UNIVERSITA’ DEGLI STUDI DI GENOVA

Scuola di specializzazione in Pediatria

TESI DI SPECIALIZZAZIONE

“Identification and analysis of risk factors on admission for unplanned transfer from Pediatric Intermediate to Intensive Care Unit”

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A mio papà,

che mi guarda ogni giorno da lassù

Summary

Chapter 1

Background (1)

In the last decades, advances in pediatric medical, surgical, and critical care have resulted in an evolution in the acuity and complexity of children, decreasing mortality and morbidity rates in critically ill neonatal and pediatric patients and, increasing the survival of children with complex chronic diseases.

This has resulted in an expansion of a growing group of patients who require more specialized care than is normally available in the general ward, but who lack the severity traditionally required to access critical care.

To address this nuanced care requirement, Pediatric Intermediate Care Units (PIMCU) emerge as a vital bridge in care delivery, filling the gap between intensive and general pediatric care.

Pediatric Intermediate Care Unit (IMCU)

Definition

This new type of organization of care is set for children who may require closer observation and monitoring than is usually available in an ordinary children's ward, with higher staffing levels than usual, in such locations. It corresponds to an intermediate level of care between general wards and intensive care units (PICU). Good communication between the three levels of care- namely the general ward, IMCU and PICU- is essential to make the system work effectively (2).

An univocal definition of the level of care that has to be provided by IMCU is not available. However, the only feature that all definitions have in common is the absence of invasive mechanical respiratory support which remains a prerogative of PICU.

The IMCU has been described in many ways, depending on the country and the organization of the hospital.

Overall, an Intermediate level of care offers a more intensive level of care than the general ward can provide, allowing for continuous/sub-continuous monitoring and non-invasive organ support (i.e. CPAP, NIV).

IMCUs have also be defined as high-dependency, progressive, or step-up units that provide close observation, monitoring and therapies to children who are, or have the significant potential to be, physiologically unstable and for whom care is beyond the capability of a general pediatric floor. IMCU may also function as a step-down units, primarily caring for patients during recovery from critical illness or surgical intervention that required ICU admission.

Figure 1 show the main definitions used in the different countries.

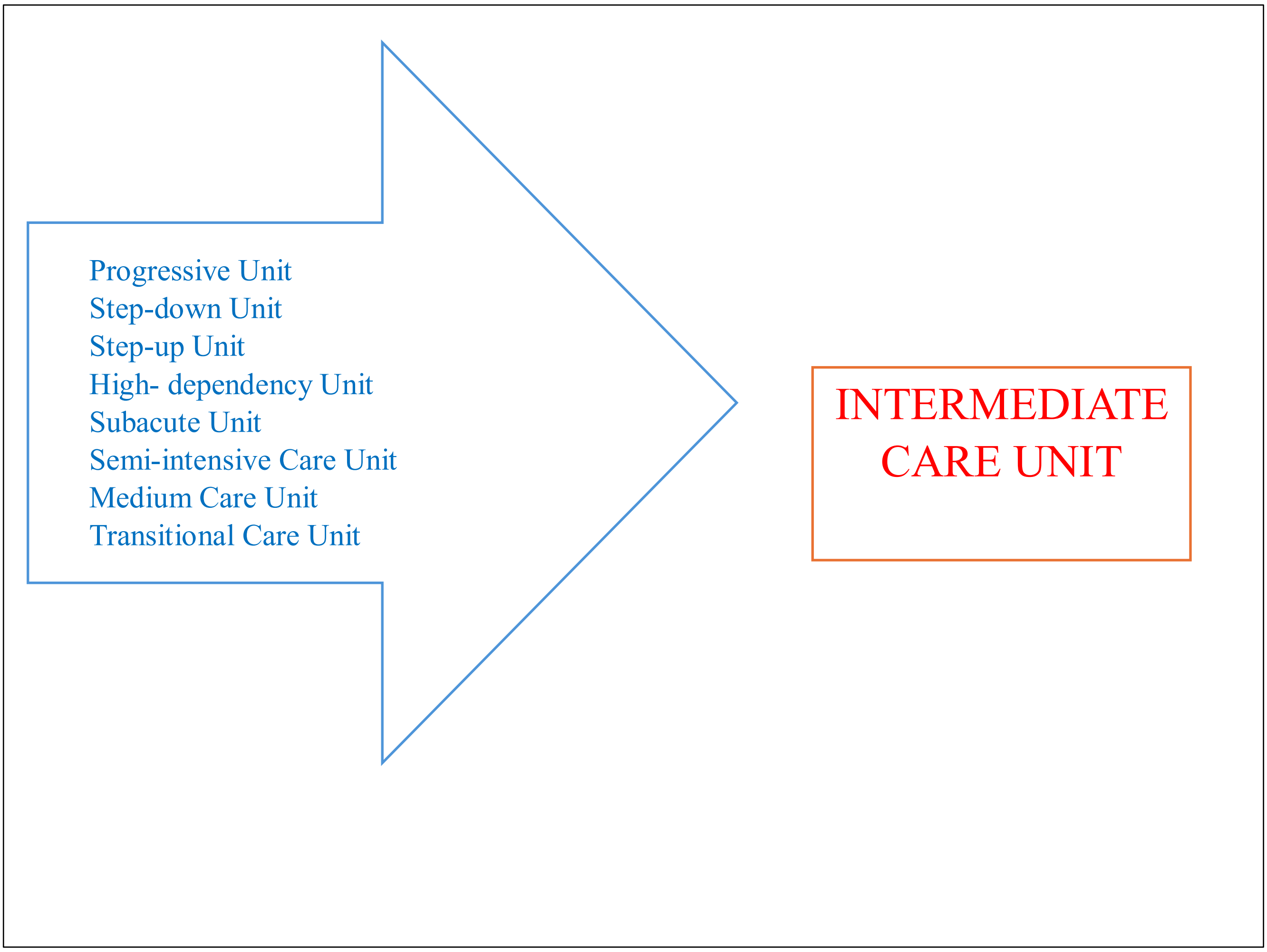


Fig 1. Main definition of IMCU used in the different countries.

Prin et All. (3) have listed all the definitions, talking about adult environment:

Term	Definition	Country
Stepdown unit	"… to allow for the care of patients who do not require full intensive care but cannot be safely cared for on a normal ward. These patient requirements may include (but are not limited to) specific organ support, nursing needs, vital sign monitoring, or ventilator weaning."	Nonspecific
High dependency care unit	"… provides the capability for all the invasive monitoring of ICU but without the provision of mechanical ventilation. With a nursing ratio that is typically 1:2, HDU is believed to be a lower cost alternative to ICU in critically ill patients who do not require mechanical ventilation."	Australia
Transitional care unit	"… units were developed to provide varying levels of noninvasive monitoring with or without the capability to ventilate patients … [patients] require a lower nurse:patient ratio and may require fewer investigations when compared to patients in ICUs."	Canada
Respiratory intermediate unit	"Respiratory intermediate care units (RICUs) within acute care hospitals manage patients with ARF or ACRF with noninvasive ventilation … may also provide multidisciplinary rehabilitation and serve as a bridge to home care programs or long-term care facilities … may work also as 'step-down' units for difficult-to-wean patients …"	Italy
Level 2 care	"Patients requiring more detailed observation or intervention including support for a single failing organ system or post-operative care and those 'stepping down' from higher levels of care."	UK
Progressive care unit	"… patients whose needs fall along the less acute end of [the patient care] continuum … moderately stable with less complexity, require moderate resources and require intermittent nursing vigilance or are stable with a high potential for becoming unstable and require increased intensity of care and vigilance."	United States
Intermediate care unit	" … does not require intensive care but needs more care than that provided on a general ward. These patients may require frequent monitoring of vital signs and/or nursing interventions, but usually do not require invasive monitoring."	United States
Intermediate care unit	" … patients who received only monitoring and floor care services … and were at such low risk of receiving active life-supporting treatment that routine ICU admission might not be necessary."	United States

Regarding children, in 2004, The American Academy of Pediatrics (AAP) (4) has published the first guidelines for the organization of IMCU that are defined as the units that care for a patient population with a severity of illness that does not require intensive care but requires greater services than those provided by routine inpatient general pediatric care. Patients with a low risk of, but potential for, significant deterioration and who are admitted for routine monitoring are excellent candidates for intermediate care.

Their guidelines intended to establish admission and discharge criteria for intermediate pediatric care, both in tertiary hospitals with a PICU and in those without. For this latter group, they provided guidance for the care of children more critically ill; these hospitals should ensure that the resources, facilities, and personnel needed to provide care beyond the level of a general pediatric medical-surgical unit are available. Furthermore, they should have the immediate availability to stabilize a child who becomes critically ill. Finally, these hospitals should identify facilities with pediatric intensive care units to which patients can be transferred if their condition worsens.

In 2022, the AAP guidelines have been updated (5): a task force composed by a group of nine clinical experts in pediatric critical care, hospital medicine, intermediate care, and surgery developed a consensus on priority topics requiring updates, reviewed the relevant evidence, and, through a series of virtual meetings, developed the document. In this paper they give a series of recommendation in which they talk about target patients, care facilities, IMCU staffing and payments (see below).

Advantages

Introducing a new IMCU gives many advantages: to the hospital, patients and PICU; much information come from studies in adults (3,6–8) .

Advantages for the PICU:

- better bed utilization, improving patient flow and reducing overcrowding
- reduction of staff overload

Advantages for patients:

- improvement of patients outcomes with a better clinical and care management, reducing mortality index
- improvement of the clinical security respect being admitted to general wards
- reduction of psychological stress resulting from hospitalization in intensive care units. Ko et all. (9) described, through a systematic review, the frequent psychological repercussions in children previously admitted to an intensive care unit. The most commonly observed disorders were post-traumatic stress disorder, cognitive deficits, and behavioral alterations, but other disorders such as anxiety, attention and developmental deficits, and depression have also been reported. This stems from a greater psychological vulnerability in pediatric patients, making them more susceptible to facing negative events, such as invasive procedures. Such disorders can be observed even a year after hospitalization.
- gradual transition towards autonomy. Young patients can be involved in a care pathway that prepares them to manage their condition better outside the hospital. This is particularly important for the psychological and social development of children, helping them maintain a sense of normalcy during a challenging time.

Advantages for the hospital:

- reorganization
- decrease of cost (the main savings may be in staffing levels, with nursing-to-patient ratios usually 2:1 compared with 1:1 in a PICU; and a reduction of median duration of PICU stays)
- collaboration among various healthcare professionals. In semi-intensive care, we often see close teamwork between doctors, nurses, psychologists, and therapists. This multidisciplinary approach enriches treatment and ensures that every aspect of the child's health is c

Admission criteria

Hospitals or health systems should design triage guidelines to guide admission to the IMCU (vs admission to the general pediatric floor or to the PICU).

Jaimovich et All. (4) listed a series of admission criteria dividing them by specialty. The 2022 AAP recommendation (5) implemented this list and identify classes of patients who need IMCU (Table 1):

- children with acute critical illness and a low risk of mortality contingent on aggressive management who do not require invasive technologies for that care. Children and adolescents with acute critical illness and a low risk of mortality contingent on aggressive management who do not require invasive technologies for that care should be well served in an IMCU.
- children that need non invasive mechanical ventilation (NIPPV) support for treating respiratory insufficiency or other conditions. NIPPV is increasingly used to manage acute respiratory failure in typically developing children. Therefore, there may be a more prominent role for IMCUs in managing the subgroup of patients with acute respiratory failure that is at low risk of requiring intubation
- children with medical complexity admitted with acute on chronic illness who are inappropriate for a regular floor admission. Those patients, particularly those dependent on technology, may require more nursing or respiratory therapy care at baseline than is available on general pediatric floors. An IMCU may become their “inpatient medical home”, unless the severity of presentation or trajectory of illness necessitates PICU admission.

  In this group are considered also the patients with tracheostomy that have to be ventilated chronically at home, and patients that depend on NIPPV chronically.

  IMCUs should have care managers and social workers well versed in the practical medical complexities of home care for those kind of patients.

Table 1. Examples (by Organ System) of Pediatric Patient Populations With Acute Critical Illness

Organ System	IMCU Care Element Likely Not Available on a General Pediatric Floor
Respiratory	
Patients with acute or acute-on-chronic respiratory failure with a low risk of requiring intubation (eg, asthma, bronchiolitis, croup, obstructive sleep apnea, pneumonia, tracheitis)	Need for noninvasive positive pressure ventilation
Patients requiring work-up of apnea	Presence of a tracheostomy +/− ventilator
Patients with impaired airway clearance requiring frequent suctioning	Close (q2–q4h) cardiorespiratory monitoring
	$F_iO_2 \geq 50\%$
	Requiring frequent (q2–q4h) respiratory treatments/ nebulizations/suctioning
Cardiovascular	
Patients with non-life-threatening cardiac dysrhythmias without need for cardioversion	Close (q2–q4h) cardiorespiratory monitoring
Patients with non-life-threatening cardiovascular disease requiring low dose intravenous inotropic or vasodilator therapy and without need for frequent titration (eg, chronic heart failure on long term milrinone therapy)	Low dose inotropic or vasodilator therapy without need for frequent titration
Patients recovering from acute cardiac surgery or cardiac catheterization with low probability of postoperative hemodynamic or respiratory compromise	
Renal	
Patients with acute or acute-on-chronic hypertension who may require continuous or frequent intermittent intravenous therapy but without any neurologic sequelae	Close (q2–q4h) neurologic and cardiorespiratory monitoring
Patients with acute or acute-on-chronic renal failure who do not require continuous renal replacement therapy	Continuous or frequent (q2–q4h) intermittent intravenous antihypertensive therapy
	Peritoneal dialysis or intermittent hemodialysis
Multisystem/Other	
Patients with uncomplicated toxic ingestions without significant cardiorespiratory compromise	Close (q2–q4h) neurologic and cardiorespiratory monitoring
Pediatric palliative care patients requiring continuous infusions to treat end-of-life dyspnea or anxiety	Need for noninvasive positive pressure ventilation

Table 1. Continued

Patients with mild to moderate electrolyte disturbances potentially requiring intravenous replenishment and frequent laboratory monitoring but without significant hemodynamic, neurologic, or respiratory compromise	Close (q2–q4h) neurologic and cardiorespiratory monitoring
Patients with inborn errors of metabolism requiring correction and close cardiorespiratory monitoring but without cardiorespiratory compromise	Frequent laboratory monitoring (≥ q2h)
Gastrointestinal	
Patients with acute gastrointestinal bleeding requiring transfusions or intravenous therapy, but without significant hemodynamic or respiratory compromise	Close (q2–q4h) neurologic and cardiorespiratory monitoring
Patients with acute or acute-on-chronic gastrointestinal or hepatobiliary insufficiency but without neurologic or cardiorespiratory compromise	Frequent laboratory monitoring (≥ q2h)
Neurologic	
Patients with seizures/epilepsy (acute or chronic) who are responsive to therapy, who may require short term electroencephalographic monitoring and who require continuous cardiorespiratory monitoring, but with low risk for cardiac arrest or intubation and/or low risk for requiring continuous electroencephalographic monitoring	Close (q2–q4h) neurologic and cardiorespiratory monitoring
Patients with acute encephalopathy who require close cardiorespiratory monitoring but with low risk for cerebral herniation, cardiac arrest, or intubation	Need for noninvasive positive pressure ventilation
Patients with acute inflammation/infection of the central nervous system but with low risk for cerebral herniation, cardiac arrest, or intubation	Short term electroencephalographic monitoring
Patients with chronic neuro-muscular disorders requiring respiratory support at or above baseline but with low risk for requiring intubation.	
Hematologic/Oncologic	
Patients with severe anemia requiring acute transfusions without serious hemodynamic compromise	Close (q2–q4h) neurologic and cardiorespiratory monitoring
Oncologic patients with anemia, thrombocytopenia, and/or neutropenia at risk for or experiencing tumor lysis syndrome but with appropriate, stable renal function and with low risk for requiring emergent dialysis	Frequent laboratory monitoring (≥ q2h)
Oncologic patients with chronic chemotherapy-related heart failure requiring low-dose inotropic or vasodilator therapy with low risk for further cardiorespiratory compromise and without need for frequent titration	Low dose inotropic or vasodilator therapy without need for frequent titration
Endocrine/Metabolic	
Patients with mild or moderate diabetic ketoacidosis requiring continuous insulin infusions but without acute severe encephalopathy and with low risk of clinically significant cerebral edema	Continuous insulin infusions and frequent glucose checks

- Select healthy pre- or postoperative patients requiring higher intensity monitoring or interventions, possibly at risk of deterioration. Pediatric surgeons and subspecialty surgeons must be involved in the perioperative care of their patients, either as the admitting service of record or as a consultant. Some trauma or burn patients who do not require the acuity of the PICU may be well served in an IMCU.

  Specific potential examples are listed in Table 2.

Table 2. Possible surgical patients population

Surgical Subpopulation	Indication for IMCU Admission
Select hemodynamically stable preoperative pediatric general surgery patients requiring ongoing fluid resuscitation and/or electrolyte correction	Frequent (q2–q4h) assessment and correction of fluid/electrolyte status before operative interventions
Select extubated postoperative patients after major surgery	At risk for postoperative bleeding or challenges with pain control
	May require close postoperative monitoring and aggressive postoperative pulmonary toilet to prevent decline
Patients with complex wounds	Require frequent, extensive and/or advanced wound care/dressing changes
Patients with postsurgical limb- or anastomosis-viability concerns	Require close (≥ q2h) neurovascular monitoring
Hemodynamically stable patients after percutaneous interventional procedures	Require frequent (≥ q2h) neurovascular checks and/or continuous anticoagulation infusions
	Close (q2–q4h) neurologic and cardiorespiratory monitoring
CMC who undergo elective or semielective surgery (eg, spinal fusion surgery) who are otherwise near their baseline level of needs	Require close (q2–q4h) postoperative monitoring and aggressive postoperative pulmonary toilet to prevent decline
	Requiring frequent (q2–q4h) respiratory treatments/nebulization
Select hemodynamically stable pediatric trauma patients	High-grade solid organ injury at risk for serious or ongoing bleeding
Hemodynamically stable patients with extremity trauma and concern for vascular injury	Require frequent (≥ q2h) pulse or neurovascular checks
Moderate traumatic brain injury not requiring an advanced airway or hyperosmolar therapy	Require frequent (q2h–q4h) neurologic assessments and close (q2h–q4h) cardiorespiratory monitoring to prevent decline
Hemodynamically stable nonintubated burn patients	Require moderate sedation for daily dressing changes

Discharge criteria (4)

Patients have to be daily re-evaluated and, when clinically stable, considered for transfer to general care or special care units when the disease process has reversed or the physiologic condition that prompted admission has resolved and the need for multiple disciplinary intervention and treatment is no longer needed .

