emergence compared to halothane ***(Piat et al., 1994).***

Rapid hepatic metabolism of sevoflurane results in the formation of inorganic fluoride and the organic fluoride metabolite, hexafluoro isopropanal (HFIP) ***(Kharasch, 1995).*** In the blood HFIP is conjugated with gluocuronic acid and excreted rapidly by the kidneys. In humans 2-

5% of the absorbed sevoflurane is metabolized compared with 0.2 and 0.02% for isoflurane and desflurane respectively. Serum inorganic fluoride concentration after sevoflurane anaesthesia has been reported to be dose dependent and reach about 10-20 U mole/liter after 1-2 MAC hours, 20-40 U mole/liter after 2-7 MAC hours and as high 90 U mole/liter with prolonged exposure ***(Kharasch and Karol, 1995).***

Investigators also studied the production of the degradation products of sevoflurane with carbon dioxide absorbents in adults under various conditions without evidence of nephrotoxicity. However production of compound A and development of nephrotoxicity in pediatric patient has not been evaluated ***(Bito and Ikeda, 1994).***

AIM OF THE WORK

The aim of this research is to examine some of the concerns about the use of low flow anaesthesia in children with a view to encourage greater use of the method in these patients. The safety and efficacy of sevoflurane and isoflurane in high and low flow anaesthesia would be assessed for children undergoing elective surgical operations.

I. Efficacy would be determined by:

- Uptake and elimination of volatile anaesthetic during high flow (HF) and low flow (LF).
- Haemodynamic stability.

II. Safety would be assessed by:

- Evaluating the hepatic and renal laboratory parameters.
- Measuring serum and urinary inorganic fluoride.
- Reporting the incidence of adverse effects as nausea, vomiting, respiratory tract irritation and postoperative agitation.

Respiratory Mechanics in Pediatrics

Respiratory mechanics change dramatically from birth to adulthood. These changes result from increasing alveolarization, increasing airway size and changes in the chest wall. In infants, the chest wall is soft and pliable because of its largely cartilaginous structure which makes the chest wall highly compliant. This compliance promotes chest wall collapse when increased work of breathing requires more negative intrathoracic pressure. In addition to the compliance of the chest wall, there is also a decrease in elastic recoil of the total respiratory system and the chest wall. This low elastic recoil tends to alter the relationship between closing volume, functional residual capacity (FRC), and residual volume.

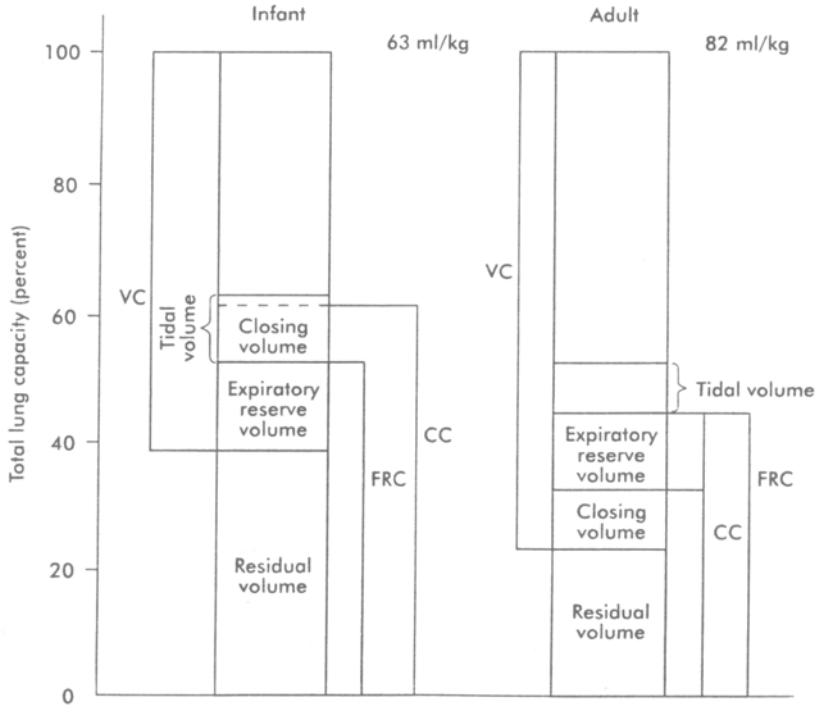

Fig (1): Bar graphs representing proportional lung volumes in infants and adults. Note the relationship of functional residual capacity (FRC) to closing volume and how this changes with age. VC = vital capacity; CC = closing capacity ***(Smith and Nelson, 1976).***

These changes in chest wall recoil, elasticity and compliance have serious impact on lung volumes (Fig 1). One of the most important factors is the tendency in younger children for airway closure and alveolar collapse with atelectasis to occur. As children breathe, tidal respiration is close to closing volume. Airway closure may occur even during tidal respiration in small infants ***(Smith and Nelson, 1976).***

Induction of anesthesia is associated with decreased elastic recoil and airway tone and decreased respiratory muscle tone. Thus, an expected lung volume decrease occurs with tidal respiration falling below closing volumes. These overall factors and those responsible for the loss of FRC on induction of anesthesia in part account for the rapid occurrence of hypoxemia in apneic infants during induction of anesthesia. The other major factor related to the rapid occurrence of hypoxemia in apneic infants is their relatively increased oxygen consumption. In neonates oxygen consumption is approximately 7 ml/kg/min ***(Hill and Rahintull, 1965).*** On a consumption-to-weight basis, this is approximately double that seen in adults, in whom oxygen consumption undergoes a gradual decrease with age. Although FRC/kg is less (30 ml versus 34 ml) in infants than adults, increased oxygen consumption is the major cause of the rapidity of desaturation in infants and small children who are apneic.

Also, development of the respiratory system affects ventilation. For example, Vd/Vt, the ratio of dead space to tidal volume ventilation, is approximately 33% in neonates and adults ***(Wetzel and Rogers, 1983).*** Thus, an infant would be expected to have a 7 ml dead space with a 20 ml tidal volume. The addition of a few millimeters of dead space by the superimposition of anesthetic equipment may increase dead space from 7

to 12 ml and have a serious effect on Vd/Vt and CO2 clearance in neonates. The dead space of all ventilatory equipment, endotracheal tubes and especially face masks and anesthesia circuits should be minimized ***(Wetzel, 1998).***

Table (1): shows the developmental differences in respiratory physiology: "Respiratory Mechanics" (Gioia et al., 1987):

	Infant	**Adult**
Respiratory frequency: (breaths/min)	30 – 40	12 – 16
Inspiratory time (sec)	0.4 – 0.5	1.2 – 1.4
I.E ratio	1:1.5 – 1:2	1:2 – 1:3
Inspiratory flow (L/min)	2 – 3	24
Tidal volume:		
ml	18 – 24	500
ml/kg	6 – 8	6 – 8
Functional residual capacity (FRC):		
ml	100	220
ml/kg	30	34
Vital capacity:		
ml	120	3500
ml/kg	33 – 40	52
Total lung capacity:		
ml	200	6000
ml/kg	63	86
Total respiratory compliance:		
Ml/cmH_2O	2.6 – 4.9	100
ml/cmH_2O/ml FRC	0.04 – 0.06	0.04 – 0.07
Lung compliance:		
Ml/cmH_2O	4.8 – 6.2	170 – 200
ml/cmH_2O/ml FRC	0.04 – 0.07	0.04 – 0.07
Specific airway conductance:		
ml/sec/cmH_2O/ml FRC	0.24	0.28
Resp. insensible water loss		
ml/24hr	45 – 55	300