



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Clinical and organizational framework of repurposing pediatric intensive care unit to adult critical care in a resource-limited setting: Lessons from the response of an urban general hospital to the COVID-19 pandemic

Franco Díaz, MD, MBA^{a,b,c}, Juan Kehr, MD^a, Camila Cores, MD^a, Patricia Rubilar, NP^a, Tania Medina, NP^a, Caroline Vargas, RN^a, Pablo Cruces, MD^{a,c,d,*}

^a Unidad de Paciente Crítico Pediátrico, Hospital El Carmen de Maipú, Santiago, Chile

^b Escuela de Medicina, Universidad Finis Terrae, Santiago, Chile

^c LARed Network, Santiago, Chile

^d Facultad de Ciencias de la Vida, Universidad Andres Bello, Santiago, Chile

ARTICLE INFO

Keywords:

COVID-19
Disaster response
PICU
ARDS

ABSTRACT

Purpose: We aim to describe the action plan and clinical results of a COVID-19 unit for adult patient care in units intended for critically ill children, proposing a clinical/administrative framework.

Methods: We reviewed the preparedness of the PICU team before the surge of cases of COVID-19 and the organizational/administrative issues to increase critical beds in a six-bed PICU allocated to adult care in a government-funded general hospital in Latin America. We analyzed the prospectively collected administrative/clinical data of severe COVID-19 cases admitted to PICU during the peak of the first wave of the pandemic.

Results: We describe a 6-step preparedness plan: recruitment and education, admission criteria, children diversion, team hierarchy, and general and respiratory equipment. The 6-bed PICU was allocated to adult care for 20 weeks, progressively increasing capacity to a 23-bed dedicated COVID-19 unit managed by the PICU team. A six-block bed organizational units were implemented, and personnel increased from 40 to 125 healthcare workers in 24 h shifts. COVID-19 incidence in personnel was 0.5/1000 workdays. One hundred thirty-six patients were admitted, median age 59 (51,65) years old, 68% were male, and 63% had P/F \leq 100. In addition, 48% received mechanical ventilation, the median length of stay was 7 (3,17), and in-hospital mortality was 15%.

Conclusions: We propose an organizational framework for the role of PICU in the hospital action plan to increase adult critical beds. The cohort of patients admitted to a PICU repurposed as a COVID-19 ICU had good outcomes. These data are valuable to plan coordinated actions of the healthcare system for future scenarios.

© 2021 Elsevier Inc. All rights reserved.

1. Background

COVID-19 outbreak spread from the far east to Europe and then the Americas. This allowed the healthcare systems in Latin America to anticipate crucial public health measures for the expected surge of cases of respiratory failure due to COVID-19. Critical bed capacity was a particular concern after the first cohorts of severe COVID-19 from Wuhan, China, and Northern Italy, which reported a high admission rate to the intensive care unit (ICU), and mechanical ventilation (MV) requirements surpassed the response capacity [1,2]. Increasing critical care beds is challenging because it carries specific infrastructure, human and technological resources, and supplies. There are protocols and recommendations that guide the reorganization of hospitals and other

physical spaces for massive care of critically ill patients to face natural disasters, attacks, or different situations of a sudden increase in demand, capable of exceeding the local and regional response capacity [3–6]. However, the clinical/administrative framework for caring for adult patients in units previously intended for critically ill children, is limited [7].

With these thoughts in mind, we aimed to describe the implementation of an ICU for adults admitted due to severe COVID-19 and analyze the clinical outcomes in a general hospital's Pediatric ICU (PICU).

2. Methods

The local institutional review board approved the analysis of a concurrent descriptive and analytical study of deidentified data prospectively collected for administrative statistics and quality benchmarking. The Comité Ético Científico of Servicio de Salud Metropolitano Central, Santiago de Chile (Acta 423/2021), approved this report, waiving the

* Corresponding author at: Camino A Rinconada 1201, Santiago, Chile.
E-mail address: pablo.cruces@unab.cl (P. Cruces).

informed consent due to the retrospective nature of the analysis and the deidentified recorded data.

Hospital El Carmen de Maipú is government-funded, serving 521,627 habitants of the districts of Maipú and Cerrillos of the Metropolitan Region of Santiago de Chile [8]. Human development index classification of these districts are upper-middle and middle, respectively. It is a 500-bed general hospital with 17,000 admissions per year, providing general medical services for adults and children. Our hospital has most of the internal medicine and women's and children's health specialties. Given its general classification, it does not have cardiothoracic, solid organ transplant, and stem cell transplant, which are centralized in dedicated hospitals in Chile's national health system. The PICU has seven beds, each in a single bed per box layout. 300–350 children are admitted per year, and 30% are mechanically ventilated. The PICU is a mixed surgical/medical unit, taking care of most pediatric critical care diseases, except for congenital heart surgery, hematology-oncology, and transplant.

