Challenges to implementing environmentally sustainable dialysis in LMICs

Dr Abdou NIANG, MD, FWACP

Professor of Medicine, Head of nephrology department
AFRAN President,
ISPD African chapter Co-chair
Dakar, Senegal.

DISCLOSURES

- No conflict of interest to disclose

Principles of sustainable health care

- The 4 principles of sustainable health care include prevention, patient empowerment (education and smarter use technology) and self-care, lean service delivery, and use of low-carbon alternatives.
- Tree **overarching strategies**: reducing demand, matching supply and demand, and reducing emissions.

Valerie L., Niang A. et al. Kidney int. 2024

Lean service delivery

- Lean service delivery (LSD) is defined as the **optimization of service delivery** with the goal of maximizing environmental sustainability.
- The **dialysis supply chain** is also of important environmental concern. Between 60% and 80% of the health care carbon footprint is contributed by the supply chain. Drug manufacturing and transportation are major generators of emissions.
- In **sub-Saharan Africa**, most dialysis consumables are imported, including large quantities of 10-liter cans of acetate and bicarbonate, which comes with both a financial and an environmental cost.

Stanford V et al. Lancet Planet Health. 2023; Richie C. J Med Ethics. 2022; Vanholder R et al. Nephrol Dial Transplant. 2023

Lean service delivery

- Bundled orders, reduced packaging, and using concentrates or powders instead of large-volume cannisters can all contribute to lower carbon emissions.
- **Calls for local manufacture of dialysis supplies**+++
- Staff and patient transportation are major contributors to HD emissions in HICs, limited impact in LMICs.

Stanford V et al. Lancet Planet Health. 2023; Richie C. J Med Ethics. 2022; Vanholder R et al. Nephrol Dial Transplant. 2023

Lean service delivery

- **Clinicians and dialysis staff can be educated** on efficient water usage, waste reduction, and energy conservation.
- Health authorities and dialysis providers must recognize the importance of **integrating green practices** into dialysis **without compromising the quality** of kidney care.
    * Upgrading of existing environmentally inefficient technology, for example, reverse osmosis (RO) systems
    * New dialysis units should be mandated to include environmentally efficient technology from the start.
- **Financial support and incentives** may be required to support quality improvement projects and foster a culture of environmental responsibility.

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Low-carbon alternatives and innovation in KRT

- Dialysis services are increasingly becoming available (although not equitably accessible) in LMICs. Given severe resource limitations, but the individual unit footprint may in contrast be high.
- PD, being performed at home and with a limited amount of fluid per day, would be more sustainable than HD; however, it is not yet clear if PD is indeed a lower carbon alternative.
- Per treatment, **PD generates more waste than HD** (Connor A et al. . Nephron Clin Pract. 2010) PD fluids are manufactured in large, centralized factories. PD fluid generation requires large volumes of water purified by RO, and the filled PD bags must be sterilized by steam in large drive-in autoclaves.

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Low-carbon alternatives and innovation in KRT

- A lower carbon innovation in the dialysis space is Ellen Medical Devices Point-of-Care Affordable Peritoneal Dialysis System, which aims to provide more financially and environmentally affordable PD fluid manufacture.
- Development and testing of this system are ongoing to support regulatory submissions and subsequent approval for commercial distribution.
- Many innovations to improve“green dialysis” are simple and implementable in LMICs.
- Solar energy, light-emitting diode (LED) lighting and variable-speed motor pumps can be considered to reduce power consumption

Valerie L., Niang A. et al. Kidney int. 2024; Elrggal ME et al. Transplantation. 2021

Regulations Policy

Clinical Interventions

Intervention	Examples	Feasibility in LMIC	Barriers/challenges	Positive impact
Mandate green dialysis	Conditions of Public Private Partnership Suppliers with environmental certification	Yes	Companies may insist on increasing prices	Incentivize companies to improve "greenness"
Monitor environmental impact	Benchmarks	May need strengthening	Need data	Improve awareness. Facilitate decision-making.
Link "greenness" to reimbursement	Benchmarks	Yes	Need data	Incentivize greener dialysis practice
Set standards for environmental benchmarks	Quality improvement exercises	May need strengthening	Need data	Education during benchmark development
Reduce unnecessary drug prescriptions	Less samples Shorter prescriptions Appropriate antibiotics Fewer prescriptions	Yes	Patients and clinicians need to be educated	Reduce C footprint of Pharma
Prevent Kidney Failure (acute and chronic)	Public health measures screening, early diagnosis and treatment	Yes	Need public health, strong primary care, UHC	Reduce need for dialysis
Promote transplantation	Living and deceased donation Speed up listing and donor evaluation processes	Not possible in all settings	Not all patients transplantable/have donors	Reduce emissions by 90-95%
Incremental dialysis	Start with 1-2 PD exchanges per day, 1 to 2 HD sessions per week	Yes	PD not available everywhere	Reduce emissions, better quality of life
Reduce dialysate flow	Maximum 400 – 500 ml/min	Yes	none	Less water use, no impact on dialysis adequacy
Self-care dialysis	HD units where patients dialyze themselves	Not available in many settings	Patient education, confidence	Less staff transport
Home dialysis	HD at home	Not available in most LMICs	Patient education, confidence	Less patient transport

