Inclusion Criteria
- Post-operative Norwood patient

Exclusion Criteria
- Patient receiving Extracorporeal Membrane Oxygenation (ECMO)

Phase I: Day of Surgery to Chest Closure

Phase II: Chest Closure to Extubation

Phase III: Extubation to Transfer to Ward

Hemostasis

Shock
Monitoring and Assessments

- Cardiorespiratory monitor
- CVP
- SaO2
- End-tidal CO2
- Cerebral/Renal NIRS
- Core/toe temperatures
- Consider continuous SvO2

Assessments

- Vitals per CICU routine, Interval physical exam
- Hourly urine output
- Hourly chest tube output
- 4 extremity blood pressure every AM
- Daily assessment of possibility for chest closure
- Chest X-ray-admission and daily
- ECG-admission: Atrial wire study as necessary

Laboratory

- Admission: Lytes, Mg, Phos, BUN, creatinine, CBC, PT/INR, aPTT, fibrinogen, monitor SVO2 if IJ present: ABG, lactate, iCa, glucose, Every 2 hours for 8 hours: SVO2 POC: ABG, lactate, iCa, glucose. Then consider increasing interval, but not less frequently than every 6 hours
- Daily at 0400: Lytes, Mg, Phos, BUN, creatinine, CBC, albumin, ABG, lactate, iCa, glucose

Lines and Tubes

- Central venous catheter
- Intracardiac lines
- Arterial line
- PICC line
- Foley catheter
- Chest tubes
- NG tube to LIWS
- Atrial and ventricular pacing wires

Inclusion Criteria

- Post-operative Norwood patient

Exclusion Criteria

- Patient receiving Extracorporeal Membrane Oxygenation (ECMO)

BT Shunt Considerations

- Goal DBP >30mmHg (coronary perfusion)
- Avoid hyper-oxygenation
- Blender on resuscitation bag to 50%
- Avoid hyperventilation
- Caution for iNO usage
- “CICU High dose heparin”

To Phase I Part II: Interventions

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Post-op Norwood v4.0: Phase I - Day of Surgery to Chest Closure

**Inclusion Criteria**
- Post-operative Norwood patient

**Exclusion Criteria**
- Patient receiving Extracorporeal Membrane Oxygenation (ECMO)

**Fluids, Electrolytes and Nutrition**
- NPO
- **Day of surgery:** IV fluids: @ total fluid limit of 50 mL/kg/day
- **Post op day 1:**
  - 1 AM rounds: consider increasing total fluid to allow for TPN and begin furosemide infusion
  - Post op day 2 → chest closure (if not closed in OR)
    - Advance TPN and TFL (range: 80-120 mL/kg/day) to optimize nutrition while minimizing fluid administration to target negative fluid balance.
    - GI prophylaxis - standard IV dosing; add to TPN when possible
    - Consider thiazide for synergy

**Lines and Tubes**
- Discussion with surgeons about intracardiac line removal at time of chest closure

**Interventions by System**

**Cardiovascular**
- Milrinone infusion
- Epinephrine infusion: Once hemodynamics have stabilized (typically POD #2-3), titrate epinephrine to maintain a MAP (typically > 45 mmHg) that promotes diuresis
- Vasopressin PRN
- For signs and symptoms of Low Cardiac Output, see Shock algorithm

**Respiratory**
- Mechanical ventilation-SIMV/PC
  - Target: PaCO2 35-50 mmHg/pH 7.3-7.4, SaO2 = 75-85%
  - If SaO2 < 75%: CXR, +/- ↑PEEP, ↑FiO2, +/- initiate iNO, consider ECHO to/r/o anatomic obstruction to pulmonary bloodflow, consider Shock

**Neurologic**
- Morphine and dexmedetomidine infusion and titrate per ICU comfort protocol
- Continuous EEG monitoring 48hrs

**Infectious Disease**
- Antibiotic prophylaxis (ensure timing related to most recent dose in operating room)
- Routine: cefazolin-standard IV dosing
- Mupirocin for total 5 days
- If MRSA or severe PCN allergy: Vancomycin standard IV dosing