In particular, the patient should be transferred to a floor or specialty care unit or discharged to home, as appropriate, if the following criteria apply:

1. The patient has stable hemodynamic parameters for at least 6–12 hours
2. The patient has stable respiratory status and has been washed-out from respiratory support with evidence of acceptable gas exchange for more than 4 hours
3. The patient has minimal oxygen requirements as evidenced by a fraction of inspired oxygen of 0.4 or less (see below)
4. Intravenous inotropic support, vasodilators, and antiarrhythmic drugs are no longer required or, when applicable, low doses of these medications may be administered in otherwise stable patients in a designated patient care unit
5. Cardiac arrhythmias are controlled for a reasonable period of time but not less than 24 hours
6. Patient has neurologic stability with control of seizures for a reasonable period of time.
7. All invasive hemodynamic monitoring devices have been removed (e.g., arterial catheter)
8. The patient who had required chronic mechanical ventilation and has had resolution of the acute illness that required intermediate or intensive care and has now returned to baseline clinical status.
9. The patient will require peritoneal dialysis or hemodialysis on a routine basis and, therefore, may receive these treatments as an outpatient or a designated patient care unit.
10. The need for multiple disciplinary intervention is predictable and compatible with policies of the receiving patient care units.
11. The healthcare team, after careful multiple disciplinary assessment, together with the patients' family decides that there would be no benefit in keeping the child hospitalized or that the course of treatment is medically futile.

However, to keep microbiological segregation, transfers to low intensity care units were restricted and some patients had to be managed in IMCU until their discharge.

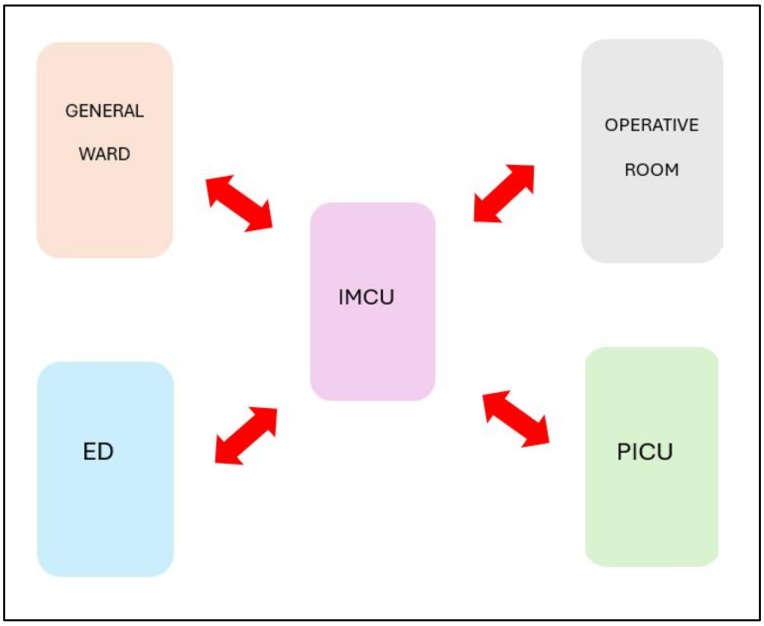
Otherwise, if the patients deteriorate at re-evaluation, he should be transferred to PICU to better manage the case. Policies and procedures should clearly delineate ongoing assessment of patients and what interventions may be performed in the IMCU versus when PICU-level care is required. There should be clear thresholds and efficient processes for rapid transfer to a PICU.

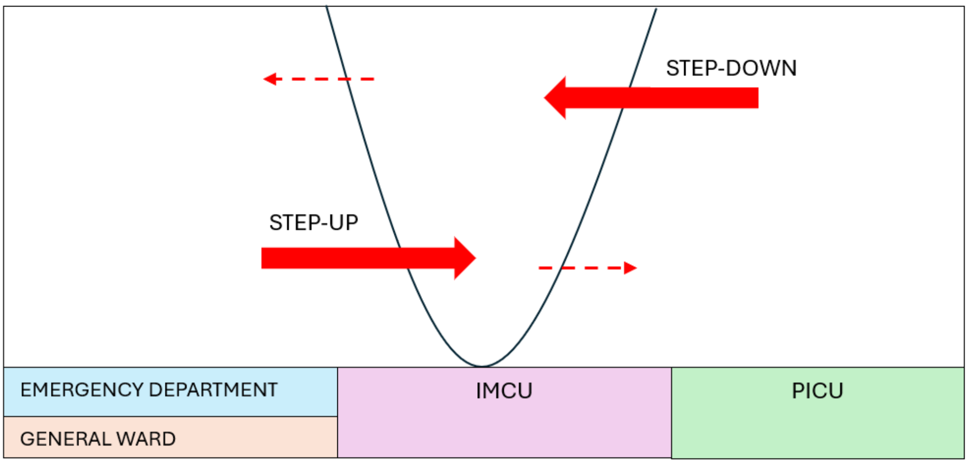
Patients flow

Hospitals or health systems should design triage guidelines to guide admission to the IMCU (vs admission to the general pediatric floor or to PICU). Policies and procedures should clearly delineate ongoing assessment of patients and what interventions may be performed in the IMCU versus when PICU-level care is required (5).

IMCU may function as (Fig 3 and 4):

- a “step-up” unit for patients coming from emergency department (ED) or general floor in a escalation of care; these patients are acutely worsening but not critically ill
- a “step-down” unit from PICU for a de-escalation of care in patients that do not require longer full intensive care but continue needing a continuous monitoring.





Organization (3,8,10)

The type of IMCU varies from centre to centre depending on the demand, with requirements in the regional specialty or tertiary hospital being different from those in an acute district general hospital (DGH). Multiple formats have been proposed and implemented and discussion about the type of unit most appropriate for a given hospital is crucial in its planning. The location of the IMCU depends on the type of hospital; it is ideally provided in facilities that have a pediatric intensive care unit. However, these resources may not be widely available, particularly in geographically remote regions, where tertiary pediatric centre may be several hours and hundreds of miles away (4).

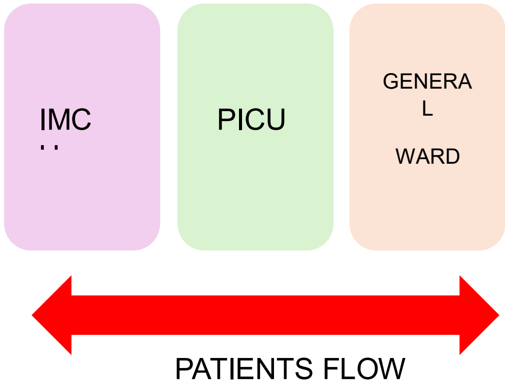
IMCUs may be beneficial to the functioning of pediatric hospitals with a tertiary or quaternary PICU, as defined by the 2019 PICU admission guideline, and should only be established in hospitals without a PICU in the same institution with caution, extensive planning, and great care. All IMCUs should have a well-established relationship, administratively and geographically, with a PICU, including delineating a clear plan to cover routine and emergency airway issues, policies and procedures for consultation with a pediatric intensivist or neonatologist when medically indicated, and clear triggers to prompt PICU consultation in patients not responding to therapies or whose disease state is worsening.

The general paediatric team will normally run the DGH unit with backup retrieval support from the regional PICU. In the tertiary centre it is often more confusing, with the unit sometimes being a peripheral unit run separately from the PICU. Other options include a IMCU on the same site as the PICU and run by intensivists.

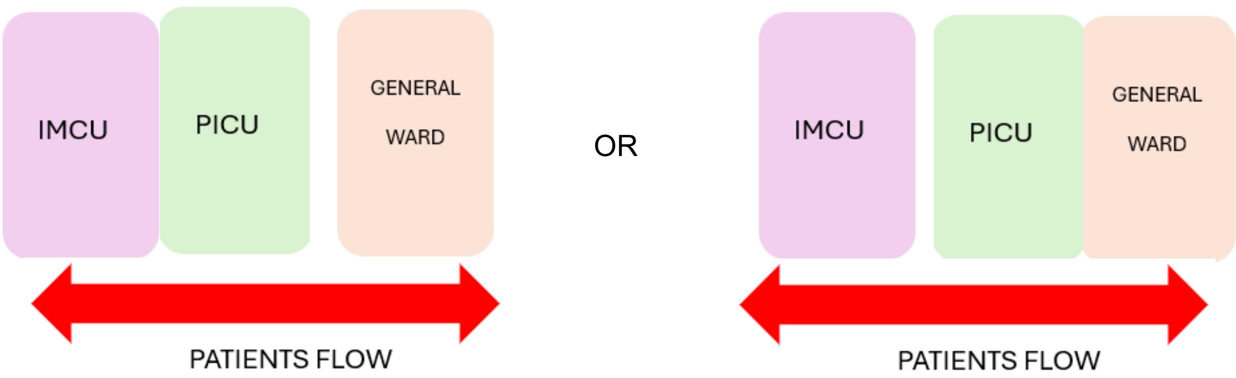
Tertiary hospital IMCU (with a PICU)

This kind of IMCU can be organised in different ways:

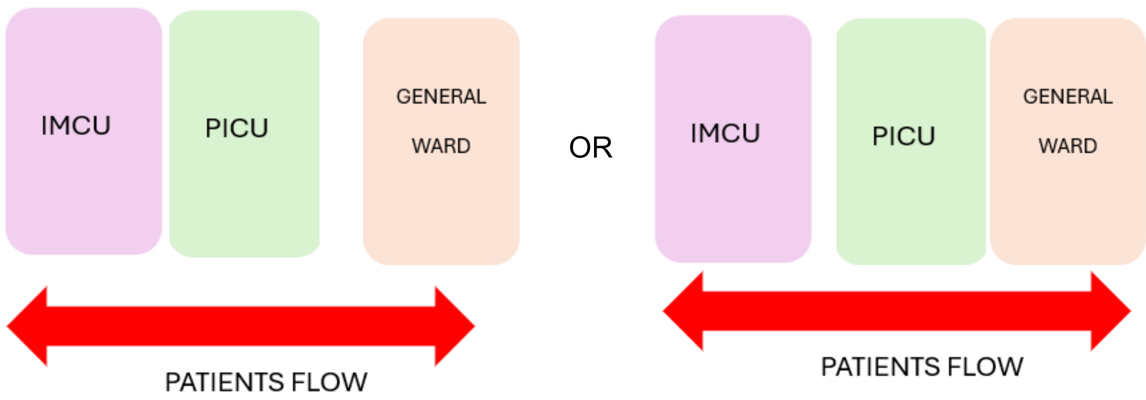
- It can be an independent stand-alone unit, managed by subspecialty units separate from PICU. May be multiple such units within the hospital (e.g. different organ transplant units) or some hospitals may have a single specialty PHDU, such as a burns unit. It requires more staff, with more cots; and a patients flow more difficult. On the other hand it is an calmer place without noises typical of PICU



- IMCU as a co-located unit with a general ward or a PICU, named "flexible beds" model. It is the most popular model in UK. It has many advantages:
- Reduction of costs: rationalization on the utilization of staff and machines
- Better stay for children with a parent presence, child friendly environment, reduction of noises typical of PICU
- Continuation of care with the same stuff even after escalation of care
- Reduction of working hours because of staff tournament between the same co-unit



- Adjacent but separate unit with a general ward or PICU. This model facilitates patients flows. A central unit that has a combined multidisciplinary approach has the benefit of improved continuity and management pre- and post-PICU. Combined rounds with intensivists and the primary care team also means that the approach is consistent and supportive rather than just consultative. A more central system adjacent to the PICU has the benefit of concentrating medical and nursing expertise, but the major difficulties are logistical, with the need to ensure all members of the multi-disciplinary team are simultaneously available. It may be more cost effective in terms of staffing and equipment provision and bed management may also be more flexible in a central IMCU/ PICU. The downside is often a lack of input from the primary care team and a focus on discharge from IMCU/PICU rather than hospital discharge planning. The PICU controlled IMCU may also suffer from staff shortages with resources going preferentially to the sicker PICU patients. The benefits of a quieter, less technological IMCU, versus PICU may also get lost in a combined unit. he type of unit can be modified according to local need and experience.



Peripheral IMCU (without a PICU)

In this case, PMCU also allows, in addition to its designated missions, the preparation of children while waiting for their transfer to intensive care. It is recommended that establishments have a IMCU when they face approximately one hundred patients per year for this activity. These continuous monitoring beds can also be adjacent to a neonatal intensive care unit, in which case they form an individualized sector.

Medical supervision can be shared with the pediatrics department, pediatric emergency services, or neonatology. It must include at least one operational on-call duty. The medical on-call coverage for the IMCU can be provided by the pediatrics department, pediatric emergency services, or neonatology. The responsibility for this unit can be combined with the leadership of the pediatrics, neonatology, or pediatric emergency services.

The 'pros' of thist type of peripheral unit include the way it provides medical and nursing personnel with an interesting case-mix and helps maintain acute medical management knowledge and skills for senior and junior staff. If all critical care was transferred centrally to PICU these skills would be difficult to maintain. One of the possible 'cons' is the role of it being a step-down unit from PICU. It could be argued in some cases that the move from PICU to the general ward will eventually occur and the peripheral intermediate unit is often an unnecessary transfer.

Staff

One of the characteristics of pediatric critical care is the skills and experience of the medical and nursing staff who cares for the critically ill child. They need both skills and knowledge in managing children and in provision of intensive care. In pediatric intensive care, specialist skills are important in achieving the best possible outcomes for children. Another important element for staff caring for critically ill children is that they should retain and develop their knowledge and skills. The small numbers of very critically ill children needing intensive care, and the complexity of the problems involved in treating them, suggest that staff should manage sufficient numbers of children needing intensive care each year to keep their skills and experience up to date. In addition, nurses and clinicians treating critically ill children must have access to specialists with multi-disciplinary expertise whenever it is needed.

Clinicians

All hospitals caring for children should have a designated lead clinician in high dependency care and whilst this does not have to be a medical practitioner, the general paediatrician is an ideal candidate for this role. As a specialist in childhood medicine, an advocate for children and a central link between nursing, allied health and administrative staff, the paediatrician is well placed to fulfill the lead clinician responsibilities. These responsibilities would include:

- availability of trained and suitably skilled staff,
- provision of appropriate equipment and drugs,
- development of protocols for the management of common conditions,
- agreed arrangements for transfer to the PICU,
- procedures to be followed in the event of bed/ staff shortages, close liaison with the relevant PICU and with other departments with in the hospital, (especially Accident & Emergency and the Children's Assessment Unit),
- training and audit,
- provision of adequate support and accommodation for parents.

The general paediatrician is also able to liaise with the numerous subspecialties whose patients may be on a IMCU.

Two single-institution (11,12) reports on pediatric IMCUs indicate they were staffed primarily by pediatric hospitalists.

It is important to maintain a high level of training for all staff, including paediatric life support and have 24 h medical cover (10).

Doctor/patients ration must be of 1 every 6 patients, in order to take care of them in a closer way.

Nursing

Close nursing care is integral to the function of an IMCU, with more intensive nursing as one of the primary benefits over general floorcare. IMCU nursing staff should attain competencies commensurate with the acuity of the patient population served and the therapies delivered. Pediatric hospital medicine fellowships should ensure that their trainees graduate with appropriate competencies to provide care for patients who meet IMCU levels of care, including general knowledge of surgical conditions (5) .

The report “A Bridge to the Future” made by The english Department of Health in 1997 made recommendations for nursing in order to provide this service effectively.

IMCU nurse-to-patient ratios should vary from 1:2 to 1:4 depending on nursing needs, the patients’ acuity, and the judgment of the team caring for the patient.

A 1:2 ratio is attended for possible step-up patients; whereas 1:4 ratio for step-down patients.

The Royal College of Pediatrics and Child Health working group recommendations made in 2014 (13) redefined “high-dependency care” into National Health Services level 1 and level 2 critical care, with different interventions corresponding to each level of critical care. The importance of differentiating these levels was affirmed by follow-up observational research (14) demonstrating both groups consumed higher staff resources, with nurse-to-patient ratios of 1:2 for level 1 critical care and 1:1 for level 2 critical care, as for PICU. In the United States, IMCU nurse-to-patient ratios of 1:2 to 1:2.5 have been reported in pediatric and adult literature (11,12).

As a PICU nurse, extended knowledge and certifications may be required. Recognition and interpretation are two of the many required skills for a PICU nurse. This allows nurses to be able to detect any changes in the patient's condition and to respond accordingly. Other skills may include route of administration, resuscitation, respiratory and cardiac interventions, preparation and maintenance of patient monitors, and psycho-social skills to ensure comfort of patient and family.

There are a variety of certificates that are required for registered nurses to acquire in order to work in a intensive care setting, for example cardiopulmonary resuscitation, pediatric basic life support, and pediatric advance life support

The history

Pediatric sub-intensive care has evolved significantly over the years, adapting to the unique needs of critically ill pediatric patients who do not require the full resources of an intensive care unit (ICU). In the 1960s and 1970s, pediatric medicine began to recognize the importance of providing a specialized care approach for children who required close monitoring and intensive treatment, but whose conditions were not immediately life-threatening. This led to the establishment of sub-intensive care units (IMCUs), which focused on managing acute illnesses, post-operative complications, and certain chronic conditions that necessitated ongoing medical intervention.

The concept of sub-intensive care has since been refined to represent an intermediate level of care, bridging the gap between general hospital wards and full-scale intensive care units. Pediatric IMCUs are designed to manage patients who require frequent monitoring and medical interventions but do not need the high-intensity resources available in a PICU (Pediatric Intensive Care Unit). These units allow for more focused care and often serve as a critical resource for children with complex needs who fall outside the realm of typical ward care.

In the 1980s and 1990s, advances in medical technology, including the introduction of non-invasive mechanical ventilation and more sophisticated monitoring tools, greatly expanded the scope of care available in pediatric sub-intensive care. As a result, new therapeutic protocols were developed, and there was a growing emphasis on a multidisciplinary approach involving pediatricians, anesthesiologists, nutritionists, and mental health professionals to address the diverse needs of critically ill children.

The term "Intermediate Care Unit" (IMCU) was first introduced in the medical literature in 1991 by Lawless et. All (1) in a multicenter study across the United States. Their research, based on a survey of 226 U.S. pediatric residency programs, highlighted the emerging role of IMCUs as a viable alternative to the PICU for children requiring sophisticated care or prolonged monitoring, but without the intensity associated with full ICU services. Despite its potential, the study revealed that IMCUs were still underutilized at the time, with only 33% of programs utilizing them. Factors contributing to this underuse included physician practice biases, a lack of experience with intermediate care units, and the absence of specific guidelines for their use.

Entering the twenty-first century, pediatric sub-intensive care units continued to evolve by integrating modern technologies such as telemedicine and advanced monitoring systems. These innovations have allowed for more efficient and timely interventions, improving both clinical outcomes and patient safety. Today, pediatric sub-intensive care is recognized as a vital component of the healthcare system, offering specialized care for critically ill children while promoting a healing environment that supports recovery and well-being.

ITALIAN REALITY

Amigoni et All. (15), in 2020 conducted a survey to map the state of pediatric IMCUs in Italy. They surveyed 280 pediatric centers and analyzed the responses, identifying 17 active IMCUs across the country: 7 in the north, 5 in the center, and 6 in the south. Of these, 9 functioned as independent units or were adjacent to PICUs or general wards, while the remaining units were co-located with either a PICU or a general ward.

