

Paediatric anaesthesia with the Ambu-Paedi-Valve and Bag

G. Kamm

Head of Department of Anaesthesia,
Machame Lutheran Church Hospital, Moshi, Tanzania

TROPICAL DOCTOR, 1980, 10, 66-71

Paediatric anaesthesia often presents some problems, especially in up-country hospitals, because the additional anaesthetic equipment is often not available or not properly working. The generally used EMO or Boyle's anaesthetic equipment are not suitable for children under 15 kg body weight without additional equipment. The new Ambu-Paedi-Bag and Valve is said to be suitable as an alternative for ventilating infants (Quoss 1978) and we feel that its suitability merits attention.

PROBLEMS OF PAEDIATRIC ANAESTHESIA

Children present distinct problems of their own and should not be treated and considered as little adults. The physical differences between children and adults are: small volume of tidal air, large anatomical dead space, rapid respiratory rate. This is shown in Table 1. *The anatomical dead space in neonates* is larger than in adults in comparison with the alveolar ventilating air as shown in Table 1. The smaller the child the smaller the possibility of compensating respiratory acidosis by increase of respiratory volume. Any increase in dead space or in respiratory resistance (valve), any depression of the respiratory centre or pathology of the lung, may lead to respiratory failure.

High metabolic rate. The metabolic O_2 requirements of the neonatal is 7 ml/kg bodyweight compared to 3.5 ml/kg in adults. This means that a child can become blue in half the time. The metabolic rate in a child even goes up with high temperature. Therefore

good O_2 suppl, at least 50%, during anaesthesia, should be secured to avoid critical errors.

Rapid circulation. This means anaesthetic drugs are quickly absorbed and act rapidly but are metabolized much more quickly. Changes in depth in either direction occur more rapidly.

Blood volume: Newborns 85 ml/kg
1-2 years 75 ml/kg
2-16 years 72 ml/kg

Table 2. Heart frequency and blood pressure at different ages

Age	Heart frequency minute		Blood pressure	
	Average	Distribution	systolic	diastolic
Newborn	120	80-170	80	40
12 months	120	80-160	90	60
2 years	110	80-130	—	—
4 years	100	80-120	90	50
12-15 years	85/90	70-110	110	50
Adults	60-80	—	140	80

Large surface area. The smaller an object the greater its surface area in comparison to its interior. Therefore a child cools under anaesthesia more rapidly than an adult. Fall of body temperature in its first year of life can be fatal to the child.

Difference in airway structure. There is a narrow air passage, a relatively large tongue, high laryngeal angled cords, and a narrow sub-glottic region.

Less vagal tone. There is great risk of cardiac inhibition and laryngospasm.

CHOICE OF EQUIPMENT

The choice of equipment for the above reasons has to be guided by: (1) minimum dead space; (2) minimum resistance to respiration (heavy valves); (3) possibility of assisted or controlled ventilation.

The normal technical equipment of the EMO or the half closed system of the Boyle's machine are not suitable without modification for children under 15 kg because of the eminent big space and respiratory

Table 1. Respiratory differences between children and adults

Age	Weight	Respiratory frequency	Volume	Deadspace
Newborn	2-3 kg	40-50	17 ml	7.5
Children:				
— 3 years	— 13 kg	30-40	— 100 ml	35
— 4 years	— 16 kg	20-30	— 200 ml	40
20 years	65 kg	12-16	— 500 ml	150

