Optimizing Kidney Replacement in Critical Care: SLED Can Play a Bigger Role in the ICU

SLED and CKRT have demonstrated equivalence in tolerance from a hemodynamic perspective as well as clinical outcomes such as renal recovery and mortality.

Sevag G. Demirjian, MD, Cleveland Clinic; J. Pedro Teixeira, MD, UNM Hospital; Bruce A. Mueller, PharmD, FCCP, FASN, FNKF, University of Michigan Hospital; William A. Rodriguez, MD, Austin Kidney Associates; Lenar T. Yessayan, MD, University of Michigan Hospital; Brendan T. Bowman, MD, UVA University Hospital; Reginald D. Gladish, MD, Decatur Morgan Hospital; Michael Aragon, MD

Background

The COVID-19 pandemic has illuminated many inefficiencies present in the healthcare system, one of the most prominent being the strain that can be placed on intensive care units (ICUs) due to patient surges in the United States. Among the multitude of challenges identified, many facilities experienced significant challenges in the delivery of dialysis due to insufficient supply of dialysis machines, sterile dialysate, and shortages of nursing staff trained to provide therapy. Due to the types of machines available, disruptions in supply chain related to high demands, and the limited efficiency with which they can be used, the typical choices for kidney replacement therapy (KRT), continuous kidney replacement therapy (CKRT) and intermittent hemodialysis (IHD), have been unable to meet the needs of many facilities and have had a significant impact on ICUs’ ability to handle patient surges like those that are occurring with COVID-19.

Despite evidence of equivalent outcomes compared to CKRT, SLED uptake as a substitute for, or a complement to CKRT, has been sporadic due to the challenges related to operationalizing a SLED program, the need to adjust drug dosing for SLED and a lesser focus on value-based care compared to the current healthcare environment. With the more recent events associated with the pandemic and patient surges, many facilities were forced to deploy SLED programs to treat their most unstable patients in order to meet patient demand and address supply shortages. This has generated a renewed interest in the modality’s value and potential to improve the efficiency in treatment of critically ill patients with AKI.

Understanding Acute Dialysis Delivery

Generally, hospitals and health systems select dialysis modalities that are best suited to their individual operational and logistical circumstances. These circumstances include factors such as annual treatment volume, staffing considerations, available technology and the accessibility of ancillary support services such as clinical engineering and pharmacy. In general, hospitals with smaller-volume ICUs (~5 beds) may not offer dialysis or may have limited need for KRT in the ICU setting. These facilities typically only offer IHD with vasopressor support if needed or, less commonly, may provide both IHD and prolonged intermittent kidney replacement therapy (PIKRT) or sustained low efficiency dialysis (SLED). In contrast, larger tertiary care hospitals offer a mixture of intermittent hemodialysis (IHD) along with continuous kidney replacement therapy (CKRT).

For smaller facilities, the startup costs for CKRT can be prohibitive and include the capital expense of investing in new machines, supply contracts and the expenses related to initial and ongoing support. Extensive time is required for initial training of nursing staff—both nephrology and ICU. Clinical support engineers require certification to provide maintenance on the new devices. Provided that nephrologists have a working knowledge regarding CKRT therapy, ongoing costs are generally related to supplies and maintaining staff proficiency. If hospital ICU KRT volumes are not high enough to maintain proficiency, nurses may quickly...
lose skills in CKRT. In addition to these obvious cost considerations, CKRT has certain “hidden” costs as well. A recent analysis demonstrated CKRT provision incurred significant storage and solution preparation costs above the acquisition costs. This can be quite variable depending on the degree of solution customization employed.

It is not surprising, then, that a number of cost analyses have found IHD and SLED to be more cost effective than CKRT. For hospitals and health systems that choose to utilize IHD- or SLED-based ICU therapy, this allows for standardization to a single device or set of devices. By utilizing a single platform, savings can be expected in the areas related to decreased training costs, decreased supply and storage costs and increased leverage in contracting. Depending on the technology, however, this model may still retain the complexity of necessitating specialized hemodialysis nursing staff to administer the therapy.

For large hospitals and health systems with high ICU KRT volumes and specialty-specific ICUs, there is some economy of scale with CKRT and possibly a small reduction in the ongoing training required to maintain proficiency. From a staffing standpoint, continuous therapies such as CKRT can be managed either completely by ICU nursing staff or with setup and troubleshooting services provided by experienced dialysis nurses with ICU staff monitoring during therapy. This frees dialysis nurses to provide typical acute hemodialysis treatments and improves staff efficiency; however, it does not address the significant supplies expense and logistical challenges, such as CKRT solution storage and preparation costs associated with the therapy.

