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REVIEW

Decarbonisation of Kidney Care in the United Arab Emirates: A Roadmap to an Environmentally Sustainable Care

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Abstract: Chronic kidney disease (CKD) remains a major public health burden and a leading cause of mortality worldwide and in the United Arab Emirates (UAE). Alongside its clinical and humanistic burden, CKD care is associated with a significant carbon footprint. In this narrative review, we present an overview of the carbon footprint of current CKD treatments and the results of an analysis estimating the carbon footprint of CKD treatments in the UAE. Using the life cycle assessment (LCA) method and local data from the published national reports and inventory sources, we estimated that haemodialysis leads to greenhouse gas (GHG) emissions of ~12.8 tons of CO_2 equivalents (CO_2eq) per person in the UAE annually. Thus, the decarbonisation of CKD care is crucial in establishing an environmentally sustainable healthcare system. We propose a framework to decarbonise CKD care in the UAE that tackles the carbon footprint of CKD care in the UAE by focusing on three main pillars: Delaying early CKD and slowing its progression; reducing anthropogenic emissions from CKD and dialysis care by promoting best practices and eco-friendly technologies; and enhancing access to kidney transplantation. Such approaches are relevant not only for the UAE but also for global healthcare systems aiming towards net-zero emissions.

Keywords: chronic kidney disease, carbon footprints, dialysis, net zero, decarbonisation, sustainable healthcare, environmental impact

Introduction

The impact of healthcare on the global environment has been increasingly recognised, but a complex multidimensional relationship between healthcare provision and population health exists. Healthcare services, pharmaceutical production, and medical wastage all contribute to global environmental damage,[1] but global warming and pollution further harm health. Healthcare systems are major consumers of energy and resources as well as generating anthropogenic emissions, contributing to nearly 4.4–5.2% of global greenhouse gas (GHG) emissions. Likewise, nearly 3% of particulate matter (PM) and nitrogen oxide (NO) emissions are attributed to the healthcare system.[2,3] Creating a more environmentally sustainable global healthcare system was a recommended goal in attempting to prevent global temperatures rising more than 1.5°C in the Paris Agreement.[4] An important part of this effort may be achieved by recognising the role of climate change on kidney disease and vice-versa and how nephrologists can mitigate the carbon footprint associated with the care of patients with kidney disease.[5]

CKD remains a major public health burden and a leading cause of mortality worldwide. In 2019, nearly 697 million patients had CKD, with an estimated global prevalence of 8.5–9.8%.[6] Moreover, it was estimated that 2.5 million patients were on kidney replacement therapy (KRT), which is projected to increase to 5.4 million cases by 2030.[6–8] The escalating number of patients requiring dialysis presents an unsustainable burden on healthcare systems. Current costs are already prohibitive, and the situation is exacerbated by the fact that the majority of patients who develop kidney failure do not

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receive the necessary treatment. This results in millions of preventable deaths annually. Therefore, there is an urgent need for innovations and new modalities in KRT that are affordable and accessible across all income levels—high, middle, and low-income countries alike.

Decarbonisation of CKD care is a potential advance in the effort towards developing an environmentally sustainable healthcare system due to the high carbon footprint of CKD treatment. KRT, particularly haemodialysis, is an energy-intensive modality with a significant carbon footprint, which has previously been estimated to be ~ 10.2 tons of CO_2 equivalent (eq) per person annually in an Australian satellite dialysis setting.[9] Additionally, the transport requirements associated with patients or staff travelling to dialysis centres or homes, together with very high consumption of single-use plastics and its associated medical waste, contribute highly to GHG emissions.[10,11] Since the carbon footprint increases as CKD progresses,[12] early recognition and treatment to slow the progression of kidney disease[13] is likely to improve patient outcomes and advance the global effort towards a lower emissions healthcare system.

The CKD burden is growing in the Middle East and North Africa (MENA) region due to the high prevalence of diabetes and other CKD risk factors.[14,15] In the United Arab Emirates (UAE), 4–5% of patients suffer from CKD stage 3–5.[16,17] It has been previously estimated that the annual growth of KRT patients was ~12–15% and projected to double in the next five years,[18] although more recent local data from Abu Dhabi suggest that growth is a more modest ~6–7% (local data, SGH). Hopefully this reduction reflects the efforts underway to detect and treat early CKD. Kidney failure and the need for KRT often present at a relatively younger age in the MENA region, including UAE, compared with European patients,[16,17] especially in the expatriate community, further highlighting the growing burden of CKD and KRT in the country. This escalating burden poses significant challenges to establishing a sustainable healthcare system. While limited local data exists regarding the footprint of current CKD treatment in the UAE, a recent report estimated that patients with CKD at each stage contribute 107–160% of CO_2eq compared with the average UAE person's annual GHG footprint (21.8 tons CO_2eq).[19]

In this review, we present an overview of the carbon footprint of current CKD treatments and the results of this analysis in the UAE. We also propose a roadmap for the decarbonisation of CKD care, which can represent a crucial element in achieving the UAE Net Zero by 2050 strategic initiative.

