



Contents lists available at ScienceDirect

# Critical Care and Resuscitation

journal homepage: [www.elsevier.com/locate/ccrj](http://www.elsevier.com/locate/ccrj)

## Original Article

# Services for critical and emergency care of children in Victoria

Trevor Duke, MD, FRACP, FCICM <sup>a, b</sup><sup>a</sup> Department of Paediatrics, University of Melbourne, Australia; <sup>b</sup> Intensive Care Unit, Royal Children's Hospital, Melbourne, Australia

### ARTICLE INFORMATION

#### Article history:

Received 28 September 2023

Accepted 10 November 2023

#### Keywords:

Victoria  
Paediatrics  
Child health  
Health systems  
Critical care

### ABSTRACT

The population of children requiring intensive care in Victoria has increased and changed markedly since the 1990s, the result of many epidemiological, demographic, and social changes, and this is more evident during and after the Covid pandemic. The model of ultra-centralised paediatric intensive care services in the 1990s is not sufficient for the current era, and services are under daily pressure. Solutions will take time and need to be wide-ranging, including increased critical care capacity in selected regional centres, decentralisation of some services for low-risk conditions, improvements and reforms in medical and nursing education, pre-service and post-graduate, including for other acute care disciplines and for general practitioners and a more structured state-wide paediatric system.

The effects of changes in disease patterns, social trends and health practice should inform the design of an expanded model of critical and emergency care for children in Victoria that is more fit for purpose in the remainder of this decade and beyond.

© 2023 The Authors. Published by Elsevier B.V. on behalf of College of Intensive Care Medicine of Australia and New Zealand. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Services for critical and emergency care of children in Victoria

### 1.1. Introduction

Critical care services for children in Victoria are under frequent stress, with often limited bed availability, cancellation of elective surgery, delayed transfer of children who need a paediatric intensive care bed from other wards or hospitals, and tragically several preventable deaths. What factors have led to this?

### 1.2. Epidemiological changes

In the 1980s and 1990s, there was a strong push for centralisation of paediatric critical care services in Victoria.<sup>1</sup> In those days there was one paediatric intensive care unit (PICU) in the state, at the Royal Children's Hospital (RCH) in Melbourne, and an efficient emergency retrieval service. The common indications for PICU admission were respiratory infections, trauma, and sepsis in otherwise well children. The population of Victoria at the time was 4 million, and there were 12 PICU beds. Much has changed in the last 20 years, and the demand for critical care services is much greater, and there are new latent stresses in the system. The expansion of critical care demand is the result of many epidemiological, demographic, and treatment trends. The good news is that many more children are surviving serious

illnesses, acute and chronic.<sup>2</sup> There are far more pre-term babies surviving at lower gestations.<sup>3</sup> More children with complex congenital heart disease are surviving with modern approaches to surgery, including heart transplantation and mechanical circulatory support. More children with congenital neuromuscular and developmental problems are having spinal surgery to alleviate pain, sit in a wheelchair comfortably and improve respiratory function;<sup>4</sup> many of these children are also having gastrostomy feeding to avoid aspiration and maintain good nutrition. Some are receiving non-invasive respiratory support - such as CPAP or BiPAP - at home, so their lungs can stay healthier.<sup>5</sup> Their life expectancy is increased and so is their quality of life; they participate in school and in the community in fuller lives, because of medical care, their committed families, and the support they receive from the National Disability Insurance Scheme, schools and other community organisations. New treatments are available for childhood cancers, and there are more survivors. More children with complex cancer, and non-malignant conditions (congenital and metabolic diseases), are receiving haemopoietic stem cell transplants. Now recombinant enzyme replacement therapy and gene therapies are available for children with congenital neurological and metabolic conditions, such as spinal muscular atrophy (SMA) and some storage disorders.

Furthermore, community and parental expectations have changed, as parents develop a voice and become advocates for their child with a chronic condition; and there is a much greater recognition of the rights of children with chronic illness or disability to have the same opportunities for optimal health care as all children should.

E-mail address: [trevor.duke@rch.org.au](mailto:trevor.duke@rch.org.au).

Between 1995 and 2023, under-5 mortality fell by more than 50 % in Australia, and PICU mortality dropped to as little as 2 %, indicating true overall progress. But these epidemiological changes have also changed the epidemiology of childhood critical illness in Victoria and many more children require ICU support at some stage in their lives. Furthermore, the population of Victoria has grown over that time, from 4 to 6.5 million, including large growth areas in the outer metropolitan north, the west, and southeast.<sup>6</sup> For various reasons, the needs for intensive care are disproportionately greater for children in the expansion population regions.