We included all patients admitted between April 1st 2020, and September 31st, 2020, equal to or older than 15 years old. All patients with positive RT-PCR for SARS-CoV-2 virus or compatible chest computed tomography scan admitted due to respiratory failure were considered COVID-19 for the analysis. We excluded patients on cardiac arrest with active chest compressions on arrival to PICU or cardiovascular collapse within 1 h after admission that resulted in death.

3. Preparedness and actions

Planning for the pandemic surge of adult critical care beds is analyzed in four periods: before adult admissions to PICU, conversion of beds and expansion, de-escalation of bed capacity, and re-conversion to PICU.

4. Variables

Staff, bed capacity, and technological resources were registered daily. In addition, patient data were prospectively recorded for administrative purposes and benchmarking. Variables included demographics, comorbidities, respiratory support, gas exchange, length of stay, and outcomes. Additionally, daily cases of COVID-19 in Chile were obtained from ourworldindata.org [10].

5. Personnel safety

In daily rounds, the nurse in chief tracked healthcare workers in the unit, medical leaves, and COVID-19 cases. SARS-CoV-2 IgG/IgM rapid test was performed on all personnel at week 20 of exposure to COVID-19 adult patients. For the analysis, cases were healthcare workers with out-of-hospital epidemiological contact, suspected work exposure, or asymptomatic [11].

6. Statistical analysis

According to data distribution, continuous data are presented as median (IQR), and categorical data as proportions. Comparisons among continuous variables were performed with the Mann-Whitney *U* test and proportions with chi [2] test. Significance was set at $p < 0.05$.

7. Results

7.1. Preparedness

A local committee led by the chief nurse and the medical head of the PICU discussed the possible containment measures and response plan.

During the six weeks before adult admissions to PICU, the following activities were done (Table 1):

Table 1
Action plan for PICU bed conversion to adult critical COVID-19 unit.

Recruitment of new healthcare workers inside and outside the hospital.
Organization of backup personnel from less complex units.
Education of specific care of adult patients. i.e., mechanical ventilation in obese patients, sedation scales in adults, vasoactive support, and deep vein thrombosis prophylaxis.
Education capsules on the assembly of mechanical ventilators and other equipment for physicians and nurses, given the possibility of the lack of ventilatory therapists in the team.
Hands-on training on the use of personal protective equipment.
Self-financed acquisition of personal protection elements (protection goggles, half and full-face reusable mask with filters) for all unit personnel, anticipating a hospital stock shortage
Ask administration for a stock of general and specific supplies to take care of critically ill adults. i.e., filters for mechanical ventilators, larger diameter tracheal tubes.
Adaptation to available technological resources.
Psychological preparation
Establish leadership in groups/shifts.
Transfer of high-risk children to long-term facilities or their homes, using complex home care services.
Continuous review of the experiences and lessons of the countries where pandemic waves preceded ours, like Italy, Spain, the UK, USA.

- i. Healthcare personnel recruitment and education: education modules for all healthcare personnel of PICU, pediatric emergency room, pediatric wards, and pediatric residents of Universidad de Santiago de Chile were done, including hands-on Personal Protective Equipment (PPE) sessions, adult MV and shock, blue code drugs, among others. A particular emphasis was given to staff education of low acuity areas, which would eventually work in the PICU due to illness of healthcare workers or bed capacity expansion (General practitioners).
- ii. Admission criteria to PICU: we decided to work as a standalone unit in the hospital to become a real solution for the surge of COVID-19 critically ill cases. PICU attendings detailed the admission criteria to PICU for COVID-19 and non-COVID-19 adults. For instance, patients on oncologic treatment, end-stage renal failure, chronic heart failure, and acute stroke would not be admitted to PICU if possible. Although, age was not an absolute criterion for admission at the peak of the pandemic.
- iii. Critically ill children diversion: A particular concern of our team was the clinical scenario of children consulting in the pediatric ER and requiring ICU care. Acutely ill children requiring PICU admission would be transferred to one of the three pediatric hospitals in Chile's Metropolitan Region. But a significant delay in critical care transport services, or even a shortage of PICU beds, can be expected during the pandemic. Children requiring MV or vasoactive drugs and the expected timing to transfer longer than 3 h would be admitted to PICU, until stabilization. If no beds were available, a stable adult patient would be transferred from PICU to another critical care unit, the operation room, or the emergency room resuscitation bay.
- iv. Team hierarchy and leadership are sketched in Fig. 1. A full staff six-patient clinical block was proposed. The initial six-bed capacity could go up to 18 beds and six mechanically ventilated patients (Fig. 1A). Although, during the admissions' peak, the maximal capacity was 25 beds and 15 patients on MV (Fig. 1B). Clinical care was primary under PICU service, and the pediatric intensivist oversaw all admissions, procedures, and discharge of patients. The most frequent specialty consults were nephrology for renal replacement therapy, general surgery for abdominal complications, and cardiology for arrhythmias and acute coronary syndrome.
- v. General equipment: one of the advantages of a PICU located in a general hospital is that ancillary services like pharmacy, radiology, speech therapy and occupational therapy are used to take care of adults. Also, clinical supplies such as endotracheal tubes, circuits of mechanical ventilators, and central catheters are available.
- vi. Respiratory support equipment: the expected demand for invasive respiratory support would certainly exceed our equipment capabilities.