Methods

The present review was supported by an online bibliographic search of Medline via PubMed from its inception to December 2023. A MeSH-based search strategy was adopted using various combinations of the following keywords: (chronic kidney failure[MeSH Terms])) OR (chronic kidney disease)) OR (end-stage renal disease[MeSH Terms])) OR (haemodialysis[MeSH Terms])) AND (carbon footprint[MeSH Terms])) OR (carbon footprints[MeSH Terms])) OR (Decarbonisation). We focused mainly on original articles or technical reports evaluating the carbon footprints of CKD therapies.

CKD in the UAE

A recent pooled analysis of 100 population-based studies estimated a global prevalence of CKD of 13.4%.[20] Thus, it is estimated that nearly 697 million adults are living with CKD.[6] The prevalence of CKD has dramatically increased by 70.9% over the past 30 years in the MENA region. Based on the Global Burden of Disease Study 2019, the prevalence of CKD showed the highest increase in Qatar, followed by the UAE.[21]

In the UAE, CKD poses a significant public health burden due to the high prevalence of risk factors such as diabetes, obesity, and hypertension.[22,23] A small study conducted in Abu Dhabi between 2011 and 2012, which analysed approximately 300,000 tests from 200,000 individuals, found a CKD stage 3–5 prevalence of about 4%. A more recent, larger study conducted between 2020 and 2024 involving 2 million tests from 700,000 people showed that approximately 24% of patients had a GFR <90mL/min/m², with 4–5% classified as CKD stage 3–5. Notably, males and expatriates were found to have a higher relative risk.[17] A nine-year retrospective chart review in the Al-Ain region of Abu Dhabi, focusing on patients at high risk for cardiovascular diseases, reported a CKD stage 3–5 prevalence of 11.4%, with an alarming incidence rate of 164.8 per 10,000 person-years (Table 1).[24]

Table 1 Data on CKD Stage 3–5 Prevalence in the UAE

Study Period	Population	Sample Size	Prevalence of CKD Stage 3–5 (%)	Ref
2011–2012	Prevalence in Abu Dhabi	300,000 tests (200,000 people)	~4%	[18]
2020–2024	Males and expatriates at higher risk	2 million tests (700,000 people)	~24% overall (4–5% in stage 3–5)	[17]
9-year Al-Ain study	High-risk cardiovascular patients	Retrospective review	11.4%	[24]

The prevalence of patients on haemodialysis was reported to be high in the UAE, approaching a prevalence of 370 per million population and an annual growth rate of up to 15%.[18] Another report estimated that the prevalence of treated kidney failure in the UAE was 152 per million population, while the prevalence of long-term KRT was 201.4 per million population.[25]

Patients with CKD, particularly those with kidney failure, are at increased risk of mortality, with a CKD-specific mortality rate of 41.5%.[26] Alongside the mortality risk, patients with CKD suffer many co-morbidities attributable in part to CKD itself, including coronary artery and vascular disease, metabolic abnormalities, psychiatric disorders, anaemia, and have impaired quality of life.[8,27,28]

Environmental Challenges in CKD Care

Climate change and GHG emissions have various adverse effects on human health and are major contributors to several infections and non-communicable diseases.[29] There is a particular concern that global warming contributes to heat-related renal injury and long-term kidney damage in workers exposed to high heats for prolonged periods.[30] Thus, anthropogenic emissions and CKD may be linked, illustrating a complex bidirectional relationship between environmental factors and health outcomes. Increased emissions, particularly air pollutants like fine PM and carbon monoxide (CO), have been linked to the development and progression of CKD due inflammation and oxidative stress.[31] Haemodialysis centres consume considerable energy and water and generate significant medical waste, contributing highly to the overall carbon footprint and environmental pollution produced by healthcare.[10,11]

Medical waste incinerators can emit significant quantities of pollutants into the atmosphere, including PM, metals, oxides of sulphur, nitrogen, and carbon, persistent organic pollutants, and other materials that directly contribute to global warming.[11,32,33]

