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Vascular and Interventional Radiology

Bronchial artery embolization for hemoptysis in a postpartum patient via cesarean section with COVID-19 while on extracorporeal membrane oxygenation

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ABSTRACT

Although COVID-19 coagulopathy typically manifests with thrombotic complications, hemorrhagic complications also occur and must be considered when making decisions about anticoagulation in these patients. Here, we report a case of massive hemoptysis occurring in a recently post-partum woman via Cesarean section with COVID-19 who was managed via bronchial artery embolization while on extracorporeal membrane oxygenation.

1. Introduction

As the COVID-19 pandemic continues to surge, uncommon manifestations of the disease are reported in increasing numbers. Many such manifestations result from the coagulopathy induced by the infection, which presents as abnormal clotting and/or bleeding and the severity of which correlates with the severity of disease. Additionally, women who are or were recently pregnant are at an even greater risk of COVID-19 complications, as well as adverse pregnancy outcomes such as preterm delivery. Understanding the spectrum of these conditions and how to manage them is essential to optimizing outcomes. Herein, we report a case of angiographically apparent bronchial artery hemorrhage which developed in a COVID-positive woman who had recently given birth and was managed via transarterial embolization.

2. Case description

Institutional review board approval was not required for this case report. A 27-year-old G5P1 female at 31 weeks gestation presented to the emergency department with worsening cough and dyspnea 4 days after being diagnosed with COVID-19. She had not undergone prior vaccination against COVID-19. Vital signs were notable for temperature 102 °F, pulse 122 beats per minute, respiratory rate 48, with oxygen saturation 95% on a non-rebreather. Chest radiography [Fig. 1] showed diffuse bilateral ground glass opacities, and laboratory values were significant for WBC 18,000/μL. She was diagnosed with acute respiratory distress syndrome due to COVID-19 and intubated shortly thereafter. Prone positioning (“proning”) initially improved her oxygenation, but on hospital day 4 her hypoxia acutely worsened necessitating delivery via cesarian section followed by initiation of venovenous extracorporeal membrane oxygenation (ECMO). Although premature, the child was otherwise healthy.

Over the next several days the patient's hemoglobin trended downwards (7.5 from 9.3 g/dL), prompting a CT angiogram [Fig. 2] which revealed hemoperitoneum with active extravasation from the uterine fundus. Angiography was performed that same day, on hospital day 10, which revealed no active bleeding; consequently, prophylactic gelfoam embolization of both uterine arteries was performed with subsequent clinical improvement.

On hospital day 12, tracheostomy creation was undertaken due to persistent inability to extubate. The following day, the patient developed massive hemoptysis, so bronchoscopy was performed demonstrating active bleeding in the left lower lobe bronchus. She was thrombocytopenic at the time but subtherapeutic on high-bleeding risk heparin gtt protocol [Fig. 3]. A standard thromboelastography (TEG with heparinase) study was also obtained at the time which was unremarkable (R 6.7 min, K 1.9 min, angle 63.7 deg, MA 57.4 mm and LY30 0.2%). Multiple unsuccessful attempts were made to control the bleeding, and chest radiography demonstrated progressive left and then right lung opacification [Fig. 4]. As the patient remained on ECMO, therapeutic anticoagulation could not be stopped so urgent bronchial artery embolization was performed on hospital day 19.

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Fig. 1. Frontal chest radiograph demonstrating bilateral hazy opacities due to COVID-19 infection.
Access was obtained in the left common femoral artery and a 6 French sidearm sheath placed. A 5 French Omni Flush catheter (AngioDynamics, Latham, NY) was advanced into the descending thoracic aorta and angiography performed, delineating the origin of the left bronchial artery. The catheter was then exchanged for a 5 French Mickelson catheter (AngioDynamics), which was used to select the left bronchial artery. Angiography demonstrated active extravasation from multiple branches [Fig. 5], so a 2.0 French TruSelect microcatheter (Boston Scientific, Marlborough, MA) was advanced more distally within the vessel and embolization performed to near stasis [Fig. 6] using 300–500 μm Embosphere particles (Merit Medical, South Jordan, UT). The left common femoral artery access site was closed with a 6 Fr Angio-Seal VIP closure device (Terumo Interventional Systems, Somerset, NJ) without complications. Patient had mild but worsening coagulopathy pre-procedure and post-procedure, characterized by elevated clotting times and thrombocytopenia [Fig. 3]. Fortunately, there was no evidence of contrast induced nephropathy (Cr of 0.23 prior to procedure and 0.30 post procedure) after the procedure. A cholecystostomy tube was also placed given concern for acalculous cholecystitis.

