Original Article

Evaluation of a Mapleson D CPAP system for weaning of mechanical ventilation in pediatric patients

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ABSTRACT

Background: Over the last years, we have used a flow-inflating bag circuit with a nasotracheal or nasopharyngeal tube as an interface to deliver effective CPAP support in infants ("Mapleson D CPAP system"). The primary goal of this study was to assess the usefulness of the "Mapleson D CPAP system" for weaning of mechanical ventilation (MV) in infants who received MV over 24 h. **Materials and Methods:** All infants who received MV for more than 24 h in the last year were enrolled in the study. Demographic data included age, gender, weight, and admission diagnosis. Heart rate, respiratory rate, blood pressure, and oxygen saturation were measured during MV, 2 h after the nasotracheal Mapleson D CPAP system and 2 h after extubation. Patients were classified into two groups: patients MV more than 48 h, and patients with MV fewer than 48 h. $P < 0.05$ was considered statistically significant. **Results:** A total of 50 children were enrolled in the study, with a median age was 34 ± 45 months (range, 1–59 months) and median weight was 11.98 ± 9.31 kg (range, 1–48 kg). Median duration of MV was 480 h (range, 2–570). There were no significant differences in PaO_2, $PaCO_2$, and pH among MV, 2 h after the nasotracheal Mapleson D CPAP system and 2 h after extubation and spontaneous ventilation with the nasopharyngeal Mapleson D CPAP system or with nasal prongs. The overall extubation failure rate was 26% ($n = 13$). Weight and age were significantly associated with extubation failure ($P < 0.05$). **Conclusions:** The Mapleson D CPAP system, in our opinion, is a useful and safe alternative to more complex and expensive noninvasive CPAP and BiPAP weaning from MV in infants.

KEY WORDS: CPAP, nasopharyngeal tube, noninvasive ventilation, prolonged ventilation, weaning

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INTRODUCTION

Intubation and mechanical ventilation (MV) are frequently necessary to treat the critically ill infant or after long surgical interventions. However, prolonged MV predisposes to nosocomial infection, tracheal injury, or difficulties with sedation of intubated children and should be discontinued at the earliest possible time.[1,2] The reported extubation failure of mechanical ventilation in infants ranges from 4.9% to 29%.[3,4] A spontaneous breathing trial for weaning mechanically ventilated children using either a T-piece or pressure support showed that children could be successfully weaned from MV. However, 12–15% of these patients required reintubation within 48 h.[5,6] To this way Chavez *et al*.[7] described the utilization of a Mapleson C circuit as a spontaneous breathing trial (SBT) to predict successful extubation, with a high percentage of patients (92%) extubated after a 15 min SBT using a flow inflating anesthesia bag.

Noninvasive positive airway pressure ventilation has been described as safe and effective in infants with mild

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to moderate hypoxemic respiratory insufficiency, upper airway obstruction, and postextubation respiratory distress.[8-10] However, more evidence is necessary to define the mode of ventilation support to be used for specific cases, the adequate type of interface, and the length of use and weaning.[8,10] Over the last years, we have used a flow-inflating bag circuit with a nasotracheal or nasopharyngeal tube as an interface to deliver effective CPAP support in children ("Mapleson D CPAP system") with acute respiratory insufficiency, for weaning of MV and to provide CPAP outside the Intensive Care Unit (ICU).[11,12] The primary goal of this study was to analyze the usefulness of the flow-inflating bag circuit with a nasotracheal or nasopharyngeal tube as an interface ("Mapleson D CPAP system") for weaning of MV in fifty infants who received MV for more than 24 h.

MATERIALS AND METHODS

Study population

La Paz Hospital Human Research Ethics Committee approved this retrospective, observational study. All infants and children who received prolonged MV for more than 72 h during 4 years and were judged by the attending physician to be ready to undergo extubation were eligible for the study. Patients were enrolled if they met the following criteria: (a) full term infants to 16 years of age; (b) improvement or resolution of the underlying cause of MV; and (c) adequate gas exchange as indicated by arterial oxygen saturation ≥92% whereas breathing an FiO_2 of ≤0.40; level of consciousness acceptable for extubation; (d) no clinical need for increased ventilator support in the last 12 h; and (e) no need for vasoactive agents except for low dose of dopamine. Patients with tracheostomy, unrepaired congenital heart disease, neuromuscular disease, and estimated gestational age ≤37 weeks were excluded.

