Caring for Critically Ill Adults With Coronavirus Disease 2019 in a PICU: Recommendations by Dual Trained Intensivists*

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Objective: In the midst of the severe acute respiratory syndrome coronavirus 2 pandemic, which causes coronavirus disease 2019, there is a recognized need to expand critical care services and beds beyond the traditional boundaries. There is considerable concern that widespread infection will result in a surge of critically ill patients that will overwhelm our present adult ICU capacity. In this setting, one proposal to add "surge capacity" has been the use of PICU beds and physicians to care for these critically ill adults.

Design: Narrative review/perspective.

Setting: Not applicable.

Patients: Not applicable.

Interventions: None.

Measurements and Main Results: The virus's high infectivity and prolonged asymptomatic shedding have resulted in an exponential growth in the number of cases in the United States within the past weeks with many (up to 6%) developing acute respiratory distress syndrome mandating critical care services. Coronavirus disease 2019 critical illness appears to be primarily occurring in adults. Although pediatric intensivists are well versed in the care of acute respiratory distress syndrome from viral pneumonia, the care of differing aged adult populations presents some unique challenges. In this statement, a team of adult and pediatric-trained critical care physicians provides guidance on common "adult" issues that may be encountered in the care of these patients and how they can best be managed in a PICU.

Conclusions: This concise scientific statement includes references to the most recent and relevant guidelines and clinical trials that shape management decisions. The intention is to assist PICUs and intensivists in rapidly preparing for care of adult coronavirus disease 2019 patients should the need arise. (*Pediatr Crit Care Med* 2020; 21:607–619)

Key Words: adult critical care; adults in pediatric intensive care unit; coronavirus disease 2019

The worldwide pandemic of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 has already resulted in critical care demands overwhelming resources in nations such as Italy (1). This has stressed local healthcare systems requiring new approaches for triage and acute care. With significant resource limitations, especially in differing geographic locales, this pandemic may exhaust existing capacity making it difficult to maintain adequate critical care necessitating adaptations.

Fortunately, COVID-19 disease has been uncommon in children with a reported mean age for most ICU patients between 65 and 70 years (2–9). Many of these patients have comorbidities such as hypertension, type 2 diabetes, coronary vascular disease, cerebrovascular events, and chronic obstructive pulmonary disease (COPD). Patients commonly present on day 5–7 of illness with acute hypoxemic respiratory failure (2, 4, 5, 7, 9) and the frequent ICU complications include shock

***See also p. 679**.

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DOI: 10.1097/PCC.0000000000002429

(30%), acute myocardial injury (22.2%), arrhythmia (44.4%), and acute kidney injury (AKI) (8.3%) (5).

Since COVID-19 is less severe in children (10) with nearly all fatalities in adults (11), one proposed strategy is the use of PICUs to provide surge capacity if adult ICUs are overwhelmed (12–15). For instance, in the United States, there are 534,964 acute care hospital beds (general medical and surgical wards, ICU, step-down, and burn beds) but only 68,558 adult ICU beds; thus use of 5,137 PICU beds may be needed for adult care (6, 15–18).This report aims to prepare PICUs to manage critically ill adults with COVID respiratory failure drawing on the experience of combined adult and pediatric critical care experts while providing confidence that many of these principles are fluent to pediatric intensivists..

GENERAL PRINCIPLES FOR ADULT CRITICAL CARE IN THE PICU

The A, B, C, Ds, and E of Caring for Adults in a PICU

Recent data from New York City shows ~20% of hospitalized patients are between the ages of 20–44 years (19, 20). Some of the complexity of managing adults in a PICU stem from greater comorbidities which can be minimized when selecting for these younger patients at triage. Before making the transition to care for adults in a PICU, one should consider the A, B, C, Ds, and E to assure these patients are cared for safely (21).

"A" represents Accreditation and licensure. Some jurisdictions require notification of changes in ICU bed numbers or patient type. The PICU's admission, discharge, and transfer criteria also need to be updated prior to accepting the first adult patient.

"B" represents Barriers obstructing the acceptance of adult patients such as space, equipment, supplies, staffing, skill mix, and medications. A multidisciplinary team can usually identify these barriers and mitigate them.

"C" represents Competency. Assuring a competent staff, comfortable in caring for the adult patients and families is essential. Just-in-time education and in-service training with unit-based educators and consultants can assist in addressing competency.

The four "D"s of patient safety for children include Developmental Stage, Differential Epidemiology, Dependence, and Demographic Patterns (21). Development is a natural competency for pediatric providers. Younger adults versus elderly represent distinct developmental stages. Differential epidemiology in adults translates to greater propensity for age-related conditions that are rare in children, like brain or cardiac ischemia. Adults are less "dependent" for care and follow-up than pediatric patients are, but Demographics including the adverse effects of the social determinants of health like poverty, insurance gaps, housing insecurity, and malnutrition which in adults have differing resources for assistance.

Finally, Expectations and Outcomes need to be monitored to assure that the structural and process changes do not result in inadvertent outcomes.

When taken together, the A, B, C, Ds, and E can provide a roadmap for integrating the care of adult patients into the PICU.

