Orientation guide to the Children's ICU

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Introduction

The Children's intensive care unit (CICU) is a 16 bedded, multidisciplinary unit catering for the needs of critically ill children. It is considered a closed unit, where day-to-day decision making and complex interventions are made by the paediatric intensivists. Consultations with relevant specialties are essential to holistic management of the patient, but the ultimate co-ordination of decision-making rests on the CICU consultant. The CICU service leverages on their academic and research strengths and is committed to providing high quality family-centred care to patients and their families.

Services offered by the CICU include:

- Extra-corporeal life support: this includes continuous renal replacement therapy (CRRT), therapeutic plasma exchange (TPE) and extra-corporeal membrane oxygenation support (ECMO)
- Children's Emergency Transport Services (CHETS)

This document serves to guide management of patients within the CICU only and should not be used as a reference for the management of patients outside of the CICU.

Golden Rules for CICU

1. **PATIENT SAFETY IS OUR PRIORITY!**
    - **Hand Hygiene/infection control**
        - Wash your hands, observe the Yellow Box rules, and wipe down the computer keyboards daily.
        - Do not leave the stethoscope on the bed after use- hang it on the drip stand
        - Do not wear watches/bangles/lanyards/sling bags when examining patients
        - For females- long hair should be tied up when examining patients
        - Please follow the ICU protocol when performing aseptic procedures
    - **Incident Reporting System (IRS) and near misses reporting**
        - Reporting incidents helps us improve our safety culture.
        - Reporting is not punitive and does not reflect individual errors but serves to trigger improvements in workflows and systems.
    - **Speak up for safety**
        - **Speak up** if you don't know, don't understand, don't agree or just want to clarify.
        - Our nurses have the right to ask the ICU registrar to call the ICU consultant about a patient, and they may call the consultant themselves if the registrar refuses to do so.
    - **Communication**
        - If you make any changes to a patient's plan (including investigations, medications, or management plans) -> **INFORM THE BEDSIDE NURSE.** This avoids confusion and potential medical errors from occurring.
2. Identify high risk patients before they deteriorate- be *proactive* rather than *reactive.*
3. ALWAYS be polite and respectful to all staff.
4. Follow up on investigations that you have ordered- **all results must be reviewed and acknowledged** on the computer system.
5. Look at the CXRs in ALL intubated children (and really look at it) – note positions of the ETT, NGT, lines and drains.
6. If you need to leave the unit urgently- inform your senior, and hand over your patients to another team member.
7. Every patient needs a morning daily round. Progress notes should be written at least twice a day, when there is a change in clinical status or clinical plan, an invasive procedure or has had an intra-hospital transport**.**
8. If an external second opinion for a patient is required, the referral letter needs to be vetted by the ICU consultant and primary physician/s before releasing to the parents.
9. If you think a patient needs a subspecialty referral/input - inform your ICU consultant **FIRST**.

10. If you think the cardiac surgical patient needs an ECHO, inform your ICU consultant **FIRST**.
11. Please return the COWS to their parking station and charge after use.

Contacting the ICU consultant

Purpose

To ensure the ICU consultants are notified of key events, so as to aid in their decision-making process for patients

There should be a low threshold to notify the ICU consultant. Even if you are able to manage the situation, the consultant needs to know that these significant events have occurred.

The ICU consultant MUST be notified in the following circumstances:

1. Admissions and referrals

- Within 1 hour of ALL admissions to ICU (elective or emergency) – a telephone conversation with the ICU consultant is required
- Any referral to ICU (**whether accepted or refused**)

2. CHETS calls

- For any emergency CHETS referrals
- At least one call must be made to the CHETS consultant during the CHETS retrieval; and additional calls should be made if there is any unforeseen events during the transfer
- Where any CHETS trip is potentially delayed due to lack of staff or transport (ambulance) unavailability

3. Post-op cardiac patients

- OT will call CICU about 30 minutes before the patient comes out from OT. **PLEASE inform the ICU consultant (via text/phone call) once you receive the update from OT that the patient will be returning to CICU soon.**

4. Patient deterioration

Cardiovascular

- All in-hospital paediatric Code blue or trauma code requiring CPR within 5 to 10 minutes of resuscitation to assess ECPR candidacy
- Cardiac arrest or significant arrhythmia
- Hemodynamic instability requiring initiation of additional vasoactive agent or escalation of current agents beyond pre-determined range
- Serum lactate > 4 mmol/L or rising lactate > 2mmol/L from baseline
- SvO2 < 50mmHg

Respiratory

- PRIOR to any endotracheal intubation (unless a code blue activation is initiated)
- If there is an unplanned extubation
- Unanticipated commencement of NIV
- Unplanned change in mode of mechanical ventilation
- Significant worsening of respiratory status Eg. doubling of FiO2 requirements, persistent respiratory acidosis or hypoxia not correcting with initial ventilator adjustments
- Upper airway obstruction that is not improving with adrenaline nebulization, and/or hypoxic

Neurological/neurosurgical

- New neurological signs or significant drop in GCS
- Intracranial hypertension for > 1 hour despite optimisation of neuro-protective strategies
- Unanticipated lack of drainage from the external ventricular drain for > 2 hours

Post-op cardiothoracic cases

- Chest tube drainage > 4ml/kg/hr (bloody) past the first 2 hours of surgery
- Low cardiac output state (eg. tachycardia, hypotension, lactic acidosis, poor urine output) not responsive to initial management

Renal

- Before commencing CRRT or issues with the CRRT run (eg. access or return pressure issues)
- Hyperkalaemia with ECG changes

Procedural

- Prior to any invasive procedure planned in the ICU (eg. Chest drain insertion, bronchoscopy, chest toilet)
- If there is a complication of any procedure

Administrative

- Prior to any referral to a subspecialty service/department (eg. Cardiology, nephrology, general surgery, anaesthesia etc).
- Excessive workload for ICU junior staff resulting in unsafe conditions or inability to complete tasks
- Disagreements with nursing, external medical staff, patients or patients' families
- Adverse medical events requiring an IRS report

5. Patient deaths within CICU

For events not listed above, so long as you have a concern, please notify your ICU consultant.

Day to day routines

- We recommend the day team (ICU registrars and residents) come into CICU around 730 to 8am to receive handover from the outgoing night team.
- The ICU registrars will assign individual patients to the residents/ ICU APNs on a weekly basis to maintain continuity of care.
- The medical team (ICU registrars, residents and ICU APNs) is expected to examine and make plans for their respective patients before 9 am, so that they can present these patients during the sit-down rounds.
- **Early Mobilisation (EM) huddles** occur daily on weekdays:
    - **830-9 am** together with ICU dr, RT, PT, Nurse Clinician and bedside nurse
    - To give brief summary of patient progress and suitability for mobilization
    - To use the EM risk/mobility guide as reference
    - To propose weekly EM goal and daily EM plan for each patient and whether these should be PT or nurse-led
    - The multi-D team should advocate and balance early mobilisation and patient safety
    - PT empowered to put up PT referrals for EM after EM huddle
- **Cardiac rounds** occur daily:
    - **8 am** on Monday to Thursday (except on Monday mornings, where cardiac rounds are integrated into the cardiac performance rounds)
    - **730 am** on Fridays
    - **9 am** on weekends
    - ICU team members should be assigned to 1) present case, read back and document plans, and 2) order investigations/medications during cardiac rounds
- Afternoon rounds with the registrars usually start around 2-4pm.
- Handover to the night team usually starts between 530-6pm.

- It is good practice to accompany subspecialists while they are reviewing their patients by the bedside so that the ICU team is aware of the subspec inputs as well as to facilitate any changes/additions to management/medications
    - Please assist subspecialty teams to order medications where needed and inform the bedside nurse of any changes at the same time

Daily ward rounds

- Weekday morning multi-disciplinary sit-down rounds are conducted in the CICU medical officer's (MO) room and start at 9am. Weekend morning rounds (consultant-led) are conducted by the patient's bedside.
- During the ward rounds: team members should have specific role assignments to:
    - **order medications and investigations**,
    - **document** consultant-led round plans or
    - **present the case** and **READ BACK** grand round plans
- **QI checklist:** please complete the QI checklist for all patients to review elements of good quality care
- **Medications**
    - The team member assigned to order medications/investigations should be in close proximity to the ICU pharmacist for easy verification of drug orders.
    - Sedation and pain targets for patients on IV sedation/analgesia need to be set DAILY. These targets also need to be indicated when ordering on the CPOE.
    - All medications should be reviewed daily to see if any can be taken off, or converted to enteral
- **Fluids and Nutrition**
    - Prescribed total fluids for the day is assumed to include all medications/ side drips unless specified by the team doctors
    - Patients should be started on the ICU feeding protocol upon initiation of feeds unless exclusion criteria
    - Refer to Dietician if there is poor weight gain or there is inability to meet adequate caloric requirements
    - Consider parenteral nutrition if unable to establish feeds within 5 days of ICU admission
- **Sedation, analgesia and delirium scoring:** Please review SBS, WAT-1, pain scores and CAPD scores according to patient needs and clinical condition.
- **Lines and drains**
    - All external hardware should be reviewed on a daily basis to see if they can be removed. These include: urine catheters, ETT, CVL, IAL, chest drains.
    - **For post-operative neurosurgical patients, please discuss with the Neurosurgical consultant PRIOR to removal of urinary catheter.**

Learning activities in the ICU

Attendance at the ICU learning activities and performance at daily morning ward rounds form part of the summative assessment for rotating residents and registrars.

- **Cardiac performance rounds**: *Mondays 8am*
    - These are presented by the cardiology, cardiothoracic and CICU teams and are held in the CICU MO room
- **CICU Grand Rounds**: *Mondays and Fridays 9am*
    - These rounds are an opportunity for more detailed presentations and discussions of patients. The out-going and in-coming ICU consultants will be in attendance.
- **CICU grey case conference**: *last Tuesday of the month*
    - An interesting case will be identified prior to the conference 1-2 weeks prior for the ICU resident to present. The case should be discussed with the registrar and consultant regarding pertinent presentation details/format.
    - **Ethics Rounds** will be held 3-4 times a year and will replace the ICU grey case for that month. Topics/themes will be decided beforehand and registrars may be asked to prepare ethical analyses of cases based on the themes.

- **Mortality rounds**: *4th Wednesday of the month*
    - Residents may be asked to prepare mortality reports for cases under their care during their ICU rotation.
    - If the primary physician designation is unclear, the resident in charge of the case should speak to their ICU consultant to clarify who should be the primary physician.
    - Mortality cases MUST be discussed with the primary physician **before presentation.**
- **Journal club/research meeting:** *2nd Thursday of the month lunchtime*
    - Residents, registrars and the allied health staff will rotate to present journal critiques or give updates on ongoing research projects.
- **CICU/HD audit meetings:** *once every 2 months*
    - CICU quality indicators will be discussed such as:
        - Mortality rates, cardiac arrest data, ECMO cannulations, accidental extubations, intubation quality compliance, hand hygiene compliance, CLABSI/CAUTI/VAP rates, accidental device removals, pressure sores, CHETS adverse event rates, readmissions within 24 hours to CICU/HD
        - RMSes will be regularly reviewed
- **National paediatric ICU rounds**: *4th Thursday of the month*
    - These are held every month at lunchtime, alternating between NUH and KKH children's ICUs. Residents and registrars will be expected to present interesting cases to the visiting ICU teams. Interesting journal articles may be presented at this time as well.

Night rounds

- The on-call residents will round with the registrars around 8-9pm, and night rounds with the consultant occur between 930pm to 1230am.
- Call room keycards are left at the nursing counter and requires signing-in and out for the card. A cost will be incurred if the card is lost.
- Please ensure that overnight events and plans are complete and up-to-date, ***do not blindly "cut-and-paste" from the previous day's entry.***

Case presentations

Residents and registrars are expected to able to present their individual patients in a **systematic, problem-based approach,** without reading off the computer screens. There should be some thought as to disease-processes and management plans.

The presentation should start with a summary of the patient's current problems, followed by a summary of individual systems evaluation, and end with a suggested management plan for the day. As part of our unit's commitment to quality care, please complete the QI checklist for each patient within each daily ward round document.

The sit-down rounds are an opportunity for the whole team to understand more about each patient, not only the ones they have seen themselves.

Specialized CICU order-sets on SCM

Specialised order-sets for CICU are available in SCM for the following:

- **Paediatric Code sheet (Emergency drugs)**
- **Concentrated KCl replacement**
    - 1:1 dilution
    - 0.8:10 dilution
- **Hyperkalaemia order-set**
- **ECMO prescription**
- **CRRT prescription**
- **Peritoneal Dialysis prescription**
- **Morphine and Midazolam infusion ordersets with rescue dose** (see CICU handbook section under "Weaning Analgesia and Sedation")
- **$MgSO_4$ order-set**
    - **status asthmaticus** (see CICU handbook section under "status asthmaticus-$MgSO_4$ infusion")
    - **status epilepticus** (see CICU handbook section under "neurocritical care, Status epilepticus")

Please see the individual sections for more details.

Electronic medical records (EMR) documentation

- New staff should get an orientation on the EMR system from the current ICU team BEFORE their rotation begins. This includes:
    - How to create, save and amend entries into the system
    - Type of medical entry notes to create:
        - **CICU Daily Ward Round:** once daily for morning rounds
        - **CICU Daily progress note**:
            - **PM Round + Night Round**
            - **Intra/Interhospital Transport Review**: to be created after any transport (eg. MRI, CT, angio-suite for interventional procedures)
            - **Post-op review**: for post op patients upon return to CICU from OT
            - **Resuscitation**: to be created after any resuscitation event
        - **CICU Transfer Summary**: Summary upon discharge from CICU
        - **Patient/Family or Physician Discussion Log:** for physician or family conferences
    - Blue letter referrals
    - **Procedure Note** (eg. arterial line, urinary catheter, lumbar puncture)
    - **Discharge summaries** (upon death)

- Please download the CICU-specific acronym expansions (details to be found in the ICU MO room)

All notes entered into the EMR system are considered medico-legal, and should be created and amended according to the Hospital's guidelines on medical documentation. **Notes should be accurate.**

Individual roles and responsibilities

Registrars/Senior Residents (SR)

Pre-requisites:

- Be current in APLS certification and competent in I/O needle insertion
- Accredited in conscious sedation administration
- Completed paediatric residency DOPS requirements for central line and intubations (2 central lines, 5 intubations for neonates/children)
- **Complete 3 tag-on night shifts (2 weekday, 1 weekend)** before starting solo calls**. The SR is expected to go home after completion of night rounds (latest 1am).** In accordance with duty hour regulations, the SR is allowed to return to normal work duties after no shorter than 8 hours of rest.

To be completed by end of rotation:

- Successfully complete **PFCCS course** before or during ICU rotation
- Refresher session on mechanical ventilators (by respiratory therapists)
- Video-laryngoscope training during the ICU rotation
- CVL simulation training during the ICU rotation
- Complete at least 2 inter-hospital transport independently
- Run at least 1 paediatric code blue resuscitation as a team leader

Residents

Pre-requisites:

- Accredited in conscious sedation administration
- Current in BCLS certification
- Successfully **completed APLS certification by R3**
- Attended acute paediatric emergency simulations (Monday lunchtime sessions)

To be completed by end of **R2**:

- Attended **orientation session by CICU nursing sisters**
- Successfully completed 1 x DOPS for intubation (simulation) by R2 (See Appendix for *intubation checklist*) and videolaryngoscope intubation training during the CICU rotation
- Successfully completed 1 x DOPS for central venous line cannulation, femoral (simulation) by R2 (See Appendix for *CVL checklist*) and the CVL simulation training during the CICU rotation
- Attended **mechanical ventilatory session by respiratory therapists** (on portable and stand-alone ventilators)

To be completed by end of **R3**:

- Presented at least one CICU grey case conference
- Completed all DOPS for central venous line cannulation (femoral) (2); and arterial catheterization (5)
- Completed attendance at mechanical ventilatory session by respiratory therapists
- Documented management of these cases:
    - Acute and chronic respiratory failure
    - Acute neurological conditions eg. status epilepticus, altered mental state, meningoencephalitis, intracranial hypertension
    - Acute metabolic disturbances eg. IEM presentation or decompensation, drug overdose, intoxication syndromes
    - Cardiovascular, circulatory and congenital heart disorders eg. cardiogenic shock or low cardiac output state, hypertension, arrhythmias (VT, VF, PEA, asystole, bradycardia, SVT) – simulation or in real patients
    - Electrolyte and acid base disorders eg. disorders of salt, potassium, acidosis, sugar* (DKA)
    - Multi-organ failure

- Neonatal emergencies
- Post operative care
- Sepsis/ septic shock
- Trauma and burns
- Metabolic, nutritional and endocrine effects of critical illness eg. poor weight gain in chronic ICU patients, nutritional requirements of burns patients, adrenocortical insufficiency in septic patients
- Hematologic and coagulation disorders associated with critical illness eg. DIVC or pancytopenia associated with sepsis

Duties

- **Registrars/Senior Residents** are expected to function as the senior staff in the ICU floor in the absence of the consultant. He/she is expected to:
  - assign patients to the residents every morning, and rotate cases on a weekly basis
  - lead the consultants on a bedside round after the morning sit-down rounds are over, as well as night rounds
  - double-check all medications/ orders at least twice a day
  - receive and manage CHETS calls (with supervision), and perform inter-hospital local transports
  - Act as Code team leaders in the event of an in-hospital code blue for children, and provide medical support in the event of a trauma code for children
  - Attend to emergency events in CSDU – there is an overhead announcement of "doctor to CSDU"

- **Residents** are expected to:
  - Clerk all new admissions and update/maintain each patient's daily medical records
  - **Complete CICU patient information leaflet (and get parent's signature for acknowledgement) within 24 hours of ICU admission (** form is available at nursing counter CICU**)**
  - Complete discharge summaries in a timely fashion
  - Carry out changes (eg. phone referrals, procedures) after the ward rounds are complete. If there is time, they should also try to follow the bedside rounds.
  - Perform intra-hospital transports under supervision
  - Complete paediatric residency training requirements as stipulated (including DOPS and mandatory teaching sessions)

Paediatric codes

The codes that may be announced in our hospital include:

- **Code blue** (collapse- neonate, woman, child)
  - Children's Emergency (CE): CE is the code team leader
  - Outside of CE: ICU is the team leader
- Code green (Crash Caesarean section)
- **Trauma code** (paediatric trauma) – CE is team leader
- Code brown (shoulder dystocia)
- Code red (maternal collapse requiring emergency Caesarean section)
- **ECMO team call** (Emergency ECMO cannulation) – CICU consultant is team leader
- Code yellow (abscondment)
- **Airway code** [advanced airway team- ENT, anaesthetist (if not already present) and OT nurse with difficult airway equipment]

Our hospital's **paediatric code blue team** comprises a minimum of:

Code Blue team Role	Responsibility	Who?	Number of staff
Code team leader	• Overall in charge of running the code • Assigns roles and responsibilities to individual team members • Oversee CPR efficiency, acknowledges arrival of defibrillator	Paediatric CE or ICU registrar/ consultant	1
Data recorder/ documentation	Records **ALL** activities relating to the code event including: • Drugs • Patient events (eg. rhythm changes, CPR start and end times, defibrillation etc) • Time intervals (Eg. between adrenaline doses or CPR duration etc.)	Area nurse	1
Airway specialist	• In charge of airway (including assisted ventilation, intubation and ventilation) • Airway assistant who prepares airway and suctioning equipment	Paeds anaesthetist area/AU nurse	1 1
CPR coach	• Ensures effective CPR with adherence to NRC guidelines • Ensures role rotation to avoid compressor fatigue	PAME / CE senior resident or consultant	1
Chest compressions	• Delivers chest compressions as instructed by CPR coach/code team leader	staff with BCLS certification	2
Circulation	• Takes charge of securing IV or IO access as well as drawing blood samples • Administers medications as and when required • Maintains closed loop communications with code team leader and data recorder re: medications administered • Circulating nurse to assist with ad – hoc requests	PAME/CE senior residents or residents area nurses	1- 2 2
Medications	• Calculates and verifies drug doses based on resuscitation drug chart • Draws and dilutes medications as instructed by code team leader • Hands diluted medications to Circulation team • Maintains closed loop communications with Circulation team and code team leader	ICU code nurse PAME/CE senior residents or R3 residents	1 2
Social support	• Provides social support to family during the code event	MSW or unit nurse manager	1
Medication top-ups	• Provides top-ups of E-drugs if the E-cart is depleted	pharmacist	1

- A **data-form** for all paediatric codes must be filled in by the CICU registrar after the code is completed. This can be found at CICU nursing counter. Important data to capture include: **time to arrival of code team**, **duration (if any) of CPR**, initial rhythm, type (and doses) of drugs administered during resuscitation, and **any adverse events**.

