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Low Flow Rate Anesthesia

Eassy

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In **Anesthesiology**

By

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بسم الله الرحمن الرحيم

قالوا

سبحانك لا علم لنا
إلا ما علمتنا إنك أنت
العليم الحكيم

صدق الله العظيم

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Abbrev.	Meaning
APL	Adjustable pressure limiting valve
APSF	Anesthesia PatientSafety Foundation
ARS	Afferent reservoir system
BW	Body weight
^{o}C	Celsius
CO	Carbon monoxide
CO_2	Carbon dioxide
CO Hb	Carboxyhemoglobin
DNA	Deoxyribonucleic – acid
EARS	Enclosed afferent reservoir system
EMO	EbsteinMakintoshOxford
ERS	Efferent reservoir system
$ETCO_2$	End – tidal carbondioxide
FAO_2	Alveolar oxygen concentration
FiO_2	Fractional inspired oxygen concentration
FG	Fresh gas
FGF	Fresh gas flow
FRC	Functional residual capacity
IPPV	Intermittent positive pressure ventilation
MAC	Minimum alveolar concentration
Min	Minute

MV	Minute ventilation
OMV	Oxford Miniature vaporizer
$PaCO_2$	Partial pressure of carbon dioxide
pH	Power of hydrogen
PO_2	Oxygen tension
ppm	Part permillion
SaO_2	Oxygen saturation
T	Time elapsed in minutes
TGC	Temperature gradient correction canister
VF	Fresh gas flow rate
VIC	Vaporiser inside the circle
VO_2	Oxygen consumption
VOC	Vaporiser outside the circle
VN_2O	Nitrous oxide uptake in ml/min.

1- Introduction and Historical Review

The practice of closed system anesthesia was described many decades ago, and the application of closed breathing systems dates back to the 18th century. Reverend Stephen Hales (1677–1761) was the first to construct a valved breathing circuit including cloth filters soaked in vinegar which allowed rebreathing of exhaled air for a certain time (fig 1). Hales suggested the use of his circuit for anyone being exposed to toxic gases for a short time ***(Schober and Loer, 2005)***.

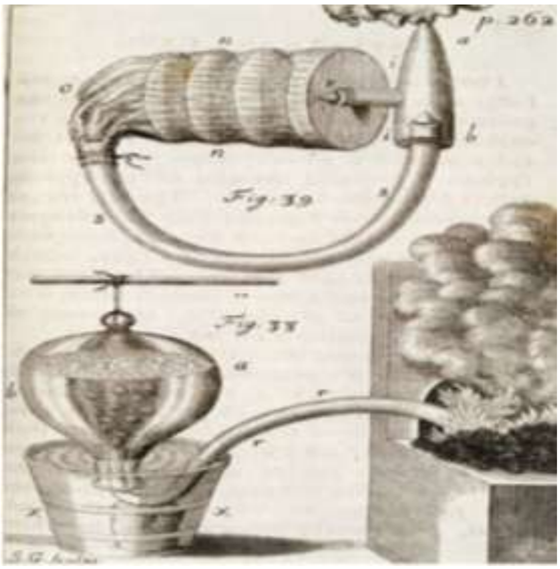

Fig. 1: Hales Stephen trough.
(http://en. wikipedia.org /wiki/ File: Hales_ Stephen_trough.jpg).

A similar system intended for the use in mine rescue operations was constructed by Theodore Schwann in 1853 (fig 2), it was not an anesthesia device, but it contained unidirectional valves, a carbon dioxide absorber, a pressure regulator and an oxygen supply from pressure tanks ***(Schober and Loer, 2005)***.

Fig. 2: Theodore Schwann Breathing apparatus.

(http://www.therebreathersite.nl/Zuurstofrebreathers/German/theodore_schwann.htm)

As early as in 1850 John Snow recognized that a considerable amount of inhalation anesthetics were exhaled unchanged in the expired air of anesthetized patients. He concluded and could prove that the anesthetic could be markedly improved by reinhaling these unused vapors ***(Baum, 1999).***

In experiments on himself, John Snow succeeded in demonstrating that rebreathing of expired vapours did, indeed, result in the prolongation of narcotic effects, provided that sufficient carbon dioxide filtration was used table (1) ***(Baum and Aitkenhead, 1995)***.