Differences Between Adults and Pediatric Advanced Life Support

Cardiopulmonary resuscitation (CPR) and life support algorithms for adults are deliberately similar to pediatric patients. Identical approaches should be taken toward both ventricular fibrillation/pulseless ventricular tachycardia and asystole/pulseless electrical activity (22). The advanced cardiac life support algorithm for symptomatic bradycardia does not include CPR and uses atropine IV (0.5 mg every 3–5 min, maximum 3 mg) as a first-line agent followed by early consideration of epinephrine or dopamine infusions and transcutaneous pacing (23). Tachycardia with hemodynamic instability due to regular rhythms (e.g., atrial flutter) requires synchronized cardioversion with 50–100 J while irregular rhythms (e.g., atrial fibrillation [AF]) require 120–200 J. CPR on adults is similar to pediatrics: push hard (although deeper, > 2 inches), fast (100–120 per min), and allow complete recoil (23). Advanced directives and patient prognosis in determining code status should be considered at PICU admission in every patient and in some cases, the team may determine to limit resuscitation.

Equipment and Supplies

PICU epidemiology favors smaller sizes/heights thus deficits in supplies tend to occur when dealing with taller (> 180 cm) and heavier (> 100 kg) adults. **Table 1** provides a list of commonly used supplies to consider for these larger individuals. Central venous catheters for vascular access or dialysis placed in the right internal jugular or subclavian often require ~15–16 cm length which most PICUs stock. We recommend adding 20 cm catheters that are better for adult left sided upper body and femoral approaches.

Common Adult Consultant Services

As the COVID pandemic has driven use of telecommunications in lieu of in person meetings, it is our anticipation that most PICUs will have access to a full suite of adult physician consult services. In **Table 2**, we outline the most likely needed consultations for acute COVID-19 issues. We include procedures which may be performed in the acute setting by the consultant (Table 2), purposely omitting those which do not offer therapeutic potential and thus may be deferred. Likewise, we omit consultative services where pediatric specialists can provide support, or the entire consultation may be performed by telecommunication. For procedures, the consulting physicians and PICU team will need to determine whether the services can be safely rendered within the pediatric facility or require transport to an adult hospital. Many procedures are now feasible at the bedside in adult hospitals such that a similar approach would appear to be less problematic than transport of a highly infectious and critically ill COVID patient across centers.

Common Adult Procedural Modifications

Procedures in adult ICUs are similar; therefore, we highlight differences in preparation and execution below and necessary equipment and supplies in Table 1. Endotracheal intubation is generally performed with a Macintosh 3 or 4 blade placing a

TABLE 1. Commonly Used Equipment and Supplies for Larger Adults

Item	Indication	Size/Length	Sample Product
Endotracheal tube	Mechanical ventilation	8.0 mm	Medtronic number 18780
Laryngoscopy (direct or video)	Intubation	Number 3 or 4 Macintosh	Welch-Allyn number 69043; number 69044
Central venous catheter	Venous access/monitoring	7F/20 cm	Teleflex number ASK-45703
Hemodialysis catheter	Dialysis, plasmapheresis, exchange	12F/20 cm	Teleflex number AK-25122
Arterial catheter	Femoral or radial arterial access/monitoring	20 gauge/12 cm or 20 gauge/4.45 cm	Teleflex number ASK-04510; number NA-04020
Pericardiocentesis set	Fluid drainage (pleural, peritoneal, pericardial)	8.3F/40 cm	Cook number G48638
Nasogastric tube	Gastric aspiration	18F/122 cm	Cardinal number 8888264986

7–8.0 mm-cuffed tube. Morbidly obese adults are often best preoxygenated in a reverse Trendelenburg position with the head of bed elevated to drop abdominal weight off the chest. With COVID-19, we recommend the use of video laryngoscopy for rapid sequence intubation (RSI) by the most experienced operator (24) to maximize success and prevent aerosols. Central venous catheters are placed infrequently in the femoral position due to heightened risk of deep venous thrombosis and infection (25). Arterial catheters are used more frequently than in the PICU and often employ a preloaded needle/wire introducer kit. Thoracentesis and lumbar puncture (LP) in a cooperative adult may have more success with the patient sitting upright and from behind with ultrasound guidance. Obese patients often require longer needle lengths than the standard 8.8 cm (3.5 in) for LP (26) with various lengths up to 18 cm available. The length needed can be estimated in cm as 0.077 × body mass index + 0.88 (27).

Adult Multiple Medications at Admission

Table 3 provides a list of commonly prescribed medications for adults which may not be commonly stocked in pediatric centers (at least not in large supply) as well as recommendations on whether continuation is critical and whether substitutions can be made with agents more often found in a pediatric formulary.

DISTINCT FEATURES OF RESPIRATORY SUPPORT FOR ACUTE HYPOXEMIC RESPIRATORY FAILURE

Noninvasive Support

Escalation of respiratory support in adults generally includes nonrebreather mask, venturi or oxymask, high-flow nasal cannula (HFNC), or noninvasive positive pressure ventilation (NIPPV) (28–32). With COVID-19, there is concern for generating infectious aerosols in when using HFNC and NIPPV such that some institutions are avoiding greater than 6 L flow (33), although recent Society of Critical Care Medicine/European Society of Intensive Care Medicine guidelines include both modalities (24). This risk is minimal with good cannula or mask fit on the patient (33, 34) and with use of protective filters (35). Negative pressure isolation rooms mitigate this concern. Oxymask allows titration of oxygen flow but not titration of the F_{IO_2}, whereas HFNC and NIPPV allow F_{IO_2} titration and use with inhaled pulmonary vasodilators (16, 36–38). Commonly used settings are listed in **Table 4**.

