DAILY PRACTICE OF MECHANICAL VENTILATION IN A PEDIATRIC INTENSIVE CARE UNIT - EXPERIENCE OF THE FIRST PEDIATRIC CLINIC TIMISOARA

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Abstract

Aim. To assess how children requiring endotracheal intubation are mechanically ventilated in First Pediatric Intensive Care Unit (PICU), Timisoara. Material and methods. A four years observational study (January 2010 – December 2012) was conducted in the Fist PICU of Emergency Hospital for Children "Louis Turcanu" Timisoara and included all mechanically ventilated children ≥ 24 hours, aged 0-18 years. Results. One hundred eight patients met the inclusion criteria. The mean age of the patients was 27 months and median duration of mechanical ventilation was 9 days. The mean PRISM III score on admission was 17. The mean duration of mechanical ventilation was 9.36 days. Major indication for mechanical ventilation was acute respiratory failure. We used pressure-limited conventional modes of ventilation. Mean peak inspiratory pressure (PIP) values were constant < 30 cmH2O, with 12% of the patients having a maximum PIP ≥ 30 cmH2O, but < 35 cmH2O. There was little variability with positive end-expiratory pressure (PEEP) choice, with a mean value of 5 cmH2O. Mean levels of tidal volume (VT) was 8.16 ml/kg, and medium inspiratory fraction of oxygen (FiO2) was < 0.6. Arterial blood gases analyses showed normo- and hypocapnia. Sixty-seven percent of the patients fulfilled the oxygenation criteria for ARDS, but only half of them had bilateral pulmonary infiltrates. No mechanical complication as pneumothorax was noted. Ventilator associated pneumonia was encountered in 39% of patients. A total of 34 (32%) children died. Conclusions. Pressure ventilation modes were standard in our PICU. Describing the standard care and how mechanical ventilation is performed in children can be useful for future clinical trials.

Keywords: children, mechanical ventilation, modes of mechanical ventilation

Introduction

Mechanical ventilation is one of the most common procedures performed in pediatric intensive care units (PICU), with 20% to 64% of patients admitted to the PICU requiring ventilator support (1). The reasons for mechanical ventilation and management strategies vary, depending not only on disease state, but also on PICU's size, patient population served, clinician's experience and local protocols (2,3).

Many mechanical ventilation modes are currently used in clinical practice to provide respiratory support for a wide spectrum of patients, ranging from no lung disease to acute lung injury (ALI) or acute respiratory distress syndrome (ARDS). No data exist so far to determine the ventilatory mode that provides the greatest benefit with the minimum risk of ventilator-induced lung injury.

The definitions of ALI and ARDS for infants (older than one month of life), children, and adolescents are essentially similar to that already reported in adults (4-6). However, there are intrinsic differences between pediatric patients and adults, which often can affect management strategies. Infants and young children, as compared to older children, adolescents, and adults, have more compliant chest walls, higher sedation requirements, lower hematocrit (which may affect global oxygen delivery), higher baseline airways resistance, and lower functional residual capacity. Additionally, the still developing and growing lung may be at greater risk for ventilator-induced lung injury at a lower airway pressure than the developed lung of an adult (7).

By the end of the 20th century, pediatric intensivists had learned important insights about mechanical ventilation based on what works in adults. Outcomes over the past 2 decades have improved for adults with ALI/ARDS, managed with lung-protective ventilation strategies. The ARDS Network study (8) demonstrated that lower tidal volumes (VT) of 6 ml/kg with limited plateau pressures decreases mortality and increases the number of days without ventilator use, than traditionally high VT of 12 ml/kg predicted body weight. In addition, the application of PEEP for lung recruitment has improved also the outcomes in adults (9-11). Much less is known about pediatric mechanical ventilation practice in ALI/ARDS. A recent prospective, cross-sectional, observational Pediatric Acute Lung Injury Ventilation (PALIVE) study (12) enrolling fifty-nine pediatric intensive care units in 12 countries in North America and Europe reveals inconsistent mechanical ventilation practice in children with ALI. Attempts at creating a PEEP/FiO2 titration grid similar to the ARDS Network model (8) were unsuccessful, as routine pediatric practice demonstrated great variability in the application of PEEP in relation to FiO2.

We conducted this study to describe the standard care and how mechanical ventilation is performed in our PICU.