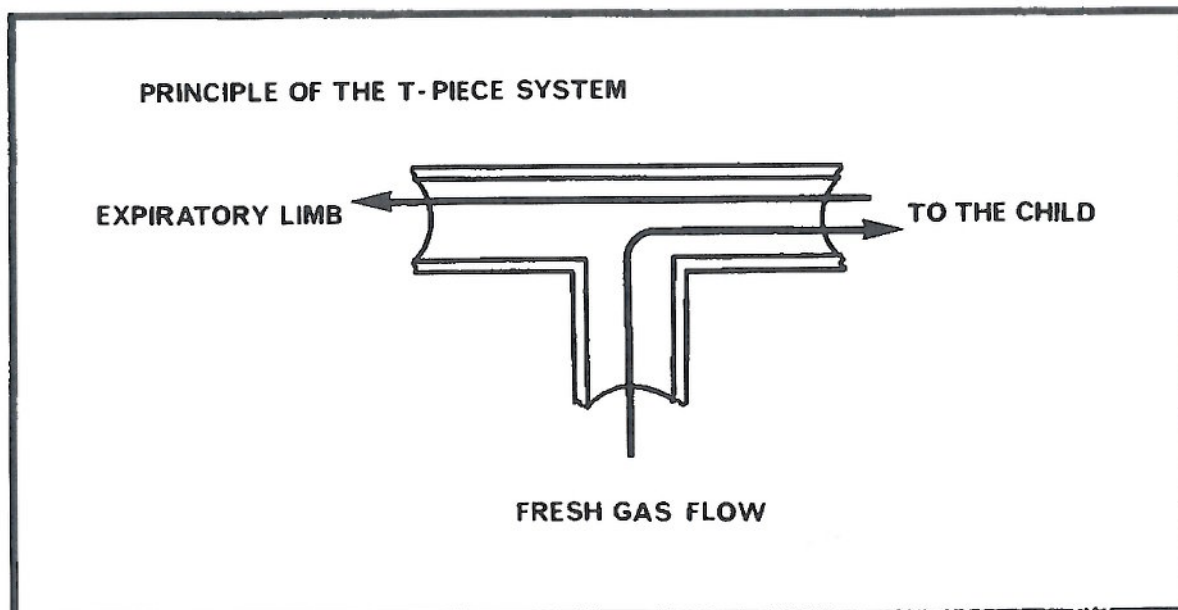


Fig. 1. Principle of the T-piece system.

resistance. Only the half-open modified systems are suitable:

- (a) the Ayresche T-piece system (Kuhn, Rees);
- (b) The non-rebreathing valve (Leigh, Lewis-Leigh, Fink, Ruben).

Fig. 1 shows the principle of the T-piece system.

There are no moving or sticking parts; there is minimum respiratory resistance and a comparatively small dead space. It is important to realize that *there must be a fresh gas flow, not a source of fresh air.*

The Kuhn or Rees-Child set shown in Fig. 2 is in principle the same. It can be used for spontaneous