Aside from cost, the likely major driving force for continuous therapies in larger institutions remains entrenched in culture and nephrologist/intensivist preference. CKRT remains the suggested modality for hemodynamically unstable patients in the most recent 2012 KDIGO guidelines for acute kidney injury (AKI). The authors of the KDIGO guidelines noted that SLED is suitable for hemodynamically unstable patients but did not include it as a suggested modality, citing a lack of sufficient evidence which, in the subsequent 9 years, has continued to grow considerably. Cited benefits of CKRT machines have been related to their compact nature. They do not require the bulky reverse osmosis devices needed with traditional hemodialysis machines which may cramp already tight ICU rooms. Additionally, in the rare case of intra-operative KRT needs, as in transplant or some cardiac surgeries, a compact, self-contained CKRT machine...
has been able to operate efficiently where a traditional dialysis machine is not feasible due to the need for an external RO system.

Arguments for the cost-effectiveness of CKRT over IHD generally rely on an assumption of improved rates of dialysis liberation in the CKRT group. This yields theoretical savings via decreased rates of CKD and ESKD. However, this possible benefit of CKRT over intermittent KRT with regard to improved renal recovery has only been demonstrated in a limited number of observational studies, has not been seen consistently in retrospective analyses and has never been demonstrated in a prospective randomized trial.

In contrast, the use of existing intermittent hemodialysis machines to try to capture the advantages of CKRT began in the 1990s. By 2000, Kumar et al. reported PIKRT was as effective as continuous veno-venous hemofiltration (CVVH) in caring for hemodynamically unstable patients. EDD, also commonly referred to as sustained low-efficiency dialysis (SLED) and prolonged intermittent kidney replacement therapy (PIKRT), was first proposed as an easier to perform, more flexible, and less nurse-intensive therapy compared to CKRT. Since that time, its utilization has been variable across the United States with several large hospitals and academic centers employing it exclusively as their prolonged therapy of choice, instead of CKRT.

The primary aim of this article is to review the indications for and clinical value of SLED therapy, provide guidance for the prescribing of SLED, and review additional considerations and historical challenges.

Defining SLED

Multiple acronyms have been used to describe KRT therapies with a duration between that of IHD and CKRT. The acronym SLED, and more recently PIKRT, encompasses convective, diffusive and hybrid methods. Treatments are delivered using either standard outpatient IHD machines with online dialysate generation or CKRT machines utilizing sterile, pre-packaged dialysate. Examples of mid duration KRT include sustained low-efficiency dialysis (SLED or SLEDD, if daily),, sustained low-efficiency daily dialfiltration (SLEDD-f), extended daily dialysis (EDD),, accelerated venovenous hemofiltration (AVVH) and accelerated venovenous hemodialfiltration (AVVHDF). Typical treatment duration is between 6 and 12 hours with dialysate flow rates of 6 to 12 L/hr and blood flow 150 to 400 mL/min, or hemofiltration from 25 to 100 mL/min. PIKRT can be performed daily or 3 to 6 days per week. Clinical trials and observational studies have demonstrated that SLED or PIKRT is non-inferior to CKRT regarding patient outcomes. Given the numerous acronyms to describe this therapy, for consistency and simplicity, we will focus on the term SLED in this manuscript to encompass all mid duration therapies, as terms like EDD infer that therapy is always provided daily.

Table 1 Typical SLED Prescribing Parameters

<table>
<thead>
<tr>
<th>Typical Qb</th>
<th>Typical Qd</th>
<th>Typical Duration of Therapy</th>
<th>Typical Net UF Rate</th>
<th>Typical Therapy Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>150–300 mL/min</td>
<td>100–300 mL/min</td>
<td>6–12 hours</td>
<td>Variable, 0–500 mL/hour</td>
<td>3–6 times per week</td>
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</table>

The SLED Prescription

There are no strictly defined standard parameters for prescribing SLED. Prescribed treatments most often utilize hemodialysis (diffusive clearance), i.e., SLED; but can be prescribed to perform hemofiltration (convective clearance), i.e., SLEDD-f; or hemodiafiltration (convective and diffusive clearance) to achieve clinical goals. In general, regardless of method of clearance, SLED uses low blood flow (Qb), with dialysate (Qd) flow rates and ultrafiltration rates that are intermediate between IHD and CKRT (Table 1).