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Material and method

A four years observational study (January 2010 – December 2013) was conducted in the First PICU of Emergency Hospital for Children "Louis Turcanu" Timisoara and included all mechanically ventilated children ≥ 24 hours, aged 0-18 years. Preterm babies, patients with congenital immunodeficiency disorders, malignant or surgical diseases were excluded from the study.

Demographic data (gender, age, weight), reason for mechanical ventilation (MV), chronic functional status, route of mechanical ventilation (nasotracheal, orotracheal, or tracheostomy), need for reintubation, ventilation tube characteristics (cuffed versus uncuffed tube or tracheostomy), suction system (opened or closed), ventilator data, number of days on ventilator, hospital length of stay, complications of MV, outcome (discharge, transfer, death), and pediatric risk of mortality score (PRISM) III (13) were collected in all patients.

Ventilator parameters were collected at two different moments of MV: at the start of MV (time A) and after 72 hours of MV (time B). It was considered that a minimum period of 48 hours on MV would be necessary for comparation, since shorter periods of MV do not generally alter respiratory mechanics (14,15). Ventilator data were referring to: peak inspiratory pressure (PIP), positive end-expiratory pressure (PEEP), respiratory rate (RR), inspiratory fraction of oxygen (FiO2), and tidal volume (VT). Values of VT were derived by measuring the exhaled tidal volume corrected by the body weight (ml/kg). The maximum and minimum values of PIP, PEEP and FiO2 were noted during the entire period of MV for each patient.

Arterial blood gases were also collected at two different moments: one hour after starting MV (time C) and after 72 hours of MV (time D). PaO2/FiO2 ratio for ALI or ARDS diagnosis was calculated for each patient.

Endotracheal intubation (oral or nasal) was performed with pre-oxygenation and after rapid sequence induction using a sedative agent, an analgesic, and a paralyzing agent. It was also part of standard care to keep ventilated patients under continuous sedation and analgesia. Central venous lines were placed in the majority of ventilated patients for drugs infusions and for blood analyses. No arterial line was present. Enteral nutrition was achieved on nasogastric tube and was completed by parenteral nutrition.

The ventilator devices of our PICU are represented by two Viasys Avea and two iVent machines. Exhaled tidal volume measured by the ventilator device was used. The following modes of ventilation were available: pressure control ventilation (PCV), volume control (VCV), volume target pressure control (VTPC), airway pressure relieve ventilation (APRV), synchronized intermittent mandatory ventilation (SIMV) with pressure support (PS) and continuous positive airways pressure CPAP with PS.

This study was approved by the Hospital institutional review board.

Statistical analysis was performed using Microsoft Excel 2007 software. Results are expressed as percent (%), minimum, maximum, and mean ± standard deviation (M ±SD). Variables were compared using Student's t test for normally distributed variables. Comparisons were unpaired and all tests of significance were 2-tailed. Statistical significance was considered at p value < 0.05.

Results

A total of 108 pediatric patients needed ventilatory support for a minimum of 24 hours and met the inclusion criteria. Study population characteristics are shown in Table1. Seventy-four (68.51%) patients were males and the mean age was 2.3 years. Overall, 11 (10.18%) were neonates under 30 days; 61 (56.48%) were infants aged less than a year; 17 (15.74%) were small children (between the ages 1 and 3 years); 5 (4.62%) were between 3 and 6 years old; and 14 (12.96%) were over 6 years of age.

Seventy percent of the patients were orotracheal intubated. All endotracheal tubes were cuffed (Microcuff Kimberly-Clark) and all suction systems were closed. Reintubation, due to accidental detubation or tube obstruction with adherent secretions occurred in 13.88% of the patients.

The mean duration of mechanical ventilation was 9.36±8.52 days and the mean hospital length of stay was 24.7±18.66 days. Of all 108 patients, 34 died before discharge, resulting in 31.48% of deaths. The median value of PRISM III score on admission was higher in non-survivors than in survivors (17 vs. 22, p <0.01). Ventilator-associated pneumonia occurred in 34.24% of the patients. No barotrauma like pneumothorax was noted. Mortality rate was 31.48%.