The Carbon Footprint of Current CKD Treatments

In the evaluation of healthcare carbon footprints, it's crucial to note a significant limitation: the variability in what components are included or excluded from different studies, such as staff travel and medication, which can make direct comparisons challenging and potentially misleading. Therefore, any interpretation or comparison of these studies should be done with caution, taking into account the specific methodologies and parameters considered in each case. A study from the United Kingdom (UK) estimated the carbon footprint of different CKD treatment modalities used to deliver maintenance haemodialysis. The results indicated that the annual per-patient emissions from weekly maintenance haemodialysis were ~3.8 tons CO_2eq (1 metric ton =1000 kg), comparable to an average-sized vehicle travelling 100 km. The study found that large contributions to the emissions resulted from medical equipment, energy use, and travel.[34] In Australia, the annual per-patient emissions from a haemodialysis patient was calculated to be 10.2 tons of CO_2eq, mainly from pharmaceuticals and medical equipment.[9] A study from Japan evaluated the GHG emissions of >70,000 patients with CKD and showed that the annual per-patient emissions were 3.9 tons CO_2eq, which increased as CKD progressed. Those patients with ≥30% reduction in eGFR per year had CO_2eq emissions of 1.44 in men and 1.27 tons of CO_2 eq in women.[35]

Peritoneal dialysis (PD) also has a significant environmental impact, although data are less robust. However, estimates for a plastic use in a 4-exchange continuous ambulatory peritoneal dialysis (CAPD) regimen generates ~21 kg of polypropylene (PP) and ~81 kg of polyvinyl chloride (PVC) plastic waste per year, and all this is potentially recyclable. The carbon footprint of disposal of this plastic if it goes to landfill is ~0.1 tons CO_2-eq. The automated peritoneal dialysis

(APD) data were similar to ~30 kg PP and ~100 kg of PVC with similar CO_2eq.[36] Nevertheless, the production, transport, and disposal of large volumes of plastic-packaged dialysate mean that emissions are estimated to be roughly equivalent to those of haemodialysis.[10,37]

In contrast, kidney transplantation has a much lower environmental impact than dialysis. Preliminary data suggest that emissions from transplantation are ~95% lower than those from haemodialysis.[38] However, comprehensive data on the carbon cost of kidney transplantation and non-dialysis conservative care are yet to be fully established, and this is a data gap. Nevertheless, initiatives to reduce the travel requirements post-transplant (eg, using telehealth) promise to reduce the carbon footprint of transplantation even further.[39] Intuitively, the carbon footprint of non-dialysis conservative care would be lower than any dialysis modality, given its generally lower resource use.

The Carbon Footprint of Current CKD Treatment in the UAE

Despite the substantial burden of CKD in the UAE and the fact that reducing this burden can potentially mitigate its environmental impact, limited local data exists regarding the footprint of current CKD treatment in the UAE. The life cycle assessment (LCA) method is widely utilised to evaluate the carbon footprint of different CKD stages and treatment modalities. LCA involves a comprehensive analysis of the environmental impacts of all stages of a product's life, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.[40]

Recently, such methodology was used to estimate the carbon footprint of different CKD stages and treatment modalities in the UAE.[19] The report evaluated the environmental impact of CKD at the patient and population levels using the Sustainable Healthcare Coalition (SHC) Care Pathway Guidance.[41] Local data on healthcare resource utilisation (HCRU) and environmental impact were retrieved from the published national reports and inventory sources. This analysis measured the overall GHG emissions per patient-year spent in each stage of CKD. Overall, the results indicated that treatment of patients with CKD at each stage contribute 107–160% of CO_2eq compared with the average UAE person's annual GHG footprint (21.8 tons CO_2eq[42]). As is readily apparent, there is an increase in per-patient GHG emissions as CKD progresses, with HD contributing most highly to the GHG emissions (Figure 1).

Additionally, it was found that there were variations in the drivers of GHG emissions according to the CKD stage. In stages 1–3, hospitalisation was the main contributor to the carbon footprint; in contrast, KRT was the main contributor to