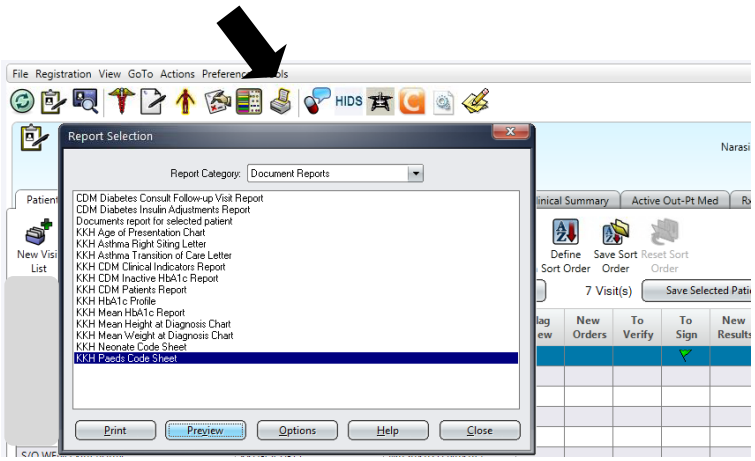
- A **clinical document** must also be entered in the patient's clinical notes- Please use either:
  - **PAM Progress Note (type): Code Blue activation**

- **CICU Progress Note (type): Resuscitation**

Paediatric code sheet for auto-calculated emergency drugs

- An auto-calculated **paediatric code sheet** for common emergency drugs is printed for every NEW admission in CICU and HD.
- For long-stayers, this needs to be updated monthly with **weight/height** to ensure accuracy.
- This code sheet will be clipped to the patient's clinical case records for the duration of his/her admission.

1. The link to the sheet can be found in **SCM** under "print reports" icon, within "document reports"



2. Doctor must verify: correct name, correct weight (most updated) and sign off on the printed code sheet

Weight : 8.7 kg (09-Jul-2018 06:06 AM)

DRUG	Route	DOSE	CALCULATED DOSE	NOTES	FINAL CALCULATED AMOUNT
Adrenaline [EpiNEPHrine] 1:10,000 (1mg/10ml) Injection	IV Bolus	0.1 mL/kg	*0.87 mL*	MAXimum dose: 1 mg (1mg = 10mL)	**0.87 mL**
Atropine Sulfate 600mcg/mL Injection	IV Bolus	0.02 mg/kg	*0.17 mg*	MAXimum dose: 600mcg Dilute 1mL(0.6mg) to final vol 6mL NS (1mL=100mcg).	**1.74 mL**
Albumin 5% Solution	IV Bolus	10 mL/kg	*87 mL*	MINimum dose: 10 mL/kg MAXimum dose: 20 mL/kg	**87 mL**
Calcium Chloride 10% (5.5mmol/10mL) Injection	IV Bolus	0.2 mL/kg	*1.74 mL*	Use Large or Central vein	**1.74 mL**
Dextrose 25% Infusion	IV Bolus	2 mL/kg	*17.4 mL*	Dilute Dextrose 50% with same amount of WFI (1:1) to get 25% solution	**17.4 mL**
Dextrose 10% Infusion	IV Bolus	4 ml/kg	*34.8 ml*	MINimum dose: 4 mL/kg MAXimum dose: 5 mL/kg	**34.8 mL**
Sodium Chloride 0.9% InFUSion	IV Bolus	10 mL/kg	*87 mL*	MINimum dose: 10 mL/kg MAXimum dose: 20 mL/kg	**87 mL**
Sodium Bicarbonate 8.4% (1mmol/mL) InFUSion	IV Bolus	1 mmol/kg	*8.7 mmol*	8.4% - Infuse in Central Vein only	**8.7 mL**
Sodium Bicarbonate 4.2% (0.5mmol/mL) InFUSion	IV Bolus	1 mmol/kg	*8.7 mmol*	4.2% - Safe for peripheral vein infusion Dilute NaHCO3 8.4% with same amount of WFI (1:1) to get 4.2% solution	**17.4 mL**
Suxamethonium Chloride 100mg/2mL Injection	IV Bolus	1 mg/kg	*8.7 mg*	Dilute 2mL (100mg) to a final vol 10mL NS (10mg/mL).	**0.87 mL**
Midazolam 5mg/mL Injection	IV Bolus	0.1 mg/kg	*0.87 mg*	Dose Range: 0.1 to 0.3 mg/kg (MAX dose: 5 mg)	**0.17 mL**
Morphine Sulfate 10mg/mL Injection	IV Bolus	0.1 mg/kg	*0.87 mg*		**0.09 mL**
Rocuronium Br 50mg/5mL Injection	IV Bolus	1 mg/kg	*8.7 mg*		**0.87 mL**

DEFIBRILLATION		
Range of 4 joules / kg (Maximum of 200J Biphasic)		
Calculated value	34.8	joules

SYNCHRONISED CARDIOVERSION		
Range of 0.5 joules / kg (Maximum of 100J Biphasic)		
Calculated value	4.35	joules

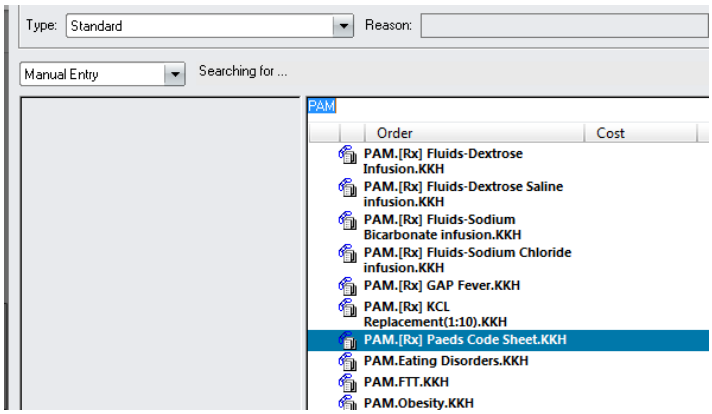
Printed By : MOK YEE HUI (Doctor) 19-Jul-2018 03:34:32 PM

Verified By : _____ Name (Dr / Pharmacist) _____ Signature _____ Date

Valid Till : 18-Aug-2018 03:34:32 PM

Requires verification by doctor or pharmacist

3. Emergency drugs that were administered can be ordered using the order-set under the hospital's **PAM.[Rx].Paeds Code Sheet**



Medication Name	Start Date	Order Priority	Route	Dose	UOM	OrderDetails/Instructions	Calc Dose Info	Frequency	Dosing Information
Adrenaline [EpiNEPHrine] 1:10,000 (1mg/10ml) Injection..	T	STAT	IV Bolus		mL			Once	MAXimum dose: 1 mg (1mg = 10mL)
Atropine Sulfate Injection (IV Bolus 600mcg STAT)	T	STAT	IV Bolus		mg			Once	MINimum dose: 100mcg (0.17 mL) ;..
Albumin 5% Solution (IV Intermittent 3mL/kg)	T	STAT	IV Intermittent		mL			Once	MINimum dose: 10 mL/kg ;...
Calcium Chloride 10% (5.5mmol/10mL) Injection (IV...	T	STAT	IV Bolus		mmol			Once	Use Large or Central vein
Dextrose 25% Infusion (IV Continuous ___mL over 24 hr..	T	STAT	IV Bolus	2	mL/kg	Dilute Dextrose 50% with same amount of WFI (1:1) to get 25% solution		Once	
Dextrose 10% Infusion (IV Bolus ___mL)	T	Routine	IV Bolus	5.004	mL/kg			Once	MINimum dose: 4 mL/kg; MAXimum..
Sodium Chloride 0.9% Injection (IV Bolus ___mL)	T	STAT	IV Bolus		mL			Once	MINimum dose:10 mL/kg;MAXimum..
Sodium Bicarbonate 8.4% (1mmol/mL) InFUSion (IV...	T	STAT	Other Route		mmol			Once	
Sodium Bicarbonate 4.2% (0.5mmol/mL) Injection (IV...	T	STAT	IV Bolus		mmol	Safe for peripheral vein infusion..		Once	
SUXAmethonium Chloride Injection (IV Bolus ___mg...	T	STAT	IV Bolus		mg			Once	MAXimum dose: 2 mg/kg
Midazolam Injection (IV Bolus 0.05mg/kg)	T	STAT	IV Bolus		mg			Once	Dose Range: 0.1 to 0.3 mg/kg (MAX..
Morphine Sulfate Injection (IV Continuous ___ mg/hr..	T	STAT	IV Bolus		mg			Once	
ROCUronium Br Injection (IV Bolus ___ mg)	T	STAT	IV Bolus		mg			Once	

Pediatric CPR high risk checklist for ICU patients

- This checklist serves as a tool to identify patients at high risk of cardiopulmonary arrest, and patients should be screened on a daily basis (during morning rounds as part of QI checklist).
- If there is an identified patient with high risk within the unit, the ICU medical and nursing team can consider performing an ICU CPR refresher session.

High Risk Clinical Indicators Checklist		Date:		Time:		Screener initials:		Page #_____ of _____							
		Unit:_____													
Check all that apply for each patient*	Room/ Bed Number														
Respiratory	Mean airway pressure >20 cm H20														
	Fi02>80% on positive pressure ventilation														
	Pulmonary hypertension requiring iNO therapy														
	Intubation / extubation of known difficult airway														
Circulatory	Bleeding requiring >20 mL/kg pRBCs or whole blood within last 24 hrs														
	Hemodynamically significant arrhythmia within last 24 hrs														
	Severe cardiac dysfunction (EF <20% or A-V O2 difference of >40%)														
	Use of any 2 vasoactive medications or single drug for shock (including dopamine >5 or epi/norepi >0.1 mcg/kg/min, any dose AVP/ phenylephrine/ dobutamine)														
	Life threatening event requiring code/emergency response activation including CA within last 24 hrs														
	ECMO decannulation/circuit failure within last 24 hrs														
	Post-operative Stage I/shunted palliation, truncus with IAA repair or neonate s/p tricuspid valve repositioning for Ebsteins within last 48 hours														
	Open and/or closure of open chest within last 24 hrs														
Neurologic	Elevated ICP requiring blood pressure augmentation to support CPP (sustained elevated ICP >20 cm H20)														
Metabolic	Initiation of any extracorporeal circuit														
	K >7.0, Mg <1 , or iCa 0.9														
	pH <7.10														
	Lactate >10 or increase in lactate of >4/hour														
High Risk Procedure	Intubation or procedural sedation for anterior mediastinal mass, developing tamponade physiology or heart failure														
Other	Provider intuition (e.g., patient being proned or too unstable for routine daily care)														
If patient met any Criteria:	Select if patient is MALE														
	Select if patient is 0-3 yo														
	Select if patient is 4-<8 yo														
	Select if patient is 8-<12 yo														
	Select if patient is 12-18 yo														
**Any one or combination of risks may indicate that patient is at high risk for cardiopulmonary arrest. Other criteria may apply and should be confirmed with patients' clinical management team.*															

pediRES-Q

The Pediatric Resuscitation Quality Collaborative

Respiratory system management in ICU

Basic respiratory physiology and determinants of oxygen delivery

Oxygenation is determined by these factors:

- Fraction of inspired oxygen (**FiO_2**)
- **Mean airway pressure** (area under pressure time curve)
    - In conventional ventilation, PEEP has a greater effect on MAP as the expiratory time is 2 to 3 times that of inspiratory time in a respiratory cycle. A larger pressure differential (between PIP and PEEP) will also result in an increase in MAP.
- Amount of **haemoglobin** and degree of haemoglobin-oxygen saturation
    - Where CaO_2 (concentration of oxygen in arterial blood) = Hb x SaO_2 x 1.36 + 0.003 x PaO_2 (amount of dissolved oxygen in blood)

Ventilation (and clearance of CO_2)

$PaCO_2 \propto CO_2$ production/alveolar ventilation

Therefore, an increase in $PaCO_2$ is secondary to an increase in CO_2 production and/or decrease in alveolar ventilation (where **alveolar ventilation = respiratory rate x tidal volume**).

Oxygen delivery and consumption (Figure 1)[2]

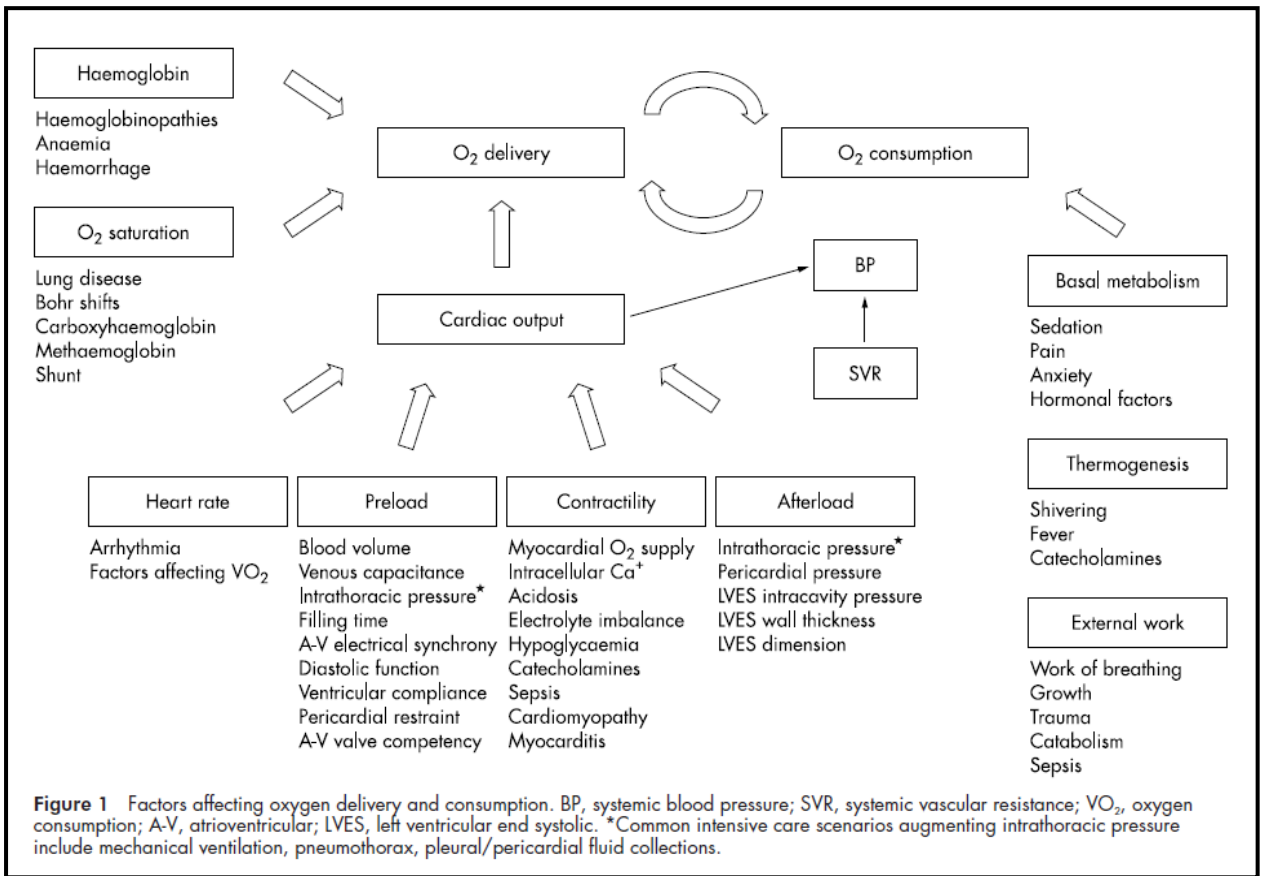


Figure 1 Factors affecting oxygen delivery and consumption. BP, systemic blood pressure; SVR, systemic vascular resistance; VO_2, oxygen consumption; A-V, atrioventricular; LVES, left ventricular end systolic. *Common intensive care scenarios augmenting intrathoracic pressure include mechanical ventilation, pneumothorax, pleural/pericardial fluid collections.

Mechanical ventilation

New staff are expected to attend a hands-on tutorial with the CICU respiratory therapists on portable and stand-alone mechanical ventilators. Staff should learn about the different types of ventilators available, modes that can be delivered on each ventilator, non-invasive mask interfaces available, and basic knobology of the individual ventilators. Please arrange a suitable time with the respiratory therapists on your own. Staff should also be familiar with how to suction a patient on the ventilator, as well as securing an ETT.

At the end of the ICU rotation, residents and registrars are expected to be able to titrate mechanical ventilator settings to manage conditions such as:

- Respiratory acidosis
- ARDS
- Acute lower respiratory tract infections
- Pulmonary haemorrhage
- Pulmonary hypertension
- asthma
- Traumatic brain injury
- Routine post-operative patient
- Cardiac failure

Transport ventilators

- Pulmonetics LTV (can be used in patients < 5kg)
- Impact/MRI compatible (can be used in patients < 5kg)
- Drager Oxylog (used in patients > 10kg. Only has volume-controlled, pressure-limited mode of ventilation)
- iVent (MRI compatible ventilator)
- Monal

Stand-alone ventilators

- Hamilton-Gallileo
- SLE
- SensorMedics HFOV

Basic ventilator terminology

- Peak Inspiratory Pressure (PIP): the highest pressure patient is exposed to during the respiratory cycle (in inspiration). Can be set by the ventilator (set PIP), however, if there is significant respiratory effort, measured PIP (by the ventilator) can be higher than set PIP.

- Positive end expiratory pressure (PEEP): the pressure present during expiration, preventing the lung from end-expiratory collapse.
    - Is usually set at minimum of +5cmH_2O in intubated patients.

- Mean airway pressure (MAP): Area under the pressure-time waveform. It is a measured parameter, and is affected by peak airway pressure, PEEP and inspiratory time.

- Tidal volume (V_t): volume produced within one respiratory cycle. Can be delivered (inspiratory V_t) or measured (expiratory V_t).
    - Expected Vt usually 6-8 ml/kg in children, 4-6 ml/kg in neonates. Lower V_t in patients with ARDS to minimise ventilator-induced lung injury.

- Respiratory rate (RR): the number of breaths a patient has within a minute. Can be set on the ventilator (set RR or *mandatory breaths*). The measured RR on the ventilator will be higher than set RR if the patient has a spontaneous respiratory effort, and the set RR is below the patient's physiological spontaneous respiratory rate.

- Inspiratory time: Time (in inspiration) where tidal volume is delivered. This is usually set according to the age of the patient
    - Neonates: 0.5-0.6 seconds, infants and children: 0.6-0.8 seconds, adolescents/adults: 0.8-1.2 seconds

- Inspiratory:Expiratory time ratio (I:E ratio): The ratio of inspiratory time over expiratory time. Physiological I:E ratio is between 1:2 to 1:3. A ratio of less than 1:1 runs the risk of inverse-ratio ventilation and breath-stacking (resulting in barotrauma, potential CO_2 retention and patient discomfort).

Breath variables

Variables which affect the initiation and termination of each breath.

- Trigger: initiates each breath. Can be flow or pressure dependent. In our unit, flow triggering is used based on patient's age.

- Control: controls the delivery of each breath. Can be volume controlled, pressure controlled or flow controlled. Paediatricians and neonatologists are most familiar with pressure controlled modes of ventilation.

- Cycle: controls the primary breath termination (time, volume or pressure)

- Limit: controls secondary breath termination (i.e. the maximal value of the control variable)

Modes of ventilation

Common modes of ventilation used in our unit include:

- **SIMV-** Synchronised intermittent mandatory ventilation (Pressure or Volume) with/without pressure support
    - The patient can trigger the ventilator spontaneously within a certain timeframe before the ventilator delivers a mandatory breath.
    - Mandatory RR and type of control parameters (eg. Pressure or Volume) are set on the ventilator. Extra spontaneous breaths can be unsupported (except for PEEP) or additionally supported with a PSV breath if the ventilatory mode allows.

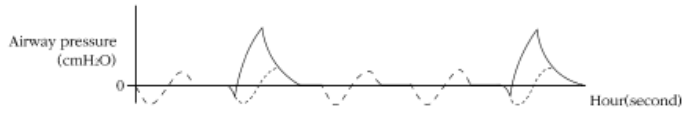


Fig. 2. Airway pressure curve of synchronized intermittent mandatory ventilation (SIMV). *Solid lines* represent mechanical breath cycle; *dotted line* represents spontaneous breaths.

- **PSV** (pressure support ventilation)/SPON
    - The patient must be able to breathe spontaneously. While PIP and PEEP are controlled by the ventilator, the inspiratory time and respiratory rate are purely determined by the patient. The minimum pressure differential between PIP and PEEP practised in our unit is +5cmH_2O.

- **ASV** (adaptive support ventilation)
    - A closed loop, pressure-targeted volume mode of ventilation where the clinician enters patient data and % minute ventilation support, and the ventilator calculates the appropriate minute volume and best RR and tidal volume to produce the least work of breathing.
    - Targeted tidal volumes are given as pressure controlled or pressure supported breaths

- **APRV** (airway pressure release ventilation)[3]
- **HFOV** (high frequency oscillatory ventilation)[4]

Please see the reference articles for greater details on the individual modes of ventilation.