Across the state, the pandemic has meant more families are less connected with primary health care, with children presenting late with serious illness. It is uncommon for a child to have a general practitioner (GP) who knows the family well these days, and since the pandemic, children are often refused GP appointments because they have a respiratory infection, the commonest reason a child will need to see a GP. It is a global phenomenon, but many local factors may have contributed the sharp increase in children needing intensive care for severe invasive Group A streptococcal sepsis and pneumococcal pneumonia in 2022 and 2023,<sup>7</sup> including barriers to primary care, the trend away from giving antibiotics for sore throat or otitis media, the rebound of respiratory viruses after Covid and the lockdowns, and limited capacity of health staff to identify the deteriorating patient in a crowded emergency department waiting room leading to delays in treatment.

During the pandemic, there has been a rise in serious mental health disorders in adolescents, and increases in family stress and violence, which impact on paediatric emergency services and paediatric intensive care.<sup>8,9</sup> More families are living on the margins economically and socially, and this impacts on care seeking and parenting when health access is challenging.

There are other demographic shifts in the Victorian population – the regional drift driven by working from home and house prices in the inner areas, and the general population expansion, means more families living in regional Victoria and the metropolitan margins. Capacity for recognising and managing serious or deteriorating patients is less and therefore more sick children are transported to RCH or Monash Children's Hospital away from their immediate communities.

The ultra-centralised model of the 1990s was underpinned by studies which showed that where a critical mass of intensive care was provided, outcomes relative to severity of illness were better, based on Standardised Mortality Rates (SMR). This was well demonstrated in a study comparing Victoria with Trent in the UK, which had the same population as Victoria at the time, but 10 district hospitals in which children with severe illness were admitted in PICUs, adult ICUs, and other wards; in Trent the SMR was significantly higher than in Victoria, suggesting excess mortality. The better results in Victoria were attributed by the authors to the centralisation of expertise in Melbourne.<sup>1</sup> This paper was influential in the design of PICU services in Australia and in many countries and has improved the quality of care for those who can access such services. However, it is a different world in 2023 than it was in 1997, for all the reasons I have explained above.

There has been an expansion of critical care beds for children in the last 20 years: PICU in Melbourne RCH was 16 beds and is now 24, whilst Monash Children's Hospital PICU was 4 beds and is now 10. This represents an increase in total PICU beds per population from 1 bed per 34,000 to 1 bed per 28,000 children under the age of 15 years (Table 1). Despite this, the system is under stress daily.<sup>10,11</sup>

There have been indirect consequences of the ultra-centralised model of the 1990s and 2000s: deskilling in paediatric critical care among nurses and doctors who work regionally, and an under-resourcing of services to care for critically ill children, outside the

**Table 1**  
Change in Victorian PICU bed capacity 2000 to 2021.

Population in Victoria in 2000: 4,765,900 with 728,235 children (15 %) under 15 years of age.
PICU beds 20 (16 RCH, 4 Monash). 1:36,000 under 15 years of age.
Population in Victoria in 2021: 6,610,000 with 1,010,000 (15 %) children under 15 years of age.
PICU beds 36 (24 RCH, 10 Monash, 2 Geelong). 1:28,000 children under 15 years of age.

two major centres in Melbourne and the retrieval service which transfers them there. A common situation now involves a sick child, in an urgent care centre in a remote area, who needs to move to a higher level of care, but the regional centre is overwhelmed, lacking sufficient or skilled staff, and cannot not safely accept the patient, so they are transported to Melbourne, at extra expense and a long way from home for a disease that should be possible to be managed more regionally.

In the last 30 years, there have only been two PICU beds funded outside the two tertiary centres (Barwon Health in Geelong). There is often a strong desire by parents to be cared for at the two tertiary centres in Melbourne, and the lack of resourcing and skilling of regional centres just reinforces and justifies this desire. On the other hand, for children with moderate illness that can be managed locally, most parents want to be managed close to home.