**Hematologic**
- Monitor chest tube output. If sanguinous output > 3 mL/kg/hr (see hemostasis algorithm).
- Target: see hemostasis algorithm
  - Hematocrit ≥ 40%
  - Normal coagulation parameters
    - INR < 1.5
    - PTT < 40
    - Fibrinogen > 200
    - Platelet count > 200
- POD#1: if hemostasis achieved, begin heparin infusion for shunt/line prophylaxis (target UFH range 0.2-0.3 International Units/ml)
  1. Consider holding heparin prior to chest closure

**BT Shunt Considerations**
- Goal DBP >30mmHg (coronary perfusion)
- Avoid hyper-oxygenation
- Blender on resuscitation bag to 50%
- Avoid hyperventilation
- Caution for iNO usage
- “CICU High dose heparin”

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Last Updated: October 2023
Next Expected Review: June 2023
**Post-op Norwood v4.0: Phase II - Chest Closure to Extubation**

**Goal Duration 1-2 Days**

### Monitoring and Assessments

**Assessments**
- Vitals per CICU routine; Interval physical exam, including assessment of surgical wound
- Hourly urine output
- Hourly chest tube output
- 4 extremity blood pressure every AM
- Chest X-ray daily while intubated and/or chest drains present, after chest closure
- Vascular US as needed if:
  1. Platelet count decreasing
  2. High volume chest tube output
  3. Signs of CVL malfunction

### Laboratory

- Immediately after chest closure:
  - every 1-2 hours: POC lactate, iCa, ABG. Then adjust interval as indicated
- Daily: Lyses, Mg, Phos, BUN, creat, CBC, ABG, lactate, iCa, glucose

### Fluids, Electrolytes and Nutrition

- NPO
- Once hemodynamically stable, initiate post-op cardiac surgery feeding protocol
- Continue TPN/ TFL to optimize nutrition
- Continue furosemide infusion

### Lines and Tubes

- Central venous catheter
- Arterial line
- PICC line
- Foley catheter
- Chest tubes
- NG tube to LIWS
- Atrial and ventricular pacing wires

**Note:**
- Patients commonly have a mild-moderate form of low cardiac output syndrome for 12-24 hours following chest closure. This is usually managed with fluid bolus administration and limited escalation of inotropes.
- Consider transthoracic ECHO
- If low cardiac output syndrome persists or worsens despite these interventions, consider reopening the patient’s sternum.

### Cardiovascular

- Continue milrinone infusion
- Wean epinephrine infusion
- Wean hydrocortisone

### Respiratory

- Mechanical ventilation-SIMV/PC
- If on nitric oxide wean as tolerated
- Daily extubation readiness testing

### Neurologic

- Wean morphine and dexmedetomidine infusion to facilitate extubation

### Infectious Disease

- Antibiotic prophylaxis for 48 hours following chest closure
- Complete Mupirocin for a total of 7 days.

### BT Shunt Considerations

- Goal DBP >30mmHg (coronary perfusion)
- Avoid hyper-oxygenation
- Blender on resuscitation bag to 50%
- Avoid hyperventilation
- Caution for iNO usage
- “CICU High dose heparin”

### Hematologic

- Maintain hematocrit > 40%
- Heparin infusion for central line/BT Shunt/RV to PA conduit prophylaxis
- Hold heparin for pacing wire and or intracardiac line removal
- Discontinue heparin infusion and begin standard dosing of ASA when:
  1. CVC has been removed (PICC does not need to have been removed) AND
  2. Tolerating enteral feeds
  3. VerifyNow
- Enoxaparin if vascular thrombus present: If using, do not start ASA
- Remove chest drains (if ≤ 1 mL/kg/hr after discussion with CV surgeon)

### Extubation

**To Phase III: Extubation to Transfer to Ward**

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Post-op Norwood v4.0: Phase III - Extubation to Transfer to Ward