Non-invasive respiratory support - initiation and titration in the acute setting

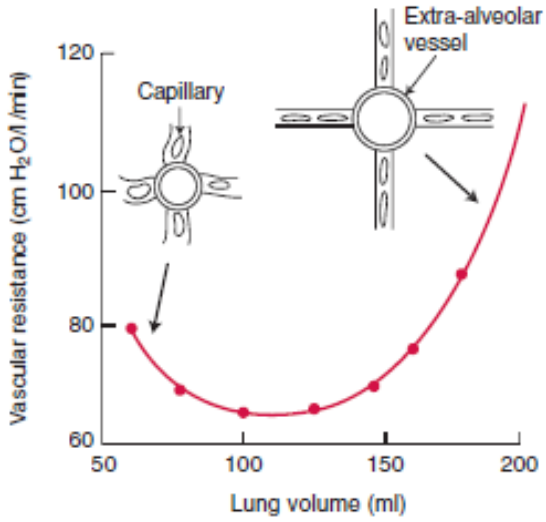
Non-invasive ventilation (NIV) may be used in acute and chronic diseases as a mechanism to support oxygenation and ventilation. In acute disease processes, NIV may reduce atelectasis and potentially offloads fatigued respiratory muscles while preserving the child's natural airway and airway clearance mechanisms. It provides a continuous level of positive expiratory pressure that maintains small airway patency, may increase end-expiratory lung volumes, and improves pulmonary compliance, thus reducing the change in alveolar pressure required to initiate inspiration. With **bilevel** support, the additional inspiratory pressure can help raise tidal volumes and support fatigued respiratory muscles.

This section only addresses the application of NIV in acute conditions.

Cardio-pulmonary interactions

Positive pressure ventilation increases intra-thoracic pressure, which will impact on heart function depending on intra-vascular volume status and cardiac status.

Figure.[1] Effect of lung volume on pulmonary vascular resistance. At low lung volumes, resistance is high because extra-alveolar vessels become narrow. At high lung volumes, the capillaries are stretched, their calibre is reduced and hence resistance increases.
Adapted from Respiratory Physiology: The essentials. John B. West



Right ventricular interactions:

In the presence of atelectasis, NIV helps the right ventricle by decreasing pulmonary vascular resistance through recruitment of the lung and decreasing of V/Q mismatching. Overdistension of lungs due to inappropriately high positive pressure settings may cause increased pulmonary vascular resistance, with decrease in systemic venous return and systemic hypotension.

Left ventricular interactions:

In the presence of left ventricular dysfunction, the application of positive pressure ventilation may help decrease transmural pressure gradients across the left ventricular wall, thus decreasing left ventricular workload.

Common clinical conditions where acute non-invasive respiratory support may be useful include:

- **Acute respiratory failure** from bronchiolitis, pneumonia, atelectasis, exacerbation of chronic lung disease, acute pulmonary edema (fluid overload, heart failure), asthma
- **Neuromuscular disorders** eg. cerebral palsy with upper airway hypotonia (causing obstruction), Spinal muscular atrophy, Duchenne's muscular dystrophy
- **Malacia of the airways** eg. laryngomalacia, tracheomalacia
- **Upper airway obstruction** eg. tonsillitis, background obstructive sleep apnoea

- **Abdominal splinting** eg. increased intra-abdominal pressures, diaphragmatic palsy
- **sepsis** (decreases metabolic demands)

Exclusion criteria for non-invasive respiratory support:

NIV ***SHOULD NOT*** be considered if any of the following are present in the patient:

- Inadequate spontaneous ventilation
- Unstable airway
- Loss of airway reflexes or poor airway reflexes
- Unstable haemodynamics
- Facial deformities or facial/base of skull trauma
- Un-cooperative
- Post-abdominal or tracheo-esophageal surgery
- Pre-existing pneumothorax or air leak

Patient-ventilator interface

The choice of patient-ventilator interface is crucial for success for NIV. A properly fitted mask must:

- Seal securely
- Avoid covering the child's eyes
- Not leak with inspiration or crying

Our institution utilises 3 different interfaces for acute NIV therapy- **nasal prongs, nasal masks or oro-nasal masks.** Nasal prongs are best suited for infants only, and can be associated with significant leak and poor patient-ventilator synchrony. While nasal masks may be better tolerated in children, oro-nasal masks may be required if the child is a mouth-breather, there is significant leak with the nasal mask interface or poor patient-ventilator synchrony.

Nasal prongs

Nasal masks

Oro-nasal masks

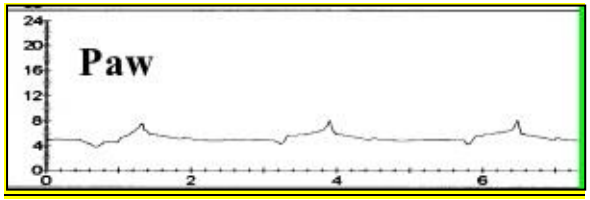
Modes of ventilation

Our institution utilises continuous positive airway pressure (**CPAP**) or bilevel positive airway pressure (**BiPAP**) support.

CPAP:

- Applies continuous baseline positive pressure to spontaneously breathing patients, helps to keep alveoli open at end of expiration
- Inspiratory effort of patient is not supported
- Can improve oxygenation through improved V/Q matching
- May be suitable for children who are unable to achieve patient-ventilator synchrony, who are using a nasal interface with high leak, or with low ventilatory requirements. All breaths are spontaneous.

May be suitable for children who are unable to achieve patient-ventilator synchrony, who are using a nasal interface with high leak, or with low ventilatory requirements

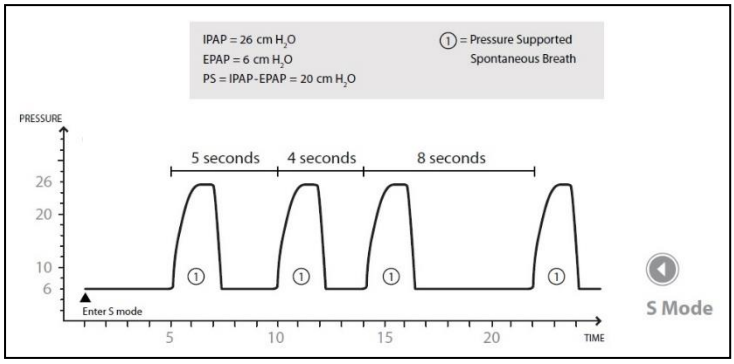


BiPAP:

- This provides an increased level of support during inspiration, which can improve oxygenation and ventilation. However, poor patient-ventilator synchrony may negate the positive effects of BiPAP.
- Patients who require acute initiation of BiPAP support should be transferred to CICU for closer monitoring.
- Well fitted oro-nasal masks should be attempted as the first mask interface for patients on BiPAP
- In our institution, commonly seen modes of BiPAP include:
    - Spontaneous/PSV
    - Spon/Timed
    - Timed/PCV
- The minimum delta-P (pressure difference between peak and end-expiratory pressure) in our institution is 4cmH2O

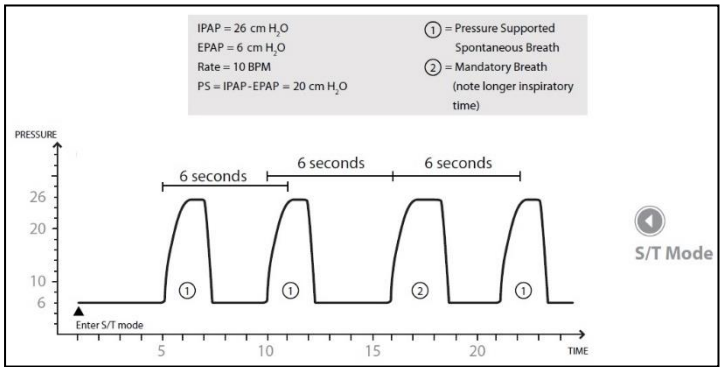
Spontaneous Mode

- Provides only spontaneous breaths, with no back up respiratory rate
- Requires that patient breathe spontaneously



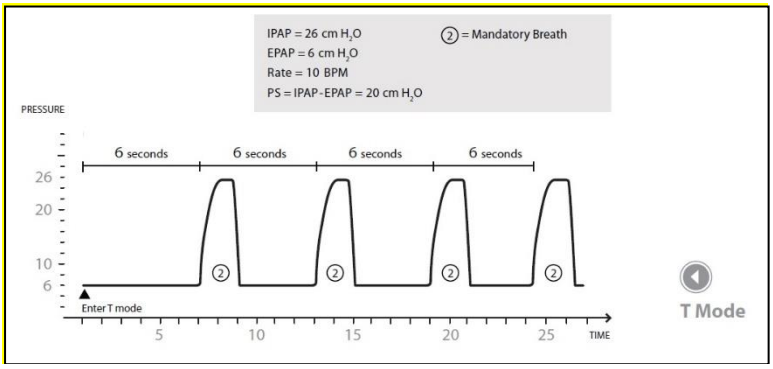
Spontaneous/Timed (S/T) or PSV mode

- Delivers mandatory and spontaneous breaths
- Has back-up respiratory rate to supplement breathing
- Functions as S mode until patient respiratory rate falls below back-up rate, then T mode takes over -> ensures patient receives minimum number of breaths per minute



Timed (T) or PCV mode

- Set respiratory rate to supplement patient's breathing
- Set respiratory rate functioning at all times regardless of patient's respiratory rate
- For patients who are unable to initiate consistent breaths or patient who hypoventilates (chronic NIV)
- This mode is not commonly utilised for patients requiring acute NIV



Comparison of BiPAP modes in different brands of machines

Vivo 40	Vivo 50	Vivo 60	Trilogy 100/200

CPAP	CPAP	CPAP	CPAP
-	-	-	S
PSV	Pressure support	Pressure support	S/T
PCV	Pressure Assist/Control	PCV	T or PC

Initial settings for CPAP

Initial setting	**How to titrate**	**Consider failure if:**
Start at minimum of 5 cm H2O Add oxygen supplementation to maintain saturations at target	Increase CPAP levels to: • Improve oxygenation • Improve lung expansion/ recruitment (if there is presence of de-recruitment)	Unable to maintain oxygen saturation targets despite CPAP + 8 and/or FiO2 > 5L/min Patient is clinically worse (respiratory fatigue)

Failure of non-invasive respiratory support

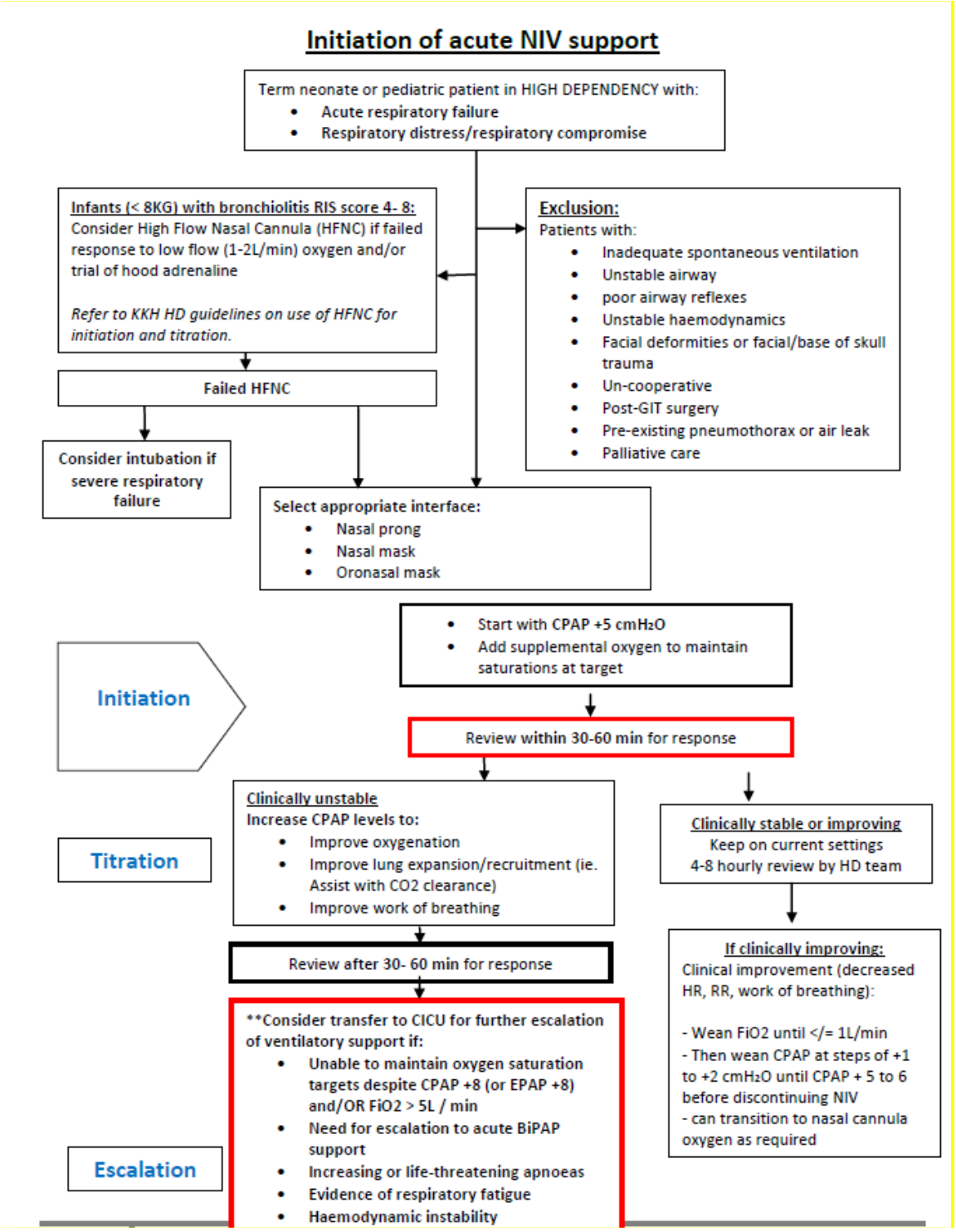
Consider overall failure of NIV if patient is unable to maintain saturation targets in CICU despite FiO2 > 15L/min, has respiratory fatigue or impending respiratory collapse. Intubation should not be delayed in these circumstances.

Monitoring

Children using non-invasive respiratory support should be closely monitored for complications associated with this therapy. This includes:

- Pressure sores (nasal bridge, nasal septum)
- Facial abrasions
- Irritation to eyes and conjunctiva
- Air leaks
- Gastric distension and risk of aspiration/vomiting
- Nasal dryness, rhinitis, sinus pain

Initiation of acute non-invasive respiratory support in High Dependency



Special considerations

- ***Transfer to CICU is subject to CICU bed availability. Where in doubt, please contact CICU senior staff (CICU consultant) for discussion re: further management plans****
- This guideline does NOT apply to patients already on long-term home NIV, or invasive ventilation via tracheostomy
    - If any escalation of home ventilator settings is required, these patients SHOULD be transferred to HD for closer monitoring
- In chronically ventilated patients, consider transfer to CICU if:
    - Acute escalation of FiO_2 requirements > 5L/min and not a palliative patient
    - Clinically unstable despite escalation of home ventilatory settings
- Patients with tracheostomy who are NOT on invasive home ventilatory support may be started on acute CPAP as per this document

Monitoring

Parameters:
Monitor patients and document hourly:

- Respiratory rate and saturations
- Oxygen requirements and ventilator settings
- Heart rate

Investigations:

- Blood gas analysis may be performed PRN, but guidance for escalation of therapy OR failure of therapy should be primarily guided by clinical examination, and not be delayed because of lack of blood gas derangements.
- Chest X-Rays where clinically indicated

Complications:
Complications of non-invasive respiratory support therapy include:

- Pressure sores (nasal bridge, nasal septum)
- Facial abrasions
- Irritation to eyes and conjunctiva
- Air leaks e.g. pneumothorax, pneumomediastinum.
- Gastric distension and risk of aspiration/vomiting
- Nasal dryness, rhinitis, sinus pain

To avoid the above complications, we recommend:

- Insertion of an oro-gastric/naso-gastric tube
- "Time-off" mask interfaces every 6-8 hours and/or for routine nursing cares
- Humidification of the NIV circuit
- Checking for pressure sores every 2-3 hours looking for irritation to eyes/conjunctiva, pressure sores, poor mask fit.

Trouble-shooting:

- **During office hours**, contact CICU/ HD respiratory therapist for device or interface-related issues
- **After office hours**, contact CICU medical and nursing team for patient or device-related issues

Maintenance:

Refer to Hospital Nursing Policy and Procedures on maintenance of NIV/home ventilator machines.

Acute respiratory distress syndrome (ARDS)

Pediatric ARDS definition (2015)

Age	Exclude patients with peri-natal related lung disease	
Timing	Within 7 days of known insult/ injury	
Chest imaging	New infiltrates consistent with ACUTE pulmonary parenchymal disease	
Origin of edema	Respiratory failure NOT fully explained by cardiac failure or fluid overload	
oxygenation	**Non invasive support**: • CPAP[1] ≥ 5cmH_2O OR bilevel support, AND • P/F[2] ratio ≤ 300 OR • S/F[3] ratio ≤ 264	**Invasive support**: • **Mild:** OI[4] between 4 to < 8, or OSI[5] 5 to < 7.5 • **Moderate**: OI between 8 to < 16, or OSI 7.5 to < 12.3 • **Severe**: OI ≥ 16, or OSI ≥ 12.3
Special populations		
Cyanotic heart disease	Criteria as above with acute deterioration in oxygenation not explained by underlying cardiac disease	
Chronic lung disease	Criteria as above with new infiltrates and acute deterioration in oxygenation from baseline which meets above oxygenation criteria	
Left ventricular dysfunction	Criteria as above with new infiltrates and acute deterioration in oxygenation from baseline which meets above oxygenation criteria not explained by left ventricular dysfunction.	

[1] CPAP: continuous positive airway pressure, [2]P/F ratio: P_aO_2 (partial pressure of arterial oxygen)/ F_iO_2 (fraction of inspired oxygen) ratio, [3]S/F ratio: SpO_2 (oxygen saturation)/ F_iO_2 ratio [wean F_iO_2 to maintain saturations ≤ 97% to calculate OSI or S/F ratio) , [4]OI: oxygenation index, [5]Oxygenation saturation index. *Adapted from: The Pediatric Acute Lung Injury Consensus Conference Group.* Pediatric Acute Respiratory Distress Syndrome: Consensus Recommendations from the pediatric acute lung injury consensus conference.
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Effects of positive pressure on patients with ARDS[6]

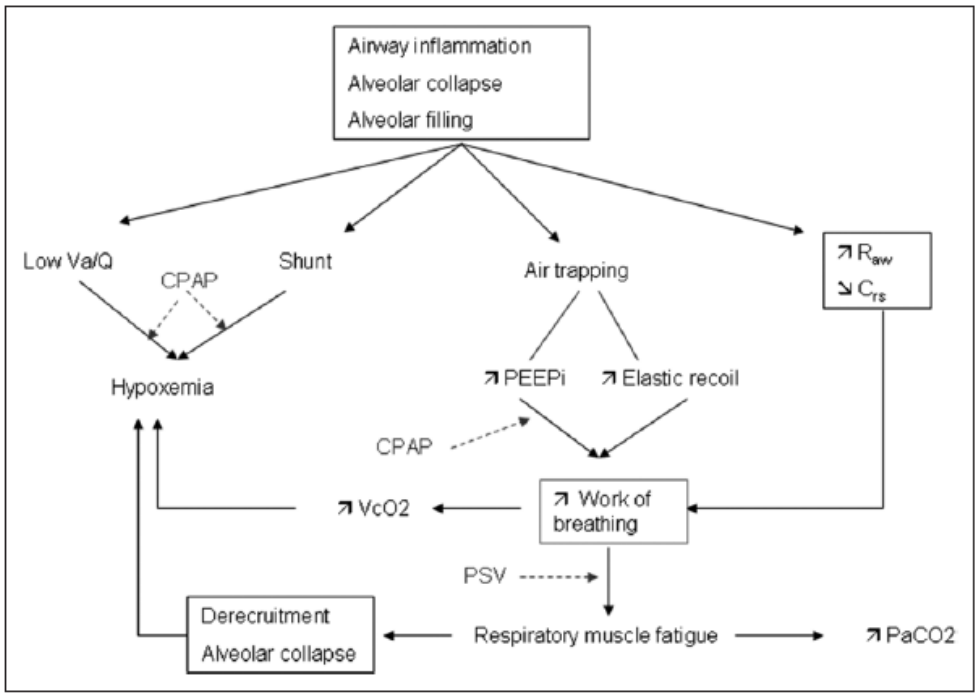


Figure 1. Diagram of pathophysiologic changes in acute respiratory distress syndrome and effects of treatment with positive pressure. C_{rs} = static compliance, CPAP = continuous positive airway pressure, PEEPi = intrinsic positive end-expiratory pressure, R_{aw} = airway resistance, Va/Q = ventilation-perfusion ratio, Vco_2 = oxygen consumption.

