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Urgent Peritoneal Dialysis in Patients With COVID-19 and Acute Kidney Injury: A Single-Center Experience in a Time of Crisis in the United States

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At Montefiore Medical Center in The Bronx, NY, the first case of coronavirus disease 2019 (COVID-19) was admitted on March 11, 2020. At the height of the pandemic, there were 855 patients with COVID-19 admitted on April 13, 2020. Due to high demand for dialysis and shortages of staff and supplies, we started an urgent peritoneal dialysis (PD) program. From April 1 to April 22, a total of 30 patients were started on PD. Of those 30 patients, 14 died during their hospitalization, 8 were discharged, and 8 were still hospitalized as of May 14, 2020. Although the PD program was successful in its ability to provide much-needed kidney replacement therapy when hemodialysis was not available, challenges to delivering adequate PD dosage included difficulties providing nurse training and availability of supplies. Providing adequate clearance and ultrafiltration for patients in intensive care units was especially difficult due to the high prevalence of a hypercatabolic state, volume overload, and prone positioning. PD was more easily performed in non–critically ill patients outside the intensive care unit. Despite these challenges, we demonstrate that urgent PD is a feasible alternative to hemodialysis in situations with critical resource shortages.

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Introduction

In developed countries such as the United States, either intermittent hemodialysis (HD) or continuous kidney replacement therapy (CKRT) are the primary modes of KRT for the management of acute kidney injury (AKI).[1] However, at the peak of the coronavirus disease 2019 (COVID-19) pandemic, our medical center's ability to provide intermittent HD and CKRT for the treatment of AKI was overwhelmed due to the surge in the number of patients with AKI requiring KRT combined with personnel shortages related to illness. From March 11, 2020 to April 26, 2020, there were 3,345 patients with confirmed COVID-19 admitted to Montefiore Medical Center (MMC) in The Bronx, NY, of which 438 (13.1%) required intensive care unit (ICU) admission (M. Fisher, personal communication, May 2020). One hundred sixty-four (4.9%) patients required KRT, which is much higher than a historical control (admissions to MMC during the same period in 2019) in which 323 of 9,859 (3.3%) required ICU admission and 93 of 9,859 (0.9%) required KRT (M. Fisher, personal communication, May 2020).

Due to the unusually high demand for dialysis at our institution during the COVID-19 pandemic, an urgent peritoneal dialysis (PD) program was initiated. PD is most commonly administered as maintenance therapy in patients with kidney failure but can also be effective in patients with AKI stage 3.[2-5] In a randomized controlled trial of patients with AKI stage 3 receiving either PD or HD, metabolic control, mortality, and kidney function recovery rates were similar.[5] Meta-analyses also showed no difference between HD and PD when used for AKI in clinical outcomes including mortality, kidney recovery, and complications.[6,7]

At MMC, the first case of COVID-19 was admitted on March 11, 2020, and the number of cases grew exponentially for several weeks afterward. In the midst of the pandemic, on April 13, 2020, there were 855 patients with COVID-19 admitted to 2 of Montefiore's major hospitals. To rapidly increase our capacity to provide KRT to meet the needs of the large number of patients with COVID-19–associated AKI, we initiated an urgent PD program on March 25. This article describes our experience with the implementation of urgent PD for COVID-19–associated AKI.

Our Process and Challenges

Before the COVID-19 pandemic, MMC did not have an established urgent-start PD program for patients with AKI stage 3. MMC surgeons had been placing PD catheters within 48 hours in patients who required urgent-start PD for chronic kidney failure; these patients were then followed up at an outpatient dialysis unit. We routinely provided maintenance manual PD services for inpatients with chronic kidney failure but not AKI stage 3. We therefore rapidly established institutional guidelines for the initiation of urgent PD during the COVID-19 pandemic and devised and progressively refined a protocol to provide a unified approach to treating patients with AKI with manual exchanges (Fig S1) or automated PD (APD) with cyclers (Fig S2). The protocol was based primarily on the International Society of Peritoneal Dialysis guidelines and several other studies.[2-4,8,9]

