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REVIEW

Advances in Human-Centered Care to Address Contemporary Unmet Needs in Chronic Dialysis

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Abstract: Advances in the treatment of kidney failure with chronic dialysis have stagnated over the past three decades, with over 50% of patients still managed by conventional in-hospital haemodialysis. In parallel, the demands of chronic dialysis medical care have changed and evolved due to a growing population that has higher frailty and multimorbidity. Thus, the gap between the needs of kidney failure patients and the healthcare capability to provide effective overall management has widened. To address this problem, healthcare policy has increasingly aligned towards a human-centred approach. The paradigm shift of human-centred approach places patients at the forefront of decision-making processes, ensuring that specific needs are understood and prioritised. Integration of human-centred approaches with patient care has been shown to improve satisfaction and quality of life. The aim of this narrative is to evaluate the current clinical challenges for managing kidney failure for dialysis providers; summarise current experiences and unmet needs of chronic dialysis patients; and finally emphasise how human-centred care has advanced chronic dialysis care. Specific incremental advances include implementation of renal supportive care; home-assisted dialysis; hybrid dialysis; refinements to dialysis methods; whereas emerging advances include portable and wearable dialysis devices and the potential for the integration of artificial intelligence in clinical practice.

Keywords: patient-centred care, chronic dialysis, kidney failure, patient preference, renal replacement therapy, innovation

Introduction

Since the advent of haemodialysis and peritoneal dialysis, innovations in chronic dialysis technology and care in patients with kidney failure have been incremental.[1] Additionally, such innovations have been unable to address the increasing care needs of a larger chronic dialysis patient population with higher morbidity and mortality.[2] Studies have consistently shown that dialysis patients have a significantly reduced quality of life compared to kidney transplant recipients and the general population.[3,4] Despite chronic dialysis patients constituting less than 1% of the general population, they require a disproportionate amount of healthcare funding.[5,6] To address this major clinical problem, healthcare systems and the nephrology community have pivoted towards human-centered care (involving renal supportive care) to better address needs while simultaneously developing dialysis technologies that improve quality of life.[7]

The aim of this narrative review is to evaluate the current clinical challenges for managing kidney failure by dialysis providers; summarise current experiences and unmet needs of chronic dialysis patients; and finally emphasise the importance on how human-centred care, leading to advances in chronic dialysis care. As this area is only in the early stages of development with limited evidence, the goal is to demonstrate how these human-centred innovations could potentially establish new care models that facilitate home-based dialysis, promote increased patient independence, and reduce symptom burden. Given major differences in global and regional differences, the content of the review will focus on a high-resource healthcare setting and clinical pathways from an Australian perspective.[8–10]

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Methods

To undertake this narrative review, databases including MEDLINE (OvidSP) and EMBASE (OvidSP) were searched on the 23rd of September 2023 using the following relevant search terms: kidney failure, dialysis, innovations, human-centred care, patient-centred care, technology, patient priorities, patient choice, renal replacement therapy, home-based dialysis, and quality of life. Reference lists of review articles, grey literature, and clinical practice guidelines were also reviewed. A total of 246 articles were screened initially, with 143 articles reviewed in full and 121 included in this review. Studies were excluded if they could not be translated into English, did not focus on human-centred innovations, or if they were not relevant to the dialysis population.

Current Clinical Challenges of Managing Kidney Failure for the Dialysis Provider

Growth of the Chronic Dialysis Population in Australia and Western Sydney

The prevalence of kidney failure is increasing worldwide. In 2022, in Australia, 15,518 patients received chronic dialysis and 3311 new patients commenced dialysis for the first time.[11] Within Australia, Western Sydney is a unique geographic cluster. It is characterised by one of the most rapidly growing regions in Australia with a population estimated to be 2.6 million people in 2022 and includes a patient population of significant cultural diversity (as ~60% are born outside Australia, with the top countries of birth being India, China, Lebanon, and South Korea).[12] Furthermore, the median weekly personal income is approximately $80 lower than the Australian median weekly income.[12] As of 2016, approximately 50,600 adults with chronic kidney disease (CKD) of any stage resided in Western Sydney, which accounts for 12% of the local population, higher than the national incidence of 10%.[13] Furthermore, this region currently manages 903 chronic dialysis patients with less than half (43%) receiving a type of home-based dialysis treatment [32% (293 patients) receiving chronic peritoneal dialysis (PD); 11% (100 patients) receiving home HD; 20% (178 patients) receiving hospital HD and 37% (332 patients) receiving satellite HD].[11] The annual incidence of kidney failure has been steadily increasing and was 232 new dialysis patients in 2022 compared to 201 in 2021 and between 175 and 201 annually between 2018 and 2021.[11]