Regarding staffing, the survey found that the majority of clinicians in Italian IMCUs were pediatricians with expertise in emergency care (44%), followed by pediatric intensivists (39%), and then adult care specialists (including intensivists and emergency physicians). The nurse-to-patient ratios varied, with a range from 1:2 to 1:8. However, most IMCUs had nurse-to-patient ratios of 1:3 or 1:4, which reflects a moderate level of intensity in care, ensuring sufficient monitoring and intervention for critically ill children.

These findings highlight the growing role of IMCUs in pediatric care in Italy, emphasizing the importance of intermediate care in bridging the gap between general medical wards and more resource-intensive ICUs. Currently, in Italy, there are 7 pediatric sub-intensive care units with a total of 60 beds.

Risk factors for transfer to PICU

During hospitalization, patients may develop significant clinical deterioration and require unplanned admission to the pediatric intensive care unit (PICU). This may result in increased morbidity and mortality (16); there should be clear thresholds and efficient processes for rapid transfer to a PICU.

The analysis of unplanned transfers is a critical component in evaluating the quality of care and patient safety in healthcare settings. It serves as a key indicator to identify adverse events and should be incorporated into the facility's quality control dashboard. Research has highlighted that transitions of care—whether from one unit to another or between healthcare providers—expose patients to heightened risks, including delays in medication administration, disruptions in oxygen supply, loss of venous access, unplanned extubations, and the failure of battery-powered medical equipment.

Moreover, these transfers place a significant strain on healthcare resources, particularly staffing, in both the general ward and the Pediatric Intensive Care Unit (PICU). This increased resource utilization can lead to "collateral damage," as it may divert attention from other patients in the same unit, heightening the risk of deterioration for those who remain in the ward and potentially delaying discharge for patients who are otherwise ready to leave.

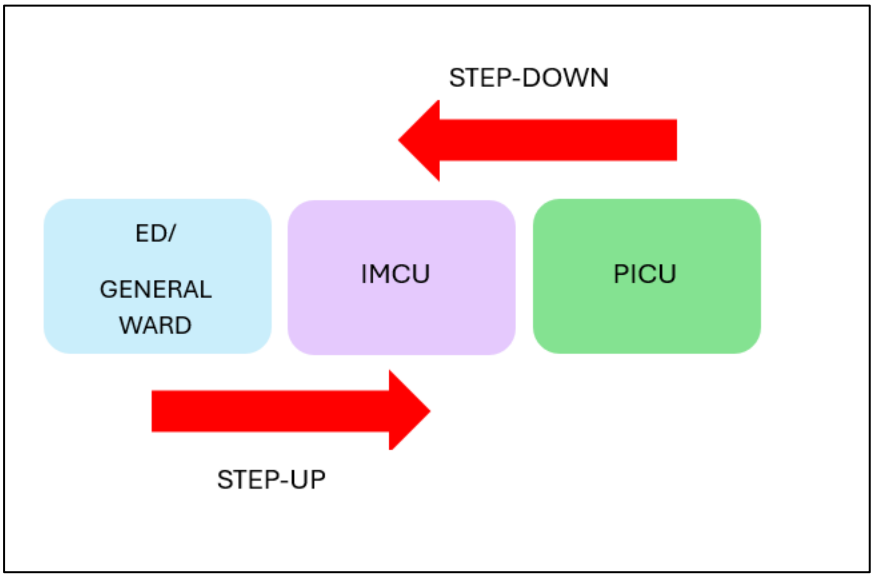
To mitigate these risks outside of the PICU, several strategies have been implemented, including rapid response teams (RRTs), early warning scores (EWS), and enhanced bedside nursing observations. These approaches are essential for the early detection of clinical deterioration. The introduction of rapid response teams (RRTs) has been shown to improve patient outcomes by enabling the timely identification and management of deteriorating patients on hospital wards. Originally designed to reduce ICU admissions and the severity of illness at ICU admission in resource-limited adult hospitals, the use of medical emergency teams (MET) in pediatric settings has also been associated with better outcomes for children whose conditions worsen while hospitalized.

Some studies have analysed risk factors for unplanned transfers to PICU from lower-intensity wards (17). It is important to identify these risk factors in order to anticipate preventable complications and improve the management of critically ill patients.

Many studies have also attempted to provide clinicians with scoring systems to help identify high-risk hospitalized children who are more likely to require unplanned admission to the PICU (17). Although a recently published predictive score used nonvital sign patient characteristics to identify children at high risk, the majority of these scores were based on changes in vital signs.

Overall, the most common reason for unplanned transfer associated with an adverse event was worsening respiratory status (18).

Cheng et All. (11) have analysed possible predictive factors for further transfer to PICU from an IMCU, and observed that the need for close monitoring of physiologic parameters remains paramount, especially in the first 48 hours of admission, in predicting the need for transfer from the IC to PICU.



Paediatric early warning systems scores (19)

Early warning scores have been developed, at first for adult patients and then for children, to aid in the identification of patients who might benefit from medical intervention or need transfer to an higher intensity department; these bedside physiology-based scoring systems repeated by periodic evaluation should alert staff to detect deterioration and accelerate access to appropriate intervention. The goal is to ensure timely recognition of patients with potential or established critical illness and to ensure a timely and appropriate response from skilled staff.

Their validation is difficult to do because at first it is necessary to establish a gold standard that stands for clinical deterioration; it can be: death, cardiac arrest, unplanned transfer to PICU or requirement for PICU, a call for urgent medical assistance or rapid response system (RRS) activation and length of hospital stay.

Implementation of PEWS has been shown to reduce severity of illness on PICU transfer, rates of cardiopulmonary arrests outside the PICU, and overall hospital mortality in high-resource and resource-limited settings.

Many paediatric early warning scores (EWS), aimed at the detection of deterioration, have been developed for patients in paediatric wards or emergency departments. These physiology-based scoring systems should alert staff to detect deterioration and accelerate access to appropriate intervention:

-Pediatric Early Warning Score (PEWS) (20): In February 2001, a working group was established at Brighton and Sussex University Hospitals NHS Trust to develop an early warning score tailored for children. This multidisciplinary group, composed of professionals from various disciplines involved in pediatric care, worked together to design a tool that could help healthcare staff more accurately assess and identify patients at risk of deterioration. The group's discussions focused on the markers that could best indicate the severity of a child's condition, with a particular emphasis on identifying concerns that staff frequently raised regarding a patient's status. The resulting early warning score aimed to provide nurses with an objective, evidence-based tool to assess pediatric patients based on vital signs. The scoring system was built around three key components of pediatric assessment:

- **Behavior**: Behavior was identified as a crucial observation, as it often serves as an early indicator of shock and is something that parents can also notice. Behavioral signs were scored based on direct observation, with children who appeared disengaged or uninterested in their surroundings scoring a three (lethargic).
- **Color/Circulatory Status**: To assess cardiovascular health, the group chose to focus on *color* and *capillary refill* rather than mean arterial blood pressure, as not all staff are trained to assess blood pressure accurately. These indicators are more widely recognized and easier to assess, making them practical for use in routine assessments.
- **Respiratory Status**: Respiratory rate and oxygen demand were included in the scoring system, ensuring that the assessment did not rely on equipment like saturation monitors. By using mean respiratory parameters, the score aims to increase sensitivity to changes in the child's respiratory condition.

Once these parameters are assessed, the nurse calculates the child's total score, which helps determine the next steps in care. The score prompts one of four possible actions:

- Informing the nurse in charge
- Increasing the frequency of observations
- Calling for a medical review and notifying the outreach team
- Activating the full medical team and outreach team

If the child's score falls into the "red" category (greater than four), the protocol recommends calling the full team immediately. This action can be adapted depending on the resources and facilities available at each unit.

This early warning scoring system is an example of a tool that integrates assessments of a patient's cardiovascular, respiratory, and behavioral status. It is designed to be used by bedside nurses during routine assessments (typically every 4 hours) to predict a hospitalized child's risk of deterioration and prompt timely interventions.

Akre et All. (21) found that the system could potentially provide up to 11 hours of advance warning, allowing the healthcare team to adjust the care plan and potentially prevent the need for an emergency response.

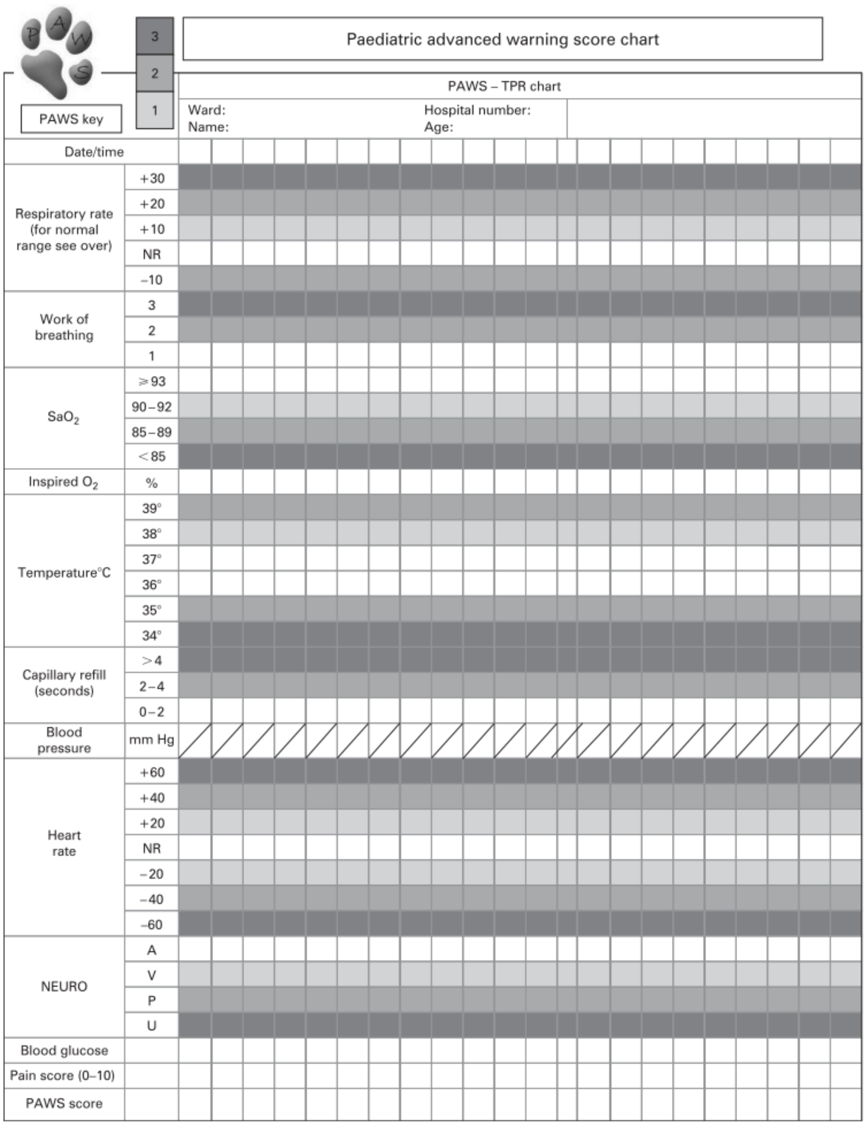
	0	1	2	3	Score
Behaviour	Playing/ appropriate	Sleeping	Irritable	Lethargic/confused Reduced response to pain	
Cardiovascular	Pink or capillary refill 1-2 seconds	Pale or capillary refill 3 seconds	Grey or capillary refill 4 seconds. Tachycardia of 20 above normal rate	Grey and mottled or capillary refill 5 seconds or above. Tachycardia of 30 above normal rate or bradycardia.	
Respiratory	Within normal parameters, no recession or tracheal tug	>10 above normal parameters, using accessory muscles, 30+% FiO2 or 4+ litres/min	>20 above normal parameters recessing, tracheal tug. 40+% FiO2 or 6+ litres/min	5 below normal parameters with sternal recession, tracheal tug or grunting. 50% FiO2 or 8+ litres/min	
Score 2 extra for 1/4 hourly nebulisers or persistent vomiting following surgery					

This score has been further implement and modified during years. Furthermore, it has been evaluated in patients admitted to different sub-specialities (cardiology, eurology, general ward, hemato-oncology (22).

Online Supplementary Appendix 3: Original PEWS Tools

PEWS Tool	Origin	Development
Brighton-Paediatric Early Warning Score (Monaghan 2005) [35]	Royal Alexandra Hospital for Sick Children (UK)	Multidisciplinary working group; developed on available adult systems (not specified)
Pediatric Early Warning System score (Duncan et al. 2006) [23]	Hospital for Sick Children Toronto (Canada)	Expert group of nurses utilised a modified Delphi approach to achieve consensus on parameters and ranges
Paediatric Early Warning (PEW) Tool (Haines et al. 2006) [10]	Bristol Royal Hospital for Children (UK)	Expert group; pilot tool based on un-validated tool developed at Derriford Hospital Plymouth with modifications from criteria developed at Melbourne Children's Hospital Australia & similar adult systems. Modifications made by expert opinion of investigating team including study research nurse, two supervisors, a PICU intensivist & PICU consultant nurse
Paediatric Advanced Warning Score (Edgell et al 2008) [27]	James Cook University Hospital (UK)	Not reported
Bedside Paediatric Early Warning System Score (Parshuram et al. 2009) [39]	Hospital for Sick Children Toronto (Canada)	Expert group & statistical methods (evaluated alongside score comparison & score progression)
Cardiff & Vale Paediatric Early Warning System (Edwards et al. 2009) [25]	University Hospital of Wales (UK)	Developed using physiological parameters based on 2005 advanced paediatric life support guidelines for recognition of sick child Expert group - general paediatricians, regional nurse educator & paediatric intensivist –reviewed other EWS to modify age-related normal ranges & identify other parameters for inclusion; the group reached a consensus opinion to agree 8 parameters & trigger criteria
Newborn Early Warning System (Roland et al 2010) [44]	Neonatal Unit, Derriford Hospital, Plymouth (UK)	Not reported
Cardiac Children's Hospital Early Warning Score (McLellan et al. 2013) [3]	Boston Children's Hospital (USA)	Expert group; developed from CHEWS - a multidisciplinary panel assessed which risk factors were unique to cardiovascular patients & incorporated these risks into new tool
Neonatal Trigger Score (Holme et al 2013) [31]	Neonatal Unit London (UK)	Developed by expert group (5 consultant neonatologists, NICU nurses & midwives) consensus & guidance from Neonatal Life Support, National Institute for Clinical Excellence Postnatal Care & a neonatal scoring chart
Paediatric Observation Priority Score (POPS) (Roland et al. 2016) [46]	Children's Emergency Department Leicester Royal Infirmary (UK)	POPS was developed locally using current evidence and the experience of senior paediatric emergency clinicians; the physiological parameters were chosen based on APLS guidance and their utilisation in other scoring systems. The visual style was based on feedback from nurses over a 1 month period which was constantly refined based on feedback. A small pilot phase in 100 patients (presented at a regional paediatric meeting) demonstrated acceptability and feasibility.

-Pediatric Advanced Warning Score (PAWS): Egdell et All. (23) developed and validated this score based on age-specific vital signs through a retrospective analysis of children attending the Emergency Department at James Cook University Hospital, Middlesbrough. The PAWS score demonstrated strong discriminatory power, with an area under the ROC curve of 0.86 ($p < 0.0001$). At a trigger score of 3, the PAWS score successfully identified children requiring PICU admission, with a sensitivity of 70% and a specificity of 90%.



- **Bedside PEWS (bPEWS)**: designed and initially validated by Parshuram et All. in 2009 (24), subsequently validated in a multicentric set (25) finding that it is able to identify patients at risk with a least one hour's notice. The seven items used to calculate the score are heart rate, systolic blood pressure, capillary refill time, respiratory rate, respiratory effort, transcutaneous oxygen saturation and oxygentherapy.

Table 1 The Bedside Paediatric Early Warning System score items

		Item subscore			
Item	**Age group**	**0**	**1**	**2**	**4**
Heart rate (bpm)	0 to < 3 months	> 110 and < 150	≥ 150 or ≤ 110	≥ 180 or ≤ 90	≥ 190 or ≤ 80
	3 to < 12 months	> 100 and < 150	≥ 150 or ≤ 100	≥ 170 or ≤ 80	≥ 180 or ≤ 70
	1-4 years	> 90 and < 120	≥ 120 or ≤ 90	≥ 150 or ≤ 70	≥ 170 or ≤ 60
	> 4-12 years	> 70 and < 110	≥ 110 or ≤ 70	≥ 130 or ≤ 60	≥ 150 or ≤ 50
	> 12 years	> 60 and < 100	≥ 100 or ≤ 60	≥ 120 or ≤ 50	≥ 140 or ≤ 40
Systolic blood pressure (mmHg)	0 to < 3 months	> 60 and < 80	≥ 80 or ≤ 60	≥ 100 or ≤ 50	≥ 130 or ≤ 45
	3 to < 12 months	> 80 and < 100	≥ 100 or ≤ 80	≥ 120 or ≤ 70	≥ 150 or ≤ 60
	1 to 4 years	> 90 and < 110	≥ 110 or ≤ 90	≥ 125 or ≤ 75	≥ 160 or ≤ 65
	> 4 to 12 years	> 90 and < 120	≥ 120 or ≤ 90	≥ 140 or ≤ 80	≥ 170 or ≤ 70
	> 80 and < 100	> 100 and < 130	≥ 130 or ≤ 100	≥ 150 or ≤ 85	≥ 190 or ≤ 75
Capillary refill time		< 3 seconds			≥ 3 seconds
Respiratory rate (breaths/ minute)	0 to < 3 months	> 29 and < 61	≥ 61 or ≤ 29	≥ 81 or ≤ 19	≥ 91 or ≤ 15
	3 to < 12 months	> 24 or < 51	≥ 51 or ≤ 24	≥ 71 or ≤ 19	≥ 81 or ≤ 15
	1 to 4 years	> 19 or < 41	≥ 41 or ≤ 19	≥ 61 or ≤ 15	≥ 71 or ≤ 12
	> 4 to 12 years	> 19 or < 31	≥ 31 or ≤ 19	≥ 41 or ≤ 14	≥ 51 or ≤ 10
	> 12 years	> 11 or < 17	≥ 17 or ≤ 11	≥ 23 or ≤ 10	≥ 30 or ≤ 9
Respiratory effort		Normal	Mild increase	Moderate increase	Severe increase/any apnoea
Oxygen saturation (%)		> 94	91 to 94	≤ 90	
Oxygen therapy		Room air		Any to < 4 L/minute or < 50%	≥ 4 L/minute or ≥ 50%

A small subset of patients admitted in IMCU can deteriorate further and require transfer to the paediatric intensive care unit (PICU); early identification of patients at risk for secondary transfer to a pediatric intensive care unit (PICU) may improve the quality of care (26). Early recognition and appropriate intervention are important in children and may prevent the need for admission to intensive care. By identifying patient characteristics at the time of admission that predict secondary transfer, specific

monitoring, resource allocation and early intervention may be implemented in order to improve quality of care (11). In IMCU setting, EWS can be well used and can help.
Lampin et All. (27) have been the first to assess the use of paediatric EWS (PAWS, PEWS and Bedside PEWS, see below) in IMCU in detecting deterioration of children: none of the three scores appeared to be better than the others for detecting deterioration, all of them are useful.
EWS can be further helpful if used in patients with comorbidities, for example oncology patients; Agulnik et All. (28) have described hospitalized pediatric oncology patients with clinical deterioration initially triaged to the IMCU in a resource-limited pediatric oncology hospital, and demonstrated that among unplanned transfers to the IMCU, those requiring early escalation to PICU care had significantly higher PEWS prior to IMCU transfer compared to patients remaining in the IMCU (PEWS 5.6 vs. 3.1, $P = 0.03$). This represents a difference between yellow (3or 4) and red (≥5) PEWS, and suggests PEWS can aid in appropriate triage of patients with clinical deterioration to IMCU or PICU level of care.

