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Severe ARDS in COVID-19-infected pregnancy: obstetric and intensive care considerations

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1 **Severe ARDS in COVID-19-infected pregnancy:**
2 **obstetric and intensive care considerations**

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9
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16
17 **Word count:** Abstract 127 words; Manuscript 2,707 words

18
19 **Condensation:** A review of the clinical findings, algorithmic approach, and clinical
20 considerations for the management of COVID-19 related ARDS in pregnancy

21
22 **Keywords:** COVID-19, SARS-CoV-2, pregnancy, ARDS, coronavirus, pneumonia,
23 acute respiratory distress syndrome

24

25 **Abstract**

26

27 Since the emergence of a novel coronavirus (SARS-CoV-2) in Wuhan, China, at the
28 end of December 2019, its infection – COVID-19 – has been associated with severe
29 morbidity and mortality and has left world governments, healthcare systems and
30 providers caring for vulnerable populations, such as pregnant women, wrestling with the
31 optimal management strategy. Unique physiologic and ethical considerations negate a
32 one-size-fits-all approach to the care of critically ill pregnant women with COVID-19, and
33 few resources exist to guide the multi-disciplinary team through decisions regarding
34 optimal maternal-fetal surveillance, intensive care procedures, and delivery timing. We
35 present a case of rapid clinical decompensation and development of severe Acute
36 Respiratory Distress Syndrome (ARDS) in a woman at 31 weeks' gestation to highlight
37 these unique considerations and present an algorithmic approach to the disease's
38 diagnosis and management.

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48 Introduction

49 As of April 3, 2020, the COVID-19 global pandemic totaled 972,303 cases with 50,322
50 deaths (5.2% mortality rate) worldwide, and it is spreading rapidly with a basic
51 reproduction number (R_0) of 2-2.5 suggesting that 2-3 people will become infected from
52 an index patient [1,2]. Although the United States now leads the world in total cases
53 (239,279), the U.S. mortality rate is less than half that seen worldwide at 2.3% (5,443
54 confirmed deaths), and the hospitalization rate remains low at 24.1 per 100,000
55 population [3]. Such statistics may embolden skeptics eager to challenge the severity of
56 this public health crisis. However, the rates of critical illness and mortality associated
57 with COVID-19 infection among pregnant women - a potentially highly vulnerable
58 population, remain unclear [4-7].

59
60 We present the clinical challenges and potential strategies for optimal maternal-fetal
61 surveillance, intensive care procedures, and delivery timing posed by a case of a
62 pregnant woman at 31 weeks' gestation who presented to a tertiary care hospital in
63 Cincinnati, Ohio, with COVID-19 symptoms, laboratory abnormalities, and chest-
64 imaging findings immediately prior to the development of rapid clinical decompensation
65 and severe Acute Respiratory Distress Syndrome (ARDS) requiring prolonged
66 mechanical ventilation and ultimately indicated preterm delivery.

68 Case:

69 A 39-year-old Caucasian G6 P2031 with a 31.0-week live singleton intrauterine
70 gestation conceived via in-vitro fertilization required admission on 3/24/2020 from the

71 emergency department of a tertiary care center in Cincinnati, Ohio, due to complaints of
72 5 days of worsening non-productive cough, shortness of breath, fever, and malaise.
73 Four days prior (3/20/2020 – COVID disease day #1 in Figure 1), she had been
74 discharged from the emergency department following work-up for a milder presentation
75 of these symptoms that included normal findings on chest x-ray, normal vital sign
76 assessment, and normal results of a respiratory viral pathogen laboratory analysis
77 including influenza A and B rapid screening. Of note, a nasopharyngeal swab for
78 COVID-19 reverse-transcriptase polymerase chain reaction (RT-PCR) was sent to the
79 Ohio Department of Health at that time, but results did not return for 8 days and were
80 still pending when she re-presented on 3/24/2020 (COVID disease day #5). She had
81 previously established early and complete prenatal care through the Maternal-Fetal
82 Medicine service due to underlying mild myotonic dystrophy (without cardiomyopathy),
83 bicuspid aortic valve (without aortic dilation, stenosis or regurgitation), history of two
84 prior low-transverse cesarean deliveries, and history of a prior mild cerebrovascular
85 accident while on combined oral contraceptives. Her pre-gravid body mass index (BMI)
86 was 24.7, and she denied any tobacco or illicit substance abuse. Serial surveillance with
87 obstetric ultrasound imaging and maternal echocardiography suggested that her
88 pregnancy had thus far been without complication, and she had been compliant with
89 prescribed daily prophylactic low-molecular weight heparin.

90 Upon re-presentation to the emergency department (3/24/2020, COVID disease day
91 #5), her symptoms had progressed to include fever to 101°F, worsening shortness of
92 breath prohibiting the ability to complete full sentences, and persistent non-productive
93 cough (Figure 1). Initial vital sign assessment identified significant tachypnea

94 (respiratory rate of 32 breaths per minute), mild tachycardia (heart rate in the low 100's
95 beats per minute), low normal blood pressure (mean arterial pressure in the low 70's
96 mmHg), and mild hypoxia (SpO₂ 93%) despite 4 liters of oxygen via nasal cannula.
97 Physical examination was notable for rhonchi and egophony throughout all lung fields. A
98 chest X-ray, CT pulmonary angiogram, and lung ultrasound assessment were
99 performed with the findings demonstrated in Figure 2. The attending emergency
100 department provider ordered the CT angiogram of the chest to investigate the potential
101 for pulmonary embolism, and the lung ultrasound imaging was performed bedside by
102 the attending MFM physician to further investigate the potential for COVID-19
103 pneumonia. Specifically, her chest X-ray identified bilateral diffuse pulmonary infiltrates,
104 and her chest CT scan identified bilateral airspace disease characterized by ground-
105 glass appearance with peripheral consolidations compatible with viral pneumonia. Her
106 lung ultrasound demonstrated bilateral pleural thickening and nodularity of the visceral
107 pleura (Figure 2). Horizontal A-lines representing normal aerated lung were absent and
108 replaced by multiple B-lines, pleural nodularity and thickening, and an overall "white
109 lung" appearance with focal areas of consolidation.