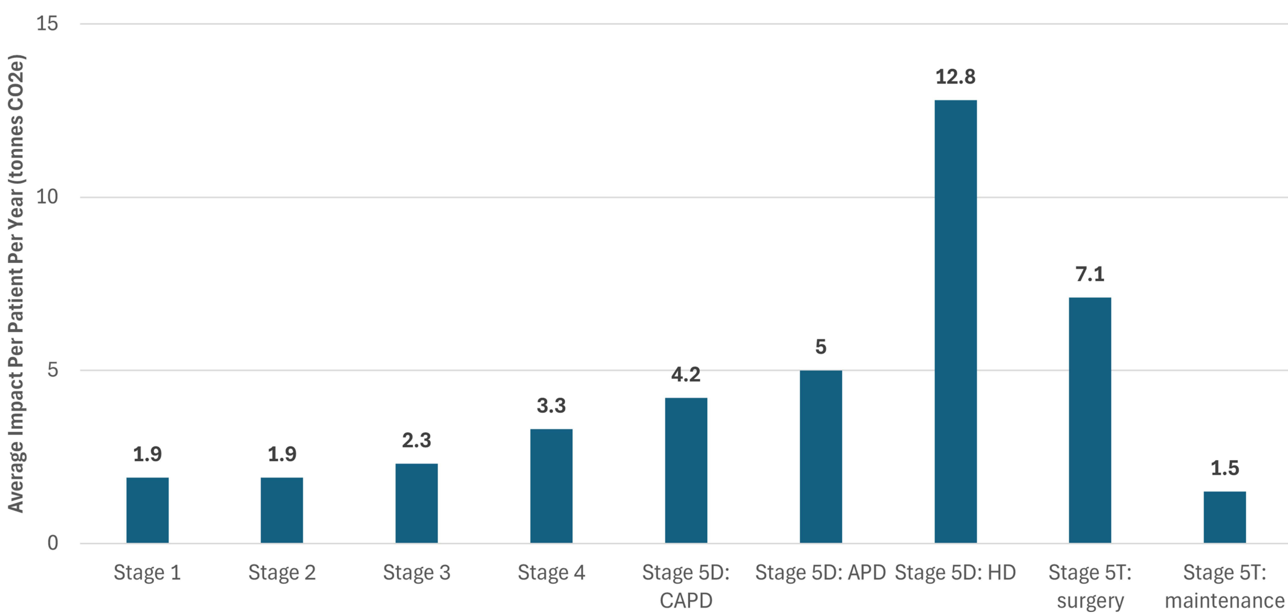

Figure 1 Per-patient carbon emissions according to the CKD stage and treatment modalities.
Abbreviations: 5D, Stage 5, dialysis; 5T, Stage 5, transplantation; CAPD, Continuous ambulatory peritoneal dialysis; APD, Automated peritoneal dialysis; HD, Haemodialysis.

Table 2 Percentage of Carbon Footprint

Stages	ED Visit	PC Visit	Hospital Stay	ICU Stay	Specialist Visit	CAPD	APD	HD	Transplant Surgery	Transport
Stage 1	0.04	0.05	56.18	6.87	0.73	0.00	0.00	0.00	0.00	36.13
Stage 2	0.07%	0.04%	55.83%	6.83%	0.78%	0.00%	0.00%	0.00%	0.00%	36.45%
Stage 3	0.06%	0.04%	58.61%	5.58%	0.74%	0.00%	0.00%	0.00%	0.00%	34.98%
Stage 4	0.06%	0.03%	57.47%	9.22%	0.62%	0.00%	0.00%	0.00%	0.00%	32.60%
Stage 5D: CAPD	0.17%	0.02%	29.11%	3.18%	0.38%	46.05%	0.00%	0.00%	0.00%	21.09%
Stage 5D: APD	0.15%	0.02%	24.48%	2.68%	0.32%	0.00%	54.63%	0.00%	0.00%	17.74%
Stage 5D: HD	0.08%	0.01%	11.93%	1.12%	0.12%	0.00%	0.00%	25.92%	0.00%	60.81%
Stage 5T: Surgery	0.15%	0.01%	20.73%	2.91%	1.51%	0.00%	0.00%	7.45%	9.21%	58.02%
Stage 5T: Maintenance	0.45%	0.05%	52.71%	11.75%	0.40%	0.00%	0.00%	0.00%	0.00%	34.63%

Abbreviations: 5D, Stage 5, dialysis; 5T, Stage 5, transplantation; PC Primary care; HD, Haemodialysis; CKD, chronic kidney disease; CAPD, continuous ambulatory peritoneal dialysis; APD, automated peritoneal dialysis; ICU, Intensive care unit; ED, Emergency department.

the carbon footprint at stages 4–5 (Table 2). The KRT-associated emissions were driven mainly by haemodialysis (450% higher than the standard treatment of stage 3).

The Role of Sustainable Healthcare in UAE 2050 Net Zero Strategy

The UAE Net Zero 2050 strategic initiative represents a national effort to achieve net-zero emissions by 2050, making it the first nation in the MENA region to implement this plan. This initiative aligns with the Paris Agreement and involves a comprehensive strategy to reduce GHG emissions and limit the rise in global temperature. It encompasses coordination across key sectors like energy, economy, industry, infrastructure, transport, waste, agriculture, and healthcare.