PRISM score (29,30)
The Pediatric Risk of Mortality (PRISM) score is one of the key prognostic indicators used in pediatric intensive care units (PICUs). Initially developed by Pollack et All. in the 1980s, it was derived from the Physiologic Stability Index (PSI) based on data from 1,415 patients across nine U.S. PICUs. The score was validated using mortality data from these patients, with 116 deaths recorded during the study period.
The PRISM score is based on 14 physiological and laboratory parameters, and it uses the highest severity values recorded during the first 24 hours of a patient's PICU admission. The score reflects the correlation between the number of impaired organ systems in the first 12-24 hours and the risk of mortality.
The risk of death is calculated through a logistic regression equation that factors in the PRISM score, the patient's age, and whether surgery was required at admission. Notably, the PRISM score is not significantly influenced by the patient's postoperative status. With its strong discriminatory ability and high predictive accuracy, the PRISM score is widely used in PICUs to assess the severity of illness and predict outcomes.

PRISM III, the third iteration of the score, was further validated by Popli et All. in 2018, and it continues to be a crucial tool in assessing pediatric patients in critical care settings.

Variables	**Age restrictions and Range**		**Score**
Systolic blood pressure in mm Hg	Infants 130-160 55-65 >160 40-54 < 40	Children 50-200 65-75 >200 50-64 <50	 2 6 7
Diastolic blood pressure in mm Hg	All ages >110		6
Heart rate in beats per minute	Infants > 160 <90	Children > 150 < 80	 4 4
Respiratory rate in breaths per minute	Infants 61-90 >90 apnea	Children 51-70 > 70 apnea	 1 5 5
PaO2/FiO2	All ages	200-300 <200	2 3
PaCO2 in torr (mm Hg)	All ages	51-65 >65	1 5
Glasgow coma score	All ages	<8	6
Pupillary reactions	All ages	Unequal or dilated Fixed and dilated	4 10
PT/PTT	All ages	1.5 times control	2
Total bilirubin mg/dL	>1 month	> 3.5	6
Potassium in mEq/L	All ages	3.0-3.5 6.5-7.5 < 3.0 > 7.5	1 1 5 5
Calcium in mg/dL	All ages	7.0-8.0 12.0-15.0 <7.0 >15.0	2 2 6 6
Glucose in mg/dL	all ages	40-60 250-400 <40 >400	4 4 8 8
Bicarbonate in mEq/L	all ages	<16 >32	3 3

Monitoring of vital signs (31)

Effective monitoring of critically ill patients is essential for successful critical care management. Both invasive and non-invasive monitoring devices have been developed to continuously assess the patient's vital signs and overall physiological status.

Non-Invasive Monitoring of Vital Signs

Non-invasive monitoring refers to techniques that assess vital signs without requiring penetration of the skin or invasive procedures. This approach is particularly important in clinical settings, especially in pediatrics and critical care, as it minimizes discomfort and reduces the risk of complications while still providing critical data on the patient's health. These methods are generally more comfortable for patients, especially children, because they avoid painful procedures; they also carry a lower risk of infection and other complications compared to invasive monitoring methods. Additionally, they are typically easier to implement and require less specialized training.

However, non-invasive methods also have certain limitations:

- Accuracy: Non-invasive measurements may be affected by factors such as patient movement, poor circulation, or ambient light.
- Delayed Response: Changes in vital signs may not be detected as rapidly as with invasive methods.
- Limited Information: Some severe conditions may require invasive monitoring for a more complete assessment.

The primary vital signs commonly monitored non-invasively include:

- **Heart Rate (HR)**: The number of heartbeats per minute, which provides insight into cardiovascular health.
- **Blood Pressure (BP)**: Measured using a sphygmomanometer, offering information about circulatory health.
- **Oxygen Saturation (SpO2)**: The percentage of oxygen in the blood, usually measured with a pulse oximeter.
- **Respiratory Rate (RR)**: The number of breaths per minute, reflecting respiratory function.
- **Temperature**: Typically measured using a non-contact thermometer or infrared sensor.

<u>Methods of Non-Invasive Monitoring:</u>

- Pulse Oximetry: A clip-like device placed on a finger or toe to measure oxygen saturation and pulse rate using light sensors.
- Automated Blood Pressure Cuffs: Devices that automatically inflate and deflate to measure blood pressure without the need for a healthcare provider to manually listen for sounds.
- Electrocardiogram (ECG): Non-invasive electrodes placed on the skin to monitor heart rhythm and rate.
- Capnometers: Devices that measure carbon dioxide levels in exhaled air, providing insights into respiratory function.

Invasive Monitoring of Vital Signs

Invasive monitoring involves the use of instruments that are inserted into the body to directly assess vital signs. This type of monitoring is critical in acute care and surgical settings, providing accurate, real-time data on the patient's physiological status. It is particularly useful when precise measurements are needed for timely interventions.

Invasive methods offer the advantage of providing continuous, real-time data that is often more accurate than non-invasive techniques. These methods also provide critical information that non-invasive approaches cannot, such as direct measurements of blood gases, intracranial pressure, and cardiac output.

However, invasive monitoring carries several risks:

- Infection: There is a risk of infection at the catheter insertion site.
- Hemorrhage: Invasive procedures can lead to bleeding, particularly if a blood vessel is inadvertently punctured.
- Thrombosis: The use of catheters can increase the risk of blood clots in veins or arteries.
- Discomfort: Patients may experience pain or discomfort from the insertion of invasive devices.

The primary vital signs typically monitored invasively include:

- Arterial Blood Pressure (ABP): Direct measurement of blood pressure within the arteries using a catheter.
- Central Venous Pressure (CVP): Pressure measurement in the central venous system, reflecting heart function and fluid status.

- Pulmonary Artery Pressure (PAP): Measured via a pulmonary artery catheter, providing insights into heart function and fluid balance.
- Cardiac Output (CO): The volume of blood the heart pumps per minute, often assessed using specialized catheters.
- Blood Gases: Direct arterial blood sampling to measure oxygen, carbon dioxide, and pH levels.

Methods of Invasive Monitoring:

- Arterial Catheters: Inserted into an artery (commonly the radial or femoral artery) to monitor blood pressure continuously and to allow blood gas sampling.
- Central Venous Catheters (CVCs): Inserted into a large vein (such as the jugular or subclavian vein) to monitor CVP and facilitate the administration of fluids and medications.
- Pulmonary Artery Catheters (Swan-Ganz Catheters): Used to measure PAP and CO, providing detailed information on cardiac function and fluid status.
- Intracranial Pressure (ICP) Monitors: Placed within the cranial cavity to monitor pressure inside the skull, essential for patients with head injuries or other neurological conditions.

Continuous Monitoring in the IMCU

In the Intermediate Care Unit, continuous monitoring of vital signs is essential for all patients. Each bed should be equipped with a bedside monitor capable of continuously monitoring the following parameters:

- Heart rate and rhythm, with arrhythmia detection.
- Respiratory rate.
- Body temperature.
- Hemodynamic pressure.
- Oxygen saturation (SpO_2).
- End-tidal CO_2 (if applicable).

Monitors must also have alarm systems that alert staff to any abnormal readings. These alarms should be both audible and visible, and the system should include high and low thresholds for heart rate, respiratory rate, and blood pressures. A permanent hard copy of the rhythm strip should be available for review.

To ensure patient safety, all monitors must undergo regular maintenance and testing to confirm that they are functioning properly and providing accurate data.

Respiratory support

Acute respiratory failure requiring respiratory support is one of the most common reasons for children to be admitted to critical care, and the use of respiratory support is a cornerstone of PICUs worldwide.

Acute respiratory failure is typically defined as a condition in which an infant or child presents with acute respiratory distress and either:

1. Acute hypoxia, requiring supplemental oxygen (fraction of inspired oxygen, FiO_2) to maintain an oxygen saturation (SpO_2) of $\geq 92\%$,
2. Acute hypercarbia, where the partial pressure of carbon dioxide ($PaCO_2$) exceeds 50 mmHg, often accompanied by an arterial pH of <7.35.

In clinical practice, however, healthcare providers often initiate interventions based on oxygen saturation levels and the observed degree of respiratory distress (such as severe tachypnea and retractions), even before obtaining blood gas measurements.

Oxygen therapy (32)

Oxygen therapy, also known as supplemental oxygen, is the administration of oxygen as a medical treatment to ensure adequate tissue oxygenation. The goal of oxygen therapy is to maintain sufficient oxygen levels in the body's tissues. The choice of device and the flow rate used for oxygen delivery must be tailored to the patient's size and clinical condition.

<u>Low-Flow Devices</u>

Low-flow oxygen delivery devices are the most commonly used in clinical practice. These devices deliver oxygen at a rate lower than the patient's natural inspiratory flow. The fractional concentration of oxygen (FiO_2) delivered by these devices can vary from 22% to 60% and depends on various factors, such as the patient's respiratory effort and the dilution of oxygen with ambient air during inhalation.

Types of Low-Flow Oxygen Delivery Devices

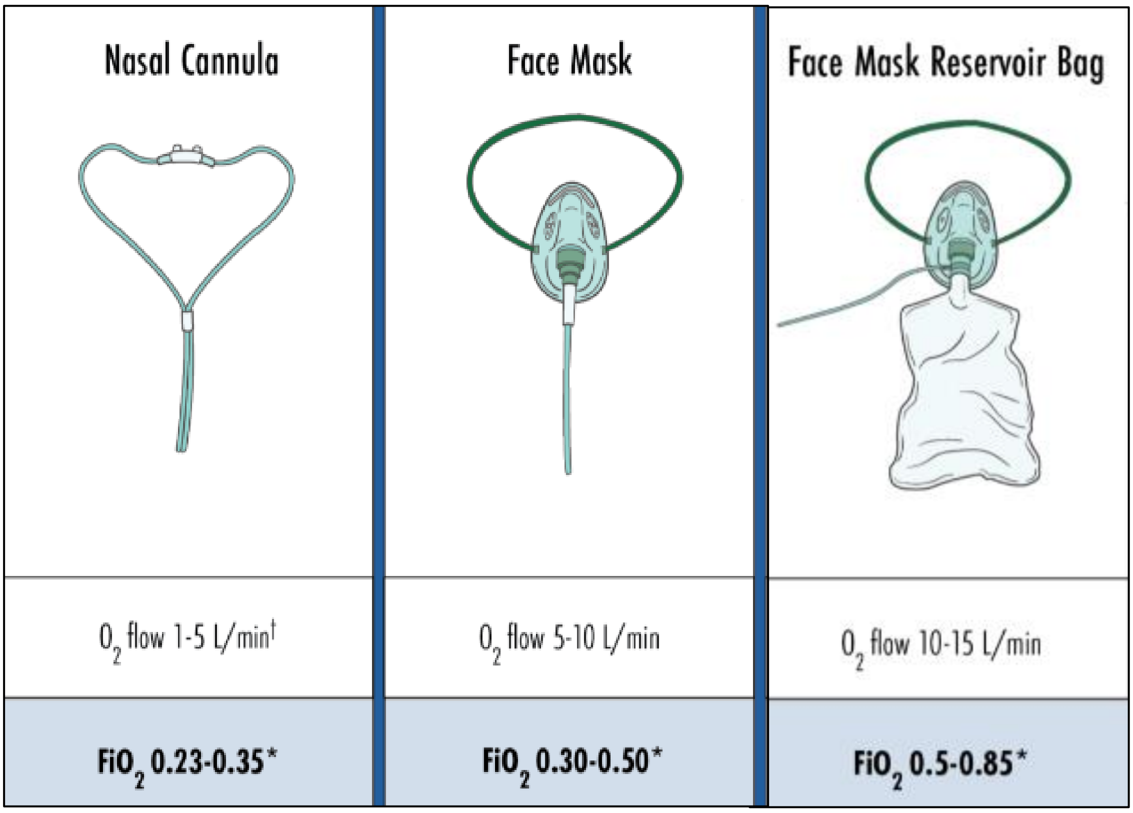
- Nasal Cannula: This is a flexible tube that delivers oxygen through small prongs that fit into the patient's nostrils. It is typically used for patients requiring low to moderate oxygen flow.
- Face Mask: The mask is placed over the patient's nose and mouth. It should be appropriately sized and secured with an elastic strap around the patient's head to prevent displacement, especially in younger or altered patients. The mask can be

uncomfortable for some, particularly if it is too tight or too loose, or if it irritates the eyes.

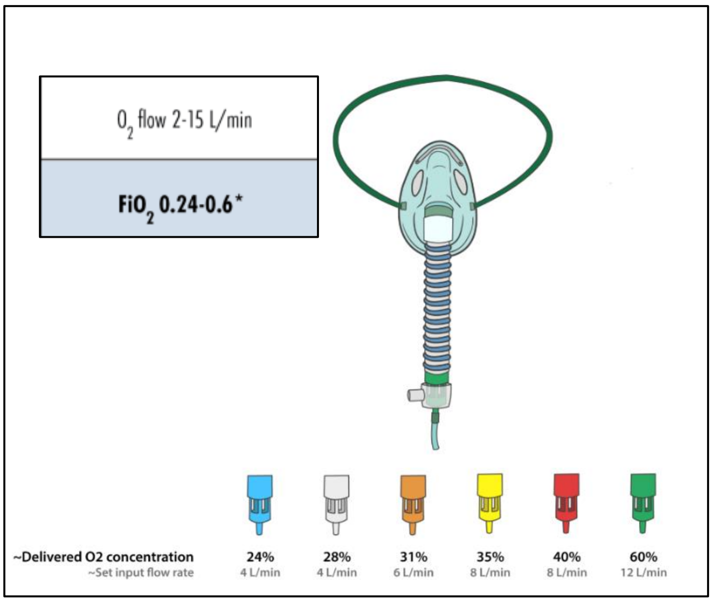
- Face Masks with Reservoirs: there are two main types of face masks with reservoirs, which allow for higher concentrations of oxygen delivery:

1. Non-Rebreather Mask:
   - This mask includes a one-way valve between the reservoir bag and the mask, preventing exhaled air from entering the reservoir.
   - The mask also has two one-way flutter valves on the exhalation ports to prevent the inhalation of room air.
   - These features prevent rebreathing of exhaled air, thereby maximizing the concentration of oxygen (FiO2) delivered to the patient, often achieving levels of 80-90% oxygen.
2. Partial-Rebreather Mask:
   - Similar to the non-rebreather mask, this mask also has a one-way valve between the reservoir bag and the mask to prevent exhaled air from entering the bag.
   - However, unlike the non-rebreather, the partial-rebreather mask does not have one-way valves on the exhalation ports. As a result, the patient can entrain room air during exhalation, which reduces the FiO2 delivered compared to a non-rebreather mask, but still provides a higher oxygen concentration than a simple face mask.

The appropriate selection of oxygen delivery method depends on the patient’s condition, required oxygen concentration, and comfort.



The Venturi mask, also known as an air-entrainment mask, is a medical device designed to deliver a precise, controlled concentration of oxygen to patients requiring oxygen therapy. Many Venturi masks are color-coded, with each color corresponding to a specific oxygen flow rate and a recommended FiO2 (fraction of inspired oxygen). When used with the prescribed flow rate, the mask ensures that the specified oxygen concentration is delivered to the patient.



High-Flow Nasal cannula oxygen (HFNC) (33) therapy is a fixed-performance oxygen delivery system designed to provide a specific oxygen concentration at flow rates that meet or exceed the patient's inspiratory flow demands. This high-flow system is increasingly used in both pediatric and adult critical care settings for respiratory support. HFNC therapy produces several clinical effects through different mechanisms:

- The bulk movement of gas delivered by HFNC reaches deep into the hypopharynx, helping to wash out carbon dioxide (CO2) and reduce anatomic dead space.
- The high-velocity gas flow into the nasal cavity helps to overcome inspiratory resistance, which in turn decreases the work of breathing.
- The high flow rates also generate a low level of positive pressure within the nasopharynx, potentially overcoming subtle upper airway obstruction.
- The conditioned gas—heated and humidified—helps improve mucociliary clearance and reduces the metabolic effort needed to warm and humidify the inspired air.
- Aerosol treatments and specialty gases, such as nitric oxide or helium-oxygen mixtures, can also be delivered via HFNC.

Components of HFNC

The HFNC system consists of:

- Oxygen and air blender: Connects to pressurized oxygen and air sources to achieve the desired oxygen concentration.
- Water reservoir: Attached to a heated humidifier, which ensures the gas is adequately humidified.
- Heated circuit: Maintains the gas at a constant temperature and humidity as it is delivered to the patient.
- Nonocclusive nasal cannula: The interface through which the conditioned gas is delivered.

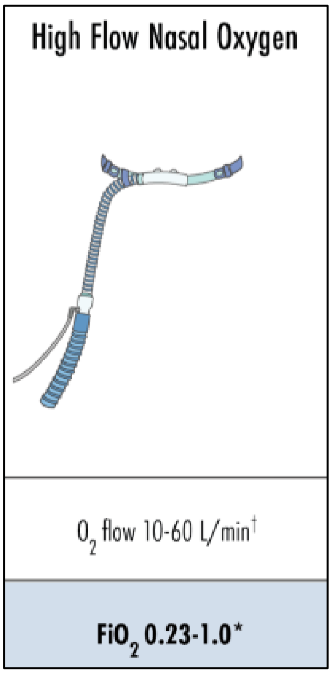
Settings and Parameters

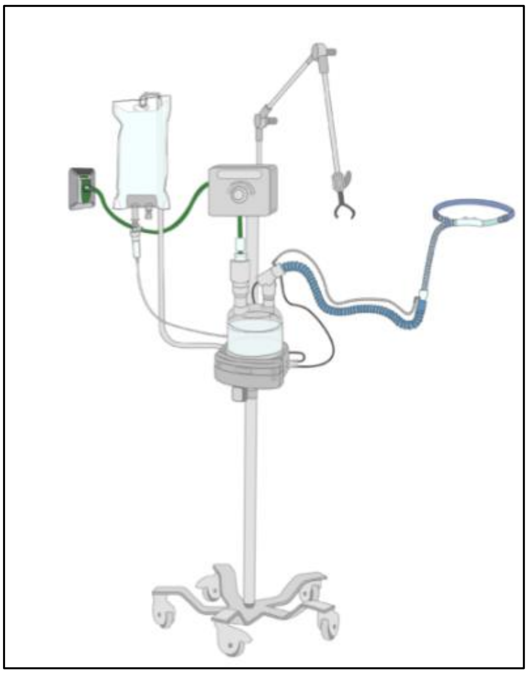
When initiating HFNC therapy, the clinician adjusts the following settings:

- Gas temperature: Typically set 1-2°C lower than body temperature for patient comfort.