The Medical Emergency Team (MET) system that was introduced in many hospitals in the early 2000s has meant fewer children deteriorating to the point of arrest on the wards.<sup>12</sup> This has been an important advance in patient safety. However, vital sign abnormalities are also the triggers for transfer to intensive care, or referral to a tertiary centre. The sensitivity of these vital signs in the red zone for clinical deterioration is high (most children who deteriorate will have one or more preceding abnormal vital signs). However, the specificity for serious clinical deterioration is low (most children with a vital sign abnormality do not have a serious deterioration, they may just have something that can be managed, or part of their illness). This trigger to admit or barrier to discharge results in many children in PICU with vital sign aberrations as their only indication; not a threat to airway, breathing or circulation, adding to the number of children who need PICU services.

### 1.3. Potential solutions

Given the numerous factors, there is no *one* solution to these problems. However, there are practical changes that will take time: including increased critical care capacity, changes and improvements in education, and a more structured system (state-wide paediatric referral guidelines, uniform guidelines on what cases can be managed in regional hospitals, back-transfer, universal use of the ViCTOR charts, and education and upskilling). The solutions involve some degree of decentralisation: not a downgrading of the tertiary services, but a better resourcing of paediatric services in key metropolitan hospitals and large regional areas to include greater capacity for intensive and high-dependency care. This will require paediatric intensivists employed in key regional areas, training for paediatric nurses from regional hospitals in critical care, peripheral hospitals managing more of their own patients, a chronic respiratory unit at RCH and Monash, new PICU beds, and an overall state-wide systems approach.

### 1.4. Improving the capacity of key regional hospitals

Develop **PICU beds in regional ICUs and criteria and guidelines for care in a regional paediatric centre**. There are five

conditions where most children affected could be managed in regional centres if they were properly resourced with high-dependency care: a paediatric intensivist, PICU-trained nurses, and a resourced space. Bronchiolitis requiring high-flow or CPAP, diabetic ketoacidosis, croup, children with neurodevelopmental on-home respiratory support, and seizures or epilepsy. Within these diagnostic groups, there will be a small number of higher-risk or critical children who still need tertiary care, so health care must remain individualised rather than mandated. But if capacity existed in busy regional and metropolitan centres, fewer children would need referral and retrieval.

Key hospitals which have shown interest in having PICU beds include The Northern Hospital, University Hospital Geelong, Bendigo Hospital, Mildura Base Hospital, and Albury Base Hospital. PICU or Paediatric HDU beds could be created and staffed in these hospitals, as has occurred in Geelong.

There are new opportunities to achieve this that did not exist in the 1990s, as it is essential that the care of children is supervised by trained paediatric doctors. Many new paediatric intensivists are graduating through the College of Intensive Care Medicine. **Creation of paediatric intensivist positions in some large regional hospitals, and main metropolitan centres** would greatly improve the overall management of children with serious illnesses. Paediatric intensivists have training in assessment of illness severity, management of the deteriorating patient, supportive and post-operative care, and emergency procedures. In regional areas, they would increase the quality of acute emergency care, pre-retrieval care for critically ill children, and reduce the number of children who needed transport, and they would improve paediatric critical care skills and training for nursing and other medical staff. They would work closely with the local paediatric, anaesthetic and emergency teams.

A program is needed to upskill paediatric nurses from these hospitals in critical care, expand paediatric wards to contain HDU beds, and employ one or two paediatric intensivists in each centre to manage patients, put systems in place, train nurses, link with tertiary units and retrieval services.

RCH and Monash could run **courses for upskilling paediatric nurses in regional and metropolitan areas**. The Paediatric Emergency Transport Service (PIPER in Victoria) has a vital role to play in outreach paediatric acute care teaching, this needs a dedicated and resourced team, with an outward education focus. And technologies relied upon during the pandemic, including telehealth and non-invasive monitoring, have created opportunities for support to regional teams and patients to be managed closer to home.

### 1.5. A state-wide systematic approach

**Back-transfer.** There should be an agreement like that which exists in New South Wales, when a child from a regional area is well enough to leave PICU in Sydney and go to the ward, and there is no other reason for them to stay in the tertiary centre (such as review or ongoing treatment by a sub-specialist or surgeon), then they are transported back to the regional or metropolitan hospital they came from. Two-way transport would free up hospital ward beds and allow better flow out of ICU. This happens occasionally now but should be systematised.

