CKD is a common illness across societies, affecting an estimated 13% of the population worldwide (1). The prevalence of CKD is thought to be rising, likely due to a combination of an aging population and increases in comorbid chronic conditions—such as obesity, diabetes, and hypertension—that contribute to its pathogenesis. In the United States, the prevalence of CKD is estimated at nearly 15%, and Medicare spent $114 billion on CKD and ESKD in 2018 (2). Whereas studies indicate that early referral to nephrologists may improve outcomes in CKD, many patients do not see nephrologists until late in the course of their disease. Barriers to early referral include geographic remoteness, with patients living far from available nephrologic care, and difficulties in traveling due to the burden of comorbidities (3-6). Rural patients with CKD have been found to have poorer quality-of-care markers, including timely measurement of urinary albumin excretion and appropriate use of angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, and experience a greater risk for hospitalization and all-cause mortality than urban patients with CKD (5,6).

Telemedicine, a video-based healthcare delivery technology, has the potential to attenuate these disparities and has been used in multiple chronic illnesses, including heart failure, diabetes mellitus, and chronic obstructive pulmonary disease. Although the approach is not appropriate for all encounters, nephrology is, in many ways, particularly suited for telemedicine. The longitudinal follow-up of patients with CKD is heavily dependent on repeat laboratory evaluations and detailed history taking. Although questions regarding changes in weight or edema can be critical, the majority of visits do not center on extensive physical examinations. Similarly, patient appointments for the management of hypertension are typically focused on reviews of BP logs and office measurements of vital signs, whereas encounters for nephrolithiasis involve appraisal of laboratory evaluations and diet history. When conducted in concert with a dedicated nurse or other telemedicine healthcare provider on the patient side, management of these conditions often does not require a face-to-face visit with a physician. There are, however, clear exceptions. Patients with rapidly progressive renal disease (and in particular those who would benefit from evaluation of urine microscopy) should always be seen for an in-person visit. In addition, many providers prefer (and often require) that patients be seen face to face for their initial consult visit. Whereas the potential for the application of telemedicine to the care of renal transplant patients and those patients with ESKD on both peritoneal and hemodialysis is beyond the scope of this review, adaptation of telemedicine to these venues is critical and has been appraised elsewhere (7,8).

Telemedicine may take a variety of forms. Using website-based platforms and applications, primary care physicians may be remotely connected to specialists via videoconferencing for consultation, nephrologists at specialized care facilities may remotely see patients in primary care offices, website-based monitoring devices can be used to collect physiologic data (such as BP and weight), and patients may even be seen for a virtual visit directly from their homes (9). Initiatives such as the Specialty Care Access Network–Extension for Community Healthcare Outcomes allow nephrologists and other specialists to provide educational sessions for primary care providers (PCPs) in rural or distant locations (10). Interest in applying technology to the care of patients with CKD is escalating commercially and clinically, with a recent review finding at least 28 distinct smartphone applications targeting patients with CKD (11). Depending of the specific modality under consideration, multiple factors may affect the logistic feasibility of establishing a telenephrology program for the management of CKD, including equipment cost and availability, local regulations, and practice-specific information technology resources. Regardless of the means by which patients are seen, Health Insurance Portability and Accountability Act of 1996 compliance regulations require implementation of appropriate safeguards for patients’ protected health information. At a minimum, such protections entail encrypted internet access, assurances video transmissions are not stored unless specifically and preemptively requested by the provider, authentication- and password-protected access control, and the provider potentially signing a business associate agreement.