Lung protective strategies:

Ventilator-induced lung injury (VILI) occurs in 4 potential ways: [7]

- volutrauma (over-distension of normal alveoli)
- atelectrauma (repetitive opening and closing of collapsed alveoli)
- barotrauma (regional lung overdistension leading to air leaks)
- biotrauma (release of inflammatory cytokines that drive ongoing lung injury)

Strategies for lung protection in a ventilated patient with ARDS include:

- Low tidal volume strategy (no more than 6ml/kg)
- Avoid Pplateau pressures > 30cmH_2O
- Allow permissive hypercapnia so long as pH > 7.25
- Allow permissive hypoxia (PaO2 55-65 mmHg, or SpO_2 88-92%) so long as no evidence of tissue ischaemia
- Ensure adequate sedation and analgesia, consider paralysis to decrease metabolic demands

Extubation readiness

All patients who have been on invasive mechanical ventilation via endotracheal tube (ETT) should have an extubation readiness test (ERT), which includes a protocol for a spontaneous breathing trial (SBT), before planned extubation.

ERT screening should be performed daily and incorporate the following criteria:

- Minimal ventilatory settings (PEEP ≤ 8, PIP ≤ 16)
- Low oxygen requirements (ideally FiO2 ≤ 40%)
- Mental status (including level of sedation)

- Ability to protect their airway (cough strength and secretion management)
- Presence of ETT leak (especially if the patient had multiple intubation attempts, or has been ventilated for a prolonged period of time)

Only patients who pass ERT screening may be subjected to an SBT. These are the **SBT parameters:**

Mode:	Pressure Support Ventilation
FIO_2:	Current FIO_2
PEEP:	Current PEEP
Pressure support:	PS 10 (ETT size 3.0 – 3.5), PS 8 (ETT size 4 – 4.5), PS 6 (ETT size ≥ 5). Consider titrating the pressure support lower if the patient tolerates initial pressure support settings for 1 hour.
Monitoring:	Hemodynamics and respiratory parameters Blood gas

Results of the ERT/SBT should be considered before finalizing an extubation plan. **An extubation plan should include whether the patient needs dexamethasone (for suspected subglottic edema/ absence of ETT leak), post-extubation respiratory support, fasting time and/or other supportive therapies (e.g. anti-sialagogues).**

Ensure that equipment for advanced airway management (oxygen mask, suction catheters, saturation monitor, BVM) is available at the bedside BEFORE attempting extubation.

Easy blood gas interpretation

STEP 1: Assess internal consistency of the values using Henderson-Hasselbach equation

Henderson-Hasselbach equation:
$H^+ = 24(PaCO_2)/HCO_3^-$

If the pH and H^+ are inconsistent, the ABG is probably not valid

pH	Approx. H^+ (mmol/L)
7.0	100
7.1	79
7.2	63
7.3	50
7.4	40
7.5	32

STEP 2: Acidaemia or alkalaemia?

pH < 7.35 = acidaemia
pH > 7.45 = alkalaemia

This is usually the primary disorder

**An acidosis or alkalosis may be present even though the pH is normal, you will then need to check the $PaCO_2$, HCO_3 and anion gap*

STEP 3: Respiratory or metabolic?

Determine the relationship of change in pH and direction of change in the $PaCO_2$

Primary respiratory: pH and $PaCO_2$ change in opposite directions
Primary metabolic: pH and $PaCO_2$ change in the same direction

Acidosis	**Respiratory**	**pH ↓**	**$PaCO_2$ ↑**
	Metabolic	pH ↓	$PaCO_2$ ↓
Alkalosis	**Respiratory**	pH ↑	$PaCO_2$ ↓
	Metabolic	pH ↑	$PaCO_2$ ↑

STEP 4: Compensatory response?

- Is there an appropriate compensation to the primary disorder?
- *Compensation usually does not return the pH to normal (7.35-7.45)*
- If the observed compensation is not the expected one, it is likely there is more than one acid-base disorder present.

Disorder	Expected compensation	Correction factor
Metabolic acidosis	$PaCO_2 = (1.5 \times HCO_3^-) + 8$	± 2
Acute respiratory acidosis	Increase in $HCO_3^- = \Delta PaCO_2 / 10$	± 3
Chronic respiratory acidosis (3-5 days)	Increase in $HCO_3^- = 3.5(\Delta PaCO_2 / 10)$	
Metabolic alkalosis	Increase in $PaCO_2 = 40 + 2(\Delta PaCO_2 / 10)$	
Acute respiratory alkalosis	Decrease in $HCO_3^- = 2(\Delta PaCO_2 / 10)$	
Chronic respiratory alkalosis	Decrease in $HCO_3^- = 5(\Delta PaCO_2 / 10)$ to $7(\Delta PaCO_2 / 10)$	

STEP 5: **Calculate the anion gap (if metabolic acidosis exists)**	**AG = Na^+ – (Cl^- + HCO_3^-) ± 2** Normal AG about 12 meq/L *hypoalbuminaemia: normal AG will be lower (expect about 2.5 meq/L lower AG for each 1g/dL decrease in plasma albumin concentration) **Causes of elevated AG (HAGMA)** – **MUDPILES** **M**ethanol **U**remia **D**KA **P**araldehyde, propylene glycol **I**ron, Isoniazid **L**actic acidosis **E**thylene glycol **S**alicylates If AG is elevated, consider calculating serum **osmolar gap** to look for osmotically active particles not explained by ketosis, lactic acid, organic acids. Calculated osmolarity = 2 (Na) + glucose + urea Osmolar gap = measured osmolarity – calculated osmolarity Normal osm gap is < 10 Causes of high osmolar gap: mannitol, methanol, ethylene glycol, sorbitol, propylene glycol **Causes of normal AG (NAGMA)** – Renal versus GIT loss of HCO_3^- • Chloride excess • Acetazolamide • GI causes- diarrhoea/vomiting, fistulae (pancreatic, ureter, small bowel, ileostomy, biliary) • Renal- eg. RTA Calculate **urinary anion gap** to differentiate between a GI or renal cause of NAGMA: Urinary AG = urinary [(Na^+ + K^+) – Cl^-] where unmeasured urinary ions are NH_4^+ and HCO_3^- Renal cause: *increased* AG (increased urinary HCO_3^- excretion) GI cause: *decreased* AG (increased NH_4^+ excretion)
STEP 6: **What is the relationship between AG and HCO_3^- (if there is HAGMA)**	If AG is elevated, assess the relationship between increase in AG and decrease in HCO_3^- , and calculate the **delta ratio** (i.e. **ΔAG/Δ HCO_3^-)** to determine if there is a concurrent NAGMA or metabolic alkalosis ΔAG/Δ HCO_3^- < 1.0: concurrent non-AG metabolic acidosis is present ΔAG/Δ HCO_3^- 1.0 – 2.0: uncomplicated HAGMA ΔAG/Δ HCO_3^-) > 2.0: concurrent metabolic alkalosis is present

Ref: Intepretation of ABGs. D A Kaufman. http://www.thoracic.org/professionals/clinical-resources/critical-care/clinical-education/abgs.php

Oxygenation defect:

- Increase FiO_2
- Increase MAP. If V_t low, can consider increasing pressure differential (pressure difference between PIP and PEEP). If lungs collapsed, or small volumes on CXR, can also consider increasing PEEP.

Ventilation defect:

- Increase RR (to physiological limits). Check normal I:E ratio not exceeded.
- Improve tidal volumes (thus increasing alveolar ventilation).
- Consider if suctioning is needed to clear secretions, before titrating ventilator settings.

Metabolic acidosis:

- Look for CAUSE. Calculate anion gap and decide if normal or high-anion gap.
- Treat the cause of metabolic acidosis
    - $NaHCO_3$ is not useful in treatment of high anion-gap metabolic acidosis. It has a role in the emergency treatment of hyperkalaemia and renal/extra-renal bicarbonate loss.
- **Situations where $NaHCO_3$ correction may be considered**:
    - Cardiac patient (correct if BE greater than -5)
    - if prolonged resuscitation is on-going
    - Evidence of renal/extra-renal bicarbonate loss
    - Emergency treatment of hyperkalaemia
    - Severe metabolic acidosis (pH </= 7.0) while awaiting treatment of cause of metabolic acidosis

Risks of $NaHCO_3$ include:

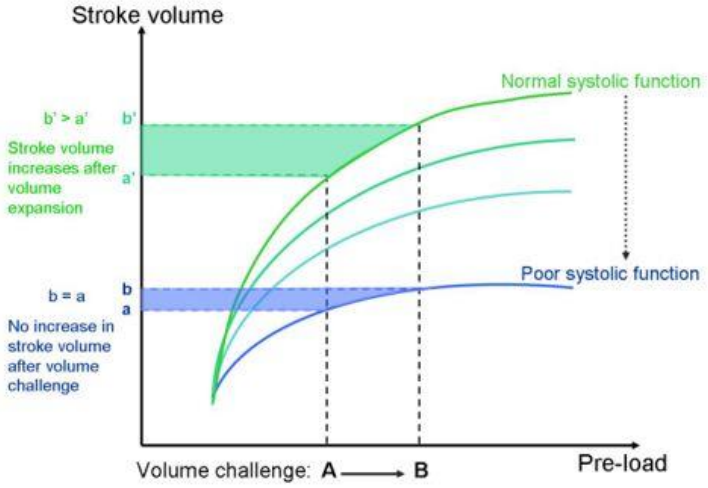
- hypernatraemia
- Paradoxical cerebral tissue acidosis
- Hypercarbia (if inadequate spontaneous respiratory drive)
- Hypokalaemia and hypocalcaemia
- Hyperosmolar, is a vesicant agent (causes blisters/vesicles at site of injection)

$NaHCO_3$ correction dose: [0.3 x wt (kg) x BE]/2
Based on 8.4%$NaHCO_3$ (1mmol/ml)

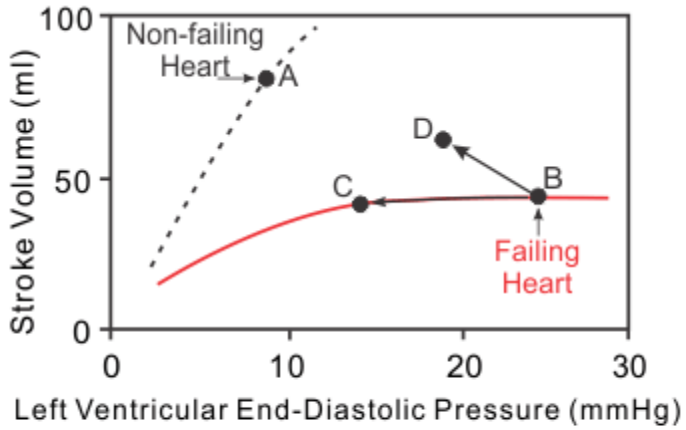
Basic cardiovascular physiology

The Frank Starling curve describes the relationship between stroke volume (SV) and pre-load/ end-diastolic volume or pressure (EDV/EDP) in the left ventricle. (*See graph A below*). The greater the LEDV, the greater the stretch, and hence a greater ejected SV in systole.

In the presence of poor systolic function (eg. heart failure, myocarditis), the curve shifts to rightward and downward, and a similar increase in LEDV results in a smaller or no change in SV. Use of inotropes shifts this curve upward, and vasodilation shifts the curve leftward.



Graph A. *Frank Starling curve with normal and poor systolic function*



A = operating point for non-failing heart
B = operating point for failing heart
C = effects of a diuretic or venodilator
D = effects of mixed vasodilator or inotropic drug

Graph B. *Relationship of dilators and inotropes on the failing heart.*

Use of vasoactive drugs in the CICU

Pharmacological support of the cardiovascular system requires an understanding of the pathophysiology resulting in haemodynamic dysfunction, as well as an understanding of the mechanisms of action and side effects of the vasoactive agents in question.

Table. Adrenergic receptor agonists

Agonists	Receptor	Cellular response	Haemodynamic effect
Adrenaline Noradrenaline Phenylephrine	α_1	Myocardium: Increase cytosolic Ca^+	vasoconstriction
Clonidine	α_2	Central and peripheral adrenergic nerve terminals: Decreased noradrenaline release and sympatholysis	vasodilation
Dopamine Adrenaline	β_1	Myocardium: Increase efflux of Ca^+ out of sarcoplasmic reticulum Kidney: increase renin production	Increase inotropy and chronotropy Increase renin-aldosterone-angiotensin activity
Adrenaline Dobutamine	β_2	Net decrease of cytosolic Ca^+	Vasodilation Bronchodilation
* Milrinone	Phosphodiesterase inhibitor	Myocardium: Increased cytosolic cAMP -> increased cytosolic Ca^+ Vascular endothelium: decrease cytosolic Ca^+	Increase inotropy, lusitropy and vasodilation

Table. Inotrope and pressor use in selected haemodynamic states.

All states require restoration of circulating volume prior to institution of cardiovascular agent.

Clinical State	Clinical features	SVR	Arterial pressure	CVP	Agent/s
Cold shock*	Cool peripheries Poor pulses Prolonged CRT Mottled peripheries	High	Maintained	High	Initial: Dopamine or dobutamine Resistant (or becomes hypotensive): titrate fluids and adrenaline
			Low	Variable	Initial: adrenaline or dopamine Resistant: titrate fluids and adrenaline. Consider adding noradrenaline/ vasopressin for persistent hypotension
Warm shock* (Eg. Anaphylaxis, neurogenic shock, sepsis)	Widened pulse pressure Bounding/full pulses Flash capillary refill	Low	Low	Low	Initial: Titrate fluids and noradrenaline Resistant: consider vasopressin. If mixed venous saturations are low, consider low dose adrenaline.
Cardiogenic shock	Similar to "cold shock" May have new/additional cardiac clinical signs	High	Maintained/ high	High	Initial: Consider milrinone or dobutamine. Consider diuretics if fluid-overloaded Resistant: consider low dose adrenaline or dopamine

	(murmur, gallop, displaced apex, hepatomegaly)		Low	Variable	Initial: Adrenaline or dopamine, limited fluid resuscitation (titrate to CVP) Resistant: Consider milrinone or dobutamine once hypotension reversed.

N.B. Septic shock may present with combined features of warm and cold shock (hypovolemia, vasoplegia and cardiac dysfunction).

Electrolyte derangements

Sodium

Derangements in sodium are common in the ICU. The intravascular fluid status of the patient needs to be considered when determining causes for the sodium derangement. Paired measurements of serum and urine osmolality may be needed to define the cause of hypo or hypernatraemia more clearly.

Serum osmolality can be calculated by the formula:

2 (serum Na) + glucose (mmol/L) + urea

Normal range: 275 – 300 mOsm/kg (hospital reference range)

Hyponatraemia

Defined as Na^+ < 135 mmol/L

- Deficit calculated as: 0.6 x Wt (kg) x (135- measured Na^+)

Causes can be divided into:

- Hypovolemic
  - GI losses (eg. Diarrhoea, vomiting, stomal losses)
  - Non-GI losses (eg. renal losses, burns, 3rd space losses, cerebral salt wasting)
- Isovolemic
  - SIADH (pulmonary or CNS disease)
  - Adrenal insufficiency
- Hypervolemic
  - SIADH
  - Heart failure
  - Renal failure
  - Nephrotic syndrome
  - Cirrhosis

Urgent treatment should be started for patients who are symptomatic (eg. seizures, neurological changes) or if the serum sodium level is < 120 mmol/L. The goal is to increase the sodium level to ≥ 125 mmol/L or cessation of seizures.

3% NaCl solution can be given to urgently raise Na levels, at a dose **of 4ml/kg** over 20-30 minutes. This should be run in a central venous line or a large bore peripheral venous cannula. 4ml/kg of 3% NaCl will raise the sodium level by 3mmol/L.

Once the acute correction is completed, correction of hyponatraemia should continue slowly at a rate no faster than 0.5 - 1 mmol/L/hr.

Specific Treatments:

- Hyponatraemia secondary to hypovolaemia
  - Should ideally be corrected with isotonic fluids. In neonates, calculate and replace deficit in the combination drip.
- Hyponatraemia secondary to SIADH
  - If SIADH is confirmed (euvolemia or hypervolemia with low urine output and inappropriately concentrated urine osmolality for a low serum osmolality), restrict maintenance fluid volumes. Can consider sodium supplements if still hyponatraemic despite severe fluid restriction.
- Hyponatraemia secondary to hypervolemia (i.e. dilutional hyponatraemia)

- Avoid unnecessary sodium supplementation in heart failure, nephrotic syndrome, or renal failure. Consider treatment of underlying disease (eg. diuretics in heart failure, dialysis in renal failure).
- If dilutional hyponatraemia is secondary to overly-diluted milk formulae, treating with appropriate sodium intake for age (with appropriate fluid requirements) will result in normalisation of sodium levels.

Hypernatraemia

Defined as Na^+ > 145 mmol/L

- Free water deficit (Litres) calculated as: [Wt(kg) x 0.6] x [1- 140/measured Na^+)]

Causes:

- Free water deficit
  - Renal losses (renal tubulopathies, post-obstructive diuresis, nephrogenic or central DI)
  - GIT losses (Diarrhoea, stomal losses)
- Sodium excess
  - Inappropriately concentrated milk formula
  - Sodium containing drugs (eg. Sodium bicarbonate)

Avoid rapid correction of hypernatraemia, as rapid shifts in serum osmolality may result in cerebral edema. We recommend no more than 0.5 - 1mmol/L/hr drop in serum Na^+ levels.

Specific treatments:

- Central Diabetes Insipidus (polyuria, raised serum osmolality with inappropriately dilute urine)
  - Replacement of free water (with strict monitoring of fluid status)
  - Administration of intranasal DDAVP or IV vasopressin (*see Unit protocol on IV vasopressin infusion orders*).

Hypokalaemia

Defined as K^+ < 3.5 mmol/L

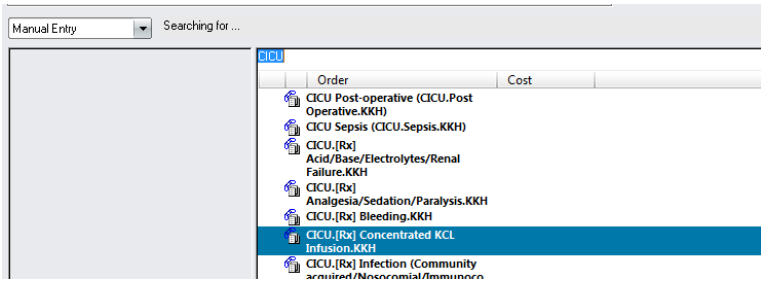
- Deficit is calculated as: 0.3 x Wt (kg) x (4- patient's K^+)

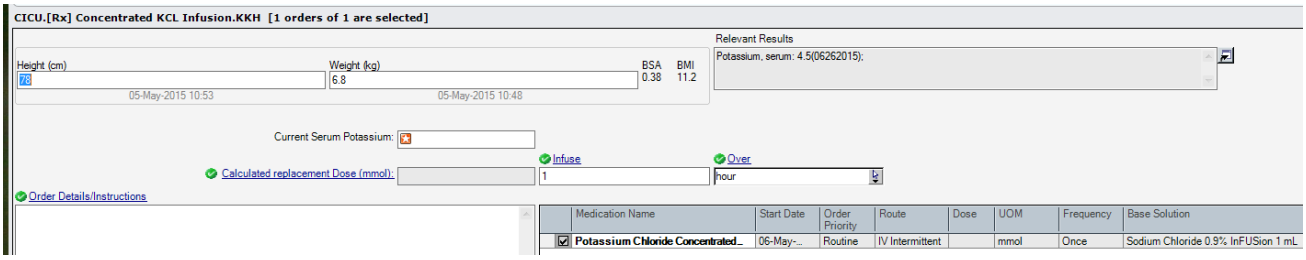
Potassium replacement can be given orally or intravenously with equivalent efficacy.[8] Always consider **ENTERAL** replacement of potassium if the patient is able to tolerate enteral feeds; or increasing TOTAL potassium requirements in maintenance fluids.

Reserve urgent replacement of K^+ (via short IV infusions) in symptomatic patients or post-op cardiac patients (who are at higher risk of arrhythmias). Asymptomatic post-op cardiac patients who are already taking enterally can have ENTERAL potassium replacement.

