Epidemiology of peritoneal dialysis outcomes

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Abstract | Peritoneal dialysis (PD) is an important home-based treatment for kidney failure and accounts for 11% of all dialysis and 9% of all kidney replacement therapy globally. Although PD is available in 81% of countries, this provision ranges from 96% in high-income countries to 32% in low-income countries. Compared with haemodialysis, PD has numerous potential advantages, including a simpler technique, greater feasibility of use in remote communities, generally lower cost, lesser need for trained staff, fewer management challenges during natural disasters, possibly better survival in the first few years, greater ability to travel, fewer dietary restrictions, better preservation of residual kidney function, greater treatment satisfaction, better quality of life, better outcomes following subsequent kidney transplantation, delayed need for vascular access (especially in small children), reduced need for erythropoiesis-stimulating agents, and lower risk of blood-borne virus infections and of SARS-CoV-2 infection. PD outcomes have been improving over time but with great variability, driven by individual and system-level inequities and by centre effects; this variation is exacerbated by a lack of standardized outcome definitions. Potential strategies for outcome improvement include enhanced standardization, monitoring and reporting of PD outcomes, and the implementation of continuous quality improvement programmes and of PD-specific interventions, such as incremental PD, the use of biocompatible PD solutions and remote PD monitoring.

Worldwide, peritoneal dialysis (PD) accounts for 9% of all kidney replacement therapy (KRT) and 11% of all dialysis[1–3]. According to the 2018 International Society of Nephrology Global Kidney Health Atlas (ISN-GKHA), the median global prevalence of PD was 38.1 per million population (pmp) but varied over 5,000-fold from 0.1 pmp in Egypt to 531 pmp in Hong Kong[2]. More than half of all patients receiving PD resided in four countries (China, USA, Mexico and Thailand)[4]. PD was not available in 30 countries, 20 of which were located in Africa. The survey further demonstrated that PD use was 60-fold lower in low-income countries (LICs; 0.9 pmp, 95% CI 0.7–1.5) than in high-income countries (HICs; 53.0 pmp, 95% CI 40.6–89.8 pmp)[4]. This observation seems initially somewhat surprising given that, compared with haemodialysis (HD), PD has a number of distinct advantages that should be attractive to LICs, such as greater technical simplicity, lesser need for trained staff and lower nurse-to-patient ratios, greater feasibility in rural and remote communities, fewer management challenges during natural disasters, greater cost-effectiveness (in most countries), improved equity of access to dialysis in resource-limited settings and possibly better survival in the first few years[1,5–8]. Indeed, because of these features of PD, a number of jurisdictions, such as Thailand, Hong Kong, mainland China, Australia, New Zealand and the USA, have implemented policies and/or financial incentives that favour the use of PD[3,9–12]. However, numerous barriers to PD utilization exist in many low- and middle-income countries (LMICs), including high PD fluid costs, lack of trained health care workforce, and variable but often poor outcomes (particularly related to infection)[2,13].

Reported PD outcomes vary greatly around the world, partly owing to discrepancies in outcome definitions, practices, and monitoring and reporting of quality indicators, as well as kidney failure care gaps, including health care workforce shortages, inadequate health care financing, suboptimal governance, lack of suitable health care information systems and poor accessibility to kidney care[3,4,14,15]. These gaps are greatest in Africa and South Asia[4].

In this Review, we describe the contemporary worldwide epidemiology of PD outcomes, including clinical,

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Key points

- Peritoneal dialysis (PD) has distinct advantages compared with haemodialysis, including the convenience of home treatment, improved quality of life, technical simplicity, lesser need for trained staff, greater cost-effectiveness in most countries, improved equity of access to dialysis in resource-limited settings, and improved survival, particularly in the first few years of initiating therapy.
- Important barriers can hamper PD utilization in low-income settings, including the high costs of PD fluids (owing to the inability to manufacture them locally and the exorbitant costs of their import), limited workforce availability and a practice culture that limits optimal PD use, often leading to suboptimal outcomes.
- PD outcomes are highly variable around the world owing in part to the use of variable outcome definitions, a heterogeneous practice culture, the lack of standardized monitoring and reporting of quality indicators, and kidney failure care gaps (including health care workforce shortages, inadequate health care financing, suboptimal governance and a lack of good health care information systems).
- Key outcomes include not only clinical outcomes (typically defined as medical outcomes based on clinician assessment or diagnosis) — for example, PD-related infections, technique survival, mechanical complications, hospitalizations and PD-related mortality — but also patient-reported outcomes. These outcomes are directly reported by patients and focus on how they function or feel, typically in relation to quality of life or symptoms; patient-reported outcomes are used less frequently than clinical outcomes in day-to-day routine care.