The 28th Conference of the Parties (COP28) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Dubai in 2023, marked a significant milestone in global efforts to address climate change. This assembly of international stakeholders, including governments, non-governmental organisations, and the private sector, underscored the urgency of collective action in mitigating climate change impacts and fostering a sustainable future. COP28 in Dubai delivered several significant outcomes, emphasising a global commitment to a transition from fossil fuels, enhancing climate finance, and focusing on nature within the first Global Stocktake outcome. The conference also marked a clear direction for parties to achieve deep, rapid, and sustained reductions in GHG in line with 1.5°C pathways, explicitly referencing the need to reduce 43% of GHG emissions by 2030 and 60% by 2035 relative to 2019 levels. Furthermore, COP28 saw the Loss and Damage Fund operationalisation, with initial pledges amounting to roughly $700 million, aiming to assist climate-vulnerable countries in dealing with impacts beyond their capacity to adapt. Negotiators also established a framework for the Global Goals of Adaptation but left financial specifics and quantifiable targets to be further developed.[43]

The Ministry of Climate Change and Environment (MOCCAE) is set to lead and coordinate this initiative, ensuring national collaboration to meet the objective. The strategy includes significant investments in clean energy, focusing on renewable energy ventures and green infrastructure projects.[44] Thus, establishing environmentally sustainable healthcare can contribute to the UAE 2050 Net Zero strategy by reducing the carbon footprint of UAE healthcare, promoting a healthier society, improving medical waste management, enhancing energy efficiency, and utilising renewable resources.[4,45] Several scientific reviews and technical reports have proposed roadmaps and strategies to ensure the integration of environmental sustainability in the healthcare sector. Briefly, these delivery plans focus on (1) changing governance and regulation to ensure that healthcare facilities are built with eco-friendly materials and incorporate green building principles, (2) multi-partner cooperation, (3) use of renewable energy sources, (4) managing medical waste in more carbon neutral ways, and (5) promoting telemedicine and digital healthcare platforms to reduce the need for physical travel to healthcare facilities.[46,47] For instance, the UK National Health Service (NHS) has provided a delivery plant to fully decarbonise services by 2040.[48]

Focusing on the care of prevalent chronic disorders represents an efficient approach to achieving sustainability goals in a timely manner. The focus on CKD as a prevalent and long-term condition producing high anthropogenic emissions would contribute substantially to reducing the healthcare sector's carbon footprint whilst maintaining or even improving the quality of patient care. Several national action plans, such as the Canadian Sustainable Nephrology Action Planning, were developed to decarbonise kidney care and implement a planetary care model; these plans primarily focus on changing the clinical practice to prompt a healthier society and reduce the burden of advanced stages, optimising transportation access, and promotion of conservative non-dialysis care.[49]

Strategies for Decarbonization of CKD Care

Breaking the re-enforcing cycle of increasing CKD causing increased anthropogenic emissions, which may promote further CKD, requires a multifaceted approach that includes reducing emissions through sustainable practices and halting the progression of CKD to advanced stages. We propose a framework to decarbonise CKD care in the UAE based on MacNeill et al's framework for sustainable healthcare[50] and the Canadian Sustainable Nephrology Action Plan.[49] Our proposed framework tackles the carbon footprint of CKD care in the UAE by focusing on three main pillars (Figure 2):

I. Delaying early CKD and slowing its progression.
II. Reducing anthropogenic emissions from CKD and dialysis care by promoting best practices and eco-friendly technologies.
III. Enhancing access to kidney transplantation.

Reducing the Demand for CKD Care and the Burden of KRT

Reducing the number of patients reaching dialysis is important for a greener CKD care model. This can be achieved by early detection and management of CKD, which can contribute substantially to the progression to kidney failure and reduce the associated mortality and morbidity.[51] A recent review proposed a framework for addressing the gaps in CKD