Repeat bronchoscopy was performed shortly after the procedure for clot evacuation, at which time no active bleeding was identified. The patient stabilized and was weaned from vasopressor and ventilatory support, and ECMO was discontinued on post procedure day 8. The remainder of her hospital course was relatively uneventful. She underwent a slow convalescence and was ultimately discharged 2.5 months after presentation.

Fig. 2. Axial CT angiogram image demonstrating a pelvic hematoma with active arterial-phase extravasation in the left pelvis (arrow).
Fig. 3. Relevant lab results including coagulation panel and platelets throughout patients' hospital course. Of note, uterine artery embolization was carried out on hospital day 10 and bronchial artery embolization was carried out on hospital day 19.
Figure 4

Fig. 4. Frontal chest radiograph demonstrating complete opacification of both lungs.
Fig. 5. Digital subtraction angiography performed from the left bronchial artery demonstrating active bleeding (arrows) from multiple arterial branches.
3. Discussion

The systemic inflammation induced by COVID-19 favors the development of a hypercoagulable state, but hemorrhagic complications of infection have also been reported. In one series, thrombotic complications occurred in 9.5% of patients whereas bleeding complications occurred in 4.8%, rates of both of which were higher in those who were critically ill. Bleeding complications have mostly been reported in the setting of pharmacologic anticoagulation, such as for extracorporeal membrane oxygenation (ECMO). Despite this, one report described a hemorrhagic complication rate of only 6% in patients on ECMO. Laboratory evaluation commonly reveals elevated D-dimer levels, mild thrombocytopenia, and prolonged prothrombin time (PTT) in a pattern reminiscent of, but distinct from, disseminated intravascular coagulation (DIC).

The exact pathophysiologic underpinning of these findings remains to be elucidated. Current theories suggest that hypercoagulability results from a combination of excessive cytokine release and endothelial damage. Pathological evaluation of lungs in patients with COVID-19 demonstrated a thrombotic microangiopathy which resulted in diffuse alveolar damage and associated hemorrhage; this process was not observed in the other organs studied and may be related to the demonstrated reduction in ADAMTS13 level. The mechanism behind hemorrhagic complications is even less well understood but may involve both coagulation factor consumption and excess anticoagulation.

The patient in the current case developed predominantly hemorrhagic rather than thrombotic complications as evidenced by development of both postpartum and bronchial artery hemorrhage. The etiology was presumed to be multifactorial. Recent intra-abdominal surgery and infection with COVID-19 was likely a major contributor, as the patient demonstrated classic coagulation factor abnormalities, including increased D-dimer levels (14.38 mg/L on hospital day 14 from 0.98 mg/L soon after admission) and a drop in platelet levels from baseline. Notably, however, one series found no increased risk of obstetric hemorrhage in patients infected with COVID-19. The administration of therapeutic anticoagulation, necessitated by use of ECMO, was almost certainly another contributor, although the patient’s coagulation studies remained largely within goal. It is possible that the coagulation factor abnormalities induced by COVID-19 infection combined with the necessary therapeutic anticoagulation to produce a synergistic effect such that standard measures of coagulability underestimated the propensity for bleeding. This is supported in small part by the case report by

![Figure 6](image-url)

**Fig. 6.** Digital subtraction angiography performed after embolization demonstrating near stasis within the treated artery (arrow).
Murgo et al., who described bronchial artery embolization for pulmo-
nary hemorrhage in a patient with COVID-19 pneumonia on ECMO.
Additionally, the delayed presentation of the postpartum hemorrhage
with subsequent negative angiography is certainly unusual and may
reflect a component of slow bleeding from a venous source.