Within the broader context of telemedicine, telehealth refers to the direct provision of remote healthcare. This can involve synchronous encounters (interactive videoconferencing or phone consults) and asynchronous systems, such as website-based electronic consultations/advice platforms and text messaging.
Clinical video telehealth (CVT) is the most common form of telehealth and frequently takes the form of specialist physicians seeing patients located in other offices for real-time, interactive, video teleconferencing. In our experience, this modality is perhaps the most readily adoptable introduction to telehealth. For patients, although they will not be seen face to face by their primary provider, the act of going to a medical office and interacting with staff can be familiar and comforting and help allay concerns that new technology will disrupt the doctor-patient relationship. From a provider’s perspective, initiating tele nephrology via an office-based model provides reassurance that patients will still be seen in an orderly and timely manner while surrounded by medical support staff. A videoconference monitor is kept in the physician’s office and a second monitor, variably enhanced with accompaniments—such as a high-resolution mobile digital video camera, stethoscope, and ultrasound probe—is located remotely in the patient examination room. A health technician trained in telenephrology is located with the patient and is available to measure vital signs and assist the physician, as needed, with remote physical examination.

In the United States, the Veterans Health Administration (VHA) has been one of the earliest and most widespread adopters of telehealth and CVT. The VHA is the largest integrated healthcare system in the United States, providing care at 1255 healthcare facilities, including 170 Veterans Affairs (VA) Medical Centers and 1074 outpatient sites to >9 million veterans (12). Roughly 36% of VA patients reside in rural communities (as compared with 19% of the overall US population) and suffer from high rates of comorbidities that make travel difficult. The nationally integrated Computerized Patient Record System allows for seamless access to remote records and, although physicians need to be credentialed at both patient and provider sites, they can see patients in multiple states without requiring separate state medical licenses by working within the VA system. The VHA is thus uniquely requiring of, and strategically positioned to provide, CVT. In 2016, 12% of veterans received elements of their care via telehealth, spanning >50 specialty areas of care. More than 307,000 veterans used CVT, with >150,000 using Home Telehealth (13).

One of the pioneering sites for telenephrology has been the James J. Peters VA Medical Center (JJPVAMC) in the Bronx, New York, where Tan et al. (14) studied the effect of tele nephrology on the adherence to appointments by patients with CKD along with its effect on clinical outcomes. The JJPVAMC serves as the primary referral center for the Hudson Valley VA Medical Center but is located 65 miles away. In response to a “no show” or cancellation rate of 53% for nephrology referrals, JJPVAMC instituted a CVT program in 2011. Over the subsequent 3 years, 112 patients from Hudson Valley were seen via CVT telenephrology, with a reduction of the no-show or cancellation rate to 28%. When compared with 116 patients seen for face-to-face consults and follow-up at JJPVAMC, there was no difference over 2 years follow-up for a composite end point of death, ESKD, or doubling of serum creatinine (P=0.96). In addition to increased patient adherence, significant financial savings were realized because travel distance for patients was reduced by 50% with patients not having to commute to the Bronx.

Whereas the study by Tan et al. required patients to come to the Hudson Valley VA Medical Center to connect to JJPVAMC via CVT, Ishani et al. (15) conducted a randomized, prospective trial testing whether patient-to-provider, home-based telemedicine improved clinical outcomes in CKD as compared with standard care. A total of 561 patients from the Minneapolis VA Health Care System were identified with an eGFR of <60 ml/min per 1.73 m². Patients were assigned in a 3:1 ratio to receive intensive home tele nephrology, via a touchscreen computer, delivered by a robust, interprofessional team that included a nephrologist, nurse practitioner, nurses, clinical pharmacy specialist, psychologist, social worker, and dietician, or usual care. The delivered telenephrology was augmented by peripherals, such as home BP cuffs, pulse oximeters, stethoscopes, and glucometers, but, after 1 year, no difference was seen in the primary composite end point of death, hospitalization, emergency-room visits, and admission to a skilled nursing facility. The authors did note there was a trend toward a lower incidence of the primary outcome in the intervention group for rural patients, but that the study was not powered to definitively demonstrate this.