PD catheters at MMC were typically placed laparoscopically in the operating room by transplant surgeons before the pandemic. Due to the high volume of patients

Table 1. Summary of Challenges and Solutions Encountered During Startup of Urgent PD Program

Situation	Challenge	Solution
Surge of patients with AKI requiring KRT	Limited resources (including machines and dialysate bags) for iHD and CKRT	Reduce iHD and CKRT duration to maximize no. of treatments; temporarily use 1.5% dextrose PD fluid as CKRT dialysate when no CKRT dialysate was available; add urgent PD to increase KRT capacity
Obtaining supplies	Identifying the quantity estimated for the surge of patients	1 experienced nephrologist and 2 nurses with extensive PD experience placed order with supplier for predicted number of 25 patients to be started on PD over the following 2 wks
Access needed to start PD	Limited/no OR time meant patients needing a PD catheter were waitlisted or unable to receive a catheter	Transplant surgeons performed bedside laparoscopically assisted flexible PD catheter placement for intubated and ICU patients; interventional radiologists performed fluoroscopy-guided flexible PD catheter placement for nonintubated non-ICU patients
Limited staff	Limited nursing staff (due to illness or higher patient to nursing ratio than usual) available to perform iHD, CKRT, or PD	For ICUs in which there were no PD-trained nurses available, a clinical educator provided a PD training session for nurses interested in/who had the time to learn PD; the urgent PD service conducted patient rounds and performed 1-2 manual exchanges per day per patient in addition to providing training to nurses and house staff residents during the daytime
More patients started on PD	As the program grew rapidly, the urgent PD service was becoming overwhelmed as demand increased	Urgent PD service increased in staff and more time was spent educating nurses and residents caring for PD patients on how to perform manual exchanges of PD; availability of cyclers helped with the work load of the urgent PD service nephrologists and the patients' nurses because interaction with machine was limited when the nephrologists set up the machine for each patient
Prone positioning	Limited the use of PD to when patients were supine to avoid increased intra-abdominal pressure during prone positioning, which may cause dyssynchrony with the ventilator	Supplemental iHD or CKRT was provided while patients were prone depending on patient location (some units did not have water connections available for iHD) as well as machine, dialysate, and nursing staff availability; patients received PD when supine but this was often limited to 1-4 exchanges depending on the duration of supination

Abbreviations: AKI, acute kidney injury; CKRT, continuous kidney replacement therapy; ICU, intensive care unit; iHD, intermittent hemodialysis; KRT, kidney replacement therapy; OR, operating room; PD, peritoneal dialysis.

needing PD and the closure of operating rooms in our institution, a plan was formulated, with the help of the transplant surgeons and interventional radiologists (who did not place PD catheters in the past), to place PD catheters. Similar to the description provided by Srivatana et al,[10] transplant surgeons placed flexible PD catheters at the bedside using laparoscopically assisted techniques for ICU patients while interventional radiologists placed flexible PD catheters under fluoroscopic guidance for non-ICU and nonintubated patients. The PD catheters were used immediately after placement with low volumes (1-1.5 L) for the first 24 hours, which were then increased to full volumes (2-2.5 L) thereafter.

Important challenges and solutions that enabled us to rapidly implement an urgent PD program to accommodate the surge in patients requiring KRT are summarized in Table 1. First, we increased the procurement of PD supplies because we previously only stocked supplies to support the needs of existing maintenance PD patients during an acute hospitalization (~5 admissions to MMC's 3 hospitals per month). For the urgent PD program, a preemptive order had to be placed with our main supplier with the help of 1 nephrologist, 1 outpatient PD nurse, and 1 inpatient pediatric dialysis nurse (who was familiar with inpatient PD) for an adequate supply of PD materials based on the projected use for the period of the COVID-19 surge (duration estimated as 2 weeks; Box 1).