Intubation and Mechanical Ventilation Strategies

For COVID-19 patients we recommend RSI in a negative pressure room (24, 33, 35, 39). In RSI, bag-valve-masking is minimized and patients receive an induction agent (Propofol at 1.5–2.5 mg/kg, or etomidate 0.3 mg/kg) "immediately" followed by a neuromuscular blocker (succinylcholine at 1.5 mg/kg, rocuronium at 1.2 mg/kg, or cisatracurium at 0.3 mg/kg) and intubation within a minute. Succinylcholine and propofol use in adults is common and offers the advantage of rapid and favorable intubation conditions with less safety concerns compared with other agents (40).

Mechanically ventilated adults are mostly managed with assist-control ventilation, rather than synchronized intermittent mandatory ventilation based on studies showing improved work of breathing, synchrony, and extubation rates (41). Volume modes, such as volume control (VC) or pressure regulated VC (VC+), permit maintenance of lower tidal volumes (4–8 mL/kg) based on predicted body weight and lower plateau pressures (< 30 cm H_2O) in acute respiratory distress syndrome (ARDS) (16, 42). In the absence of ARDS, 10 mL/kg is safe (43). Positive end-expiratory pressure (PEEP) is titrated based on F_{IO_2} using validated protocols (44, 45) to levels higher (18–24 cm H_2O at F_{IO_2} = 1) than encountered in pediatrics (46). Our experience and that of many centers is that COVID-19 hypoxemia responds well to PEEP increases. However, notable exceptions have been found where lower PEEP is preferred (47). These cases may be the result of pulmonary microthrombi reducing blood flow (47) as COVID-19 patients are recently reported to develop coagulation abnormalities (48). In these cases, higher PEEP may be deleterious by increasing pulmonary vascular resistance. High-frequency oscillation is not used in adults due to randomized trials showing increased mortality (49) and greater need for sedation (49, 50). Assessment for extubation readiness is typically done using a combined spontaneous awakening-spontaneous breathing trial (51) in which all sedation is lifted and the patient is placed on a continuous positive airway pressure

TABLE 2. Common Acute Consultations and Procedures Required in Critically Ill Adults

Consultant	Diagnoses Requiring Consultation	Acute Procedures
Cardiology	Acute coronary syndromes (includes myocardial infarction), heart failure	Transesophageal echocardiogram[a], Cath/percutaneous intervention (angioplasty and stent placement)
Electrophysiology	Heart block, tachyarrhythmias	IV[a] or permanent pacemaker
Gastroenterology	Gastrointestinal bleeding, cholecystitis, or cholangitis	Esophagogastroduodenoscopy[a] (injection, sclerotherapy, banding), endoscopic retrograde cholangiopancreatography[a] with biliary drainage
Neurology	Stroke, subarachnoid bleed	Cerebral artery thrombectomy or embolization
General surgery	Refractory gastrointestinal bleed, gastrointestinal ischemia, acute abdomen, toxic megacolon	Laparoscopy ± excision[a]
Interventional radiology	Gastrointestinal bleed, stroke, aneurysm, abscess or fluid collections	Vessel embolization, percutaneous drainage[a]

[a]Bedside option.

of 5 cm H_2O and pressure support set at 0–8 cm H_2O (52, 53). Success is defined as a rapid shallow breathing index score (respiratory frequency/tidal volume) less than 105 (54) after at least 30 minutes (52, 53) without objective evidence of distress.

Sedation and Analgesia in Adults (Table on Dosing)

Opioid, benzodiazepine, and dexmedetomidine IV infusions and/or boluses are used for sedation in adults and pediatrics in similar dose ranges despite the common practice in adults of using absolute doses (e.g., mg/hr) as opposed to weight-based dosing (e.g., mg/kg/hr). Propofol use is common in adults due to few reports of propofol infusion syndrome (55, 56) with dose range of 5–60 µg/kg/min employed for continuous prolonged sedation or up to 200 µg/kg/min for brief procedures. Multiple randomized trials have failed to demonstrate any optimal adult sedative (57–61). Propofol or dexmedetomidine produces more hypotension than midazolam and opioids but are metabolized more rapidly. Sedation interruptions or closely titrated sedation based on clinical scores (i.e., Richmond Agitation-Sedation Scale) are superior to both or minimal sedation in producing patient comfort and hemodynamic stability (62–64).

Prone Positioning

Prone positioning for at least 12 hours daily in adults with severe ARDS may increase ventilator-free days, reduce in-hospital mortality, and reduce the need for rescue therapies like inhaled nitric oxide and extracorporeal membrane oxygenation (ECMO) (16, 65–68). The Surviving Sepsis guidelines for COVID-19 for moderate to severe ARDS recommend proning within 24 hours of presentation (24). Our collective experience supports impressive responses in oxygenation following proning in COVID-19. Prone patients typically require additional staff for patient manipulation, deep sedation, and often neuromuscular blockade. Care should be taken to minimize complications such as endotracheal tube obstruction, pressure sores, facial edema, and ocular injury (65–68).

COPD Acute Exacerbations Initiated by COVID-19

COPD is a common chronic illness worldwide and leading cause of both morbidity and mortality (69). Patients with COPD are at high risk to develop acute exacerbation of COPD (AECOPD) during the COVID-19 pandemic and early recognition and treatment is essential. The mainstay of treatment for AECOPD are short-acting bronchodilators, short courses of steroids, oxygen therapy to target oxygen saturations of 88–92%, and short courses of antibiotics (5–7 d [70]).