Increasing Multimorbidity and Frailty in Kidney Failure Patients

Similar to the general population, the prevalence of multimorbidity and frailty has increased in chronic dialysis patients.[5] Multimorbidity is defined as the presence of at least two significant comorbidities,[14] with frailty being a clinical syndrome of increased vulnerability in the elderly population.[15] In Australia, the presence of comorbid diabetes in patients commenced on dialysis has increased by 30% over the past 2 decades, with a relatively static presence of coronary artery disease, peripheral artery disease, chronic lung disease, or cerebrovascular disease.[5] Recent large-scale cohort studies have shown that greater than 95% of patients with CKD have at least one significant comorbidity.[16,17] Multimorbidity is inherently linked to frailty in the CKD population.[14] As such, patients with CKD have high rates of frailty (up to 82%) that increase with age and duration of dialysis.[14,18] Similar trends are demonstrated in the Australian population.[19] Frailty is linked to heightened mortality risk and diminished quality of life. Consequently, managing patients becomes more intricate, demanding a delicate balance between optimising symptom relief and enhancing overall prognosis.[18]

Hub and Spoke Model of Chronic Dialysis Care Delivery

The model of chronic dialysis care in Australia has advanced gradually over the last 50 years[20] and currently operates mainly through government-funded tertiary centres (underpinned by some private-partnerships), which serve as hubs for dialysis and transplantation services.[8] These centres extend their reach through smaller facilities that provide satellite dialysis at varying distances, following a "hub and spoke" model.[8] Within these centres, dedicated training units support patients in the use of both home HD and PD.[8] The key advantages of the Australian system are the provision of universal government-funded healthcare to all dialysis patients[8] and a high global ratio of nephrologists to dialysis patients (~10–13 per 1000 patients).[21] These reasons likely explain why Australia is one of the nine countries where over 20% of the population opts for home-based dialysis modalities, and this percentage continues to rise.[22–24] In contrast, the incidence of home-based dialysis was less than 15% in the United States (US), but this has increased over the last decade.[24,25]

Are Current Systems for Delivering Chronic Dialysis Services Optimal?

The best evidence-based approach for delivering chronic dialysis services is not known, and current methods may not be sustainable and/or fully integrated with other parts of the healthcare system.[26] In the Western Sydney Renal Service (a speciality renal network, combining two metropolitan jurisdictions see Figure 1),[27] dialysis services are delivered by three major (level 5–6) Hospitals (Westmead, Nepean, and Blacktown), consisting of three in-hospital HD units at each hospital; three public satellite HD units located on the grounds of Auburn, Blacktown, and Mount Druitt hospitals, and a private satellite HD unit at Norwest Hospital (satellite HD consists of patients with the ability to self-care).[13] There are also two PD Units for training and service at Blacktown and Nepean hospitals; a single Home HD training unit is located at satellite unit of Blacktown Hospital; one pre-dialysis educator across the network; a newly established renal supportive care team with a renal physician and clinical nurse consultant, and one renal social worker and psychologist.

Some of the current pressures on the effectiveness of dialysis service delivery in Australia include workforce capacity to provide pre-dialysis education and support chronic dialysis patients due to population growth in kidney failure;[28] declining number of patients capable of undertaking home-based dialysis[22] and infection control problems due to COVID-19.[29] Policy changes to address these problems include employment of highly skilled nurse consultants;[21,28] use of remote patient monitoring;[30] encouraging family-assisted automated PD;[31] and forward government planning.[32]

What are the Emerging Problems with Current Clinical Pathways?

Figure 2 summarises the standard clinical pathways and transitions for patients with kidney failure, which includes three options, which are chronic dialysis, kidney transplantation, or conservative management without dialysis (renal supportive care). In Australia, the conventional clinical pathway for kidney failure involves referral from a general practitioner to a nephrologist with CKD to provide treatment advice to slow disease progression. This includes treatment of the underlying cause of CKD; control of blood pressure, diabetes, and proteinuria, with lifestyle interventions, treatment with renin angiotensin aldosterone inhibitors and consideration of SGLT2 inhibitor therapy.[33] Typically, when the eGFR falls below 30 mL/min/1.73 m^2, the nephrologist refers the patient for pre-dialysis education to enable patients to make an informed choice regarding dialysis modality or pre-emptive kidney transplantation (if a donor is available). This is followed by the surgical review for planning long-term chronic dialysis access (either arteriovenous fistula creation or PD catheter insertion).[34]

The standard clinical pathway to renal replacement therapy attempts to ensure that there is a smooth transition from pre-dialysis care to chronic dialysis, minimising the risk of acute hospitalisation and maintaining outpatient care and