Obtaining the necessary supplies was logistically complicated because there was a nationwide shortage and items were backordered. Timely placement of the orders allowed us to deploy supplies to all units in which PD was needed. The decision to start intermittent HD versus CKRT versus PD was made by the treating nephrologist based on several factors, including but not limited to patient's location, hemodynamic status, need for prone positioning, and availability of supplies and personnel (Box 2).

As with all hospitals in New York City, MMC increased its medical ward and ICU capacity to accommodate the surge in patients. To address nursing staff shortages in the ICU and wards, the Division of Nephrology formed an "urgent PD service" to perform bedside rounds of patients treated using this modality. On the first day, the PD service

Box 1. Total Amount of Supplies Ordered for PD

PD Dialysate Fluid

- For manual PD, ordered 2-L low-calcium (2.5-mEq/L) PD solutions with Y connectors with the following dextrose concentrations:
  - ◇ 1.5% dextrose: enough to supply 25 patients for 14 d
  - ◇ 2.5% dextrose: enough to supply 50 patients for 14 d
  - ◇ 4.25% dextrose: enough to supply 25 patients for 14 d
- For cycler-assisted PD, ordered 6-L PD solutions with the following dextrose concentrations:
  - ◇ 4.25% dextrose: enough for 25 patients for 14 d (with expected use of 2 bags/patient/d)
  - ◇ 2.5% dextrose: enough for 50 patients for 14 d
  - ◇ 1.5% dextrose: enough for 25 patients for 14 d

PD Disposables

- Drain bags (15-L capacity): ordered enough for 25 patients for 14 d
- Clamps: ordered enough for 25 patients for 14 d
- Caps: ordered enough for 100 exchanges for 14 d
- Transfer sets and titanium adapters: ordered 50 of each

Cycler Machines and Supplies

- Ordered 15 cycler machines
- Cycler manifolds (5-pronged cassettes): enough for 25 patients for 14 d
- Drain bags (15-L capacity): enough for 25 patients for 14 d

Note: Based on predicted use of PD for 25 patients over 2 weeks.
Abbreviation: PD, peritoneal dialysis.

Box 2. Factors Affecting Decision to Choose Intermittent HD Versus CKRT Versus PD

Patient Factors

- Some temporary ICUs lacked water connections for iHD so CKRT and PD were the only available options
- Patients receiving vasopressors for hemodynamic support were placed on either CKRT or PD to avoid worsening hemodynamics when possible
- Patients who required prone positioning for the treatment of hypoxemia due to ARDS were placed on CKRT or iHD

Availability of Dialysis Equipment

- When CKRT machines were in limited supply, this necessitated increased use of iHD and PD
- When ICU staffing levels limited ability to perform CKRT, PD could allow for increased accessibility to KRT

Shortage of KRT Resources

- Due to nationwide shortage of CKRT solutions, urgent PD and iHD in critically ill patients was necessary to maximize access to KRT for critically ill patients
- Shortage of iHD machines and dialysis nurses (due to illness and increased demand for dialysis) contributed to increased need for CKRT and PD
- Initially, the inpatient dialysis unit was closed to COVID-19–positive patients, which limited our ability to use iHD; all inpatients received iHD in private rooms (which are limited and required 1-to-1 nursing care) or PD

Abbreviations: COVID-19, coronavirus disease 2019; CKRT, continuous kidney replacement therapy; HD, hemodialysis; ICU, intensive care unit; iHD, intermittent hemodialysis; KRT, kidney replacement therapy; PD, peritoneal dialysis.

consisted of 1 nephrology attending and 1 nephrology fellow. They demonstrated manual exchanges to teach the nursing staff and house staff residents how to do the exchanges for future treatments, conducted rounds, wrote orders, performed catheter exit-site care, and performed manual exchanges for patients when nursing expertise with PD and/or workload were limiting factors. These nephrologists also shared information with the nurses on logistical issues, including how to order and maintain adequate PD supplies from the hospital stockroom and how to provide exit-site care. We also created laminated cards with instructions on performing manual exchanges (which were provided to nurses), and a link to an instructional video (provided by a supplier) on how to provide a manual PD exchange was shared with all nurse managers.