Inhaled bronchodilators (short-acting β_2 agonists and muscarinic antagonists) are effective in the treatment of acute exacerbations. Nebulization should be avoided due to risk of viral aerosolization rather these medications should be administered via meter-dose inhalers. Prednisone or IV methylprednisolone (30–50 mg daily) for 5–7 days is recommended (70). NIPPV is the standard of care especially for AECOPD as it has been demonstrated to decrease intubation rates, and overall mortality due to respiratory failure (70, 71). Akin to intubated asthmatics, intubated AECOPD with COVID may require lower respiratory rates and higher tidal volumes to avoid auto-peep and increased intrathoracic pressure, decreased venous return, and hemodynamic compromise.

Venovenous Extracorporeal Life Support

Adults with ARDS may receive a survival and disability benefit from venovenous ECMO when offered within 7 days of initiation of mechanical ventilation (72–74). Venovenous ECMO has been found to be safe and effective, especially in ARDS patients during the H1N1 influenza pandemic (75–77). Evidence from adults with COVID-19 in Japan and South Korea suggest that carefully selected patients with severe ARDS failing conventional treatment can be successfully supported with venovenous ECMO (72, 78, 79). Venovenous ECMO flow rates needed to support oxygenation in adults are generally 60–80 mL/kg/min (80). "Lung rest" ventilation should target F_{IO_2} less than or equal to 60%, PEEP ~10, and plateau pressure ~20–25 (77). COVID-19 appears to cause myocardial injury with increased mortality in these patients

TABLE 3. Frequently Encountered Medications in the Adult Population

Class	Examples	Continue in ICU?	Comment/Alternative Therapy
Anti-hypertensives	β blockers, Ca^{2+} channel blockers, angiotensin-converting enzyme-I, angiotensin receptor blocker, thiazide diuretics, vasodilators	No	As needed IV hydralazine, labetalol, nicardipine
Oral anti-hyperglycemics	Metformin, sulfonylureas, dipeptidyl peptidase 4 inhibitors, sodium-glucose cotransporter-2 inhibitors, thiazolidinediones	No	Substitute with insulin
Injectable anti-hyperglycemics	Insulin (short, medium, long-acting), glucagon-like peptide agonists	No	Substitute with insulin
Anti-platelet medications	Aspirin, clopidogrel, prasugrel, ticagrelor	Possibly	Indication: Drug-eluting stent, ≥ 6 mo dual anti-platelet therapy; bare-metal stent, ≥ 1 mo
Hydroxymethylglutaryl-coenzyme A reductase inhibitors	Atorvastatin, rosuvastatin, simvastatin	No	Restart on discharge
Thyroid replacement	Synthroid, levothyroxine	Yes	If enteral is not tolerated, IV levothyroxine is available
Neuropathic pain medications	Pregabalin, gabapentin, duloxetine	Possibly	Discontinuation of gabapentin may result in seizures
Antidepressants	Tricyclic antidepressants, selective serotonin reuptake inhibitor, serotonin-norepinephrine reuptake inhibitor, monoamine oxidase inhibitors	Possibly	Withdrawal may cause mood and cognitive adverse effects
Smoking cessation aids	Bupropion, nicotine patch, nicotine gum, varenicline	No	Consider nicotine patch in active smokers
Anticoagulation	Dabigatran, apixaban, rivaroxaban, warfarin	Possibly	Indication: Deep venous thrombosis/pulmonary embolism and mechanical valves, continue (substitute heparin); atrial fibrillation, hold
Chronic opioid therapy	Buprenorphine (suboxone) and methadone	Yes	Daily dosing to avoid withdrawal

(81). Selected adults progressing to cardiovascular failure may benefit from venoarterial ECMO, although this is associated with a higher risk of stroke, bleeding, and renal failure and should only be considered only in experienced, resourced centers (82).

MANAGEMENT OF COMMON ADULT COMORBIDITIES AND COMPLICATIONS

Stroke and Intracranial Hemorrhage

Cerebrovascular accident (CVA) is a leading cause of death in the United Sates with an overall prevalence of 2.5% in those greater than 20 years old (83) (**Table 5**). Most CVA (85%) is ischemic. Immediate evaluation to stabilize hemodynamics, decipher if intracranial hemorrhage or ischemia is present, and then decide on reperfusion therapy is temporally critical. Sudden loss of focal brain function is a core feature of ischemic stroke onset. Management of CVA includes stabilizing the patient's airway, breathing, and circulation (ABCs), reversing contributing issues, determining the etiology (for ischemic strokes, consider thrombolysis or endovascular thrombectomy), and preparation for post intervention surveillance/management. Pediatric intensivists should calculate a National Institutes of Health stroke scale score, obtain immediate acute imaging to exclude hemorrhage, assess the degree of brain injury, and identify the vascular lesion responsible for the deficit. Imaging may be difficult given isolation for COVID-19; however, these studies are time critical as thrombolysis must occur in less than 4.5 hours from symptoms (83–89). Imaging includes hyperacute MRI, noncontrast CT, or CT angiography. Reperfusion is the most effective maneuver for salvaging ischemic brain that is not already infarcted and is time sensitive as the benefits of reperfusion for ischemic stroke diminish over time. Recent guidelines for early stroke management are published (90). Consultation with a stroke team (telestroke) is recommended.