There are 2 ordersets for IV KCL replacement:

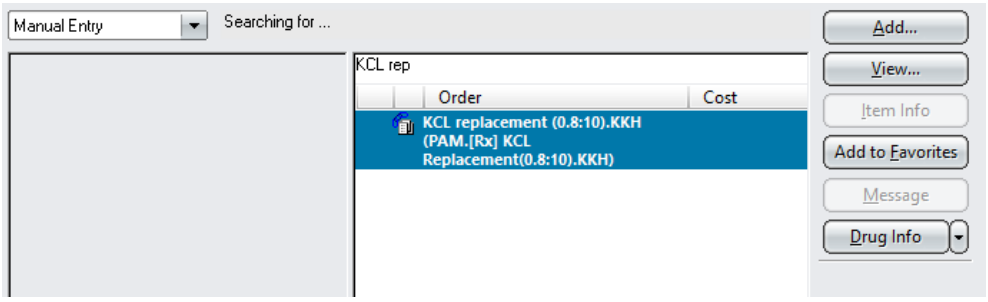
1. **Concentrated IV potassium correction (1:1 dilution of 7.45%KCl)**
   - **Can only be administered in the CICU under continuous cardiac monitoring and via CENTRAL VENOUS ACCESS.**
   - **To be used when K < 2.5 mmol/L(non cardiac patients) or k < 3.0 mmol/L (post-op cardiac patients)**
   - Please order via the hospital's **CICU.[Rx] Concentrated KCL Infusion orderset** (see below) -> search "CICU_concentrated" and the orderset will appear. This orderset is auto-calculated to correct a deficit to a potassium value of **4.0 mmol/L.**





2. Concentrated KCL replacement (0.8:10 dilution of 7.45% KCL)

- This dilution is suitable for peripheral and central replacement of KCL
- Can be used when K < 3 mmol/L in patients who are unable to tolerate oral K replacement
- Please order via PAM. [Rx] KCL replacement (0.8:10) orderset -> search as "KCL replacement" and the orderset will appear (see below)
- This orderset is auto-calculated to correct a deficit to a potassium value of **3.5 mmol/L, with a rate limit of < 0.5mmol/kg/hr**



Hyperkalaemia

Defined as K ≥ 5.5 mmol/L in children, and ≥ 6.0 mmol/L in term neonates.

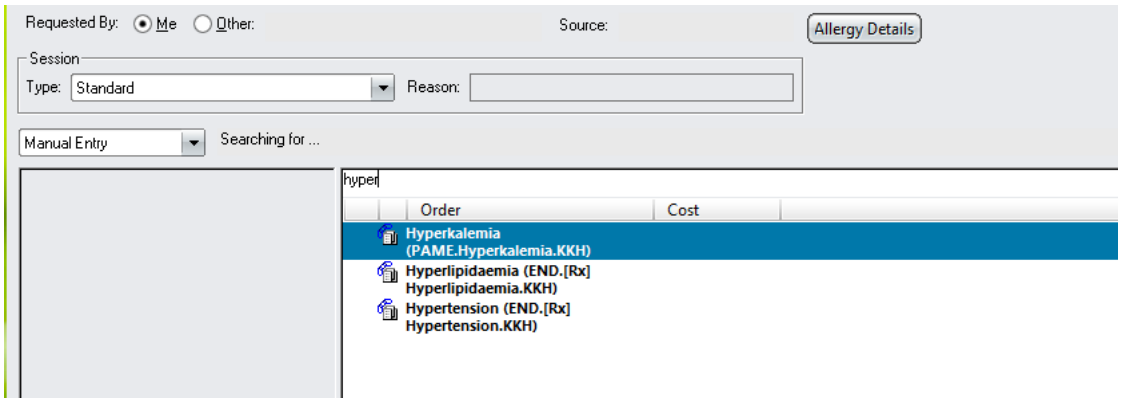
- Review all medications and infusions to look for exogenous K+ sources
- Perform ECG immediately.

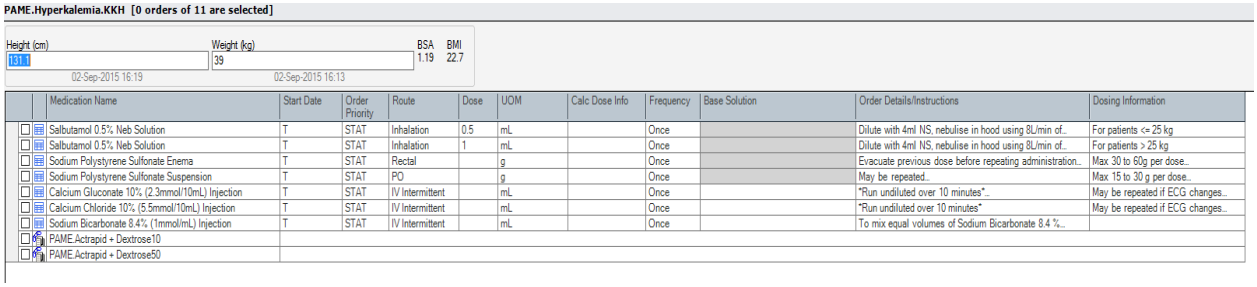
Follow as per EMERGENCY MANAGEMENT OF HYPERKALAEMIA guidelines available in *infopedia/department of paediatric subspecialties/libraries.*

Medical treatment of hyperkalaemia

The order-set for medical treatment of hyperkalaemia can be found via the hospital's orderset: **PAME.Hyperkalemia.**

Please note that concentrated insulin should be further diluted to a final concentration of 1 unit/mL before use.





Derangements in blood glucose

Management of hyper- and hypo-glycaemia in the ICU are in accordance with department of paediatric medicine's guidelines and protocols.

Fluid and nutrition prescriptions in the CICU

Usual recommended daily maintenance fluid requirements for infants and children may be inappropriate for critically ill children in the ICU, who are at higher risk for salt-water imbalances such as SIADH, or fluid overload states.

Holliday and Segar (1957) proposed a maintenance fluid regime for children which assumed that caloric requirements were equivalent to fluid requirements (i.e. 1000cal/day = 1000ml/day). This may not be the case in **critically ill children** for the following reasons:

- Energy expenditure in ICU patients may be lower than normal (especially if patients are sedated, paralysed, or on assisted ventilation)
- Insensible water losses from respiration are lower for ventilated patients as our ventilator circuits are humidified
- Most ICU patients manifest with increased ADH secretion – either as Syndrome of Inappropriate ADH secretion (SIADH), or from an appropriate ADH release in response to stress, hypovolemia, pain etc. Hence, they are usually in a water-retentive state with decreased urinary losses.
- Some ICU patients have increased vasopressin secretion in response to stress, pain, hypovolemia etc. Again, these patients are water-retentive, with decreased urinary losses.

Maintenance intravenous fluid volumes

In patients who are NBM and on intravenous fluids, with NO evidence of volume-depletion, renal impairment or high fluid losses, the INITIAL fluid volume prescription should be:

- Neonates < day 4 of life: as per usual department policy
- Neonates (day 4 to day 30 of life): 100-120 ml/kg/day
- Children > 30 days old: 80% of calculated maintenance fluids

It is assumed that prescribed total fluids per day includes ALL side drips and medications unless otherwise specified.

Maintenance intravenous fluid concentrations

The standard intravenous maintenance fluid concentrations used in our Unit include:

- Neonates: Combination drip (dextrose 10% with NaCl and KCl additives)
- Infants and children: 0.45% Saline with dextrose 5%, with added KCl
- Children > 20kg: 0.9% Saline with dextrose 5%, with added KCl

*(**chloride load in 0.9% saline may cause normal anion-gap metabolic acidosis in children**)*

Re-assessment is mandatory, and subsequent IV fluid prescriptions MUST be titrated to individual patients' fluid status and electrolytes.

Guidelines for initiation of short-term parenteral nutrition (PN) in the Children's Intensive Care Unit (CICU)

These guidelines are meant to aid ordering of PN when PN is initiated within the CICU and may not apply to children outside of the CICU as nutrient requirements may be different.

1. **Considerations for starting PN in the CICU**
   a. Where possible, enteral nutrition (EN) should be the preferred route of nutrition. However, PN may be indicated if the patient is:
      - Deemed unable to receive ANY oral nutrition/EN within the first 7 days of CICU admission (e.g. patients without a functioning gastrointestinal tract) [a]
      - ≥1 month old and unable to progress past 50% of prescribed EN feeds by 5-7 days of admission
      - <1 month old and unable to progress past 50% of prescribed EN feeds by 2-3 days of admission

2. **Exclusion groups**
   The macronutrient goals below do not apply to the following populations:
   a. Patients who are already on PN prior to CICU admission.
   b. Patients with renal or liver injury or failure, on ECMO or CRRT, inborn errors of metabolism, burn injury, or requiring ketogenic diet.
   c. Patients who are severely overweight/obese (BMI for age >97% centile)
   d. Patients at high risk of refeeding syndrome (will need lower initiation and slower progression): [b, d, e]
      - No intake for longer than 7 – 10 days
      - BMI <3rd centile for age and gender
      - Weight loss ≥10% within 1 – 2 months

Please consult a dietician for individualised nutritional optimization.

3. **Initiation and advancement of PN**
   a. Ensure that patient is hemodynamically stable before PN initiation.
   b. Initiate and progress PN according to Table 1 & 2. These are starting recommendations for central PN.
      - **Macronutrients** (Table 1): These are goals for critically ill children requiring full PN for the short-term. Energy goals CICU patients are typically lower than that of non-CICU patients as CICU patients are often sedated and mechanically ventilated [a]. Aside from non-nutritive feeds, EN calories should be factored into total energy intake, with downward adjustment of PN in a proportional manner.
      - **Electrolytes** (Table 2): Electrolytes guidelines apply to the general paediatric population and may need to be adjusted in CICU patients according to serum levels.

Table 1. Suggested CICU PN macronutrient initiation and goals [a, b, c]

				Stop here if intubated	*Stop here if not-intubated*
Weight	**Macronutrient (daily doses)**	**Day 1**	**Day 2**	**Day 3**	**Day 4**
3 – 5kg	**Dextrose, g/kg**	8	10	12	14
	Amino Acids, g/kg	1	2	2	3
	Lipids, g/kg	1	2	2	2
	Energy provided, kcal/kg	41	62	69	80
	Energy goal, kcal/kg	60 – 70 (intubated)			75 – 85 (non-intubated)
6 – 10kg	**Dextrose, g/kg**	8	10	If patient is intubated, provide same values as on Day 2. If patient is not intubated, progress to values in next column → on Day 3.	12
	Amino Acids, g/kg	1	2		3
	Lipids, g/kg	1	2		2
	Energy provided, kcal/kg	41	62		73
	Energy goal, kcal/kg	60 – 65 (intubated)			70 – 80 (non-intubated)
11 – 20kg	**Dextrose, g/kg**	6	8		10
	Amino Acids, g/kg	1	2		2
	Lipids, g/kg	1	1.5		2
	Energy provided, kcal/kg	34	50		62
	Energy goal, kcal/kg	50 – 60 (intubated)			60 – 70 (non-intubated)
21 – 40kg	**Dextrose, g/kg**	4	6		8
	Amino Acids, g/kg	1	1.5		2
	Lipids, g/kg	0.5	1		1.5
	Energy provided, kcal/kg	23	36		50
	Energy goal, kcal/kg	35 – 45 (intubated)			45 – 55 (non-intubated)
>40kg	**Dextrose, g/kg**	3	5		6
	Amino Acids, g/kg	1	1.5		1.5
	Lipids, g/kg	0.5	1		1
	Energy provided, kcal/kg	19	33		36
	Energy goal, kcal/kg	25 – 35 (intubated)			35 – 45 (non-intubated)

Note: Above initial goals are based on energy requirements calculated using Schofield equations and Dietary Reference Intakes. These are meant to be a rough guide only and should be further individualization of nutrition by dietitian depending on medical and nutrition status.

Table 2. Suggested electrolytes, vitamins and minerals [b, f]

Nutrient (daily doses)	3 – 5kg	6 – 10kg	11 – 40kg	>40kg
Sodium, mmol/kg	2 – 3	2 – 3	1 – 3	1 – 3
Potassium, mmol/kg	1 – 3	1 – 3	1 – 3	1 – 2
Calcium, mmol/kg	0.8 – 1.5	0.5	0.2	0.2
Phosphate, mmol/kg	0.5 – 1.3	0.5	0.2	0.2
Magnesium, mmol/kg	0.1 – 0.2	0.2	0.1	0.1
Chloride/ Acetate	As needed to maintain acid-base balance			
Water soluble vitamin mixture (Soluvit®)	1ml/kg/day (Max 10ml/day) *			
Fat soluble vitamin mixture (Vitalipid®)	4ml/kg/day (Max 10ml/day) *			
Trace elements (Peditrace®)	1ml/kg/d (Max 15ml/day) *			
Zinc, mcg/kg/day	TPN trace elements at 1ml/kg/d already provides 250mcg/kg/day zinc. Additional 200mcg/kg/d may be given for wound healing, severe diarrhea or high stoma losses. Max = 5mg/day			

**see Table 4 for composition*

Note: Above electrolyte doses are suggested starting points; adjust as necessary.

Table 3. Suggested monitoring of laboratory values for PN in CICU

	Before PN initiation	During first 3 days of PN, or if unstable	Stable patients
Electrolytes (renal panel and Ca/Mg/PO4)	Y	Daily	2x/week
Hypocount	Y	3-4x/d, until stable	1x/day
Serum triglycerides*	Y	1x/week	1x/week
Liver function tests	Y	2x/week or daily for deteriorating LFTs	1-2x/week
Weight	Y	-	1-2x/week
Copper, Zinc	-	-	Every 3 months for long-term PN

****In CICU, lipids should be stopped for 4 hours prior to testing of serum triglycerides***

4. Monitoring and troubleshooting

a. Monitor labs as suggested in Table 3.

b. Refer to dietitian if nutrition optimization is required, e.g. patient is malnourished, or requires >5 days of PN.

c. Troubleshooting:

i. Hypertriglyceridemia [c]

In the CICU, lipids should be stopped for 4 hours prior to testing triglycerides (TG).

Fasting lipid levels

Serum Triglycerides	Action	Comments
1.7-3.0 mmol/L	Acceptable	Gradually increase lipids to goal. If goal achieved, maintain same lipid dose. If concerned about borderline high TG, may reduce lipid dose but aim to provide minimum of 0.5g/kg/day for infants and younger children to prevent essential fatty acid deficiency
> 3.0mmol/L	Stop lipids and recheck TG in 24hrs	If hypertriglyceridemia resolves (i.e. TG < 3.0mmol/L), to restart lipids at 50% of previous dose and recheck TG in 24hrs. For each subsequent increment in lipids > to recheck TG in 24hrs

d. Preventing PN associated liver disease (PNALD) [b, c]

Prolonged PN dependence (>2 – 4 weeks) can increase risk of PN-associated liver disease. To avoid PN associated liver disease, consider:

- Providing trophic EN feeds and weaning off PN whenever possible.
- Ensure that lipids and dextrose doses are not excessive, and that lipids do not exceed 40% of non-protein calories if on exclusive PN >2 weeks.

NOTE: Deranged LFTs may be indicative of PNALD or other underlying liver diseases. If LFTs are deranged, refer to Gastro for further management.

Table 4. Composition of vitamin and minerals

Water soluble vitamins (Soluvit®)	Per 10ml	Fat soluble vitamins (Vitalipid ®)	Per 10ml	Trace minerals (Peditrace®)	Per ml
Vitamin B12	5 mcg	Vitamin A	2300 IU (690 mcg)	Zinc	250 mcg
Vitamin B2	3.6 mg	Vitamin D2	400 IU (10 mcg)	Selenium	2 mcg
Nicotinamide	40 mg	Vitamin E	7 IU (6.4 mg)	Iodine	1 mcg
Vitamin B6	4 mg	Vitamin K1	200 mcg	Copper	20 mcg
Pantothenic acid	15 mg			Manganese	1 mcg
Vitamin C	100 mg			Fluorine	57 mcg
Biotin	60 mcg				
Folic acid	0.4 mg				

References

a. Mehta, Nilesh M., et al. "Guidelines for the provision and assessment of nutrition support therapy in the pediatric critically ill patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition." *Journal of Parenteral and Enteral Nutrition* 41.5 (2017): 706-742.

b. Corkins, Mark R. *The ASPEN Pediatric Nutrition Support Core Curriculum, 2nd Edition.* American Society for Parenteral & Enteral Nutrition, 2015

c. Joosten, K, et al. "ESPGHAN/ESPEN/ESPR guidelines on pediatric parenteral nutrition: Energy". *Clin Nutr 2018 (In press)*

d. *Dunn, R, et al.* "Refeeding Syndrome in Hospitalized Pediatric Patients". *Nutrition in Clinical Practice* 18:327 – 332.

e. Byrnes, Matthew C, et al. "Refeeding in the ICU". *Curr Opin Clin Nutr Metab Care* 13:186 – 192.

f. Mihatsch W, et al. "ESPGHAN/ESPEN/ESPR guidelines on pediatric parenteral nutrition: Calcium, phosphorus and magnesium". *Clin Nutr 2018 (In press).*

Enteral feeds

Enteral feeds should be started in patients as soon as possible. Our Unit practices a nursing-led **feeding protocol** that allows for scheduled progression of enteral feed volume. Please refer to our Unit nursing protocol for more information on the feeding protocol. Patients excluded from the feeding protocol include:

- Post op cardiac patients
- Patients after gastrointestinal surgical procedures

If patients are on severe fluid restriction, or have poor weight gain in CICU, a referral to the dietician for maximisation of feed calories is warranted.

Please see Baby bear handbook chapter on fluids and electrolytes for further details.

Management of post-operative patients

The CICU receives patients from multiple surgical disciplines including general surgery, cardiothoracic, neurosurgical, orthopaedic, ENT and plastics.

General management of these patients include:

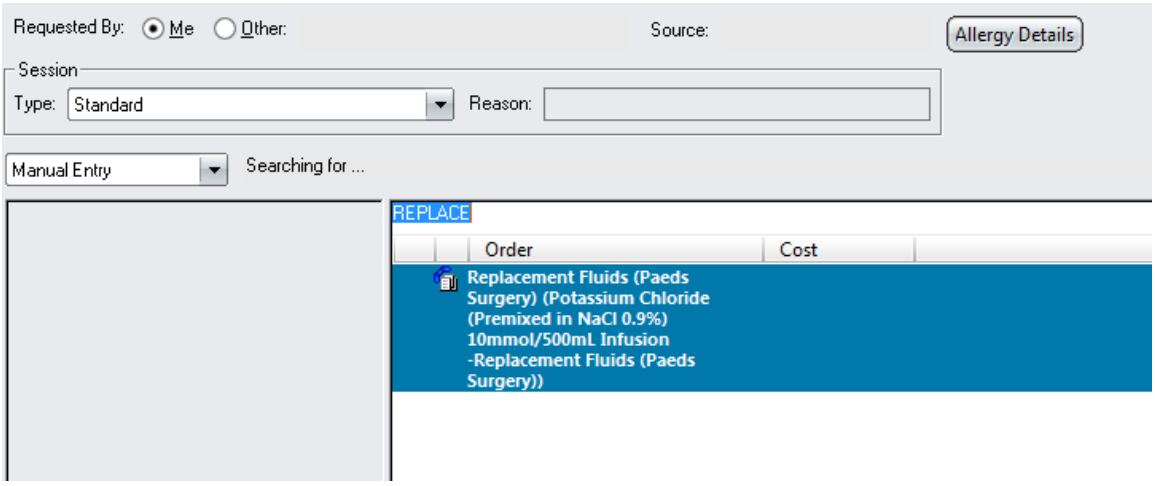
- Receiving adequate handover from the intra-operative team (surgeons and anaesthetists) regarding the anaesthetic management, surgical procedure, adverse events intra-operatively and recommendations for the post-operative care.
    - An adequate handover improves patient outcomes, minimises risk of errors and delays in therapy.
- Examination of patients documenting all hardware (eg. lines, tubes etc) in case these have migrated during the transfer process.
- Ordering up post-op care instructions and medications.
- Note that specific disciplines have protocols for their surgical patients (eg. posterior instrumentation for spinal scoliosis)

The post-operative **HANDOVER process**:

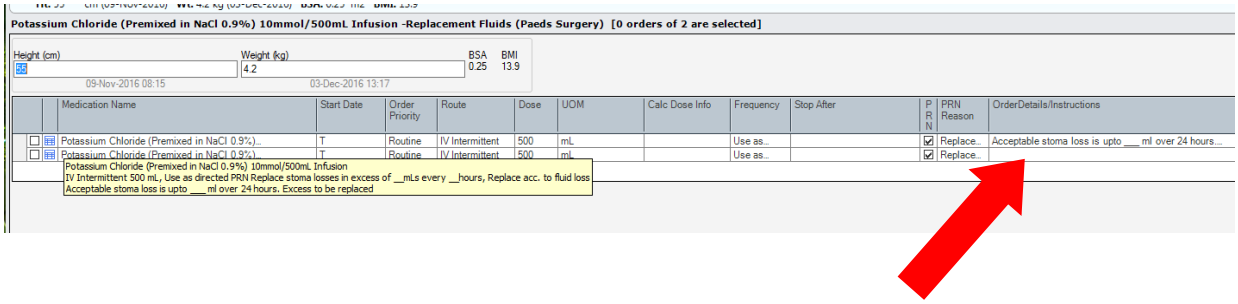
- All members (transferring and receiving team) should be present and ready to take handover
- There should be no/minimal distractions or disruptions during the handover process
- The quality of information should be structured, there should be clear documentation and communication *(Refer to "PETS handover checklist" chapters in CICU online handbook)*

Post-operative replacement of losses

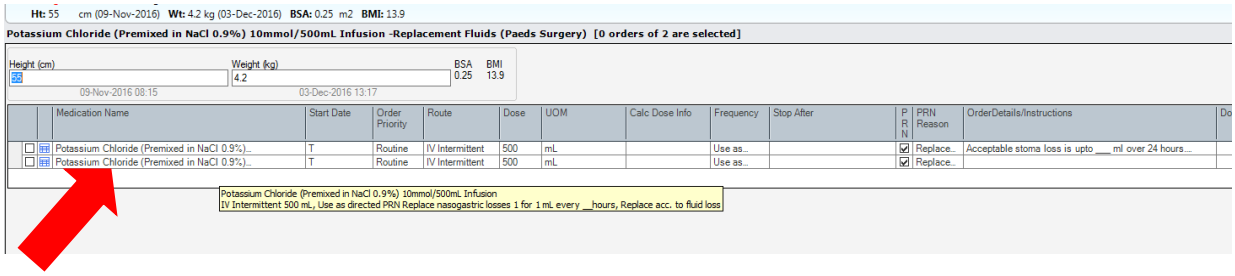
GIT losses can be replaced using the order-set **Replacement Fluids (Paeds Surgery) KCl Premixed in NaCl 0.9% 10mmol/500ml infusion (see below)**



Ileostomy losses:
Ileostomy losses may be **replaced in excess of __ ml every __ hours (usually in excess of 20ml/kg/DAY) with premix NaCl 0.9% + Potassium Chloride.** This regime must be confirmed with primary surgeon- see order-set below



Gastric losses:
Gastric losses may be replaced **ml for ml every __ hours with Premix 0.9%NaCl + Potassium Chloride** (to confirm with primary surgeon re: replacement regime)- see order-set below



EVD losses:
External ventricular drain losses may be replaced **ml for ml every hour with 0.9% NaCl (normal saline**). This must be confirmed with the primary neurosurgeon.