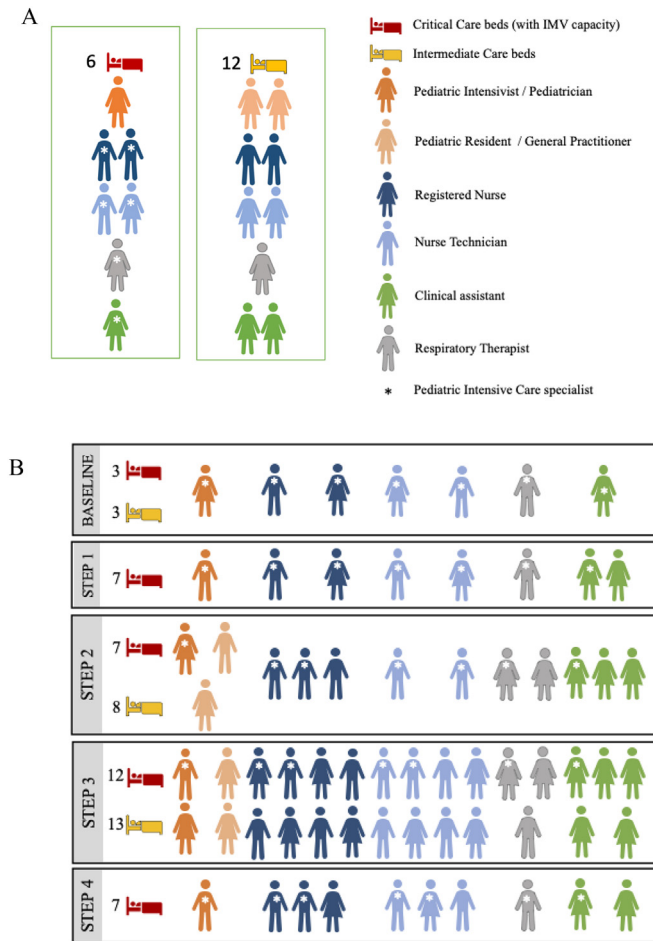


Fig. 1. Distribution of healthcare personnel by shift according to the number of critical beds. (A) The proposed arrangement of six-bed structured progressive tiers. (B) The actual number of beds and healthcare workers to balance the patient complexity, equipment, and available personnel during the study period.

We anticipated that the pandemic would cause a national and international shortage of equipment, such as MV. Therefore, we adapted eight non-invasive ventilators (Puritan Bennett™ 560, Galway, Ireland) to provide MV support to adults with low ventilatory demand (<12 L/min) and moderate to high respiratory system compliance.

7.2. Credentialing

The National Health Ministry ordered a special ordinance to give pediatricians and pediatric intensivists privileges to direct medical care for patients with COVID-19 regardless of age [12]. Our department policy was that pediatric intensivist credentials were broadened to take care of critically ill COVID-19 adults. General practitioners were also included under the same conditions but for intermediate care patients (not requiring MV). The credentials of pediatric intensive care nurses and pediatric respiratory therapists were fully extended for COVID-19 adult critical care patients. In addition, general nurses' and respiratory therapists' credentials were given after short-term education and supervision by certified nurses.

7.3. Organizational

The first COVID-19 case in Chile was identified on March 3rd, 2020, and the first patient admitted to our hospital was on March 18th, 2020. However, in the following weeks, there was a shortage of critical

care beds in adult services of the hospital, despite the progressive opening of beds planned. Initially, the PICU was thought to be ideal for allocating young adults with non-COVID-19 related diseases, like trauma, after surgeries, etc. Therefore, the first non-COVID-19 adult patient was admitted to the PICU on April 9th, 2020. Nonetheless, due to national and hospital beds shortage, the beds of the PICU were needed for critical COVID-19. Thus, the first COVID-19 adult was admitted four weeks after opening the PICU for adults (May 8th, 2020). The bed capacity of our unit was as follows:

- a) Mixed pediatric and adult critical care non-COVID-19: 17 non-COVID-19 adults were admitted to our seven-bed PICU over six weeks. At the same time, children dependent on technology were transferred to dedicated hospitals or discharged home under government or private care providers.
- b) COVID-19 unit: there was a progressive increase in bed space. First, we moved to a reconditioned anesthesia recovery unit, an open layout bed space with a capacity for ten ventilated COVID-19 patients for two weeks. Initially, it was thought to be a short-term transition (2 or 3 weeks) until new critical care units open for the total required space estimated. As the admissions nationwide spiked, it was evident that we could not go back to taking care of children, and even more, due to critical beds shortage, an expansion was urgently needed for critical COVID-19 cases. We moved to an adapted geriatric ward, with a capacity of 15 critical beds (8 MV) for two weeks, and then we increased to 23 critical beds (15 MV) for seven weeks.
- c) De-escalation of bed capacity: we moved back to our original unit 11 weeks after, handing over our COVID-19 critical care unit to an adult critical care team. Back in our unit, we worked as a 7-bed adult critical COVID-19 unit for three weeks.
- d) Re-conversion to pediatric care: After 20 weeks since our first adult admission, we re-admitted two acutely ill children with complex conditions and progressively discharged post-COVID-19 adults to intermediate care over two weeks.

