

# Experience in a Pediatric Prolonged Mechanical Ventilation Unit from a public hospital in Chile

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## ABSTRACT

**Introduction:** Hospitalized patients with high respiratory technology dependency are increasingly common and result in lengthy stays in intensive care units. Strategies mitigating its impact have been scarcely described.

**Objective:** To describe a 6-year experience in a Pediatric Prolonged Mechanical Ventilation Unit.

**Methods:** Retrospective study. All children admitted to the unit between October 2012 and December 2018 were included. Descriptive and inferential statistical methods were used, analyzing lengths of stay and readmissions. Different outcome measures were compared according to the type of pathology and mechanical ventilation.

**Results:** A total of 113 patients had 310 admissions to the unit. Age at admission: 2.2 years (0.6-8.8); males: 60.2 %. Pathologies: neuromuscular disease (22.1 %), chronic lung disease (20.4 %), neurological damage (34.5 %), upper airway obstruction (9.7 %), heart disease (3.5 %), Down syndrome (9.7 %). A total of 10507 bed-days were used; with a 92.6 % occupancy rate, 54.8 % of transfers to the intensive care unit, and 66.1 % of readmissions. Mean length of stay: 16 days (6.5-49.0); differences in age at admission observed by pathology ( $p = 0.032$ ). More readmissions were observed in children with neurological damage and Down syndrome ( $p = 0.004$ ). Children with invasive ventilation were observed to have a longer length of stay ( $p < 0.001$ ) and more readmissions ( $p < 0.001$ ).

**Conclusion:** The occupancy rate at the PMVU was over 90 %, which allowed more available intensive care beds and discharging all patients. Children with invasive ventilation had a longer length of stay and more readmissions.

**Keywords:** mechanical ventilation, home health care, chronic respiratory diseases, tracheostomy, pediatrics.

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## GLOSSARY

CLD: chronic lung disease.

CRD: chronic respiratory disease.

DS: Down syndrome.

IV: invasive ventilation.

NIV: non-invasive ventilation.

ND: neurological damage.

NMD: neuromuscular disease.

PICU: pediatric intensive care unit.

PMVU: prolonged mechanical ventilation unit.

UAO: upper airway obstruction.

## INTRODUCTION

The advances made in pediatric and neonatal intensive care units, the use of more effective treatment regimens, and the development of programs focused on child health interventions have helped to increase survival among children with chronic respiratory diseases (CRDs). These patients require technological resources and a high level of professional specialization for an adequate diagnosis, treatment, and follow-up of their condition.<sup>1,2</sup>

This reality favors the hospitalization of these patients in tertiary care units, such as pediatric intensive care units (PICUs), with lengthy stays, which reduces the rotation of acute complex patients in critical condition in the health care network and increases direct costs and the health care opportunity cost.<sup>3</sup> Implementing innovative and effective alternatives for the in-hospital management of these patients with CRDs is a challenge for health care models.<sup>4,5</sup> A high percentage of these children require prolonged mechanical ventilation, defined as needing invasive or non-invasive ventilation during more than 21 days for more than 6 hours per day with interruptions of up to 48 hours.<sup>6</sup>

Reported experiences, both locally and internationally, suggest that ventilation can be initiated at the hospital and continued at the patient's home. This requires reducing the probability of adverse events, as well as ensuring the social inclusion of the child and their family, which entails the need for technological equipment, trained staff, training patients' parents and caregivers, and doing a follow-up.<sup>3,7</sup>

In Chile, the prevalence of children with CRDs has increased significantly in the last 20 years, and this has propelled the creation of governmental programs for the treatment, rehabilitation, and support of specific technological needs.<sup>8-10</sup> In this context, the Prolonged Mechanical Ventilation Unit (PMVU) was created in 2012, with 5 beds in the Division of Pediatrics of Hospital Guillermo Grant Benavente, in the city of Concepción. Since its creation, the PMVU was targeted at providing multidisciplinary care for children with complex CRDs by a multidisciplinary team made up of staff nurses and kinesiologists; with the support of speech therapists, occupational therapists, social workers, and a psychologist, and coordinated by a pediatrician specialized in bronchopulmonary conditions. The team requests regular assessments conducted by multiple medical specialists (ear, nose, and throat specialist, neurologist, endocrinologist, ophthalmologist, and surgeons), which allows the transition between the PICU and the patient's home, with the delivery of educational and clinical rehabilitation tools in order to ensure a safe and effective hospital discharge.<sup>3,11</sup> More complex exacerbations with poor clinical course are referred to the PICU.