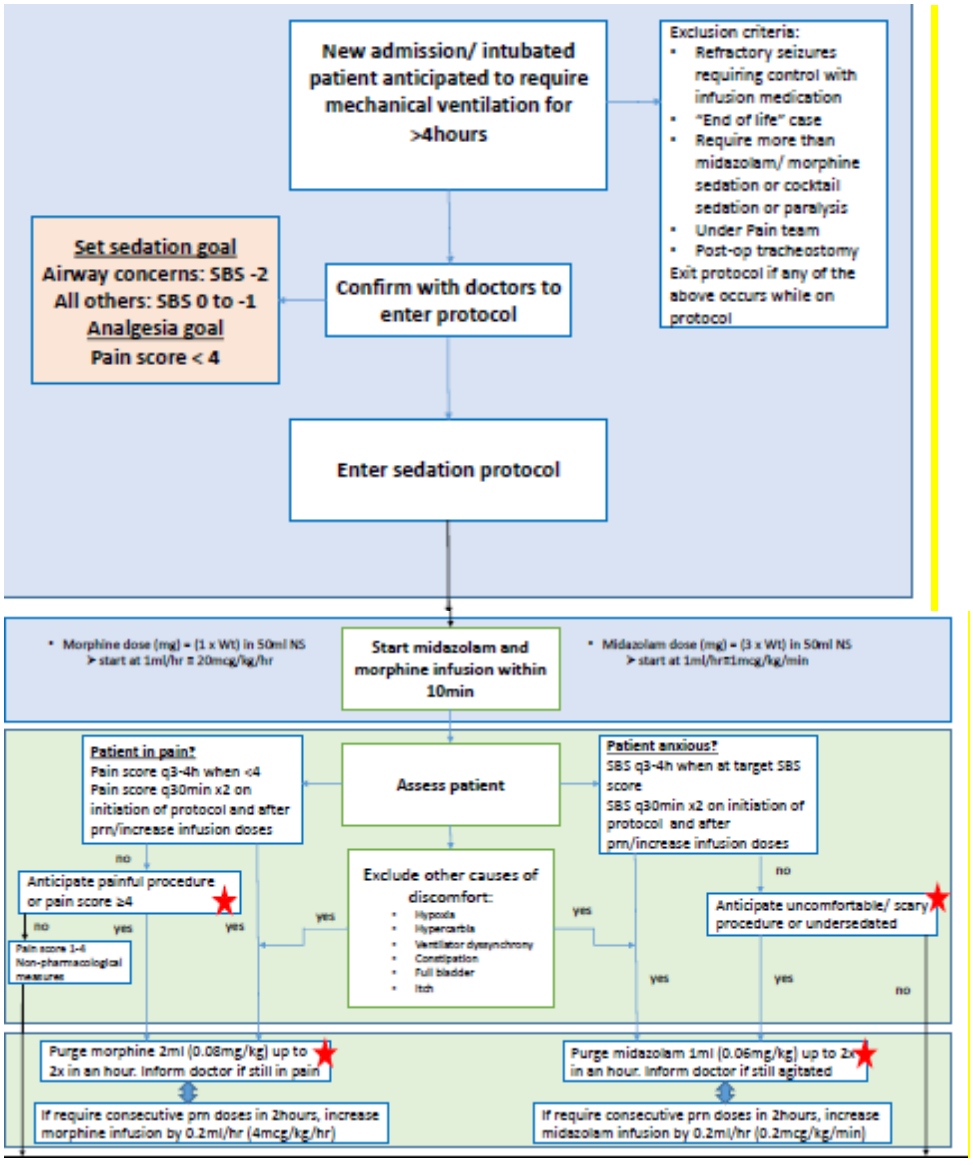
More specific management of cardiac patients after surgery can be found in the CICU handbook chapter on post-operative cardiac care.

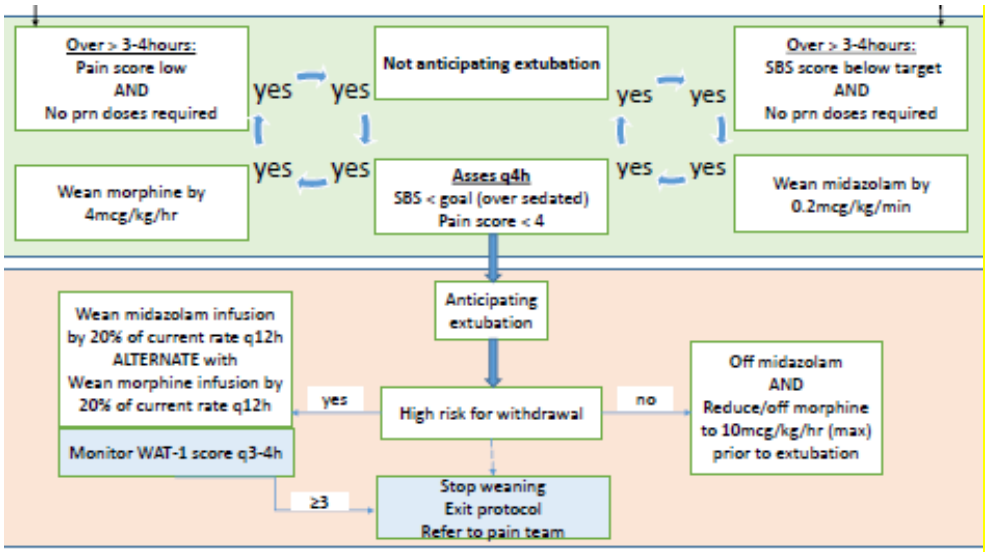
Sedation and analgesia monitoring in the CICU

- All **intubated patients** will be monitored for adequacy of sedation and/or analgesia, as well as for signs of iatrogenic withdrawal via monitoring tools.
- Unless indicated, nurses will target an SBS score of -1 or 0, unless extubation is planned within 4 hours.
- For iatrogenic drug withdrawal, any patient with a WAT-1 score of 3 or more should be reviewed for an intervention plan.

CICU sedation initiation protocol

v.Jan2018





Guidelines on initiation and type of sedatives, analgesics and neuromuscular blockade can be found in the separate chapter on "Pain, sedation and neuromuscular blockade" in the online CICU handbook. Guidelines on the "weaning of sedation/analgesia and withdrawal syndrome", as well as "delirium in critically ill children" can be found in the online CICU handbook.

STATE BEHAVIOR ASSESSMENT (SBS)

Every patient who is on at least one continuous analgesia or sedative infusion will have his/her state behavior assessed and documented at least every four hours using the State Behavioral Scale (SBS) [9]. The SBS is a 6-point scale that describes state behavior on a scale of -3 to +2.

Definition of State Behavior:
In pediatric patients supported on mechanical ventilation, state behavior is described as a summative characteristic of the following dimensions:
1. Respiratory Drive/ Response to ventilation
2. Coughing
3. Best Response to Stimulation
4. Attentiveness to Care Provider
5. Tolerance to Care
6. Consolability
7. Movement after Consoled

State behavior may range from anesthesia to agitation.

Assessment/Documentation:
Patient's state behavior is documented under the "Pain/ Sedation Monitoring"
1. On admission
2. Before and after sedative administration or any intervention to decrease or alleviate agitation
3. At a minimum of every 4 hours with vital signs and pain assessment.

Bedside nurses will assess the patient during normal cares. Progressive stimuli will be applied to elicit the patient's response; specifically, using a calm voice call the patient's name. If no response, call the patient's name and gently touch the patient's body. If no response, asses the patient's response to a planned noxious procedure, e.g., planned endotracheal suctioning. If a noxious procedure is not planned and assessment is critically important then, using a pencil/pen, provide < 5 seconds of direct pressure to the patient's nail bed.

Interpretation:

More negative scores reflect a sedated state. More positive scores reflect a more agitated state. Zero scores reflect a patient who is awake and able to be calmed. Clinical judgment is used to interpret state behavior considering the context of the situation to differentiate behavioral distress from pain behavior. **The targeted SBS score is 0 or -1.**

- ***If patient's SBS more positive (+) than prescribed:***
  - **Exclude reversible causes of agitation & provide comfort measures.**
  - **If ineffective, administer a morphine and/or midazolam rescue dose.**
  - **If ineffective then increase analgesia and/or sedative infusion**
- ***If patient's SBS more negative (-) than prescribed,*** **then decrease analgesia and/or sedative infusion.**

State Behavioral Scale (SBS) **Score as patient's response to voice then touch then noxious stimuli** (Planned ETT suctioning or <5 seconds of nail bed pressure)		
Score	**Description**	**Definition**
-3	Unresponsive	• No spontaneous respiratory effort • No cough or coughs only with suctioning • No response to noxious stimuli • Unable to pay attention to care provider • Does not distress with any procedure (including noxious) • Does not move
-2	Responsive to noxious stimuli	• Spontaneous yet supported breathing • Coughs with suctioning/repositioning • Responds to noxious stimuli • Unable to pay attention to care provider • Will distress with a noxious procedure • Does not move/occasional movement of extremities or shifting of position
-1	Responsive to gentle touch or voice	• Spontaneous but ineffective non-supported breaths • Coughs with suctioning/repositioning • Responds to touch/voice • Able to pay attention but drifts off after stimulation • Distresses with procedures • Able to calm with comforting touch or voice when stimulus removed • Occasional movement of extremities or shifting of position
0	Awake and able to calm	• Spontaneous and effective breathing • Coughs when repositioned/Occasional spontaneous cough • Responds to voice/No external stimulus is required to elicit response • Spontaneously pays attention to care provider • Distresses with procedures • Able to calm with comforting touch or voice when stimulus removed • Occasional movement of extremities or shifting of position/increased movement (restless, squirming)
+1	Restless and difficult to clam	• Spontaneous effective breathing/Having difficulty breathing with ventilator • Occasional spontaneous cough • Responds to voice/ No external stimulus is required to elicit response • Drifts off/ Spontaneously pays attention to care provider • Intermittently unsafe • Does not consistently calm despite 5 minute attempt/unable to console • Increased movement (restless, squirming)
+2	Agitated	• May have difficulty breathing with ventilator • Coughing spontaneously • No external stimulus required to elicit response • Spontaneously pays attention to care provider • Unsafe (biting ETT, pulling at lines, cannot be left alone) • Unable to console • Increased movement (restless, squirming or thrashing side-to-side, kicking legs)

Curley, M. A. Q., Harris, S. K., Fraser, K., Johnson, R., & Arnold, J. H. (2006). State behavioral scale: A sedation assessment instrument for infants and young children supported on mechanical ventilation. Pediatric Critical Care Medicine, 7(2), 107-114

Withdrawal assessment tool (WAT-1)

Definition of Iatrogenic Withdrawal Syndrome:
Iatrogenic withdrawal syndrome is the term used for a characteristic pattern of unpleasant signs and symptoms that typically follows too rapid tapering or abrupt cessation of opioid, benzodiazepines or other drugs with central nervous system depressant effects. Prominent manifestations include nervous system hyperirritability, autonomic system dysregulation, gastrointestinal dysfunction and motor abnormalities.

Definition of the Start of Weaning:
The date and time associated with a deliberate attempt to discontinue narcotics (opioids) and/or benzodiazepines.

Pediatric Assessment:
Withdrawal assessment, especially in preverbal or nonverbal children, can be challenging. The WAT-1 is used to identify iatrogenic withdrawal syndrome. The nurse should tailor their assessments to the child's developmental level, medical status and temperament using the WAT-1.

Assessment Frequency and Documentation:

- The patient's WAT-1 score can be found under the Pain/ Sedation Monitoring section in the flowsheets
- Start WAT-1 scoring from the first day of weaning in patients who have received opioids +/or benzodiazepines by infusion or regular dosing for prolonged periods (e.g., ≥ 5 days). Continue thrice daily scoring until 72 hours after the last dose.
- The WAT-1 is completed and documented with the SBS at least once per 8 hour shift at 08:00hrs, 16:00 hrs and 20:00 hrs (± 2 hours) until 72 hours after the last PRN narcotic (opioid) and/or benzodiazepine dose.
- More frequent assessment may be necessary in patients who show symptoms of withdrawal from narcotics (opioids) and/or benzodiazepines. The increased frequency of the WAT-1 assessments in these patients should follow the assessment – intervention – reassessment cycle for treating patients' withdrawal.

Interpretation:
A higher WAT-1 score indicates more withdrawal symptoms while a lower score indicates fewer withdrawal symptoms. WAT-1 scores should be interpreted based on their trend over time. **An intervention is recommended if the WAT-1 score ≥ 3 (from the baseline).**

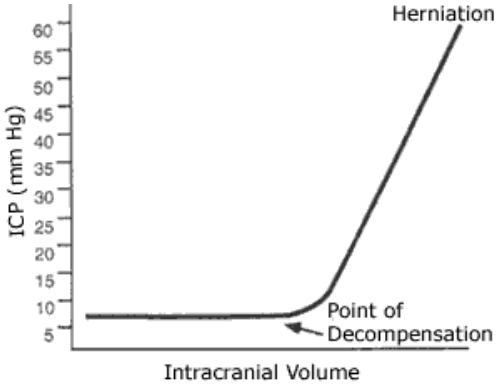
More information on weaning analgesia and sedation can be found under the chapter "Weaning Analgesia and Sedation and management of withdrawal syndrome" in the online CICU handbook.

	PAIN SCORE	SEDATION BEHAVIORAL STATE (SBS)	WITHDRWAL ASESSMENT TOOL-1 (WAT-1)
WHY?	To assess the presence and severity of pain	To assess level of sedation (ie, patient should be asleep by easily arousable)	To assess risk for iatrogenic withdrawal syndrome due to rapid cessation or tapering of opioids and/or benzodiazepine.
WHO?	ALL PATIENTS	All patients who are on at least ONE continuous analgesia and/or sedative infusion (ie: drugs that that reduce patient's wakefulness)	• When weaning of drug is ordered for patients who have received opioids and/ or benzodiazepines by infusion or regular dosing for 5 days and more. • Exclude: regular intermittent benzodiazepines for seizure control.
EXCLUSION	**1) ALL PATIENTS WHO ARE PARALYZED/ ON NEUROMUSCULAR BLOCKING AGENT INFUSION (eg, rocuronium, thiopental)** • Assess train-of-four once a day • Assess pain and SBS during "paralysis holiday" **2) ALL COMATOSE PATIENTS WITH GCS ≤3 AND PUPILS ARE DILATED & NON-REACTIVE TO LIGHT**		
WHEN?	• On admission • **BEFORE EVERY SBS ASSESSMENT OR** • At least 3 times a day - 8am, 4pm, 12MN (± 2hr) • NCA Pumps: Hourly • Post-op : Hourly x 6 • Not more than 4 consecutive hourly "Asleep" status • Before and after any intervention, administration or titration of analgesia	• On admission/ before sedation is first initiated • At least every 4 hourly or during handling • Before and after any intervention, administration or titration of continuous analgesia/ sedative infusion ****More frequent assessment may be necessary in patients who sedation is poorly controlled*	• Before the drug is first weaned (baseline) • At least 3 times a day - 8am, 4pm, 12MN (± 2hr) • Until 72 hours after the last PRN opioid and/or benzodiazepine dose ****More frequent assessment may be necessary in patients who show severe withdrawal symptoms.*
HOW?	• Screen for any history/ possibilities of pain • Indicate site(s) of pain • Choose the most appropriate tool: Numerical Rating Scale/ FACES/ FLACC/ NIPS • Report and provide intervention if pain score > 4 (for NIPS if pain score is >3)	Assess patients during normal care and apply progressive stimulation • Voice • Touch • Planned noxious procedure/ pain stimulus • Consoling	4 points of observation periods: • Patient's record from previous 12 hours • 2 minutes observation with patient at rest • 1 minute stimulus observation • Post-stimulus recovery
WHAT?	• Choose the most appropriate tool based on age and wakefulness of patient: Numerical Rating Scale/ FACES/ FLACC/ NIPS • Review the choice on tool as patient becomes more awake	• Assess pain score first • Choose the more appropriate SBS score (-3 to +2) • Indicate if you think patient is over-/ under- or well-sedated. • Report if SBS is -3, -2 or +2	• Add up the score (out of 12) • Compare with baseline • Report if score is ≥3 (from baseline)
CSDU	• As above	• **SBS AND WAT-1 ARE NOT APPLICABLE TO CSDU PATIENTS** • If patient is on any continuous opioids infusion, perform hourly Pain assessment and Sedation Score	

Paediatric neuro-critical care

Basic intracranial physiology

Monro-Kellie doctrine = cranial vault contains a fixed volume consisting of the brain, blood and cerebrospinal fluid. These components exist in a state of volume-pressure equilibrium (see graph below), and expansion of one induces the reduction in volume of the other/s.



Graph: ICP in relation to intracranial volume. Decompensation occurs when any further increases in intracranial volume (from a mass lesion) results in exponential rise in ICP, which may be life-threatening.

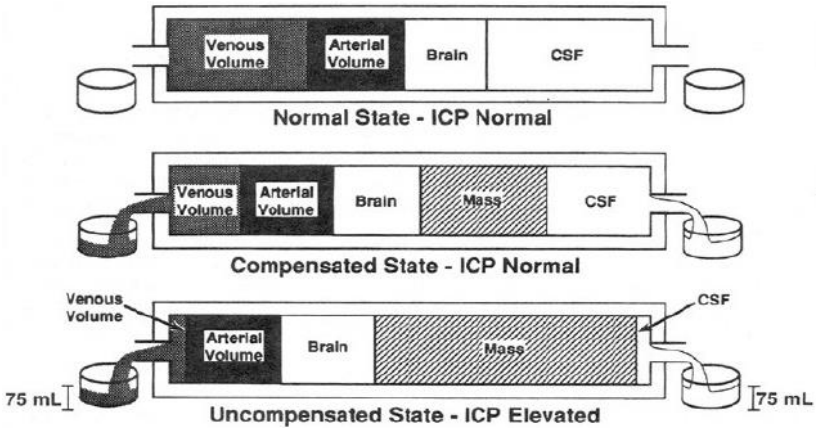
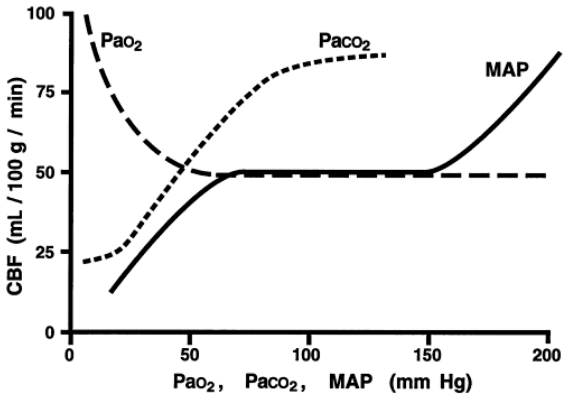


Figure: Intracranial compensation for expanding mass. In the presence of an increasing intracranial mass lesion, compensatory mechanisms include extrusion of CSF and venous volume from the intracranial vault. When maximal compensatory fluid displacement is exceeded, intracranial hypertension occurs.