The causes of PICU admission are listed in Table 2. Acute pulmonary conditions were the primary reasons for mechanical ventilation in 57.37% of the patients. Bacterial pneumonia was the most common primary diagnosis present in 18.51% of patients and bronchopneumonia was the second most common in 17.59% of patients. Among patients with acute respiratory failure, 16.66% had severe sepsis/septic shock. Nonpulmonary conditions, including neurologic diseases, cardiac diseases, and other diagnoses constituted 25.87% of patient condition.

Table 3 lists preexisting chronic medical conditions of the patients. Chronic neurologic diseases, represented mainly by cerebral palsy were found in 27.78% of patients, followed by malnutrition in 20.37% of patients. Chronic respiratory diseases (bronchopulmonary dysplasia and congenital pulmonary fibrosis) were present in 8.33% of patients.

At time A (start of MV), pressure assist-control (PC-A/C) mode was predominantly applied (89.91%), whereas pressure synchronized intermittent mandatory ventilation (PC-SIMV) was used in 10.18% of the patients. At time B (MV at 72 hours), PC-A/C was applied in 62.03% of patients, PC-SIMV in 12.03%, and CPAP in 14.81% of patients (Table 4).

Descriptive characteristics of ventilation parameters at time A and B are shown in Table 5. At time A, mean PIP was 25 cmH2O, PEEP was 5 cmH2O, ventilator rate (VR) was 32 b/min, FiO2 was 0.58, and VT was 8.16 ml/kg.

Table 1. Study population characteristics

	N=108
Age (M ±SD) month (0-216)	27.65±51.00
Age, N (%):	
0-1 month	11 (10.18)
1 month-1 year	61 (56.48)
1-3 years	17 (15.74)
3-6 years	5 (4.62)
> 6 years	14 (12.96)
Sex, N (%)	
Male	74 (68.51)
Female	34 (31.48)
Intubation characteristics, N (%)	
Orotracheal	75 (69.44)
Nasotracheal	29 (26.85)
Tracheostomy	4 (3.70)
Endotracheal tube type, N (%)	
Cuffed	108 (100)
Uncuffed	0 (0)
Suction system, N (%)	
Closed	108 (100)
Opened	0 (0)
Reintubation, N (%)	15 (13.88)
Ventilator days (M ±SD)	9.36±8.52
Hospital length of stay (M ±SD)	24.7±18.66
Complications of MV, N (%)	
Ventilator-associated pneumonia	37 (34.25)
Pneumothorax	0 (0)
Outcome, N (%)	
Discharged	68 (62.96)
Death	34 (31.48)
Transferred to another hospital	6 (5.55)
PRISM III score (M ±SD)	17±6.83

Table 2. Cause of PICU admission

Cause of PICU admission	N (%)
Respiratory causes	**62 (57.37)**
Bacterial pneumonia	20 (18.51)
Bronchopneumonia	19 (17.59)
Pneumocystis jiroveci pneumonia	14 (12.96)
Neonatal respiratory distress	6 (5.55)
syndrome	1 (0.92)
Meconium aspiration	1 (0.92)
Acute laryngitis	1 (0.92)
Pulmonary edema	**8 (7.39)**
Cardiac causes	3 (2.77)
Congenital cardiac malformations	4 (3.70)
Congestive cardiac failure	1 (0.92)
Cardiac tamponade	**16 (14.80)**
Neurologic causes	9 (8.33)
Status epilepticus	5 (4.62)
Viral encephalitis	2 (1.85)
Bacterial meningitis	**18 (16.66)**
Severe sepsis	**4 (3.68)**
Others	1 (0.92)
Phenobarbital poisoning	1 (0.92)
Hemolytic-uremic syndrome	1 (0.92)
Severe depression	1 (0.92)
Guillaine-Barre syndrome	

Table 3. Preexisting chronic medical conditions

Concomitant diseases	N (%)
Malnutrition	**22 (20.37)**
Chronic respiratory disease	**9 (8.33)**
Bronchopulmonary dysplasia	7 (6.48)
Congenital pulmonary fibrosis	2 (1.85)
Chronic neurologic disease	**30 (27.78)**
Hydrocephaly	5 (4.62)
Cerebral palsy	14 (12.96)
Spinal muscular atrophy type 1	2 (1.85)
Duchenne muscular dystrophy	2 (1.85)
Hypoxic-ischemic encephalopathy	7 (6.48)
Others	**5 (4.62)**
Chronic renal disease	3 (2.77)
Hemolytic disease of newborn	1 (0.92)
Pierre-Robin syndrome	1 (0.92)