Protocol

The physicians determined extubation readiness using the standard clinical practice of our unit, including assessment of physical exam, blood gasses, chest radiographs, and ventilator settings. Once, the team has identified a patient who was ready for extubation, in a first step patient ventilator was disconnected allowing the patient to breathe spontaneously with the "Mapleson D CPAP system" and a nasotracheal tube as interface [Figure 1]. This step was made by a nurse in the absence of the attending or other physician staff to blind the medical team of the results.

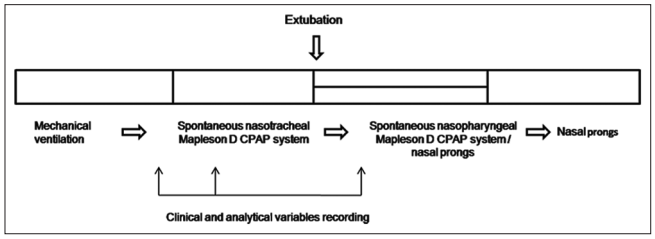

Figure 1: Protocol

The patient was reconnected to the ventilator if the patient experienced (a) signs of increased respiratory work, as the use of accessory respiratory muscles, paradoxical breathing; (b) pulse oxygen saturation <90%; and (c) increase in systolic blood pressure >20% baseline. In a second step, if the nasotracheal Mapleson D CPAP system was well tolerated, the patient was extubated to nasal prongs or to the nasopharyngeal Mapleson D CPAP system by a nurse in the absence of the attending or other physician staff to blind the medical team of the results, but according of the criteria of the medical team. Extubation failure was defined as respiratory distress requiring reintubation within 48 h of extubation or patients which were not able to maintain 6 h continuous spontaneous ventilation with the nasotracheal Mapleson D CPAP system.

Design of continuous positive airway pressure system

The "Mapleson D CPAP system" was made by a Mapleson D system (Intersurgical, Wokingham, England) with a 0.5 or 1 L reservoir bag and a 20 mm corrugated tubing that was connected to a lubricated uncuffed endotracheal #3.5 to #5.0 Portex® tube, as nasopharyngeal or nasotracheal airway. Airway pressure was measured at the proximal end of the system with a manometer (Vygon, Ecouen, France) [Figure 2]. Fresh gas was enriched with a Siemens O_2-air mixer and was warmed and humidified using a Bennett Cascade (Bennett, London, UK) humidifier. We used a fresh gas flow rate of 2–3 times total ventilation at least to prevent rebreathing of CO_2.[7] The leak valve was adjusted to provide 5 cm H_2O CPAP.

Data collection

Demographic data included age, gender, weight, and admission diagnosis. Laboratory results were obtained from data collected within 2 h before spontaneous ventilation, 2 h after the nasotracheal Mapleson D CPAP system, and 2 h after extubation, with the patient breathing spontaneously with nasal prongs or with the nasopharyngeal Mapleson D CPAP system [Figure 1]. Oxygenation data were evaluated only from patients who had arterial blood gas determinations performed

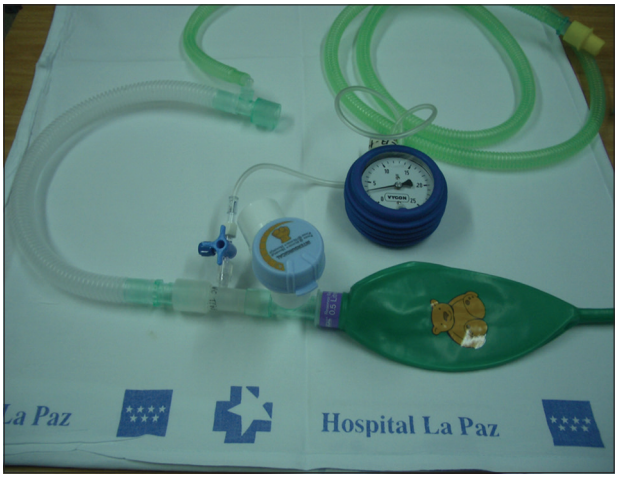

Figure 2: The "Mapleson D CPAP system"

both before and after initiation of this modality. The following variables were measured during MV, 2 h after the nasotracheal Mapleson D CPAP system and 2 h after extubation, with the patient breathing spontaneously with nasal prongs or with the nasopharyngeal Mapleson D CPAP system: heart rate, respiratory rate, blood pressure, and oxygen saturation. Recorded clinical information included the duration of MV, duration of spontaneous ventilation with the nasotracheal Mapleson D CPAP system and duration of spontaneous ventilation with or without the nasopharyngeal Mapleson D CPAP system or nasal prongs. Patients were classified into two groups according to the length of MV: patients with acute respiratory failure with MV for more than 48 h (MV >48 h), and patients with MV fewer than 48 h (MV <48 h).