Data to guide the dosing of SLED are limited, as the vast majority of data available on dosing of KRT for AKI or ESKD have been obtained with IHD or CKRT. Much like the data with CKRT, the few studies comparing higher or lower doses of KRT specific to SLED have generally yielded negative results relative to any benefit of higher dose therapy. Standard Kt/V assessments used for IHD may accurately quantify urea clearance with SLED and can be used to guide dosing to specific clinical targets, such as the target currently recommended by KDIGO for acute dialysis of three or more treatments per week, each with a Kt/V of 1.3 or greater. SLED can be prescribed using the same dialyzers typically used for IHD, with dialyzer choice being dictated by availability and compatibility with available KRT devices. The size of dialyzer appears to have only modest influence on clearance during SLED as compared to Qd and treatment duration. Previous reports have demonstrated that changing to small-sized dialyzers (to decrease risk of circuit clotting) had no appreciable change in clearance or solute control.

In general, prescribing UF with KRT, including SLED, requires serial assessments of patient volume status and volume goals followed by adjustments to meet those goals. Target fluid removal is prescribed as a total treatment net UF, similar to IHD. Limited data exist evaluating optimal UF rate targets during any KRT for AKI. The data that do exist are largely observational correlating UF rates during CKRT with outcomes and, notably, have been contradictory. Higher net UF rates have been associated with both decreased mortality and increased mortality, suggesting the relationship is likely variable. These data may be confounded by the well-established association between volume overload and mortality in AKI, as well as the tendency for less ill patients to tolerate higher rates of net UF. Some experts have used these observational data to propose limits on net UF during CKRT to 1.5–2 mL/kg/hr, though whether such limits or similar limits should apply to SLED is unclear.

There are no data specifically on the optimal UF rates for SLED; however, the extended treatment times that accompany the modality do allow for slower ultrafiltration compared to IHD, while achieving metabolic clearance goals in considerably less time than CKRT. It is the opinion of this group that it is more reasonable to establish an upper limit for total hourly UF instead of net UF when prescribing SLED. Conservatively, a target total hourly UF rate not to exceed 300 mL/hr was suggested, although it was noted that rates exceeding this have been well tolerated in some critically ill patients within this population. Until a larger body of clinical evidence is available, this max UF rate should likely remain site dependent, and customized to the individual patient.

The need for anticoagulation for SLED treatments is significantly lower than that of CKRT with the majority of...
Figure 3 Overall Mortality in Patients Treated with Continuous Kidney Replacement Therapy (CKRT) Versus Sustained Low-Efficiency Dialysis (SLED). Kovacs 2017

Figure 4 30-day Mortality, KRT Dependence and Early Clinical Deterioration by KRT Modality. Kitchlu 2015

treatments able to be performed with no anticoagulation. In cases where anticoagulation is necessary, heparin protocols combining a small bolus, approx. 1000 units, with a continuous rate of approx. 500 units/hr. have been suggested as effective starting doses with titration to effect or titration to a PTT that is 1.5x normal. Citrate anticoagulation has been performed successfully with SLED therapy utilizing trisodium citrate solutions. While effective, citrate does add complexity and risk to the therapy. Given the generally low risk of clotting with SLED therapy, it is the opinion of this group that this may be best reserved for patients that are particularly thrombogenic and have either a contraindication to or have failed heparin anticoagulation.

The Clinical Evidence for SLED and CKRT

To date, SLED has been shown to yield equivalent clinical outcomes compared
to CKRT across independent studies as well as more rigorous systematic reviews and meta-analyses. In terms of hemodynamic tolerance, it has been demonstrated that there is no statistically significant difference between the two modalities in hemodynamic variables including mean arterial pressure (MAP), heart rate (HR), cardiac output (CO), and systemic vascular resistance (SVR). Similar to CKRT, SLED can be used in hemodynamically unstable patients. Additionally, in a meta-analysis of both RCTs and observational studies by Zhang et al., no difference was seen in days spent in the ICU, renal recovery, or fluid removal. This was echoed in the meta-analysis by Kovacs et al., which found no significant difference between CKRT and SLED in the proportion of renal recovery, time to renal recovery, the number of hypotensive events, or the number of vasopressors or the dose of vasopressors needed. Finally, in RCTs mortality rates with SLED have not been demonstrated to be inferior to those with CKRT. Evidence from observational studies, however, have suggested that SLED potentially has lower mortality risk compared with CKRT. 

**Benefits of SLED Compared to CKRT**

Interestingly, additional evidence has shown that SLED may potentially be superior to CKRT in other aspects. Kielstein et al. showed that acidosis was corrected faster with SLED compared with continuous therapy. SLED also offers more prescription flexibility which can facilitate other care needed for a critically ill patient, like proning those with severe respiratory failure. By minimizing anti-coagulation and overall drug exposure, choosing SLED over CKRT may minimize the risk of errors in medication dosing and administration. SLED therapy also increases the likelihood of achieving clearance targets as procedures can be timed around dialysis instead of interrupting therapy for any procedure or test that is not dialysis. Although additional research is necessary to determine if SLED modalities are superior to CKRT, sufficient evidence is available in the literature to support the claim that SLED is, at minimum, equivalent to CKRT.