Table 4. Modes of mechanical ventilation

	Modes of MV	N (%)
A	PC-A/C	97 (89.91)
	PC-SIMV±PSV	11 (10.18)
B	PC-A/C	67 (62.03)
	PC-SIMV±PSV	13 (12.03)
	CPAP±PSV	16 (14.81)
	Without MV	12 (11.11)

Time A – Start of MV, Time B – MV at 72 hours

Table 5. Ventilator parameters

Ventilator parameters	Time of MV	N	Min.	Max.	Mean	Std.Dev.	p
PIP (cmH_2O)	**A**	108	19	33	25.18	2.70	***<0.01***
	B	96	14	32	23.42	4.10	
PEEP (cmH_2O)	**A**	108	3	8	5.07	0.83	0.075
	B	96	2,5	8	4.80	0.98	
VR (breaths/min)	**A**	108	18	60	31.91	11.13	0.158
	B	81	15	60	28.89	10.09	
FiO_2	**A**	108	0.21	1	0.58	0.20	***<0.01***
	B	96	0.21	1	0.45	0.18	
VT (ml/kg)	**A**	108	5	12	8.16	1.47	***<0.01***
	B	96	5	11	7.14	1.44	

Time A – Start of MV, Time B – MV at 72 hours

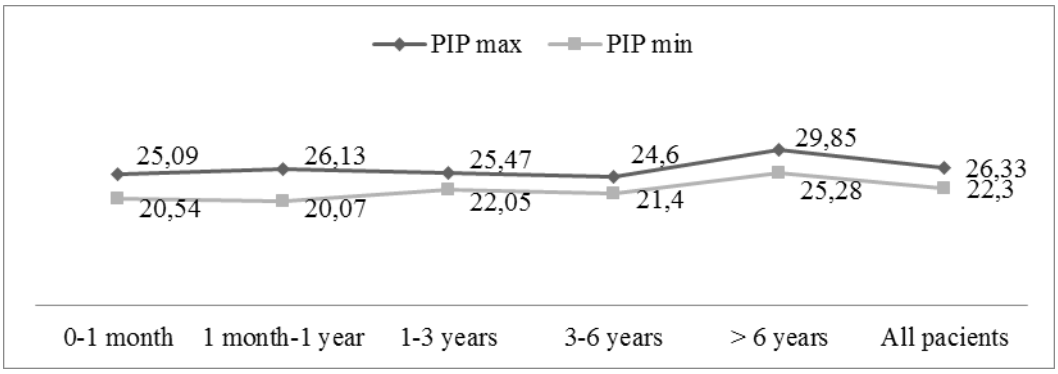

Figure 1. Maximum and minimum PIP

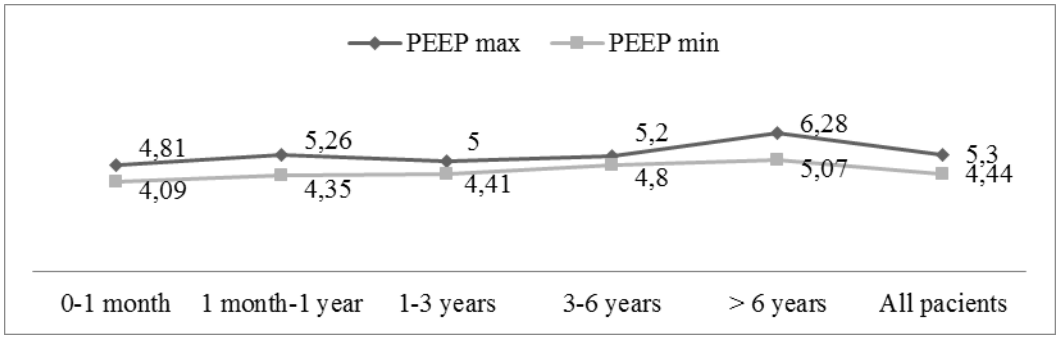

Figure 2. Maximum and minimum PEEP

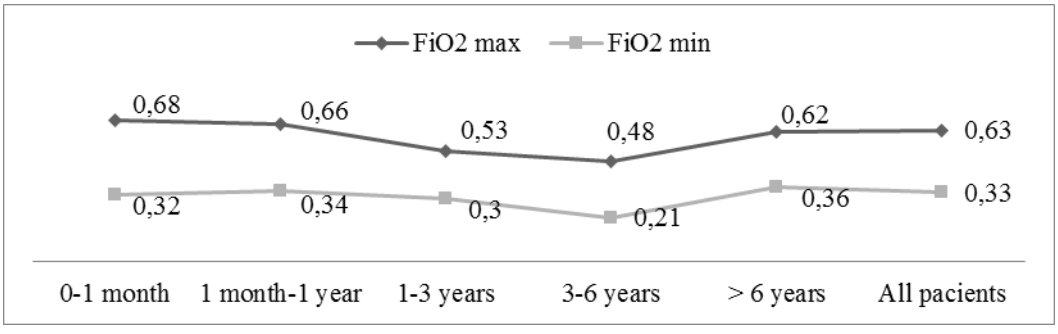

Figure 3. Maximum and minimum FiO_2

Table 6. Arterial blood gases and PaO_2/FiO_2 ratio

	Time of MV	N	Min.	Max.	Mean	Std.Dev.	p
pH	**C**	108	7.13	7.63	7.38	0.09	0.286
	D	96	7.01	7.66	7.40	0.08	
PaO_2 (mmHg)	**C**	108	49	166	89.84	18.68	0.665
	D	96	51	149	89.50	15.52	
$PaCO_2$ (mmHg)	**C**	108	19	84	41,09	11,68	0,187
	D	96	21	82	39,55	9,16	
PaO_2/FiO_2 (mmHg)	**C**	108	62	510	182.09	97.73	***<0.01***
	D	96	60	523.8	245.5	124.01	

Time C – one hour after starting MV, Time D – after 72 hours of MV
PaO_2 – partial pressure of oxygen, $PaCO_2$ –partial pressure of carbon dioxide

Values of PIP, FiO2 and VT were statistically improved at time B ($p<0.01$).

Mean PIP values were constant < 30 cmH2O in both times of determination. At time A, values of PEEP ≤ 5 cmH2O encountered in 75.92% of the patients and PEEP≤ 8 cmH2O in 95.38% of the patients. At time B, 80.2% of the patients had a PEEP ≤ 5 cmH2O. Values of FiO2 ≤ 0.6 had 69.15% of the patients at time A and 82.10% of patients at time B.