Monitoring
- Cardiorespiratory monitor
- SaO2
- Core/toe temperatures
- NIRS

Lines and Tubes
- Central venous catheter
- Arterial line
- PICC line
- Chest tubes
- NG tube
- Atrial and ventricular pacing wires

Monitoring and Assessments
Assessments
- Vitals per CICU routine; Interval physical exam
- Urine output
- Chest tube output
- Chest X-ray daily until chest drains removed:
  1. Assure that patient has had chest X-ray following most recent chest tube removal to r/o pneumothorax
  2. Otherwise as indicated by clinical status
- Consider ECHO
- Vascular US if:
  1. Platelet count decreasing
  2. High volume chest tube output
  3. Signs of CVL malfunction

Laboratory
- Following extubation: POC ABG, Lactate
- Daily: Lytes, Mg, Phos, BUN, Cr, glu, iCa; consider ABG, lactate
- Weekly: CBC
- Consider trending CRP if concern for infection

Interventions by System

Fluids, Electrolytes and Nutrition
- Begin/continue feeding as per post-op cardiac surgery feeding protocol
- Wean TPN/IL
- Discontinue ranitidine when at 50% goal feeding rate, and if no concern for GERD
- OT swallow evaluation prior to attempting PO
- Consider otolaryngology consultation if specific concern for vocal cord dysfunction
- Transition to enteral diuretics

Lines and Tubes
- Discontinue NIRS monitors
- Remove central venous catheter
- Remove arterial line
- PICC line and NG/ND tube consider pulling ND back to NG

Cardiovascular
- Wean milrinone off
- Consider maintenance afterload reduction with ACE inhibitor if:
  1. Hypertension
  2. Decreased myocardial function
  3. AV valve regurgitation
- Initiate digoxin with cardiology discussion (obtain pre-initiation EKG)

Infectious Disease
- Antibiotic prophylaxis for 48 hours following chest closure
- Complete mupiricin

Respiratory
- Wean from non-invasive ventilation
- Wean from oxygen

Hematologic
- Discontinue heparin infusion and begin standard dosing of ASA when:
  1. CVC has been removed (PICC does not need to have been removed) AND
  2. Tolerating enteral feeds
  3. Consider Verifynow
- Enoxaparin if vascular thrombus present: If using, do not start ASA

Neurologic
- Wean sedatives/analgesics
- Transition sedatives/analgesics to enteral if has been on infusion for >7 days
- Create weaning plan with pharmacy

Evaluate readiness to transfer to ward
- SaO2 > 75% with stable respiratory status for >24 hours
- Tolerated 24 hours of feeding protocol
- Stable hemodynamics for >24 hours without need for vasoactive infusions
- Tolerating intermittent diuretics
- Invasive monitoring discontinued
- Chest X-ray stable following most recent chest tube removal

Transfer Criteria: Met? (all must be met)
- Yes: Transfer to Ward
- No: Continue ICU care

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Last Updated: October 2018
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Common Causes of Shock
- Low cardiac output syndrome
- Pericardial tamponade
- Pneumothorax
- Dysrhythmia
- Residual cardiac lesion
- Infection
- Bleeding/anemia
- Ventricular dysfunction

Signs of shock in patients status-post Norwood procedure

Note: all signs may not be present in all patients; numeric values are guidelines and must be considered in the clinical context.

- Tachycardia (HR > 180 bpm)
- Hypotension (SBP < 55 mmHg, MAP < 40 mmHg)
- Desaturation (SaO2 < 75%)
- Cool or mottling of extremities (Toe temp < 28 degrees)
- Urine output < 1mL/kg/hr
- Serum lactate > 2 mmol/L
- SaO2-SvO2 > 30
- Cerebral or renal oximetry by NIRS < 40%

Evaluate Heart Rate (HR)
- HR < 130
  - Evaluate for dysrhythmia
  - Consider atrial or atrioventricular sequential pacing
  - Wean excessive sedation
- HR > 180
  - Primary fever: Antipyretics, consider cooling to low-normal temperature.
  - Note: Elevated core temperature due to peripheral vasoconstriction is a sign of shock. Therefore, specific therapies to treat fever will often be ineffective. Rather, efforts should be focused on improving cardiac output.
  - Evaluate and treat for dysrhythmia
  - If SBP > 60 mmHg (MAP > 45mmHg) consider weaning chronotropic infusions
  - Consider chest X-ray and ECHO to rule out intrathoracic air/ fluid collection

