Preparedness of Kidney Replacement Therapy in the Critically Ill During COVID-19 Surge

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The devastating and rapidly spreading coronavirus disease 2019 (COVID-19) pandemic has challenged the health care system worldwide. COVID-19 primarily affects the lungs and is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2); however, multiple other organ systems also may be affected, including kidneys, blood (hypercoagulability), brain, and heart. The incidence of acute kidney injury secondary to COVID-19 is estimated at approximately 15% to 25%,[1,2] and requirement of kidney replacement therapy (KRT) has been variably reported, with many large centers describing an incidence of up to 30% in critically ill patients.[3,4] Further, emerging observations have described 2 phenotypes of COVID-19 pneumonia that may require a more individualized approach of KRT.[5] One phenotype has higher lung compliance, ventilation perfusion mismatch, and low lung recruitability (type-L), whereas the other has lower lung compliance, higher right to left shunt, and higher lung recruitability, mimicking acute respiratory distress syndrome (type-H). Therefore, it is possible that patients with type-L are more susceptible to hypovolemia due to dysregulation in pulmonary perfusion, whereas patients with type-H may benefit from timely KRT for fluid management if severe acute kidney injury develops and there is lack of response to diuretics.

In this perspectives piece, we complement prior contingency planning recommendations by Burgner *et al.*,[6] with some specific considerations for KRT preparedness in the intensive care unit (ICU) under a model including vulnerability assessment, crisis planning, and crisis challenges.

Vulnerability Assessment

It is critical to monitor surveillance models of COVID-19 projections, as well as sustain continuous communications with state and local leaders of the preparedness plan. A commonly used reference is from the Institute for Health Metrics and Evaluation at the University of Washington (https://covid19.healthdata.org, last accessed April 30, 2020). Relevant information for nephrologists is the projection of total hospitalized patients with COVID-19 and, specifically, total patients in the ICU; therefore, a projection of approximately 25% of critically ill patients needing KRT can be established.

Crisis Planning

Stepwise operational approaches with fluent channels of communication are recommended (Figure 1), starting with assembling a multidisciplinary team encompassing all stakeholders involved in KRT delivery in the ICU (e.g., ICU and dialysis nurses, technicians, pharmacists, clinicians, supply chain management, administrative leadership). It is also important to accommodate the preparedness plan to specific logistics and hindrances of each institution, including the provision of KRT to non–COVID-19 patients with end-stage kidney disease or kidney transplant. Overall, we recommend consideration of activation of the *contingency plan* when KRT resource utilization exceeds 80% of available KRT supply continuously for a period of 7 days and activation of the *crisis plan* when KRT resource utilization exceeds 100% of available KRT supply continuously for a period of 7 days