Maximum and minimum values of PIP, PEEP, and FiO2 by age groups are listed in Figures 1-3. The mean values of maximum PIP was < 30 cmH2O, with 12% of the patients having a PIP ≥ 30 cmH2O, but < 35 cmH2O. Two percent of the patients had a maximum PEEP ≥ 8 cmH2O. The mean values of maximum FiO2 was ≤ 0.65, and the mean values of minimum FiO2 was ≤ 0.35.

Arterial blood gases values at time C and D of determination and PaO2/FiO2 ratio are shown in Table 6. There was no statistical differences for pH (p=0.286), PaO2 (p=0.665), and PaCO2 (p=0.187) at time C and D of determination. Most patients (58%) were normocapnic and 22% of them were hypocapnic.

The mean value of PaO2/FiO2 ratio was < 200 at time A and < 300 at time B. ARDS was defined as bilateral pulmonary infiltrates, acute onset, PaO2/FiO2 ratio of 200 or less, and no suspicion of left heart failure (or a pulmonary capillary wedge pressure of 18 or less). Sixty-seven percent of the patients fulfilled the oxygenation criteria for ARDS, but only half of them had bilateral pulmonary infiltrates.

Weaning and extubation criteria and sedation protocols were not focused in this study.

Discussions

The patients enrolled in the study were hospitalized in a medical PICU and the practitioners are pediatric specialists with subspecialty in intensive care. This study reflects the real situation of mechanically ventilated children in our unit in the last 4 years. The weaknes of this study is that data extraction was performed in the last 4 years and practice changed in the last 2 years.

In our study, the main reasons for intubation and mechanical ventilation were quite variable, but almost 60% of the patients had acute respiratory failure. A much lower incidence, of 26% was reported by Khemani et al (1) in a multicenter clinical trial witch enrolled 12,213 children intubated and mechanically ventilated from 16 US PICUs.

