Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Role of interventional radiology in the treatment of COVID-19 patients: Early experience from an epicenter

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ABSTRACT

Objective: To highlight the role of interventional radiology (IR) in the treatment of patients hospitalized with coronavirus disease 2019 (COVID-19).

Methods: Retrospective review of hospitalized patients who tested positive for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and had one or more IR procedures at a tertiary referral hospital in New York City during a 6-week period in April and May of 2020.

Results: Of the 724 patients admitted with COVID-19, 92 (12.7%) underwent 124 interventional radiology procedures (79.8% in IR suite, 20.2% at bedside). The median age of IR patients was 63 years (range 24–86 years); 39.1% were female; 35.9% in the intensive care unit. The most commonly performed IR procedures were central venous catheter placement (31.5%), inferior vena cava filter placement (9.7%), angiography/embolization (4.8%), gastrostomy tube placement (9.7%), image-guided biopsy (10.5%), abscess drainage (9.7%), and cholecystostomy tube placement (6.5%). Thoracentesis/chest tube placement and nephrostomy tube placement were also performed as well as catheter-directed thrombolysis of massive pulmonary embolism and thrombectomy of deep vein thrombosis. General anesthesia (10.5%), monitored anesthesia care (18.5%), moderate sedation (29.8%), or local anesthetic (41.1%) was utilized. There were 3 (2.4%) minor complications (SIR adverse event class B), 1 (0.8%) major complication (class C), and no procedure-related death. With a median follow-up of 4.3 months, 1.1% of patients remain hospitalized, 16.3% died, and 82.6% were discharged.

Conclusion: Interventional radiology participated in the care of hospitalized COVID-19 patients by performing a wide variety of necessary procedures.

1. Introduction

Coronavirus disease 2019 (COVID-19) is a global pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. SARS-CoV-2 enters human cells via the angiotensin-converting enzyme 2 (ACE2) receptors that are found in the lung, heart, kidney, intestine and vascular endothelium [2]. In severe COVID-19, patients may develop respiratory distress, renal failure, cardiac injury as well as venous and arterial thromboembolism [3,4]. Working alongside other medical and surgical specialties, interventional radiology (IR) can play a role in the management of coronavirus-related complications [5–7]. For COVID-19 patients with renal failure, IR physicians may leverage their expertise in image-guided techniques to place hemodialysis catheters even in patients with challenging anatomy due to venous thromboembolism (VTE) [8]. For select patients with VTE, interventional radiologists may place inferior vena cava (IVC) filters as well as perform catheter-directed thrombolysis/thrombectomy for massive or submassive pulmonary embolism and proximal deep vein thrombosis [9–11]. Furthermore, in COVID-19 patients who develop life-threatening bleeding complications while on anticoagulant therapy for VTE, interventional radiologists may perform embolization procedures to treat arterial bleeding. In critically ill coronavirus patients who develop acute cholecystitis and abscesses, IR physicians may place percutaneous cholecystostomy tubes and drainage catheters. For COVID-19 patients who may be suffering from severe dysphagia and malnutrition, percutaneous gastrostomy feeding tubes may be placed in IR with theoretically less aerosolization risk than endoscopic methods.

At the peak of the coronavirus pandemic, limitations in operating

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room facilities and ventilators at our hospital shifted the paradigm of care to minimally invasive therapies requiring minimal sedation. As physicians specializing in minimally invasive and image-guided techniques, interventional radiologists are ideally suited to adapting to the COVID-19 environment and delivering safe and effective care to patients. In this study, we describe the utilization of interventional radiology services in coronavirus patients at a tertiary care center in New York City, the epicenter of the COVID-19 pandemic, in April and May of 2020.