110

111 Laboratory analysis identified a normal PaO₂:FiO₂ ratio > 300 (suggesting no evidence
112 of ARDS) but definite leukopenia (7,700/mcL), lymphopenia (800/mcL),
113 thrombocytopenia (114,000/mcL), elevated transaminases (AST 65 IU/L), and a mildly
114 elevated procalcitonin (0.33 ng/ml). Although the results from her prior COVID-19 RT-
115 PCR were pending, her clinical presentation supported the diagnosis of COVID-19
116 infection with pneumonia and the potential for development of Acute Respiratory

117 Distress Syndrome (ARDS). The emergency department physician felt that her SpO₂ of
118 93% on 4 liters/minute (L/min) nasal cannula oxygen and PaO₂:FiO₂ ratio > 300 was
119 appropriate for admission to the hospital's lower-acuity COVID floor, and her disposition
120 was planned to that unit. However, the staff Maternal-Fetal Medicine physician
121 recognized her SpO₂ as abnormal for pregnancy and re-directed her care to the
122 intensive care unit (ICU). The degree of her probable COVID-19 infection at this point
123 was severe [8].

124

125 Upon arrival to a negative pressure room in the ICU, she was placed in strict isolation
126 with airborne precautions. Reassessment of her SpO₂ revealed worsening hypoxia
127 (78%) despite 4 L/min oxygen via nasal cannula. A non-re-breather mask was applied,
128 and the inhaled oxygen rate was increased to 15 L/min. Her SpO₂ increased to 82%,
129 but she complained of feeling exhausted with inspiration and the decision was made to
130 proceed with rapid sequence intubation with planned mechanical ventilation for
131 respiratory failure and critical illness severity (approximately 9.5 hours after presentation
132 to the emergency department). Continuous electronic fetal monitoring was initiated and
133 demonstrated a 3-minute prolonged fetal heart rate deceleration to the 80 beat-per-
134 minute range that spontaneously resolved following intubation. During this brief period,
135 the consideration for emergent delivery was entertained. Maximal ventilatory assistance
136 was applied, however, and both the maternal and fetal status improved - prompting
137 initiation of both antenatal corticosteroid administration and magnesium sulfate for the
138 dual benefit of fetal neuroprotection and control of maternal bronchospasm (6-gram
139 bolus over 20 minutes intravenously followed by 2 grams per hour IV). She required

140 large dosages of intravenous benzodiazepines and narcotics for sedation, and her
141 mean arterial blood pressures (MAPs) dropped below 65 mmHg requiring continuous
142 infusion of norepinephrine.

143

144 Over the next 8 hours, the ventilator settings were increased to 100% FiO₂ and PEEP
145 (positive end-expiratory pressure) of 10 cm H₂O, without complete resolution of her
146 hypoxia (SpO₂ ~ 90-93%). A volume control ventilation modality with automatic pressure
147 augmentation (VC+) was employed to minimize volu- and baro-trauma with the following
148 settings: respiratory rate of 20 breaths per minute, tidal volume of 6 ml/kg, FiO₂ of
149 100%, inspiratory-to-expiratory time of 1:1.3, and PEEP of 10 cm H₂O. The PaO₂:FiO₂
150 ratio remained below 150 signifying severe ARDS per American-European Consensus
151 Conference criteria [9]. Surprisingly, the fetal heart rate remained reassuring and
152 signified a certain degree of maternal stability. Per recommendations by the infectious
153 disease specialist, the following medications were initiated: ceftriaxone, azithromycin,
154 oseltamivir, and hydroxychloroquine. Marked improvement in her oxygenation was not
155 witnessed until the team manually placed her in a prone position per the PROSEVA
156 study protocol [9]. The initial plan included utilization of a mechanical rotating bed
157 designed for prone ventilation, but manual prone positioning was preferred due to the
158 ability to more quickly return her to supine positioning for performance of CPR or
159 emergent delivery. Manual pronation required a collaborative effort involving the
160 intensive care and obstetric team members to establish invasive hemodynamic
161 monitoring (central venous access and arterial line access), secure her airway, cushion
162 and support her gravid abdomen, and maintain continuous tocodynamometry and

163 electronic fetal heart rate monitoring (Figure 3). This allowed for gradual diminishment
164 of the FiO_2 and PEEP requirements.

165

166 Her care throughout the following week involved twice daily multi-disciplinary “huddles”
167 to elicit input from the Infectious Disease specialists, Pulmonology and Critical care
168 teams, Maternal-Fetal Medicine teams, Anesthesia Critical Care specialists, Cardiology,
169 CardioThoracic surgeons, Neonatology, and Obstetric nursing teams. Plans were
170 established regarding staff exposure mitigation, emergency preparedness, delivery
171 timing, neonatal resuscitation, nutritional support (oral gavage feedings), venous
172 thromboembolism prophylaxis (subcutaneous heparin twice daily), and adjunctive
173 measures including the potential for inhaled pulmonary vasodilators (epoprostenol) and
174 extracorporeal membrane oxygenation (ECMO). Her COVID-19 RT-PCR result returned
175 positive on hospital day 4 (COVID disease day #8), and strict isolation with airborne
176 droplet precautions was maintained. Consent and regulatory permission was obtained
177 to allow for initiation of a 10 day course of remdesivir – a promising antiviral agent
178 targeting a wide array of RNA viruses including SARS/MERS-CoV [7]. Daily lung
179 ultrasound assessments revealed a lack of visual improvement to her sonographic
180 findings. She was rotated between the prone and left lateral decubitus positions each
181 day with a gradual tolerance toward longer durations out of the prone position on
182 hospital days 6 and 7. This tolerance combined with a gradual reduction in FiO_2 and
183 PEEP requirements negated the need to move forward with delivery or to institute
184 inhaled pulmonary vasodilators or ECMO.