Almost 30% of the patients associated chronic neurologic pathology, mainly represented by cerebral palsy, and 20% associated various degrees of malnutrition. The children with malnutrition were mostly recovered premature babies.

The mean age of the patients was 2.3 years; with 57% having less than one year old. Principi et al (16) and Randolph et al (2) reported almost the same incidence of mechanically ventilated infants.

The mean duration of mechanical ventilation was 9.36 days, corresponding to the same duration reported before both in children and adults (2,17). A shorter median length of ventilation of 4 days was reported in studies enrolled children hospitalized in medical and surgical PICUs (18,19).

The main route of intubation was oral in 70% of the cases; this route being performed in emergent intubation. There are studies reporting only orotracheal intubation and no nasotracheal intubation (20).

In all patients we used cuffed endotracheal tubes (Microcuff Kimberly-Clark), because they have several advantages: decrease the rate of ventilator-acquired pneumonia (21); reduces the need for tube exchanges (22,23); provides a perfect seal with the trachea even at low inflation pressure, without air leaks (22,24); and do not increase the risk of post-extubation stridor (22,23).

The mean PRISM III score on admission in PICU was 17, a higher value than previously reported (25,26), suggesting a more severe illness on admission. A PRISM score of 16 was found by Dahlem et al (27) in ARDS patients, and a score of 22 in non-survivor ARDS patients. Ventilator-associated pneumonia occurred in 34% of the cases, also a higher prevalence than reported (28), reflecting the level of health-care of this patients in a low socio-economic country.

The mortality of the study group was 31.48%, comparable with the mortality found by Zhu et al (25) for ARDS patients. Overall PICUs mortality was 2.5%.

We used exclusively pressure-limited modes of ventilation, even though other modes were available. The

most used mode was PC-A/C. As pressure ventilation was used, and no volume ventilation at all, more attention was paid to inspiratory pressure limits than to tidal volume control.

Mean PIP values were constant < 30 cmH2O, with 12% of the patients having a maximum PIP ≥ 30 cmH2O, but < 35 cmH2O. There was little variability with PEEP choice, with a mean value of 5 cmH2O. Only 2% of the patients had a maximum PEEP ≥ 8 cmH2O. Low levels of PEEP applied can be explained by the fact that patients had no central venous pressure monitored, as it is well known that high PEEP predominantly decreases cardiac output through a decrease in preload of right ventricle (29). In general, most patients who are managed without arterial lines are receiving modest ventilator support (1).

There was no direct connection between PEEP and FiO2, preferring low levels of PEEP and high levels of FiO2. This was also noted by Khemani et al (1) and Santschi et al (12). Mean FiO2 levels at the start o MV was < 0.6, and decreases at 0.45 after 72 hours of MV. The mean levels of FiO2 reported before varies between 0.35 and 0.5 (1,25,30).

In our study, mean levels of VT at the start of MV were 8.16 ml/kg, and decreased at 7.14 ml/kg after 72 hours of MV. Reported levels of VT in the era of "low VT" varies between 7.4 and 9.5 ml/kg (12,20,25,30).

Arterial blood gases showed normocapnia and hypocapnia, and as the mean PaO2/FiO2 ratio was < 200 at the start of MV and < 300 after 72 hours of MV, results that the ALI/ARDS strategies were not fully implemented. Kemani et al (30) proposed in 2011 a computer protocol for ALI/ARDS for children aged over one year old in a retrospective cohort study. The authors concluded that clinicians infrequently decreased FiO2, even when the PaO2 was high (>68 mmHg) and the protocol would have recommended more positive end expiratory pressure (PEEP) than was used in actual practice. Also, the clinicians often made no change to either PIP or VR when the protocol would have recommended to change, even when the pH was greater than 7.45 with PIP at least 35 cmH2O, being lost opportunities to minimize potentially ventilator induced lung injury for children with ALI/ARDS.

Conclusions

Pressure-limited ventilation modes were standard in our PICU. Protective lung strategies for ALI/ARDS were not fully implemented, as ventilatory settings resulting in normocapnia/hypocapnia were still being used. Describing the standard care and how mechanical ventilation is performed in children can be useful for future clinical trials.

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