In addition to the VHA, telenephrology for the management of CKD has also been used by the Indian Health Service (IHS). Rates of both diabetes and CKD are high among IHS patients, but access to nephrologists is often limited in rural communities. Narva et al. (16) examined a program established to allow nephrologists located at the National Institutes of Health (NIH) in Bethesda, Maryland to delivering care to patients at the Zuni Comprehensive Health Center, located 150 miles west of Albuquerque, New Mexico. Beginning in 2007, a program was established where patients from an exam room at the Zuni Indian Hospital would be seen remotely by a nephrologist located at the NIH during a twice-monthly clinic. There was no specific eGFR threshold a patient had to meet to be referred, but referring physicians were strongly advised to complete a form documenting data on eGFR trends, albuminuria, presence of diabetes, screening laboratory measures, and medications. Over 9 years, 1870 visits were conducted. During this period, 44 patients were referred for initiation of dialysis. Whereas data is not available comparing hard outcomes with a control group, this program demonstrated the feasibility of connecting nephrologists to a large number of patients with CKD who otherwise would likely not have received specialized care.

Outside of the United States, Australia has long been a pioneer and leader in telehealth in general and telenephrology due to its expansive rural areas and great distances between population centers. Venuthurupalli et al. (17) investigated the effect of telenephrology on CKD care at a referral hospital in Queensland. All patients over a 6-year period seen in the renal clinic (prevalent and incident) residing ≥50 km away were offered follow-up care through video teleconference (TC), accessed at their local hospital or clinic. A total of 234 (referred to as “almost all”) patients agreed to be seen via TC, and outcomes were compared with 817 historic controls. Patient experience with TC was very positive, with >98% of those being seen expressing a preference to continue to be seen in this manner once enrolled. There were few differences between the groups in regards to demographics or comorbidities, although the TC groups...
exhibited a higher prevalence of diabetes, diabetic nephropathy, and arthritis. Compared with controls, patients receiving care via TC demonstrated increased adherence to appointments and a greater likelihood of visit accompaniment by a family member or caregiver. Over the course of the study, patients seen via TC had a statistically significant reduction in incident RRT (2.0 versus 3.5 cases per 100 patient-years) and overall mortality (4.5 versus 5.3 cases per 100 patient-years). The number of hospital admissions per patient trended lower in the TC group, 1.63 versus 2.25, but did not reach statistical significance. Patients seen via TC lived an average of a 417-km round trip from the referral hospital and thus benefited from significant reductions in travel time and cost by being seen remotely from local facilities.

In The Netherlands, Scherpbier-de Haan et al. (18) studied website-based nephrology consultations between PCPs and hospital-based nephrologists. After receiving a consult question containing abstracted clinical and laboratory data, the nephrologists could either reply to the question, request additional data, or recommend that the patient be sent for an in-person evaluation. A total of 122 consults were placed, with PCPs identifying 43 (35%) of them as patients that would have been referred for consultation absent the website-based option. Critically, after evaluating the consultation, nephrologists determined that only seven of the 43 (16%) would actually have required such an evaluation. In addition, of the 79 patients where PCPs would not have otherwise placed a consult, nephrologists determined that in ten of the 79 (13%), such a referral would have been appropriate. These data suggest that even when a face-to-face nephrology consult is indicated, prior screening via telemedicine can more accurately triage patients appropriately. A second, much larger study on approximately 3000 patients in The Netherlands did not find any difference in referral rates for face-to-face nephrology consults when general practitioners were randomized to first use or not use a new electronic consult system, but overall referral rates were much lower than anticipated and the trial may have been underpowered (19). The utility and challenges of telenephrology have also been explored in Jordan, France, and Chile (20–22).

Over the past 6 months, the burgeoning field of telehealth has undergone the catalyptic challenge of adapting, on the fly, to unprecedented disruptions in world healthcare systems engendered by the coronavirus disease 2019 (COVID-19) pandemic. An extraordinary number of providers were forced to adopt telehealth almost overnight, with a mandate to provide high-quality and safe care during a period of extreme uncertainty and upheaval. In light of the temporary closing of many offices, the model of delivering telehealth to the home via remote provider visits has experienced a rapid increase in utilization, and data on outcomes associated with it are under intense study, although few results are yet available. Chen et al. (23) developed a cohort in China of 1164 patients with CKD who had received a kidney biopsy between 2017 and 2019. At the beginning of the COVID-19 pandemic, 82% were being seen for regular follow-up, and 45% were being treated with immunosuppression. Face-to-face clinic visits were interrupted in 836 (72%) patients. As a result, 60%, 67%, and 27% of patients reported difficulties in laboratory examinations, medicine adjustments, and medicine purchases, respectively. In an attempt to maintain follow-up, 255 patients (22%) used telemedicine, including 122 patients (10%) using video telehealth visits, 62 (5%) using instant messaging tools, 48 (4%) using telephone consultation, and 23 (2%) using email. Approximately 80% of telemedicine users were generally satisfied with the experiences. In contrast to much pre-COVID-19 data, the utilization of telemedicine was not statistically associated with the patients’ location (urban versus rural), nor was it affected by sex, age, or education. In patients receiving immunosuppressive treatments, 32% partook in a telemedicine experience compared with 17% of patients not receiving immunosuppression (P<0.001).

