PEDIATRIC ACUTE CHEST SYNDROME (ACS)
Algorithm- Acute Chest Syndrome Management

CLINICAL PATHWAY

Sickle Cell Pain Guideline
Apheresis Catheter Guidelines: Short Term Use
Automated Red Blood Cell Exchange for Sickle Cell Patients (CHCO DSR)
TARGET POPULATION

Inclusion Criteria

• Patients with sickle cell disease (SS, SC, Sβ0 thalassemia, Sβ+ thalassemia, other sickle cell disease variants)

Exclusion Criteria

• Patients without infiltrate on chest radiograph (e.g., asthma exacerbation)
• Patients with previously known severe pulmonary hypertension
  • Tricuspid Regurgitant Velocity (TRV) ≥3 m/s or confirmation by right heart catheterization
• Patients post bone marrow transplant

BACKGROUND | DEFINITIONS

Acute chest syndrome (ACS) is the second most common reason for hospitalization in children with sickle cell disease and a leading cause of mortality. ACS is defined as a new pulmonary infiltrate on chest radiograph with evidence of lower respiratory tract disease (e.g., some combination of cough, shortness of breath, retractions, rales, hypoxia, chest pain etc.) with or without fever. In the majority of cases of ACS, a source is not identified. The most commonly identified etiology of ACS is infection, but it may also result from pulmonary vaso-occlusion, pulmonary infarction, fat embolism or hypoventilation. The primary infectious agents implicated in ACS include *Chlamydia pneumoniae*, *Mycoplasma pneumoniae*, *Streptococcus pneumoniae*, and viruses. Risk factors for ACS include vaso-occlusive pain crisis, anesthesia, and surgery. Patients are at increased risk for stroke in the two weeks immediately following an episode of ACS.
CLINICAL PATHWAY

CLINICAL MANAGEMENT

- Admit to hematology service at Anschutz or Colorado Springs campuses
- Vital signs q 2-4 hours depending upon degree of respiratory compromise
- Record pain score every 4 hours
- Continuous cardiorespiratory monitor and pulse oximetry
- Maintain oxygen saturations ≥95% in order to prevent additional red cell sickling. Frequent assessments of respiratory status. May refer to the clinical respiratory score (CRS) Table 1 for a means of objective monitoring.
- Encourage ambulation: out of bed to chair or ambulating at least 2-3 times per day
- Appropriate isolation precautions
- Continue medication for reactive airway disease if applicable. Steroids should be used with caution as their use may be associated with increased "rebound" acute pain episodes and rehospitalization.
- Encourage incentive spirometry use. May use pinwheels in younger patients. Some patients may benefit from EZPap.
- Consider simple transfusion after discussion with hematology attending to achieve a hemoglobin of 10 g/dL to decrease the percentage of circulating sickle cells. For patients who are at 10 or higher, an automated red blood cell exchange (RBE) should be strongly considered (see treatment section for additional details)

DIAGNOSTIC TESTS

- CBC with differential, CMP, platelet count, and reticulocyte count initially and daily until improving (compare with patient's baseline values)
- Order an initial type & screen and then prn
- CXR initially, repeat for respiratory decompensation (be aware that the x-ray often underestimates the degree of involvement and may appear worse when the child is clinically improving)
- Blood cultures (do not need to repeat daily)
- Viral testing as appropriate
- Consider:
  - If severe abdominal pain, consider an ultrasound for gallstones
  - Echocardiography is not recommended routinely in patients with acute chest syndrome. Consult cardiology if concern for pulmonary hypertension arises (prolonged hypoxemia, fixed split S2 or pronounced pulmonary component of S2, hepatomegaly, persistent peripheral edema, or persistent pulmonary edema despite adequate fluid status)