During the first weekend of the urgent PD program, several nephrologists volunteered to receive training on manual PD exchanges and assist the urgent PD service by providing manual exchanges to PD patients. This was essential to patient care because many nurses unfamiliar with PD had not yet been trained to perform manual PD exchanges. Furthermore, to accommodate the surge in patients, nurses in the ICUs and wards had increased patient to nurse ratios, which made it difficult to train nurses to perform PD. This meant that nephrologists frequently had to perform exchanges to compensate. PD exchanges were therefore performed during an 8- to 12-hour period during the daytime shift. Though all patients were prescribed standard PD dosages, technical and logistical challenges often reduced the number of exchanges performed during the height of the crisis.

More than half the patients receiving PD were receiving mechanical ventilation during their hospitalization. Patients receiving mechanical ventilation were often placed in a prone position to improve oxygenation. PD was discontinued while patients were in a prone position to avoid increasing intra-abdominal pressure, which may cause dyssynchrony with the ventilator. This reduced the number of hours available for PD, and given the hypercatabolic state and electrolyte disturbances common in critically ill patients with COVID-19, supplementation of PD with CKRT or intermittent HD was often necessary (Table 2). The determination of which modality to use was made daily by the patient's nephrologist based on criteria mentioned in Box 2. Given limitations in nursing and equipment, the amount of time receiving intermittent HD or CKRT treatments was often truncated to maximize the number of patients for whom we could provide those modalities.

Table 2. Descriptive Statistics for the Urgent PD Program

Characteristic	Value
No. of patients started on PD, April 1-22	30
Patient location at time of PD initiation	
Ward	12/30 (40%)
ICU	18/30 (60%)
Mechanical ventilation status	
Intubated	22/30 (73%)
Placed in prone position	16/22 (73%)
Never placed in prone position	6/22 (27%)
Nonintubated	8/30 (27%)
Placed in prone position	1/8 (13%)
Never placed in prone position	7/8 (88%)
Supplemental KRT[a]	
CKRT (at any point after starting PD)	5/30 (17%)
iHD (at any point after starting PD)	6/30 (20%)
Modality switch[a]	
To CKRT (at any point after starting PD)	2/30 (7%)
To iHD (at any point after starting PD)	7/30 (23%)
Follow-up as of May 14, 2020	
Still hospitalized	8/30 (27%)
Still on PD	0/8 (0%)
Still on iHD/CKRT (no longer on PD)	4/8 (50%)
With kidney recovery (no longer on KRT)	4/8 (50%)
Died during hospitalization	14/30 (47%)
With AKI requiring KRT at time of death	13/14 (93%)
With kidney recovery (no longer on KRT) at time of death	1/14 (7%)
Discharged home	8/30 (27%)
Still on PD	3/8 (38%)
With kidney recovery (no longer on KRT)	5/8 (63%)

Abbreviations: AKI, acute kidney injury; CKRT, continuous kidney replacement therapy; ICU, intensive care unit; iHD, intermittent hemodialysis; KRT, kidney replacement therapy; PD, peritoneal dialysis.
[a]Subgroups are not mutually exclusive.