Non-clinical Interventions

water

Power

Intervention	Examples	Feasibility in LMIC	Barriers/challenges	Positive impact
Educate patients	Low carbon life-style	Yes	none	Improve awareness
Recycle canisters, packaging	Patients may use/sell cannisters	Should be possible	Requires system in place	Reduce waste
Separate waste for disposal	Contaminated vs. non-contaminated, plastic, paper etc	yes	Requires training, discipline	Reduce incineration,
Use re-usable food/drink containers	Own drink bottles vs paper cups	yes	none	Reduce waste
Reduce waste of RO water	Less reject water. RO in series.	Yes	Needs equipment installation, up-front cost	Cost effective after 5.8 years
Careful with priming volumes	Online priming	Yes	Requires training, discipline	Reduce water consumption
Reduce dialysate flow	Relative to blood flow	Yes	none	Reduced water use, No change in adequacy up to a lower limit
Value of HDF	Assess indication	Yes	Need data to individualize prescriptions	Would reduce water consumption
Regenerate dialysate	Requires sorbents	challenging	expensive	Reuse of waste water
Re-use post-dialysis water	Crop irrigation after sorbents	challenging	Technically challenging, not cost-effective	Could use methane emissions from crops/fermentation for power
Central dialysate	With dry/semi-dry concentrates mixed centrally	Requires equipment installation	Need equipment	Reduces water consumption and transport costs/emissions
Reduce electricity	Natural gas Solar power Wind Methane	Needs strengthening	Up front costs high	Recuperate costs over time
Retrofit heat exchanger	Refit machine	Requires equipment installation	Up front costs high	Reduce heat loss during dialysis
Reduce dialysate temperature (?)	Programmable	Yes	Patients may be uncomfortable	May reduce hypotensive episodes

Waste

Intervention	Examples	Feasibility in LMIC	Barriers/challenges	Positive impact
Recycle	Plastic, paper, water	May need strengthening	Requires education, discipline	Could create jobs
Landfill	Plastic, metal	Needs to be reduced	Need alternative waste system in place	Could re-use Methane emissions for power
Incineration	Contaminated waste	Yes	Contributes to air pollution	Less volume than landfill
Dialyser re-use	Requires safety limits, controversial	Possible	Requires infrastructure. *Benefit unclear given chemicals, heat and water used and waste generated*	If prolonged reduces dialysis adequacy
Empty dialysis circuit and bicarbonate cartridge prior to discard	At end of treatment	yes	Requires education, discipline	Reduces weight of waste

Technology

Intervention	Examples	Feasibility in LMIC	Barriers/challenges	Positive impact
Optimize dialysate flow/blood flow	Built-in machine capability	yes	Requires education	Reduced water use, No change in adequacy
Online priming	Built-in machine capability	yes	Requires education, machine capability	Reduced waste from saline bags and sets
Use standby mode	Built-in machine capability	yes	Requires education, discipline	Less electricity use
Low-water machines	Portable HD machines	Machines may not be available	expensive	Reduce water, portable
Dialysate	Dry/semi-dry > canisters	possible	Requires renegotiations	C footprint reduced by 1/3 to 1/4
Bicarbonate	Cartridges > canisters. Appropriate size.	possible	Requires renegotiations	
Acid concentrate	Higher concentrations – lower volumes required	possible	Requires renegotiations	
Telehealth	Mobile phone, computer Home or clinic	possible	Requires infrastructure, mobile technology	Cost-saving
Optimize disinfection protocols	Reduce cycles if short time-intervals. Use efficient heat disinfection. Correct chemical disinfection.	yes	Requires education, discipline	Reduces water consumption, r]less environmental contamination
Equipment repair/re-use	HD machines	possible	Companies nudge towards new machines	Reduces waste, landfill
Point-of-Care PD System	Machine requires to generate sterile water, bags with salts	possible	expensive	Reduce transportation, emissions

Smart Buildings

Intervention	Examples	Feasibility in LMIC	Barriers/challenges	Positive impact
Climate resilient	Location, structure, design,	Possible, especially if new units being built	Up front costs high	Safe in disasters
Insulation	Materials, windows	Possible, especially if new units being built	Up front costs high	Reduce energy consumption
Fix leaky windows	Detect leaks	yes	Maintenance	Reduce energy consumption
Ventilation	windows	yes	Maintenance	Reduce energy consumption
Space	In case of infection risk	yes	Options may be limited	
Stairs and ramps > lifts	Locate dialysis units on lower floors	yes	Lifts required for disabled patients	Reduce energy consumption
Efficient air-conditioning	Use wisely	yes	Expensive, climate impact	Reduce energy consumption
Natural light	windows	yes	Need insulation for winter if large windows	Reduce energy consumption

TRANSPORT

Intervention	Examples	Feasibility in LMIC	Barriers/challenges	Positive impact
Dialysate formulation	Dry/semi-dry > canisters	Possible, especially if new units being built	Requires infrastructure	Reduce transportation costs, emissions
Reduce packaging	Ship without boxes	yes	planning	Reduce transportation costs, emissions
Point of care PD fluid generation	Distillation device, PD bags	Needs machine	expensive	Reduce transportation, emissions
Pool transport	Patients, staff	yes	planning	Reduce transportation, emissions
Bicycle stands	Staff/patient commute	yes	Planning, security	Reduce transportation, emissions
Locate dialysis units near critical mass of patients	HD units or promote PD in remote settings	Needs planning	Health systems planning	Reduce transportation, emissions

STAFF EDUCATION

Awareness	Education about climate change	yes	Educational opportunities	Improve practice
Environmental policy	Practical guide	yes	May be lacking	Improve practice
Batch orders	Coordinate supplies for single suppliers, timely ordering	yes	Reduce transportation	Reduce energy consumption, emissions
Switch off machines when not in use	When safe to do so (water circuit remains on)	yes	quires education, discipline	Reduce energy consumption
Turn off lights	action	yes	quires education, discipline	Reduce energy consumption
Conserve water	action	yes	quires education, discipline	Reduce water consumption
LED bulbs	purchase	yes	Cost to purchase	Reduce energy consumption
Paperless records	Electronic medical record	Possible	Requires electronic medical records	Reduce paper waste, energy for printing.