FLUIDS | NUTRITION

- Daily weight
- Record intake and output strictly
- Maintain "euvolemia". Encourage oral hydration. If IV fluids are needed use IV + P.O. = 1 x maintenance order. More fluid is appropriate only if patient is dehydrated or if insensible losses are increased (e.g., persistent fever), but boluses are preferred over increased fluid rates. IV fluid should be D5 1/4 NS to avoid exacerbating the sickling process.
RESPIRATORY THERAPY

- Consult Pulmonology
- Maintain oxygen saturations ≥95%
- Clinical features suggestive of asthma or acute bronchospasms; trial Albuterol 4 puffs with a spacer or 2.5 mg nebulized once. Reassess patient. If improvement is noted, order Albuterol 2-4 puffs or Albuterol 2.5mg nebulized Q4 and PRN. If at any time CRS worsens by 2 or more may increase frequency of the Albuterol and notify the provider
- Steroids should be used cautiously as they have been associated with rebound pain crises and readmissions.
- Consider lung expansion strategies to include EZPAP and/or IS to support bronchial hygiene: EzPAP (along with IS) Q4 hours for 72 hours. 72 hours after the initiation of the therapy, the patient will be evaluated by the respiratory therapist for pulmonary stability. If the chest x-ray (if done) remains stable, there are no signs of pulmonary infection, there is good aeration throughout all lung fields upon auscultation, and the patient can consistently achieve 14mL/kg with the IS, the EzPAP will then be discontinued. The patient will then receive IS Q2 hours while awake and Q4 hours at night by their RN
- Transfer to the ICU if patient is requiring escalating respiratory support, or if invasive or non-invasive (CPAP, BiPAP) mechanical ventilation is being considered

TABLE 1. CLINICAL RESPIRATORY SCORE (CRS)

<table>
<thead>
<tr>
<th>ASSESS</th>
<th>SCORE 0</th>
<th>SCORE 1</th>
<th>SCORE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>1-5 YEARS: &lt;30; &gt;5 YEARS: &lt;20</td>
<td>1-5 YEARS: 30-40; &gt;5 YEARS: 20-30</td>
<td>1-5 YEARS: &gt;40; &gt;5 YEARS: &gt;30</td>
</tr>
<tr>
<td>AUSSCULTATION</td>
<td>GOOD AIR MOVEMENT, SCATTERED WHEEZING (ONLY EXPIRATORY), LOOSE CRACKLES</td>
<td>DEPRESSED AIR MOVEMENT, INSPIRATORY AND EXPIRATORY WHEEZES</td>
<td>DIMINISHED OR ABSENT BREATH SOUNDS, SEVERE WHEEZING, OR MARKED PROLONGED EXPIRATION</td>
</tr>
<tr>
<td>USE OF ACCESSORY MUSCLES</td>
<td>MILD TO NO USE OF ACCESSORY MUSCLES. MILD TO NO RETRACTIONS OR NASAL FLARING ON INSPIRATION</td>
<td>MODERATE INTERCOSTAL RETRACTIONS, MILD TO MODERATE USE OF ACCESSORY MUSCLES, NASAL FLARING</td>
<td>SEVERE INTERCOSTAL AND SUBSTERNAL RETRACTIONS, NASAL FLARING</td>
</tr>
<tr>
<td>MENTAL STATUS</td>
<td>NORMAL TO MILDLY IRRITABLE</td>
<td>IRRITABLE, AGITATED, RESTLESS</td>
<td>LETHARGIC</td>
</tr>
<tr>
<td>ROOM AIR SPO₂</td>
<td>&gt;95%</td>
<td>90-95%</td>
<td>&lt;90%</td>
</tr>
<tr>
<td>COLOR</td>
<td>NORMAL</td>
<td>PALE TO NORMAL</td>
<td>CYANOTIC, DUSKY</td>
</tr>
</tbody>
</table>
**TREATMENT**

**Antipyretics**
- Acetaminophen dose according to CHCO Formulary PRN temperature greater than or equal to 38.3°C after blood cultures have been obtained on at least one occasion.