7.4. Clinical results

During the study period, we admitted 155 critically ill adults. One hundred thirty-eight were COVID-19. Two patients were excluded from the analysis because they arrived after prolonged cardiopulmonary resuscitation and died shortly after admission.

Pediatric and adult consecutive admissions to our unit and daily new cases of COVID-19 in Chile during the year 2020 are shown in Fig. 2. The highest admissions per day to our unit (steep section of the red line) was concurrent with the peak of national cases (Fig. 2).

Table 2 shows demographics and clinical characteristics. Most patients were male, and comorbidities were very frequent. 85 (62.5%) patients had a PaO₂/FiO₂ ratio at admission lower than 100, 43 (31.6%) patients between 101 and 200, and 8 (5.9%) greater than 200 at admission. Sixty-five (47.8%) patients received MV. Mechanically ventilated patients had a lower PaO₂/FiO₂ ratio and lower absolute lymphocyte count at admission. In addition, they had more frequent nosocomial infections, renal replacement therapy, and longer ICU stay. ICU mortality was 13.2%, and in-hospital mortality was 15.4%. The medical team directed end-of-life care, and nurse shifts coordinated in-person visits of relatives. For instance, 18 of the 21 deceased patients were visited by their families within 48 h before death, and in half of them, the family stayed in the room until the patient died. All remaining patients were discharged home.

Pediatric ER consults decreased to a historical minimum during the study period, and most children requiring hospital admission were transferred from the pediatric ER to the referral hospital without issues. Two pediatric cases were transiently admitted to the COVID-19 ICU unit, a newborn with cardiogenic shock due to congenital heart disease and an infant with cardiogenic shock due to myocarditis. Both were transferred to the cardiac referral center within 12 h of admission.

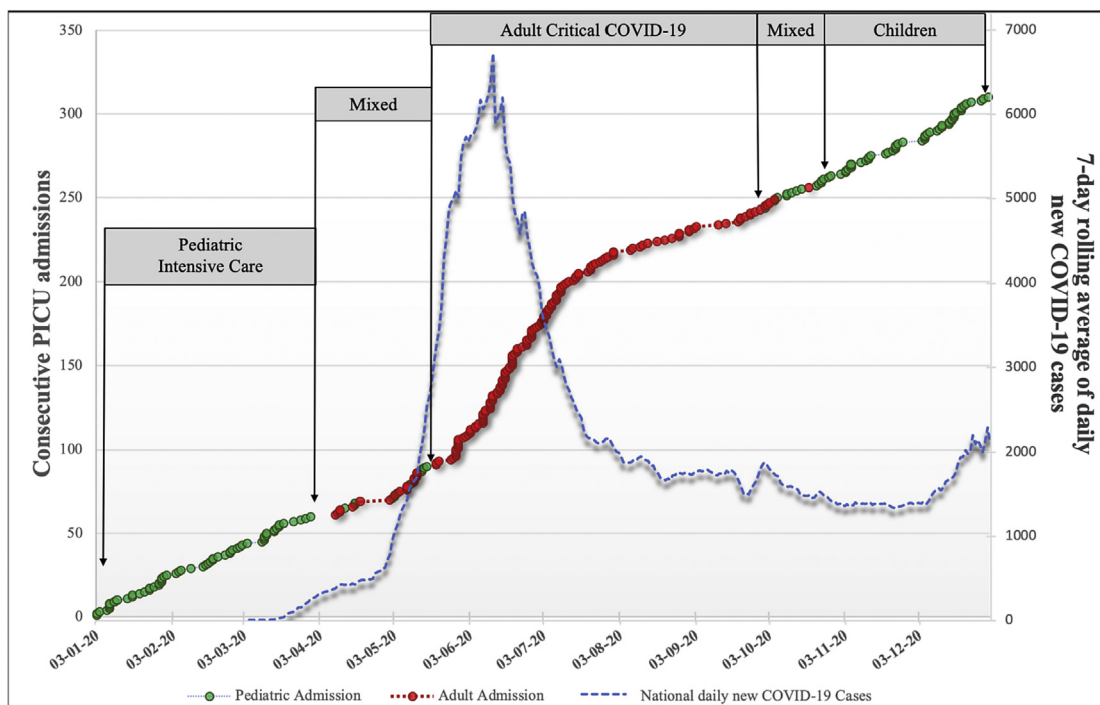


Fig. 2. Comparison between pediatric and adult admissions to Pediatric Intensive Care Unit and national daily new COVID-19 cases.