To reduce the burden of manual exchanges on staff and optimize delivered PD dosing, we sought to implement APD. Because we had not previously used APD cyclers on our inpatient services, we had to procure cyclers and related supplies from our supplier (Table 1). On April 6 (when there were 18 patients receiving urgent PD), members of the urgent PD service team (now comprising 2 attendings and either a nurse practitioner or nephrology fellow) were trained to program and troubleshoot the cyclers for provision of APD. Because the nurses and house staff residents were trained on only manual PD exchanges, the urgent PD service team provided the APD setup for each patient on a cycler. They also obtained data from the cyclers for the therapy session completed, discarded the cassettes and used PD bags, and set up the new prescription and dialysate bags for that day's therapy. Heparin (500 U per 1 L of dialysate) was instilled to each bag to prevent fibrin clot formation (Figs S1 and S2). This was especially important because patients with COVID-19 had notably increased fibrinogen, D-dimers, lactate dehydrogenase, prothrombin time, and activated partial thromboplastin time values and were at risk for thrombotic complications.[11,12] Because several patients were receiving multiple antibiotics, fluconazole use for prophylaxis of fungal peritonitis was considered.[13] However, due to the risk for QT interval prolongation, particularly in combination with hydroxychloroquine, we opted against prescribing fluconazole.

Patient Outcomes

From March 11 to April 26, MMC had a total of 164 patients with severe AKI that required KRT (M. Fisher, personal communication, May 2020). Of these, 27 (16.5%) received PD as the initial mode of dialysis. An additional 3 patients were switched from another modality to PD; 2 patients who were receiving intermittent HD initially were switched to PD when it became available in the MMC Weiler Hospital, and 1 patient who was receiving CKRT was switched to PD at MMC Moses Division. As of May 14, 2020, a total of 14 of the 30 (47%) patients who were started on PD died during the hospitalization (of whom 1 had kidney recovery and dialysis was discontinued before death), 8 patients were discharged to home or rehabilitation facilities (of whom 3 were receiving PD and 5 no longer needed KRT due to kidney recovery by the time of discharge), and 8 patients were still hospitalized. Of those 8 patients who remained hospitalized, no patient remained on PD; 4 patients were switched to either CKRT or intermittent HD, and 4 patients had kidney recovery and no longer needed KRT (Table 2).

Of the 30 patients started on PD in the first 22 days of April, 22 patients were intubated before the start of PD and 8 were started on PD and were never intubated. There were no patients who were intubated after starting PD. Sixteen of the 22 intubated patients required prone positioning for treatment of hypoxemia. One of the 8 nonintubated patients was also placed in prone positioning for treatment of hypoxemia. Of the 30 patients receiving PD, 5 patients were supplemented with CKRT during their hospitalization, 4 of whom needed supplementation with CKRT due to prone positioning limiting PD exchanges and 1 due to persistent hyperkalemia. Ultimately, 2 of the 5 patients remained on CKRT and PD was discontinued. In 1 patient, PD was discontinued due to fungemia but peritoneal fluid fungal cultures remained negative. The second patient was taken off PD due to positive peritoneal fluid fungal culture; however, this was preceded by positive fungal blood cultures. Six of the 30 patients required intermittent HD supplementation during their hospitalization. Of those 6 patients, 2 needed supplementation with intermittent HD for additional clearance and 4 patients needed additional ultrafiltration due to refractory volume overload despite high-dextrose PD dialysate solution (icodextrin was not available).

Of the 6 patients who needed intermittent HD supplementation, 4 were ultimately switched to intermittent HD and PD was discontinued (due to ultrafiltration failure and

fluid retention while receiving PD). In addition, 3 patients were switched to intermittent HD from PD (without concurrent intermittent HD supplementation while receiving PD) for a total of 7 patients who were ultimately switched to intermittent HD. One of those additional 3 patients was switched due to a hypercatabolic state leading to severe electrolyte derangements necessitating higher clearance rates. One patient was switched due to a persistent peritoneal fluid leak from the PD catheter exit site. One patient was switched due to peritoneal catheter malfunction leading to intraperitoneal bleeding (Table 2). Due to hemodynamic instability, the patient with the persistent peritoneal fluid leak was not a candidate for laparoscopic repair in the operating room (multiple bedside repairs were unsuccessful in stopping the leak).