Biocompatible PD solutions
PD solutions that have a neutral pH and relatively low concentrations of glucose degradation products.

patient-reported and surrogate outcomes (BOX 1). In particular, we will focus on prioritization and standardization of PD outcomes, comparisons with HD, potential mechanisms underlying PD outcomes, and strategies for outcome improvement, including PD-related interventions such incremental PD, the use of biocompatible PD solutions, remote PD monitoring, prescription changes and the use of assisted PD.

Standardizing and prioritizing PD outcomes

A major limitation to monitoring, reporting and benchmarking of outcomes in patients receiving PD has been the lack of use of standardized outcomes that are relevant and meaningful to patients and their caregivers. For example, PD-related infection is widely monitored and reported by PD units around the world because it is a major barrier to patients selecting PD as a dialysis modality, it is the commonest reason for patient transfer to HD and has a mortality of 2–6%[16]. However, in a systematic review of 120 randomized controlled trials (RCTs) in PD up to 2019, PD-related infection was reported in 59 (49%) studies using 383 different measures, of which 317 were only used once[17]. From 2016 to 2020, the Standardized Outcomes in Nephrology in PD (SONG-PD) initiative conducted a five-phase mixed methods process[18], including systematic review, nominal group technique[19], stakeholder interviews, an international Delphi survey[20] and an international consensus workshop[21], to identify the top five most important outcomes based on the shared priorities of patients, caregivers and health care professionals. These outcomes were, in descending order of priority, PD infection, cardiovascular disease (CVD), mortality, technique survival and life participation (FIG. 1). Notably, they differ somewhat from the core outcomes of critical importance identified for HD (fatigue, CVD, vascular access and mortality)[22]. In 2022, the International Society for Peritoneal Dialysis (ISPD) published its standardized definition for PD-related peritonitis, which should be diagnosed when at least two of the following are present: clinical features consistent with peritonitis (that is, abdominal pain and/or cloudy dialysis effluent); dialysis effluent white cell count $>100/\mu l$ or $>0.1 \times 10^9/l$ (after a dwell time of at least 2 h), with >50% polymorphonuclear leukocytes; and positive dialysis effluent culture[23]. Work is currently underway to develop validated outcomes for technique survival and life participation[24,25].

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Clinical PD outcomes across the globe

Clinical outcomes are medical outcomes based on clinician assessment or diagnosis. In this section, we discuss the clinical outcomes of infection, mortality, CVD, technique survival, hospitalization, encapsulating peritoneal sclerosis, mechanical complications and cognitive function.

PD-related infection. PD-related infection was rated as the most critically important outcome by PD patients, caregivers and clinicians in the SONG-PD initiative[21]. However, despite PD-related infection being associated with increased morbidity and mortality[21], a systematic review found that, out of 59 countries with dialysis registries, only 33 high- or middle-income countries monitored peritonitis rates[26]. Within these countries, global average peritonitis rates decreased from 0.6 episodes per patient-year (ppy) in 1992 to 0.3 episodes ppy in 2019; Asia–Pacific countries had the highest peritonitis rates followed by Europe, the Middle East and Africa. The lowest rate was reported in America (including North, South and Central America)[26]. Another systematic review (1980–2019) of data from seven African countries (17 studies, 1,894 participants) reported median peritonitis rates of 0.75 (95% CI 0.56–2.20) episodes ppy (specifically, 0.63 and 1.78 for adults and children, respectively)[27]. By contrast, a multicentre study that included 734 children in the USA, reported a peritonitis rate of 0.46 episodes ppy, with lower rates being associated with provider compliance with collaborative training and a quality assurance initiative that involved 29 paediatric centres in the US and was developed to facilitate uptake of standardized care bundles (that is, catheter insertion bundle, patient and caregiver training bundle, and catheter exit follow-up care bundle)[28].