Pulmonary hemorrhage is an uncommon manifestation of COVID-19
infection, occurring in 0.9–3% of cases. Most cases do not require
intervention, but a few reports of bronchial artery embolization in the
setting of COVID-19 are available. These suggest that embolization
with particles is safe and effective, despite the increased bronchial-
pulmonary shunting that results from widespread pulmonary micro-
emboli. In contradistinction with these reports, in this case active
hemorrhage was visualized angiographically, which has not been pre-
viously reported. Additionally, this patient was much younger, female,
and recently postpartum, extending the spectrum of patients in which
this has been safely performed.

In conclusion, bronchial artery embolization for pulmonary hemor-
rhage appears safe and effective in the setting of COVID-19 infection,
although larger case series will be needed to determine whether efficacy
and/or complication rates differ from embolization performed in pa-
tients who do not have COVID-19.

References
1. Lu H, Chen M, Tang S, Yu W. Association of coagulation disturbances with severity
of COVID-19: a longitudinal study. Hematology 2021;26(1):656–62. https://doi.
org/10.1080/16078454.2021.1966648.
2. Centers for Disease Control and Prevention. Pregnant people at increased risk for
severe illness from COVID-19. https://www.cdc.gov/coronavirus/2019-ncov/need-
extra-precautions/pregnant-people.html; 2021.
3. Al-Samkari H, Karp Leaf RS, Dzik WH, et al. COVID-19 and coagulation: bleeding
and thrombotic manifestations of SARS-CoV-2 infection. Blood 2020;136(4):
489–500. https://doi.org/10.1182/blood.2020060260.
4. Barbaro RP, MacLaren G, Boonstra PS, et al. Extracorporeal membrane oxygenation
support in COVID-19: an international cohort study of the Extracorporeal Life
Support Organization registry. Lancet 2020;396(10257):1071–8. https://doi.org/
10.1016/S0140-6736(20)30208-0.
5. Levi M, Thachil J, Iba T, Levy JH. Coagulation abnormalities and thrombosis in
patients with COVID-19. Lancet Haematol 2020;7(6):e438–40. https://doi.org/
10.1016/S2352-3026(20)30145-9.
6. Fox SE, Akmatsbekov A, Harbert JL, Li G, Quincy Brown J, Vander Heide RS.
Pulmonary and cardiac pathology in African American patients with COVID-19: an
autopsy series from New Orleans. Lancet Respir Med 2020;8(7):681–6. https://doi.
org/10.1016/S2213-2600(20)30145-9.
7. Mancini I, Baronciani L, Artoni A, et al. The ADAMTS13-von Willebrand factor axis
in COVID-19 patients. J Thromb Haemost 2021;19(2):513–21. https://doi.org/
10.1111/jth.15191.
8. Wang MJ, Schapero M, Iverson R, Yarrington CD. Obstetric hemorrhage risk
associated with novel COVID-19 diagnosis from a single-institution cohort in the
United States. Am J Perinatol 2020;37(14):1411–6. https://doi.org/10.1055/s-
0040-1718403.
9. Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in
China. N Engl J Med 2020;382(18):1708–20. https://doi.org/10.1056/
NEJMoa2002032.
10. Lapostolle F, Schneider E, Viana I, et al. Clinical features of 1487 COVID-19 patients
with outpatient management in the Greater Paris: the COVID-call study. Intern
Emerg Med 2020;15(5):813–7. https://doi.org/10.1007/s11739-020-02379-z.
11. Barral M, Sirol M, El Hajjam M, Zhang N, Petit A, Cornelis FH. Bronchial artery
embolization performed in COVID-19 patients: tolerance and outcomes. Cardiovasc
Intervent Radiol 2020;43(12):1949–51. https://doi.org/10.1007/s00270-020-
02621-3 (In eng)
12. Murgo S, Lheureux O, Taccone F, Vouche M, Golzarian J. Haemoptysis treated by
bronchial artery embolisation in severe acute respiratory syndrome coronavirus 2:
Case report. CVIR Endovasc 2020;3(1). https://doi.org/10.1186/s42155-020-
00154-x (In eng).