185

186 On hospital day 8 / COVID disease day #13 (32.0 weeks' gestation), the
187 continuous tocodynamometry and fetal heart rate tracing began to demonstrate regular
188 uterine contractions with persistent late decelerations. This prompted a "huddle" and
189 mobilization of all teams to prepare for urgent but non-emergent delivery via repeat
190 cesarean section. Her ICU ventilator circuit was maintained and transported with her to
191 the operating suite to minimize exposure during transport. Bedside echocardiography
192 was utilized to monitor her intravascular volume status to help guide fluid resuscitation.
193 Repeat laboratory assessment revealed a mild coagulopathy (elevated INR 1.7, PT 20.2
194 sec, aPTT 35.1 sec), and preparations were made for prevention of massive
195 hemorrhage including procurement of blood products and uterotonics (oxytocin and
196 misoprostol) in the operating room. A vertical midline skin incision was made to optimize
197 exposure and minimize vascular injury in case hemorrhage was encountered. Delayed
198 cord clamping was intentionally not employed, and the neonatology team utilized an
199 adjacent operating room for neonatal resuscitation to minimize staff and newborn
200 exposure to the mother. The patient tolerated the repeat low-transverse cesarean
201 delivery quite well without postpartum hemorrhage or respiratory compromise. She
202 returned to the ICU where her status continued to improve over the next several days. A
203 "de-brief" was held among all team members to review opportunities for improvement.
204 Umbilical cord blood gas analysis revealed a normal pH (7.2), PCO₂ (63 mmHg), PaO₂
205 (21 mmHg), base deficit of 3, and the male newborn transitioned to extra-uterine life
206 without complication and was extubated on day of life (DOL) 3. His amniotic fluid and
207 nasopharyngeal swabs were sent for COVID-19 RT-PCR analysis on DOL 1 and 2 (24
208 hours apart), and both results returned negative. The need to maintain strict isolation

209 and airborne droplet precautions prohibited the patient's husband from visiting either his
210 wife or his newborn son for a total of 14 days. Currently (hospital day 17 / COVID
211 disease day #22), she is improving but continues on synchronized intermittent
212 mandatory ventilation (SIMV) with an FiO₂ of 35%, no PEEP requirement, and daily
213 attempts of spontaneous breathing trials.

214

215

216

217 **Discussion:**

218 This case highlights the rapidity of COVID-19 infection in pregnancy with development
219 of severe COVID-19 ARDS within 10 hours of admission, and the importance of
220 considering physiologic maternal adaptations in delineating an algorithmic approach.
221 The maternal physiologic adaptations to pregnancy not only leave the woman more
222 vulnerable to cell-mediated viral infections such as COVID-19 but also more susceptible
223 to rapid cardio-pulmonary decompensation due to the reduced cardiac and pulmonary
224 reserves. Such considerations may not be forefront in the minds of the intensive care
225 team members, and these physiologic alterations must be emphasized by the obstetric
226 providers as they assist in serving in a "quarter-back" role leading the implementation of
227 the algorithmic approach. Such approach must entail input from multiple disciplines and
228 establish a framework for optimal team dynamics utilizing daily "huddles" or other open
229 means of direct communication. This planning should occur prior to any patient's arrival
230 where the myriad of team members establish a consensus regarding the optimal
231 imaging investigations, laboratory studies, COVID testing, fetal assessment, and

232 admission locations for these women. The team's safety must also remain a priority
233 ensuring appropriate personal protective equipment, staffing (nurse-to-patient ratio),
234 facilities equipped to minimize exposure, and mobile or hand-held equipment with easy
235 cleaning / disinfecting. An example of our management algorithm is included for
236 reference but should be individualized to one's own institution (Figure 4).

237

238 One of the most difficult yet crucial aspects of the management approach is the
239 determination of delivery timing. The physiologic adaptations to labor, delivery, and the
240 immediate postpartum period include maximization of the maternal cardiac output, auto-
241 transfusion of up to 500 mL of blood volume back into the intravascular compartment, a
242 catecholaminergic surge, release of inflammatory mediators within the endothelium, and
243 considerable fluid shifts between the interstitial, intracellular, and intravascular
244 compartments. In the setting of severe systemic infection, these physiologic changes
245 can serve to exacerbate the dysregulated inflammatory cascade leading to a higher
246 potential for endothelial dysfunction, pulmonary edema, myocardial edema and cardiac
247 dysfunction [11]. Thus, the decision to proceed toward delivery should be deferred in
248 the setting of severe and critical maternal COVID-19 infection until maternal cardio-
249 pulmonary stability can be achieved unless the pregnancy has reached full term, fetal
250 status is non-reassuring, or the maternal status is so dire that evacuation of the uterus
251 is likely to facilitate improvement in cardio-pulmonary function [4]. Consideration for
252 administration of antenatal corticosteroids prior to anticipated preterm birth is
253 controversial in the setting of severe maternal COVID-19 infection. Evidence from
254 treatment studies for SARS suggested that high dosages of corticosteroids posed a risk

255 for severe side effects that drastically affected prognosis, but shorter courses of low-to-
256 moderate dosages may be considered in the care for the critically ill COVID-19 patient
257 [12]. The decision regarding administration of magnesium sulfate for fetal
258 neuroprotection prior to 32 weeks' gestation should proceed per standard indications in
259 that this agent may provide an additional benefit of bronchodilation in the setting of
260 bronchospasm following intubation. Caution is advised to minimize fluid overload with
261 the administration of magnesium sulfate due to the potential for development of
262 additional pulmonary edema, and we recommend restricting the total volume of infused
263 intravenous fluids to 125 ml/hour or less. Delayed cord clamping and immediate skin-to-
264 skin maternal contact should be avoided [4]. Table 1 represents our approach to
265 delivery considerations including timing, location, and medications.