In addition, as mobility has become a central focus in modern critical care medicine, SLED facilitates earlier ambulation of patients by allowing significant “dialysis-free” time for nursing and therapy staff to work with the patient un-restrained by blood tubing and additional connections. Earlier mobilization has been associated with reduction in both ICU and overall length of stay (LOS) and has been associated with improved overall outcomes.

**Challenges with SLED Therapy**

Although SLED offers many benefits, it is not without challenges. First, there is significant variability in clearance based on the duration of therapy prescribed. While there is no consensus on what the ideal SLED treatment duration or dialysate flow rate should be, some successful SLED programs have addressed this by attempting to standardize the therapy to a specific duration, typically around 9–10 hours, to allow two treatments per device per day. Aside from standardization, other limitations center around the capabilities of the device or devices a facility has available. Using CKRT devices for hybrid therapies like SLED can be prohibitively expensive due to the requirement for sterile bags of dialysate. In addition, this significantly increases nursing workload intensity in treatment management and may be limited in ability to achieve the target clearance in 6–12 hr. treatment times due to technical device constraints and the inability to achieve clearance with 12 hour thrice weekly therapy with CKRT devices. Reducing treatment time but increasing dialysate flow rate on a CKRT device does not reduce the cost or number of supplies needed to perform the therapy. Providing SLED therapy with traditional IHD devices that require portable water purification systems can often lead to staffing challenges due to managing both a complex dialysis device and a portable water purification system. In most cases, this has required hemodialysis nurses to manage the therapy or at least perform the set up and monitor at frequent intervals. These models can potentially stress a hospital’s limited hemodialysis nurse resources and may lead to delays of IHD treatments elsewhere in the hospital.

A final challenge is the lack of available guidance on drug dosing when using SLED. Guidance is available for some medications; however, guidance has been limited by the wide variability of prescriptions associated with SLED. Opportunities may exist to try to standardize the prescription and, as such, allow pharmacists more consistent clearances from which to calculate doses; however, this has not been common practice. Additionally, newer technologies now available (see accompanying article on the following pages) may also be of significant benefit in addressing this challenge.

**Summary**

For smaller facilities, a mid-duration KRT such as SLED represents a way to effectively manage hemodynamically unstable patients, potentially with the same device used for IHD. SLED also enables these facilities to better handle patients who decompensate and may greatly reduce or eliminate the need to transfer patients out to higher level of care facilities when these patients are in their most critical state.

In larger facilities currently using CKRT, SLED can improve practice patterns by increasing surge capacity and allowing for the adaptability to provide patients more optimal therapy instead of the therapy that is available. Surge capacity is increased with SLED because of the shorter treatment times, which allows a single dialysis machine to be used for two critically ill patients per day (and potentially more, depending on treatment time). SLED also increases the ability to mobilize patients earlier, which has been associated with improved patient outcomes in the ICU. This would subsequently lead to shorter average lengths of stay in the ICU and allow for step-down therapy.

Overall, no concrete guidance exists on what constitutes the best dialysis modality in the ICU setting for hemodynamically unstable patients. SLED and CKRT have demonstrated equivalence in tolerance from a hemodynamic perspective as well as clinical outcomes such as renal recovery and mortality. SLED does offer some advantages in terms of lower program initiation cost and ongoing cost, allowing earlier patient mobilization, reduced need for anticoagulation and offering a more robust treatment.

When considering SLED therapy, it is important to understand device capabilities. Traditional IHD or CKRT machines pose certain challenges and may be inefficient in the delivery of SLED, i.e., dependence on highly trained dialysis nurses, cost of supplies, and limited flow rates. Careful evaluation of these criteria, in addition to a better understanding of the technological advancements that exist in the market today, should be considered when starting a SLED program. Hospitals and healthcare systems offering KRT must consider both financial and logistical factors in addition to patient outcomes when selecting the best fit for their facilities. Based on much of the available evidence, CKRT is more costly than SLED, and the current COVID-19 pandemic has illustrated that it is also less adaptable and less efficient. Flexibility in KRT will be paramount to maintaining and expanding capabilities in the ICU as we move through the rest of the COVID-19 pandemic and patient surges into the future. Mid-duration dialysis therapies like SLED have the potential to provide this much-needed adaptability, especially if the historical staffing challenges stemming from device complexity can be overcome and standardization throughout hospital and healthcare systems can be established to ensure more predictable clearance and drug dosing.
References