Evaluate Central Venous Pressure (CVP)
- CVP ≤ 8 mmHg
  - Consider fluid administration (10 mL/kg NS). Repeat up to 2 times (e.g. total 30 mL/kg) as needed, then consider increasing epinephrine infusion
  - Reassessment of CVP
- CVP > 8 mmHg
  - Consider an initial fluid bolus (10 mL/kg NS), and reassess hemodynamics. If no improvement and CVP remains > 8 mmHg, consider increasing epinephrine infusion

Evaluate Arterial Oxygen Saturation (SaO2)
- SaO2 > 85%: try to optimize balance of Qp:Qs by:
  1. Decrease FiO2 as tolerated to 0.21
  2. Increase milrinone
  3. Consider echocardiogram to assess:
     a. Pericardial effusion
     b. Ventricular function
     c. AV valve regurgitation
     d. RV-PA conduit/PA stenosis
     e. Residual systemic outflow/ arch obstruction
  4. If elevated BP, consider initiating vasodilator and titrate to target goal BP

Evaluate Systolic Blood Pressure (SBP)
- SBP > 75 mmHg (MAP > 55 mmHg)
  1. Consider weaning vasconstrictors
  2. Ensure sedation and analgesia are adequate
  3. Consider increasing vasodilation
     a. increase milrinone
     b. consider initiating vasodilator and titrate to target goal BP

If shock is present, evaluate the following clinical parameters to determine appropriate intervention:

- Frequent reassessment to determine the adequacy of the intervention is essential

Return to Phase I!
General Approach

Normalize the coagulation profile in the initial management period. If bleeding is minimal or seems to be decreasing, one may take a more conservative approach to blood product replacement. However, the general parameters to maintain are:
1. INR < 1.5
2. PTT ≤ 40
3. Fibrinogen > 200
4. Platelet count > 200
5. Hematocrit ≥ 40%

Monitor Chest Tube Output (hourly)

Transition from sanguinous to serous over first several post-operative hours

Sanguinous Output > 3 mL/kg/hr

 Bloody Output > 10 mL/kg/hr or > 5 mL/kg/hr for 2 consecutive hours

Notify surgeon for bleeding > 10 mL/kg/hr or 5 mL/kg/hr for 2 consecutive hours

Maintain
1. INR < 1.3
2. PTT < 40
3. Fibrinogen > 200
4. Platelet count > 200

Continued serous output

Continue to monitor chest tube output

Return to Phase I

Bloody Output > 10 mL/kg/hr or > 5 mL/kg/hr for 2 consecutive hours

Maintain
1. INR < 1.3
2. PTT < 40
3. Fibrinogen > 200
4. Platelet count > 200

Continued sanguinous output past several post-operative hours

Monitor
- Coagulation profile
- Hematocrit
- Consider Thromboelastography
- Continue to monitor chest tube output

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Last Updated: October 2018
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Post-Op Norwood pathway: Inclusion Criteria

Neonates admitted to the Cardiac ICU following the Norwood operation

Post-Op Norwood Pathway: Exclusion Criteria

• Infants requiring ECMO support
Ductal Dependent Systemic Blood Flow

Infants with ductal dependent systemic blood flow have left ventricular outflow obstruction

- Hypoplastic left heart syndrome (HLHS)
- Interrupted aortic arch
- Critical aortic stenosis

HLHS

- HLHS and related functional single ventricle conditions remain the highest risk and costliest group of lesions among the commonly occurring congenital heart defects

- No congenital heart defect has undergone a more dramatic change in diagnostic approach, management, and outcomes than hypoplastic left heart syndrome (HLHS)

- Outcome data is highly regarded and often synonymous with overall programmatic success

- Tend to have long lengths of stay
  - Provides scope to make measurable improvements that are significant (days not hours)
  - Potential for increased risk of iatrogenic harm
Norwood Procedure

In HLHS the single ventricle must be connected to both the systemic and pulmonary circulations.