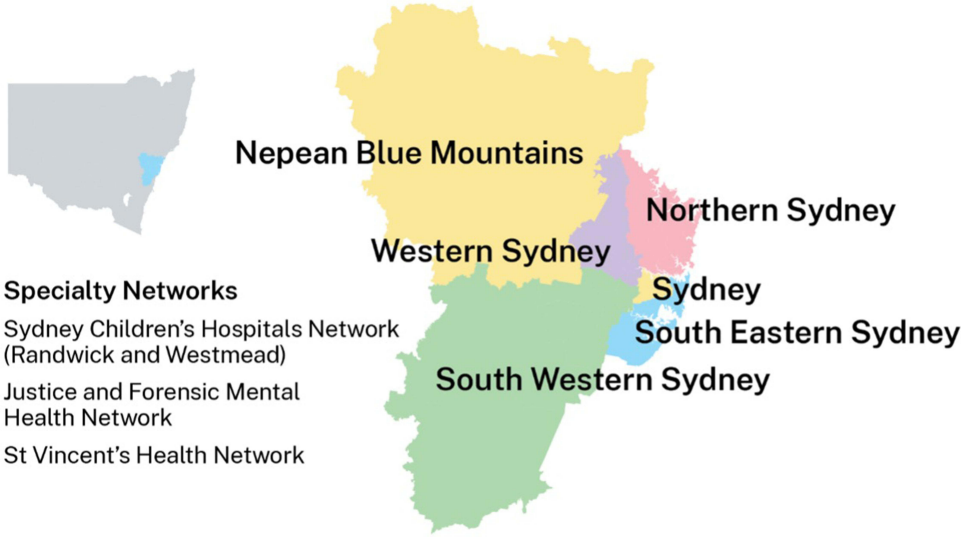

Figure 1 This figure shows the geographic locations of the Local Health Districts within Sydney. Reproduced from © State of New South Wales NSW Ministry of Health under the Creative Commons Attribution 4.0 licence.[27] The Western Renal Service comprising the Western Sydney Local Health District and the Nepean Blue Mountains Local Health District serve a population of 1.3M and a total area of 9959 square kilometres.