2. Materials & methods

In this institutional review board-approved retrospective study, we reviewed patients admitted with COVID-19 who underwent one or more interventional radiology procedures during a 6-week period between April 3, 2020 (first date of increased IR utilization in coronavirus patients) and May 15, 2020 at a tertiary referral hospital in New York City. Increased IR utilization was defined as more than one IR procedure on a COVID-19 patient per day. Clinical outcomes were observed until September 4, 2020, the final date of follow-up. COVID-19 status was confirmed prior to the IR procedure by a reverse-transcriptase–polymerase-chain-reaction (RT-PCR) assay detecting the presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) RNA in a nasopharyngeal swab specimen. IR procedures were performed by or under the supervision of a board-certified interventional radiologist, and appropriate personal protective equipment was used as per institutional and IR division guidelines. Patient demographic information and clinical data were collected from the electronic medical record system, including: type of IR procedure; location of the IR procedure; type of sedation utilized during IR procedure; complications of the IR procedure; status and length of the hospital stay at the time of last-follow-up. Adverse events were categorized based on the Society of Interventional Radiology (SIR) adverse events classification system.

3. Results

Among the 724 patients hospitalized with confirmed COVID-19, there were 92 (12.7%) patients who underwent a total of 124 interventional radiology procedures. Of these 92 patients, the median age was 63 years (range 24–86 years). Thirty-six (39.1%) patients were female and 56 (60.9%) male. The most common medical comorbidities included hypertension (51.1%), diabetes (27.2%), and chronic kidney disease (17.4%). At the time of the IR procedure, 33 (35.9%) patients were receiving care in the intensive care unit (ICU) and 59 (64.1%) in the medical wards.

The following IR procedures were most commonly performed: placement of central venous catheter (39 [31.5%]), placement of inferior vena cava filter (12 [9.7%]), arterial angiography/embolization (6 [4.8%]), placement of percutaneous gastrostomy feeding tube (12 [9.7%]), image-guided percutaneous biopsy (13 [10.5%]), abscess drainage (12 [9.7%]), and placement of percutaneous cholecystostomy tube (8 [6.5%]) (see Fig. 1). Thoracentesis/chest tube placement (4 [3.2%]) and nephrostomy tube placement (4 [4.2%]) were also performed. Catheter-directed thrombolysis of massive pulmonary embolism was performed in one patient, and thrombectomy of extensive proxima deep vein thrombosis was performed in another patient. Additional procedures (14 [11.3%]) included removal of tunneled central venous catheters, arteriovenous (AV) fistula declot, placement of an external-internal biliary drain, removal of internal ureteral stent from a transplant kidney, paracentesis, port placement, and tunneled peritoneal catheter placement.

Interventional radiology procedures were performed utilizing general anesthesia in 13 (10.5%) patients, monitored anesthesia care in 23 (18.5%), moderate sedation in 37 (29.8%), or local anesthetic only in 51 (41.1%). Moderate sedation was given by the interventional radiologist with monitoring of the patient's level of consciousness and physiological status during the procedure. Ninety-nine (79.8%) procedures were performed in the IR suite and 25 (20.2%) were performed at bedside. Bedside procedures included placement of cholecystostomy tube, placement of non-tunneled central venous catheter, removal of tunneled central line, biopsy, paracentesis, and drainage of abscess.

The median follow-up from the time of the IR procedure was 4.3 months. There were three (2.4%) minor complications (SIR adverse event class B); in all three cases, there was superficial bleeding requiring only nominal therapy (i.e., manual compression). One (0.8%) major complication (class C) occurred; a tunneled central venous catheter placement was complicated by bleeding that resulted in the withholding of anticoagulation. There were no deaths attributable to interventional radiology procedures. At the time of this review, 15 (16.3%) of patients had died, 1 (1.1%) remain hospitalized and 76 (82.6%) had been