Differences in peritonitis rates across countries have been attributed to several modifiable factors, including practice patterns[15]. The Peritoneal Dialysis Outcomes and Practice Patterns Study (PDOPPS), which included

7,051 adult receiving PD patients from 209 centres across seven countries (Canada, Japan, Australia, New Zealand, Thailand, UK and the USA), reported appreciable differences in peritonitis rates (episodes ppy), for example, 0.26 in the USA, 0.27 in Japan, 0.35 in Australia and New Zealand, 0.38 in the UK and 0.40 in Thailand. Practices such as higher use of automated PD, prescription of antibiotics before catheter insertion, longer duration of PD training and larger facility size were associated with a lower risk of peritonitis[15].

Gram-positive peritonitis predominates in most countries. In a 2011 registry analysis of 5,336 episodes of peritonitis in Australia and New Zealand, Gram-positive peritonitis accounted for 53.4% of episodes, with coagulase-negative staphylococci (27.2%) and *Escherichia coli* (6.3%) being the most common Gram-positive and negative organisms[29], respectively. Similar findings were reported in 2006 for North America — 62.0% of infections in the USA and 61.0 % in Canada were caused by Gram-positive organisms (predominantly coagulase-negative staphylococci)[30]. By contrast, a 2014 study reported a 33.7% rate of Gram-positive peritonitis in Northern India[31]. An international 2020 study found lower proportions of Gram-positive peritonitis in Australia and New Zealand (39.0%), US (37.0%) and Canada (45.0%) than those reported in earlier studies. These subsequent rates were similar to those observed in Japan (37.0%), UK (38.0%) and Thailand (26.0 %)[15]; another 2020 study reported a 37.0% rate in Africa[27], whereas a 2021 study from Spain[32] reported infections in 55.9% of patients. Although the ISPD recommends that culture-negative peritonitis rates should be kept <15%[23], most countries, including Canada (16.0%), Japan (21.0%), US (16.0 %)[15] and India (18.2 %)[28], were unable to achieve the target. Culture-negative peritonitis rates were also extremely high in Africa (28.7 %)[27] and Thailand (28.0 %)[15], and high antimicrobial resistance has been reported in parts of China[33].

Peritonitis outcomes vary markedly across countries, including medical cure (69.0–80.7%), catheter removal (10.8–20.4%) and mortality (1.8–6.0 %)[29,30,32,34]. Of note, implementation of Continuous Quality Improvement (CQI) programmes can reduce peritonitis rates and improve outcomes[35,36]. Furthermore, peritonitis rates were relatively low when homemade PD solutions were used in an aseptic technique to treat patients with acute kidney injury (AKI), which has implications in low-resource settings[37,38].

Exit-site or tunnel infections are important causes of peritonitis and subsequent technique failure[39]. In the PDOPPS, 8.5–20.8% of peritonitis episodes were associated with concomitant exit-site or tunnel infection[15]. These infections should therefore be monitored and reported as an important PD infection outcome in kidney registries and future studies.

Mortality. Overall, mortality on dialysis has gradually improved since the technique was introduced in the 1960s. Registry data suggest a contemporary adjusted 5-year survival of 52% and 42% for PD and HD, respectively[40]. Survival on PD has improved at a higher rate than that reported for HD. For example, from 2009–2019, the US Renal Data System (USRDS) reported an all-cause mortality decrease of 19.7% among all patients with kidney failure, including decreases of 10.5% for kidney transplant recipients, 17.5% for patients receiving HD and 21.3% for those receiving PD[41]. These improved survival rates for both dialysis modalities seem to be driven by a significant reduction in early mortality (within the first 2 years of dialysis initiation) owing to decreases in late dialysis referral and hospitalization rates. A 2017 review of the worldwide epidemiology of PD reported that 5-year patient survival varied between 48.4% and 64% across North America, Latin America, Europe and Oceania[42].