The objective of this study was to describe the experience at the PMVU of the Division of Pediatrics of Hospital Guillermo Grant Benavente, the characteristics of admitted patients and their readmissions, after 6 years of operation.

## METHODS

This study is a retrospective case series, written according to the *Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement*.<sup>12</sup> All children admitted to the PMVU from its opening (October 2012) to December 2018 were included. *Figure 1* shows the flow chart of admissions, discharges, and readmissions at the PMVU. No exclusion criteria were defined.

The reason for admission to the PMVU was categorized as follows: (a) initiation of mechanical ventilation: patients admitted in order to assess

the need for home invasive ventilation (IV) or non-invasive ventilation (NIV) and receive training on oxygen therapy, aerosol therapy, mechanical ventilation and artificial airway care, respiratory exercises and basic cardiopulmonary resuscitation, in charge of a multidisciplinary team, with brochures, handbooks, and theoretical-practical activities organized by trained staff; (b) scheduled multidisciplinary re-assessment: patients admitted in order to be assessed by multiple specialists; (c) post-exacerbation: clinically stable patients admitted after a respiratory or non-respiratory exacerbation, coming from critical care units or the emergency department; (d) decannulation process: patients with a tracheostomy admitted to start or adapt their decannulation plan; (e) medical or surgical procedure: patients with chronic respiratory conditions admitted for medical or surgical procedures without fulfilling the above-mentioned reasons.

Upon admission to the PMVU, the demographic outcome measures of patients were recorded, such as age, sex, diagnosis, referring unit, type of mechanical ventilation (IV, NIV), reason for admission, and length of hospital stay in days. The admission diagnosis was classified into neuromuscular disease (NMD), chronic lung disease (CLD), central neurological damage (ND), upper airway obstruction (UAO), heart disease, and Down syndrome (DS).

## Statistical analysis

Data were analyzed using the Kolmogorov-Smirnov normality test. Normal distribution was ruled out and quantitative outcome measures were expressed as median and interquartile range, qualitative outcome measures as percentage, and the Kruskal-Wallis test was used to compare length of stay in days, number of admissions, and readmissions by diagnosis and type of mechanical ventilation. In addition, the occupancy rate was expressed as percentage and determined by dividing the total number of occupied bed-days in a certain period by the total number of available beds in the same period.<sup>8</sup>

The analysis was done using the IBM SPSS Statistics® software for Windows, v23.0 (IBM Corporation, Armonk, New York, USA), and a value of  $p < 0.05$  was considered significant. The study was approved by the Ethics Committee of Universidad de Concepción. Data were entered into a spreadsheet with no identifiable personal history and coded, and the file was password protected.