Data analysis

Statistical analysis consultation was provided by the Biostatistics Department at the La Paz University Hospital. Data are reported as the number of patients, median and associated standard deviation. Changes in the mean response of measured vital signs were explored 2 h before spontaneous ventilation, 2 h after the nasotracheal Mapleson D CPAP system and 2 h after extubation using analysis of variance. A $P < 0.05$ was considered statistically significant.

RESULTS

We enrolled fifty children who required prolonged MV. Their median age was 34 ± 45 months (range, 1–59 months) and median weight was 11.98 ± 9.31 kg (range, 1–48 kg). Nearly 44% were female ($n = 22$) and 56 were male ($n = 28$). About 26% of the patients were intubated and ventilated for more than 48 h, and 11 required MV fewer than 48 h, due to prolonged surgery. Median duration of MV was 480 h (range, 2–570). Selected specific features of the study population are summarized in Table 1. There were no significant differences in respiratory rate, heart rate, oxygen saturation, systolic blood pressure, and diastolic blood pressure among baseline, 2 h after the nasotracheal Mapleson D CPAP system and 2 h after extubation [Table 2]. Twenty-five patients have oxygenation data from arterial line. There were no significant differences in PaO_2, $PaCO_2$, and pH among MV, 2 h after the nasotracheal Mapleson D CPAP system and 2 h after extubation and spontaneous ventilation with the nasopharyngeal Mapleson D CPAP system or with nasal prongs [Figure 3].

The overall extubation failure rate was 26% ($n = 13$). Of these, 3 required reintubation and 10 patients were not able to maintain proper spontaneous ventilation with the nasotracheal Mapleson D CPAP system. The reasons included fatigue (8), hypoxemia (2), and upper airway obstruction (3). Weight and age were significantly associated with extubation failure [Table 3]. We did not found significant differences in heart rate, oxygen saturation, and systolic blood pressure among baseline and 2 h after the nasotracheal Mapleson D CPAP

Table 1: Characteristics of the study population

Characteristic	All patients (n=50)
Gender, *n* (%)	
Male	28 (56)
Female	22 (44)
Median age, median (range)	34 (1-59)
Median weight	12 (1-49)
Median duration of MV, hours (range)	240 (3-480)
Cause of MV, *n* (%)	
Surgery (MV <48 h)	23 (46)
Congenic cardiopathy	9 (18)
Esophageal surgery	4 (8)
Abdominal surgery	3 (6)
Neurosurgery	6 (12)
Trauma	1 (2)
Acute respiratory insufficiency (MV >48 h)	27 (54)
Pneumonia	9 (18)
Heart failure	7 (14)
ARDS	5 (10)
Others	4 (8)
Tracheomalacia	2 (4)

MV: Mechanical ventilation, ARDS: Acute respiratory distress syndrome

Table 2: Respiratory rate, heart rate, oxygen saturation, systolic blood pressure and diastolic blood pressure during the study

	Baseline CMV	2 h post-NT CPAP	2 h postextubation	*P*
RR (bpm)	34±16	41±8	38±18	0.09
HR (bpm)	145±31	147±9	142±12	0.12
SpO_2 (%)	96±6	92±12	91±13	0.13
SBP (mmHg)	84±9	89±12	79±7	0.08
DBP (mmHg)	58±9	61±5	53±9	0.09

Dates were recorded at control MV, 2 h after the nasotracheal Mapleson D CPAP system and 2 h after extubation. MV: Mechanical ventilation, RR: Respiratory rate, HR: Heart rate, SpO_2: Oxygen saturation, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, CMV: Continuous mandatory ventilation, CPAP: Continuous positive airway pressure, NT: Nasotracheal

Table 3: Characteristics between extubation failure group and extubation success group

	Extubation failure (n=13)	Extubation success (n=37)	*P*
Age (months)	15.17±14.3	41.18±51.64	0.004
Weight (kg)	8.57±5.61	13.13±10.21	0.048
MV>48 h/MV<48 h	19/2	13/12	
Time NT spontaneous ventilation (h)	13.09±14	45.12±58.30	0.36
Time NF spontaneous ventilation (h)	3.09±7.55	13.24±18.64	0.29
Time MV (days)	8±3.9	12±8.4	0.06