The leading cause of mortality among patients receiving PD is CVD, which accounts for 52.7% of all deaths with a known cause[41], followed by dialysis withdrawal (17.8%), sepsis (9.6%) and other causes (13.3%), including cancer, and gastrointestinal or respiratory disease[41]. Of note, the COVID-19 pandemic has partially counteracted decades of progress in mortality reduction in patients treated with kidney replacement therapy, owing to their high baseline prevalence of comorbidities and their vulnerability to severe COVID-19 (REFS.[43,44]).

In terms of dialysis modality comparisons, some studies have suggested that the mortality risk was lower in patients receiving PD compared with HD, particularly in the first 2 years of dialysis[45,46]. These findings might be related to better preservation of RKF with PD than with HD (discussed below), but it might also reflect selection bias with residual confounding because some observational studies reported similar survival between PD and HD when only elective, outpatient, incident dialysis patients were analysed. Notably, patients who are frail or have a high comorbidity burden are more likely to initiate in-centre HD than a home therapy such as PD[46]. The time after dialysis initiation at which the relative survival benefit apparently switches from favouring PD to favouring HD is related to a number of factors including demographics (for example, age, sex and socioeconomic status), geography (for example, country and within-country centre variation), cause of kidney

Box 1 | **Summary of PD outcomes**

Clinical peritoneal dialysis (PD) outcomes
- PD-related infection
- Mortality
- Cardiovascular disease
- Technique survival
- Other infections
- Hospitalization
- Encapsulating peritoneal sclerosis
- Mechanical complications
- Cognitive function

Patient-reported PD outcomes
- Life participation
- PD-related pain
- Gastrointestinal symptoms
- Fatigue
- Depression
- Anxiety
- Cramps
- Pruritus
- Restless legs syndrome
- Sexual function
- Sleep quality

Surrogate PD outcomes
- Residual kidney function
- Fluid volume status
- Blood pressure
- Chronic kidney disease–mineral bone disorder
- Anaemia

Other outcomes
- Impact on family and friends
- Financial burden

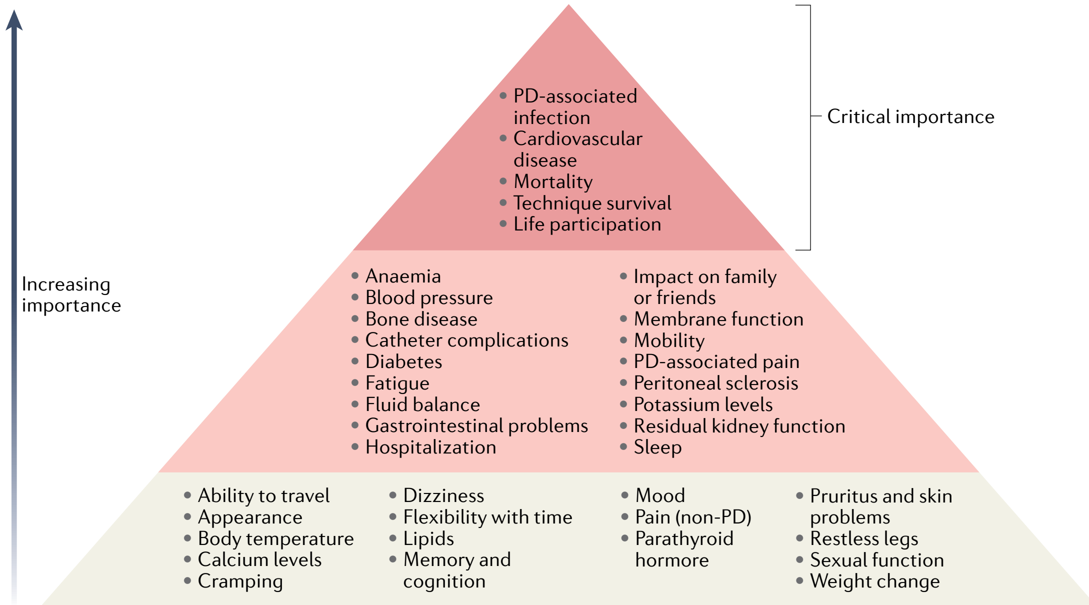

Fig. 1 | **Hierarchy of importance of peritoneal dialysis outcomes to patients, caregivers and clinicians.** The Standardized Outcomes in Nephrology in Peritoneal Dialysis (SONG-PD) initiative identified a hierarchy of PD outcomes according to their level of importance to stakeholder groups. The outcomes in the top tier are critically important to all stakeholder groups, those in the middle tier are critically important to some stakeholder groups and those in the bottom tier are important to some or all stakeholder groups. Adapted with permission from REF.[21], Elsevier.