Typically, the average prescribed dose for patients receiving manual PD (for a 70-kg male) after the initial 48 to 72 hours of PD was a 2-L fill volume, 6 exchanges per day, with a dwell time of 3 hours (Fig S1). Assuming a 2-L ultrafiltration rate per day, this prescription would confer a weekly Kt/V of 2.52 (a weekly Kt/V of 2.1-3.5 is the goal for PD in the AKI setting).[2] The average prescribed dose for APD (for a 70-kg male) after the initial 48 to 72 hours of PD was a 2-L fill volume, total daily volume of dialysate of 16 L, 2-hour dwell time, with 8 exchanges per day for an average duration of 20 hours receiving APD. Assuming a 2-L ultrafiltrate volume, this prescription would confer a weekly Kt/V of 3.24. Due to the feasibility issues mentioned previously and in Table 1, the actual dose of PD received by the patient varied and supplementation with CKRT or intermittent HD was necessary in many cases to provide additional clearance.

Discussion

There are many advantages to using PD in the setting of AKI stage 3. First, there is no need for vascular access. Patients with elevated levels of D-dimers and fibrin degradation products, as seen in COVID-19, are more likely to have disseminated intravascular coagulation.[14,15] Due to severe sepsis and the concomitant coagulopathy associated with COVID-19, it is preferred to avoid vascular access when possible. Second, the overall cost of PD is significantly less than intermittent HD or CKRT, which require more expensive machinery and supplies. Third, staff can be educated on how to safely perform PD with few resources and in a short time. As mentioned in El Shamy et al,[16] PD training is less technically challenging as compared with intermittent HD or CKRT machine training and is therefore an obvious choice for nurse and technician training during a pandemic. Finally, unlike intermittent HD, PD does not require a dialysate supply water connection, which was a limiting factor in several temporary ICU locations constructed in our medical center in response to the COVID-19 surge.

With adequate PD, solute clearance, ultrafiltration, and correction of metabolic acidosis can improve the morbidity of patients with severe AKI.[4,5,9] However, there is a notable discrepancy in the frequency of use comparing intermittent HD and CKRT with PD as the primary choice for dialysis in patients with AKI stage 3.[1] In an international survey of nephrologists and intensivists, PD use accounted for less than one-third of patients, whereas CKRT modalities were used in almost half.[1] Although there are many reasons for this incongruence, there have been studies that demonstrate the use of urgent PD in AKI settings with success.[3-5,17] Gabriel et al[5] (2008) demonstrated that high-volume continuous PD proved to be an effective form of dialysis in patients with AKI with multiple comorbid conditions, including those with a high level of acuity requiring ICU admission.[17]

Because the pandemic overwhelmed our capacity to provide intermittent HD or CKRT to all patients needing dialysis at MMC, an urgent PD program was started to accommodate the surge in patients with AKI requiring KRT. As expected, clearance and ultrafiltration rates were less predictable in patients who were hypercatabolic from severe sepsis.[18] This prompted supplemental intermittent HD or CKRT use in several patients, which meant additional catheter placement and therefore increased catheter-related infection risk and clotting.

Although we expected some resistance from critical care physicians who were not familiar with PD, this was extremely rare because clinicians understood the dire situation given the severe shortage of intermittent HD and CKRT resources and staff. We do not have data for reimbursement for PD procedures because review of billing submissions revealed that nearly all nephrologists billed for follow-up consult evaluation and management services and not the PD procedure.

Based on our experience, urgent PD was feasible in a time of crisis. We are currently investigating the efficacy of PD in relation to morbidity and mortality in patients treated in both the ICU and medical wards during the COVID-19 pandemic. We hope that our experience can help others prepare for any future surge in patients with AKI requiring KRT.

Supplementary Material

Supplementary File (PDF)

Figure S1: Manual PD algorithm.

Figure S2: Cycler PD algorithm.

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