Using Technology to Inform and Deliver Precise Personalized Care to Patients With End-Stage Kidney Disease

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Summary: Consistent with the increase of precision medicine, the care of patients with end-stage kidney disease (ESKD) requiring maintenance dialysis therapy should evolve to become more personalized. Precise and personalized care is nuanced and informed by a number of factors including an individual's needs and preferences, disease progression, and response to and tolerance of treatments. Technology can support the delivery of more precise and personalized care through multiple mechanisms, including more accurate and real-time assessments of key care elements, enhanced treatment monitoring, and remote monitoring of home dialysis therapies. Data from health care and non−health care sources and advanced analytical methods such as machine learning can be used to create novel insights, and large volumes of data can be integrated to support clinical decisions. Health care models continue to evolve and the opportunities and need for novel care approaches supported by technology and health informatics continue to expand as the delivery and organization of health care changes. Ultimately, precise personalized care for ESKD, including dialysis therapy, will become more feasible as the biological, social, and environmental determinants of health are more broadly understood and as advances in science, engineering, and information management create the means to provide truly precise care for ESKD.
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Nephrologists aspire to deliver precise personalized care for individuals with kidney disease. What defines precise personalized care? First is the concept of care, which delineates what is necessary for the health, welfare, maintenance, and protection of an individual. Personalized care is intended to meet the unique individual needs of a patient and precise care requires that diagnosis and management be exact and accurate. Precise personalized care is more than greater diagnostic precision and classification of kidney disease states—precise personalized care individualizes care to meet each patient's unique needs and goals based on augmented knowledge and a greater understanding of the individual.

Precision medicine is understood to be "an approach for disease treatment and prevention that takes into account individual differences in lifestyle, environment, and biology."[1] Precision medicine continues to evolve with the laudable goal of providing treatment that is tailored to each individual and informed by numerous factors and interactions including genetics, physiology, and social and environmental factors.[2] Despite the significant gaps in our understanding of how these factors interact to influence kidney disease, there are a number of opportunities to individualize care for patients with end-stage kidney disease (ESKD) requiring dialysis and to use technology and data to support more precise and personal care.

TECHNOLOGY AND PRECISE PERSONALIZED CARE IN NEPHROLOGY

A significant amount of time is spent receiving dialysis and care related to complications of ESKD, with approximately 10% of a person's time devoted to preparing for and undergoing in-center hemodialysis. It is well recognized that the treatment of ESKD with dialysis, whether in-center or at home, can be a tremendous burden for patients, their families, and caregivers. Precise personal care in patients with ESKD requires an understanding of the individual patient, family/caregiver, community, and health care needs at that moment in time and the flexibility to accommodate change over time. Hence, the delivery of precise and personalized care is multifaceted and technology can support the application of this approach in patients with ESKD through multiple mechanisms including facilitating the optimal site for dialysis services (eg, home, in-center, or self-care) and providing more accurate and real-time assessments of key care elements (eg, hemodynamic and volume measures, electrolytes).

In-center and home dialysis are evolving to allow for greater autonomy and personalization, in part supported by technologic advances in dialysis machines.[3-5] In-center hemodialysis models are expanding to expect and support more participation by patients in full or partial self-care,[6] encouraged by the emergence of more intuitive dialysis device technology that can support,

train, and enhance a patient's participation in their own care.[7-9] Intuitive user interfaces and connected health devices that electronically transmit physiologic data (eg, temperature, blood pressure, heart rate, and weight), treatment information, and diagnostics, and allow for centralized patient monitoring with remote adjustment of the dialysis prescription, are finding their way into the home dialysis paradigm.[3,10] Such features and functionality contribute to more precise and personalized care and can lessen the burden of home dialysis. Recently, the US Food and Drug Administration approved one device for solo home dialysis therapy, allowing the patient to fully manage and monitor their home hemodialysis treatment without caregiver support.[5] Telehealth and technologies to support remote patient monitoring and management in the home dialysis setting are garnering greater attention and focus in the nephrology community.[10,11]