failure, dialysis vintage, comorbidity and centre effects or experience[47]. A large-scale study involving 398,940 patients who initiated dialysis in the USA (1995–2000) reported that the mortality risk was higher with HD than with PD in younger populations without substantial baseline comorbidity[47]. By contrast, HD was linked to a lower mortality rate than PD with increasing age and comorbidity index[47]. With PD, survival also seems to correlate positively with centre experience with PD[48]. Overall, the choice between PD and HD should be guided by the patients' preferences, values and quality of life (QOL). Importantly, mortality comparisons between HD and PD require patient stratification according to major risk factors known to interact with treatment modality to avoid confounding effects. Moreover, the survival differences between HD and PD are not constant over time or across regions, but rather vary according to demographic, clinical, geographic, sociocultural and centre factors within and across regions.

In LICs, data on PD-related mortality are extremely limited[13]. In many of these countries, PD is either not used or used in <10% of patients needing KRT. Risk and mortality patterns also seem to differ from those of countries with higher incomes because in LICs, infection, rather than CVD, is reported to be the leading cause of mortality[49].

Centre effects
Variations in outcomes between centres that are related to centre characteristics (for example, practices, experiences and/or organization) rather than patient characteristics.

Cardiovascular disease. The risk of CVD mortality among patients receiving dialysis is estimated to be 10- to 20-fold higher than that of the general population[50]. The types of CVD affecting these patients are diverse and range from atherosclerosis-related complications, such as acute coronary syndromes and stroke, to heart failure and arrhythmias.

The CVD risk factors in patients receiving PD can be broadly classified into three categories: general ('traditional'), specific to patients with kidney failure ('non-traditional') and unique to PD. 'Traditional' CVD risk factors, including hypertension, dyslipidaemia and diabetes mellitus, are frequently present in patients with kidney disease. For example, in a cross-sectional study involving four PD centres in Greece, 95% of patients receiving PD had ambulatory hypertension and adequate blood pressure control was only achieved in 38.3% of patients[51]. Second, kidney dysfunction itself is a risk factor for CVD, which is evident even among patients with mild kidney dysfunction[52], and has been attributed to 'non-traditional' CVD risk factors, such as inflammation, endothelial dysfunction and calcification[53]. For example, loss of kidney excretory function leads to the accumulation of advanced glycation end-products, which are thought to trigger the production of pro-inflammatory mediators, such as pro-atherogenic adhesion molecules that promote atherosclerosis, and thus contribute to the pathogenesis of vascular and kidney diseases[54]. Moreover, high levels of inflammatory markers (for example, CRP[55], IL-6 (REF.[56])) are associated with increased incidence of CVD. PD-specific risk factors include advanced glycation end-products present in PD solutions and volume overload caused by the loss of ultrafiltration[57].

Despite the many CVD risk factors in patients receiving PD, no intervention has consistently or reliably reduced CVD burden in this population[58]. In 2020, 61.3% of people receiving PD in the USA were reported to have CVD and 52.7% of deaths in this group were attributed to CVD[41,59]. Specifically, the commonest cause of death among patients treated with PD in the USA was sudden cardiac death (39.7%)[41]; in patients treated with HD, sudden cardiac death accounted for 44.2% of deaths. Similarly, CVD was the most common cause of death among patients receiving PD in Australia (36%) and New Zealand (24%)[60]. However, the extent to which geographical variation influences the burden of CVD in PD remains uncertain owing to large disparities in measurement and reporting. Currently, less than half of the 79 registries that collect data from patients with kidney failure from 77 countries capture data related to CVD[61]. Moreover, disease definitions varied considerably across registries, which challenges direct comparison of CVD burden. For example, coronary artery disease (in the Australia and New Zealand Dialysis and Transplant Registry (ANZDATA)), ischaemic heart disease (in the USRDS), myocardial infarction (in the Swiss Renal Registry) and angina pectoris (in the Finnish Registry for Kidney Diseases) have all been used to categorize the same disease entity[61]. The global community is awaiting the development and validation of a standardized core outcome measure for CVD in PD that can be implemented to better inform shared decision-making and improve outcomes.