266

267 When attempting to defer delivery and achieve resolution of the acute maternal illness
268 with supportive care, several adjunctive therapies should be considered. Emerging
269 evidence suggests that antiviral agents including hydroxychloroquine and remdesivir
270 may demonstrate efficacy in treating the SARS-CoV-2 virus, but neuraminidase
271 inhibitors such as oseltamivir have no proven benefit [10,13]. Although the safety of
272 these agents in pregnancy has not been definitely determined and their efficacy remains
273 controversial, the pharmacokinetic properties and mechanisms of action may support
274 their judicious use while we await further clinical trials. Non-invasive modes of
275 ventilation such as "CPAP" or "BiPAP" are not recommended for managing acute
276 hypoxemic respiratory failure due to their increased likelihood of failure with need for
277 more urgent transition to invasive ventilation [14]. Rapid sequence endotracheal

278 intubation should be performed per routine but with consideration for a slightly smaller
279 endotracheal tube size due to the potentially edematous and narrowed airway calibers
280 in pregnancy. Oxygenation and ventilatory goals include consideration for the
281 physiologic mild respiratory alkalosis of pregnancy, the diminished functional residual
282 volume, a higher PEEP requirement, and potential for less lung compliance with higher
283 innate plateau pressures due to diaphragmatic compression by the gravid uterus and
284 chest wall compression by enlarged breast tissue. Physiologic tidal volumes in
285 pregnancy are greater than the target value of 6ml/kg ideal body weight utilized in the
286 ARDS Network study [15]. This coupled with the decreased chest wall / diaphragmatic
287 compliance present a challenge to the “lung protective” strategy for mechanical
288 ventilation in pregnant patients. Our clinical observation suggests a 5 cm H₂O difference
289 in plateau pressures prior to and immediately following evacuation of the gravid uterus.
290 Therefore, it seems reasonable to increase tidal volume and/or PEEP to meet goal
291 PaCO₂ and oxygenation targets remaining mindful not to allow alveolar plateau
292 pressures to exceed 35 cm H₂O.

293

294 The prone position can help overcome some of these issues. Prone ventilation has
295 been found to significantly improve oxygenation in the setting of ARDS, and its
296 feasibility and safety in pregnancy have been documented [16,17]. Lastly, veno-venous
297 ECMO is a proven life-saving salvage therapy for severe, reversible respiratory failure,
298 and its benefit among critically ill pregnant women has been reported [18].

299 Consideration for ECMO cannulation should be entertained among a multi-disciplinary
300 team of experienced providers in situations where the patient’s oxygenation is so

301 severely compromised as to require maximal ventilatory support early in the disease
302 process (less than 7 days of mechanical ventilatory support). Often therapeutic
303 anticoagulation is required, and the postpartum period appears to be a potentially
304 tenuous timepoint for initiation of ECMO with 100% maternal mortality in a recent case
305 series [18].

306

307 In summary, this case of rapid clinical decompensation and development of severe
308 ($\text{PaO}_2:\text{FiO}_2 < 150$) COVID-19 related ARDS in a woman at 31 weeks' gestation
309 highlights many of the physiologic and management considerations for the care of
310 critically ill pregnant women with COVID-19. Few contemporary resources exist to guide
311 the multi-disciplinary team through decisions regarding optimal maternal-fetal
312 surveillance, intensive care procedures, and delivery timing. This detailed case reviews
313 the thought process, team-based strategy, and algorithmic approach to this emerging
314 disease's diagnosis and management.

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379

1 **Figure Legend**

2

3 Figure 1. Clinical course, major symptoms, and outcomes from illness onset in this
4 patient with COVID-19 related critical illness and severe ARDS (acute respiratory
5 distress syndrome.

6

7 Figure 2. Patient's chest imaging including chest CT (A) with ground glass opacities and
8 peripheral consolidation bilaterally (arrows), chest X-ray (B) demonstrating bilateral
9 diffuse pulmonary infiltrates (arrow), normal (different healthy patient) lung ultrasound
10 (C) with characteristic normal A-lines (arrow), and the patient's abnormal lung
11 ultrasound images (D, E, F) demonstrating abnormal B-lines (arrow, D), pleural
12 thickening and nodularity (arrow, E), and focal sub-pleural consolidation (arrow, F) with
13 underlying "white lung" (arrow, F). G represents a schematic demonstrating the 12
14 anatomic locations to thoroughly evaluate the lung with sonography.

15

16 Figure 3. A depiction of pad placement and body positioning to achieve manual prone
17 ventilation in a pregnant woman with severe COVID-19 related ARDS. When the patient
18 is supine, six to eight standard hospital bed pillows are placed across the patient's face,
19 upper chest and arms, lateral abdomen on each side, pelvis, and upper legs. A
20 bedsheet is draped over these pillows and then rolled together with the bedsheet
21 beneath the patient's back on each side to create a "sandwich". The rolled sheets on
22 each side are grasped by the team members and used to roll the patient onto her side
23 and then prone such that the pillows remain in position as shown.