Cerebral blood flow (CBF) correlates linearly with $PaCO_2$, and alterations occur independently of changes in pH. (see graph below). Hypocarbia results in cerebral vasoconstriction, and can decrease CBF and hence ICP, but does so at the expense of perfusion to ischaemic brain tissue. Hypercarbia results in cerebral vasodilation, which increase CBF and ICP.

Hypoxaemia below 40-50 mmHg causes dilation of cerebral blood vessels, resulting in an increase in CBF and maintenance of oxygen delivery to areas of low oxygen content. This occurs at the expanse of cerebral blood volume and hence ICP.



Graph. *Relationship between CBF and PaO_2, $PaCO_2$ and mean arterial pressures (MAP)*

Acute brain injury can occur from various causes (infection, inflammation, ischaemia, trauma etc.) but the response to brain injury is fairly uniform and comprise of:

- Altered conscious level
- Change in behaviour
- Seizures
- Respiratory dysfunction (bradypnoea, tachypnoea)
- Cerebral swelling and potential rise in ICP
- SIADH

General management includes ensuring cardiorespiratory stability (avoiding hypoxia and hypotension), close control of serum sodium levels, ensuring adequate nutrition and preventing any further secondary brain injury.

Management of patients with traumatic brain injury[11-21]

The goal in the management of children with moderate to severe traumatic brain injury is to avoid secondary brain injury. Key management goals include:

- Avoiding hypoxia
- Avoiding hypotension

Unless specifically instructed, general neuro-protective measures include maintaining:

- PaO_2 > 100 mmHg
- Normocarbia (PCO_2 35-40 mmHg)
- Normothermia (aggressively avoid hyperthermia)
- Intra-cranial Pressure < 20 mmHg
- Cerebral Perfusion Pressure: 40 – 50 mmHg (infants), 50 – 60 mmHg (children)
    - CPP = mean arterial pressure (MAP) - ICP
- Normoglycaemia
- Serum Sodium 145-150 mmol/L
- Adequate sedation and analgesia +/- paralysis
- Head up at 30° with head in mid-line position
- +/- Seizure prophylaxis

For more details on the specific management aspects for pediatric severe traumatic brain injury, please see references (*Brain Trauma Foundation guidelines on severe pediatric traumatic brain injury 2019, chapter on "Management of severe TBI" in the CICU handbook*).

Management of acute intracranial hypertension

Cushing's reflex results in an ominous triad of systemic hypertension, bradycardia and Cheyne-Stokes respirations, in response to cerebral ischaemia. This suggests imminent brainstem herniation, and urgent interventions. In the presence of an ICP monitor, intracranial hypertension is usually defined as sustained ICP > 20 mmHg.

Treatment includes the following:

- Ensure all neuro-protective measures are in place (eg. well sedated? Not in pain? No fever? Normocarbic? Sodium levels adequate? Is this a seizure?)
- If an EVD is in place, check that it is not obstructed
- Active interventions include:
    - Osmotic therapy
        - 3% NaCl 4ml/kg over 30 minutes (or infusions to maintain Na within therapeutic targets) [avoid sustained (> 72hr) serum Na > 160 mmol/L] OR
        - 20% Mannitol 0.5g/kg over 30 minutes (up to limit of serum osmolality 320 mOsm/L)
    - Optimise ventilation to achieve normocarbia (consider SIMV or ASV modes of ventilation)
    - Ensure adequate CPP, consider inotropes to support the BP if needed while intervening to lower ICP
    - Consider need for CT head to exclude new intracranial pathology
        - If new CT head findings present, consider surgical intervention (eg. evacuation of bleed, decompressive craniectomy)
        - In the absence of new CT head findings- consider barbiturate coma (phenobarbitone or thiopentone)

Guidelines for the Management of Pediatric Severe Traumatic Brain Injury, 3rd edition: Update of Brain Trauma Foundation Guidelines. P M Kochanek et al. PCCM 2019; S51-82

*Please also refer to the **management of severe TBI** guideline found online in the CICU handbook.*

Extracorporeal Life Support Systems

Acute kidney injury

Critically ill children are at high risk of acute kidney injury (AKI). Risk factors include:

- Underlying disease conditions
  - Heart failure
  - Chronic renal disease
  - Liver failure
  - Congenital heart disease
- Acute conditions
  - Sepsis
  - Hypoperfusion (from any shock state)
  - Abdominal compartment syndrome
  - HUS
  - Rhabdomyolysis
  - Tumour lysis syndrome
- Nephrotoxic agents
  - Anti-microbials
  - Immunosuppressive agents
  - Chemotherapeutic agents
  - NSAIDS
  - Contrast media

AKI can be categorised into pre-renal, renal and post-renal (obstructive) causes.

Fractional excretion of sodium (FeNa) can be calculated to help differentiate causes. FeNa < 1% is more likely pre-renal; FeNa > 3% more likely secondary to intrinsic renal disease.

FeNa (%) = (Urine Na x Serum Creatinine) / (serum Na x Urine Creatinine) x 100

Continuous renal replacement therapy (CRRT)

Indications for CRRT **include:**

- Fluid overload
  - Pulmonary edema, heart failure, refractory hypertension, inability to provide nutrition due to oliguria and high fluid requirements
- Electrolyte derangements
  - Hyperkalaemia, hyperphosphatemia or sodium derangements refractory to medical intervention
- Refractory metabolic acidosis
- Uraemia
- Toxin removal
  - Eg. Ammonia, uric acid, drugs
- Cytokine removal (Eg. in sepsis)

Prior to initiation of CRRT, consent must be taken (for insertion of vascular access and the process of dialysis). The consent form and patient information leaflet are available in the ICU.

- To prescribe CRRT, use the "**CRRT**" order form in SCM -> search "CRRT"
- This prescription needs to be updated DAILY, and can be found under "Dialysis/ExtracorporealTherapy" header in the patients' "Orders" tab.

There are 2 main types of anti-coagulation used for CRRT: systemic (heparin) or regional (citrate).

- In **heparin** systemic anti-coagulation, a continuous heparin infusion needs to be ordered, and titrated according to ACT (activated clotting time)
- In **citrate** regional anti-coagulation, continuous calcium chloride 10% infusion is ordered for the patient, while ACDA (citrate) is ordered to be run through the haemodialysis machine.

There are 2 types of dialysate fluid used for CRRT:

- **Hemosol BO**: is used in heparin-free dialysis or dialysis with **systemic heparin coagulation**. Potassium and phosphate free.
- **Biphozyl**: is used in dialysis with **regional citrate anticoagulation** as it does not contain calcium. Biphozyl contains physiological concentrations of potassium (4mmol/L) and phosphate.
- If the indication for renal replacement therapy is for hyperkalaemia or hyperphosphataemia, consider using Hemosol BO with heparin anticoagulation until the hyperkalaemia and hyperphosphataemia have been controlled.

Compositions of Biphozyl and Hemosol BO:

	Biphozyl	**Hemosol BO**
Na (mmol/l)	140	140
K (mmol/l)	**4**	**0**
Cl (mmol/l)	122	109.5
Ca (mmol/l)	**0**	**1.75**
Mg (mmol/l)	0.75	0.5
Lactate (mmol/l)	3	3
Glucose (mmol/l)	0	0
HCO3 (mmol/l)	22	32
$H_2PO_4^-$	**1**	**0**

Potassium replacement required for Hemosol BO:
Hemosol BO: Initial starting **order [KCL (2mmol/L) + KH_2PO_4 (2mmol/L)]** into each dialysate bag (use CRRT orderset) unless individual adjustments to K^+ or $H_2PO_4^-$ needed.

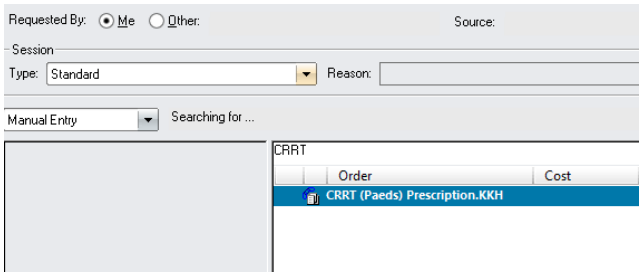
There are 3 main modes of CRRT:

- Continuous veno-venous hemofiltration (**CVVH**): convective process with ultrafiltration
- Continuous veno-venous hemodialysis (**CVVHD**): diffusive process with counter-current flow
- Continuous veno-venous hemo-dia-filtration (**CVVHDF**): convective and diffusive process

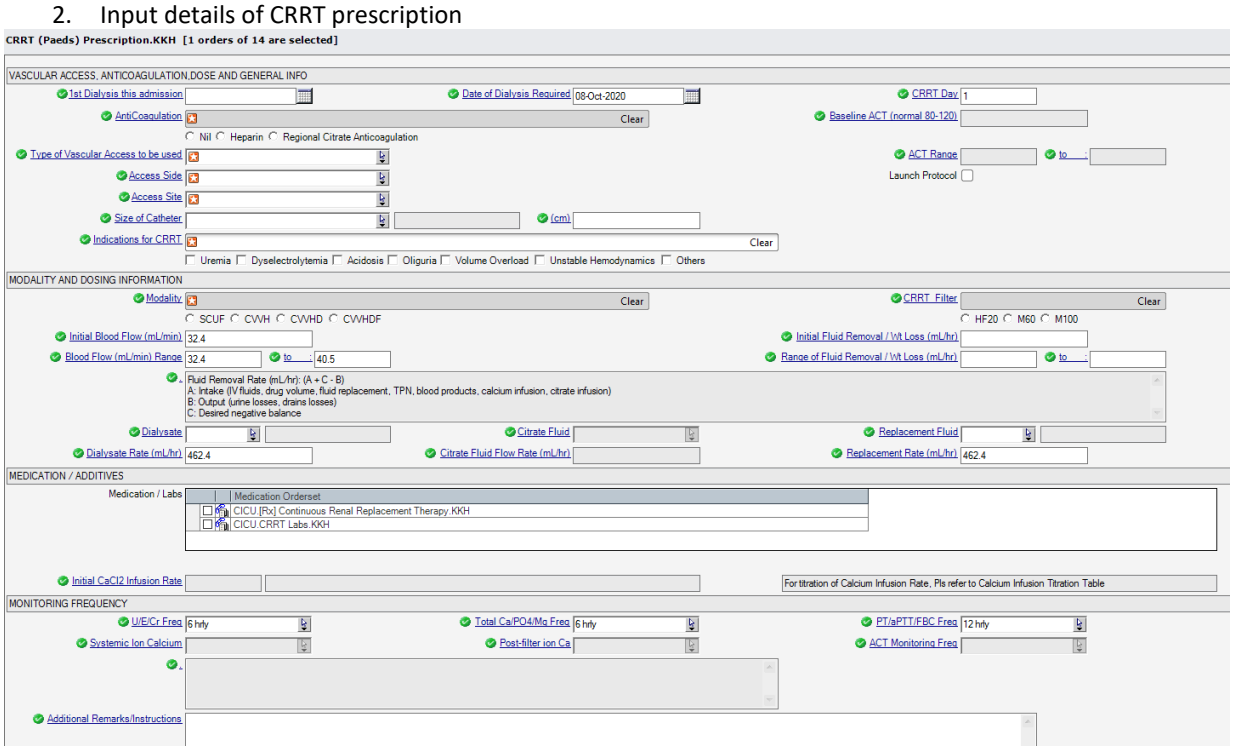
Our unit policy is to start **CVVH** for all patients as a first-line therapy, titrating CRRT prescriptions based on patient requirements thereafter.

Steps to order CRRT

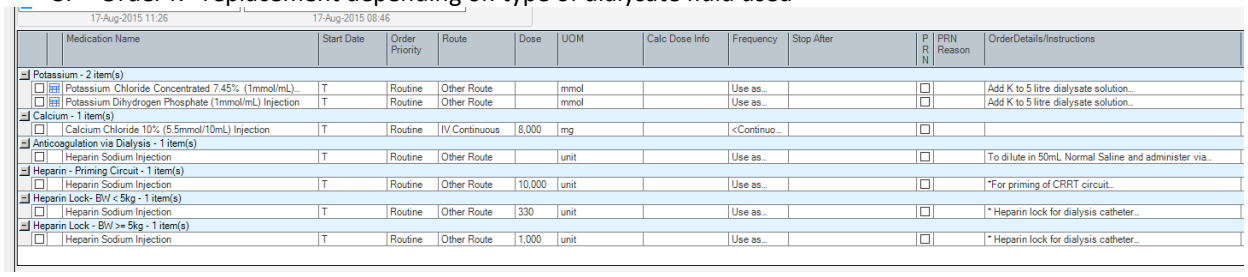
1. Search for “CRRT”



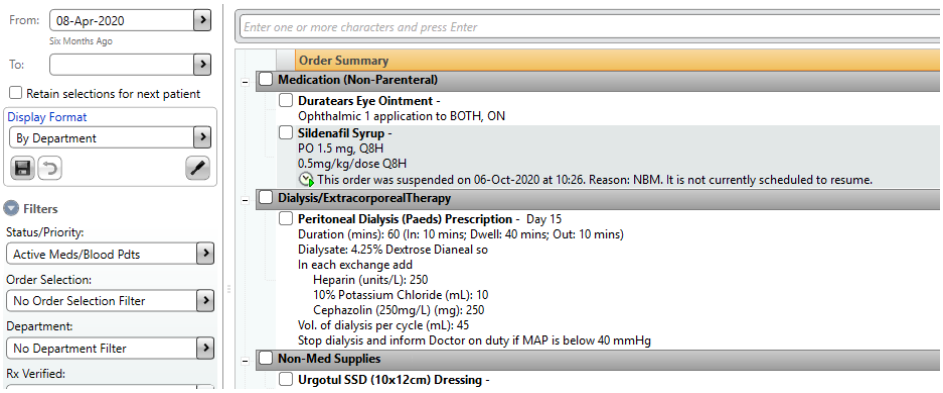
2. Input details of CRRT prescription



3. Order K+ replacement depending on type of dialysate fluid used



4. Confirm Prescription has been submitted (check under "Orders" tab, under "Dialysis/ExtracorporealTherapy" header)
5.



More information on our unit's dialysis policies for monitoring and trouble-shooting can be found on intraweb and in the ICU.

Extra-corporeal Membrane Oxygenation (ECMO)

ECMO is a cardiopulmonary bypass device that is able to provide complete respiratory or cardio-respiratory support when conventional modes of support have failed. Basic techniques include veno-arterial or veno-venous. Veno-venous ECMO is the technique of choice when cardiac function is adequate.

In the event of an emergency ECMO, the ICU team activates an ECMO announcement "ECMO team to CICU bed….". This will trigger the OT staff (anaesthetists, scrub nurses) and surgeons to the bedside.

In preparing for initiation, the ICU resident is expected to:

- Inform Hospital blood bank of the need for ECMO blood (neonatal or paediatric pack based on weight) as below

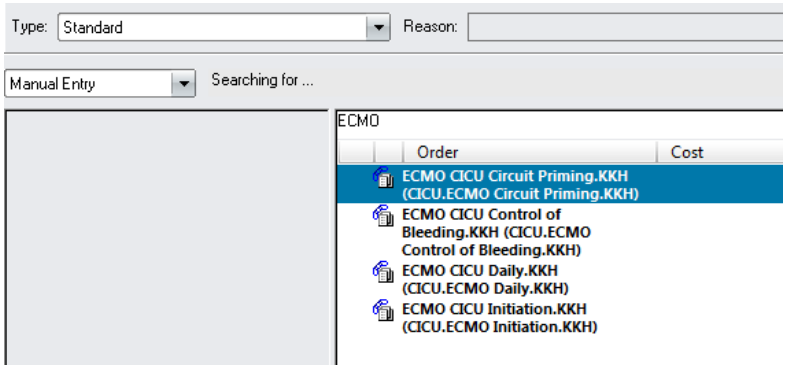
Weight of patient	**< 10kg (Neonatal pack)**	**> 10kg (paediatric pack)**
Packed red cells, leucodepleted) for **CIRCUIT PRIMING**	**COLLECT**: 1 adult unit	**COLLECT:** 1 adult unit
	STANDBY: 1 adult unit	**STANDBY:** 1 adult unit
Packed red cells (cross-matched), not leucodepleted. **FOR PROCEDURE**	0 units	1 unit (FOR **STANDBY**, do not bring up to ICU unless specifically told to)

EMERGENCY ECMO initiation

In the case of an **EMERGENCY ECMO initiation**:

- please inform Hospital Blood bank that "ECMO (paediatric or neonatal) pack un-crossmatched" is needed
- ICU resident to fill up the blood product requisition form and the emergency blood request form (in ECMO P and P)
- ICU resident will run to the blood bank with the forms and ice box to collect the blood products -> **COLLECT ONLY 1 UNIT for PRIMING first,** the 2nd unit can be collected later if needed.
- The ICU registrar will be in charge of the acute resuscitation until the arrival of the consultant, and supervise the drawing of drugs required for initiation.
- ICU resident will also activate perfusionist and CTS surgeon on call (contact numbers are found on ICU nursing counter whiteboard)

Order-sets for drugs and investigations for circuit priming, initiation, control of bleeding while on ECMO are available on CLMM under the "**ECMO**" search-word.



- Daily ECMO goals and guidelines should be documented by the ICU consultant/registrar on the form.

Indications, contraindications, techniques, monitoring and trouble-shooting can be found on the ECMO guidelines document available on intraweb and in the CICU online handbook.

Transport of ill patients

Safe transport of critically ill children requires co-ordination, communication, and appropriate equipment and monitoring to ensure stability and prevent clinical deterioration. Depending on stability of the patient, the components of the transport team include:

- Doctor (resident or senior staff)
- bedside nurse
- respiratory therapist (available during office hours only)

Local inter-hospital transports are currently performed by the ICU registrars/senior residents. **ALL ECMO inter/intra-hospital transports are to be performed by ICU Associate Consultant and above only.**

Intra-hospital transports can be performed by the ICU resident or senior resident. All intra-hospital transports require a medical documentation note after completion of the transport.

The minimum equipment required in the transport process includes:

- Cardiac monitor with pulse oximeter
- Oxygen tank/s with enough oxygen for the patient's requirements
- Transport ventilator (if patient is intubated)
- Ambu bag with appropriate mask and appropriate oxygen tubings/connectors
- stethoscope
- Infusion pumps
- A functioning peripheral/central IV cannula on the patient
- Resuscitation drugs (drug kit)

Some considerations before transport include:

- Will this patient be sufficiently stable for the duration of the transport (eg. MRI scan or interfacility transport)
- Is there special equipment required for this transport? (Eg. MRI compatible equipment)
- Will this patient require additional sedation/paralysis during the transport? How will this be administered?
- Are all parties aware of the transport (parents, receiving facility, ICU senior staff)?
- Are all tubes/lines/drains securely fastened to patient before transport? (eg. ETT plaster, IV cannula, chest drains etc).
- Has consent been obtained?

Paediatric Organ and Tissue Donation

Paediatric tissue and organ donation in Singapore is governed by the Medical (Therapy, Education and Research) MTERA Act. This Act is opt-in, and allows any organ, tissue or whole body to be donated for the purposes of transplantation, education or research. Avenues for donation include donation after brain death certification or after cardiac death. **Referral to the Coroner's office does not preclude organ/tissue donation after death.**

The main steps in the donation process include:

- Family expresses interest in donation after death
- Medical suitability evaluation –contact transplant co-ordinator for pre-screening
- Family meets with transplant co-ordinator to understand donation process and makes decision re: consent
- Once consent is obtained, a more thorough donor suitability is performed
- Upon death certification, transplant co-ordinator organizes process by which organs/ tissue is recovered

The National Organ Transplant Unit (NOTU) maintains a transplant co-ordinator roster which is available at the ICU nursing counter. In the event that family are open to organ or tissue donation, please contact the transplant co-ordinator on-call to speak to family.

Brain death testing

Testing of brainstem function may be warranted if there is need to certify brain death. In Singapore, brainstem death testing is not necessary for withdrawal of life support. Prior to testing, the examiners must be satisfied that there is no other pathology that may confound test results.

The pre-conditions should be met prior to brain death testing:

- Have an identifiable, irreversible structural cause for brain death present (CT or MRI evidence)
- Exclude other reversible causes of CNS depression:
    - Hypothermia (ensure core body temperature ≥ 35 °C)
    - Hypotension (for age) or hypoxia (PaO2 < 60mmHg)
    - Electrolyte and/or acid base disorders, hypoglycaemia. Ensure:
        - Serum Na between 125- 155 mmol/L
        - Serum glucose between 4.0-15.0 mmol/L
        - Serum K between 3.0-5.5 mmol/L
    - No clinical evidence of significant renal or hepatic failure
    - Drugs (narcotics, benzodiazepines, barbiturates, TCA, phenothiazines, lithium, ethanol)
- Ensure absence or reversal of neuromuscular blockade

The test includes:

1. Motor response to painful stimuli (exclude spinal reflexes)
2. corneal reflex
3. pupillary reflex
4. oculo-cephalic reflex (Doll's eyes reflex)
5. oculo-vestibular reflex
6. gag/cough reflex
7. Apnoea test – no spontaneous respirations despite hypercarbia

Our hospital maintains a list of practitioners accredited to perform brain-stem testing. For more details, please see the "Death procedures" and "Organ transplantation" files in ICU, as well as "MOH Manual on Organ Donation and Transplantation handbook on brain death testing" available in ICU.