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Tablo Hemodialysis System: Utilizing Adaptive Dialysis to Address the Challenges of ICU Kidney Replacement Therapy

Sevag G. Demirjian, MD, Cleveland Clinic; J. Pedro Teixeira, MD, UNM Hospital; Bruce A. Mueller, PharmD, FCCP, FASN, FNKF, University of Michigan Hospital; William A. Rodriguez, MD, Austin Kidney Associates; Lenar T. Yessayan, MD, University of Michigan Hospital; Brendan T. Bowman, MD, UVA University Hospital; Reginald D. Gladish, MD, Decatur Morgan Hospital; Michael Aragon, MD

Background

In the United States, dialysis is a large, expensive sector of healthcare that has seen little technological innovation in the last 30 years. The Tablo Hemodialysis System (Tablo) represents a significant technological advancement, enabling novel, transformational dialysis care in multiple care settings.

Tablo is a next-generation, self-contained, enterprise solution hemodialysis system capable of delivering adaptive kidney replacement therapy, a term used to describe the Tablo system’s unique ability to span a wide spectrum of treatment modalities from intermittent to prolonged dialysis (2–24 hours daily), with or without ultrafiltration. This clinical versatility enables providers the ability to meet the hemodynamic needs of all patients and standardize dialysis with Tablo across the continuum of care, from hospital to home.

Designed to improve the dialysis experience for patients and help providers overcome traditional care delivery challenges, Tablo requires only an electrical outlet, tap water and a drain to operate, freeing providers from the burdensome infrastructure and costly supplies required to operate traditional dialysis machines.

The Tablo system contains three primary components:

1. Tablo Console: A compact, 35-inch tall, easily transportable console with integrated water purification, on-demand dialysate production and touchscreen interface.

2. Tablo Cartridge: A proprietary, disposable, single-use, color-coded organizer with pre-strung bloodlines compatible with any dialyzer that clicks into place, minimizing steps, touchpoints and connections.

3. TabloHub: Designed to bring data to dialysis and information to the care team, TabloHub is the web-based portal enabling Tablo to live in a connected setting with 2-way wireless communication, cloud-based system monitoring, treatment analytics, machine and clinical recordkeeping that can be integrated with hospital EMRs.

Tablo is an all-in-one dialysis machine that combines consumer product simplicity, wireless connectivity, and real-time integrated water purification in a compact unit. Its intuitive touchscreen interface with step-by-step instructions and 3-D animations is easy to learn and use. Tablo’s independence from infrastructure enables bedside dialysis in the acute setting, saving the time and expense of transporting patients elsewhere for dialysis. Tablo’s clinical versatility and effectiveness has been shown to achieve clinical targets for clearance and volume control across a wide range of settings, while patients treating on the device have reported experiencing fewer symptoms related to dialysis.

Adaptive Dialysis with Tablo

Outside of a global pandemic, for decades, dialysis in the ICU has been primarily isolated to two modalities: continuous kidney replacement therapy (CKRT) and intermittent hemodialysis (IHD). Sustained low efficiency dialysis (SLED) therapy has been proposed as an alternative to continuous KRT since the early 2000s, with evidence supporting equivalent outcomes related to mortality, and renal recovery, and potential benefits related to cost, reduction in the need for anticoagulation and potential to mobilize patients earlier in their clinical course. It has been performed in some ICUs but has only rarely been offered alongside CKRT and IHD to allow a full complement of kidney replacement therapy options. While several possible reasons exist, the limitations of dialysis technologies have played a significant role as offering all
Therapies required at least 3 different devices and usually involved coordination of 2 different nursing groups, ICU RNs and HD RNs, as well as pharmacy and biomedical engineering staff, making this option too complex for all but the most sophisticated academic centers.

Tablo’s ability to streamline delivery of most dialysis modalities into a single device and single workflow makes the full complement of treatment times and options a reality for today’s hospital systems. With the option of hemodialysis, isolated ultrafiltration and sequential therapy (mixed HD and UF mode) therapy and the ability to use any dialyzer, the right combination of metabolic and volume clearance and the appropriate rate of removal can be achieved. Tablo allows prescribers to choose the right duration and intensity of therapy to meet each patient’s metabolic and clearance needs, while utilizing the same staff and staffing ratio to provide the treatment. Tablo utilizes consistent, familiar prescription orders to provide therapy of any duration. Whether prescribing 24-hour or 4-hour therapy, the same order set can be used for all treatments. Meaningful evidence has been generated to demonstrate that providers can realize significant operational efficiencies, including reducing the cost of their ICU dialysis programs by up to 64%.14

See Table 1, Therapeutic Capabilities of the Tablo Hemodialysis System, for full prescription ranges.