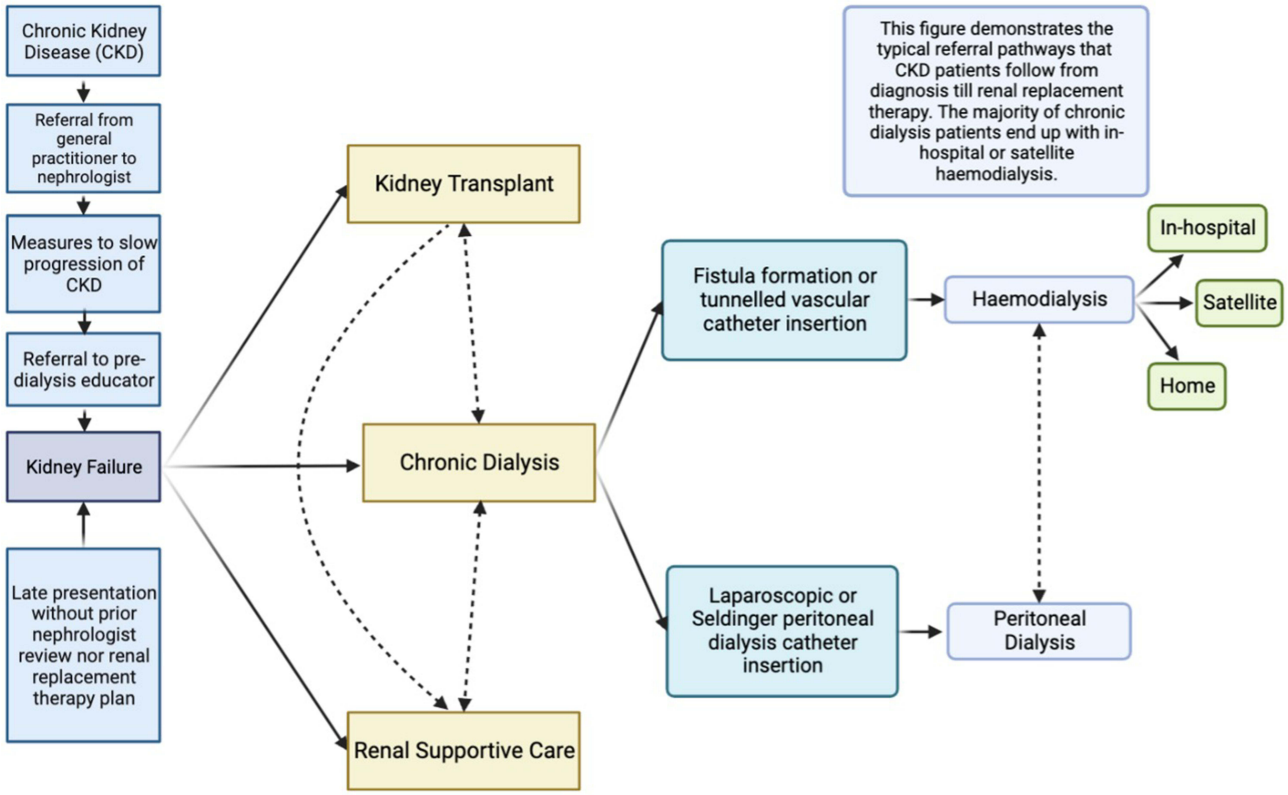

Figure 2 This figure demonstrates the standard clinical pathways for kidney failure patients in the Western Renal Service. The ideal pathway is early referral from the general practitioner to a nephrologist for pre-dialysis medical care (eg treatment with ACE/ARB inhibitors, SGTL2 inhibitors and other measures) and assessment by the pre-dialysis educator to provide education and determine the optimal renal replacement plan with a preference for encouraging home-based treatments. Planning for dialysis involves surgical referral for either the creation of a fistula for haemodialysis (including Doppler vascular mapping) or consideration of insertion of a peritoneal dialysis catheter (either by laparoscopy or the Seldinger method). Recently, there has been a marked increase in patients who present with kidney failure without a prior plan who often require insertion of a tunnelled vascular catheter for acute start haemodialysis. Additionally, these patients can commence acute dialysis through peritoneal dialysis catheter insertion using the Seldinger method. Once established on chronic dialysis, patients undergo peritoneal dialysis; or haemodialysis either in-hospital, at a satellite centre or at home. Other management pathways include kidney transplantation or renal supportive care, and importantly patients can transition between these options at any time.

uptake of home-based chronic dialysis. However, over the last five years in Australia, there have been more patients deviating from this path, presenting to hospital late with kidney failure and thus requiring emergency and acute HD or PD. For example, in 2023, 23.6% of patients (39/165) patients in Western Sydney presented late, a notable increase from 2022, where only 8.2% (19/232) required acute dialysis.[11] In addition, among those requiring acute dialysis in 2023, 25 out of 39 patients were from culturally diverse backgrounds, posing challenges in meeting individual care needs. The reasons for the increase are complex and poorly understood, but hypotheses include insufficient pre-dialysis educators together with reduced patient engagement with healthcare due to the pandemic and cultural barriers as well as misinformation.[35–37] Additionally (similar to other countries), managing patients who are non-permanent residents (who do not have national insurance coverage) is an emerging challenge, adding to the financial burden of the dialysis process.[38]

What is the Financial Burden of Kidney Failure

Kidney disease disproportionately affects populations of lower socioeconomic status, and healthcare funding and infrastructure fall behind other medical specialties.[6] For reasons that are not clear, this is despite kidney failure patients representing approximately 1% of the population but needing greater than 6% of national healthcare funding.[6] The financial costs for treating kidney failure are significant and rising. Approximately 80% of the allocated expenditure attributed to patients with CKD in Australia was allocated to public hospital services.[5] Furthermore, the rate of increase in expenditure for CKD patients is rising faster than the rate of general healthcare expenses.[5] This high burden of public

hospital expenditure is likely to be true for CKD patients in Western Sydney, with over 60% of this attributed to those with kidney failure on dialysis.[5]

The percentage of home-based dialysis carries significant implications for overall dialysis costs. Notably, PD and home HD in Australia cost approximately $15,000 to $20,000 less per patient annually compared to satellite or in-hospital HD (2009 prices: home HD $49,137, PD $53,112, satellite HD $65,315, in-hospital HD $79,072). Whilst these costs do not account for the underlying patient comorbidities that may necessitate someone to require in-hospital dialysis compared to a home-based modality, they demonstrate the significant economic benefits associated with widespread adoption of home-based dialysis modalities in those who are suitable.[13]

Current Experiences and Unmet Needs for the Dialysis User

From limited data available, a view of chronic dialysis patient needs and preferences to inform future innovation is emerging. In a mixed-methods study assessing the important characteristics of dialysis for pre-dialysis and dialysis patients across two dialysis units in Sydney, found that patient groups not only valued survival but also placed strong favour on the convenience of home-based dialysis, increased independence, and the opportunity for dialysis-free days.[39] A system that better reflects these values therefore has the potential to improve patient morbidity and mortality. Additionally, such a system should also promote kidney transplantation to improve patient quality of life, patient survival, and cost-effectiveness.[1] Based on this knowledge, several themes emerge:

Need for Focus on Symptom Management

Many dialysis patients place a greater emphasis on symptom management rather than survival or biochemical markers.[40] Physical symptoms of fatigue and cramping and psychosocial symptoms of anxiety and depression were key areas that patients prioritised for future research.[41] Furthermore, the 2023 recommendations from Kidney Disease: Improving Global Outcomes (KDIGO) emphasise the importance of integrating patient preferences into the decision-making process surrounding renal replacement therapy and underscore the significance of considering the impact of symptoms, not just the frequency.[42] This highlights the increasing traction in the dialysis community on the importance of renal supportive care. Despite this, there has been a dearth of new interventions specifically addressing symptom management. The limited number of interventions is likely due to a lack of data on the importance of monitoring patient-reported outcomes across clinical trials.[41]