To personalize the dialysis prescription, more real-time patient-specific diagnostic data are needed at the time of dialysis and point-of-care (POC) testing, which may be particularly beneficial in the setting of acute symptoms, high-risk clinical conditions, or after hospitalization. Innovations and advances in POC testing heighten the likelihood for broader use in ESKD care. As an example, a POC test that can be administered in the home has been developed to identify peritonitis.[12] Current technology allows for online monitoring of hematocrit level and oxygen saturation during the dialysis treatment.[13,14] Accurate online electrolyte monitoring (eg, potassium) may be possible as microsystem technologies advance.[15] The further development of implantable nanosensors ($<1\ \mu$m circulating or anatomically fixed in vivo sensors) may provide an alternative mechanism for real-time physiologic monitoring.[16]

Accurate volume assessment is central to the care of patients receiving dialysis. Devices can be used in the assessment of fluid status, including bioimpedance spectroscopy to measure extracellular volume, chest ultrasound to assess excess fluid in the lungs, and ultrasound of the inferior vena cava to evaluate intravascular volume.[17-19] Device technology has been developed that can help guide volume removal during each hemodialysis treatment and can provide insight into the individual hemodynamic response. These instruments can be connected to the dialysis machine with an alerting mechanism that influences the volumetric controls of the machine.[13] Optimal volume management may require a combination of devices to achieve more precise volume assessment and ultrafiltration.[17]

The potential role for wearable sensors in the care of patients with ESKD continues to expand with miniaturization and advances in technology.[20] A number of important wearable sensors including cuffless blood pressure monitors and unobtrusive ECG monitors are in various stages of development and real-world application.[20] As wearable sensors continue to advance, there will be greater opportunity to integrate information from these instruments into the care of patients with ESKD: more detailed and complete information on blood pressure, cardiac rhythms, and physical activity may provide the opportunity for individualized disease management or closely monitored rehabilitation.[20]

Precise and personalized care will require a greater understanding of how to use patient-reported symptoms to improve clinical outcomes. Routine computer- or tablet-based collection of patient-reported symptoms coupled with reports at clinic visits and an alerting system was associated with better outcomes in patients with cancer receiving chemotherapy.[21,22] The systematic collection of patient-reported symptoms with integration of the information into clinical care processes may be an opportunity to improve ESKD care.

In summary, the ongoing advances in device technology may create pathways for greater autonomy and self-care and personalized treatment based on accurate and timely assessment of clinical parameters. Ideally, further advances in technology would allow for truly individualized dialysis prescribing. Conceptually, the future model of care would include the use of POC clinical parameters, information on prior dialysis tolerability, and medical history to generate an individualized dialysis prescription before each treatment; and real-time monitoring with a feedback loop would allow for continuous adjustment of the dialysis prescription throughout therapy (Fig. 1). As the field continues to advance, the potential opportunities for technology integration will expand within the home and in-center hemodialysis settings. Importantly, further research and evidence will be needed to truly understand and delineate the impact and benefits of using more advanced telehealth and specific technologies in the care of patients with ESKD.[10,11,23]

USING DATA TO CREATE NOVEL INSIGHTS THAT DRIVE DELIVERY OF PRECISE PERSONALIZED CARE

The aspiration of precise personalized care in the context of the broader evolution of precision medicine presents the Nephrology community with a unique opportunity to use the high volume of data generated and collected as part of routine ESKD care to drive care improvements. The traditional definition of big data includes the three domains of volume, variety, and velocity,[24] and in dialysis care these domains are supplemented by patient-specific information collected longitudinally at predefined intervals throughout the clinical course of dialysis.

Few fields in health care have the same prospect to gain insight from this type of routine health care data collection and structure. As an example, Fresenius Medical Care North America has accumulated data on more than 1.1 million dialysis patients, including more than 1