**Prescribing Intermittent Hemodialysis with Tablo**

Tablo has demonstrated, at a maximum dialysate flow rate of 300mL/min, the ability to achieve comparable clearance and clinical target adequacy in standard treatment times.6,7 At a dialysate flow rate of 300mL/min, a typical IHD prescription on Tablo utilizes a blood flow between 300–400mL/min and is typically 3–4 hours in duration. Estimated URR difference compared to higher flow rates is approximately 3–5%. For patients where additional clearance is needed, an increase in time by 15 mins. or a larger dialyzer can be utilized to achieve higher clearance goals. Unlike CKRT devices, Tablo allows thrice-weekly ICU IHD to be performed with the same device that is used for 24-hour therapy. Tablo is compatible with any commercially available high flux dialyzer and can utilize a wide range of dialysate compositions. Ultrafiltration is within 50mL/hr of accuracy and can be set as high as 2L per hour or programmed to disallow UF above a certain volume per hour to avoid inadvertently high UF rates that could impact hemodynamics.8,9

**Prescribing SLED Therapy with Tablo**

Compared to conventional dialysis devices, Tablo allows SLED to be delivered with a single device as opposed to needing a dialysis machine and a portable water filtration system. This not only has the advantage of a much smaller footprint in the normally very tight ICU setting but eliminates the complexity of managing two different devices. This has allowed ICU nursing staff at numerous hospital systems throughout the US to quickly adopt SLED therapy with Tablo and has greatly reduced, and in many cases eliminated, the additional burden SLED has previously placed on Hemodialysis nursing staff.9,12 Compared to CKRT devices, Tablo is able to achieve the clinical goals for clearance at a significantly lower cartridge cost while eliminating the complexity and cost associated with attempting to transport and hang over 60 liters of dialysate fluid for each SLED treatment. Tablo adaptive dialysis allows SLED to be performed in a more

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**1. WIRELESS CONNECTIVITY**
Two way data communication can automatically send treatment data to the cloud.

**2. TREATMENT MODALITIES**
Flexible kidney replacement therapy options including extended therapy (XT), SLED, IHD, and UF only

**3. TOUCHSCREEN GUIDANCE**
Animations and conversational instructions make Tablo easy to learn and use

**4. TABLO CARTRIDGE**
Minimizes setup and takedown time by removing manual steps

**5. SENSOR-BASED AUTOMATION**
Tablo sensors help to automate much of the setup, treatment management and maintenance

**6. DIALYSATE ON DEMAND**
Purifies water and produces dialysate in real-time

**7. MOBILITY**
All you need is an electrical outlet and tap water

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Figure 1  Tablo Hemodialysis System
Main Components and Features
Six-hour therapy can be ordered with the same dialyzer and dialysate flow rate provides consistent clearance across devices. In addition, Tablo’s sequential or “Mixed mode” therapy allows the delivered dose of metabolic clearance with SLED to be consistently prescribed and delivered while allowing ultrafiltration to be adjusted based on the individual patient’s need. For many patients, sequential therapy allows the prescription of 4-hour dialysis therapy with the predictable clearance and drug dosing that accompanies IHD treatment, then conversion to isolated ultrafiltration for whatever duration is needed to achieve volume management goals. This can be preprogrammed as part of the initial prescription or added at any time during treatment. With onboard water purification and dialysis on demand the switch between modes is immediate.

While further data is needed, the clearance of medications and removal of electrolytes during isolated ultrafiltration is considerably lower than during diffusive therapy and should greatly reduce electrolyte replacement and drug clearance variability previously encountered in SLED programs.

**Prescribing Sequential Therapy with Tablo**

Sequential therapy was developed in partnership with ICU nephrologists and early Tablo clinical sites. An identified limitation of prior therapy models, ICU kidney replacement therapy is often prescribed primarily for volume management but results in requisite metabolic clearance that may not be desirable. In clinical practice, this results in recurrent episodes of hypophosphatemia, hypomagnesemia and hypokalemia. These electrolyte deficiencies in the ICU have not only been associated with adverse events in critically ill patients but also have been associated