**RESULTS**

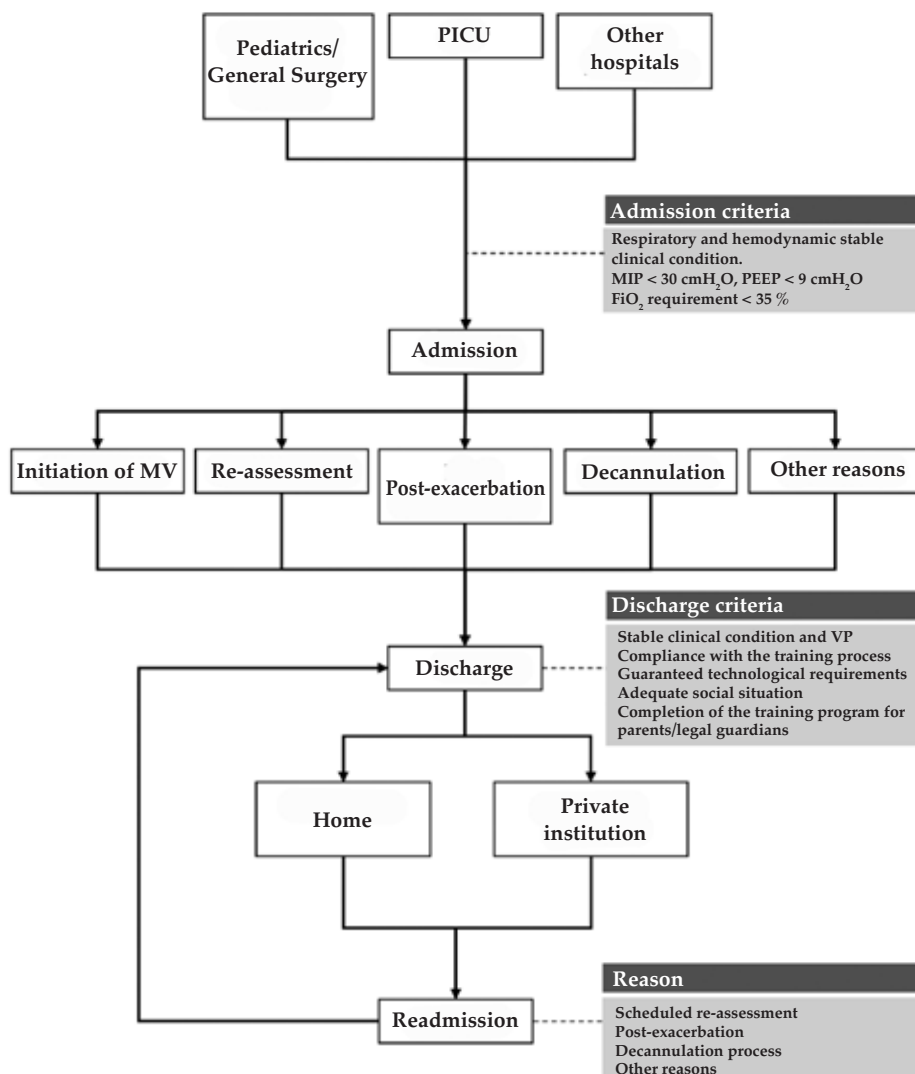
During the 6 years considered, 113 children were admitted to the PMVU, age at admission was 2.2 years (0.6-8.8), and 60.2 % were males (Table 1). NMD was observed in 22.1 % of the sample; CLD, in 20.4 %; ND, in 34.5 %; UAO, in 9.7 %; heart disease, in 3.5 %; and DS, in 9.7 % (Table 1).

Of the 113 admitted children, 87.6 % were assessed for mechanical ventilation initiation and, finally, 61.9 % of all patients required prolonged invasive or non-invasive ventilation. Out of all patients, 38 children were only admitted for the initial assessment, with no readmissions. The remaining 75 children were readmitted for

different reasons: 36 for a re-assessment, 56 for an exacerbation, 6 for decannulation planning, and 9 for medical or surgical procedures (Table 2).

The 5 beds available at the PMVU allowed 310 admissions in the study period, with a total of 10 507 bed-days and a 92.6 % overall occupancy rate. Of these admissions, 46.1 % were directly referred from critical care unit beds (intermediate or intensive care), who accounted for 8577 bed-days, with a 17-day stay (7-44). Of all admissions, 63.9 % corresponded to readmissions; 73.2 % of which were post-exacerbation; of the latter, 84.8 % were due to respiratory conditions; and 15.2 %, for other reasons. In the first year after being discharged, 38.9 % of patients were readmitted.

FIGURE 1. Flow chart of admissions, discharges, and readmissions at the Prolonged Mechanical Ventilation Unit.



In the total sample, differences were observed in the age at admission to the PMVU; UAO was seen in younger patients and NMD, in older ones ( $p = 0.032$ ). Children with ND and DS had a longer length of stay compared to other categories; whereas NMD patients had a shorter length of stay ( $p = 0.169$ ) (Table 1).

In the analyzed period, a median of 2 readmissions was observed in children with ND and DS ( $p = 0.004$ ); whereas the greatest number of post-exacerbation readmissions was seen in children with CLD, ND, and UAO, with a median of 1 ( $p = 0.046$ ). Table 2 shows admitted and readmitted children by pathology subgroup.

According to the type of mechanical ventilation, differences were observed among the groups regarding length of stay ( $p < 0.001$ ), number of readmissions ( $p < 0.001$ ), number of re-assessments ( $p = 0.001$ ), post-exacerbation readmissions ( $p < 0.001$ ), and readmissions due to medical or surgical procedures ( $p = 0.018$ ); children with IV had a longer length of hospital stay and more readmissions than the other groups (Table 3). A successful decannulation process was observed in 18 % of the patients in this group.

Among children with NIV, post-exacerbation hospitalizations were less common and were mainly due to respiratory conditions in 79.7 % of admissions. Elective hospital admissions were related to more invasive procedures, such as the need for gastrostomy (1.6 %) or multidisciplinary re-assessments, when faced with complex cases difficult to assess at the outpatient offices (16.4 %).