**Antibiotics (see Table 2 for choices and doses)**

Ampicillin and azithromycin are the regimen of choice for initial inpatient management:
- If there is a known or suspected penicillin allergy (excluding a SCAR, see details below), ceftriaxone should be used as second line therapy.
- If cephalosporine allergy, levofloxacin is the regimen of choice and azithromycin can be omitted because levofloxacin has adequate coverage of atypical organisms.
- Strongly consider adding vancomycin for severe illness, or if large infiltrate with pleural effusion present and *S. aureus* is suspected.
- Consider discontinuing azithromycin if respiratory viral panel is negative for *M. pneumoniae* and *C. pneumoniae*.

Hold home penicillin prophylaxis if receiving broad-spectrum antibiotics:
- If antibiotics are continued upon discharge, an appropriate oral antibiotic should be continued to complete a course of 5 days (including inpatient IV therapy received): Amoxicillin is recommended as first line, cefpodoxime is the drug of choice in the presence of a penicillin allergy, and levofloxacin is the drug of choice in the presence of a cephalosporin allergy. Patients may be candidates for penicillin delabeling through the Penicillin Allergy Delabeling Clinical Pathway and then receive ampicillin (first line therapy).
- If the allergy history with PCN is consistent with a severe cutaneous adverse drug reaction (SCAR) (i.e., SJS/TEN, DRESS etc.), consider consulting allergy & immunology prior to administration of ceftriaxone. While these are exceedingly rare, the cross reactivity between penicillin’s and cephalosporins is not well characterized in these conditions. The Penicillin Allergy Delabeling Clinical Pathway also has questions to evaluate for SCARs.

**Analgesia (if indicated)**
- If pain is present patients should start on scheduled anti-inflammatories and opiates if there are no contraindications.
  - Start ketorolac, but limit to 48-hour maximum duration then start ibuprofen PO q6h (not PRN) if no contraindication present (i.e., gastritis, ulcer, coagulopathy, renal impairment).
  - If pain does not respond to anti-inflammatory alone, consult the sickle cell vaso-occlusion guidelines. Be aware narcotic administration may further suppress respiration.

**Transfusions**
- Consider giving a simple blood transfusion (discuss volume with Hematology) to achieve a hemoglobin of 10 g/dL. This effectively reduces the % sickle cells. If baseline hemoglobin is near or above 10 g/dL, and symptomatic, strongly consider automated red cell exchange procedure. Do not transfuse acutely to hemoglobin greater than 10 g/dL, hematocrit greater than 30 percent if percent sickle hemoglobin is or is presumed to be greater than 30 percent since it is associated with inducing pain and stroke.
  - Blood orders should include the following specifications:
    - No irradiation (unless receiving myeloablative chemotherapy as part of preparative regimen for bone marrow transplantation)
    - Phenotypically matched (which will trigger the hemoglobinopathy blood bank protocol)
Automated Red Blood Cell Exchange (RCE)

- **Indications:**
  - Severe respiratory distress (CRS ≥4)
  - Persistent increase in O2 requirement or rapid decompensation
  - Worsening of clinical exam (not attributable to fluid overload)
  - If transfusion needed and Hgb at 10 g/dL or greater
  - PICU admission or transfer
  - NIPPV or intubation

- **Automated RCE Process**
  - If patient is located in Colorado Springs or a network of care site, they should be sent to the Anschutz campus as apheresis services are not available elsewhere.
  - Place Apheresis Consultation through EPIC and contact on-call TM provider.
  - Appropriate central line placement is often the time-limiting factor. Central venous catheter placement is usually required. See Apheresis Catheter Guidelines: Short Term Use for appropriate size catheter options
    - **Options include:**
      - Power PICC line placement (consultation with Interventional Radiology)
      - In emergent situations, line placement by the ICU may be more appropriate (i.e., double lumen femoral or IJ catheter).
  - Remove central venous catheters as soon as possible after exchange procedure(s) to reduce the risk for thrombosis.
    - Red blood cell exchange hematologic targets are a HgS percentage <30% and end procedure hematocrit of 30%.
    - Pre- and post-exchange hemoglobin variant samples will be ordered by the TM provider.