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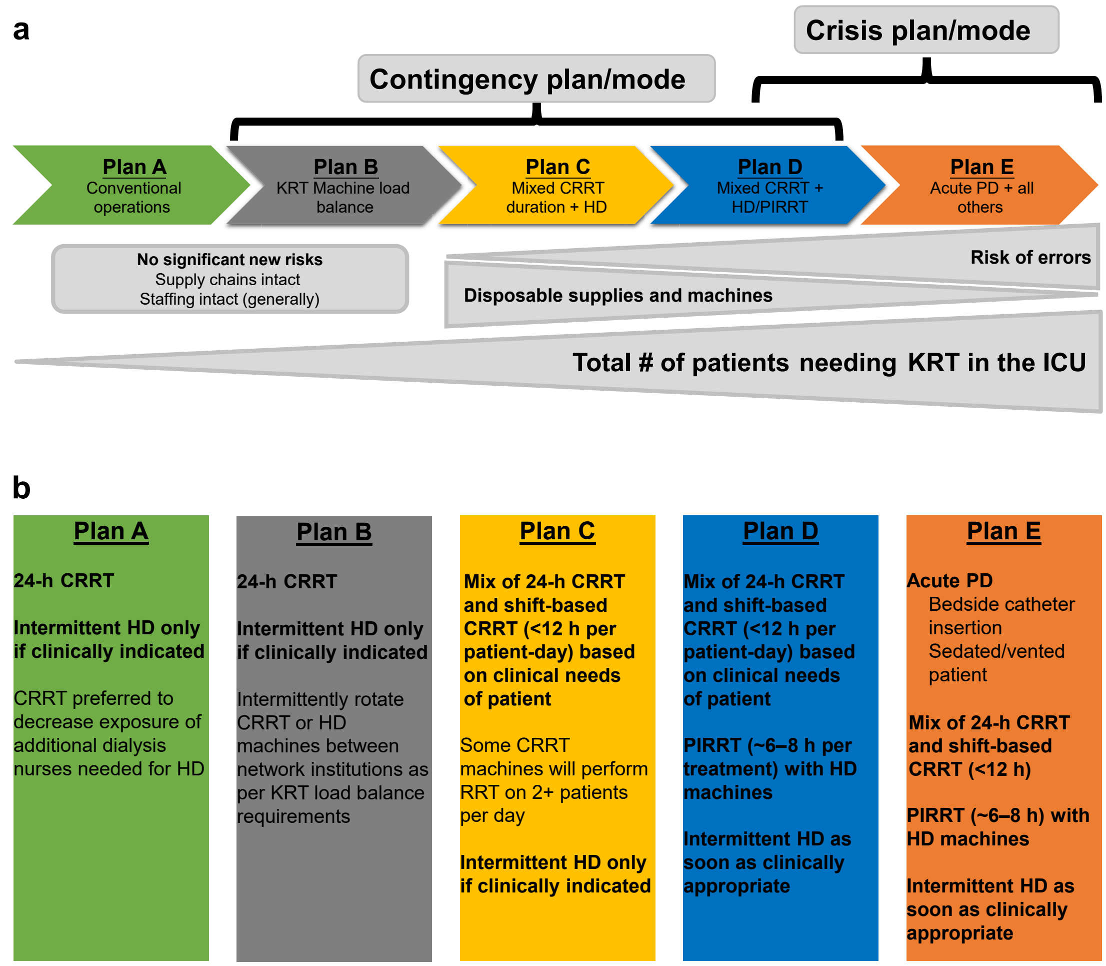

Figure 1. (a) Overview of a stepwise plan from conventional to contingency and crisis plan operations for the provision of kidney replacement therapy (KRT) during surge of patients with coronavirus disease 2019 (COVID-19) in the intensive care unit (ICU). (b) Specific allocation of KRT resources to support the stepwise plan of operations. Plan A denotes conventional/standard operations. Plan B (contingency) denotes rotation of continuous renal replacement therapy (CRRT) or hemodialysis (HD) machines between network institutions based on KRT load balance requirements. Plan C (contingency) denotes combining 24-hour CRRT and shift-based CRRT (<12 hours per patient-day) in 24-hour KRT cycles based on individual patient needs and KRT load balance requirements (e.g., some CRRT machines will perform KRT on 2 or more patients per day). Plan D (contingency/crisis) denotes adding prolonged intermittent renal replacement therapy (PIRRT) (approximately 6–8 hours per treatment) as an alternative modality of KRT in the ICU. Plan E (crisis) denotes systematic utilization of all aforementioned KRT modalities plus the addition of acute peritoneal dialysis (PD) as an alternative modality of KRT for selected patients.

during a foreseeable COVID-19 local surge.

Continuous renal replacement therapy (CRRT) is the most common modality of KRT used in critically ill patients. However, other KRT modalities, such as prolonged intermittent renal replacement therapy (PIRRT), hemodialysis (HD), or peritoneal dialysis (PD), also can be considered for critically ill patients, particularly in settings with limited availability of CRRT machines. When using PIRRT, duration of therapy is approximately 6 to 8 hours using a blood flow rate of approximately 200 ml/min, dialysate flow rate of 200 to 300 ml/min, and ultrafiltration rate limited to less than 1 liter per hour. Additional considerations for PIRRT and HD include low temperature (35.5 °C) and high calcium bath (3 mmol/l) to attenuate intradialytic hypotension. If acute PD is used, cycler use is recommended, with each fill limited to 1 liter in cycles of 1.5 to 2 hours for a total of 8 to 12 hours to minimize risk of catheter leak. Several variations to the outlined plan in Figure 1 should be contemplated. A few examples are as follows: (i) the movement/rotation of CRRT or HD machines between network institutions may not be feasible because of logistic restrictions (e.g., geographic distance); (ii) the combination of 24-hour CRRT and shift-based CRRT (<12 hours per patient-day) in 24-hour KRT cycles may or may not require CRRT dose adjustments; (iii) the provision of PIRRT using sequestered HD machines in isolated COVID-19 ICUs can be done during daytime or nighttime according to availability of dialysis nurses; and (iv) the utilization of the acute PD program can be expanded to non–COVID-19 patients with advanced chronic kidney disease or kidney transplantation in need of chronic dialysis to spare HD machines being used in COVID-19 ICUs.