- Fraction of inspired oxygen (FiO2): The FiO2 is selected based on the patient's needs and adjusted to target the desired peripheral capillary oxygen saturation (SpO2).
- Flow rate: Although there is no universally agreed-upon initial flow rate, weight-based flow dosing is commonly preferred, especially for infants, ranging from 1 L/kg/min to 2 L/kg/min. Flow rates above 2 L/kg/min generally do not offer additional clinical benefit.

HFNC therapy provides a well-tolerated, effective method of respiratory support, particularly in patients with respiratory distress, while reducing the need for more invasive interventions.





Mechanical ventilation

Mechanical ventilation is a medical intervention used to assist or replace spontaneous breathing in patients who are unable to breathe effectively on their own. It is commonly employed in critical care settings, to manage patients with respiratory failure, whether due to underlying diseases, trauma, or surgical recovery. (33).

Non-invasive respiratory support (NIV) (34) provides respiratory support without the need for an invasive airway device. It uses masks or nasal interfaces to deliver pressurized air or oxygen. NIV works by creating a positive pressure in the airway, so that the pressure outside the lungs is greater than the pressure inside the lungs. This pressure gradient forces air into the lungs, which reduces the effort required for breathing and helps decrease the work of respiration. In addition, NIV helps to maintain lung expansion by increasing the functional residual capacity (FRC)—the amount of air remaining in the lungs after a normal exhalation. This residual air, which remains in the alveoli, is crucial for efficient gas exchange.

NIV offers several advantages over invasive mechanical ventilation via an artificial airway, including:

- Reduced need for sedation
- Easier oral feeding
- Earlier mobilization
- Preservation of the natural cough reflex and pulmonary clearance
- Lower risk of ventilator-associated pneumonia (VAP)

However, one of the main challenges of NIV in children is ensuring tolerance of the interface and proper synchronization with the device, especially in cases of acute respiratory distress. In some cases, sedation may be required to help the child remain calm and achieve better outcomes.

Research supports the effectiveness of NIV in preventing intubation in pediatric patients. For instance, Fortenberry et All. (35) demonstrated a low incidence of intubation (11%) and significant improvement in oxygenation, ventilation, and dyspnea in children with hypoxemic respiratory failure treated with NIV. Pediatric intensivists often use NIV to facilitate the transition from invasive mechanical ventilation to non-assisted ventilation.

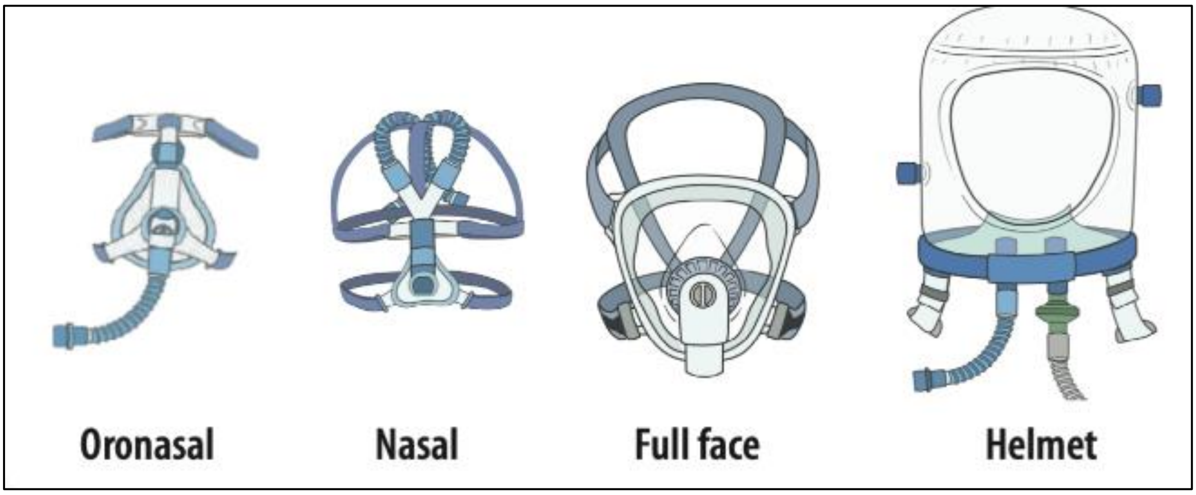
There are two main types of NIV:

Noninvasive Positive Pressure Ventilation (NIPPV)

This involves providing positive pressure during both inhalation and exhalation, supporting both ventilation and oxygenation.

The advantages of non-invasive ventilation (NIV) include unloading fatigued respiratory muscles, increasing or maintaining end-expiratory lung volume, preventing the collapse of peripheral small airways during exhalation, and reducing the overall work of breathing.

For effective delivery of NIV, it is crucial to use a well-fitted and properly sealed interface (e.g., nasal or full-face mask). A poor fit or air leakage around the interface can prevent the maintenance of the desired airway pressures and may cause discomfort for the patient. On the other hand, applying the interface too tightly can lead to skin irritation, breakdown, or pressure ulcers, particularly with prolonged use. Several types of patient interfaces are available for delivering positive pressure, each designed to provide a secure seal while minimizing discomfort and potential complications.



Non-invasive positive pressure ventilation (NIPPV) is delivered using two main modalities:

1. **Continuous Positive Airway Pressure (CPAP)**: This device delivers a constant, continuous positive pressure throughout the entire respiratory cycle while the patient breathes spontaneously. CPAP helps keep the airways open, reducing the work of breathing. The flow may be either fixed or variable, depending on the specific device used.
2. **Bilevel Positive Airway Pressure (BiPAP)**: BiPAP delivers different pressures for inspiration and expiration. The operator sets both the expiratory positive airway pressure (EPAP) and the inspiratory positive airway pressure (IPAP), as well as the fraction of inspired oxygen (FiO2). In BiPAP modes with mandatory breaths, the inspiratory time and the mandatory respiratory rate must also be specified. The tidal volume is directly influenced by the difference between the IPAP and EPAP. The IPAP enhances tidal volume by supporting inspiratory effort, while the EPAP helps maintain airway patency

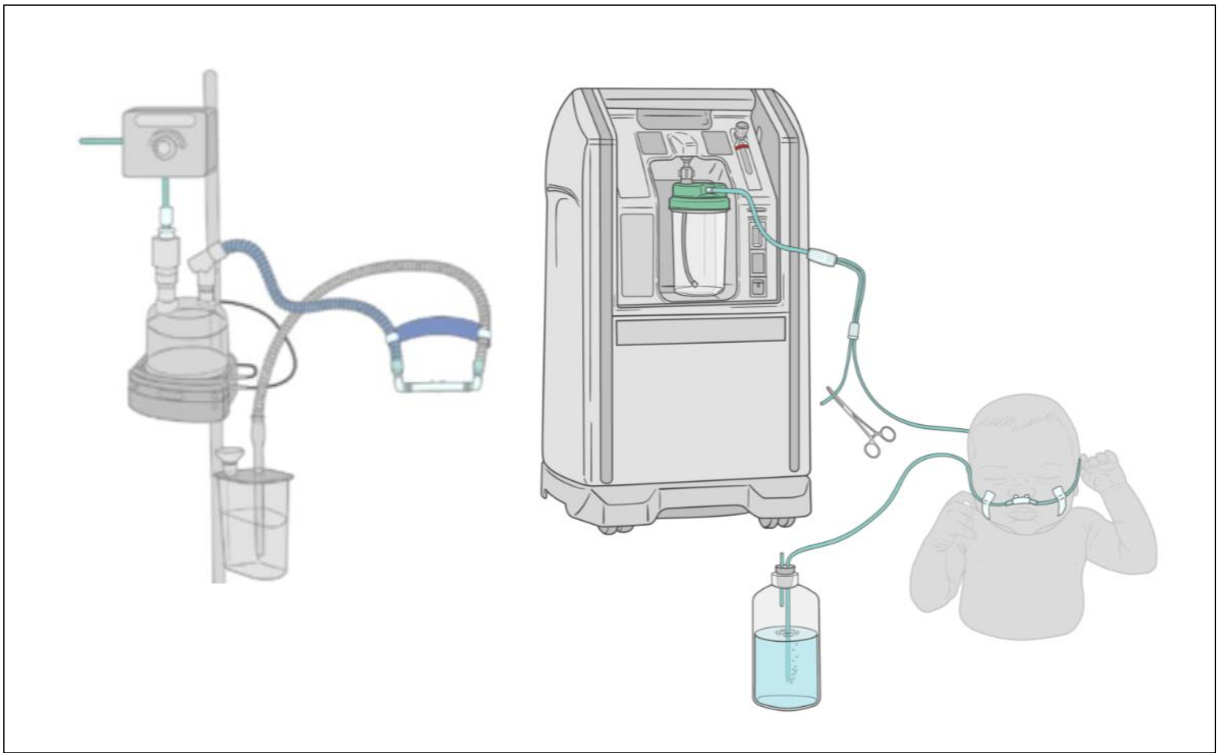
during expiration, prevents alveolar collapse (derecruitment), reduces fluctuations in intrathoracic pressure, and can improve patient-triggering synchrony with the ventilator. Each modality serves to optimize ventilation and reduce respiratory effort, but the choice between CPAP and BiPAP depends on the patient's clinical condition and the level of support needed.

Bubble CPAP (36)

Bubble CPAP is a form of non-invasive ventilation that delivers continuous positive airway pressure (CPAP) to a spontaneously breathing infant. In this method, oxygen that is blended and humidified is delivered through short binasal prongs or a nasal mask. The pressure in the circuit is maintained by immersing the distal end of the expiratory tubing into a water reservoir. The depth at which the tubing is submerged in the water controls the level of pressure generated in the infant's airways.

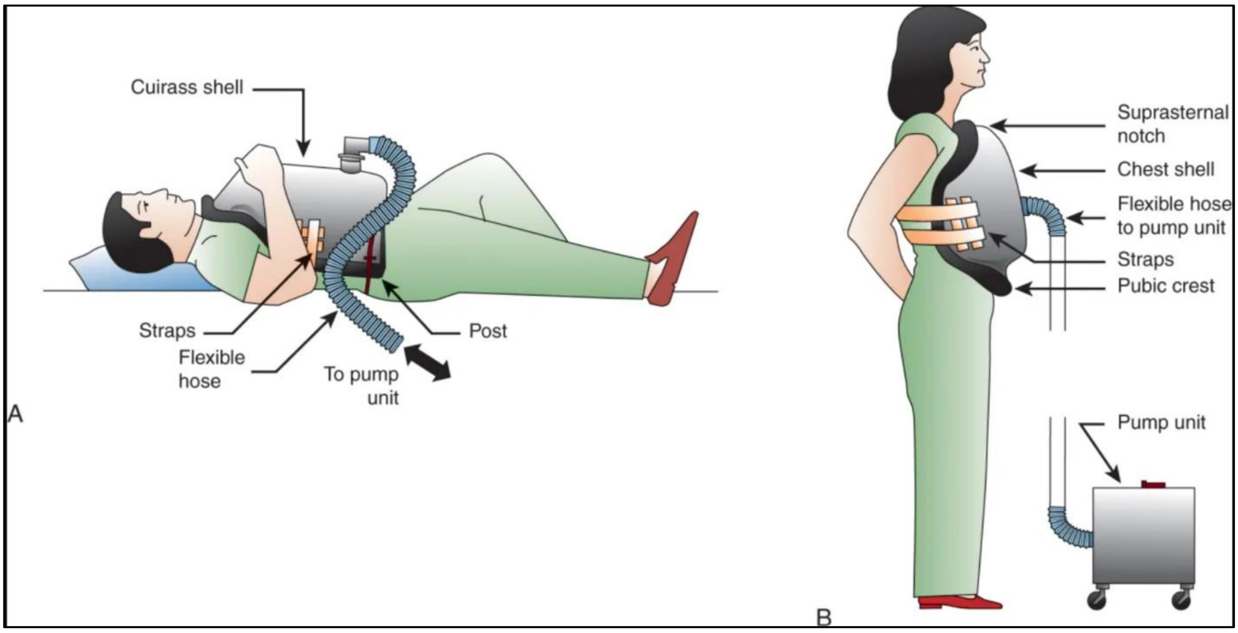
Bubble CPAP is primarily used in neonates, especially premature infants, to help maintain airway patency and support breathing. While it has been widely used in neonatal care, there is limited data on its effectiveness and safety in older children, particularly outside well-resourced settings, such as in low- and middle-income countries.

(37). In our reality, we recently started the utilisation of this devices with promising results.



Negative Pressure Ventilation (NPV)

It provides ventilatory support using a device that encases the thoracic cage, lowering the pressure surrounding the thorax, thus creating subatmospheric pressure which passively expands the chest wall to inflate the lungs. Exhalation occurs with passive recoil of the chest wall.

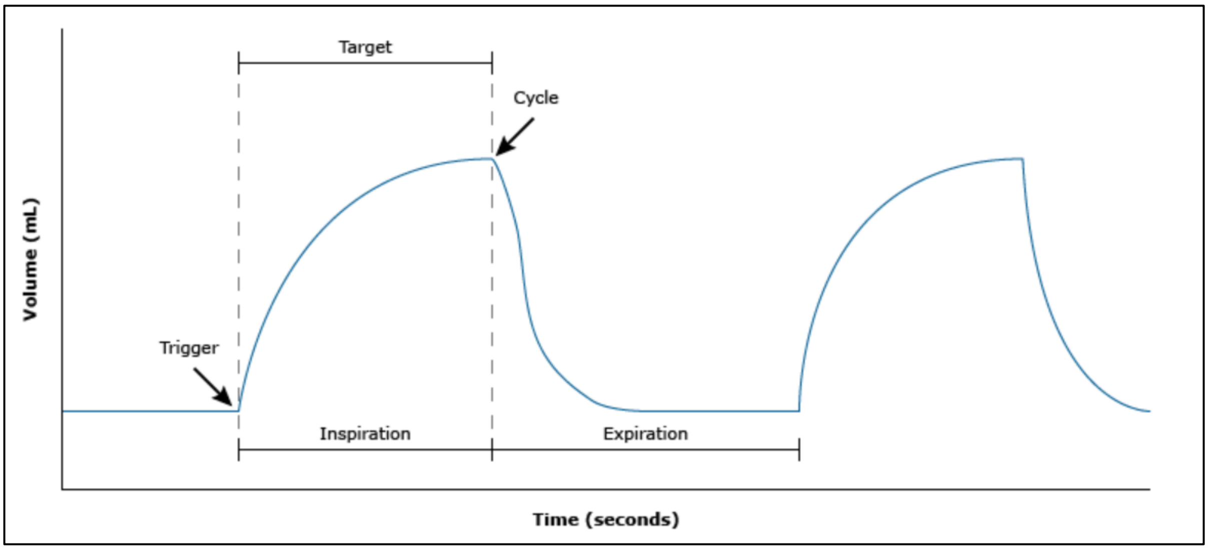


Invasive mechanical ventilation (33) involves providing ventilatory support through an endotracheal tube or tracheostomy. In this type of ventilation, there are two key parameters that must be set:

1. **Breath strategy**: This refers to whether the ventilator operates in **volume-controlled** or **pressure-controlled** mode. These strategies define how the ventilator delivers breaths and regulate the pattern of ventilation. In volume-controlled ventilation, a set volume of air is delivered with each breath, regardless of the pressure required to achieve that volume. In pressure-controlled ventilation, a set pressure is delivered, with the volume varying depending on the lung compliance and airway resistance.
2. **Modes of ventilation**: These describe the interaction between the ventilator and the patient, particularly how breaths are triggered, delivered, and cycled. Each breath involves three major physiological phases:

- **Trigger**: This determines how the ventilator initiates inspiration. The trigger can either be **time-triggered** (based on a set respiratory rate, i.e., the ventilator triggers the breath) or **patient-triggered** (initiated by the patient's own effort, i.e., the patient triggers the breath).
- **Target**: The target is the set parameter (either volume or pressure) that the ventilator aims to achieve during inspiration and should not be exceeded.
- **Cycle**: The cycle refers to the point when the ventilator switches from inspiration to expiration. This is usually determined by a set pressure, volume, or time.

In most ventilator modes, the trigger is either time-based (ventilator-triggered) or patient-based (patient-triggered), but the specific parameters for target and cycle will vary depending on the selected breath strategy and mode of ventilation.

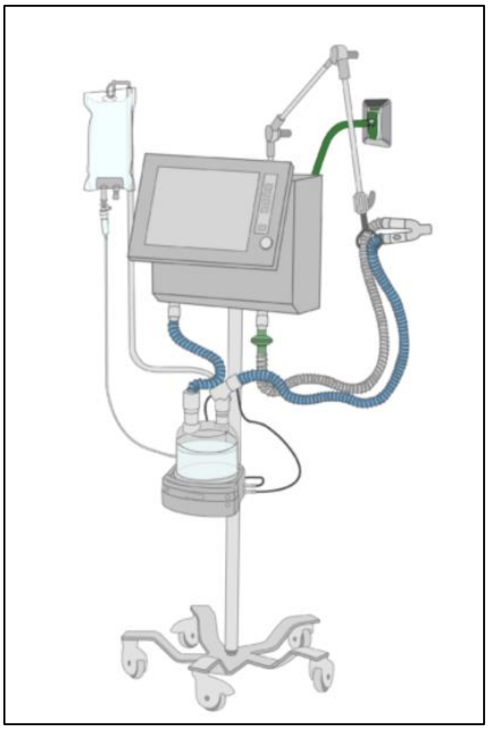


The description of the possibles modes is below the intention of this manuscript; we remand at Alibrahim et. All ((33) for further information.

Volume-Controlled Ventilation requires the clinician to set several parameters, including the flow rate, flow pattern, tidal volume, respiratory rate, positive end-expiratory pressure (PEEP), and the fraction of inspired oxygen (FiO2). In this mode, inspiration ends once the target tidal volume has been delivered. In other words, the trigger for the breath can

either be ventilator-initiated or patient-initiated, depending on the mode. The target is the volume to be delivered, while the cycle is determined by the volume reaching the preset target.
The inspiratory time and inspiratory-to-expiratory (I:E) ratio are influenced by the set inspiratory flow rate and the respiratory rate. Airway pressures—such as peak, plateau, and mean pressures—are influenced by both the ventilator settings and patient-specific factors, including lung compliance and airway resistance.

Pressure-Controlled Ventilation requires the clinician to set the inspiratory pressure level, I:E ratio, respiratory rate, PEEP, and FiO2. In this mode, inspiration ends once the preset inspiratory pressure is achieved over a defined inspiratory time, which is regulated by the I:E ratio. The target in pressure-controlled ventilation is pressure, the cycle is time-based, and the trigger can either be ventilator-initiated or patient-initiated, depending on the mode. In pressure-controlled ventilation, the tidal volume is variable and depends on several factors: the set inspiratory pressure, lung compliance, chest wall compliance, and airway resistance (including the resistance of the ventilator tubing). Importantly, the inspiratory airway pressure remains constant during pressure-controlled ventilation. This pressure is the sum of the set inspiratory pressure and the applied PEEP.