Spurred by changes wrought by COVID-19, telehealth is likely to have an expanded and permanent role in many, if not most, nephrology practices going forward. Nevertheless, several hurdles exist to widespread adaptation that must be overcome before telehealth is fully integrated into clinical practice. These barriers can be designated into three broad categories: (1) clinical/societal, (2) legal/privacy/security, and (3) reimbursement. Advantages and challenges of telenephrology are shown in Table 1.

**Societal/Clinal Barriers**

For thousands of years, the distilled essence of the practice of medicine has been the physician, as confidant and healer, laying hands upon a patient. It is not hyperbole to call the uncoupling of this relationship via telehealth profoundly revolutionary. It will be critical to acknowledge the difficulty some providers and patients may have in using the new technology, and in accepting telehealth visits as legitimate replacements for traditional face-to-face interactions. For some patients, such as those with impaired hearing, being seen remotely may never be able to fully replicate an in-person office visit. Nonverbal cues may not be picked up on camera for the provider to notice and address. In addition, it takes practice for the provider to consistently look at the camera rather than at the video screen or around the room. Such a technique is critical, however, to maintain “eye contact” and convey a sense of physical presence to the patient, even at a distance. Such challenges need not limit the adaptation of telehealth, but will require understanding and patience on behalf of providers and patients. To assuage public concerns about any diminution in quality of care associated with a conversion to telehealth, the development and adaptation of accurate quality-assessment measures (24). Such efforts should be enthusiastically embraced and expanded upon. Care should be taken to ensure continuity between patients and providers to the greatest extent possible. It is likely that physician uptake will not initially be universal, with providers coming to telehealth over time due to the specifics of their practices and workflow. Older patients who are perhaps less comfortable and familiar with technology may prefer traditional visits. However, such generalizations may no longer be appropriate in the era of COVID-19, when caution dictates attempting to minimize exposure of the elderly to healthcare settings.
Table 1. Advantages and challenges to telenephrology

<table>
<thead>
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<th>Advantages to telenephrology</th>
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<tr>
<td>Improved access to specialized care in rural or remote areas</td>
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<tr>
<td>Improved access to care for patients with limited mobility and transportation barriers</td>
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<tr>
<td>Savings in time and expense via reduced travel</td>
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<td>Reduction in requirements for limited clinic space allows for an increased number of providers and reduced wait times for visit scheduling</td>
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<tr>
<td>Ability to maintain continuity of care during COVID-19 pandemic and environmental disasters</td>
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<tr>
<td>Increased patient engagement and ownership with own healthcare via mobile applications</td>
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<td>Opportunity for education and professional engagement with PCPs via SCAN-ECHO</td>
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<th>Challenges with telenephrology</th>
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<tr>
<td>Necessary alteration to doctor-patient relationship</td>
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<tr>
<td>Limited ability for physical exam</td>
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<td>Lack of standardization in cross-state and facility licensing and credentialing</td>
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<tr>
<td>Incomplete options for dedicated telemedicine coding</td>
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<tr>
<td>Uncertain malpractice and legal frameworks</td>
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<tr>
<td>Security of data and synchronous communications</td>
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<tr>
<td>Challenging for patients with hearing or visual impairments</td>
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<td>Costs and time required to acquire and train on equipment</td>
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COVID-19, coronavirus disease 2019; PCPs, primary care providers; SCAN-ECHO, Specialty Care Access Network—Extension for Community Healthcare Outcomes.