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Appendix 1: Endotracheal intubation checklist

Please record: 1) Saturations at end of bagging, 2) Lowest saturations during 1st intubation attempt, and 3) Time between (1) and (2)

Plan

- Is the environment optimal?
- Do I need more help?
- Previous difficult intubation/mask ventilation?

Equipment

- ECG, BP cuff (2 minute cycle), saturations, end tidal CO_2
- Bag valve mask, suction (Yankauer), ETT (half size up and down), laryngoscope and blades, ETT tapes, McGill's forceps, Guedel airway, Stylet/Bougie
- Drugs - RSI, rescue drugs (CONSIDER fluid boluses, atropine, adrenaline); check iv line patency

Patient

- Pre-oxygenate - 4 minutes in 100% oxygen
- CONSIDER nasal cannulae for apnoeic oxygenation
- Optimise patient's position
- Inotropes required?
- Aspirate naso/orogastric tube
- Draw up maintenance sedation infusion

Roles

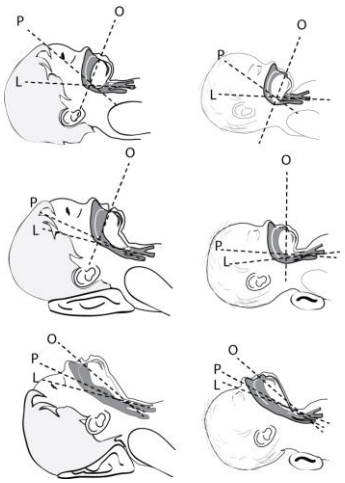
- Role allocation - Team Leader, Airway Assistant (able to give cricoid pressure if needed?), Doctor in charge of drugs, Nurse in charge of drugs, Scribe

Time-out

- Briefing to whole team: Any specific complications expected, contingency plan in case of difficulty
- Does anyone have any questions or concerns?
- Record saturation trend and timing (see box at top of page)

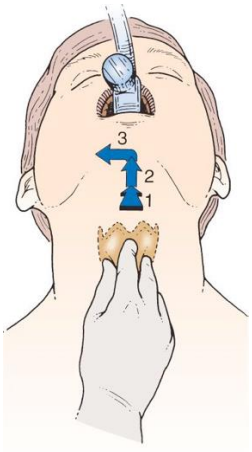
Optimise patient's position

- **Neck flexion/extension as appropriate**
  - Aim to get oral, pharyngeal and laryngeal axes in line for optimal view
  - Child: aim for 'sniffing the morning air' position, i.e. flexion at the cervical spine and extension of the atlantoaxial joint. Consider placing pillow under the child's head to achieve this.
  - Neonates and infants (due to prominent occiputs) as well as patients with unstable cervical spine and Trisomy 21, consider aiming for a neutral head position instead. Consider placing a small towel under the infant's shoulder to achieve this.
- **Head position**
- **Height of bed**



P: Pharyngeal axis
O: Oral axis
L: Laryngeal axis

Cricoid Pressure:
B - Backwards
U - Upwards
R - Rightwards
P - Pressure



Apnoeic Oxygenation Flow Rates (standard nasal cannulae):
<1yr: 5L/min
1-10yr: 8L/min
>10yr: 12L/min

Appendix 2: Arterial catheter placement

** You may view the video on arterial catheter insertion (adult) via this link http://www.nejm.org/doi/full/10.1056/NEJMvcm044149. We practice "over-the-needle" technique in our unit, and do not use sutures for securing.*

Indications:

- Beat-to-beat blood pressure monitoring
- Frequent sampling of blood required
- Use of vasoactive agents that requires close BP monitoring and titration

Common sites (in descending order):

- *Radial
- Dorsalis pedis
- Posterior tibalis
- Femoral
- Umbilical artery (newborns)
- Axillary
- Brachial
- *Ulnar

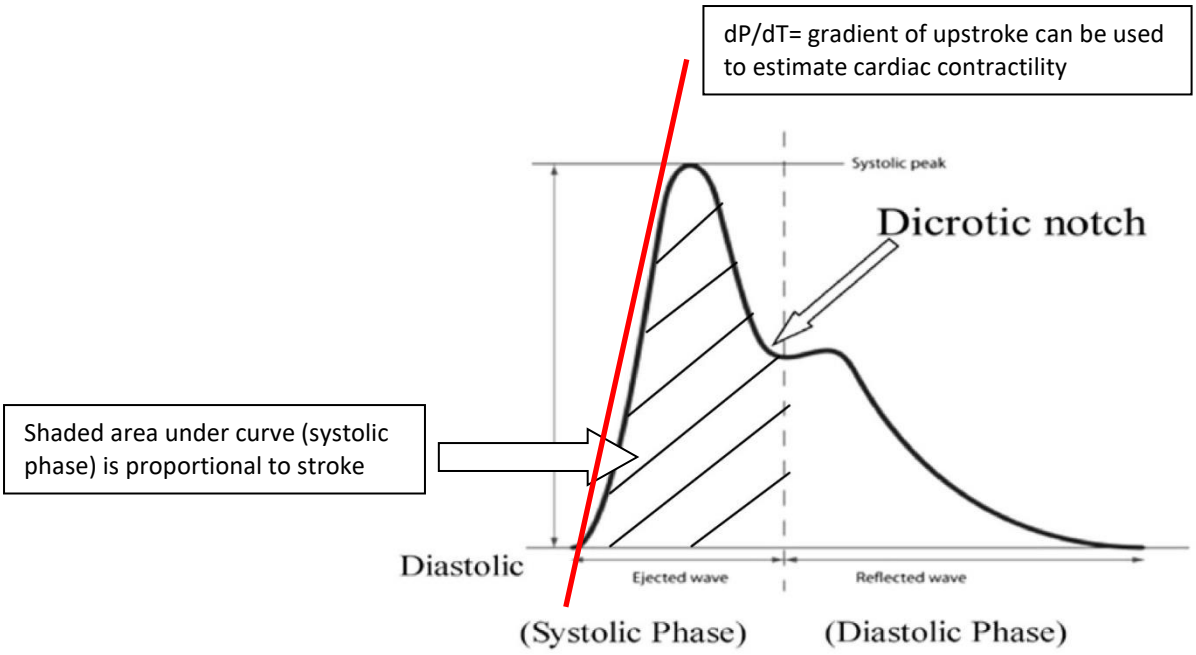
**Perform Allen's test if using radial or ulnar artery cannulation.*

Contra-indications	Complications
Distal ischaemia/thrombosis	Distal ischaemia already present
Infection	Infection over puncture site
Haemorrhage	Raynaud disease
Arterial air embolism	Prior vascular surgery or cutdown involving arter to be punctured
Arterio-venous fistula	
Arterial aneurysm	

Arterial waveform interpretation

Gives information about:

- Pulse pressure
  - narrowed or widened
- Left ventricular contractility
  - Correlates with degree of slope in upstroke of wave. Slow rise upstroke suggests poor myocardial contractility
- Stroke volume
  - Proportional to the area under arterial curve up to dicrotic notch
- Vascular tone/systemic vascular resistance
  - Vasodilation and low SVR: steep downstroke and low dicrotic notch
  - Vasoconstriction, hypovolemia: short systolic time (from beginning of systole to dicrotic notch)
- "Swinging trace" with respiration (i.e. pulsus paradoxus) is seen in:
  - Hypovolemia
  - Pericardial effusion
  - Asthma
  - High PEEP/ high peak pressures (lung overdistension)



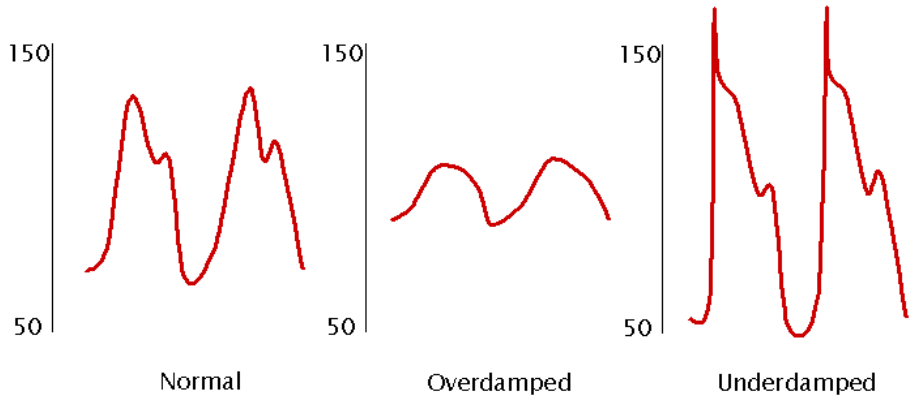
*Adapted from Porhomayon *et al. International Journal of Emergency Medicine* 2012

Dampening

An under-dampened system will result in a "spiky" waveform, and will over-estimate the systolic pressure. An over-dampened system will result in a "rounded" one, and underestimate the systolic pressure (see below diagrams).

To check for dampening, briefly flush the system:

- Correctly dampened – returns to waveform immediately
- Under-dampened – return to waveform is slow
- Over-dampened – multiple oscillations before returning to waveform



Appendix 3: Intra-osseous (IO) needle placement

**You may view the video on IO needle placement (children) via this link http://www.nejm.org/doi/full/10.1056/NEJMvcm0900916.* [22]

The relative ease of IO line placement allows for rapid establishment of access for administration of resuscitation fluids/drugs, even under combat situations or where there is no IV access.

Indications

- Emergency vascular access and IV attempts delayed/failed > 90 seconds.
- Any medications or fluids that can be given IV may also be given intra-osseously at the same dosages.

Discontinue IO infusion and withdraw needle after IV access established (preferably within 1-2 hours).

Sites (in descending order of preference)

- Proximal tibia (1 to 2cm distal and medial to the tibial tuberosity on the flat part of the tibia)
- Distal tibia (1cm superior to medial malleolus on flat part of tibia)
- Distal femur (midline 2-3cm above femoral epicondyles)
- Proximal metaphysis of humerus
- Anterior iliac spine
- Distal radius and distal ulnar

Complications

- Inability to site needle
- Subcutaneous or subperiosteal infiltration of fluid
- Fracture
- Compartment syndrome
- Infection
- Pain

Contraindications

- Infection at entry site
- Osteogenesis imperfecta
- Fracture of ipsilateral long bone
- Previous attempt at same site

Appendix 4: CICU outcome-based objectives for residents and senior residents

=	R1	R2	R3	SR 1-3
Current training opportunities	1. HO/MO Recognition of the sick child workshop 2. 1 simulation session	1. 2-4 simulation sessions 2. 1 month ICU 3. ICU journal presentation/grey case presentation x 1 4. Mortality presentation x 1 5. 1 month HD 6. ICU-based calls	1. 2-4 simulation sessions 2. 1 month ICU 3. ICU journal presentation/ Grey case presentation x 1 4. Mortality presentation x 1 5. 1 month HD 6. ICU-based calls	1. 2 week orientation lectures/tutorials (ICU rotation) 2. PFCCS 3. 3 months ICU 4. ICU Journal presentation x 2 5. 3 months ICU calls 6. 3 months local CHETS roster 7. 1 multi-disciplinary in-situ trauma code sim
Current ICU resources available	1. ICU handbook (online) 2. Baby bear book (online)	1. ICU handbook (online) 2. Baby bear book (online) 3. E-journal articles (selected) 4. Orientation to CICU guide		1. ICU handbook (online) 2. Baby bear book (online) 3. Orientation to CICU guide 4. ICU text (personal libraries of ICU staff) 5. E-journal articles (selected)
Requirements	**1. Must be BCLS certified**	1. Orientation lectures/tutorials (together with SR rotation) within 2 years **2. MUST complete APLS by R3** **3. Must complete at least 1 ETT intubation (simulation) DOPS by R2** **4. Must complete at least 1 CVL insertion (simulation) DOPS by R3** **5. Must perform at least 2 intra-hospital transport of a critically ill child**		**1. MUST be BCLS and APLS accredited** **2. MUST pass PFCCS before end of 1st month of rotation** 3. Must demonstrate ETT intubation DOPS pass with supervision; demonstrate competent WITHOUT supervision x 1 during rotation 4. Must demonstrate CVL line insertion competence (DOPS) 5. Must demonstrate competence in leading a resuscitation as a code leader 6. Must demonstrate competence in completing an inter-hospital transport independently
Mapped outcomes	1. Able to recognize airway compromise 2. Novice: Provide airway support (Airway positioning, BVM) 3. Recognize haemodynamic instability 4. Fluid resuscitate and call for help 5. Provide CPR and first line resuscitative drugs 6. Recognize a sick child	1. Beginner: Advanced airway support (attempt intubation under supervision) 2. Initiation of haemodynamic management, considers vasoactive drugs 3. Recognize and initiate management of paediatric emergencies 4. Interpretation and management of simple acid base imbalances 5. Team leader: novice learner 6. Intra-hospital transfer (simple case) 7. Active member of multi-disciplinary team; attempts to recognize areas for process improvement	1. Competent: Advanced airway support (intubation, trouble-shoot intubation issues under supervision) 2. Competent: Initiation of advanced haemodynamic support with guidance 3. Initiate and continue management of paediatric emergencies 4. Interpretation and management of complex acid base imbalances 5. Team leader: Novice learner 6. Intra-hospital transfer (complex) 7. Active participation in multi-disciplinary management; identifies and suggests solutions for areas of process improvement	1. Confident Competent: Advanced Life Support (Airway/ breathing, Circulation, Neurology) 2. Management of complex paediatric emergencies 3. Prescribe and manage mechanical ventilation (with supervision) 4. Prescribe vasoactive agents with justification 5. Team leader: competent 6. Competent :Local inter-hospital transfer 7. attempts to lead multi-disciplinary communications; initiates solutions for areas of process improvement

Appendix 5: Detailed CICU learning objectives for residents and senior residents

R1: Learning outcome objectives for Paediatric Critical Care

1. Recognize and manage respiratory compromise
    - Clear airway
    - Provide supplemental oxygen
    - Describe types of supplemental oxygen
    - Look for cause
2. Identify when BVM is required
3. Administer BVM effectively
    - Put together components of BVM correctly
    - Correct holding of mask and airway
    - Troubleshoot if unable to oxygenate/ventilate
4. Identify when intubation is required
    - Discuss indications for intubation
5. Recognize haemodynamic compromise
    - Recognize tachycardia/hypotension/late bradycardia
    - Set IV access/IO access and administer correct bolus of fluids
    - Look for cause
6. Identify when CPR is needed
    - Able to interprete ECG changes correctly
    - Able to identify PALS algorithms
7. Administer CPR effectively
    - Correct position of compressions
    - Correct rate of compressions
    - Correct sequence of CPR/drug/shock
8. Initial management of seizures
    - Recognize seizure
    - Administer correct AED
    - Look for cause
    - Monitor airway

8. Appropriate disposition of patient
    - When to call for help and who to call for help
    - Indications for ICU or HD transfer

R2: Learning outcome objectives for Paediatric Critical Care

All of R1 objectives AND:

1. Identify and plan for various intubation scenarios
   - Identify which group of patients require RSI
   - Discuss benefits of RSI
   - Discuss potential risks of RSI and intubation
   - Discuss risks/benefits of mechanical ventilation

2. Attempt intubation with supervision
   - Able to prepare appropriate equipment (laryngoscope blade, ETT size etc.)
   - Identify various roles of team members
   - Correct skills in holding laryngoscope
   - Check for correct tube placement
   - Plaster correctly
   - Troubleshoot issues with ETT (DOPE)

3. Initiate management of PALS algorithms including looking for causes (Novice):
   - Manage VT/VF
   - Manage symptomatic bradycardia
   - Manage unstable SVT
   - Manage PEA/asystole

4. Management of haemodynamic instability
   - Able to differentiate types of shock based on history, P/E and investigations
   - Discuss use of vaso-active drugs
   - Interpret adjunct investigations eg. CXR, ECG, ABG

5. Initial management of other paediatric emergencies
   - DKA
   - Status epilepticus
   - Hyperkalaemia
   - Raised ICP

6. Identify and manage simple acid-base disturbances
   - Metabolic acidosis: causes and management
   - Respiratory acidosis: Causes and management

7. Mechanical ventilation
   - Discuss indications/contra-indications for invasive vs non-invasive mechanical ventilation

8. Competent to transfer simple intra-hospital transports
   - Transfer of haemodynamically stable intubated patients
   - Understanding of transport ventilator
   - Proficient in BVM

9. Team work and communications
   - Develops awareness of roles of team leader/ team members
   - Understands the need for clear communications, closed loop feedback
   - Demonstrates ability to be an effective part of a multi-disciplinary team
   - Understands the process of identifying areas for process improvement in clinical work and communications

R3: Learning outcome objectives for Paediatric Critical Care

All of R1 and R2 objectives AND:

1. Competent in intubation with supervision

2. Mechanical ventilation
   - Able to monitor for complications associated with mechanical ventilation
   - Able to justify titration of simple mechanical ventilation support based on patient's pathophysiology

3. Competently manage all PALS algorithms < 5 minutes into algorithm:
   - VF/VT
   - Unstable SVT
   - Symptomatic bradycardia
   - PEA/asystole

4. Advanced management of haemodynamic instability
   - Able to use markers of end-organ perfusion to justify titration of patient therapies
   - Initiate appropriate management of cause of instability

5. Advanced management of DKA
   - Initiate correct fluid and insulin regime
   - Consider and recognize potential complications of DKA eg. GCS, acidosis, hypoK, rapid osm shifts
   - Correct disposition of patient after completing initial management

6. Advanced management of Status Epilepticus (SE)
   - Initiate correct AEDs following hospital guidelines
   - Justifies possible causes based on history, clinical findings and investigations
   - Correctly treats possible causes (eg. hyponatraemia, CNS infection, TBI etc)
   - Manage complications of SE including airway compromise and hypoxia

7. Management of hyperkalaemia
   - Identifies risk factors for hyperkalaemia
   - Identifies "symptomatic" hyperkalaemia (ECG changes)
   - Administers appropriate therapy and able to justify choice of therapies

8. Advanced management of raised ICP
   - Identifies patients at risk of raised ICP
   - Recognizes Cushing's reflex and initiates management for acute elevation of ICP under supervision
   - Initiates neuroprotective measures correctly under supervision

9. Competent to transfer complex intra-hospital transports
   - Transfer of potentially haemodynamically unstable intubated patients
   - Able to manage haemodynamic instability

10. Teamwork and communications
    - Attempts team leader role
    - Active team member in a multi-disciplinary team
    - Competent and respectful in multi-disciplinary communications
    - Able to identify areas for process improvement in clinical work and communications and suggest possible solutions

SR: Learning outcome objectives for Paediatric Critical Care

All of R1-R3 objectives, AND:

1. Ventilation
   - Justifies mode of mechanical ventilation (MV) and initial MV settings
   - Competent in set up of mechanical ventilator
   - Troubleshoots de-saturating patient on MV
   - Able to interpret blood gas readings and adjust MV based on patient's pathophysiology
   - Able to manage unconventional ventilation modes with supervision (HFOV, APRV)
   - Understands and applies lung protective strategies for patients with ARDS

2. Haemodynamics
   - Able to justify need for advanced haemodynamic monitoring aids
   - Able to interpret haemodynamic parameters based on patient's pathophysiology
   - Able to prescribe vasoactive drugs based on patient's pathophysiology
   - Able to manage patients with post-operative congenital heart disease; understands the mechanisms affecting cardiac contractility and pulmonary vascular resistance

3. Competence in neurocritical care
   - Uses understanding of tenets of neuroprotective interventions to manage patients at risk of neurological injuries

4. Competent to transfer local inter-hospital transfers
   - Has advanced airway competence (can BVM, confident of intubation)
   - Able to implement advanced haemodynamic monitoring and management
   - Displays good teamwork behaviours and communications with allied health professionals
   - Demonstrates competence in leadership skills

5. Extra-corporeal life support
   - Understands the indications and contra-indications for various extra-corporeal life support therapies
   - Able to monitor for complications associated with extra-corporeal life support therapies (eg. CRRT, ECMO, plasma exchange)

6. Procedural skills
   - Competent in advanced life support skills eg. Intubation, IO needle, CVL/PICC insertion, IA line insertion, thoracocentesis/chest drain insertion

7. Education and research
   - Supports and educates junior staff in critical care management of patients
   - Demonstrates ability to critically appraise current literature as applied to critically ill patients

8. Teamwork and communications
   - Competent team leader, demonstrates ability to prioritize clinical problems and maintain oversight of a patient with multiple issues
   - Competent in multi-disciplinary communications; attempts to lead multi-disciplinary team communications
   - Able to initiate solutions to areas which require process improvement (clinical work and communications)