SatO2/FiO2 Index

The traditional definition of hypoxia is based on the PaO2/FiO2 (P/F) ratio, with a ratio of ≤300 indicating acute lung injury (ALI) and a ratio of ≤200 indicating acute respiratory distress syndrome (ARDS). However, recent studies (38) have shown that non-invasive methods of oxygenation assessment, such as using pulse oximetry to estimate SpO2, can effectively replace the PaO2 measurement as a surrogate for diagnosing ALI and ARDS, particularly in children. The SpO2/FiO2 (S/F) ratio can be used as a substitute for the PaO2/FiO2 ratio with sufficient sensitivity and specificity to assess the severity of acute respiratory insufficiency. For example, an S/F ratio of 253 corresponds to a P/F ratio of 300, while an S/F ratio of 212 corresponds to a P/F ratio of 200.This concept have been confirmed by Khemani et All. (39) who demonstrated that lung injury severity markers that use SpO_2 are adequate surrogate markers for those that use PaO2 as long as SpO_2 is between 80% and 97%.

Based on these results, the "Pediatric Acute Lung Injury Consensus Conference" guidelines (40) ow include the S/F ratio as part of the definition of ARDS in children, particularly for those supported by CPAP/BiPAP with a minimum CPAP of 5 cm H2O.

Age	Exclude patients with peri-natal related lung disease			
Timing	Within 7 days of known clinical insult			
Origin of Edema	Respiratory failure not fully explained by cardiac failure or fluid overload			
Chest Imaging	Chest imaging findings of new infiltrate(s) consistent with acute pulmonary parenchymal disease			
Oxygenation	**Non Invasive mechanical ventilation**	**Invasive mechanical ventilation**		
	PARDS (No severity stratification)	Mild	Moderate	Severe
	Full face-mask bi-level ventilation or CPAP ≥5 cm H_20 [2] PF ratio ≤ 300 SF ratio ≤ 264 [1]	4 ≤ OI < 8 5 ≤ OSI < 7.5[1]	8 ≤ OI < 16 7.5 ≤ OSI < 12.3[1]	OI ≥ 16 OSI ≥ 12.3[1]
Special Populations				
Cyanotic Heart Disease	Standard Criteria above for age, timing, origin of edema and chest imaging with an acute deterioration in oxygenation not explained by underlying cardiac disease. [3]			
Chronic Lung Disease	Standard Criteria above for age, timing, and origin of edema with chest imaging consistent with new infiltrate and acute deterioration in oxygenation from baseline which meet oxygenation criteria above.[3]			
Left Ventricular dysfunction	Standard Criteria for age, timing and origin of edema with chest imaging changes consistent with new infiltrate and acute deterioration in oxygenation which meet criteria above not explained by left ventricular dysfunction.			

Medical devices

A medical device is any device intended to be used for medical purposes. A lot of patients, especially those affected by complex diseases, use devices that help them in everyday life and in the treatment of their pathologies. Medical devices vary in both their intended use and indications for use.

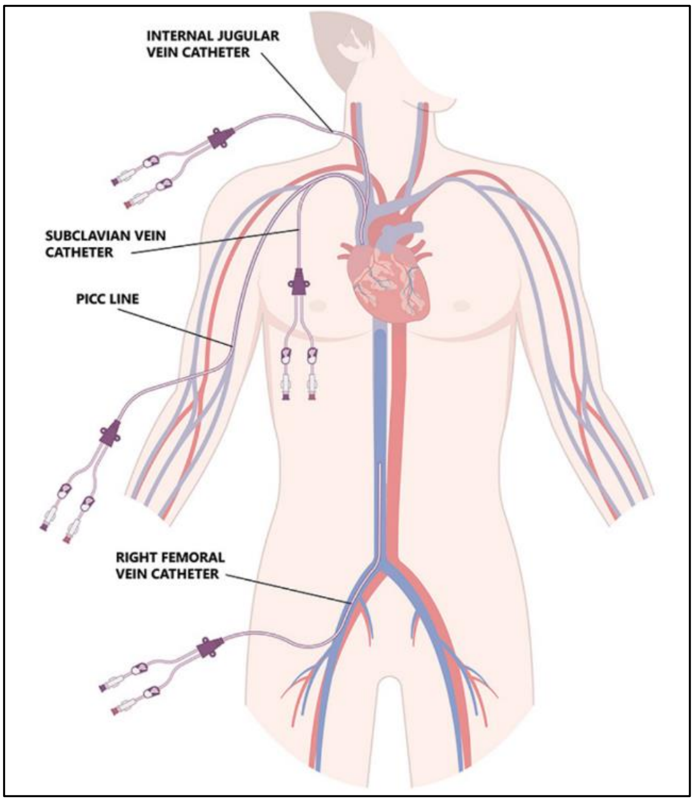
Central venous catheter (CVC) (41)

The central venous catheter (CVC) is a type of vascular access device inserted into a large, central vein—typically the internal jugular, subclavian, or femoral vein—and advanced until the catheter's tip resides in the inferior vena cava, superior vena cava, or right atrium. This allows for the administration of medications and fluids, collection of blood samples, and minimizes the need for repeated venipunctures.

CVCs are often referred to as "central lines" and may also be known by brand names such as Broviac, Hickman, and Port-a-Cath.

The use of long-term CVCs for managing chronic medical conditions in infants and children has significantly enhanced the quality and safety of care. Various access techniques and devices have been developed for a range of medical indications, including the administration of total parenteral nutrition (TPN), dialysis, plasmapheresis, medications, hemodynamic monitoring, and for facilitating more complex procedures, such as transvenous pacemaker placement.

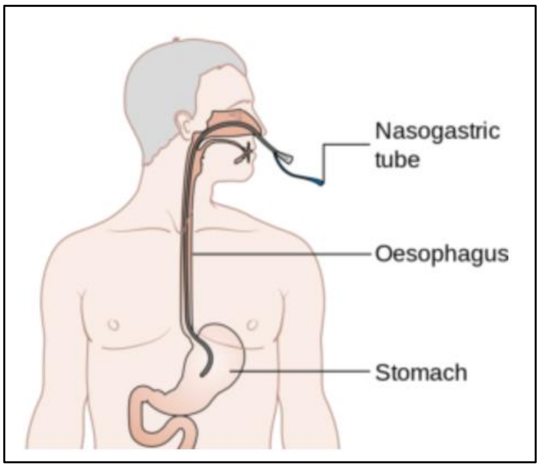
Long-term CVCs are typically used when intravenous medication or nutritional support is needed over an extended period. Certain hypertonic medications—such as vesicant chemotherapy drugs, specific antibiotics, and parenteral nutrition—cannot be safely administered through peripheral venous catheters. For children with cancer or other chronic conditions requiring such treatments, a CVC provides a safer alternative, often remaining in place throughout the course of treatment.



Gastric tube

A gastric tube is a flexible tube inserted either through the nose or mouth directly into the stomach. When inserted through the nose, it is called a nasogastric tube (NG tube); when inserted through the mouth, it is referred to as an orogastric tube. The tube passes through the esophagus and into the stomach.

Gastric tubes are commonly used for several purposes, including stomach decompression in cases of intestinal obstruction or ileus, as well as for administering nutrition or medication to patients who are unable to tolerate oral intake.

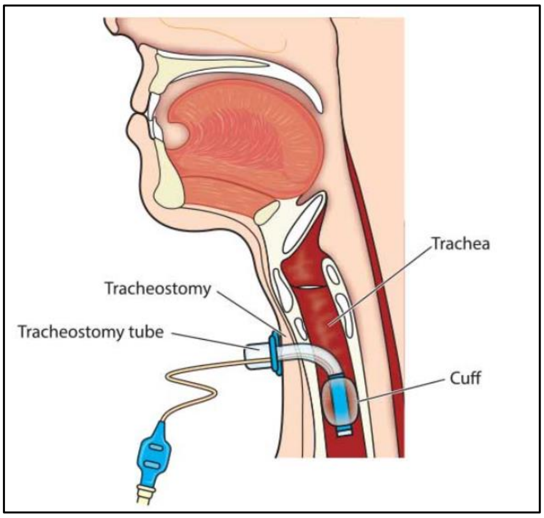


Tracheostomy (42)

A tracheostomy is a surgical procedure that creates an opening in the trachea (windpipe). This opening is kept open by inserting a tracheostomy tube— a short, curved device typically made of soft plastic or silicone— through the front of the neck into the windpipe. The tube is secured in place with a soft strap that wraps around the neck.

Pediatric tracheostomy tubes are most commonly used for three main reasons:

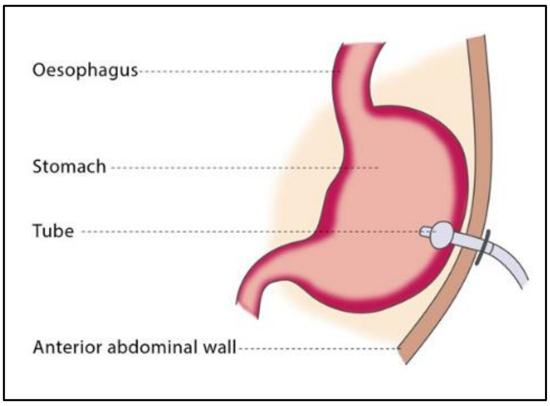
1. To provide a stable airway for children with a narrow or collapsing upper respiratory tract.
2. To enable long-term respiratory support through a ventilator (breathing machine) for children who are unable to breathe on their own due to conditions such as prematurity, severe illness, or trauma.
3. To facilitate the passage of a suction tube into the windpipe, making it easier to remove mucus, saliva, food, or liquids that may enter the airway during swallowing.



Gastrostomy

A gastrostomy is a surgical procedure that creates an opening in the stomach wall, connecting the stomach directly to the skin through the abdominal wall. The anterior stomach wall is typically brought into contact with the parietal peritoneum using sutures and/or the feeding tube itself. This forms a planned gastrocutaneous fistula, which is the most common method of long-term enteral access performed by surgeons.

Gastrostomy is often preferred for long-term feeding because it minimizes patient discomfort, avoids the irritation associated with nasal feeding tubes, and eliminates the need for frequent tube replacements due to clogging or accidental dislodgement. The procedure can be performed through various approaches, including surgical, percutaneous (via interventional radiology), percutaneous endoscopic gastrostomy (PEG), or percutaneous ultrasound gastrostomy techniques.



Ileostomy

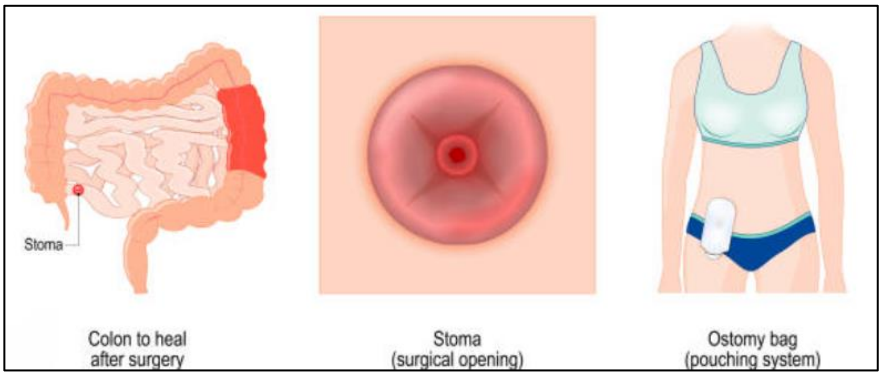
An ileostomy is a surgically created opening (stoma) in the abdomen that allows the end or loop of the ileum (the last part of the small intestine) to be brought to the surface of the skin. Waste from the intestine is then passed through the ileostomy and collected in an external ostomy system, which is secured over the stoma. Ileostomies are typically located above the groin, on the right side of the abdomen.

Ileostomies are usually necessary when injury or surgery has compromised the large intestine's ability to process waste, often due to the partial or total removal of the colon and rectum.

There are two main types of ileostomies:

1. End ileostomy: This is typically a permanent solution. In this procedure, the end of the ileum is everted (turned inside out) to form a spout, and the edges of the ileum are sutured under the skin to secure it in place.
2. Temporary or loop ileostomy: In this procedure, a loop of the ileum is brought through the skin to create a stoma, while the lower part of the ileum remains intact to allow for future reattachment. This type of ileostomy is often used when the colon and rectum have not been fully removed but need time to heal. It is also commonly created as the first stage of an ileo-anal pouch surgery, allowing the bowel to heal before waste can enter the newly constructed pouch, which is typically left to heal for eight to ten weeks.

Once the healing process is complete, the temporary ileostomy is reversed (or "taken down") by surgically closing the skin incision and reconnecting the loop of intestine.
Patients with ileostomies use an ostomy pouch to collect waste. The most commonly used pouches are drainable one- or two-piece systems, which are secured with a leak-proof clip or Velcro fastener at the bottom. These pouches typically need to be emptied five to eight times a day. An alternative option is a closed-end pouch, which must be discarded once it is full.

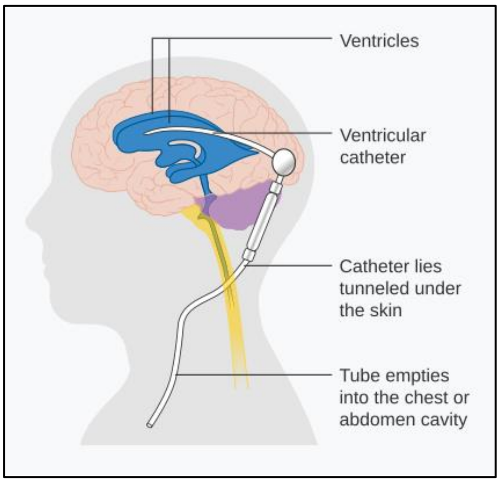


Cerebral shunt

A shunt is a medical device implanted into the brain's ventricle to drain excess cerebrospinal fluid (CSF) in patients with hydrocephalus—a condition characterized by an abnormal buildup of CSF, leading to an increase in brain volume. The shunt typically consists of a valve and two catheters. Its primary purpose is to redirect the excess fluid to other areas of the body where it can be absorbed, thereby relieving pressure on the brain. The distal end of the catheter can be placed in various parts of the body, where there is sufficient tissue to absorb the fluid. Some common types of shunts include:

- External shunt: The CSF is drained and collected outside the body, typically in an external collection bag.
- Atrial shunt: The CSF is directed into the right atrium of the heart, where it is then absorbed into the bloodstream.
- Peritoneal shunt: The CSF is drained into the peritoneal cavity (the space within the abdomen), where it is absorbed by the peritoneal lining.

These shunts help manage the fluid buildup, reducing the risk of damage to the brain and improving the patient's quality of life.


Ventricles
Ventricular
catheter
Catheter lies
tunneled under
the skin
Tube empties
into the chest or
abdomen cavity

Study objectives

The general aim of our study is to explore the demographic, clinical, and laboratory characteristics at the time of admission to the Pediatric Intermediate Care Unit (IMCU) of a tertiary academic institute.

In particular, we aimed to:

1. Describe the characteristics of patients managed in a newly established pediatric IMCU
2. Compare the characteristics of patients who required transfer to Pediatric Intensive Care (PICU) with those who did not.
3. Evaluate the presence of any factors at the time of admission that may predict the further transfer of patients to PICU.

Chapter 2

Patients and methods

Study design

We conducted a retrospective observational single-center cohort study.

Study setting

IRCCS Gaslini is a tertiary care freestanding children's hospital with a level one pediatric trauma center, serving a region of 1.5 million inhabitants in the North West of Italy, but with a catchment area extended to the whole Nation and many European and foreign countries for highly specialized medical and surgical pediatric care.

The hospital has 328 pediatric beds, and it is equipped with an 18–20-bed-level IV pediatric ICU with critical care transport and extracorporeal mechanical oxygenation (ECMO) retrieval capability.

In 2020, during the COVID-19 pandemic, at the Gaslini Institute, a new pediatric IMCU was established, managed by pediatricians who work in close connection with the team of intensive care, making use of the different specialist figures present within the hospital. The IMCU functions as a standalone unit collocated near the pediatric ICU, functioning as an adjacent but separate unit from PICU.

In terms of equipment, the IMCU is provided with emergency carts, a point-of-care blood gas analyzer, an electrocardiograph, infusion and enteral nutrition pumps, devices for non-invasive respiratory support, a dedicated system for point-of-care ultrasonography, aspiration systems, devices for the delivery of medical gases and emodialisis predisposition.

It is designed with twelve beds, all equipped with single rooms and an anteroom, with HEPA filters, and in seven of them, there is the possibility to create negative pressure. Admission to negative-pressure rooms is primarily reserved for patients with a high risk of transmission as those requiring ventilation support. One parent is allowed to care for the child 24/7 in the room and has his bed. In IMCU all rooms have a multiparameter monitor connected to a control station located in the nurse's room and could be transformed into an ICU room in case of patients' worsening, escalating care up to ECMO. In this case, the ICU medical and nursing staff took over the leadership, bringing all the necessary materials (e.g., ventilators, ECMO pumps, hemodialysis systems) without moving the patient.

Eight physicians cover the IMCU 24/7, two/three of them at once daily (8 a.m.- 8 p.m.), and one during the night (8 p.m.- 8 a.m.). All clinicians in the IMCU are pediatric emergency medicine specialists, with extensive experience in the treatment of severely ill children in the Emergency Department (ED) and with a master's degree in pediatric intensive care. As for the medical team, a new nursing team was assembled. Four nurses are present on day shifts and three at night, with a variable 1:3–1:4 nurse-to patient ratio. The head nurse came from the PICU and provided all the necessary training and supervision with the aid of a senior nurse with an emergency medicine background.

Patients admitted to the IMCU can come from (Table 3):

- The Emergency Department of the Gaslini Institute
- Another general ward in the hospital or directly from another pediatric hospital in a process of care intensification
- The operating rooms
- The PICU during the step-down phase of care

Patients can be transferred to the PICU if further intensification of care is needed, or to general wards if clinical stability is achieved, or they may be directly discharged home if conditions permit. The admission and discharge criteria for the IMCU (Table 3) were developed with input from multiple stakeholders and reflect the availability of resources and clinical experience.

Table 3. Patients were admitted to Pediatric IMCU in case of:
- Acute or acute-on-chronic respiratory failure with a low risk of requiring intubation including patients with a need for NIPPV, patients with a tracheostomy with or without a ventilator, and patients with impaired airway clearance requiring frequent suctioning - Non-life-threatening cardiovascular disease, including cardiac dysrhythmias without the need for cardioversion - Hypotension /need for non-invasive blood pressure monitoring

- Seizures/epilepsy, acute encephalopathy, or acute inflammation/infection of the central nervous system requiring continuous cardiorespiratory monitoring but with low risk for cardiac arrest or intubation - Anemia or thrombocytopenia or gastrointestinal bleeding requiring acute transfusions and close monitoring without significant hemodynamic compromise - Signs of acute infection/sepsis without the need for inotropic drugs - Electrolyte disturbances requiring intravenous replenishment and frequent laboratory monitoring - Acute or acute-on-chronic hypertension without any new neurologic sequelae - Acute renal failure who do not require continuous renal replacement therapy - Need for continuous monitoring of diuresis and fluid balance - Palliative care patients requiring continuous infusions to treat end-of-life dyspnea or anxiety - Extubated postoperative patients after major surgery - Other needs for close cardiorespiratory monitoring and/or frequent clinical reassessment
Patients were transferred to low-intensity care units when clinical conditions returned to baseline status and the management complexity was compatible with policies of the receiving unit

Study cohort

We included all patients (without age limits) admitted to the IMCU of the Giannina Gaslini Hospital in Genoa from 01/01/2022 to 30/06/2023.