24

25 Figures 4A, 4B, and 4C. Example management algorithm for the pregnant patient with

26 COVID-19.

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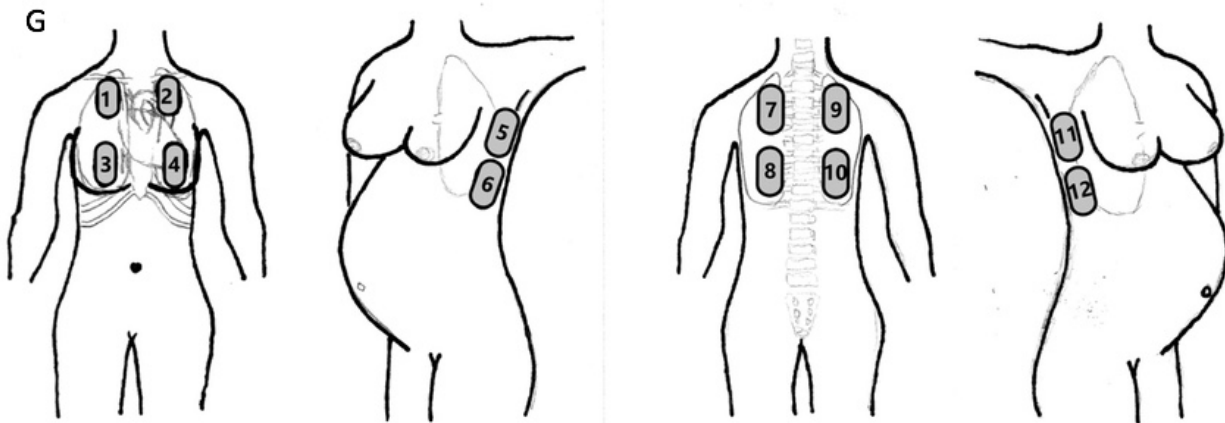
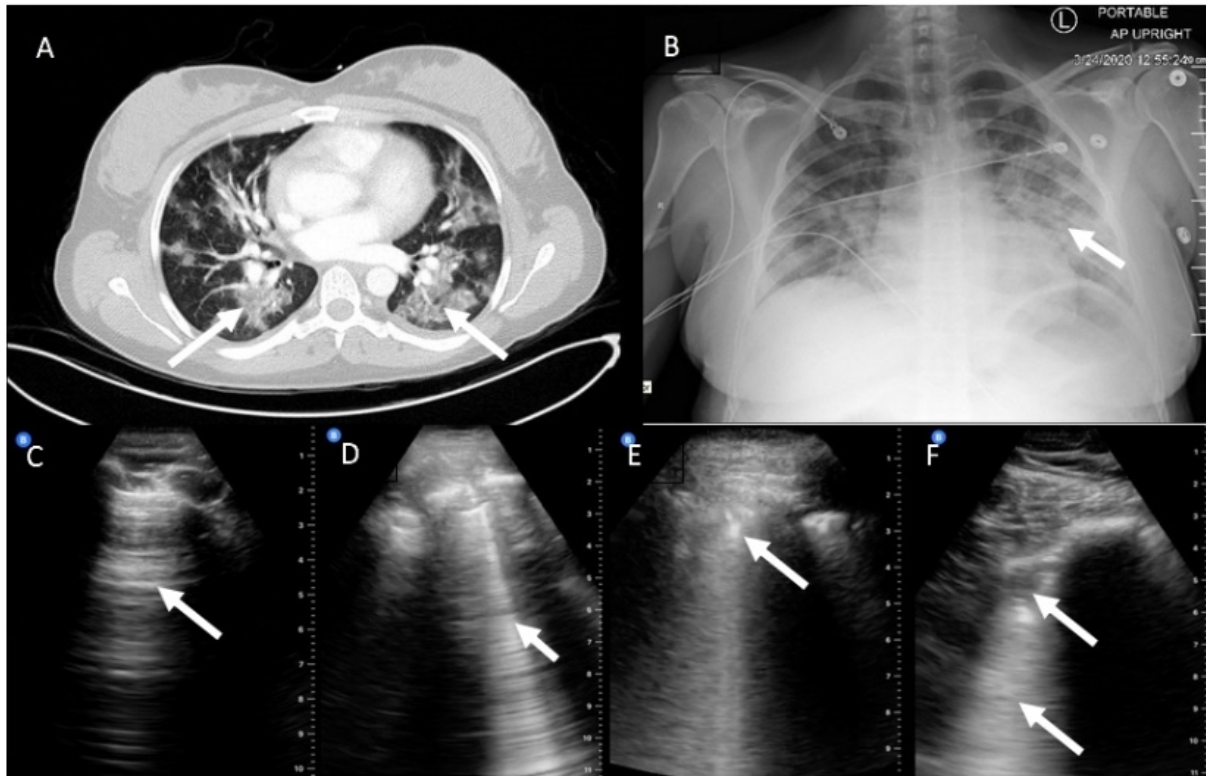
Delivery Considerations		
GA < 24 weeks	Non-Critically ill	<ul style="list-style-type: none"> • If previsible PTL – can deliver in COVID unit or LDR
GA < 24 weeks	Critically ill	<ul style="list-style-type: none"> • Avoid delivery in an UNSTABLE mother • If previsible PTL – deliver in ICU, main OR if D&C required
GA 24-34 weeks	Severe but Non-Critically ill	<ul style="list-style-type: none"> • Attempt to delay delivery and stabilize/ treat mother • Betamethasone if imminent delivery within a week • MgSO₄ for fetal neuroprotection if GA < 32 weeks (if benefits outweigh risk of pulmonary edema) • Consider delivery for NRFHTs (category 3 or persistent category 2 fetal tracing) if stable mother • Imminent need for SVD – move to LDR • Imminent need for C/section – move to L&D OR
GA 24-34 weeks	Critically ill	<ul style="list-style-type: none"> • Avoid delivery in UNSTABLE mother • Attempt to delay delivery & stabilize / treat mother • Case by case determination of delivery for maternal or fetal benefit if stable mother • Betamethasone ONLY if HIGH risk for imminent delivery within a week • MgSO₄ for fetal neuroprotection if GA < 32 weeks (if benefits outweigh risk of pulmonary edema) • Imminent need for SVD – deliver in ICU • Imminent need for C/section – move to Main OR • Perimortem c/section – proceed in ICU
GA ≥ 34 weeks	Severe but Non-Critically ill	<ul style="list-style-type: none"> • Attempt to delay delivery and stabilize / treat mother • Case by case determination of delivery for maternal or fetal benefit if stable mother • Consider delivery for NRFHTs if stable mother • Avoid late preterm betamethasone • Imminent need for SVD – move to LDR • Imminent need for C/section – move to L&D OR
GA ≥ 34 weeks	Critically ill	<ul style="list-style-type: none"> • Avoid delivery in UNSTABLE mother • Case by case determination of delivery for maternal or fetal benefit if stable mother • Avoid late preterm betamethasone • Imminent need for SVD – deliver in ICU • Imminent need for C/section – move to Main OR