Cardiac Complications

Mounting evidence demonstrates that up to 40% of COVID-19 patients have direct cardiac injury with increases in arrhythmia, myocardial infarction (MI), myocarditis, and acute

TABLE 4. Advanced Noninvasive Respiratory Support

Modality	Initial Settings[a]	Titratable Range	F_{IO_2} range
HFNC: Optiflow	40 L/min, 100% F_{IO_2}	10–60 L/min[c]	21–100%
HFNC:Vapotherm	40 L/min, 100% F_{IO_2}	1–50 L/min[c]	21–100%
Oxymask	10 L/min, 100% F_{IO_2}	1–15 L/min	100%
Noninvasive positive pressure ventilation[b]	IPAP = 10, EPAP = 5, 100% F_{IO_2}	IPAP up to 24 EPAP up to 20	21–100%

EPAP = expiratory positive airway pressure, HFNC = high-flow nasal cannula, IPAP = inspiratory positive airway pressure.

[a]In general, start with 100% F_{IO_2} but consider titrating down to 60% if patient tolerates.

[b]If using a conventional ventilator to deliver noninvasive positive pressure ventilation, use the continuous positive airway pressure (CPAP)/pressure support (PS) mode with CPAP = 5, PS = 5 (which delivers IPAP = 10).

[c]Can typically transition from HFNC to low flow at ~15 L/min, 60% F_{IO_2}.

heart failure (7, 20, 81, 91, 92). Thus, we provide considerations for these common complications with guidance on management.

Acute or New Onset Atrial Fibrillation. AF is the most common cardiac arrhythmia in adults, more prevalent in men, and prevalence increases with age (93, 94). AF presents as an irregularly irregular pulse which on electrocardiogram (ECG) has RR intervals without repetitive pattern and often absent P waves. AF and resultant tachycardia may compromise cardiac output and result in atrial thrombus formation with potential for embolic stroke. Understanding the immediate etiology for AF is important, as some causes are reversible (i.e., MI, active infection, electrolyte disturbance). Management of AF centers on rate and rhythm control. Rate control to slow the ventricular rate is best achieved via use of beta-blockers (metoprolol or esmolol) or calcium channel blockers (diltiazem). A transesophageal echocardiogram is recommended to evaluate for signs of acute heart failure or left atrial appendage thrombus. To immediately restore normal sinus rhythm direct electric cardioversion within 48 hours of onset is warranted if AF is causing hemodynamic embarrassment. Direct current cardioversion may be more successful with use of amiodarone infusion for 24 hours. In the setting of persistent AF with lower blood pressures, digoxin and amiodarone may be considered for rate control. Management of AF is the subject of a recent guideline update (95).

Acute Coronary Syndromes (Including Demand Ischemia). Assessment of chest pain and acute coronary syndrome (ACS) must be undertaken immediately. If a patient experiences chest pain, arm pain, dizziness, or new onset arrhythmia a STAT ECG should be ordered to determine if there is ST elevation. Patients experiencing an acute ST elevation myocardial infarction (STEMI) require immediate interventional cardiology consultation to consider percutaneous intervention within 90 minutes. If angiography is deemed unacceptable due to COVID-19 infection risk, thrombolysis is an option (96). In the absence of STEMI, these symptoms with troponin elevation mark unstable angina (USA) or non-STEMI. Treatment of USA/non-ST elevation myocardial infarction (NSTEMI) consists of anticoagulation, aspirin (162–325 mg), β blockade and if needed, oxygen (97). These same treatments applied for USA/NSTEMI are often employed initially in the setting of STEMI until reperfusion occurs. Persistent chest pain may be treated with 0.4 mg sublingual nitroglycerin every 5 minutes or a nitroglycerin drip assuming blood pressure is adequate.

Severe critical illness in adults with limited coronary perfusion may result in troponin elevation due to demand-mediated myocardial ischemia (DMMI). Management of DMMI is to minimize myocardial oxygen demands and patient stress (e.g., β blockade, sedation/paralysis); however, there is no role for aspirin or anticoagulation (98). Bedside echocardiogram or point of care ultrasound to evaluate for focal wall motion abnormality can help distinguish infarction from DMMI. Laboratory evaluation of ACS should include electrolytes (with correction of abnormalities), serial troponins, platelets, and coagulation indices.

MI should be treated with high dose statin therapy (e.g., 80 mg atorvastatin daily). Recommendations from 2019 suggest NSTEMI patients should also receive $P2Y_{12}$ inhibitor (89). Typically, before administering additional antiplatelet therapy, a cardiology consult is warranted to discuss the timing of angiography.

Congestive Heart Failure. Acute decompensated heart failure (ADHF) is one of the main causes of respiratory distress in adult patients requiring the ICU (99). Heart failure with preserved ejection fraction (HFpEF) or reduced ejection fraction (HFrEF) have similarities and differences in management. HFrEF shares similarities to the congestive heart failure (CHF) seen in the PICU. Respiratory distress is typically a result of elevated left ventricular end-diastolic pressure (LVEDP) resulting in pulmonary congestion. Diuresis is helpful in both clinical presentations, although patients in HFrEF generally are more hypervolemic. In general, ICU patients in ADHF do not require maintenance IV fluids.

HFpEF patients have diastolic dysfunction and often present with tachycardia and hypertension; subsequently elevating LVEDP. These respond well to vasodilators and β blockade directed at restoring “normal” range heart rates and blood pressures (100). AF should be rate controlled immediately as it can exacerbate HFpEF. Point of care cardiac ultrasound can assist in identifying patients with reduced ejection fraction (101–104).