Increasing Barriers to Undertake Home-Based Dialysis

Chronic dialysis patients value their independence and the ability to do dialysis at home.[41,43] Currently, only less than half of Western Sydney dialysis patients decide to undertake home-based chronic dialysis, which is below proposed national targets.[44] The disinterest in home-based dialysis therapies may, in part, be due to insufficient resources for pre-dialysis education to overcome perceived fears, and the absence of culturally sensitive patient educational approaches and materials.[44,45]

With regard to PD, the reasons for the reduced uptake and technique survival of PD are complex and include inadequate patient education and/or social factors that impair the ability to self-care.[46] An online survey in Australia suggested large variations in standardised curricula and competency assessments between different PD units.[47] This could account for the marked difference in PD peritonitis rates between centres.[48,49] Furthermore, the uptake of PD in patients residing in nursing homes is reduced[46] despite evidence showing that training of nursing home staff is achievable with good patient outcomes.[50] Internationally, varying administrative factors influence the uptake of PD, as in the US reimbursement per patient for HD is higher than PD,[51,52] whereas in Australia and New Zealand, the cost of providing in-centre HD is ~1.5-fold higher than home-based therapies, and thus there is a preference for PD.[53] Addressing these deficiencies will likely boost PD adoption and reduce complications, enabling patients to continue to perform dialysis at home. Similarly, despite home HD allowing for more intensive treatment protocols that improves patient uraemic symptoms,[54] its reduced uptake may be related to patient discomfort at self-cannulation and perceived lack of support in troubleshooting problems.[55] A key concern for HD patients was the lack of assistance at home.[56] Furthermore, prior to

the COVID-19 pandemic, there was a lag in the uptake of telehealth and remote monitoring to support home HD patients,[57] potentially limiting the number of patients benefiting from it.

Patient Interest for Portable Dialysis Technology

Over the last decade, there has been increasing interest in portable dialysis devices to enhance key patient-centred outcomes like satisfaction and independence.[1,58] Progress has been hampered by limited funding for research that has impeded translation to clinical practice.[6] Qualitative studies have identified patient preferences for such a device, which include heightened flexibility and independence. For example, one of the goals for haemodialysis patients was to travel internationally without issue.[59] Also, patients wanted such devices to be simple to operate and compact, ideally worn like a vest.[60] Currently, a multi-centre Kidney Health Initiative mixed methods study is underway to establish patient preferences for a device.[61] This study will assist in the widespread development of portable dialysis technology.

As summarised in Figure 3 these factors (rapid population growth, cultural diversity, financial disadvantage, sub-optimal healthcare literacy, frailty, multimorbidity, late presentation) have all led to a significant imbalance between optimal healthcare service delivery and patient satisfaction.

Human-Centred Care as a Model to Address Unmet Needs in Chronic Dialysis Care

The negative impacts of dialysis on quality of life and the recognition of patient needs, as well as cost of managing complex care, have led to a push for innovations in dialysis delivery.[62] As noted earlier, key patient priorities include independence, the ability to do dialysis at home and symptom control.[41,43,63] Recent studies have shown that chronic dialysis patients prioritise the management of fatigue, pain, and optimisation of mental health.[64] Therefore, the main ways in which dialysis delivery could be improved involve prioritising home-based dialysis, either through changes in dialysis pathways or using emerging technologies that allow for portable dialysis. Furthermore, there is an increasing trend towards incorporating symptom recognition and management in healthcare protocols.

Over the last decade, the focus on human-centred care (or patient-centred care) has been a paradigm shift in healthcare.[65] It is defined as an approach to the planning, delivery, and evaluation of healthcare (systems, devices, and services) that places the needs of patients and families as the prime' end-user.[66] It was conceptualised with the aim of