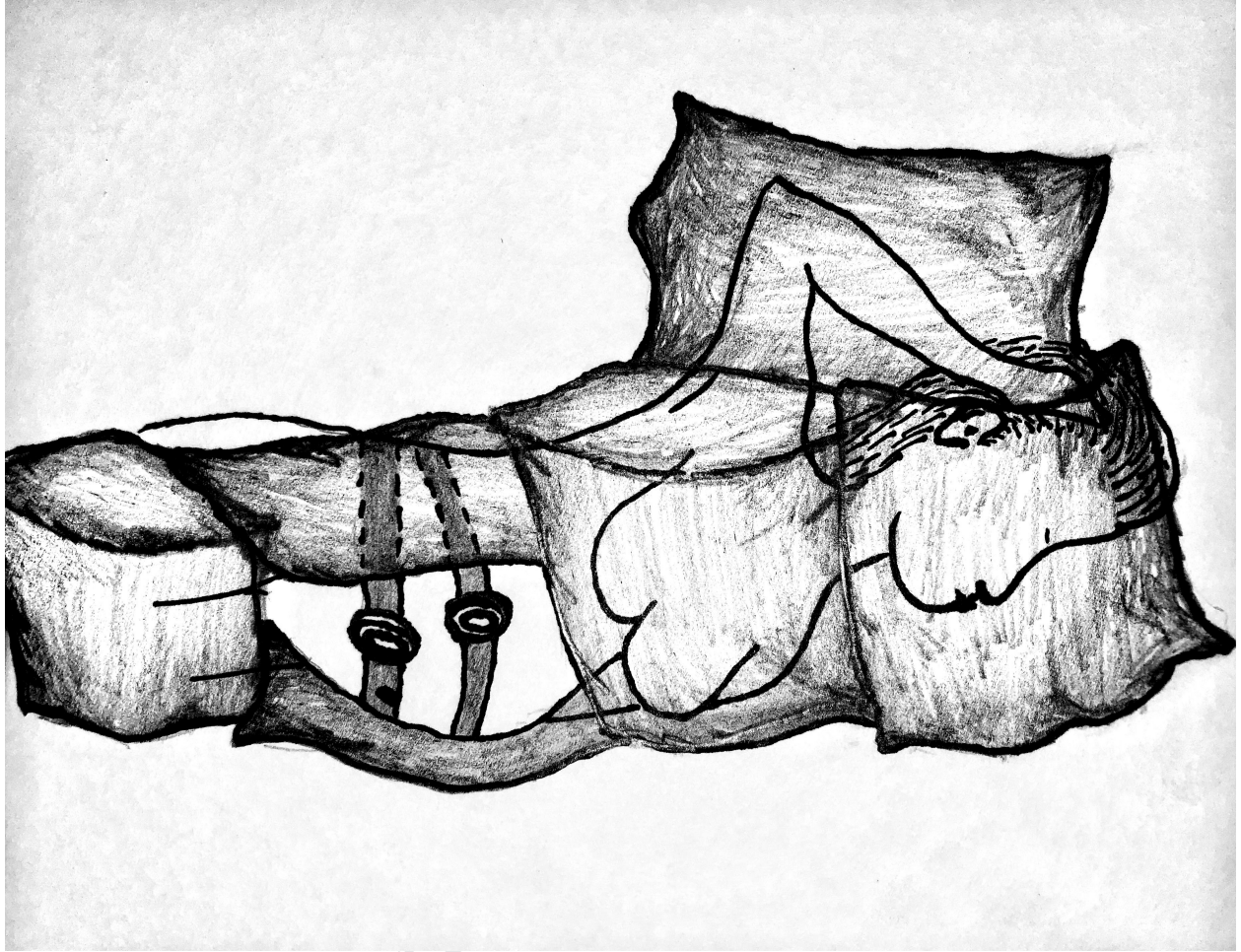
- Perimortem c/section – proceed in ICU

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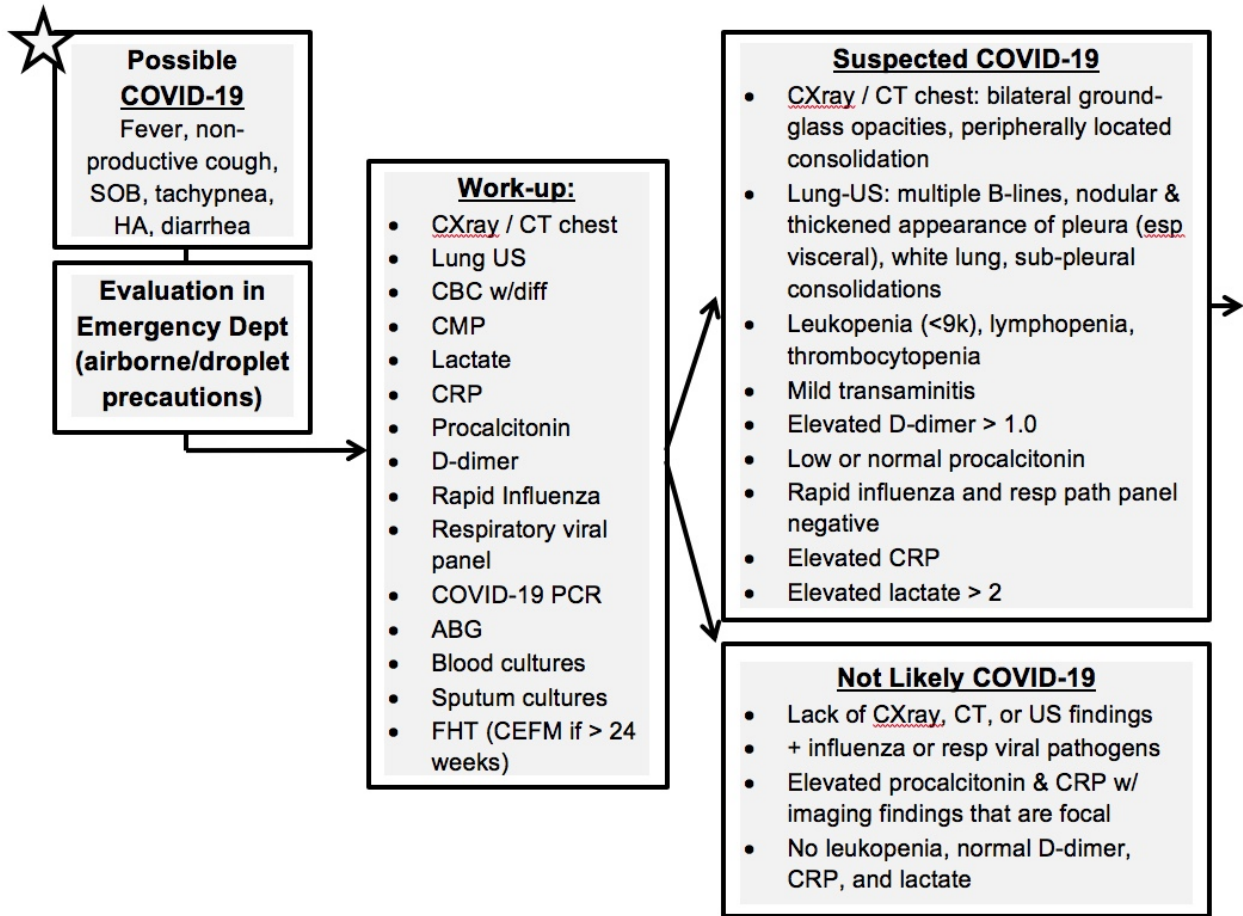
Critical Care Goals