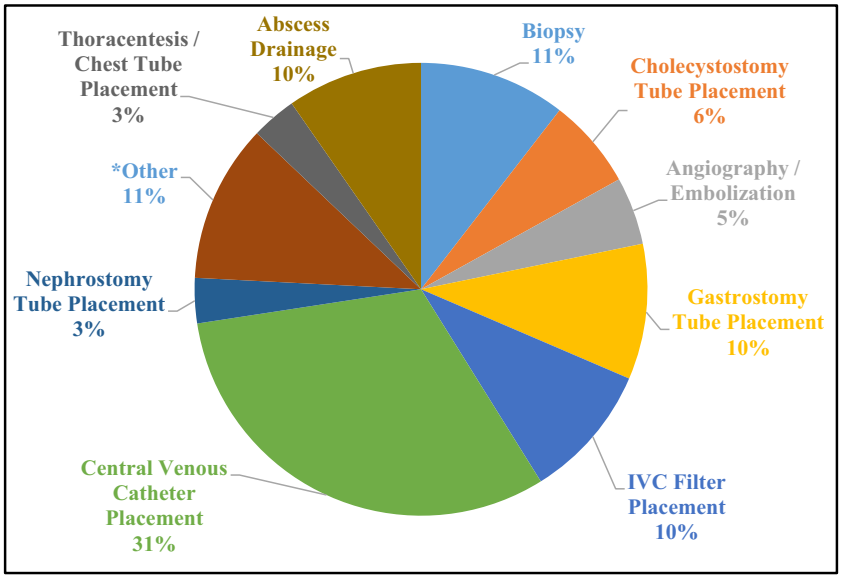

Fig. 1. Interventional radiology procedures in hospitalized COVID-19 patients.
*Other = PE thrombolysis, DVT thrombectomy, arteriovenous (AV) fistula declotting, biliary drain placement, removal of renal transplant internal ureteral stent, paracentesis, tunneled line removal, port placement, peritoneal catheter placement.

discharged from the hospital. The mean length of hospitalization was 1.4 months (range 0.1–4.7 months).

4. Discussion

During a 6-week period at the height of the coronavirus pandemic, 92 of 724 COVID-19 in-patients underwent 124 interventional radiology procedures at our institution. The most commonly performed IR procedures were placement of central venous catheters, inferior vena cava filters, gastrostomy tubes, cholecystostomy tubes as well as image-guided biopsy and abscess drainage. 20% of IR procedures were performed at the bedside by relying on portable ultrasound imaging equipment. More than 70% of IR procedures were performed with local anesthetic or moderate sedation, not requiring the support of an anesthesiologist. At the time of the IR procedure, approximately one-third of patients were receiving care in the intensive care unit. Mean length of hospitalization was 1.4 months. Overall complications rates were low, and no deaths were attributable to IR procedures.

Interventional radiology procedures have contributed to the care of COVID-19 patients worldwide. Reports from Europe, Asia, and North America outline the safety precautions utilized during the COVID-19 pandemic in performing IR procedures [7,12–14]. In the largest study of IR procedures during the COVID-19 pandemic, 550 patients underwent 671 procedures at a tertiary care hospital in Italy [12]; this study found that there were no incidents of cross-infection and no reports of COVID-19 infection of healthcare worked in the IR service. However, in this Italian study, only nine (1.34%) patients were classified as "suspected" and only one patient (0.15%) was confirmed positive for SARS-CoV-2. In contrast, all patients in our study had confirmed SARS-CoV-2 by RT-PCR testing. In treating COVID-19 patients, infectious prevention strategies were instituted including altering the workflow to minimize contact time, using adequate PPE, following proper wait times as well as following strict cleaning protocols between cases [15]. Bedside procedures were utilized as much as possible to minimize transport of patients and to conserve PPE. Compared to surgeries in the operating room, interventional radiology procedures may potentially require less PPE and less support staff [16,17].