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Typical Tx length (hours)</th>
<th>When used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemodialysis</td>
<td>IHD 0–6</td>
<td>Hemodynamically stable</td>
</tr>
<tr>
<td></td>
<td>SLED 6–12</td>
<td>High acuity unstable patients</td>
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<tr>
<td></td>
<td>XT up to 24</td>
<td>High acuity unstable patients</td>
</tr>
<tr>
<td>UF-Only</td>
<td>0–6hr</td>
<td>Isolated volume removal in hemodynamically stable AKI or ESRD</td>
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<td></td>
<td>&gt;6hr (SCUF)</td>
<td>Slow isolated volume removal in the hemodynamically unstable patient</td>
</tr>
<tr>
<td>Sequential Therapy (Mixed mode HD and UF therapies)</td>
<td>Sequential IHD 0–6</td>
<td>Dialysis initiation in vol overloaded</td>
</tr>
<tr>
<td></td>
<td>Sequential SLED 6–12</td>
<td>Slow UF with reduction in metabolic clearance</td>
</tr>
<tr>
<td></td>
<td>XT up to 24</td>
<td>Slow UF with reduction in metabolic clearance</td>
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</tbody>
</table>

Table 1 Therapeutic Capabilities of the Tablo Hemodialysis System

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With Tablo, 10–12 hour SLED treatments can allow 2 patients to be treated with a single device per day and allow for slower ultrafiltration in highly unstable patients. Tablo’s simple take-down and set-up allow efficient transition between ICU patients, maximizing time when patients are receiving treatment and minimizing time spent in tear down, transportation and set up. Dialysate flow rates for 10–12 hour therapy are suggested to be low, as there is potential for over-dialysis with SLED therapy of this duration. A Qd of 100mL/min provides 6 liters of diffusive therapy per hour in addition to convection achieved through ultrafiltration and removal of any pre or post filter replacement fluid. Dialysate composition can often utilize a 4K bath or conversion to a 4K bath during therapy. Prescribed Total Buffer will vary based on the degree of acidosis present. Ultrafiltration is prescribed as a Total UF goal for the entire treatment, based on assessment of volume status and anticipated volume to be received. Unanticipated volume given throughout the day (blood products, medications, drips, etc.) can be added at any time to the total goal and will be removed evenly over the remaining treatment time to minimize variability in hourly volume removal and potential impact on hemodynamics.

From a standardization and drug-dosing perspective, a single device across all ICUs with a single user group offers unprecedented opportunity to simplify and protocolize SLED delivery. Tablo prescribed

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**Table 1** Therapeutic Capabilities of the Tablo Hemodialysis System

Recommended considerations for prescribing SLED in general, and more specifically with Tablo, are to strongly consider standardizing SLED treatment time and dialysate flow rate. Ideally SLED can be utilized to care for 2–3 patients with a single device per day, and dialysis times and flow rates could be protocoled to provide more predictable treatments and clearances.

Six-hour SLED treatments could potentially allow 3 patient treatments per device in one day and be beneficial in times of patient surges where demand is high; however, shorter SLED treatments may involve ultrafiltration rates that may be higher than desired in highly unstable patients (see the prior accompanying article, “Optimizing Kidney Replacement in Critical Care: SLED Can Play a Bigger Role in the ICU”, for UF recommendations). Six-hour therapy can be ordered with the same low Qb mentioned above and would be recommended to have a Qd of approximately 200mL/min to provide sufficient clearance during a 6-hour treatment. Total UF, dialysate composition and dialyzer would be patient specific and site dependent.

When ordering SLED with Tablo, the prescription stays very much the same with slower flow rates to balance the longer duration therapy and the potential for hemodynamic instability:

<table>
<thead>
<tr>
<th>Blood Flow</th>
<th>Duration</th>
<th>Dialyzer</th>
<th>Qd</th>
<th>UF</th>
</tr>
</thead>
<tbody>
<tr>
<td>150–250mL/min</td>
<td>6–12 hours</td>
<td>Any High Flux</td>
<td>100–200mL/min</td>
<td>Total volume to be removed</td>
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</tbody>
</table>

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cost effective, staff efficient manner while allowing dialysis programs to standardize the clearance achieved with SLED and maintain the clinical flexibility needed by nephrologists and intensivists to care for the critically ill.

When ordering SLED with Tablo, the prescription stays very much the same with slower flow rates to balance the longer duration therapy and the potential for hemodynamic instability:
with delays in extubation, increases in length of stay and delays in renal recovery. Sequential therapy allows prescribing of hemodialysis for the number of hours needed to accomplish metabolic clearance goals, then an automated conversion to isolated ultrafiltration mode to allow continuation of slow volume removal without additional metabolic clearance.

Prescriptions can start in either mode and switch at any point during therapy, for any duration therapy up to 24 hours. Prescription parameters such as ultrafiltration goal and blood flow can be kept constant through both modes or individualized on a per segment basis. Conversion between modes occurs automatically without nursing intervention and is recorded automatically on the treatment flowsheet for documentation purposes.