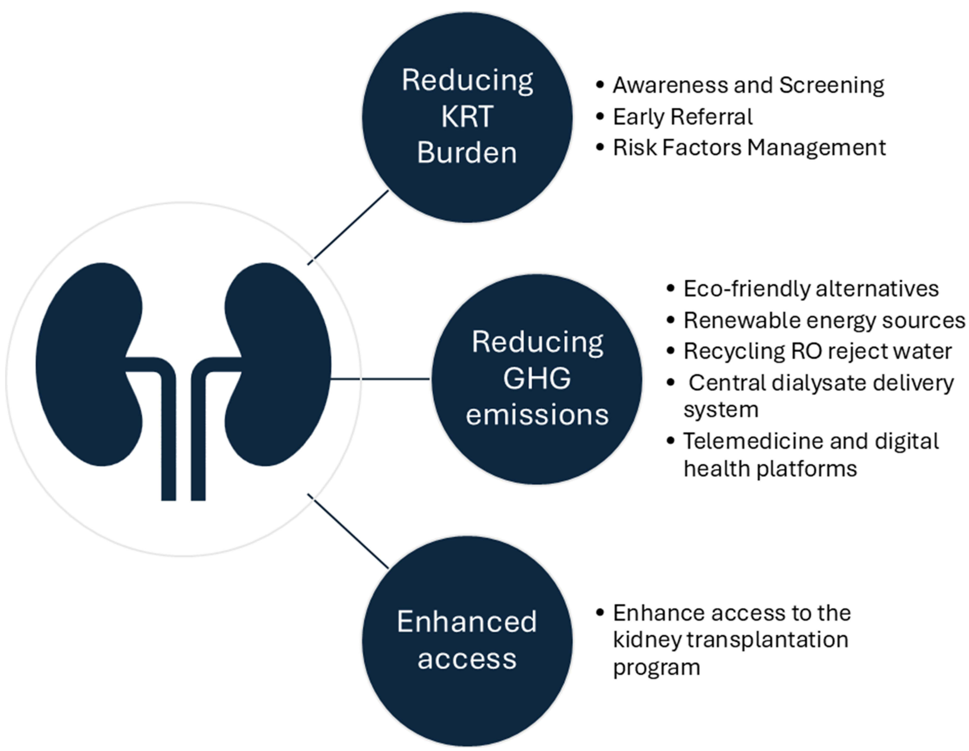

Figure 2 Strategies for Decarbonization of CKD Care.
Abbreviations: KRT, Kidney Replacement Therapy; GHG, Global greenhouse gas; RO, Reverse osmosis.

detection and management, reducing the burden in the MENA region by focusing on awareness, screening, early diagnosis, referral, and management.[52]

Awareness and Screening

Several risk factors contribute to the development and progression of CKD, including diabetes, older age, proteinuria, and hypertension.[53] Thus, the current international guidelines recommend early screening and monitoring of kidney functions in high-risk patients.[54] Although the prevalence of CKD is notably high in the MENA region, recent reports highlighted that screening for CKD is still suboptimal in primary care in the MENA region.[52] It was also found that several CKD risk factors are underdiagnosed and undertreated in the Arab world, suggesting that patients with CKD might be discovered at advanced stages.[15] Additionally, data regarding the efficacy of screening programs in developing countries is limited.[15] This is coupled with limited awareness among the general population and medical community regarding the requirements for CKD screening and the advances in preventive strategies.[55] An additional issue is that there are a high number of expatriates in the UAE, each with differing CKD risk profile and different and unequal access to preventative, screening and treatments.[17]

Therefore, national and regional guidelines may be needed to ensure optimal implementation of CKD screening programs, including establishing criteria for at-risk patients and the frequency of screening. There is also a need to ensure routine evaluation of eGFR and perhaps also urinary albumin–to–creatinine ratio (UACR) in higher-risk patients. Educational efforts should target primary care physicians and non-specialists to increase their awareness of CKD screening in at-risk populations. Efforts should also be made to improve public awareness around kidney risk and interaction with other cardiometabolic disease prevention schemes.

Early Referral

Pivotal clinical trials have shown that early detection and referral of CKD for aggressive management may significantly slow the progression of kidney decline and improve renal and CVD outcomes.[56] It is not, however, known what is the optimal frequency of monitoring in CKD, and frequent attendance and review with testing may actually increase carbon emissions; thus it will be important to develop strategies to limit testing and use telehealth and home monitoring as far as possible to efficiently care for patients with CKD.[49] However, many patients with CKD still present to the nephrology services with advanced CKD. Data from developing countries also suggest a high rate of late referral of CKD patients, which may be primarily driven by limited awareness, low socioeconomic and educational status, and limited healthcare resources.[57,58] However, even in high-income countries, the referral patterns of CKD patients appear to be suboptimal. Older UAE data suggested that the average referral time of CKD stage 3 patients in the UAE was eight months, compared to three months for patients with CKD stage 5.[18] However, recent work with primary care, at least in Abu Dhabi, may have significantly reduced this time. Given the high prevalence of CKD in the expatriate community, implementing CKD screening at visa application may well improve detection and treatment rates in some of the highest-risk populations, increasing the need for a comprehensive model of care for at-risk patients to ensure early referral to nephrology.