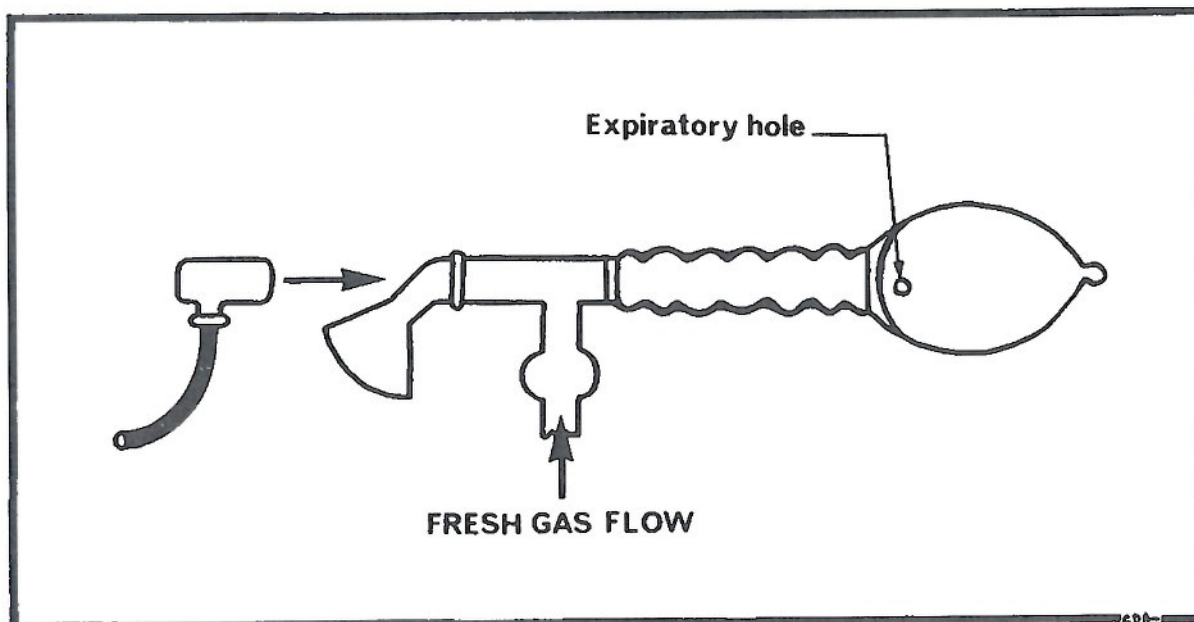


Fig. 2. The Kuhn or Rees-Child set.

and controlled respiration. From the fresh gas, part of the gas is blown in and inhaled by the child, while expiratory air goes to the expiratory port or bag. *The fresh gas supply should be at least 200 mg/kg bodyweight/minute, or three times the respiratory volume. At least one half of it should be oxygen.* Insufficient gas flow results in rebreathing if the volume of the expiratory limb is greater than the patient's tidal volume. If controlled ventilation is required for inspiration, the expiratory hole must be closed with the thumb while the bag is squeezed rhythmically. The bag must never be allowed to over-distend and the finger must only be on the expiratory hole for the inspiration period, otherwise the hole must be free.

Of major importance therefore are: (a) fresh gas flow; (b) an airtight system; (c) three times the respiratory volume.

TECHNIQUE AND METHOD OF AMBU-PAEDI-BAG ANAESTHESIA

Using the Ambu-Paedi-Bag and valve in anaesthesia, we insist on intubation-relaxation and controlled ventilation. The ventilation is achieved with the Ambu-Paedi-Bag and air with a slight increase of volume and normal frequency. There is the possibility of adding oxygen, using an additional reservoir. Analgesia, not anaesthesia, is maintained with ether (Technique I below) or with the ketamine drip (Technique II below).

Technical data of Ambu-Paedi-Bag and Valve:

Weight: 18 g; Nominal dead space: 4.0 cm³ (3.2 cm³ in the adapter); Forward-leakage: ca. 3 cm³; Backward-leakage: ca. 2 cm³.

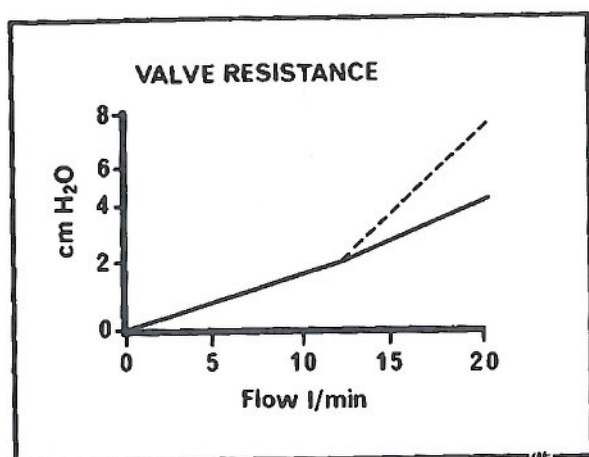


Fig. 3. Valve resistance.