A total of 99 % of children were discharged from the hospital and sent home or to a private institution in cases of patients struggling with social determinants; and, out of patients requiring home ventilation upon discharge, 47.1 % corresponded to IV and 52.9 %, to NIV. The length of hospital stay was 16.0 days (6.5-49.0). Only one child with IV died at the PMVU; he received palliative care due to the advanced state of his underlying condition.

## DISCUSSION

This article reports a 6-year experience at a PMVU from a public hospital in Chile, which included study and treatment respiratory strategies, individualized rehabilitation, and training for parents and caregivers. During the

TABLE 1. General characteristics of the total sample and by pathology subgroup in the first admission, expressed as median and interquartile range

Outcome measures	Total (n = 113)	NMD (n = 25)	CLD (n = 23)	ND (n = 39)	UAO (n = 11)	Heart disease (n = 4)	DS (n = 11)
Age at the time of admission (years)	2.2 (0.6-8.8)	5.5 (1.4-12.6)	0.8 (0.5-12.4)	4.6 (1.2-9.5)	0.7 (0.3-1.0)	0.9 (0.3-3.0)	1.5 (0.6-2.2)
Sex (M/F)	68/45	14/11	18/5	19/20	8/3	2/2	7/4
Mechanical ventilation (IV/NIV)	33/37	7/13	4/5	13/14	4/3	0/1	5/1
Length of stay (days)	16.0 (6.5-49.0)	7.0 (3.0-63.5)	14.0 (6.0-35.0)	30.0 (10.0-63.0)	13.0 (6.0-61.0)	9.5 (5.3-14.5)	20.0 (13.0-79.0)

NMD: neuromuscular disease; CLD: chronic lung disease; ND: neurological damage; UAO: upper airway obstruction; DS: Down syndrome; M: male; F: female; IV: invasive ventilation; NIV: non-invasive ventilation.

TABLE 2. Number of patients admitted by cause, by total group and pathology subgroups

Diagnosis	Initiation of MV	Re-assessment	Post-exacerbation
DS (n = 11)	11	6	5
Heart disease (n = 4)	4	0	1
UAO (n = 11)	11	4	6
ND (n = 39)	36	15	23
CLD (n = 23)	17	4	13
NMD (n = 25)	20	7	8
Total (n = 113)	99	36	56

MV: mechanical ventilation; DS: Down syndrome; UAO: upper airway obstruction; ND: neurological damage; CLD: chronic lung disease; NMD: neuromuscular disease.

study period, 310 admissions were recorded among 113 patients, who accounted for a total of 10 507 days of hospital stay, with an occupancy rate > 90 % at the PMVU. This resulted in more available beds at the PICU for acute, critical patients and prevented lengthy stays among patients with high chronic respiratory technology dependency in said unit.

Our results were consistent with those reported by Paulides et al., who also documented lengthy hospital stays in this group of patients, which limited bed availability in pediatric critical care units. Their report shared a 30-year experience, with more than 300 ventilator-dependent children, who were hospitalized during 12440 days before being discharged and sent home, and required 9335 hospitalization days due to severe readmissions to the PICU.<sup>3</sup>

A previous report made by our group confirmed that the implementation of the PMVU helped to increase rotation rates and reduce the length of stay at the PICU significantly.<sup>11</sup> This was consistent with the findings of Amirnovin et al., who reported a decreased average length of stay at the PICU, from 70 to 36 days, with the implementation of a similar hospital strategy.<sup>5</sup>

The most common diagnoses were NMD, CLD, ND, and UAO; a significantly lower age at admission was observed among patients with UAO, and a higher age, among those with NMD. In the case of UAOs, this was related to the severity observed in patients during early life, since in our cohort of admitted UAO children younger than 1 year, 78 % required tracheostomy and/or ventilation at home after discharge, as it was previously described in severe cases. However, many times, its final resolution entails maxillary or mandibular advancement surgery.<sup>13</sup> Mandibular distraction was performed in 33 % of our UAO patients younger than 1 year in

order to avoid tracheostomy, a procedure which was previously reported in neonates with severe micrognathia and was shown to be safe and effective and reduce respiratory dependency.<sup>14,15</sup>