**Systemic circulation**
- The main pulmonary artery is separated from the pulmonary artery branches and connected to the ascending aorta. The remainder of the aorta is reconstructed using homograft material. Blood is now pumped from the single right ventricle out the “neo-aorta” to the systemic circulation.

**Pulmonary circulation**
- Since the pulmonary artery is now committed to the systemic circulation there needs to be a source pulmonary blood flow. The Sano shunt is a Gore-Tex conduit that connects the lungs to the single ventricle via an incision made in the anterior wall of the right ventricle.

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Post-Operative Management Strategies

**Optimizing oxygen delivery**
- Goal: to achieve normal systemic oxygen delivery. This requires that the Pulmonary to systemic blood flow ratio (Qp:Qs) is close to 1
  - SvO2 to SaO2 difference of ~25% suggests adequate O2 delivery

**Balancing the pulmonary and systemic circulations**
- Univentricular output is apportioned by the balance of systemic and pulmonary resistances
Post-Operative Norwood Algorithm

The algorithm is divided into three phases with each phase having specific targets:

- Phase I: Day of surgery to chest closure
- Phase II: Chest closure to extubation
- Phase III: Extubation to ward transfer
- Ward transfer is based on achieving specific transfer criteria

Post-Operative Norwood Algorithm (Cont’d)

Each phase is presented in a system based fashion. There are two additional sub phases of the algorithm:

- Shock
- Hemostasis
Phase I: Day of Surgery to Chest Closure

Primary objective:
- Hemodynamic stability

Recommendations:
- The next 4 slides reference specific clinical questions (CQ) that were researched to help promote the optimal evidenced based care when available.
CQ: What is the optimal fluid management of post-op Norwood patients?

During the first post-operative day and night, patients should receive a ½ maintenance rate of IV fluid, using additional bolus fluid administration to optimize hemodynamics.

(Expert Opinion)
CQ: What is the optimal diuretic management for post-op Norwood patients?

Diuretic therapy should be initiated the first post-operative morning.

CQ: What is the clinical benefit of stress dose hydrocortisone in post-op Norwood/cardiac surgery patients with hemodynamic instability?

- Patients with evidence of shock should be started on stress dosing of hydrocortisone at 1mg/kg/dose IV every 6 hours.
- Hydrocortisone should be discontinued 48 hours after initiation unless evidence of adrenal insufficiency exists.

Phase II: Chest Closure to Extubation

Primary objective:

- Hemodynamic stability with ongoing diuresis in preparation for chest closure

Protocols:

- Once hemodynamically stable initiate post-op cardiac surgery feeding protocol
Phase III: Extubation to Ward Transfer

Primary objective:
• Wean support in preparation for ward transfer.

Recommendations:
• Patient should be given H2 blockers until they are at 50% of their goal enteral feeds. The drug should be discontinued unless there is concern for ongoing stress gastritis or evidence of gastroesophageal reflux.
  (Expert opinion)

Transfer to Ward Criteria

• SaO2 > 75% with stable respiratory status for >24 hours
• Tolerated 24 hours of feeding protocol
• Stable hemodynamics for >24 hours without need for vasoactive infusions
• Tolerating intermittent diuretics
• Invasive monitoring discontinued
• Chest X-ray stable following most recent chest tube removal
Subphase: Shock

- Primary objective:
  - Recognize shock and intervene in a timely fashion

- Recognition:
  - Includes standard clinical parameters of poor perfusion:
    - Tachycardia, hypotension, desaturation, mottling, decreased urine output and acidosis

- Intervention:
  - Standardized interventions based on distortions of heart rate, central venous pressures, arterial saturation and blood pressure

Subphase: Shock (Cont’d)

Cardiogenic shock (“Low cardiac output”)