COVID-19 may target the pulmonary, cardiovascular, renal, hepatobiliary, intestinal and neurologic systems [18–22]. The resultant multi-organ dysfunction associated with COVID-19 necessitates a multidisciplinary approach to treatment, with interventional radiology contributing to the care of many patients (see Table 1). In severe COVID-19, venous thromboembolism appears to be common, with early studies showing VTE in 36% of patients and acute pulmonary embolism (PE) in 30% of patients who underwent imaging tests [23–25]. However, the management of VTE is challenging due to the complex relationship between coagulation abnormalities and antithrombotic therapy in COVID-19 patients [9,10]. In particular, the role of inferior vena cava (IVC) filters in coronavirus patients is not entirely clear. At our institution, indications for filter placement in COVID-19 patients were DVT/PE with contraindication to anticoagulation due to bleeding, new DVT/PE while on anticoagulation, and acute iliofemoral DVT extending into the IVC. For select patients with massive or submassive pulmonary embolism, escalation of therapy to catheter-directed thrombolysis may have less bleeding risk than systemic lytic therapy [11]. In our early COVID-19 experience, one patient was treated with catheter-directed thrombolysis for massive pulmonary embolism; this coronavirus patient was successfully discharged home 6 days after the IR procedure. Thrombectomy of extensive proximal deep vein thrombosis was also performed in one COVID-19 patient at our institution; this patient demonstrated symptomatic improvement post-procedurally and was discharged 3 weeks afterwards. Renal complications are also common in COVID-19 with acute kidney injury occurring in 36.6% of hospitalized patients, among which 14.3% required renal replacement therapy [8]. Patients needing hemodialysis will need placement of large bore central venous catheters, which may be provided by interventional radiologists. IR physicians can also place peritoneal dialysis catheters as well as provide maintenance of arteriovenous access site (fistula and graft management).

Table 1
COVID-19 complications, interventional radiology procedures and potential clinical benefits.

COVID-19 complication	Interventional radiology procedure	Potential clinical benefit
Renal disease	Central venous catheter placement	Perform hemodialysis
	Peritoneal catheter placement	Perform peritoneal dialysis
	Nephrostomy tube placement	Relieve urinary obstruction
	Renal biopsy	Guide treatment of renal disease
Thromboembolic disease - acute pulmonary embolism (PE), deep vein thrombosis (DVT), acute limb ischemia	IVC filter placement	Potentially prevent life-threatening PE in patients unable to be anticoagulated
	Catheter-directed thrombolysis	Treat massive PE with potentially less bleeding risk than systemic lytic therapy
	Thrombectomy	Restore blood flow, limb salvage
Bleeding (secondary to anticoagulant therapy)	Angiography with embolization	Treat life-threatening arterial bleeding
Dysphagia/malnutrition	Gastrostomy feeding tube placement	May be performed with less sedation and less aerosolization than endoscopic approach
Pleural effusion/ascites	Chest tube placement, thoracentesis, paracentesis	Improve oxygenation and provide symptomatic relief
Abscess	Percutaneous drainage	Drain purulent fluid to resolve infection
Cholecystitis	Cholecystostomy tube placement	Treat inflammation and infection of gallbladder

COVID-19 has a wide spectrum of clinical manifestations ranging from asymptomatic patients to severely and critically ill patients that require treatment in the intensive care unit. Patients with serious coronavirus-related complications may need image-guided procedures by an IR physician as part of their hospital course. IR has several advantages during the COVID-19 pandemic: procedures may be performed at the bedside, which minimizes viral exposure; majority of procedures do not require general anesthesia, which obviates the need for aerosol-generating intubation; and IR therapies are associated with low morbidity and very low mortality. In the context of the highly contagious novel coronavirus, infection control measures are critical during IR procedures in COVID-19 patients. Currently, there is still a large knowledge gap in the exact transmission rate of coronavirus associated with IR procedures. Additional studies are needed to determine the risk of viral spread during aerosol-generating IR procedures as well as to further refine infection prevention and control strategies.

This study has several limitations. First, our study cohort only included patients at a single tertiary referral center. Second, this study was retrospective in nature and the median follow-up was only 4.3 months. Third, image-guided procedures performed at the bedside by radiologists redeployed to the medical wards or ICU were not documented as interventional radiology procedures; this may have underestimated the true utilization of image-guided interventions by radiologists.