In order to optimize the ventilatory management of UAO patients younger than 1 year, NIV was used in 22 % of cases, avoiding intubation and tracheostomy, as demonstrated by Leboulanger et al., in a cohort of newborn infants with Pierre Robin sequence, where they proposed considering this type of support as a first-line treatment.<sup>16</sup>

Home NIV was indicated in 63 % of included NMD cases, which mainly corresponded to the slowly progressive NMD group, which required respiratory care and ventilatory support later on in life.<sup>17,18</sup> Nowadays, there is consensus regarding the need to initiate NIV in an early manner in patients with progressive NMD, given the positive impact it has on its clinical course.<sup>17,18</sup> Although the need for ventilatory support should be determined by observing sleep-disordered breathing, this therapy is frequently initiated after a hospitalization for a respiratory condition.<sup>18,19</sup> This situation has been reported in the bibliography and will depend on the type of NMD, available treatments, and other related prognostic factors.<sup>18,20</sup>

Several countries have implemented strategies to provide home invasive and non-invasive ventilatory support, with a marked increase in the last 30 years, and favorable results have been observed both in patients and health care systems.<sup>3,4,11,21,22</sup> In our group of children, those who met the required socioeconomic conditions at home were admitted to government programs implemented in Chile since 2006 for NIV and since 2008 for IV, which included 658 active pediatric patients and 1212 admitted patients at the beginning of 2019.<sup>8-10,23</sup> For the group

TABLE 3. Length of hospital stay in days, number of readmissions, and reasons for readmission by type of mechanical ventilation

Type of mechanical ventilation	Length of stay Days	Readmission		Re-assessment		Post-exacerbation	
		n	No. of admissions	n	No. of admissions	n	No. of admissions
IV (n = 33)	61,0 (14,0-179,5) <sup>ab</sup>	21	73	11	15	18	54
NIV (n = 37)	14,0 (5,0-35,8) <sup>a</sup>	17	66	12	16	16	51
Without MV (n = 43)	13,0 (7,3-30,8) <sup>b</sup>	3	5	0	0	4	6

Data expressed as median and interquartile range. IV: invasive ventilation; NIV: non-invasive ventilation; MV: mechanical ventilation. a, b: p < 0.05 between assessed outcome measures by type of mechanical ventilation.

of patients who did not meet the required socioeconomic conditions for this programs in order to go back home with ventilatory support, a technical and professional team was introduced in an institution external to the hospital.<sup>8-10,24</sup>

Of all children included in our study, 54 % required an unscheduled readmission to the PMVU, most of them with IV, which may be explained by their highly complex underlying conditions, associated complications, and the need for regular assessments in order to determine behaviors that may suggest an advancement or regression of their underlying condition.<sup>25-27</sup> Kun et al., described unscheduled readmissions in patients with home IV and reported 40 % readmissions 12 months after hospital discharge, of which 64 % were related to respiratory reasons.<sup>25</sup> Results were similar in our group of children with home IV: 30 % had an unscheduled readmission in the first year, and 67 % of them were due to respiratory reasons.

Scheduled readmissions were also more common among IV children, who generally had limitations to undergo multiple check-ups and tests. Individualized plans were elaborated, according to clinical condition and specific problems. Specialist assessment, upper airway assessment, sleep studies, and general examinations were mainly included. Henningfeld et al., described a ventilation weaning and decannulation process in 46 children with IV, which entailed hospital admission and tests in order to plan it and achieve a higher success rate.<sup>27,28</sup> This was done in 6 of our children who were on IV for less than three years since tracheostomy was done, and liberation from the ventilator was more common before 5 years since its initiation.<sup>28</sup>

Our study has certain limitations, such as the variety of categorized pathologies and their sample size, which limits comparisons among them. The study was exclusively conducted in our hospital; therefore, it only allowed to show the local reality with a limited number of participants, which may have affected the results of our analysis. Nevertheless, to date, there are no reports on the national situation in Chile, and international reports on this type of care dependency are scarce. In addition, comorbidity severity and the socioeconomic characteristics of our population were not included as potential confounding factors.

## CONCLUSION

Based on the results of this study, it may be concluded that unscheduled readmissions are common at our PMVU; these are mainly for respiratory reasons and IV-related. At the same time, all patients managed at the PMVU were successfully discharged from the hospital, regardless of the complexity of their conditions. At a local level, developing a unit specialized in the respiratory care of patients with high respiratory technology dependency resulted in more available PICU beds for acute, critical patients. ■

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