When patients had multiple IMCU admissions, each was reported as a separate encounter.

The following data were collected from patients included in the study:

- **Demographic Data:** Name, age, gender, date of admission
- **Patient Origin:** Emergency Department, pediatric/neonatal Intensive Care Unit, general ward, another hospital, operating room, own home
- **Main Reason of Admission:** Categorized based on the relevant subspecialty.

  In particular, twelve groups of pathologies were created:

  • Respiratory

• Cardiac
• Infection
• Neurologic and/or Psychiatric
• Hemato-oncologic
• General or specialized surgical (orthopedic, neurosurgic, otorhinolaryngologic, etc.)
• Gastroenterologic
• Nephro-urologic
• Endocrinologic
• Immunologic/inflammatory
• Continuation of care
• Other

- **Presence of Pre-existing Conditions:** Categories were also created to define their relevant subspecialty:
  • Respiratory
  • Cardiac
  • Infectious
  • Neurological and/or Psychiatric
  • Gastroenterological
  • General or specialized surgical (orthopedic, neurosurgical, otorhinolaryngological, etc.)
  • Nephro-urological
  • Hemato-oncological
  • Endocrinologic
  • Immunological/inflammatory
  • Metabolic
  • Prematurity
  • Other

  Patients suffering from more than one conditions have been counted in more than one category.
- **Vital Parameters at Admission:** Arterial oxygen saturation, body temperature, blood pressure (systolic and diastolic), heart rate (HR), and respiratory rate (RR).

The last three parameters listed were compared to their respective age-specific reference ranges as stated in the 2021 guidelines of the European Resuscitation Council.

- **Laboratory Data at Admission:** White blood cell count, platelet count, hemoglobin, creatinine, albumin, lactate, and inflammatory markers (C-reactive protein, procalcitonin)
- **PEW Score** (20) **at Admission:** Calculated by nursing staff
- **Presence of Any Devices:**

  • Tracheostomy

  • Non-invasive ventilation

  • Gastrostomy/ileostomy

  • Nasogastric/orogastric tubes (NG/OG)

  • Central venous catheter (CVC)

  • Cerebrospinal fluid shunt (ventriculoperitoneal, ventriculoatrial, external)

  • Chest/abdominal drainage

  • Peritoneal dialysis catheter

  • Other

  Patients having more than one device have been counted in all the devices they had.
- **Presence of Respiratory Support:** low-flow or high-flow oxygen therapy, non-invasive mechanical ventilation, invasive mechanical ventilation via tracheostomy, Venturi mask; and FiO2 administered
- **Length of Stay (LOS):** Duration in days in the unit
- **Outcome:** The patient's destination at the end of the stay in Intermediate Care (discharge home, transfer to a lower intensity care unit, transfer to PICU, death)

Data were collected using the electronic records available at the Giannina Gaslini Hospital.

Statistical analysis

To analyse data, a descriptive analysis was first conducted, reporting measures of central tendency (mean or median) and dispersion (standard deviation or interquartile range) for continuous variables, and absolute and relative frequencies for categorical variables. The choice between mean and median was made based on the distribution of the variables (whether normal or nonnormal), assessing the presence of skewness or outliers. To assess the association between risk factors and outcome (admission to intensive care unit-PICU), comparisons were made between the two groups of patients. The choice of statistical test was based on the type of variable and the distribution of data. For continuous variables, Student's t test for independent samples was preferred, assuming normality of the distribution, while for nonparametric variables, Mann-Whitney's U test was used. For categorical variables, the chi-square test (or Fisher's exact, depending on the count and distribution of the variables) was used. The association between outcomes and a number of potentially variables was also assessed by binomial logistic regression in which variables significant to the univariate analysis were considered for the multivariate.

Chapter 3

Results

A total of 929 patients were included in the study, all admitted to the Intermediate Care Unit of the Giannina Gaslini Hospital during the examined period.

Baseline data

The patients' baseline data are summarized in Table 4.

The median age was 4 years and 1 month (range 0-64 years old), with a prevalence of male patients (516, 55.6% vs. 413, 44.4%).

Most patients came (Figure 2) from the Emergency Department (595 children, 64%), followed by those transferred from a general ward (in the same hospital or from another hospital) (190, or 20.5%). Patients transferred from the Intensive Care Unit were 99, representing 10.7% of the total.

The most common admission criterion (Figure 3) was a respiratory problem (241, 25.9%), followed by neurologic condition (178, 19.2%), infectious and hemato-oncologic causes.

628 (67.5%) children had a pre-existing condition. Among them, the most frequent were represented by neurological (16.9%) and hemato-oncological (12.8%) diseases.

Regarding outcomes (Figure 4), the majority of patients (512, 55.1%) were transferred to a lower intensity care unit, 360 (38.7%) were directly discharged home, 53 (5.7%) were admitted to PICU for a worsening of the conditions, and finally 4 (0.4%) were discharged home against medical decision.

The median length of stay in IMCU was 4 days (IQR 5). 11 (1.2%) died within 28 days from IMCU discharge.

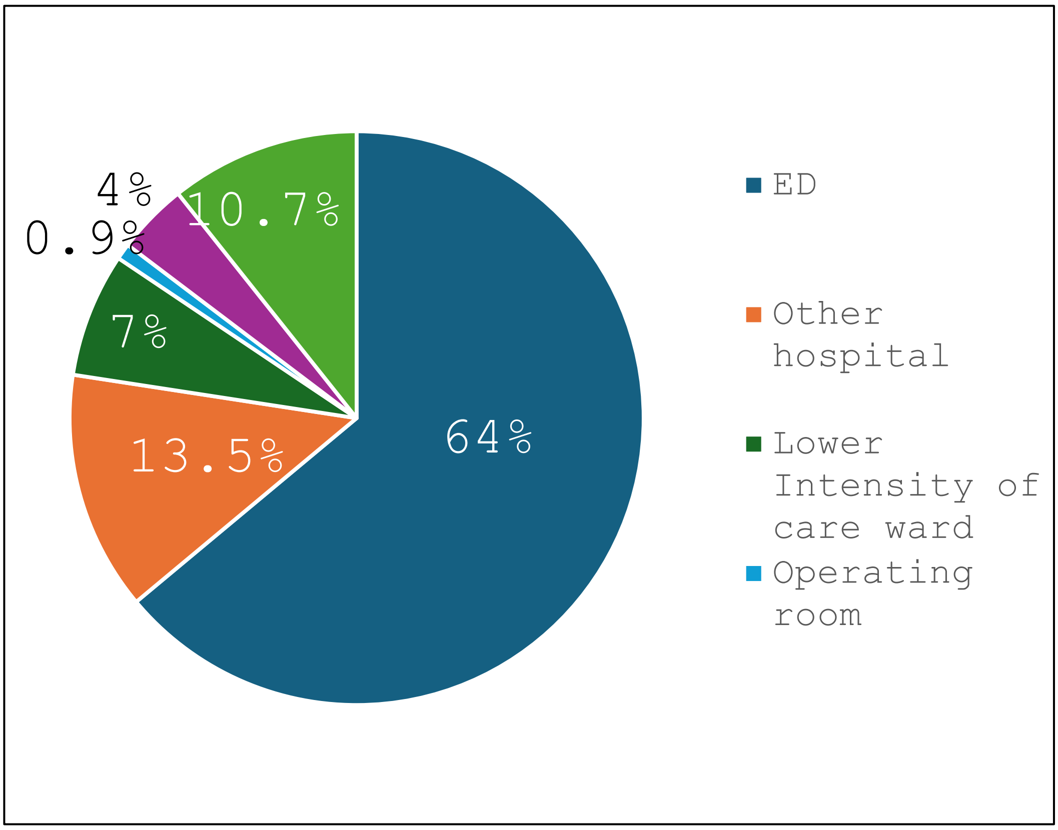


Figure 2. Department of origin

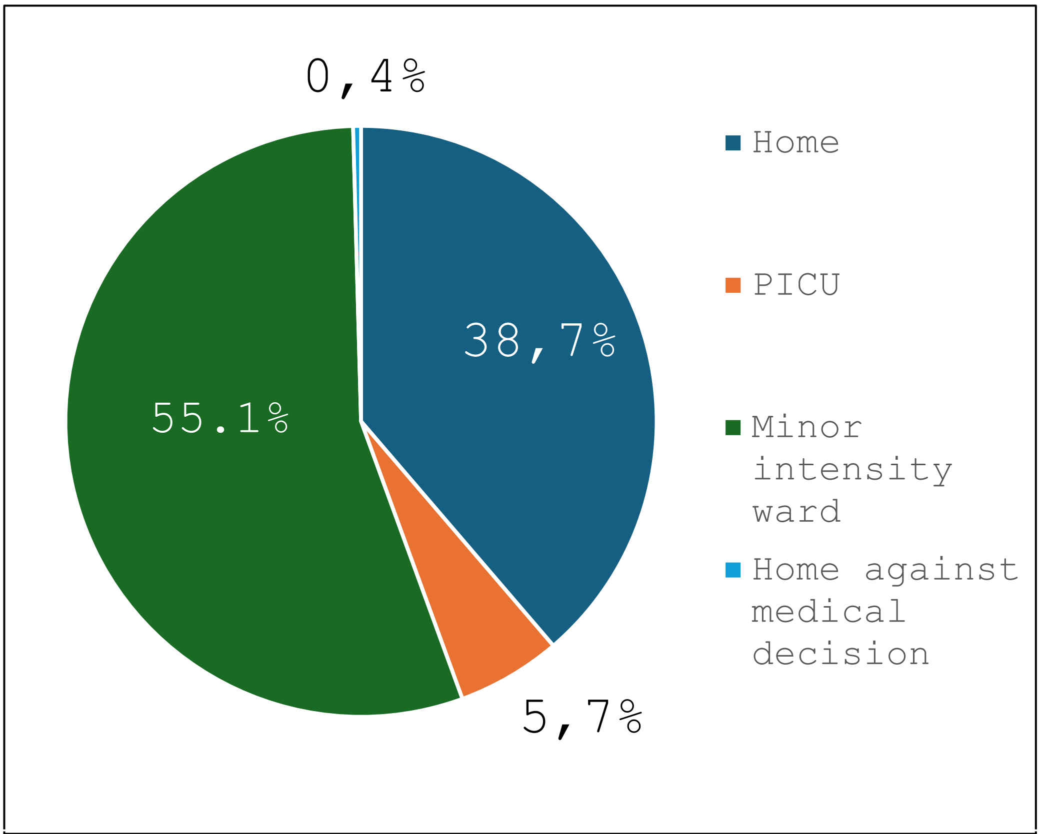


Figure 4. Outcomes

Table 4. Baseline data of the patients admitted to IMCU	
	n = 929 total
Sex, n (%)	
Female	413 (44.4)
Male	516 (55.6)
Age in months, median (IQR)	49 (123)
Main reason of admission, n (%)	
Respiratory	241 (25.9)
Cardiac	54 (5.8)
Infection	127 (13.7)
Neurologic and/or Psychiatric	178 (19.2)
Hemato-oncologic	101 (10.9)
General or specialized surgical	76 (8.2)
Gastrointestinal	47 (5.1)
Nephro-urologic	11 (1.2)
Endocrinologic	15 (1.6)
Immunologic/inflammatory	19 (2)
Continuation of care	13 (1.4)
Other	47 (5.1)
Pre-existing Conditions, n (%)	
Any	628 (67.5)
Respiratory	54 (5.8)
Cardiac	71 (7.6)
Infection	14 (1.5)
Neurologic and/or Psychiatric	157 (16.9)
Gastrointestinal	29 (3.1)
General or specialized surgical	43 (4.6)
Nephro-urologic	27 (2.9)
Hemato-oncologic	119 (12.8)
Endocrinologic	21 (2.3)
Immunologic/inflammatory	16 (1.7)
Metabolic	45 (4.8)

Prematurity	54 (5.8)
Other	87 (9.4)
Outcome	
Length of stay in days (median, IQR)	4 (5)
Deceased within 28 days, n (%)	11 (1.2)

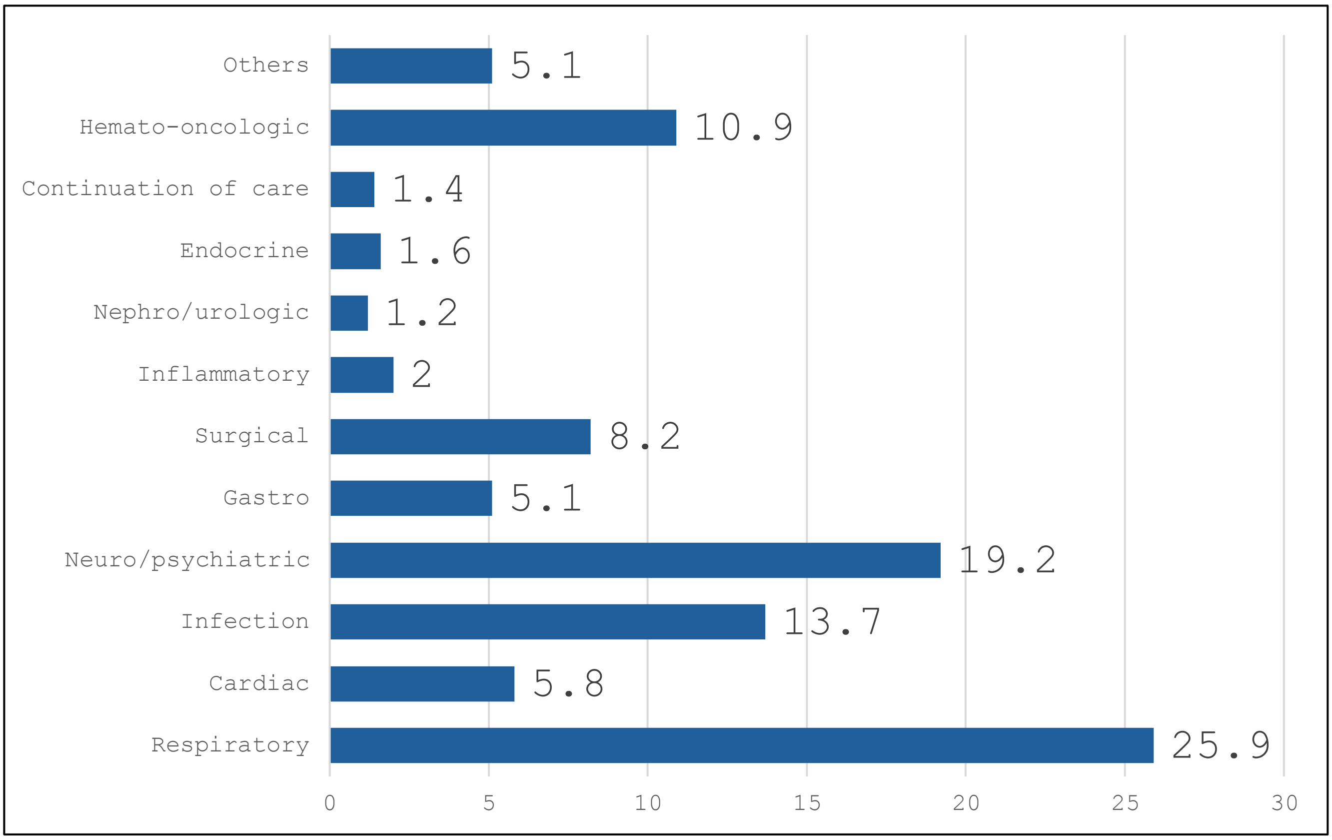


Figure 3. Main reason of IMCU admission

Clinical data

The PEW score filled by nurses on admission was lower (0-2) in 744 (93.7%) people, medium (3-4) in 44 (5.5%) patients, and score 5 or above in 6 (0.8%) people.

Regarding vital signs, the majority of people was apyretic (72.8%), only the 3.7% was hypotensive (comparing values with those expected for age); the median heart rate was 123bpm (IQR 49), 15.5% were tachycardic and 2.1% were bradycardic. The median respiratory rate was 27rpm (IQR 14), 23.8% were tachypnoeic and 16.9% were bradypnoic. The median S/F ratio was 471 (IQR 19).

215 out of 929 (23.1%) patients had a respiratory support on admission in IMCU; of them, 132 (61.1%) were supported by HFNC, 60 (27.8%) by low-flow oxygen therapy, 17 (7.9%) by NIV and 7 (3.2%) by invasive mechanical ventilation.

307 out of 929 had one or more devices, of whom 155 (16.7%) had central venous catheter, 88 (9.5%) a gastrostomy/ileostomy, and 68 (7.3%) a naso/orogastric tube.

Talking about laboratory test, the median value of CRP was 0.76mg/dl (IQR 3.5), just a little above the values to consider it positive (0.5mg/dl); the median values of PCT was below the limit to consider it positive, but the 30.2% of the patients had positive values.

All other data are summarized in Table 5.

Table 5. Clinical data of the patients admitted to IMCU

	n = 929 total
PEWS, n (%)	
0-2	744 (93.7)
3-4	44 (5.5)
5	2 (0.3)
≥6	4 (0.5)
Temperature, n (%)	
< 37°C	678 (72.8)
<38.5°C	199 (21.4)
>38.5°C	54 (5.8)
Blood systolic pressure (mmHg, median, IQR)	103 (20)
Blood diastolic pressure (mmHg, median, IQR)	63 (18)
Hypotension (mmHg < 5° adjusted for age), n (%)	34 (3.7)
HR (beats per min, median, IQR)	123 (49)
Tachycardia (adjusted for age), n (%)	144 (15.5)
Bradycardia (adjusted for age), n (%)	20 (2.1)
RR (rpm, median, IQR)	27 (14)
Tachypnea (adjusted for age), n (%)	221 (23.8)
Bradypnea (adjusted for age), n (%)	157 (16.9)
SatO2/FiO2 (median, IQR)	471 (19)
Respiratory support type, n (%)	
Any	215 (23.1)
Low-flow Oxygen therapy	60 (27.8)
High-flow Oxygen therapy	132 (61.1)
NIV	17 (7.9)
Mechanical ventilation	7 (3.2)

Device presence, n (%)	
Any device	307 (33)
Tracheostomy	21 (2.3)
Non-invasive ventilation	11 (1.2)
Gastrostomy/ileostomy	88 (9.5)
Nasogastric/orogastric tube (NG/OG)	68 (7.3)
Central venous catheter (CVC)	155 (16.7)
Cerebrospinal fluid shunt	30 (3.2)
Thoracic/abdominal drainage	14 (1.5)
Peritoneal dialysis catheter	3 (0.3)
Other	63 (6.8)
Blood tests	
CRP (median IQR)	0.76 (3.5)
PCT (median, IQR)	0.15 (0.84)
PCT *if > 0.5 (n, %)*	121 (30.2)
WBC (median, IQR)	9 (7.17)
Neutrophils (median, IQR)	4.6 (5.1)
Lymphocyte (median, IQR)	2.22 (2.83)
Platelets (median, IQR)	291 (200)
Hb (median, IQR)	11.7 (2.6)
Albumin (median, IQR)	3725 (912)
Creatinine (median, IQR)	0.31 (0.25)
Lactates (median, IQR)	11 (9.75)

Escalation of care

Results of the comparative analysis of patient secondarily transferred to PICU (53, 5.7%) with those non transferred (876, 94.3%) are show in Table 6 (both baseline and clinical data).