Prescribing Beyond 12 Hours

A significant benefit of adaptive therapy is the ability to span all potential treatment times. Tablo’s 24-hour therapy (XT) allows slow, continuous hemodialysis over an entire prescribing period with a dialysate flow rate of 50mL/min, providing 3L/hr of diffusive clearance in addition to convection achieved through ultrafiltration and removal of any pre- or post-filter replacement fluid. Blood flow rates remain low at 150–250mL/min. UF is prescribed as total UF with the ability to adjust as often as hourly, based on site-based protocols. Unlike traditional CKRT, Tablo XT allows on-demand rapid adjustment to dialysate sodium and buffer. This contrasts with other devices that require sterile, prepackaged dialysate which can be limited and/or require compounding in the pharmacy, lending to the potential for medication error. With Tablo, adjustments to dialysate potassium and calcium are made through simple bedside changes in dialysate concentrates, greatly simplifying the dialysate changes, compared to the process required to stop treatment, order, change, and hang liters of sterile dialysate bags every time these parameters are adjusted.

Prescribing Anticoagulation on Tablo

The Tablo system was designed to minimize the blood-air interface by efficiently removing air from the system during the automated priming sequence. This allows many treatments performed with Tablo in the acute and chronic environments to be performed without anticoagulation. Tablo does allow a manual dialyzer flush to be performed with a simple button press at any point during therapy and will account for that flush by adjusting the treatment UF goal to ensure the patient volume removal remains as prescribed. Tablo also offers the ability to prescribe recurrent scheduled dialyzer flushes at a wide range of intervals (5–60 mins) and volumes (50–200mL/flush), which will be automatically administered and adjusted for by the device. This allows prescribers additional anticoagulation strategy options outside of pharmacotherapy to minimize clotting without complicating the nursing workflow.

Tablo is compatible with heparin and has been used with regional citrate anticoagulation (RCA) as well. Heparin is typically prescribed as a bolus through the injection port on the cartridge (Tablo does not have an incorporated heparin pump) at the initiation of treatment for IHD and has been delivered as a continuous drip for longer duration therapy (see the prior accompanying article, “Optimizing Kidney Replacement in Critical Care: SLED Can Play a Bigger Role in the ICU,” for dosing suggestions). Anecdotally, RCA has been used effectively with Tablo using site-based protocols.

Final Note: Tablo’s Critical Role in the COVID-19 Response

Tablo’s unique advantages enabled providers that adopted the technology the ability to navigate a complex clinical environment compounded by surges of COVID-19-positive patients. Facilitated by its design and data capabilities, including Remote Monitoring, Tablo has helped enhance operational versatility, clinical flexibility and safety that have proven anecdotally to be invaluable in the setting of COVID-19 patient surges. Outlined below are a few examples of benefits experienced by Tablo customers responding to these unprecedented circumstances:

Highly mobile and compact, Tablo has helped providers to quickly repurpose existing locations, and enabled an increase in bedside dialysis (without needing an external RO), to deliver isolated treatments to COVID-infected patients while at the same time easing pressure on usual 1:1 patient-to-staff ratios and decreasing staff exposure—in any area of the hospital.

Step-by-step instructions and onscreen animations have allowed providers to expedite the completion of Tablo training in roughly 4 hours, and leverage the pool of nurses and technicians being freed by the reduction of elective procedures to manage and/or support treatments.

Offering a broad range of treatment modalities and enabling an adaptive approach to therapy, providers have found that by shifting from Extended Therapy (XT) to SLED in the ICU has helped balance the individual patient need with the increased demand for treatments, machines and supplies.

Tablo’s Remote Monitoring capability has enabled nurses to manage critical treatment parameters remotely, from an online dashboard accessible through any connected device, thereby ensuring staff safety and reducing PPE use, while maintaining a high quality of patient care.

Summary

Specifically designed to simplify dialysis treatment for patients and providers, the Tablo Hemodialysis System is a first-of-its-kind enterprise solution that is approved for use across the entire continuum of care—from hospital to home. Capable of providing dialysis of any duration for any level of patient acuity, Tablo allows physicians and hospitals to expand their clinical capabilities to include 24-hour and intermediate-duration SLED therapies, without the cost and complexity that has typically accompanied this type of expansion.

Prescribing on Tablo is familiar and consistent across all therapeutic ranges, with an adaptive dialysis model that allows achievement of metabolic clearance and volume management goals in single-mode or mixed-mode therapies which can help standardize prescribing and potentially minimize the complexity of electrolyte replacement and drug dosing in ICU kidney replacement. The Tablo Hemodialysis System’s adaptive therapy model allows clinicians and facilities the opportunity (even under the pressures of the COVID-19 pandemic) to expand their current KRT capabilities while reducing cost and potentially reducing complications and outcomes in patients requiring KRT in the ICU.

References


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