Crisis Challenges

Important challenges to consider are the following: (i) the supply chain (e.g., filters/tubing, solutions); (ii) shortage of staffing, specifically of dialysis nurses for HD and for PIRRT, as dialysis nurses are likely to be in charge of starting, monitoring, and stopping PIRRT; (iii) training of ICU nurses not familiarized with HD machines for the provision of PIRRT and cyclers for PD; (iv) complex schedule and/or rotation for provision of mixed KRT with structured allocation of 2 or more patients to a single KRT machine during a 24-hour cycle; (v) availability of portable reverse osmosis systems and dialysis water supply in ICU rooms; and (vi) local expertise by surgeons for placement of PD catheters at the bedside for acute PD start.

Other Considerations

Anticoagulation

Severe COVID-19 induces a hypercoagulable state in many critically ill patients, as evidenced by a markedly high rate of KRT blood circuit failures (clotting) and higher rates of venous thromboembolism. The pathophysiology of this hypercoagulable state is still unknown, but possible mechanisms include macrophage activation with cytokine release, deficiencies in fibrinolytic pathways, and endothelial injury leading to platelet activation. In this context, regional citrate anticoagulation[7] or systemic anticoagulation[8] is used exclusively or synergistically. Unfortunately, regional citrate anticoagulation has not proven to be nearly as effective in COVID-19 as in other critically ill patients. Alternatives using direct thrombin inhibitors, such as bivalirudin or argatroban, also can be considered, although data in the overall KRT population are limited. Importantly, some type of anticoagulation, regionally in the CRRT/PIRRT circuit or systemically, should be used in patients with COVID-19 on KRT unless there are contraindications, taking into consideration specific logistics available locally at each institution.

Extension Tubing

Limiting direct exposure of health care professionals is pivotal to mitigate contamination and horizontal transmission. Therefore, placing CRRT machines outside the patient's airborne-isolated room with extension tubing provides a way to do it. Careful consideration should be taken to verify tubing does not preclude airborne isolation when exiting the room and of the additional amount of blood in the extracorporeal circuit, which could impair hemodynamics in some patients, particularly if frequent treatment interruptions occur. Some additional complications may arise, such as impairment of return/access pressure monitoring, lack of detection of return line disconnections or blood circuit pressure drops, and consequently inability to timely detect unintended severe blood loss. Therefore, vigilant monitoring is advised. Hypothermia is another potential complication that can be mitigated by wrapping a Bair Hugger blanket around the extension lines.

Customized Solutions

Although there are options to locally compound CRRT solutions, it is recommended to use commercially available solutions as much as possible to decrease the risk of nursing and compounding errors. This is particularly important in the context of COVID-19, given the high volume of patients receiving KRT and the limited direct exposure.

Machine Disinfection

Meticulous disinfection of the KRT machine surface is recommended by using registered bleach wipes products against coronavirus. In isolated COVID-19 units, machines will typically remain sequestered and disinfected there. If machines are to be transported back to the dialysis unit or storage, disinfection should occur before mobilization, and precautions during transport procedures should be taken.

Ethics Consideration

There are no conclusive data to support one mode of KRT is superior to another. When delivered to the right patient at the right time with the optimal KRT prescription, all KRT modalities are effective in achieving patient-centered goals of solute and volume control. Nonetheless, iterative assessment of goals of therapy is highly recommended.[9] In terms of resource allocation or priority setting, the goals are legitimacy, fairness, and equity. Parameters acceptable to the public in resource allocation decisions are need, survivability (prognosis/life expectancy), and social value.

There is no doubt that this pandemic has challenged our health care system, economy, and society as a whole. Nonetheless, positive things arise from debilitating times: creativity to surpass the obstacles and meaningful connections to work as a team and dynamically learn together about a disease we have never faced before. We should leverage on this positive thinking and continue working on preparedness to what is here today and what is coming tomorrow. Finally, paraphrasing a vigorous quote of Napoleon

Bonaparte, we should all dress slowly (carefully work on preparedness) because we are all in a hurry (to beat this invisible enemy).

DISCLOSURE

All the authors declared no competing interests.

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