Management

Preventive strategies, including better blood pressure management and glycaemic control, are strongly recommended to slow the progression of CKD in at-risk patients.[59] Several newer therapies now introduced to the CKD management algorithms and guidelines have shown great promise in slowing CKD progression. Initially, such protocols focus on effectively controlling blood pressure using renin-angiotensin system (RAS) blockage and reducing proteinuria. More recently, antidiabetic medications, such as sodium-glucose transport protein 2 (SGLT2) inhibitors and glucagon-like peptide-1 receptor agonists (GLP-1 RAs), have been shown to be highly effective in slowing CKD. SGLT2 inhibitors can significantly reduce albuminuria, slow eGFR decline, and improve cardiovascular function and weight loss in patients with diabetes.[60] In the DAPA-CKD trial, dapagliflozin was found to significantly reduce the risk of renal decline (≥50% eGFR), CVD and reduced kidney-related deaths and all-cause mortality in patients with or without type 2 diabetes mellitus (T2DM).[61] The study also showed the protective effects of dapagliflozin in people with diabetes regardless of their baseline antidiabetic medications.[61,62] Dapagliflozin was well-tolerable, even in patients with a low eGFR (≥25 mL/

minute/1.73 m^2).[61] Subsequent trials, such as DECLARE, DAPA-HF, and EMPA-KIDNEY, have confirmed the cardio-renal protective effect of dapagliflozin.[63–65] Other SGLT2 inhibitors, such as canagliflozin and empagliflozin, have also demonstrated similar outcomes in patients with T2DM, confirming a class effect.[66,67]

Other recent additions include GLP-1 RA, which also exhibits a cardio-renal protective benefit in patients with T2DM, although their use is currently only licenced in patients with an eGFR >30 mL/min/1.73 m^2.[68,69] Other therapies for CKD include finerenone, a non-steroidal mineralocorticoid receptor antagonist, which exhibited a significant reduction in the risk of CKD progression, sustained ≥40% eGFR decline, and adverse cardiovascular outcomes.[70] Recent guidelines recommended SGLT2 inhibitors for patients with T2DM and CKD, as well as patients with T2DM and eGFR ≥30 mL/min/1.73 m^2.[59]

Despite the guideline's recommendations, there appears to be a considerable evidence-practice gap in managing CKD at earlier stages. Previous reports demonstrated that up to 64% of patients with CKD do not receive the guideline-recommended antihypertensive and lipid-lowering medications.[71,72] In developing countries, shortage of care specialists, financial barriers, and healthcare infrastructure play a significant role in this evidence-practice gap; however, even developed countries showed suboptimal management of CKD due to limited awareness of novel therapies.[72]

The awareness and adoption of all therapies should be implemented within the care model for CKD in the UAE, alongside increased accessibility and appropriate management of hypertension and diabetes in at-risk patients. This should be coupled with establishing an integrated care model, decision-support tools, and policy changes to increase treatment accessibility. Real-world evidence and cost-effectiveness analysis are also important to establish the benefits of novel therapies within the local setting where there is the potential to reduce the number of patients receiving KRT, along with its enhanced carbon footprint.

Reducing GHG Emissions by Adopting Green Technologies

Adopting green technologies in CKD treatment, particularly in dialysis, is an important step towards decarbonising CKD care. The concept of a green nephrology unit, which England NHS adopted, revolves around monitoring and reducing water and energy use in the building, material conservation, waste reduction and on-site processing, and training management and staff in sustainable practices.[73] Additionally, eco-friendly alternatives, such as biodegradable linen and motion-sensor energy-saving lights, were proposed for a "greener" dialysis facility.[74]

With regard to power consumption, dialysis is an energy-intensive process, largely due to the power requirements of water purification (reverse osmosis, [RO]) and dialysis machines, as well as cooling systems in the UAE. Previous reports showed that the power consumption of a single dialysis session is 12.0–19.6 kWh, which is substantial given that most dialysis units operate 2–3 dialysis 'shifts' a day, operating six days a week.[75] The power consumption of the dialysis unit depends heavily on the power sources; previous reports showed that electricity contributed to 18.6% of dialysis-related emissions in brown coal areas, compared to 5% in hydro sources.[9,75] Transitioning to renewable energy sources in dialysis facilities can aid in decarbonisation. Utilising solar, wind, or geothermal energy to power these facilities can significantly reduce dependence on fossil fuels. For instance, a study from Australia found that using solar arrays reduced the dialysis unit's grid power consumption by 91% and power costs by 76.5%.[76] Equipping the dialysis units with heat exchangers might further reduce power consumption.[77]