7.5. Personnel safety

During the six months, 125 employees worked on the front-line of COVID-19 patient care under PICU service: 37 nurses (10 PICU certified), 44 nurse technicians (8 PICU certified), 30 clinical-assistant staff, 13 respiratory therapists (4 PICU certified), and 26 physicians (6 PICU consultants, eight pediatricians, six pediatric residents, two anesthesia fellows, four general practitioners). Four employees were diagnosed with COVID-19 during the study period. Three healthcare workers had mild COVID-19 after contact with a confirmed case outside the hospital. Only the suspected nosocomial infection case had a severe (non-critical) course, requiring hospital admission and oxygen support.

Rapid tests for all healthcare workers confirmed the previous known COVID-19 cases and diagnosed two additional asymptomatic cases. Overall, we estimated an incidence of COVID-19 of 3.1 cases per 1000 workdays (6 cases over 1988 workdays), but only 1 case related to exposure at work (0.5 per 1000 workdays).

8. Discussion

The role of PICU in bed capacity expansion to manage critically ill adults during the COVID-19 pandemic was essential in our center during the first wave. When the national health network was on the verge of collapse, we converted our PICU, increasing the bed capacity,

Table 2

Demographic and clinical characteristics of adults severe COVID-19 admitted to the pediatric intensive care unit. MV: mechanical ventilation; ALC: acute lymphocyte count; MV FD: mechanical ventilation free days; RRT: renal replacement therapy; PE: pulmonary embolism; ICU LOS: Intensive care unit length of stay.

	All n = 136	no-MV n = 71	MV n = 65	p-value	Alive n = 115	Dead n = 21	p-value
Age	59(51,65)	58(51,65)	60(51,66)	<0.01	57(50,63)	66(61,73)	<0.01
M:F ratio	2.1:1	2.2:1	2.1:1	0.86	2.1:1	2.5:1	0.74
Comorbidities	114 (83)	58 (82)	56 (86)	0.49	95 (83)	19 (90)	0.36
Number				0.75			0.17
0	35 (26)	21 (30)	14 (22)		33 (29)	2 (10)	
1	42 (31)	21 (30)	21 (32)		35 (30)	7 (33)	
2	48 (35)	24 (34)	24 (37)		37 (32)	11 (52)	
3	11 (8)	5 (7)	6 (9)		10 (9)	1 (5)	
Obesity	40 (29)	20 (28)	20 (31)	0.74	35 (30)	5 (24)	0.54
Diabetes	62 (46)	31 (44)	31 (48)	0.64	53 (46)	9 (43)	0.79
Hypertension	69 (51)	33 (46)	36 (55)	0.29	51 (44)	18 (86)	<0.01
PaO ₂ /FiO ₂ ratio	86 (70,118)	94 (78,131)	77 (63,108)	0.02	91 (71,119)	77 (61,98)	0.05
ALC	813 (518,1114)	830 (652,1134)	666 (445,1043)	0.02	824 (565,1122)	529 (367,899)	0.02
MV	65 (48)	N/A	N/A		44 (38)	21 (100)	<0.01
MV FD	8 (0,21)	N/A	8 (0,21)		N/A	N/A	
MV days	9.5 (5,19)	N/A	9.5 (5,19)		9 (5,17)	14 (2,22)	0.92
Nosocomial infections	50 (37)	4 (6)	46 (71)	<0.01	36 (31)	14 (67)	<0.01
RRT	12 (9)	0 (0)	12 (18)	<0.01	7 (6)	5 (24)	0.03
Tracheostomy	15 (11)	0 (0)	15 (23)	<0.01	10 (9)	5 (24)	0.04
PE	15 (11)	5 (7)	10 (16)	0.11	10 (9)	5 (24)	0.04
ICU LOS	7 (3,17)	3 (2,6)	15 (9,25)	<0.01	6 (3,13)	16 (6,24)	0.02
Mortality	21 (15)	0 (0)	21 (32)		N/A	N/A	

into a dedicated COVID-19 unit for adults with severe respiratory failure. The characteristics of patients admitted were similar to international cohorts of the first wave of COVID-19 in age and comorbidities [13,14]. Thus, despite the important limitations of facilities, technology, and training, it was possible to appropriately support complex patients with good outcomes regarding mortality, nosocomial infections, and complications.

The COVID-19 pandemic has demonstrated the inadequate preparedness in the world to face it, the asymmetric geopolitical integration, and the lack of coordination between nations in the economic, social, and health fields. Moreover, it has revealed the particularities of a pandemic compared to other disasters and the shortcomings of traditional crisis preparedness, response, and management models, like the All-Hazards Approach [15,16]. The PICU is the best-equipped location for advanced respiratory support for adults outside ICU. PICU healthcare workers are skillful and competent for adult acute care. Although, as pointed out by Remy et al. [17], the frequency of specific illnesses and complications are different in elderly patients. Some practical problems in the transition include drugs and doses not commonly used in pediatrics, multi-resistant pathogens, psychomotor agitation, and mobilization and positioning (pronation) of morbidly obese patients [18].