Compared with non transferred patients, patients who were secondarily transferred to PICU showed no significant difference in age and sex.

Regarding patients flows, the department of origin showed a significantly different (p=0.008) distribution between the two groups, whereas the distribution of primary etiology of admission did not.

The length of stay was significantly different between them (2 days in PICU group toward 4 in the other group; p<0.001); and the number of deaths in the following month was also significantly different (10 vs 1 patient; p=0.008).

48 out of 53 between PICU patients had an underlying disease (90.6%), significantly more (p<0.001) than non transferred people (66%); between them people with a cardiologic condition and a surgical one were significantly more in PICU group (respectively p=0.005 and p=0.009).

We did not observe differences in the two groups in the distribution of PEW score on admission, but in both group around the 93% of patients had the lowers values (0-2).

Regarding vital signs, we did not register significant differences in term of body temperature, heart rate and blood pressure; the same talking about the number of hypotensive and tachy/bradycardic patients. Whereas, concerning respiratory rate, PICU patients had a higher RR (p=0.011) and were more tachypnoeic (p <0.001).

S/F was almost significantly lower (p=0.056) in the PICU group.

People respiratory supported were significantly more in the PICU group (p=0.029), but we did not find differences in the distribution of types of respiratory support.

Regarding devices, patients with one or more devices were more in PICU group (66% vs 31.1%, p<0.001); between all the possible devices, only gastro/ileostomies were more presented in this group (p=0.003). All other devices were not significantly more present in one or the other group.

No differences were found in blood tests between the two groups; although we can say that PICU people had higher inflammatory markers and WBC.

By multivariate analysis, suffering from a cardiac (p=0.003, OR 3.19) or a surgical condition (p=0.33, OR 2.89), being tachypnoeic (p<0.001, OR 3.17), and having a gastro/ileostomy (p=0.026, OR 2.39), were significant predictive factors for transfer to the PICU. Analysing departments of origin, coming from home (p=0.004, OR 4.55) or a general ward (p=0.039, OR 2.08), was an independent risk factor, compared with ED.

Table 6. Comparative analysis of patients transferred to PICU vs non transferred

	IMCU then PICU	IMCU only	Univariated p-value	Multivariated p-value
Number (%)	53 (5.7)	876 (94.3)		
Sex, n (%)			----	----
Male	26 (49.1)	490 (55.9)		
Female	27 (50.9)	386 (44.1)		
Age in months (median, IQR)	43 (163)	49 (121)	----	----
Department of origin, n (%)			0.008	
Emergency Department	24 (45.3)	571 (65.2)		
Operating room	1 (1.9)	7 (0.8)		
Lower intensity ward	15 (28.3)	175 (20)		0.039 (vs ED)
PICU/NICU	7 (13.2)	92 (10.5)		
Own home	6 (11.3)	31 (3.5)		0.004 (vs ED)
Main reason of admission, n (%)			0.372	----
Respiratory	19 (35.8)	222 (25.3)		
Cardiac	3 (5.7)	51 (5.8)		
Infection	5 (9.4)	122 (13.9)		
Neurologic and/or Psychiatric	5 (9.4)	173 (19.7)		
Hemato-oncologic	5 (9.4)	96 (11)		
General or specialized surgical	8 (15.1)	68 (7.8)		

Gastrointestinal	3 (5.7)	44 (5)		
Nephro-urologic	1 (1.9)	10 (1.1)		
Endocrinologic	0 (0)	15 (1.7)		
Immunologic/inflammatory	1 (1.9)	18 (2.1)		
Continuation of care	1 (1.9)	12 (1.4)		
Other	2 (3.8)	45 (5.1)		
Pre-existing Conditions, n (%)				
Any	48 (90.6)	579 (66)	<0.001	
Respiratory	6 (11.3)	48 (5.5)		
Cardiac	10 (18.9)	61 (7)	0.005	0.003
Infection	0 (0)	14 (1.6)		
Neurologic and/or Psychiatric	14 (26.4)	143 (16.3)		
Gastrointestinal	4 (7.5)	25 (2.9)		
General or specialized surgical	7 (13.2)	36 (4.1)	0.009	0.033
Nephro-urologic	2 (3.8)	25 (2.9)		
Hemato-oncologic	8 (15.1)	111 (12.7)		
Endocrinologic	2 (3.8)	19 (2.2)		
Immunologic/inflammatory	1 (1.9)	15 (1.7)		
Metabolic	4 (7.5)	41 (4.7)		
Prematurity	5 (9.4)	49 (5.6)		
Other	4 (7.5)	83 (9.5)		
Outcome				
Length of stay in days (median, IQR)	2 (5)	4 (5)	0.008	----
Deceased within 28 days (n, %)	10 (18.9)	1 (0.1)	<0.001	----
PEWS, n (%)			0.187	----
0-2	40 (93)	702 (93.7)		
3-4	2 (4.7)	42 (5.6)		
5	1 (2.3)	1 (0.1)		
≥6	0 (0)	4 (0.5)		
Temperature, n (%)			----	----
< 37°C	38 (71.7)	638 (72.8)		
<38.5°C	12 (22.6)	187 (21.3)		

>38.5°C	3 (5.7)	51(5.8)		
Blood Systolic pressure (mmHg, median, IQR)	105 (17)	103 (20)	----	----
Blood Diastolic pressure (mmHg, median, IQR)	63 (19)	65 (17)	----	----
Hypotension, n (%)	2 (5.9)	32 (94.1)	----	----
HR (beats per min, median, IQR)	125 (33)	122 (49)	----	----
Tachycardia (adjusted for age)	10 (6.9)	134 (93.1)		
Bradycardia (adjusted for age)	1 (5)	19 (95)		
RR (rpm, median, IQR)	32 (11)	27 (14)	0.011	----
Tachypnea (adjusted for age)	24 (10.9)	197 (89.1)	<0.001	<0.001
Bradypnea (adjusted for age)	5 (3.2)	152 (96.8)		
SatO2/FiO2 (median, IQR)	467 (57)	471 (19)	0.056	----
Respiratory support type, n (%)				----
Any	19 (35.8)	196 (22.4)	0.029	
Low-flow oxygen therapy	8 (42.1)	52 (26.5)		
High-flow Oxygen therapy	9 (47.4)	123 (62.8)		
NIV	2 (10.5)	14 (7.1)		
Mechanical ventilation	0 (0)	7 (3.6)		
Device presence, n (%)				
Any	35 (66)	272 (31.1)	<0.001	
Tracheostomy	3 (5.7)	18 (2.1)		
Non-invasive ventilation	2 (3.8)	9 (1)		
Gastrostomy/ileostomy	12 (22.6)	76 (8.7)	0.003	0.026
Nasogastric/orogastric tubes	7 (13.2)	61 (7)		
Central venous catheter	11 (20.8)	144 (16.4)		
Cerebrospinal fluid shunt	3 (5.7)	27 (3.1)		
Thoracic/abdominal drainage	1 (1.9)	13 (1.5)		
Peritoneal dialysis catheter	0 (0)	3 (0.3)		
Other	4 (7.6)	59 (6.7)		
Blood tests			----	----

CRP (median IQR)	0.89 (8.18)	0.75 (3.4)		
PCT (median, IQR)	0.44 (2.43)	0.15 (0.77)		
PCT *if > 0.5 (n, %)*	10 (45.5)	111 (29.3)		
WBC (median IQR)	9.27 (8)	8.99 (7)		
Neutrophils (median IQR)	3.79 (5.86)	4.64 (5.08)		
Lymphocyte (median IQR)	1.99 (2.78)	2.22 (2.84)		
Platelets (median IQR)	254 (175)	295 (207)		
Hb (median IQR)	11.2 (2.7)	11.7 (2.6)		
Albumin (median IQR)	3518 (762)	3732 (923)		
Creatinine (median IQR)	0.31 (0.25)	0.31 (0.25)		
Lactates (median IQR)	9 (9)	11 (10)		

Chapter 4

Discussion

This study is the first Italian one that describes the operativity of a pediatric IMCU and the characteristics of patients managed in it. Additionally, our study explores the correlations between possible factors on admission to IMCU and the risk of further transfer to PICU. To our knowledge, only few other studies (11,26,43) have attempted to assess this topic, albeit analysing a lower number of children. Although there is a growing interest around the development of pediatric IMCUs, research on this topic is very limited.
In our series, the median age of patients hospitalized in IMCU was around five years. This finding was comparable to what reported by Cheng et All. (11), while other authors have described a lower median age (26,43). As is widely known, infants represent a particularly vulnerable population, at high risk of decompensation. In our work, children with less than 1 year of age were 20% of the series, thus representing a considerable population well served by the IMCU. Interestingly, the young age was not associated with an increased risk of transfer to PICU, although PICU patients were younger (43 vs 49 months). This underlines the effectiveness of specialized care for young children by a healthcare team trained in the interpretation of age-related vital parameters and the recognition of early signs of decompensation.
We observed a mild prevalence of male gender, according to literature findings (11,26), although this was not associated with a risk for transfer.
Considering the operativity of our pediatric IMCU and patients flow, in our series most patients (64%) came from ED, followed by ordinary wards. This finding is similar to that reported in other studies (44) and reflects the primary role of IMCU as an ideal place of care for children needing treatment for an acute illness or who have had a worsening condition requiring an escalation of care. However, in our study, a significant group of patients came from PICU (11%), in a process of step-down of care. The value of pediatric IMCUs as step-down units is crucial for the operativity of the hospital as it may determine a decrease in PICU stays with beneficial effects for the whole healthcare system. In particular, although not assessed in our study, we expect that the establishment of pediatric IMCUs may result in lower healthcare costs and reduced complications associated with intensive care settings, may reduce pressure on ICU beds, and improve

appropriate ICU patient care. Finally, the decrease in PICU stay may enhance family and patient comfort.

Our ICU admission rate was low (5.7%) supporting the efficacy and safety of the IMCU management. The lower percentage of people transferred to PICU is similar to what is described in other studies, varying from 3 to 15% (26,43). We did not analyse the reason why these patients needed more intensive care, nor what these children required in terms of escalation of treatment in PICU (respiratory support, vasopressor agents).

Most of patients have been transferred to a minor intensity of care ward (55%) or have been discharged home after the resolution of the acute illness (39%), whereas only a minority part went towards an escalation of care going to PICU (5.7%).

Lampin et All. (44) found similar outcomes: 55% of patients went to general wards and 36% people went home.

The mortality rate in our population had been weak (1.5%) and corresponds to literature data (0.45 to 1.6%) (26,43). These figures are in line with the objective of IMCUs: intensifying patient monitoring to detect signs of early worsening and defusing an acute medical situation without resorting to techniques of replacement. The majority of dead people were between transferred to PICU patients, underlying the acuity of their condition that requires a more intensive monitoring and treatment, that can not be sufficient.

Focusing on the most relevant clinical data emerging from our analyses, children were more frequently admitted for respiratory, neurologic, or infectious problems and these findings were similar to what was observed in literature (43,45), with respiratory failures (31.7 to 47.4%), then neurologic (23.6 to 17%) and hemodynamic (5 to 15%) as major reasons of admission. In the study by Lampin et All. (44) respiratory and neurologic conditions were the most frequent ones (respectively 44 and 23%).

A significant patient group of children who can be an ideal target for IMCU care is children with medical complexity. These children can be admitted for acute on chronic illness and are often inappropriate for a regular floor admission. In our series 67% of patients had a pre-existing condition, and the 33% had one or more devices, underlying the value of the IMCU in managing this population. This group of children is more vulnerable than the general population and, supporting this, only 5 children out of 53, among those transferred to PICU, had no pre-existing condition and the 66% had a device. Among the most represented pre-existing conditions, we found neurological and hemato-oncologic diseases. This is easily understandable, as patients with neurological disease, may often develop respiratory failure or acute decompensation of their primary condition (seizure recrudescence, epileptic state, etc.). On the other side patients with hemato-oncologic disease represent a group of fragile patients, prone to acute complications and infectious episodes.

Russ et All. (6) found that if a child with a home continuous positive airway pressure requirement was admitted with a mild respiratory exacerbation, 59% of providers would admit the child to the PICU in hospitals with no IMCU, whereas in hospitals with an IMCU, 18% would admit to PICU and a majority of providers would admit to IMCU.

Interestingly we found that children with cardiac disease or surgical conditions had an increased risk of PICU admission. This can be easily explained considering that this group of patients may be more likely to receive interventional or surgical procedures in case of decompensation and therefore require access to intensive care.

Similarly, patients with at least one device were more frequently admitted to the PICU. This is likely due to the fragile underlying condition that exposes these children to a wide range of complications and an increased risk of deterioration.

Surprisingly, among medical devices, we found a correlation between PICU admission and gastrostomy. Conversely, we did not detect any significant association with the presence of tracheostomy. This is relevant considering that patients with tracheostomy represent a population group that can be well-served by an IMCU. Supporting this, in a national survey of US hospitals, children with tracheostomy and ventilator support, admitted to the hospital for mild non-respiratory infections, were triaged to a pediatric ICU in 65% of hospitals with no IMCU versus 46% in hospitals with an IMCU. Long-term tracheostomy in children is associated with higher complication rates when compared to adults, especially in those who have underlying conditions such as neuromuscular impairment. Outcomes of children with a tracheostomy are strongly influenced by other medically complex conditions (feeding pumps, mechanical ventilation, etc.), and complications due to tracheostomies such as ventilator-associated respiratory infections are known to be associated with longer ICU length of stay.

Although requiring specialized care, trained staff, and a higher level of surveillance, the favourable outcome in our study suggests that the IMCU can be the appropriate location of care for this population group.

In our series, we found a median length in days of 4 days, and this was in line with what is reported in other studies, varying from two to five days (43,46). This short period reflects the value of the IMCU as a location of care where children with acute illness can be promptly treated and transferred to a low-intensity care unit or directly discharged home in case of rapidly favourable evolution. On the other hand, children with deterioration can be promptly assessed and transferred to the PICU for an escalation of care. Children who needed PICU transfer spent a median of 2 days in the IMCU. This was similar to what is reported in other studies and underlies the need for strict monitoring in the first 48 hours of admission, as in the first two days children show a higher risk of deterioration.

Monitoring signs of patient deterioration is essential, rather than simply focusing on one or the other. Many current pediatric early warning or prediction systems have been incorporated as a standard of care across our institution to highlight patient deterioration, containing a combination of vital signs and clinician observation and assessment, recognizing the need for a synergistic approach to identify deterioration and the potential need for transfer.

Differently from other studies (11,26,43), we did not find a correlation between PEWS on admission and the risk of transfer to PICU, suggesting that the PEW score in isolation may not be an absolute predictor of transfer. Rather, PEWS needs to be considered with other measures and algorithms that incorporate situational awareness and assessment to add more insight into the prediction of deterioration, as they do other score (PAWS, bPEWS, PRISM) used by the other studies.

However, children with increased respiratory rate on admission and lower S/F indexes showed a significant association with PICU admission, supporting the value of initial clinical evaluation in predicting the risk of clinical deterioration.

All these data can be explained by the fact that most of the reason why a patient need an escalation of care is the worsening of the respiratory dynamic so that is need an increase of the respiratory support.

We also found a correlation between the presence of any respiratory support on admission with PICU transfer. The significance of respiratory support at the time of admission offers an important predictor to explore. This subgroup may require specific attention, such as the provision of nursing resources and provider education around specific types of respiratory diseases, monitoring, and various supportive therapies when admitted to ICU. Among the respiratory supports, we had a significant group of patients who required non-invasive positive pressure ventilation (NIPPV). Pediatric IMCU may be the appropriate setting where patients at non immediate risk of requiring intubation can start or potentiate NIPPV. Similar protocols have been successfully implemented in adult IMCUs while pediatric experiences are still limited. Non-invasive positive pressure ventilation is increasingly used to manage acute respiratory failure in patients with medical complexity (i.e. children with neuromuscular disorders) and have a tremendous impact on prolonging survival in this population. However, it requires qualified and skilled staffing with strong interdisciplinary team communication, rigorous monitoring, and frequent reassessment processes.

In our Institute some patients affected by chronic disease aged over 18 years are regularly followed by the different specialistic centers. Although this may be considered a limit of the study, they have been included to reflect and describe as faithfully as possible the reality of our setting. As survival rates for patients affected by chronic diseases improve, complexity and criticalness consequently increase with age, along with the need for specialized tertiary care, intense monitoring, and advanced therapies.

However, regardless of major complexity, more comorbidities, and chronic therapies, the length of stay and the rate of ICU admission of these patients alone was comparable to the whole population, highlighting the value of IMCU management.

Our work has several limitations. Our study's main challenge was its retrospective design and our heterogeneous patient population. Therefore, we relied on standardized markers such as vital signs and PEWS to achieve objectivity in assessing predictors of patient transfer.

We did not conduct a cost analysis, which might have better revealed the importance of the decreased ICU bed use. Furthermore, we did not analyse the reason why these patients needed more intensive care, nor what these children required in terms of escalation of treatment in PICU (respiratory support, vasopressor agents). The short period included in the study reduces the statistical power of our analysis. We carried out a limited comparison with literature evidence considering that the research focusing on pediatric

IMCU is very limited. In Italy, this likely depends on the lack of specific regulatory legislation which leads to a marked variability in terms of structuring, equipment, and staffing of pediatric IMCUs. Following this, the single-center nature of the study may also limit the generalizability of our findings because of site-specific practices and policies, including the availability of staff and equipment, and the hospital organization.

Chapter 5

Conclusions and future prospectives

- Pediatric IMCUs prove to be the ideal location for critically ill children needing acute care coming from the ED or for children who deteriorate their condition in the ordinary wards. Children can be rapidly stabilized (4 days of median length of stay) and diverted to the appropriate low-intensity care units.
- In the meanwhile, pediatric IMCUs have a major role as step-down units, with beneficial effects on ICU bed use, patients, and families, decreasing healthcare costs, although not assessed in the study.
- Their effectiveness of their job is demonstrated by the low percentage of patients requiring further transfer to PICU and deaths.
- The target patients are those affected by medical complexity conditions, being mostly young, affected by one or more underlying diseases, having at least one device and being usually chronically respiratory supported. This requires trained staff (clinicians and nurses) with competencies in their management.
- Most patients further transferred to PICU is mostly respiratory supported, tachypnoeic with lower S/F index, with one or more underlying diseases and devices.
- Having a cardiac or surgical underlying disease, and having a gastro/ileostomy, are independent risk factors for a deterioration that requires transfer to PICU with a median latency of two days.
- The need for close monitoring of physiologic parameters remains paramount, especially in the first 48 hours after admission, and IMCUs fit well the opportunity to care about these patients having an appropriate staff and all the necessary equipment. However, the PEWS score do not show to correlate with PICU admission.

More research is needed to better define the characteristics of children who require intense surveillance on admission to IMCU to discover other risk factors and to properly assess the impact on PICU and hospital activity.

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