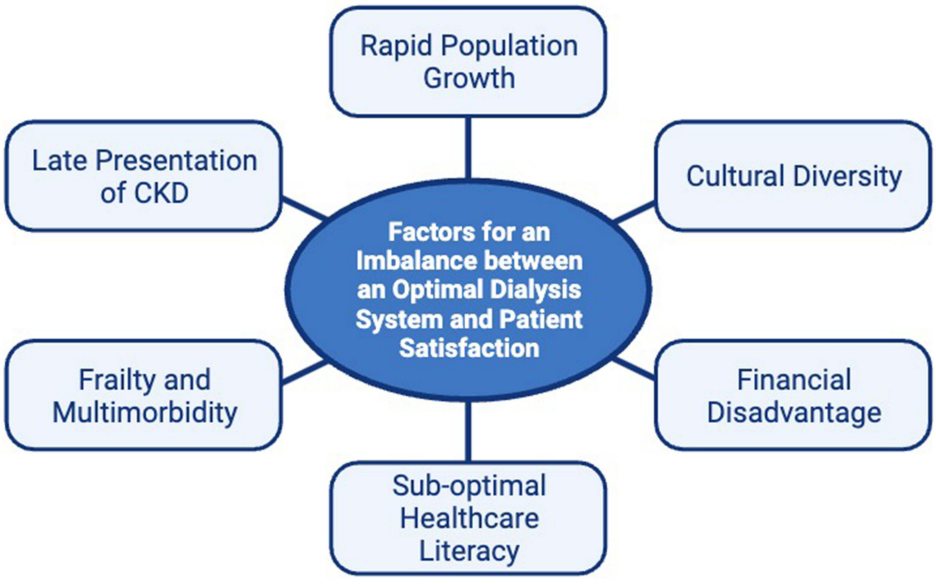

Figure 3 This figure demonstrates the factors that lead to an imbalance between an optimal healthcare system and patient satisfaction in the treatment of kidney failure. Rapid population growth in Sydney with increasing frailty multimorbidity, and cultural diversity are factors impacting service delivery in Western Sydney as well as most other high-resource healthcare systems across the world. Higher rates of sub-optimal healthcare literacy and financial disadvantage, have particularly negative impacts in the dialysis population, due to the complexity of the medical condition.

improving patient-relevant outcomes within healthcare systems.[66] This approach entails placing patients and families at the core of organisational processes and transforming existing facilities and services to integrate patient viewpoints, which includes increasing the "usability" with innovative technology.[7] Studies have suggested that this approach improves patient satisfaction,[67] may improve adherence to treatment,[68] reduces inpatient mortality,[69] with shorter hospital stays[70,71] and lower healthcare costs.[72]

In response to the mismatches between patient needs and the current dialysis system, efforts are underway to develop human-led innovations to disrupt the standard clinical dialysis pathways. These include both new technologies and enhancing the identification and management of distressing chronic and disabling symptoms, which are prioritised by patients (and have been overlooked historically by healthcare providers). For descriptive purposes, we have categorised these either as (i) incremental innovations (that facilitate current clinical pathways) or (ii) disruptive innovations (that radically change current clinical pathways). While these advances do not address all the unmet needs of the dialysis provider or the end-user, they emphasise a human-centred approach to solving problems by putting the needs of the patients as the priority.

Incremental Advances in Human-Centred Dialysis Care

Over the last decade, several incremental changes to the standard dialysis pathways have been implemented. These include renal supportive care pathways; improved home-based support structures; and hybrid/incremental dialysis or PD/HD to improve the uptake of home HD or PD.

Renal Supportive Care and Optimisation of Symptom Management

Without doubt, the most important human-centred advance in chronic dialysis patients has been the introduction of renal supportive care. Since 2013, Australian renal units have embedded these pathways into routine nephrology clinical practice (described in detail in previous reviews).[73,74] It is defined as holistic, multi-disciplinary patient-centred approaches that combine the principles of palliative care with general symptoms experienced by patients with kidney failure.[73,74] In a prospective observational cohort study of 127 chronic dialysis patients referred to renal supportive care clinics, there were significant improvements over time in depression, some symptoms (lack of energy, insomnia, itching, pain, and skin changes) but without change in dialysis delivery.[75] In addition, renal supportive care programs are highly favoured and provide empowerment for patients and their families with healthcare decisions,[76] and significantly reduce the number and length of hospitalisations.[77] Four multicentre clinical trials that aim to provide further high-quality evidence on the role of renal supportive care in chronic HD patients, are currently in progress. These are summarised in Table 1.

Home-Assisted Dialysis

Home-assisted dialysis, where nursing and clinical support is provided to home HD patients, is gaining traction. In Western Sydney, home HD patients historically have received support from both senior nurse practitioners and nurse consultants, who troubleshoot problems ranging from cannulation to issues with the dialysis prescription. In addition, over the last 10 years, services affiliated with hospitals or independent accredited national healthcare providers (such as Dialysis Australia) provide home nursing support to enable patients them to undertake HD or automated PD at home.[82,83] Internationally, home haemodialysis has been made more accessible through increased telemonitoring with regular input from nursing staff, and upgrades in technology allowing for more efficient storage.[84] This type of active nurse-assisted home dialysis program addresses patient priorities whilst maintaining the mortality benefits of home dialysis therapies with significant health-economic advantages.[83,85,86]

Other models of care include the empowered in-centre units where patients have an active role in their haemodialysis treatment while benefiting from the safety net provided by the centre.[87,88] In addition, in the US, home-assisted dialysis is being formalised through the creation of transitional care units (TCUs), which offer a comprehensive 4-week educational and decision support program to patients newly initiated on dialysis.[89] A retrospective cohort study of 724 patients initiating dialysis across 48 TCUs compared to 2892 matched controls with no TCU history showed that patients initiating dialysis in a TCU were significantly more likely to utilise home dialysis and more likely to be referred for a kidney transplant at 14 months.[90]