Develop **state-wide paediatric referral criteria for high-risk diagnoses**. These currently do not exist, so a child with a diagnosis at high risk of deterioration can be declined referral from a metropolitan hospital because they have not breached MET criteria, or for lack of beds. There are some conditions in each speciality that can only be managed safely at a tertiary referral centre and seen by sub-specialists, with a tertiary PICU backup because of their high risk of deterioration. We do not, for example, question whether a

child with newly diagnosed acute leukaemia will be transferred to RCH or Monash. However, because there are no formal state-wide referral criteria a child with haemolytic uraemic syndrome can be declined transfer to a tertiary hospital and wait in a peripheral hospital until their physiology worsens to the point of needing urgent transfer. Each speciality will have a small number of conditions that should, regardless of the apparent clinical severity at the time, be managed where there are sub-specialist and critical care expertise. Not necessarily transfer to PICU, but to a children's hospital, day, or night. This is like the paediatric PIPER Go Now criteria, which dictate when urgent retrieval is needed, based on clinical severity. But it is different; with referral criteria, it is just stating that a child with this diagnosis, which is known high risk, must come to a tertiary centre, because it will be inappropriate to manage the complications in a metropolitan or regional paediatric ward.

### 1.6. Care for children with chronic respiratory care technology needs

To free up acute PICU beds, some children with chronic respiratory care needs may be better managed as they improve in a dedicated ward at RCH or Monash, or in their home regional hospital. This requires organisation at the tertiary hospitals and some decentralisation so children can have acute support for intercurrent infections closer to where they live.

RCH could develop a **long-term respiratory care unit with 2–6 dedicated HDU beds**, so children with complex needs who are on home CPAP or BiPAP can have the time they need to improve from intercurrent respiratory virus infections, rather than bed pressure force them out of PICU at a time that does not take account of the rate of natural recovery, which is often prolonged in such patients. This could be an agile system where resources can be shared: this might lead to extra available resources in the summer months when only two beds might be occupied and six in winter when the demand is higher.

Further, there should be a **state-wide paediatric home respiratory support service** that would work with hospitals and health services to build capacity in the home management of these children, their technological needs, and support them to be managed in hospitals closer to their community when they are unwell. An emerging respiratory physician, who would do at least 1-year training in PICU, can be a lead physician running this unit, with support from the respiratory unit and from PICU.

### 1.7. The role of education and training in critical care paediatrics

**Improve education and exposure of other disciplines in paediatrics.** This centralisation of services is most evident in PICU but is a pattern across all the levels of the system caring for children. Looking after unwell children has become scary for cadres not working exclusively in paediatrics. Developing a model that can provide high-dependency care in regional centres will start with paediatricians, paediatric emergency physicians, paediatric intensivists, and paediatric nurses with training in critical care. But it needs broader support: from anaesthetists and anaesthetic registrars that can back up emergency department and ward teams if required; adult emergency physicians comfortable in dealing with sick children, adult ICU teams that are willing to support those children that present when the single paediatric intensivist or where the nurse trained in PICU is not on; junior staff on overnight shifts who have had more training and exposure to paediatrics; leadership by the executive that enables their clinical staff to feel secure and indemnified (morally and legally) in the face of greater exposure in looking after sicker children. The drive to transfer

children is sometimes also just a feeling of discomfort with the level of real or perceived risk, the sense that the child would be safer elsewhere. This has been particularly strong during the pandemic. When everyone is operating under environments that feel under-resourced and unsafe, the simplest solution is often to send the child up the level of care. We need more exposure to general paediatric care across the board. Medical students need to be seeing children not just during their paediatric rotation, but throughout clinical rotations. Interns and junior residents should have more opportunities to do paediatric rotations, either at RCH, Monash, or other paediatric centres. Nursing students need to graduate with credentialing to do basic paediatric care (it is not an uncommon scenario in ED for nursing staff to not do observations or give salbutamol because they are not 'paediatric certified'). Speciality colleges, Anaesthetics and Emergency could require more paediatric experience. The development of regional PICU beds and paediatric HDUs will provide a good opportunity for paediatric trainees to get acute care experience and reduce the bottleneck that currently exists in getting time in PICU.

**Reforms in General Practice and GP education** that will improve primary care for children. Consideration should be given to development of a **Diploma in Child Health**, for Victorian General Practitioners and GP trainees, who would be recognised as having skills and expertise in the care of children.<sup>13</sup> Remuneration for seeing children by GPs needs to be addressed, as this often requires higher time resources than care of adults. Links between RCH and GP that existed many years ago should be strengthened.

## 2. Conclusions

The stresses on the current system are the sum of advances large and small, epidemiological, demographic, and social changes, and ultra-centralisation as the Victorian population has grown. There are solutions, not all of which are mentioned here, because many will be better thought out by clinicians and leaders in regional and metropolitan health services and wards and emergency departments who have their own experiences and can design solutions for their own problems.