5. Conclusion

Our early experience shows how interventional radiology participated in the care of hospitalized COVID-19 patients at a tertiary care center in New York City during the height of the coronavirus pandemic.

Interventional radiologists used image-guided procedures to treat coronavirus complications in the lung, kidney, intestine, gallbladder and vasculature. Future investigations may evaluate the true benefit of the minimally invasive nature of IR procedures in COVID-19 patients and their reduced risk of viral transmission compared to surgery.

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Ethical approval

This retrospective study was approved by the Institutional Review Board (IRB). For this type of study, formal consent is not required.

Informed consent

This study has obtained IRB approval from the Weill Cornell Medicine IRB committee and the need for informed consent was waived.

Consent for publication

For this type of study, consent for publication is not required.

Declaration of competing interest

Dr. Lee received honorarium from Embolx, Inc., outside of submitted work. The other authors (Dr. Talenfeld, Dr. Browne, Dr. Holzwanger, Dr. Harnain, Dr. Kesselman, Dr. Pua) declare that they have no conflict of interest.

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References

[1] Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. Lancet Infect Dis 2020;20:533–4. https://doi.org/10.1016/S1473-3099(20)30120-1.
[2] Zhang H, Penninger JM, Li Y, Zhong N, Slutsky AS. Angiotensin-converting enzyme 2 (ACE2) as a SARS-CoV-2 receptor: molecular mechanisms and potential therapeutic target. Intensive Care Med 2020;46:586–90. https://doi.org/10.1007/s00134-020-05985-9.
[3] Chen T, Wu D, Chen H, Yan W, Yang D, Chen G, et al. Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. BMJ 2020;368:m1091. https://doi.org/10.1136/bmj.m1091.
[4] Zaim S, Chong JH, Sankaranarayanan V, Harky A. COVID-19 and multi-organ response. Curr Probl Cardiol 2020:100618. https://doi.org/10.1016/j.cpcardiol.2020.100618.
[5] Ray CEJ. Interventional radiology and the response to COVID-19. Semin Intervent Radiol 2020;37:107–8. https://doi.org/10.1055/s-0040-1710003.
[6] Zhu H-D, Zeng C-H, Lu J, Teng G-J. COVID-19: what should interventional radiologists know and what can they do? J Vasc Interv Radiol 2020;31:876–81. https://doi.org/10.1016/j.jvir.2020.03.022.
[7] Monfardini L, Sallemi C, Gennaro N, Pedicini V, Bnà C. Contribution of interventional radiology to the management of COVID-19 patient. Cardiovasc Intervent Radiol 2020;43:837–9. https://doi.org/10.1007/s00270-020-02470-0.
[8] Hirsch JS, Ng JH, Ross DW, Sharma P, Shah HH, Barnett RL, et al. Acute kidney injury in patients hospitalized with COVID-19. Kidney Int 2020;98:209–18. https://doi.org/10.1016/j.kint.2020.05.006.
[9] Zhai Z, Li C, Chen Y, Gerotziafas G, Zhang Z, Wan J, et al. Prevention and treatment of venous thromboembolism associated with coronavirus disease 2019 infection: a consensus statement before guidelines. Thromb Haemost 2020. https://doi.org/10.1055/s-0040-1710019.
[10] Bikdeli B, Madhavan MV, Jimenez D, Chuich T, Dreyfus I, Driggin E, et al. COVID-19 and thrombotic or thromboembolic disease: implications for prevention, antithrombotic therapy, and follow-up. J Am Coll Cardiol 2020. https://doi.org/10.1016/j.jacc.2020.04.031.