MV: Mechanical ventilation, NF: Nasopharyngeal, NT: Nasotracheal

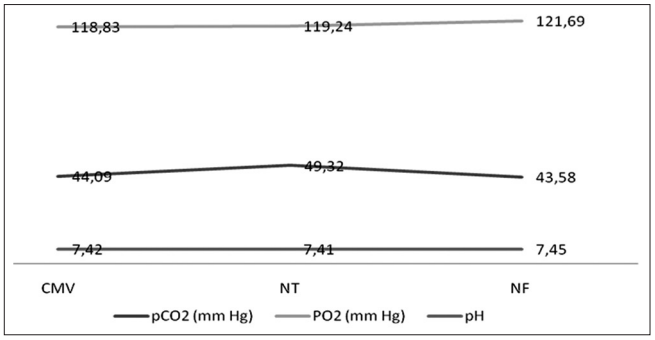

Figure 3: PO_2, PCO_2 and pH during the study

system in patients where nasotracheal Mapleson D CPAP system failed.

DISCUSSION

This study has a major finding by applying the Mapleson D CPAP system to the nasotracheal tube and successively withdrawing the tube from trachea to pharynx; we provided CPAP both before and after extubation. By this simple technique, we were able to predict successful extubation as well as to minimize extubation failure.

The goal extubation failure rate in a pediatric ICU is not known. Unnecessary delays in extubation increase costs and the complication rate associated with MV; however, aggressive discontinuation of ventilator support must be balanced against the possibility of extubation failure. Our study revealed an extubation failure rate of 26%. This, added to the longer duration of intubation in the success group, may indicate that our current practice of extubation children with the Mapleson D CPAP system was aggressive. Pediatric studies have shown that patients with a longer duration of intubation, younger age, and chronic respiratory and neurologic disorders have higher extubation failure rates.[3,5]

Putensen *et al*.[13] showed that patients recovering from acute lung injury create an intratracheal positive end-expiratory pressure by breaking the expiratory airflow, probably by glottis narrowing. Despite compensatory glottis narrowing, extubated patients with reduced lung function may benefit from higher levels of continuous positive airway pressure. This is in aligned with Ishaaya *et al*.,[14] who showed that neither tracheal nor laryngeal disease caused the increase in work of breathing after extubation. Chavez *et al*. described the utilization of a Mapleson C circuit as an SBT to predict successful extubation. According to these authors, an important advantage of this method over the T-piece is that it could readily provide CPAP to maintain functional residual capacity. In contrast to our study, Chavez *et al*. extubated their patients directly to nasal prongs. Nasal CPAP has also been shown to prevent extubation failure in preterm infants.[15] One of the advantages of "Mapleson D CPAP system" is the possibility of withdraw the tube from trachea to pharynx, providing CPAP after extubation with the use of a nasopharyngeal tube as an interface. In pediatric patients problems with mask leaks and inability to attain the adjusted peak inspiratory pressure are common with nasal and facial masks in the acute setting. In addition, the volume of the mask itself leads to increased dead space, especially in young children, thus limiting the benefit of noninvasive MV.[9,10] Moreover, children's natural fear of any device that covers their nose or mouth represents a major limitation of using face masks.[8,10] The use of a nasopharyngeal tube as an interface avoids discomfort and facial bruising as well as the increase in dead space secondary to the use of nasal or face masks. Potential disadvantages of the nasopharyngeal tube are nasal trauma and the leaks through an open mouth, which we minimized using a dummy.

Other advantage of the "Mapleson D CPAP system" is the needlessness of a ventilator. Currently, available BiPAP ventilators were primarily designed to treat adults and their often inefficient inspiratory triggering systems, expiratory valve mechanics, and flow delivery pattern may increase respiratory workload, especially in young children.[16-18] The absence of a ventilator would reduce the additional work of breathing and avoid asynchrony events due to inspiratory and expiratory triggers. Moreover, the utilization of a reservoir bag and an airway pressure limiting valve minimize the inspiratory workload[19] and may be useful as defensive mechanism against barotrauma. However, elevated gas consumption due to higher fresh gas flow rates must be taken into account.

CONCLUSIONS

The Mapleson D CPAP system, in our opinion, is a usefulness and safe alternative to more complex and expensive noninvasive CPAP and BiPAP weaning from MV in infants.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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