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Home monitoring of patients with chronic kidney disease

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The increasing prevalence of chronic kidney disease (CKD) is placing a growing burden on healthcare systems, which results in considerable economic and environmental challenges. Sustainable CKD care and optimization of patient outcomes requires a new approach to the organization of healthcare systems, in which home monitoring will have a pivotal role.

The current global prevalence of chronic kidney disease (CKD) is approximately 10%, of which 0.3% comprises patients with CKD stage 5 or kidney failure treated by dialysis¹. The number of patients who require resource-intensive kidney replacement therapy is increasing, partly owing to the increasing prevalences of diabetes and obesity as well as ageing of the population, which places a growing burden on healthcare systems. In particular, in-centre haemodialysis is associated with considerable economic challenges and an exceptionally high environmental impact².

Advances in technology and improvements in the reliability of monitoring platforms facilitate home monitoring of patients with chronic diseases. The COVID-19 pandemic led to an increased application of eHealth modalities and greater awareness of the need to avoid exposing vulnerable patients to unnecessary clinic visits. Patients with advanced CKD are a vulnerable group who are prone to comorbidities, including cardiovascular disease. These patients represent an important target population for home monitoring.

The close monitoring of kidney function is required for patients with advanced CKD and recipients of kidney transplants. Various advances in point-of-care testing in standard clinical practice facilitate home-based testing. For example, the results of immunosuppressant drug monitoring using capillary blood samples collected from finger pricks via dried blood spot methods or volumetrically accurate micro-sampling collection devices showed a good correlation with results obtained using whole-blood venous samples³. Sweat analysis could serve as an alternative to blood analysis to detect abnormalities in serum electrolyte levels, although adjunct strategies such as pilocarpine induction are necessary to provide more reliable estimates⁴. Developments in flexible biochemical sensors are promising but these devices have not yet been applied in clinical settings. At-home urine analysis using dipsticks is a well-established, simple and feasible method for the detection of proteinuria and haematuria. The use of smartphone-integrated technology to analyse these tests eliminates the need for individual interpretation and leads to more

accurate results⁵. Management of blood pressure and fluid status is already widely supported by monitoring with simple digital sphygmomanometers and weighing scales. Progressive advances in micro-electronics now enable multiparametric continuous monitoring using wearable devices, which can combine various techniques including photoplethysmography (PPG), electrocardiography (ECG) and bioimpedance.

PPG is a well-known optical technique to monitor heart rate by measuring volumetric changes in the peripheral blood circulation. This technique is now used in commercially available wearable devices together with dedicated algorithms to screen for atrial fibrillation⁶. Assessment of the pulse propagation velocity is a promising approach to obtain cuffless blood pressure measurements. As this technique provides relative measures, calibration using a conventional blood pressure monitor is still required. Continuous tracking of blood pressure could aid in the prevention of burdensome symptoms of hypotension such as dizziness and fainting as well as more critical effects such as organ hypoperfusion.

Wearable devices also enable recording of single-lead ECG and bioimpedance spectroscopy data. Non-invasive screening for hyperkalaemia based on two-lead ECG recordings is possible by applying deep-learning algorithms⁷. Validation using ambulatory ECG monitoring is required to develop models for single-lead ECG data and make this approach a feasible option to support dietary management or other interventions for prevention and treatment of hyperkalaemia. Longitudinal bioimpedance spectroscopy could be used to provide insights on total body water and fluid shifts during interdialytic intervals. These data might empower patients to effectively manage their fluid status between dialysis sessions. In addition, data on longitudinal trends in extracellular fluids could be used to help to fine-tune ultrafiltration volumes during dialysis.

In the future, digitization of patient data enabled by home monitoring will have a pivotal role in healthcare. A platform in which physiological and behavioural data are assembled and visualized would provide an objective overview of the health status of a patient (a digital phenotype), which is required to enable increased use of home-based care. Longitudinal data collection enables advanced predictive analytics by machine-learning techniques to facilitate personalized medicine. The transition to a more digitized approach to healthcare entails the risk of false-positive detection of events (such as atrial fibrillation), which may potentially induce patient anxiety and unnecessary interventions, as well as liability issues that arise from signals that are 'missed' by caregivers. However, a systematic review of patient experiences and expectations regarding remote monitoring in a range of chronic diseases reported enhanced awareness and knowledge of the diseases as well as increased self-management and shared decision-making⁸. From a technological point of view, devices should be user-friendly, robust and as simple as possible to ensure safe usage