TABLE 5. Summary of Common Complications in Adult Critically Ill Patients

Complication	Clinical Features	Diagnosis and Management
Atrial fibrillation	Most common tachyarrhythmia in critically ill adults	Rate control with beta-blockers and/or calcium channel blockers
	Often secondary to other medical problems (ACS, congestive heart failure, infection, etc.)	Rhythm control with direct current cardioversion and antiarrhythmics
	RVR with hemodynamic compromise and thromboembolism are most serious complications	Stroke prophylaxis with anticoagulation
Acute coronary syndrome	STEMI characterized by ST elevation with anginal symptoms and elevated troponin	STEMI requires immediate revascularization, percutaneous intervention is preferred
	Non-ST elevation myocardial infarction/unstable angina have these features without ST elevation	ACS treated with anticoagulation, aspirin, nitroglycerin, $P2Y_{12}$ inhibitors (timing varies for STEMI) and statins
	DMMI can occur without coronary stenosis	DMMI does not require anticoagulation or aspirin
Congestive heart failure	Subtyped as HFpEF or HFrEF	Diuresis, HFpEF often requires less diuresis
	Both subtypes cause elevated left ventricular end-diastolic pressure and pulmonary congestion	Afterload reduction in HFrEF
	HFrEF presents with more fluid overload and can benefit from afterload reduction	Rate control with concomitant atrial fibrillation with RVR
		Avoidance of maintenance IVF
Pulmonary embolism/deep venous thrombosis	Presents with chest pain, dyspnea, hypoxia without chest radiograph findings, tachycardia, and hypotension	Systemic anticoagulation
	Can progress to hemodynamic collapse	Delay in imaging should not delay treatment
	Diagnosed with CT angiography or ventilation/perfusion scan	Thrombolysis should be considered in pulmonary embolism with shock and/or right heart strain
		Expert consultation for consideration of catheter-directed procedures
		Deep venous thrombosis chemoprophylaxis and sequential compression devices should be considered in all critically ill adults
Gastrointestinal bleeding	Common causes of upper gastrointestinal bleed are peptic ulcer disease, varices, Mallory-Weiss tear, neoplasms	Airway, breathing, and circulations first if in shock
	Common causes of lower gastrointestinal bleed are diverticular disease, hemorrhoids, and neoplasms	Two large-bore peripheral IV catheters
	Upper gastrointestinal bleeding more likely to be life threatening	Volume expansion with blood and crystalloid
		Bid proton pump inhibitor
		Expert consultation for endoscopic intervention
Hypertonic hyperosmolar syndrome	Common complication of type 2 diabetes mellitus	Fluid resuscitation, insulin, electrolyte replacement
	Characterized by hyperglycemia, dehydration, without acidosis or ketosis	Treatment of precipitating condition(s)
Acute kidney injury	Most common organ injury in critically ill adults	Use of balanced crystalloids
	Chronic kidney disease predisposes to acute kidney injury	Avoidance of nephrotoxic agents
		Correction of electrolyte and acid/base disturbances
		Dialysis
Delirium	Extremely common in adult critically ill patients	Use of validated screening tools
	Associated with increased mortality and poor cognitive outcomes	Reorientation, engaging visitors, cognitive stimulation, avoidance of centrally-acting medications, pain management
	Risk factors are polypharmacy, exposure to centrally-acting medications, sleep-wake cycle disruption, immobility, and unmanaged pain	Judicious use of antipsychotics in severe agitation

(*Continued*)

TABLE 5. (*Continued*). Summary of Common Complications in Adult Critically Ill Patients

Complication	Clinical Features	Diagnosis and Management
Pressure-related injury	Major contributor to morbidity in critically ill adults	Prevention includes use of silicone foam dressings, frequent repositioning, use of support surfaces, and nutritional optimization
	Severity ranges from superficial erythema to full-thickness tissue necrosis	Treatment includes consultation of wound care team, dry coverage for stage 1 injuries, occlusive dressings for stage 2 injuries, and debridement for stage 3 and 4 injuries
	Risk factors are advanced age, obesity, immobility, and poor nutrition	
Alcohol withdrawal	Begins 6–24 hr and peak 72 hr after last drink	Thiamin and folate supplementation
	Symptoms include anxiety, agitation, tremors, diaphoresis, hallucinosis, withdrawal seizures, and delirium tremens	Monitoring of symptom severity with a validated scale
		Symptom-triggered administration of benzodiazepines
		Adjunctive use of dexmedetomidine, ketamine, barbiturates, and antipsychotics

ACS = acute coronary syndrome, DMMI = demand-mediated myocardial ischemia, HFpEF = heart failure with preserved ejection fraction, HFrEF = heart failure with reduced ejection fraction, RVR = rapid ventricular response, STEMI = ST elevation myocardial infarction.

Hypertensive patients with HFrEF require afterload reduction to optimize cardiac output and may require low-dose inotropic support. Home medications (angiotensin blockade and β blockers) should be discontinued at admission to the ICU and assessed for continuation after the patient has reached clinical stability. In patients with significant hypervolemia, high venous pressures may contribute to poor renal perfusion and poor diuretic response ("cardiorenal syndrome"). Aggressive diuresis (occasionally dialysis) with inotropic or vasodilator support may be needed to improve oxygenation. Weighing the patient daily may assist in targeting appropriate fluid balance. Myocardial ischemia should be considered as a cause of ADHF and ruled out with serial troponins.