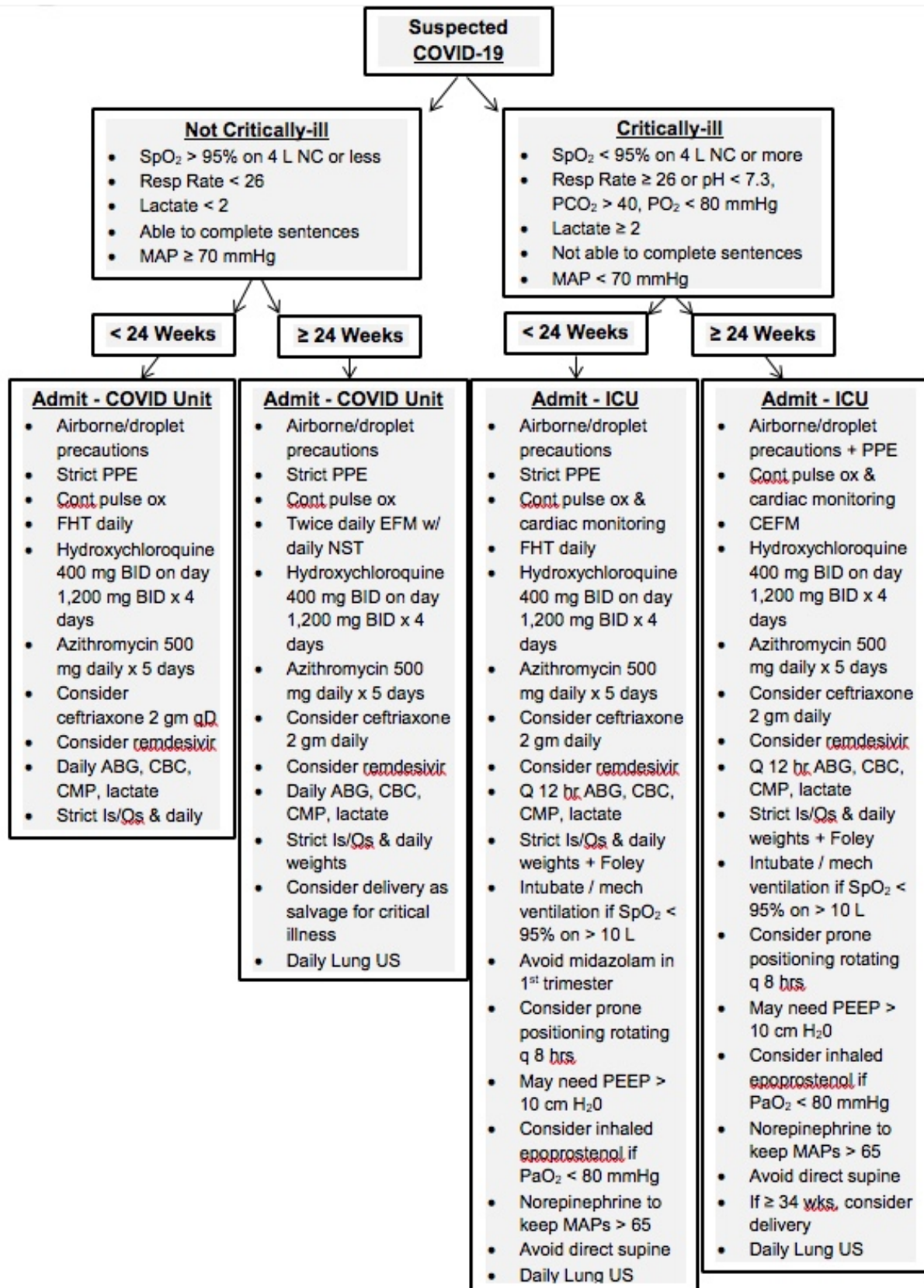
MAP	> 65 mmHg	<ul style="list-style-type: none"> • First assess if fluid responsive with passive leg raise or bolus LR 500 mL to see if MAP raises > 65 mmHg • Start norepinephrine @ 5 mcg/min (up-titrate to 10 mcg/min) for MAP < 65 mmHg • Ensure CEFM if GA > 24 weeks
SpO ₂	> 94%	<ul style="list-style-type: none"> • Increase PEEP to 10-24 cm H₂O • Consider VC+ modality • Consider prone positioning • Ensure finger is warm or place monitor on forehead
PaO ₂	> 80 mmHg	<ul style="list-style-type: none"> • Increase PEEP to 10-24 cm H₂O • Increase I:E ratio • Consider prone positioning
PaCO ₂	< 40 mmHg	<ul style="list-style-type: none"> • Increase ventilatory / respiratory rate to 20-25 bpm • Consider higher tidal volume than 6 ml/kg ideal body weight • Ensure no "auto-PEEP" – keep plateau pressure < 35 cmH₂O
pH	7.3-7.5	<ul style="list-style-type: none"> • First assess if acidemic or alkalemic • Then assess which is more out-of-range (PO₂ or PCO₂) • If metabolic acidosis, assess anion gap & ensure appropriate ventilatory compensation (Bicarb x 1.5) + 8 = PCO₂
Bicarb	16-22 mmHg	<ul style="list-style-type: none"> • Consider addition of IV bicarb if low AND pH is < 7.1
Anion Gap	6-15	<ul style="list-style-type: none"> • Correct for hypoalbuminemia (add 2.5 to gap for every 1 g/dl albumin below level of 2.5 g/dl)
PiP	< 35 mmHg	<ul style="list-style-type: none"> • Check peak inspiratory pressure on vent & ensure < 40 cm H₂O • Consider VC+ modality
UOP	> 20 ml/kg/hr	<ul style="list-style-type: none"> • Place foley and ensure strict Is/Os + daily weights
Skin	No break-down	<ul style="list-style-type: none"> • Evaluate skin front & back daily (esp under fetal monitors)
VTE	prophylaxis	<ul style="list-style-type: none"> • Consider institution of Heparin 7,500 U BID in 2nd trimester & 10,000 U BID in 3rd trimester if delivery is not imminent
Peptic Ulcer	prophylaxis	<ul style="list-style-type: none"> • Consider H2 blockade
CEFM	Category 1-2	<ul style="list-style-type: none"> • Delivery for category 3 if GA > 28 weeks • Worsening category 2 may signal worsening maternal status