Table 1 Current Clinical Trials Addressing Symptom Management in Haemodialysis Patients

Study	Patient Population	Intervention	Outcome
Roumelioti et al 2018[78]	150 adult haemodialysis patients from Pennsylvania and New Mexico	Two-site parallel group randomised controlled trial comparing a 12-week stepped collaborative care intervention [includes Cognitive Behavioural Therapy (CBT)] with a control arm of technology-delivered health education. The delivery of CBT will be with live videoconferencing.	Patient symptoms, health-related quality of life, treatment adherence and inflammatory biomarkers,
Johnson et al 2020[79]	Participants from eligible (in-centre haemodialysis with clinicians able to review patient-reported data) haemodialysis units in Alberta and Ontario.	Multi-centre randomised controlled trial to evaluate the use of disease-specific and generic patient-reported outcome measures (PROMs). The patients will be randomised to one of four groups: 1) complete a dialysis specific PROM, 2) complete a generic PROM, 3) complete both types of PROMs, 4) receive usual care with no PROMs.	The primary outcome is improvement in patient-provider communication with secondary outcomes of patient symptom management, use of healthcare service and cost-effectiveness.
Unruh et al 2020[80]	126 adult participants treated with haemodialysis in community-based facilities in Seattle and Alburquerque with chronic insomnia	Patients will be randomised 1:1:1 over 31 months to either a 6- week treatment with CBT, trazodone, or placebo.	Short term improvement in insomnia at 6 weeks and long-term effectiveness at 25 weeks.
Greenham et al 2022[81]	Up to 2400 adult haemodialysis participants from 143 satellite haemodialysis centres in Australia and New Zealand.	Registry-based cluster randomised controlled trial to determine the clinical and cost effectiveness of symptom monitoring using the Integrated Palliative Outcome Scale-Renal (IPOS-Renal) survey. Patients in the intervention arm will complete the IPOS-renal survey 3-monthly over a 12-month period.	Change in health-related quality of life as measured by the EQ-5D-5L and compared between the intervention and control arm. Secondary outcomes are dialysis withdrawal, overall survival, fatigue, cause-specific mortality, symptom severity, haemodialysis duration and adequacy and cost-effectiveness,

Incremental and Hybrid Dialysis

There is renewed interest in incremental dialysis, which is defined as HD administered less than thrice weekly or limiting dialysis prescription by duration to allow for a more gradual transition.[91] This approach addresses patient concerns about the potential loss of independence and ability to work when adhering to a conventional haemodialysis regimen. A recent Australian study among individuals who were either presently undergoing HD or on the verge of starting demonstrated that all 26 participants preferred an incremental approach to HD. Their foremost priorities were about quality of life and preserving residual kidney function.[92] Similarly, patients with failing PD do not necessarily need to be transitioned immediately to HD but rather had a hybrid model of PD and HD can be utilised.[93] This strategy was employed more frequently during the COVID-19 pandemic where patients with hybrid PD/HD needed in-hospital HD only 1–2 times per week rather than the usual three when completely transitioned from PD to HD.[94] Several studies have shown that combined therapy provides the improved dialysis adequacy that HD offers whilst still optimising patient quality of life with the home-based advantage of PD.[95–97] The recognition of incremental and hybrid dialysis as being important modalities to address patient needs has led to their integration in nephrology education programs.[98]

Refinements to Dialysis Technology

Several refinements to dialysis membranes and HD methods may improve symptom control and survival. Until recently, progress to advance dialysis membranes has been slow.[99] The key limitations are suboptimal removal of uraemic toxins

and a non-continuous function when compared to natural kidneys.[99] The use of mixed matrix membranes, which contain polyethersulfone, polyvinylpyrrolidone, and activated carbon, may allow for increased clearance of uraemic toxins. These membranes may also have improved haemocompatibility, potentially allowing for continuous kidney replacement therapy without an increased risk of clotting or infection.[100] Enhanced toxin removal could improve patient symptoms and significantly enhance the quality of life for dialysis patients.[101]

Similarly, haemodiafiltration (HDF), as a concept, has been around for decades and combines the principle of diffusion for solute removal in traditional HD with convective solute removal in haemofiltration.[102] Registry studies and clinical trials have demonstrated the potential for HDF in reducing all-cause mortality[103,104] and improving intra-dialytic patient symptoms such as cramping and hypotension.[105] Despite these promising findings, concerns about participant attrition during follow-up in these trails may have hindered widespread HDF adoption outside of Europe and Japan.[106] This is despite an individual-participant meta-analysis of four randomised controlled trials showing a reduction in all-cause mortality and cardiovascular mortality with high-dose HDF compared to HD.[107] Recently, the landmark CONVINCE study, a randomised-controlled trial of 1360 patients randomised to high-dose HDF and HD, demonstrated an absolute risk reduction in mortality of 4.6% (HR 0.77, 95% CI: 0.65–0.93).[108] The anticipation is that the outcomes of the CONVINCE study will serve as a catalyst, paving the way for the widespread adoption of HDF. A pivotal step in this trajectory involves seeking Food and Drug Administration (FDA) approval for online generation HDF, ultimately facilitating the transition of HD centres to incorporate HDF equipment.[109]