Privacy/Security/Legal Barriers

As the generation and transmission of remote data becomes more commonplace, concerns about data security and the potential for liability will necessarily increase. Patient privacy and confidentiality must be protected, but in a way so as not to render telemedicine encounters unduly cumbersome or impractical. In much the same way that the US healthcare system as a whole lacks standardization, guidelines and requirements for telehealth security and privacy are discordant between federal and state regulatory bodies (25). Multiple entities have proposed administrative, physical, and technical safeguards to enhance security, but a piecemeal adaptation during this inchoate period risks the inauguration of an unworkable patchwork of regulations (26,27). With telemedicine still in its infancy, it remains possible to envision the establishment of a comprehensive national policy governing security, privacy, and confidentiality standards for telemedicine (28). It will be critical to develop such a consensus guideline before the disparate standards becomes too entrenched.

There is currently no standardized practice regarding liability insurance for telehealth practitioners, and insurance providers have often extended coverage on a case-by-case basis. To date, most liability carriers lean toward using the physician’s state of licensure rather than the patient’s location, when they are discordant, to define coverage. With little legal precedence, providers seek guidance as to whether malpractice insurance will cover telemedicine and the extent to which such coverage will affect malpractice rates. In the face of this uncertainty, physicians responded to a recent American Medical Association survey that liability coverage was a “must have” for adoption of telehealth (29). Because telehealth service delivery frequently crosses state lines, telehealth providers are potentially confronted with the extremely burdensome need to fulfill licensing and credentialing requirements for each state and facility in which they “see” patients. In 2013, the Interstate Medical Licensure Compact was enacted to increase the efficiency in multistate licensing of physicians (30). Currently, 27 state legislatures have enacted the compact into state law, enabling their participation in the Interstate Medical Licensure Compact, while two additional states have passed it through the legislature but have not yet implemented the compact (31).

Reimbursement Barriers

The majority of telehealth utilization before COVID-19 was in single-payer health organizations, either internationally or in the United States through VA or the IHS. A major reason for delayed uptake in the private insurance sector has been concerns regarding reimbursement. Providers have sought data assuring a return on the initial financial investment involved in establishing a telehealth program. Such a return could be realized either through increasing intake (improved efficiency, recruiting new patients, increasing number of patients visits), or by decreasing outlays (reduced overhead, improving outcomes with a resulting decrease in costly emergency-room visits and hospitalizations). Crucially, Medicare has, in response to COVID-19 and under the Coronavirus Aid, Relief, and Economic Security Act, waived the requirement for the use of video technology in the provision of telehealth, thus allowing full reimbursement for telephone visits for evaluation and management visits, behavioral health counseling, and educational services (32). In addition, the Act waived requirements regarding the types of healthcare professionals that can provide telehealth services so as to include all those eligible to bill Medicare for their professional services. Although adjustments to these practices will surely be made once the COVID-19 crisis has abated, it will be critical that
the Centers for Medicare and Medicaid Services continue working to adjust coding and billing requirements to meet the new telehealth world (33). With an overall movement toward value-based reimbursement, systematic data collection will be critical to document the economic advantages of telehealth in both fee-for-service and value-based models of care and payment (34–36).

Telenephrology, via multifaceted and innovative modalities, is poised to revolutionize the care of CKD and the means by which it is delivered. For many future patients with CKD, obtaining care from a nephrologist will not involve traveling to a specialty clinic, nor, in many instances, even necessitate leaving their homes. The potential benefits of this revolution in regards to the quality, efficiency, and access to care are immense. Challenges remain, and providers and patients are to be commended for adapting, on the fly, during the extraordinarily challenging time of the COVID-19 pandemic. Despite hurdles, remote management of CKD is poised to continue expanding across practice settings, with the potential to improve access, satisfaction, and outcomes for patients and their providers.

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Author Contributions

J. Belcher wrote the original draft.

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