The long warning phase of the pandemic allowed us to have education and training, followed by a period of management and care of non-COVID young adults. COVID-19 pandemic is different from other disaster planning situations in terms of duration and severity. There is a superposition of the impact phase and the response phase. As the surge of cases overwhelms the ER and urgent ambulatory care, the hospital beds and critical care services occupation built up, stressing the response for many weeks.

There are several forms of integration of the PICU to the hospital response, especially in a general hospital [19–24]. Fig. 3 depicts the relationships between ICU and PICU for a surge of critical care beds needs. In the type A response, technological and human resources from PICU can be transferred to the adult ICU to overcome the extraordinary demand for critical care beds. Type B response includes that some of the beds in the PICU are assigned to the care of critically ill adults. It is essential to highlight that in this situation, the trained personal and equipment assigned to the critical care bed stays within the unit, usually under PICU management (service of origin). In type C and D responses, all beds of the PICU are reassigned to adult critical care. The main difference between both is the organizational structure. In type C, physical space, equipment, and human resources of the PICU are placed under the adult care division authority. In type D, PICU leadership and administrative structure are independent of the adult critical care division. According to the critical care bed needs, our unit initially responded as a type A, then type B, and finally, to type D. We chose a type D response because clinical/administrative independence between ICU and PICU can provide real help and relief from the excessive demand for many months. Our experience also shows how PICU may play a dynamic role in increasing or decreasing bed space transiently, while more definitive measures are implemented, like opening mid/long term critical beds.

Most of the PICUs of the general hospitals took some of these actions during the first year of the pandemic [19–24]. Other centers chose to open COVID-19 adult beds in PICUs for non-acute care, like long-term MV, weaning from MV, management of non-COVID-related complications, or low complexity step-down unit. These measures strengthen the hospital's response to the high demand for critical beds but have a detrimental and potentially risky impact on providing adequate care to critically ill children [25,26]. Fortunately, during the first wave of the pandemic, pediatric consultations to the ER and admissions to PICU decreased worldwide [27]. Also, the incidence in children of severe COVID-19 and associated diseases like MIS-C and myocarditis was low.

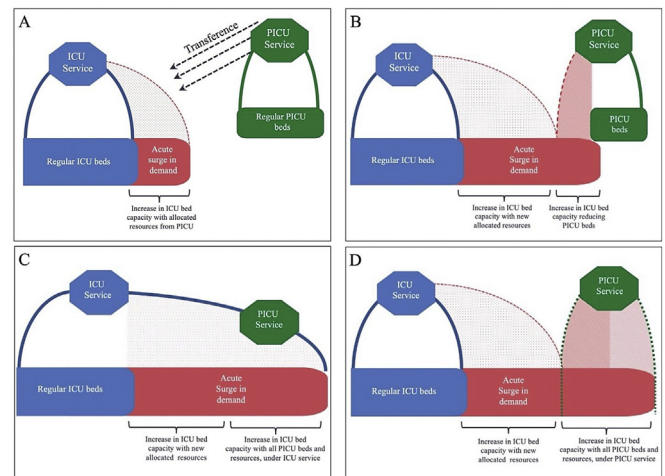


Fig. 3. Organizational Framework for Pediatric Intensive Care Unit response to an acute surge in critical beds in a general hospital. Experience of COVID-19 pandemic.

- Independent clinical/administrative PICU provides space for critical pediatric patients, but equipment, supplies, and human resources are transferred to ICU to meet demand.
- Limited opening of critical PICU beds to adult patients, reduced pediatric quotas are maintained. Independent clinical/administrative PICU. Acute increase of ICU required.
- Full incorporation of PICU to ICU. Medical staff and health professionals to ICU administrative/clinical structure. There are no critical pediatric beds, and seriously ill children must be referred to other centers.
- PICU beds are converted in their entirety to adult but maintain clinical/administrative independence. Therefore, there are no critical pediatric beds, and seriously ill children must be referred to other centers.

We report a particularly severe cohort of COVID-19 respiratory failure. More than half of patients had a $\text{PaO}_2/\text{FiO}_2$ ratio less than 100 mmHg, almost 50% were obese, and 10% received renal replacement therapy, known risk factors for COVID-19 mortality [28]. Remarkably, about half of the patients were managed without MV, although we carefully assessed the risks of delayed intubation [29]. Overall clinical outcomes were good, and PICU and in-hospital mortality were lower than most of the first wave cohorts published [13,14,28,30–32].

healthcare workers infection rate was low, despite the high exposure in the front line of SARS-CoV-2 patients. Many respiratory support modalities cataloged as a high risk of contagion, like high flow nasal cannula and non-invasive ventilation, were used to prevent intubation. The hospital administration was a pioneer in developing protocols for protection from COVID-19 infection before the virus's arrival to our country, and we were fortunate that our hospital did not have a PPE shortage. Another factor in the low infection rate among pediatric healthcare workers is the usual seasonal epidemic of viral respiratory infections. Every winter, we face a sudden increase in up to 400% of children with acute respiratory failure due to respiratory viruses [33]. Our greatest strengths are the interventions aimed at preventing respiratory failure progression, balancing the risks of overtreatment and futile treatments, and delaying lifesaving therapies, like MV. Thus, managing the limited available resources locally and in a stressed healthcare network is part of our everyday clinical duties.