### TABLE 2. ANTIMICROBIAL MEDICATIONS

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dosing</th>
<th>Indication/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoxicillin (PO)</td>
<td>90 mg/kg/day (maximum 3,000 mg/day) PO divided TID x 5 days</td>
<td>Antimicrobial – Outpatient 1st Choice Discontinue prophylactic penicillin while patient is receiving amoxicillin.</td>
</tr>
<tr>
<td>Ampicillin (IV)</td>
<td>200 mg/kg/day (maximum 8,000 mg/day) IV divided every 6 hours</td>
<td>Antimicrobial – Inpatient 1st Choice</td>
</tr>
<tr>
<td>Azithromycin (IV/PO)</td>
<td>10 mg/kg/day (maximum 500 mg/day) PO x 1 dose, followed by 5 mg/kg/day (maximum 250 mg/day) PO once daily x 4 doses</td>
<td>Antimicrobial – Inpatient/Atypical Coverage Discontinue if RPP results negative for <em>Chlamydia phila</em> and <em>Mycoplasma</em> Not necessary to use azithromycin with levofloxacin as levofloxacin covers atypical bacteria</td>
</tr>
<tr>
<td>Cefpodoxime (PO)</td>
<td>10 mg/kg/day (maximum 400 mg/day) PO divided BID</td>
<td>Antimicrobial – Outpatient for penicillin allergy</td>
</tr>
</tbody>
</table>
*Ensure prescription sent in advance (variable stock at some outpatient pharmacies) May consider cefuroxime or cefprozil if unable to obtain cefpodoxime

<table>
<thead>
<tr>
<th><strong>Ceftriaxone (IV)</strong></th>
<th>50 mg/kg/day (maximum 2,000 mg/day) IV q24h</th>
<th>Antimicrobial – Outpatient clinic or emergency department; transition to ampicillin upon admission for ACS Discontinue prophylactic penicillin while patient is receiving broad-spectrum antimicrobials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Levofloxacin (IV/PO)</strong> <em>Highly Bioavailable</em></td>
<td>Less than 5 years: Levofloxacin 20 mg/kg/day (maximum 500 mg/day) IV or PO divided q12h 5-10 years: 14 mg/kg/day (maximum 500 mg/day) IV or PO divided q12h Greater than 10 years: 10 mg/kg/day (maximum 500 mg/day) IV or PO q24h</td>
<td>Antimicrobial – Inpatient and/or Outpatient for cephalosporin allergy Discontinue prophylactic penicillin while patient is receiving broad-spectrum antimicrobials Not necessary to use azithromycin with levofloxacin as levofloxacin covers atypical bacteria</td>
</tr>
<tr>
<td><strong>Vancomycin (IV)</strong></td>
<td>Contact pharmacy for recommended dosing Dosing interval based on age/renal function</td>
<td>Antimicrobial – Inpatient for patients with severe illness or with large infiltrate with pleural effusion present and S. aureus suspected *Must monitor renal function (SCr, BUN, urine output) at baseline and minimum twice weekly thereafter</td>
</tr>
</tbody>
</table>