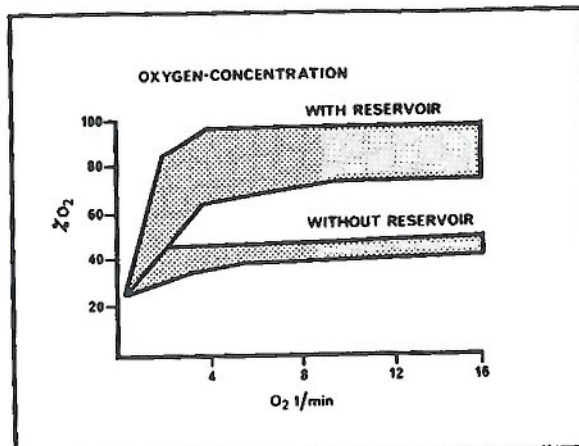


Fig. 4. Oxygen concentration.

CHOICE OF RELAXANTS

For relaxation we use muscle relaxants. For light anaesthesia the muscle relaxants are of best assistance. Deep anaesthesia should by all means be avoided.

1. Short-acting muscle relaxants

For intubation suxamethonium at 1 mg/kg i.v. or 2 mg/kg i.m. (contraindicated in shock.) Repeated dosages are suitable for short operations of up to 30 minutes' duration. It is known that smaller children need higher dosages of suxamethonium as a result of quick metabolization, but after suxamethonium bradycardia and arrhythmia do occur. Parasympathetic effect which makes premedication with atropine compulsory and obligatory.

2. Long-acting muscle relaxants

When ether is used, the dosages can be kept quite low; ether can be omitted in the newborn.

TECHNIQUE I

1. Premedication: atropine 0.01 mg/kg i.m. 20-30 min. pre op. + haloperidol 0.1 mg/kg per os.
2. Induction: ketamine 2 mg i.v. or 5 mg i.m.
3. Relaxation: suxamethonium 1 mg i.v. and intubation.

Remember: Oxford non-kinking tubes are most suitable. Do not use force. No cuffed tubes! Preferably hyperventilation via a mask for two minutes before intubation. After intubation fix the tube securely and connect it with a valve and with the bag and atmospheric air ether. The addition of a length of elephant tubing between Ambu "E" valve and Ambu Bag and between the Ambu Bag and EMO machine gives the anaesthetist very great freedom of movement and can be recommended (see Fig. 5). Ether concentration is

Table 3. Dosages of relaxants

Relaxants	Prematures	Neonatal	Children	Reversion
<i>d</i> -Tubocurarine	0.25 mg/kg	0.3 mg/kg	0.5–0.7 mg/kg	Atropine 0.01 mg/kg
Nor-allyltrocurium (Alcuronium)	0.1 mg/kg	0.2 mg/kg	0.3 mg/kg	Neostigmine 0.05–0.07 mg/kg
Pancuronium	0.04 mg/kg	0.06 mg/kg	0.1–0.12 mg/kg	

Repetition-dosage = $\frac{1}{3}$ – $\frac{1}{4}$ of the initial dosage.
After second repetition, from third dosage on, $\frac{1}{6}$ – $\frac{1}{8}$ of initial dosage.

set on 3–4", and ventilation will be ether air: eventually oxygen may be added, if required.

If muscle relaxation is compulsory, a non-depolarizing muscle relaxant should preferably be used. Maintenance of analgesia – ether via the EMO machine.

Monitoring

In infants it is best to have a stethoscope strapped to the left chest (Fig. 6). In this way you can listen to both the apex beat and the air entry into the left lung. Thus the respiration and the heartbeat can easily be observed. Also observe colour of blood and of the muscle membranes. Press the skin with your finger for an instant. The speed of return of colour indicates the quality and condition of circulation.

Shortly before the end of operation stop ether, continue ventilation, eventually reversing muscle relaxation with atropine neostigmine. Ventilate until

complete spontaneous respiration is restored, apply suction of mouth and pharynx, possibly endotracheal suction which, however, must be short and must be followed by a short period of IPPR. Extubation should be effected under positive intrapulmonary pressure (cough extubation). Observe carefully respiration and the child itself.

Prevention of cooling

Always keep the child warm with hot water bottles with a cloth cover. As much as possible of the baby is wrapped in cotton cloth or bandages. Avoid wet sheets near the body of the baby. Undercooling will effect: (1) respiratory depression; (2) metabolic acidosis; (3) failure of reversion of muscle relaxation.