Technique survival. PD technique survival refers to PD duration before transfer to HD, whereas technique failure refers to transfer to HD. Reported 3-year technique survival rates vary around the world from 29% to 91%[62,63], but such variations have been attributed at least in part to differences in defining PD start date (for example, date of catheter insertion, training commencement or training completion), end date (for example, 1, 2 or 3 months after HD transfer) and inclusion of other relevant events (for example, death, transplantation or recovery of kidney function)[25]. A unified definition of technique survival has been proposed to include a composite end point of transfer to HD for >30 days or death[64]. Although technique survival is one of five core patient outcomes identified by the SONG-PD initiative[21], a review of 120 PD RCTs showed that only 18% ($n = 22$) of studies reported technique survival[17].

Factors associated with technique survival can be categorized as patient-related, centre-related and treatment-related[25,65] (BOX 2). Peritonitis and PD-related infections are the major cause of technique failure[23,66,67] and accounted for 60% of HD transfers in a systematic review comprising 3,645 patients treated with PD[25]. Accordingly, a South African study that assessed PD outcomes from a predominantly rural area reported that patients with multiple episodes of peritonitis had a significantly higher likelihood of HD transfer than patients with 1 or no episodes (HR: 1.90; 95% CI: 1.04–3.47; $P = 0.038$)[68]. In other studies, reductions in peritonitis rates were accompanied by improvements in technique survival[27,69]. For instance, studies from seven African countries showed that, between the mid-1980s and late 2010s, peritonitis rates dropped from 2.72 to 0.44 episodes/patient year and 2-year technique survival improved from 50% to 90%[27]. Similar trends were reported by a French Language Peritoneal Dialysis Registry study of 14,673 patients who initiated PD — lower rates of peritonitis over time were accompanied by lower HD transfer rates[69].

Centre effects are also a major factor in PD technique survival. In particular, larger PD centre size has been associated with better technique survival in numerous cohort studies in the Netherlands[70], USA[71], and Australia and New Zealand[34]. Having a higher proportion of patients treated with PD in a centre has also been associated with improved technique survival[34,70]. These findings might reflect greater cumulative PD experience, PD specialization or availability of a variety of clinical competence and experience (nurses, social workers, dietitians, surgeons and physicians). Other factors, such as adequate nutritional status[72], use of automated PD[73] and use of assisted PD[74], have been associated with improved PD technique survival; this association was especially significant in paediatric age groups.

Technique failure is associated with a number of adverse outcomes. An ANZDATA analysis of all incident PD patients with technique failure between 1989 and 2014 showed overall mortality of 62%, with a significantly higher risk of death in those with technique failure related to infection or social reasons, compared with inadequate dialysis or mechanical issues ($P < 0.0001$)[75]. Moreover, an analysis of incident dialysis patients in Canada from 1999–2003 reported higher cost of care in those transferred from PD to HD than in those treated only with HD due to higher costs of dialysis provision, hospitalization, medications, and physician fees[76].

There are no PD-specific strategies for improving technique survival. However, early interventions by dialysis centres to screen for modifiable risk factors for technique failure, such as diabetes mellitus and other comorbidities, extreme obesity, low adherence to PD prescriptions, low literacy, living in rural or remote areas, history of HD before PD, and previous episodes of peritonitis, have been suggested[65].