[11] Kuo WT, Sista AK, Faintuch S, Dariushnia SR, Baerlocher MO, Lookstein RA, et al. Society of Interventional Radiology position statement on catheter-directed therapy for acute pulmonary embolism. J Vasc Interv Radiol 2018;29:293–7. https://doi.org/10.1016/j.jvir.2017.10.024.
[12] Iezzi R, Valente I, Cina A, Posa A, Contegiacomo A, Alexandre A, et al. Longitudinal study of interventional radiology activity in a large metropolitan Italian tertiary care hospital: how the COVID-19 pandemic emergency has changed our activity. Eur Radiol 2020:1–10. https://doi.org/10.1007/s00330-020-07041-y.
[13] Gogna A, Punamiya S, Gopinathan A, Irani F, Toh LHW, Wen Cheong LH, et al. Preparing IR for COVID-19: the Singapore experience. J Vasc Interv Radiol 2020;31:869–75. https://doi.org/10.1016/j.jvir.2020.03.021.
[14] Manna S, Voutsinas N, Maron SZ, Cedillo MA, Toussie D, Nowakowski FS, et al. Leveraging IR's adaptability during COVID-19: a multicenter single urban health system experience. J Vasc Interv Radiol 2020;31:1192–4. https://doi.org/10.1016/j.jvir.2020.04.030.
[15] Lamparello NA, Choi S, Charalel R, Lee KS, Kesselman A, Scherer K, et al. Transforming positive pressure IR suites to treat COVID-19 patients. J Vasc Interv Radiol 2020;31:1496–9. https://doi.org/10.1016/j.jvir.2020.06.019.
[16] Patriti A, Baiocchi GL, Catena F, Marini P, Catarci M. Emergency general surgery in Italy during the COVID-19 outbreak: first survey from the real life. World J Emerg Surg 2020;15:36. https://doi.org/10.1186/s13017-020-00314-3.
[17] De Simone B, Chouillard E, Di Saverio S, Pagani L, Sartelli M, Biffl WL, et al. Emergency surgery during the COVID-19 pandemic: what you need to know for practice. Ann R Coll Surg Engl 2020;102:323–32. https://doi.org/10.1308/rcsann.2020.0097.
[18] Guo T, Fan Y, Chen M, Wu X, Zhang L, He T, et al. Cardiovascular implications of fatal outcomes of patients with coronavirus disease 2019 (COVID-19). JAMA Cardiol 2020. https://doi.org/10.1001/jamacardio.2020.1017.
[19] Su H, Yang M, Wan C, Yi L-X, Tang F, Zhu H-Y, et al. Renal histopathological analysis of 26 postmortem findings of patients with COVID-19 in China. Kidney Int 2020. https://doi.org/10.1016/j.kint.2020.04.003.
[20] Mao L, Jin H, Wang M, Hu Y, Chen S, He Q, et al. Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China. JAMA Neurol 2020. https://doi.org/10.1001/jamaneurol.2020.1127.
[21] Bhatraju PK, Ghassemieh BJ, Nichols M, Kim R, Jerome KR, Nalla AK, et al. Covid-19 in critically ill patients in the Seattle region - case series. N Engl J Med 2020. https://doi.org/10.1056/NEJMoa2004500.
[22] Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020;395:497–506. https://doi.org/10.1016/S0140-6736(20)30183-5.
[23] Lodigiani C, Iapichino G, Carenzo L, Cecconi M, Ferrazzi P, Sebastian T, et al. Venous and arterial thromboembolic complications in COVID-19 patients admitted to an academic hospital in Milan, Italy. Thromb Res 2020;191:9–14. https://doi.org/10.1016/j.thromres.2020.04.024.
[24] Grillet F, Behr J, Calame P, Aubry S, Delabrousse E. Acute pulmonary embolism associated with COVID-19 pneumonia detected by pulmonary CT angiography. Radiology 2020;201544. https://doi.org/10.1148/radiol.2020201544.
[25] Leonard-Lorant I, Delabranche X, Severac F, Helms J, Pauzet C, Collange O, et al. Acute pulmonary embolism in COVID-19 patients on CT angiography and relationship to. Radiology 2020:201561. https://doi.org/10.1148/radiol.2020201561.