Table 1: Milestones of closed system anesthesia ***(Schober and Loer, 2005).***

Period	*Developer*	*Description*
18th century	Stephen Hales	First valved breathing circuit
About 1846	William G. Morton	Early anesthesia apparatus for ether administration containing non-rebreathing valves
1853	Theodore Schwann	Breathing circuit for mine rescue operations containing unidirectional valves, a CO2 absorber, a pressure regulator and an oxygen supply from pressure tanks
1877	Joseph T. Clover	Closed system for the application of ether which, however, contained neither an oxygen supply nor a carbon dioxide absorber
1886	Hermann T. Hillischer	Machine for anesthetic use which allowed semi-quantitative blending of oxygen and nitrous oxide
1924	Ralph Waters	Introduction of soda lime as a practical and highly potent means for CO2 elimination into clinical practice
1925	Carl Gauss Drager (Lu¨ beck, Germany)	First commercially available circle systems
1975	Barton, Nunn	Totally closed circuit nitrous oxide/ oxygen anesthesia
1981	Lowe, Ernst	The quantitative practice of anesthesia in closed systems
1983	Ross et al.	Servo controlled closed circuit anesthesia
1990	Verkaaik, Erdmann Physio (Haarlem, Netherlands)	PhysioFlex closed circuit anesthesia machine
2005	Dra¨ger (Lu¨ beck, Germany	Zeus closed circuit anesthesia machine

In 1877, Joseph Thomas Clover (1825–1882) described a closed system for the application of ether, which, however, contained neither an oxygen supply nor a carbon dioxide absorber**.** Therefore, hyopxia and hypercapnia readily occurred. The understanding of the dangers associated with rebreathing of expired air have led to the development of a variety of techniques to prevent inhalation of carbon dioxide, such as the integration of unidirectional valves and carbon dioxide absorbers ***(Schober and Loer, 2005)***.

In 1886, Hermann Theodor Hillischer (1850–1926) was probably the first to describe a machine for anesthetic use which allowed semi-quantitative blending of oxygen and nitrous oxide ***(Schober and Loer, 2005)***.

In 1924, rebreathing systems equipped with carbon dioxide absorbers were introduced into anesthetic practice. While Ralph Waters used a to-and-fro system, the German gynecologist Carl J. Gauss and the chemist Hermann D. Wieland did advocate the use of a circle system for application of purified acetylene as an inhalation anesthetic ***(Baum, 1999)***.

The advantages of using of anesthetic circuit with carbon dioxide absorbers were summarized comprehensively in 1924 by Ralph Waters as reduced loss of heat and moisture, economical use of anesthetic gases, and reduction of operating theatre pollution ***(Baum and Aitkenhead, 1995)***.

The first commercially available circle system was developed by Carl Gaus and manufactured by the Dra¨ger Company (Lu¨ beck, Germany) in 1925. Almost simultaneously, a circle system was constructed in the United States by the Foregger Company (New York, USA) in 1927 ***(Schober and Loer, 2005)***.

The introduction of highly explosive anesthetic agents, such as acetylene and cyclopropane, stimulated the adoption of the rebreathing technique and the use of CO_2 absorption systems with almost total rebreathing. However, the development of trichloroethylene, which is incompatible with soda lime, and of halothane, in conjunction with the poor performance of fresh-gas flow controls and vaporizers in the low-flow range, at that time, resulted in low-flow anesthesia being largely abandoned ***(Baum and Aitkenhead, 1995)***.

Although nearly all anesthetic machines were already equipped with sophisticated rebreathing circle systems, paradoxically, it became clinical routine to use fresh gas flows as high as 4 to 6 l/min, completely excluding any significant rebreathing. In many countries this is still the routine way to execute inhalational anesthesia ***(Craverao et al., 1996)***.

However, due to the development of modern anesthetic apparatus, the availability of comprehensive gas monitoring, an increasing environmental awareness, the introduction of new