Our study has some limitations. This is a single-center cohort in an urban area deeply hit by the pandemic. During the first wave, institutional protocols for therapies frequently changed regarding hydroxychloroquine, ivermectin, biological drugs, immune convalescent plasma, and steroids, but its use was very heterogeneous within the hospital. None of those experimental drugs were used in our unit, although some patients might have received some futile therapies before admission. One exception is steroids. We standardized dexamethasone use for all admissions one month after the RECOVERY trial was

published (for the last five weeks of the study). ECMO and other extracorporeal therapies are not available in our center because we have a National Advisory Commission for Adult ECMO that centralizes in a few centers the therapy, and only selected patients with potential good outcomes are accepted [34].

9. Conclusion

In summary, we analyzed a large cohort of severe COVID-19 adults admitted to a PICU repurposed as a COVID-19 ICU. Our unit role was fundamental in the coordinated response of our hospital, allowing the respiratory support and treatment of severely hypoxemic patients with good outcomes. Based on our experience, we present a framework for PICU response to the sudden increase in the requirement for critical beds in a general hospital. This organizational framework intends to complement other proposed guidelines and recommendations, like the 4S (Staff, Stuff, Structure, and Systems) and the All-Hazards Approach but considering the particularities of a Pandemic [35].

Funding

none.

Availability of data and material

The datasets generated during and analyzed during the current study are available from the corresponding author on reasonable request.

Code availability

Not applicable.

Authors' contributions

FD and PC conceptualized, planned the study, and supervised all stages.

CC, TM, and CV participated in data curation.

FD and PR participated in the analysis.

FD, PC, and PR participated in writing the manuscript draft.

PC, JK, CC, TM, and CV reviewed and edited the manuscript.

All authors read and approved the final version of the manuscript.

Ethics approval

Local IRB approved the analysis of deidentified data prospectively collected for administrative issues. This report was approved by Comité Ético Científico of Servicio de Salud Metropolitano Central, Santiago de Chile (Acta 423/2021).

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Declaration of competing interest

Authors declare no conflicts of interest.

Acknowledgments

We are deeply grateful to healthcare workers and pediatric teams worldwide, especially the Unidad de Paciente Crítico Pediátrico at

Hospital el Carmen de Maipú, Chile, for their courage, professionalism, and dedication to patient care during the COVID-19 pandemic.