Acute Pulmonary Embolism and Deep Vein Thrombosis Prophylaxis. Acute pulmonary embolism (PE) is a common and fatal complication of hospitalization that account for over 100,000 deaths in the United States annually. The diagnosis and management of PE is summarized (102–105). PE in the ICU may present as hemodynamic stability or increased hypoxia not explained by new chest radiograph findings. This diagnosis is rarely seen in the PICU and a high index of suspicion should be maintained when caring for adults. Definitive imaging includes CT pulmonary angiography and less commonly ventilation/perfusion scan (102, 106). Treatment is identical to PE for presence on ultrasound of deep vein thrombosis (DVT) in the setting of PE symptoms. The mainstay of therapy is systemic anticoagulation (105) with unfractionated heparin or low molecular weight heparin that should not be withheld due to delay in obtaining imaging especially due to quarantine for COVID-19. Hemodynamic instability including right heart strain should warrant consideration for thrombolysis or acute thrombectomy (103, 104, 106). To prevent DVT, especially given immobility with COVID-19 in the ICU, the use of sequential compression devices and, if not contraindicated, prophylactic anticoagulation (107, 108) is recommended.

Gastrointestinal Bleeding

The common adult conditions causing acute gastrointestinal bleeding (GIB) are distinguished based on whether their origin is in the upper or lower gastrointestinal tract. The most common etiologies of upper gastrointestinal bleeding are peptic ulcer disease, variceal bleeding, Mallory-Weiss tears, and carcinoma (109). The most common cause of lower gastrointestinal bleeding are diverticular disease, angiodysplasia, neoplasms, colitis, and anal lesions like hemorrhoids and fissures (109). In critically ill intubated adults stress ulcer prophylaxis with a proton pump inhibitor (PPI) has a small benefit in preventing GIB (110).

As with pediatric patients experiencing acute GIB, the initial priorities are managing the ABCs particularly hemorrhagic shock. To facilitate transfusion, two large bore (18 gauge) IV catheters should be established and hypotension managed aggressively with IV fluids and the transfusion of blood and blood products as necessary. A PPI should be administered for upper GIB. We recommend pantoprazole 40 mg IV bid as an initial approach with an immediate gastrointestinal consult. Upper endoscopy can be both diagnostic and therapeutic in upper GIB, whereas colonoscopy is primarily diagnostic. A nasogastric tube may be helpful to differentiate the source of bleeding or remove stomach contents and blood prior to endoscopy. This helps to identify a source and allow specific treatments to be provided. If no source is found on the initial endoscopy and the patient remains unstable, additional diagnostic testing including computerized tomography and/or angiography can be pursued while resuscitation continues. Surgery remains an option for those in whom the source remains elusive.

Hypertonic Hyperosmolar Syndrome

Hyperosmolar hyperglycemic state (HHS) is an acute metabolic emergency classically affecting type 2 diabetics. It is distinct from diabetic ketoacidosis (DKA) in that it typically presents with higher levels of hyperglycemia (plasma glucose > 600 mg/dL), a greater degree of dehydration, minimal acidosis (pH > 7.30) and ketosis (111, 112). Treatment principles of HHS are insulin infusion titrated to decrease blood glucose to less than 180 mg/dL (which is the threshold of glucosuria which drives dehydration/electrolyte abnormalities) and aggressive hydration. Total fluid resuscitation requirements are usually much greater than in DKA (111), although in COVID-19 this must be balanced against the risks of volume overload and CHF. Resolution of HHS is indicated by improvement in osmolality, dehydration, and altered mental state (111).

Acute Kidney Injury Superimposed on Chronic Kidney Disease

AKI is the most common organ dysfunction in critically ill adults (34%) and is associated with high in-hospital mortality (62%) (113). Patients with advanced chronic kidney disease or end-stage renal disease may already be on intermittent hemodialysis (iHD) through a tunneled percutaneous hemodialysis catheter or a matured arteriovenous fistula. Temporary catheters can be used for iHD or continuous renal replacement therapy, but an arteriovenous fistula is reserved for iHD.

The prevalence of AKI in COVID-19 is low (7%) similar to that seen in the severe acute respiratory syndrome (SARS) epidemic (6.7%) (7, 114). Like SARS, COVID-19 may cause an acute tubular necrosis (114). Patient in the SARS epidemic who developed AKI had a higher overall mortality compared with those without renal impairment (91.7% vs 8.8%) (114). Management should include avoidance of nephrotoxic agents and use of pH balanced crystalloids (115).

Delirium

Delirium is common among adult ICU patients (prevalence: 16–89%) (116) and caused by an underlying medical condition, intoxication, or medication effect. It is a significant contributor to both morbidity and mortality, including worse long-term cognitive outcomes (117–119). Delirium can occur in agitated, hypoactive, and mixed subtypes, with the overwhelming majority of patients falling into the latter two categories. There are several validated scales for delirium assessment in the ICU, with the Confusion Assessment Method for the ICU being the most widely used (114, 115). Many of the risk factors are modifiable and include exposure to psychoactive or centrally-acting medications, sleep-wake cycle disruption, immobility, polypharmacy, and unmanaged pain (117–119). Nonpharmacologic approaches to these modifiable risk factors include frequent environmental reorientation, cognitive stimulation, minimizing sleep interruptions, engaging familiar visitors, limiting use of sedative medications, and scheduled sedation "holidays." These strategies have consistently shown improved clinical outcomes in critically ill patients and are now considered standard of care (117). Although there is some evidence suggesting the prophylactic use of certain pharmacologic agents (antipsychotics, dexmedetomidine, ketamine, etc.), this is currently not recommended due to the inconsistency and lower quality of most of the studies and lack of benefit in other patient-centered outcomes (117). For severe agitation posing risk of self-harm or interruption of care, a trial of short-term low-dose antipsychotics (haloperidol, quetiapine, and olanzapine) may be helpful (117).