The effect of cooling may not be reversible, therefore strict prevention is the best safeguard. Undercooling is often the reason for fatal results in neonatal

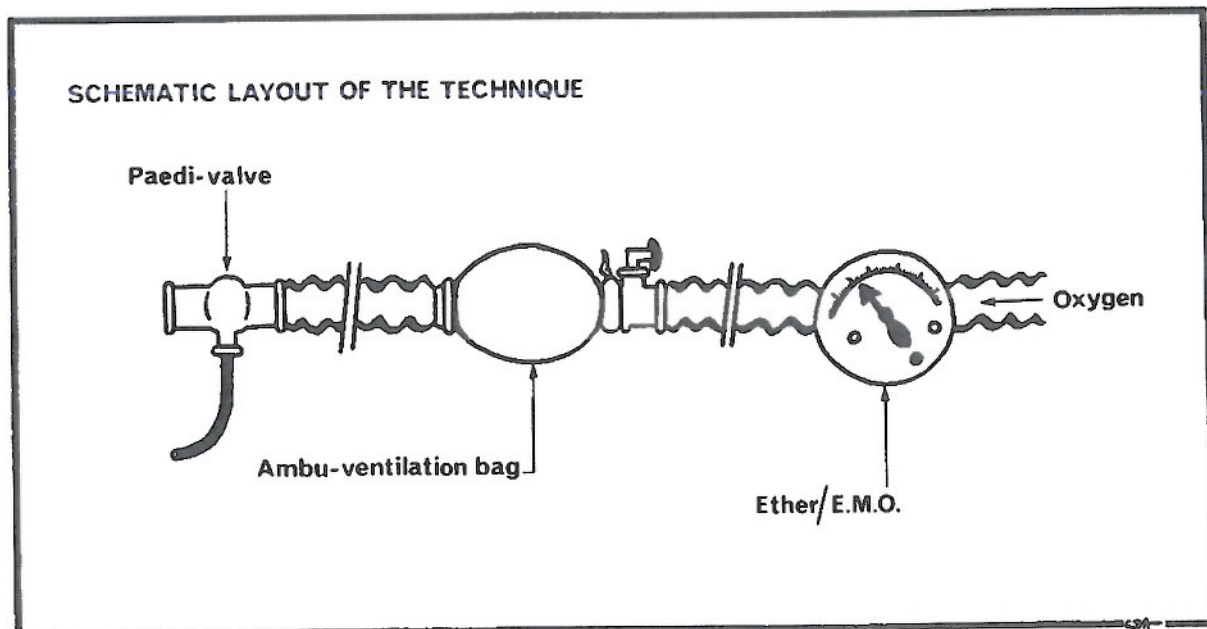


Fig. 5. Schematic layout of the technique.