In terms of water consumption, haemodialysis/haemodiafiltration requires significant amounts of product water for the dialysate (18–30 thousand Litres/year), each litre of which requires far more water through the RO to create the dialysate.[78] Many RO systems are not highly efficient,[79] but recycling RO reject water can reduce environmental impact. RO reject water can be redirected into storage tanks or used as grey water instead of being wasted and is cost-saving. Previous reports demonstrated that the RO reject water recycling saved nearly £10,600 per year in the UK.[80] In Abu Dhabi, many facilities recirculate RO-reject water and use it for toilet flushing and planting around the facilities. Upgrading low-efficiency RO's to more efficient water treatment plants is another key step. Additionally, considering incremental dialysis or reducing the dialysate flow rate where appropriate can further decrease water demand.[78]

Other climate-friendly adaptations include using a central dialysate delivery system, implementing recycling programs for non-infectious waste, and exploring biodegradable or eco-friendly alternatives for necessary disposables.[78]

Current medical waste treatment in the UAE consists of transport to an incineration facility and burning; this is suboptimal from an environmental perspective and a major producer of dioxins.[81] The World Health Organisation (WHO) report on medical waste suggests that

> where feasible, favouring the safe and environmentally sound treatment of hazardous health care wastes (e.g., by autoclaving, microwaving, steam treatment integrated with internal mixing, and chemical treatment) over medical waste incineration.

Work is underway to attempt to move to local waste reprocessing by shredding, mixing, and steam sterilisation, which would substantially reduce the carbon footprint.[32]

Leveraging telemedicine and digital health platforms for the management of CKD can contribute to decarbonisation by enabling remote monitoring and consultations. Telemedicine reduces the need for patients to travel frequently to healthcare facilities, thereby cutting down on transportation-related emissions.[39] This approach also enhances patient accessibility and convenience, particularly for those residing in remote areas.[82] In a recent systematic review of 48 studies, it was found that the telemedicine consultation saved 692,000 tons of CO_2 emissions due to reduced travelling, which was combined with significant time and cost savings.[83]

Where patients perform their own dialysis at home, transportation costs may decrease. However, current UAE HD practice involves a full nurse-supported model where one (or two) nurses travel to patients in their homes, and this increases travel-related emissions because the nurse-patient ratios for dialysis patients increase dramatically. Worse still, many home dialysis providers are using relatively inefficient dialysis systems requiring 4 or 5 sessions a week, making the environmental impact substantially worse for such home patients. Future research should aim to estimate the increased eCO2 from such practice.

Enhance Access to the Kidney Transplantation Program

Kidney transplantation and PD are more sustainable and environmentally friendly options compared to in-centre haemodialysis. Kidney transplantation offers a more sustainable approach for patients with kidney failure and significantly improves the quality of life, life expectancy, and cost-effectiveness compared with dialysis treatment.[84,85] Additionally, transplantation requires less frequent medical intervention and vastly less medical waste compared to dialysis, leading to lower energy consumption and reduced GHG emissions.[86] Despite this, the current modality of KRT is inverted, with a higher prevalence of in-centre haemodialysis over kidney transplantation and PD. Barriers to more transplantation include the limited availability of suitable donor kidneys, exacerbated by cultural and religious beliefs about organ donation in some communities.[87] In addition, access to transplantation is often limited by economic factors and legal and policy frameworks, limiting organ availability and transplantation opportunities.[88]

Raising awareness about the benefits of organ donation can help expand the donor pool. Improving transplant and donation infrastructure, including facilities and training, can greatly increase the capacity for transplantation. The UAE has been recently recognised by the International Society for Organ Donation and Procurement (ISODP) as the fastest growing organ procurement program in the world in the last five years. Policy reforms that simplify the organ donation process while ensuring ethical practices are critical, and recent UAE law changes are likely to further improve donation rates. Providing financial assistance and insurance coverage can help overcome economic barriers to transplantation. Overall, increasing transplantation not only improves quality of life and is substantially cheaper than dialysis but also substantially improves GHG emissions.

Conclusion

CKD and dialysis therapies generate a substantial environmental burden in the UAE, and there is an urgent need to mitigate the carbon footprint and environmental impact by moving towards a decarbonisation strategy. In this paper, we propose a roadmap towards greener care in the UAE by focusing on early identification and treatment of CKD, adopting efficient dialysis technology, better waste management, and increasing kidney transplantation. Such approaches are relevant not only for the UAE but also for global healthcare systems aiming towards net-zero emissions.

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