Sedation	Lowest achievable	<ul style="list-style-type: none"> • Goal is to achieve RASS of 0 (alert & calm) while on mechanical ventilation • May need to increase sedation with propofol, fentanyl, & midazolam • May need paralytic (cisatracurium) esp when proning





READINESS	RECOGNITION	RESPONSE	REPORTING
<ul style="list-style-type: none"> • Pre-Hospital <ul style="list-style-type: none"> • Awareness • Testing • Transport • Therapies 	<ul style="list-style-type: none"> • Presentation <ul style="list-style-type: none"> • Signs Symptoms • Physiologic considerations 	<ul style="list-style-type: none"> • Bed Placement <ul style="list-style-type: none"> • Nurse : patient • Capabilities • Isolation 	<ul style="list-style-type: none"> • Internal <ul style="list-style-type: none"> • Debrief • Iris reporting • QA
<ul style="list-style-type: none"> • Hospital <ul style="list-style-type: none"> • Staffing • Bed space • Equipment • PPE • Preparedness / simulation 	<ul style="list-style-type: none"> • Work-up <ul style="list-style-type: none"> • Labs • Imaging • Ancillary teams • Point people / champions 	<ul style="list-style-type: none"> • Multi-disciplinary <ul style="list-style-type: none"> • Communication • Huddles • Assign “Captain” • Delivery preparedness & decision tree 	<ul style="list-style-type: none"> • External <ul style="list-style-type: none"> • Regional HD • State ODH • National - CDC, SMFM registry
	<ul style="list-style-type: none"> • Logistics <ul style="list-style-type: none"> • Timely triage • Timely dispo • Communication • Minimizing exposure 	<ul style="list-style-type: none"> • Treatment <ul style="list-style-type: none"> • Medications • Ventilation/Oxy • Positioning • Surveillance • Family / support • Care for self 	





CRedit Author Statement

William Schettler: Conceptualization, Writing – Original Draft, Visualization, Supervision.

Yousef Al Ahwel: Writing – Review & Editing, Resources, Methodology

Anju Suhag: Conceptualization, Writing – Review & Editing, Validation, Resources, Methodology, Supervision

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