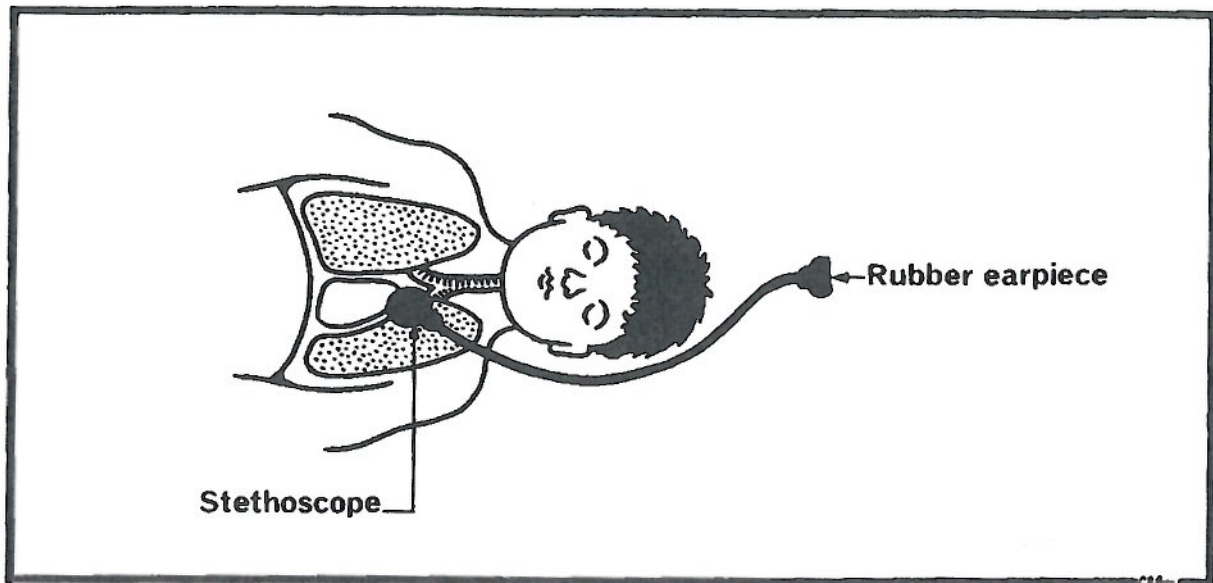


Fig. 6. Monitoring the anaesthetized child.

anaesthesia. For maintenance of fluid and electrolytes use $\frac{1}{2}$ normal saline in glucose. Never use normal saline dextrose. Replace blood and fluid carefully.

TECHNIQUE 2

The technique of ketamine drip anaesthesia (See *Tropical Doctor*, 1978, 8, 68-70) may also be used in children, employing the Ambu-Paedi-Bag and Valve. This

Table 4. Fluid requirements according to body weight (in 24 hours)

Age	Weight kg	Size cm	Fluid required per kg	Calories per kg
Newborn	3.5	52	600-680	100-120
3 months	5.7	60	750-850	90-110
9 months	8.6	70	1100-1250	90-110
2 years	12.5	87	1350-1500	100
4 years	16.5	110	1600-1800	90

Table 5. Normal electrolyte requirements

mmol/kg		
Natrium	3-4	Na ⁺ (Sodium)
Kalium	2	K ⁺ (Potassium)
Chlor	2	Cl ⁻ (Chlorine)

1st-3rd day of life 50% only of this dosage.
(Kidney function!)

technique may be of great value especially where no anaesthetic machinery is available.

Set of an i.v. ketamine drip: 500 ml dextrose, containing 500 ml ketalar.

Drip speed: as quick as possible.

As patient loses consciousness - drip speed is reduced to $\frac{1}{2}$ drop/minute/kg. Now suxamethonium is given in a dose of 1 mg/kg in order to intubate the patient. Following intubation, respiration is maintained with Ambu bag and atmospheric air. As soon as neuromuscular function returns suxamethonium, or other non-depolarizing relaxant, is given (e.g. *d*-tubocurarine, gallamine triethiodide).

Artificial respiration is kept up by Ambu Bag-ventilation-air.

Ten minutes before end of operation, the ketamine drip is stopped. The relaxant is reversed if necessary; ventilation is maintained until full spontaneous respiration is restored. Extubation is then performed in the usual way.

DISCUSSION

The new Ambu-Paedi-Valve and Bag provides a suitable alternative for paediatric anaesthesia up to 3 years or respiratory volume of up to 270 ml. The valve has a minimum dead space of 0.8 ml. In case the child is intubated, which means reduction of the anatomical dead space, the technical dead space of *maximum 4 ml* is tolerable. The valve resistance is of minor importance when controlled ventilation is used.