Disruptive Advances in Human-Centred Dialysis Care

Radical changes to dialysis technology may in the future lead to major disruption to the traditional models of care for kidney failure. Current medical advancements in this area centre around developing portable and/or wearable dialysis devices; establishing implantable "bioartificial kidneys" without immunosuppression; and artificial intelligence. The need for social distancing during the COVID-19 pandemic created an aggressive push for such technological innovations.[110]

Portable/Wearable Dialysis Devices

Several groups are evaluating the feasibility of wearable or portable dialysis devices (both HD and PD) for the treatment of kidney failure. Gura et al piloted a portable HD device that could be worn as a belt over 24 hours and found that the five patients who completed the study had effective solute clearance and maintenance of fluid haemostasis without any adverse effects.[111] A similar belt-like device that instead regenerated PD fluid (using a modified sorbent system with a single lumen PD catheter) was tested in 15 PD patients for 72 hours. Whilst 60% of patients complained of abdominal pain, there was optimal fluid removal and reductions in urea, creatinine, and beta2-microglobulin.[112] Despite these pilot studies showing the proof-of-concept for portable or wearable dialysis devices, large-scale clinical trials have yet to be conducted.[113] The challenges limiting wide-spread development have included the need to enable continuous regeneration of a small volume dialysate, miniaturisation with current devices being around 10–30 kg and the optimisation of toxin removal.[114]

Development of Bioartificial Implantable Kidneys

"kidneys" that replicate the metabolic and endocrine activity of kidneys could in the future replace the need for standard thrice weekly haemodialysis. The bioartificial kidney consists of renal tubular cells cultured on a membrane, which is then surgically implanted and connected to the urinary bladder. Initial devices had problems with membrane storage due to cellular degradation, and device rejection by the animal's immune system.[115] In 2023, a bioartificial kidney system created with tubular cells cultured on silicon nanopore membranes was implanted into pigs, with minimal cellular damage despite no systemic anticoagulation or immunosuppression.[116] Consequently, patient studies are likely to follow.

Artificial Intelligence in Dialysis Care

Artificial intelligence (AI) holds the promise of empowering clinicians to deliver highly personalised care to their patients. Current studies have shown that AI could help to ensure optimum haemoglobin by recommending suitable erythropoietin-stimulating agents based on the patient profile[117] or predict the risk of intradialytic hypotension by considering patient clinical factors.[118] Furthermore, a recent cross-sectional study of 195 patients showed that patients rated AI responses to questions higher in terms of quality and empathy than physicians,[119] which could potentially pave the way for the use of AI

in pre-dialysis education. In the future, there could be a system that integrates multiple facets of a patient's clinical and social situation into a thorough management plan. Key issues that slow the adoption of AI in medicine include concerns with data privacy and security; issues regarding maintaining transparency and accountability of decision-making; and the formidable task of attaining the requisite computing power for timely processing of healthcare data.[120]

Human-Centred Care to Address Problems Faced by Dialysis Providers

In Australia, government funding of the latest evidence-based innovations is required to change the healthcare practice in dialysis patients. The substantial economic impact of dialysis and CKD underscores the necessity for government priorities to be strategically aligned with the efficiency and cost-effectiveness of dialysis systems. In the US, this is often through a singular focus on in-centre HD due to corporate ownership of dialysis units.[121] However, it is expected that human-centred care will improve patient outcomes and may also alleviate the economic burden of kidney failure. For example, a nurse-assisted home dialysis program in the Middle East offered economic benefits with a 27% reduction in costs.[86] This will render the adoption of innovative changes in dialysis technology and delivery not only feasible but highly advantageous to healthcare providers.

Conclusion

Human-centred innovations in dialysis care offer a transformative solution to enhance outcomes for all stakeholders in all regions. By understanding and addressing patient needs, integration of new technology and the implementation of system changes are expected to improve outcomes, and this will need to be evaluated in future studies. Whilst these innovations have thus far been reviewed in high resource healthcare settings, the general principles of human-centred care (based on the needs of a population in a specific region) are applicable to all countries. As would be expected, the means of delivering innovations inherently vary between settings dependent on the healthcare system and available resources. After years of slow progress, these human-led developments could lead to new systems that could radically change how kidney failure is treated. Furthermore, these patient-led initiatives should serve to alleviate the economic burden of kidney failure. This may pave the way for a future where the quality of life for dialysis patients matches that of transplant recipients, or even a future without the need for dialysis altogether. Clearly, these changes will need to be based on rigorous and robust practice-changing clinical trials.

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