**TABLE 3. RESPIRATORY MEDICATION TABLE**

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dosing</th>
<th>Indication/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Albuterol</strong></td>
<td>4 puffs MDI OR 2.5 mg nebulized x 1 dose. If effective (improved working of breathing, respiratory rate, wheezing, aeration) order scheduled albuterol MDI 2-4 puffs with spacer or 2.5mg nebulized q4h</td>
<td>Increased work of breathing</td>
</tr>
<tr>
<td><strong>Prednisone or Methylprednisolone</strong></td>
<td>1 mg/kg (maximum 40 mg/dose) PO/IV q12h x 5 days Followed by steroid wean to prevent rebound: 0.5 mg/kg (maximum 20mg/dose) PO/IV q12h x 3 days 0.5 mg/kg (maximum 20mg/dose) PO/IV q24h x 3 days 0.25 mg/kg (maximum 20mg/dose) PO/IV q24h x 3 days *Use of steroids has been associated with rebound pain crisis and readmissions; hold until further discussed with heme</td>
<td>Consider in patients if wheezing/crackles/rales present or history of concurrent asthma exacerbation</td>
</tr>
<tr>
<td><strong>Famotidine</strong></td>
<td>PO: Less than 3 months- 0.5mg/kg/dose once daily greater than or equal to 3 months- 0.5mg/kg/dose, (max dose 20mg) BID. IV: less than 3 months - 0.25mg/kg/dose once daily greater than or equal to 3 months- 0.25mg/kg/dose (max dose 20mg) BID</td>
<td>GI prophylaxis for steroid use</td>
</tr>
<tr>
<td><strong>Furosemide</strong></td>
<td>0.5 – 1 mg/kg (maximum 40 mg/dose)</td>
<td>Consider if signs of fluid overload present</td>
</tr>
</tbody>
</table>

*SCr: Serum creatinine, BUN: Blood urea nitrogen, MDI: Metered dose inhaler, GI: Gastrointestinal*
TABLE 4. PAIN MEDICATION

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dosing</th>
<th>Indication/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaminophen</td>
<td>Dose according to manufacturer’s recommendations Maximum daily dose 75 mg/kg/day or 4,000 mg/day</td>
<td>Temperature greater than or equal to 38.3°C</td>
</tr>
<tr>
<td>Ketorolac</td>
<td>0.5 mg/kg (maximum 30 mg/dose) IV q6h x 48 hours</td>
<td>Pain/inflammation</td>
</tr>
<tr>
<td>Ibuprofen</td>
<td>10 mg/kg (maximum 600 mg/dose) PO q6 after 48-hours of ketorolac completed Maximum daily dose 2,400 mg/day</td>
<td>Pain/Inflammation</td>
</tr>
<tr>
<td>Morphine</td>
<td>0.1 – 0.15 mg/kg (maximum 8 mg/dose) IV x 1 dose followed by 0.05 – 0.15 mg/kg (maximum 4 mg/dose) IV q2-4hr PCA Dosing: 0.01 – 0.02 mg/kg (maximum 10 mg/hr) with lockout of 8 minutes Continuous Rate: 0.03 – 0.05 mg/kg/hr *Morphine should be dosed on IBW in obese patients</td>
<td>Pain *Obesity defined as greater than 95th percentile BMI for age in children &gt; 2 years old</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>Intermittent Dosing: 0.015 – 0.02 mg/kg (maximum 1 mg/dose) q3-4hr PCA Dosing: 2-3 mCg/kg (maximum dose 1.2 mg/hr) with lockout of 8 minutes Continuous Rate: 3 – 5 mCg/kg/hr *Hydromorphone should be dosed on adjusted BW in obese patients</td>
<td>Pain *Obesity defined as greater than 95th percentile BMI for age in children &gt; 2 years old</td>
</tr>
</tbody>
</table>

DISCHARGE CRITERIA

- Afebrile >24 hours
- Improved pulmonary symptoms and documentation of adequate oxygenation on room air. Home oxygen may be appropriate to maintain baseline oxygen saturations for a short time as an outpatient.
- Negative cultures for greater than or equal to 24-48 hours
- Stable hemoglobin/hematocrit for at least 24 hours
- Taking adequate oral fluids and able to take oral medications if applicable
- Adequate pain relief, if needed, with oral analgesics
- Follow-up plans coordinated with sickle cell team. Patients discharged with oxygen should return to clinic in 1 week. All patients require a follow up CXR 4-6 weeks from discharge
- Pulmonology follow up arranged

RELATED CHILDREN’S HOSPITAL COLORADO DOCUMENTS

- Apheresis Catheter Guidelines: Short Term Use
- Bronchial Hygiene Therapy Policy
REFERENCES


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