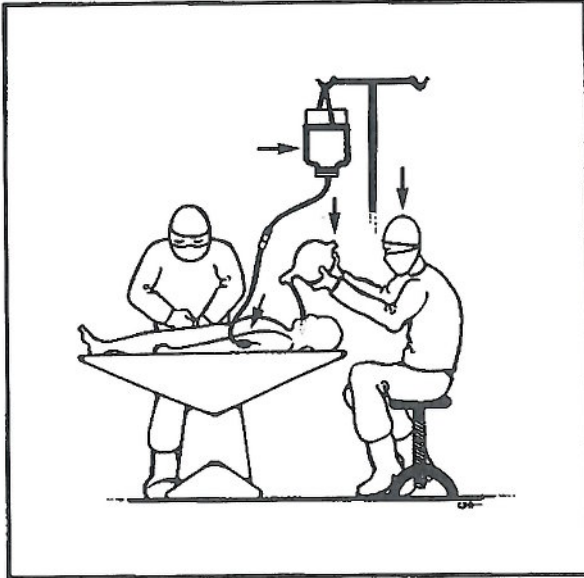


Fig. 7. Possible human and technical sources of error with anaesthetic ketamine drip and relaxant

As shown in Fig. 3, as well as in recent studies, there is relatively low respiratory valve resistance.

Choice of ether — Technique 1

Even though there are many new inhalation anaesthetic drugs, we feel that ether is still a very suitable agent, even in children. Ether is a very good analgesic, hypnotic, and muscle relaxant. If used only to produce analgesia, which means a light level anaesthesia, ether is the agent to produce the least number of problems. The induction as well as the recovery period with ether is markedly shorter in children than in adults. Average time of recovery in the child: 3 minutes.

Choice of ketamine

The usefulness of ketamine especially in children is well known and need not be explained. Atropine for premedication is recommended.

Major advantage of this technique and equipment are: (a) minimum dead space; (b) relatively low respiratory resistance; (c) possibility of controlled and assisted ventilation; (d) simple to operate; (e) limited sources of possible human or technical errors; (f) the half-open system reduces the possibility of cross-infection. Both techniques described appear to demonstrate the essential requirements of good anaesthesia, namely good analgesia, hypnosis, and muscle relaxation. Ether and ketamine produce a profound state of analgesia and a light analgesia with a quick recovery period. Muscle relaxants provide adequate relaxation while the atmospheric air offers enough oxygen, with a slight increase of the respiratory volume.

This technical equipment has been used over a period of two years for children of up to 15 kg body weight for operations lasting up to 180 minutes. Recent studies even show that employing the Ambu-Paedi-Bag and Valve anaesthesia under spontaneous or assisted respiration, using $O_2:N_2O = 1:2$, gave no evidence of respiratory acidosis.

The new Ambu-Paedi-Bag and Valve gives us the possibility of an alternative technique in paediatric anaesthesia.

FURTHER READING

- Benzer, H., Frey, R., Hügin, W., and Mayrhofer, O. (1977). *Lehrbuch der Anaesthesiologie, Reanimation und Intensivtherapie*. Berlin, Heidelberg and New York: Springer-Verlag.
 Dick, W. and Ahnefeld, F. W. (1976). *Kinderanaesthesie*. Berlin, Heidelberg and New York: Springer-Verlag.
 Quoss, A. (1978). *Anaesthesiologie und Reanimation*, 3, 41.

Notes and News

Two professorial appointments at Liverpool University

Professor W. W. Macdonald, Professor of Entomology, London School of Hygiene and Tropical Medicine, has been appointed to the re-established Chair of Medical Entomology in the Liverpool School of Tropical Medicine in the Faculty of Medicine, University of Liverpool, from 1 April 1980. The Chair is designated as the Selwyn-Lloyd Chair in Medical Entomology in honour of the association of

Lord Selwyn-Lloyd with the School of Tropical Medicine as its President.

Professor G. Nelson, William Julien Courtauld Professor of Helminthology, University of London, has been appointed to the Walter Myers Chair of Parasitology in the Liverpool School of Tropical Medicine in the Faculty of Medicine, University of Liverpool, in succession to Professor W. Peters. Professor Nelson took up his appointment on January 1, 1980.