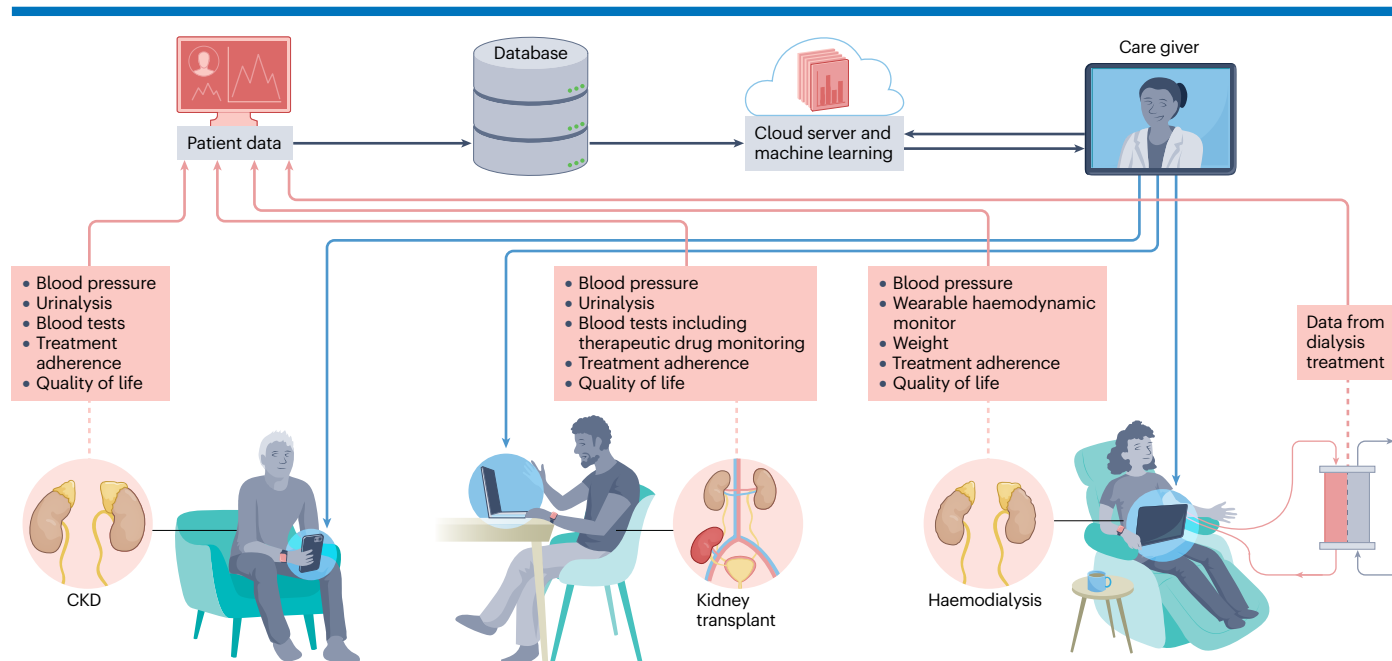


Fig. 1 | Home monitoring of patients with chronic kidney disease. Overview of current and advancing techniques for remote monitoring in the home setting of patients with chronic kidney disease (CKD) at different stages of the disease,

and the processing of the obtained data to optimize their use for the interaction of patients and their caregivers.

and alleviate the concerns of patients regarding their proficiency with the technology.

The assimilation and processing of remotely obtained data can provide a detailed representation of a patient's health status (Fig. 1). For example, data on physical activity measured by an accelerometer together with the average action radius detected using the GPS signal of a smartphone can provide an objective indication of the physical state and societal participation of a patient. Data from wearable devices and patient-reported outcomes could be represented in a dashboard that could be accessed by the patient and their caregivers and used to help to direct clinical interventions to improve outcomes that are important to the patient. This type of data visualization could also help to target lifestyle approaches to slow disease progression and optimize treatment outcomes. Artificial intelligence-based personal health assistants integrated into smartphones could further empower patients in their self-management and potentially aid transitions towards home dialysis⁹.

In the past few years, technological advances have enabled the tracking of biological and lifestyle-associated parameters that are relevant to the management of CKD. The design of appropriate infrastructure to collect the resulting high quantities of data and translate them into clinically meaningful information is becoming a major priority. When implementing such infrastructure, it is crucial to minimize intrusion on patient privacy, especially when using continuous home monitoring, and to guarantee safe and secure storage and transfer of data¹⁰.

Sustainable CKD care requires a different organization of our healthcare system, in which home monitoring will have a pivotal role. This approach will not only benefit patients with CKD, but also aid in the transition towards more sustainable healthcare with minimal environmental impact and help to address the growing challenge of a shortage of healthcare personnel by enabling home-based management of chronic diseases.

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Competing interests

The authors declare no competing interests.