References

- [1] Tonetti T, Grasselli G, Zanella A, et al. Use of critical care resources during the first 2 weeks (February 24th–March 8th, 2020) of the Covid-19 outbreak in Italy. *Ann Intensive Care*. 2020;10:133.
- [2] Grasselli G, Pesenti A, Cecconi M. Critical care utilization for the COVID-19 outbreak in Lombardy, Italy. *JAMA*. 2020;323:154–6.
- [3] Kisson N. Task force for pediatric emergency mass critical care: deliberations and recommendations of the pediatric emergency mass critical care task force: executive summary. *Pediatr Crit Care Med*. 2011;12:S103–8.
- [4] Frogel M, Flamm A, Sagy M, et al. Utilizing a pediatric disaster coalition model to increase pediatric critical care surge capacity in New York City. *Disaster Med Public Health Prep*. 2017;11:473–8.
- [5] Christian MD, Toltzis P, Kanter RK, Burkle FM, Vernon DD, Kisson N. Treatment and triage recommendations for pediatric emergency mass critical care. *Pediatr Crit Care Med*. 2011;12:S109–19.
- [6] Hick JL, Einav S, Hanfling D, et al. Surge capacity principles care of the critically ill and injured during pandemics and disasters: CHEST consensus statement. *CHEST*. 2014;146:e15–16S.
- [7] Christian MD, Kisson N. Caring for critically ill adults in PICUs is not “Child’s play”. *Pediatr Crit Care Med*. 2020;21:679–81.
- [8] Resultados Censo Chile. <http://resultados.censo2017.cl/Region?R=R13>; 2017. Accessed March 31st 2021.
- [10] New daily COVID-19 cases in Chile. <https://ourworldindata.org/coronavirus/country/chile>; 2021. Accessed March 31st.
- [11] Shah ASV, et al. Risk of hospital admission with coronavirus disease 2019 in healthcare workers and their households: nationwide linkage cohort study. *BMJ*. 2020;371:m3582.
- [12] Mandate of National Comptroller office regards the State of Emergency due to COVID-19 pandemic. <https://www.contraloria.cl/pdfbuscador/dictamenes/003610N20/html>; March 17th, 2020. accessed November 10th, 2021.
- [13] Grasselli G, Zangrillo A, Zanella A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy region, Italy. *JAMA*. 2020;323:1574–81.
- [14] Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. 2020;395:1054–62.
- [15] Peleg K, Bodas M, Hertelendy AJ, Kirsch TD. The COVID-19 pandemic challenge to the all-hazards approach for disaster planning. *Int J Disast Risk Re*. 2021;55:102103.
- [16] Faccincani R, Pascucci F, Lennquist S. How to surge to face the SARS-CoV-2 outbreak: lessons learned from Lombardy, Italy. *Dis Med Public*. 2020;14:e39–41.
- [17] Remy KE, Verhoef PA, Malone JR, et al. Caring for critically ill adults with coronavirus disease 2019 in a PICU: recommendations by dual trained intensivists. *Pediatr Crit Care Med*. 2020;21:607–19.
- [18] Williams L. Adults in the pediatric intensive care unit: a pediatric Nurse’s perspective. *AACN Adv Critical Care*. 2017;28:107–10.
- [19] Sinha R, Aramburo A, Deep A, et al. Caring for critically ill adults in paediatric intensive care units in England during the COVID-19 pandemic: planning, implementation and lessons for the future. *Arch Dis Child*. 2021;106:548–57.
- [20] Vázquez Martínez JL, Alonso García R. Adaptación de una UCI pediátrica a Unidad de Adultos Críticos durante la pandemia COVID-19. *An Pediatr (Engl Ed)*. 2020;93:216–7.
- [21] Gist RE, Pinto R, Kisson N, et al. Repurposing a PICU for adult Care in a State Mandated COVID-19 only hospital: outcome comparison to the MICU cohort to determine safety and effectiveness. *Front Pediatr*. 2021;9:665350.
- [22] Wasserman E, Toal M, Nellis ME, et al. Rapid transition of a PICU space and staff to adult coronavirus disease 2019 ICU care. *Pediatr Crit Care Med*. 2021;22(1):50–5.
- [23] Niño-Taravilla C, Bravo-Valladares CA, Morales C, et al. Clinical characteristics and outcomes of adults with COVID-19 admitted to a Pediatric Intensive Care Unit. *Andes Pediatr*. 2022;93(2). <https://doi.org/10.32641/andespediatr.v93i2.3974> epub ahead of print.
- [24] Kneyber MCJ, Engels B, van der Voort PHJ. Paediatric and adult critical care medicine: joining forces against Covid-19. *Crit Care*. 2020;24:350.
- [25] Kanthimathinathan HK, Pollak U, Shekerdemian L. Paediatric intensive care challenges caused by indirect effects of the COVID-19 pandemic. *Intensive Care Med*. 2021;47:698–700.
- [26] Camporesi A, Díaz-Rubio F, Carroll CL, González-Dambrauskas S. Protecting children from iatrogenic harm during COVID19 pandemic. *J Paediatr Child H*. 2020;56:1010–2.
- [27] Vázquez-Hoyos P, Díaz-Rubio F, Monteverde-Fernandez N, LARed Network, et al. Reduced PICU respiratory admissions during COVID-19. *Arch Dis Child*. 2021;106:808–11.
- [28] Auld SC, Caridi-Scheible M, Blum JM, et al. ICU and ventilator mortality among critically ill adults with coronavirus disease 2019. *Crit Care Med*. 2020;48:e799–804.
- [29] Cruces P, Retamal J, Hurtado DE, et al. A physiological approach to understand the role of respiratory effort in the progression of lung injury in SARS-CoV-2 infection. *Crit Care*. 2020;24:494.
- [30] Armstrong RA, Kane AD, Kursumovic E, Oglesby FC, Cook TM. Mortality in patients admitted to intensive care with COVID-19: an updated systematic review and meta-analysis of observational studies. *Anaesthesia*. 2021;76:537–48.

- [31] Tan E, Song J, Deane AM, Plummer MP. Global impact of coronavirus disease 2019 infection requiring admission to the ICU a systematic review and Meta-analysis. *Chest*. 2021;159:524–36.
- [32] Richardson S, Hirsch JS, Narasimhan M, et al. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. *JAMA*. 2020;323:2052.
- [33] Serra JA, González-Dambrauskas S, Hoyos PV, et al. Therapeutic variability in infants admitted to Latin-American pediatric intensive units due to acute bronchiolitis. *Rev Chil Pediatr*. 2020;91:216–25.
- [34] Diaz RA, Graf J, Zambrano JM, et al. Extracorporeal membrane oxygenation for COVID-19-associated severe acute respiratory distress syndrome in Chile: a Nationwide incidence and cohort study. *Am J Resp Crit Care*. 2021;204:34–43.
- [35] Siow WT, Liew MF, Shrestha BR, Muchtar F, See KC. Managing COVID-19 in resource-limited settings: critical care considerations. *Crit Care*. 2020;24:167.