The effects of these changes in disease patterns, social trends and health practice need to be better understood, and they should inform the design of an expanded model of care for children that is more fit for purpose in the remainder of this decade and beyond.

## Conflict of interest

I am employed at the Royal Children's Hospital, and work in the Paediatric Intensive Care Unit. I am a member of the Child and

Adolescent sub-committee of the Consultative Council of Obstetric and Paediatric Morbidity and Mortality. The opinions expressed in this article are mine, and not necessarily those of the institutions with whom I work. I have no other conflicts of interest.

## CRediT authorship contribution statement

Trevor Duke is the sole author of this article. I gratefully acknowledge the ideas and input from paediatric colleagues, especially: Rami Subhi, David Tran, Sophie Treleven, David Fuller.

## References

- [1] Pearson G, Shann F, Barry P, Vyas J, Thomas D, Powell C. Should paediatric intensive care be centralised? Trent versus Victoria. *Lancet* 1997;349:1213–7.
- [2] Namachivayam P, Shann F, Shekerdemian L, Taylor A, van Sloten I, Del Zoppo C, et al. Three decades of pediatric intensive care: who was admitted, what happened in intensive care, and what happened afterward. *Pediatr Crit Care Med* 2010;11(5):549–55.
- [3] Boland RA, Cheong JL, Doyle LW. Changes in long-term survival and neurodevelopmental disability in infants born extremely preterm in the post-surfactant era. *Elsevier*; 2021 *Semin Perinatol* 2021:151479.
- [4] Antolovich GC, Cooper MS, Johnson MB, Lundine C, Yang Y, Frayman K, et al. Perioperative care of children with severe neurological impairment and neuromuscular scoliosis—a practical pathway to optimize peri-operative health and guide decision making. *J Clin Med* 2022;11(22):6769.
- [5] Chawla J, Edwards EA, Griffiths AL, Nixon GL, Suresh S, Twiss J, et al. Ventilatory support at home for children: a joint position paper from the Thoracic Society of Australia and New Zealand/Australasian Sleep Association. *Respirology* 2021;26(10):920–37.
- [6] Australian Bureau of Statistics: States and territories, annual population change: <https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/latest-release#states-and-territories>. 2022 [Accessed December 7 2022].
- [7] MacPhail A, Lee WJ, Kotsanas D, Korman TM, Graham M. A rise in invasive and non-invasive group A streptococcal disease case numbers in Melbourne in late 2022. *Med J Aust* 2023;218(8):378–9.
- [8] Hiscock H, Chu W, O'Reilly G, Freed GL, White M, Danchin M, et al. Association between COVID-19 restrictions and emergency department presentations for paediatric mental health in Victoria, Australia. *Aust Health Rev* 2022;46(5):529–36.
- [9] Collins M, Crowe M, Cleak H, Kallianis V, Braddy L. The effects of the COVID-19 pandemic on patients experiencing family violence presenting to an Australian Health Service. *Br J Soc Work* 2022;53(2):1161–82.
- [10] Australian Bureau of Statistics. 3235.2 - Population by Age and Sex, Victoria, Jun 2000. [https://www.abs.gov.au/ausstats/abs@nsf/PrimaryMainFeatures/32352?OpenDocument#:-:text=The%20estimated%20resident%20population%20\(ERP,annual%20growth%20rate%20of%201%25](https://www.abs.gov.au/ausstats/abs@nsf/PrimaryMainFeatures/32352?OpenDocument#:-:text=The%20estimated%20resident%20population%20(ERP,annual%20growth%20rate%20of%201%25) [Accessed 29 September 2023].
- [11] Australian Bureau of Statistics. Victoria. Latest release. In: 2021 Census All persons; 2021. <https://www.abs.gov.au/census/find-census-data/quickstats/2021/2> [Accessed 29 September 2023].
- [12] Tibballs J, Kinney S, Duke T, Oakley E, Hennessy M. Reduction of paediatric in-patient cardiac arrest and death with a medical emergency team: preliminary results. *Arch Dis Child* 2005;90(11):1148–52.
- [13] Royal College of Paediatrics and Child Health. Diploma in Child Health (DCH) <https://www.rcpch.ac.uk/education-careers/examinations/about-diploma-child-health>. [Accessed December 7 2022].