- Common after Norwood palliation
- Definition: inadequate systemic O2 delivery
- Clinical picture: Tachycardia, hypotension, desaturation, mottling, decreased urine output and acidosis
- Common causes:
  - Low cardiac output syndrome
  - Arrhythmia
  - Pericardial tamponade
  - Hemorrhage/anemia
  - Pneumothorax
  - Ventricular dysfunction
  - Residual cardiac lesion
Subphase: Hemostasis

- **Primary objective:**
  - Normalize coagulation profile to reduce bleeding
- **Recognition:**
  - High volume chest tube output or tension of the membrane covering the open chest
    - Bleeding that may require surgical exploration
    - Coagulopathy
- **Intervention:**
  - Notify surgeon for bleeding > 10mL/kg/hr or > 5mL/kg/hr for 2 consecutive hours
  - Otherwise target normal parameters for:
    - INR, PTT, Fibrinogen, Platelet count, and HCT
Approved by the CSW Post-op Norwood team for June 25, 2018 go-live

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Please cite as:
This pathway was developed through local consensus based on published evidence and expert opinion as part of Clinical Standard Work at Seattle Children’s. Pathway teams include representatives from Medical, Subspecialty, and/or Surgical Services, Nursing, Pharmacy, Clinical Effectiveness, and other services as appropriate.

When possible, we used the GRADE method of rating evidence quality. Evidence is first assessed as to whether it is from randomized trial or cohort studies. The rating is then adjusted in the following manner (from: Guyatt G et al. J Clin Epidemiol. 2011;4:383-94.):

Quality ratings are *downgraded* if studies:
- Have serious limitations
- Have inconsistent results
- If evidence does not directly address clinical questions
- If estimates are imprecise OR
- If it is felt that there is substantial publication bias

Quality ratings are *upgraded* if it is felt that:
- The effect size is large
- If studies are designed in a way that confounding would likely underreport the magnitude of the effect OR
- If a dose-response gradient is evident

Guideline – Recommendation is from a published guideline that used methodology deemed acceptable by the team.

Expert Opinion – Our expert opinion is based on available evidence that does not meet GRADE criteria (for example, case-control studies).
Summary of Version Changes

- **Version 1.0 (8/15/2012):** Go-Live
- **Version 2.0 (11/21/2012):** Added Exclusion Norwood procedure with BT Shunt
- **Version 3.0 (6/25/2018):** Scheduled review update. BT shunt removed from exclusion criteria; literature review updated.
- **Version 4.0 (10/8/2018):** Changed mupirocin to 5 days to align with institutional surgical site infection work
Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required.

The authors have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication.

However, in view of the possibility of human error or changes in medical sciences, neither the authors nor Seattle Children’s Healthcare System nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they are not responsible for any errors or omissions or for the results obtained from the use of such information.

Readers should confirm the information contained herein with other sources and are encouraged to consult with their health care provider before making any health care decision.
Literature searches were executed by a medical librarian (PC) in two phases, in July and September 2017. The initial search targeted synthesized evidence and the subsequent search targeted primary studies. Both searches used the following search concepts: Norwood procedure or surgical repair of hypoplastic left heart syndrome; peri-operative care and cardiovascular abnormalities in infants; or, corticosteroids, fluid therapy or diuresis and cardiac surgery in infants. All results were limited to items published in English from Jan 2012-forward, in human populations. The search for synthesized literature was executed in Ovid Medline, Cochrane Database of Systematic Reviews, Embase, National Guideline Clearinghouse and TRIP. The subsequent search for primary literature was conducted in Medline and Embase. Results were exported to RefWorks for de-duplication, then to Excel for screening.

Identification

Records identified through database searching (n= 961)  Additional records identified through other sources (n=0)

Screening

Records after duplicates removed (n=718)

Records screened (n= 696)  Records excluded (n=22)

Eligibility

Records assessed for eligibility (n=22)

Articles excluded (n=18)
- Did not answer clinical question (n=15)
- Did not meet quality threshold (n=3)
- Outdated relative to other included study (n=0)

Included

Studies included in pathway (n=4)

Flow diagram adapted from Moher D et al. BMJ 2009;339:bmj.b2535