Skin Breakdown and Pressure Ulcers

Although children can develop pressure-related injury (PI), it affects a higher frequency (~17–24%) of critically ill adults (120). Severity ranges from nonblanchable skin erythema (stage 1) to full-thickness destruction of dermis and subcutaneous tissue (stage 4) (121). Some of the healthcare burden from PI's is preventable with good risk assessment and implementation of skin care protocols (120). Distinct ICU risk factors include prolonged mechanical ventilation and bedbound status which is often exacerbated by higher prevalences of neuromuscular weakness in adults (122–124), hypotension and vasopressor administration (125) and should be considered along with general risk factors (age, comorbidities, obesity, mobility, and nutrition) when utilizing risk assessment tools like the Braden Scale (125). PI preventative strategies include use of protective silicone foam dressings, frequent repositioning, use of support surfaces, and nutritional optimization. Although the use of silicone foam dressings has proven effective, evidence for the other strategies remains limited (126). Early consultation of a wound care team (if available), coverage with a transparent film for stage 1 injuries, maintaining a moist wound environment with occlusive dressings for stage 2 injuries, and possible debridement for stage 3 and 4 injuries form the basis for preventing PI progression (127). Efforts should be made to efficiently incorporate these strategies into the overall care of the patient in a way that limits patient staff interactions.

Alcohol Withdrawal

About 20–30% of adult ICU patients have an alcohol use disorder and are at risk for developing alcohol withdrawal syndrome (AWS) (128, 129). AWS carries significant morbidity and mortality in hospitalized patients and requires careful management. Without treatment, symptoms begin within 6–24 hours after cessation of drinking and may include anxiety, agitation, tremors, diaphoresis, headache, hallucinosis, withdrawal seizures, and delirium (i.e., delirium tremens). Symptoms may be measured using the Clinical Institutes Withdrawal Assessment Scale for Alcohol and management tailored based on severity of symptoms. A high index of suspicion and preemptive treatment with folate (5 mg daily) and thiamin (100 mg IV daily) is important to avoid Wernicke-Korsakoff syndrome. Withdrawal symptoms are managed first line using titrated doses of benzodiazepines with potential benefit from other therapies such as dexmedetomidine, ketamine, phenobarbital, and antipsychotics (128–130). Propofol may be added in agitated intubated patients.

ETHICAL ISSUES INCLUDING PALLIATIVE CARE AND END OF LIFE DECISION-MAKING

Critically ill adults typically require surrogate decision-making while incapacitated (131) and many have a prepared advanced care document (i.e., durable powers of attorney for healthcare

(DPAHC) and living wills) to express healthcare wishes (132, 133). DPAHCs authorize particular person(s) as legally recognized medical decision-makers if the patient lacks capacity. Living wills summarize medical care that a patient would or would not want under specific circumstances such as serious illness or hospitalization. Particularly in a setting of critical resource limitation, an ethical duty to plan compels physicians to identify these advanced directives or identify a surrogate decision-maker, as misapplication of these resources may detract from other patients. Do-not-resuscitate (DNR) orders should be entered in the medical record for patients who do not desire CPR.

Public health ethics, which focuses on overall community good, differs from clinical ethics, which focuses on the good of the individual patient (134, 135). Crisis resource allocation and rationing strategies, often designed to save the most possible lives and the most possible life years, deserve early institutional articulation (136). Such policies may create tension during the care of adults in pediatric settings, as many allocation guidelines give preference to younger patients. Palliative care consultation should be engaged early, which may reduce ICU resource utilization by increasing transition to DNR status without increasing overall mortality (137). Additionally, if crisis resource allocation is used, patients (and/or surrogates) should be proactively informed and palliative care should be provided to those who do not receive ICU resources. Consultation with adult practitioners in cases where limitation of life sustaining therapy is being considered would be prudent.

Finally, adults receiving medical treatment in a pediatric facility will certainly recognize differences in the typical standard of care and should receive transparent communication about these deviations. Hospitals should clearly define and document their triggers for adopting altered standards of care. This approach creates a helpful framework for physicians and also engenders discussions with patients about the care they can expect to receive.

CONCLUSIONS

With significant resource limitations, the COVID-19 pandemic may challenge PICUs to adapt to the care of adult patients after existing capacity is exhausted. Surprisingly, the majority of care delivered to these "big children" will be familiar to the pediatric intensivist. Understanding and preparing for the differences and anticipating complications is important to optimize care in the setting of COVID-19 or other situations where adults may be cared for in a PICU (e.g., adult congenital heart disease).

The authors would like to offer support and expertise to our pediatric critical care colleagues caring for adult patients during this pandemic. As such, we have provided the emails of the combined adult and pediatric critical care medicine authors and will do our best to respond promptly to questions: Kenneth E. Remy, MD, MHSc (kremy@wustl.edu); Philip A. Verhoef, MD, PhD (Philip.a.verhoef@kp.org); Timothy B. Kaselitz, MD, MPH (kaselitzt@upmc.edu); Frank Lodeserto, MD (flodeserto@geisinger.edu); Eliotte L. Hirshberg, MD (ellie.hirshberg@have.utah.edu); Anthony Slonim, MD, PhD (aslonim@renown.org); and Cameron Dezfulian, MD (dezfulianc@upmc.edu).

Dr. Verhoef's institution received funding from National Institutes of Health National Heart, Lung, and Blood Institute K08 award. Dr. Dezfulian's institution received funding from Mallinckrodt Pharmaceuticals. The remaining authors have disclosed that they do not have any potential conflicts of interest.

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