Other infections. Compared with HD, PD is primarily home based and offers advantages in terms of reduced

Box 2 | **Factors associated with technique failure in patients receiving PD**

Patient-related factors
- Age
- Sex
- Race
- Body size (body mass index)
- Baseline nutritional status
- Educational level or difficulty learning peritoneal dialysis (PD)-related tasks
- Socio-economic status and income
- Depression or other psychosocial problems
- Previous stroke
- Diabetes mellitus
- Other comorbidities (for example, blindness or congestive cardiac failure)
- Inguinal or abdominal hernias
- Frailty or inability to cope with PD
- Patient choice

Treatment-related factors
- Peritonitis or PD-related infections
- Residual kidney function
- Prior treatment with haemodialysis
- Prior kidney transplant
- PD modality (automated PD versus continuous ambulatory PD)
- Ultrafiltration difficulties
- Catheter malfunction or migration
- Dialysate leak
- Reduced dialysis solute clearance
- PD solution

Centre-related factors
- Centre size and experience with PD, including volume of cases
- Centre location
- Timely referral
- Access creation time

Information obtained from Elphick et al.[25] and Da Luz et al.[65].

PD vintage
The length of time (measured in months or years) during which a patient with kidney failure receives PD as a treatment modality.

Executive function
A set of mental processes that enable people to plan, focus attention, retain and process information, and handle complex tasks.

exposure to hospital-acquired infections. For example, various studies reported lower rates of SARS-CoV-2 infection in patients receiving PD than in those treated with HD[77–79]. In Wuhan, China, one study reported a SARS-CoV-2 infection incidence rate of 2.44 per 1,000 patient-months amongst patients receiving PD, which was similar to that of the general population[77]. Lower rates of SARS-CoV-2 infection in patients receiving PD than in those treated with HD were also reported in Italy (1.38% versus 3.55%, respectively)[78] and in the UK (2.9% versus 9%)[79].

PD is also associated with a lower risk of hepatitis B (HBV) and C (HCV) infections than HD[80,81]. In a study of 10 Asia–Pacific countries involving 201,590 patients (PD 27,802; HD 173,788), HCV prevalence ranged from 0.7 to 18.1% across countries, with lower HCV infection in PD populations than in those receiving HD (3.0% versus 7.9%), whereas HBV prevalence ranged from 1.35–14.6% with comparable prevalence between PD and HD[80]. A Brazilian study observed lower seroconversion rates with PD than with HD for HBV (0.01 versus 0.19 ppy) and HCV (0.03 versus 0.15 ppy)[81]. These differences probably reflected virus transmission within HD units.

Pneumonia is associated with high mortality among PD patients[82]. The incidence of pneumonia has been reported to be lower in PD than in HD in the USA (18.2 versus 29.0 ppy, respectively)[83], but death due to pneumonia was similar in the two modalities in Australia and New Zealand (0.44 versus 0.43 per 100 patient-years)[84].

Hospitalization. Hospitalization has been graded by patients, caregivers and clinicians in the SONG-PD initiative as a middle-tier outcome that is critically important to some stakeholder groups[21]. In the USA, hospitalization of patients receiving PD has fallen from 1.8 episodes ppy in 2009 to 1.5 episodes ppy in 2019, which appeared to have been partly driven by decreased peritonitis-related hospital admissions from 0.08 to 0.03 episodes ppy, respectively[85]. Importantly, between 2014 and 2017, most PD peritonitis episodes were managed by hospitalization in the USA (54.7%), Canada (51.7%), UK (64.7%), Japan (87.8%), Thailand (78.7%), and Australia and New Zealand (75.9 %)[15]. In Japan, peritonitis-related hospitalization (0.21 episodes ppy) was more common than cardiovascular-related hospitalization (0.16 episodes ppy)[86], whereas the converse was true in the USA (0.03 episodes ppy versus 0.42 episodes ppy)[85] and Canada (16% versus 28%)[87]. Hospitalization rates for infections other than peritonitis were 0.44 episodes ppy in 2019 in the USA[85].

Encapsulating peritoneal sclerosis. EPS is a rare complication of PD that is characterized by intraperitoneal inflammation and fibrosis, and the development of a fibrocollagenous membrane that encases bowel loops, which leads to ultrafiltration failure and bowel obstruction, and increases mortality risk[88]. Reported incidence of EPS varies between 0.7 and 13.6 per 1,000 patient-years, depending on the population studied, owing to variation in demographic and clinical characteristics[89,90]. A substantial variation in EPS risk has also been reported both within and between countries owing to practice differences, including treatment protocols, fluid types and long-term dialysis duration; for example, the risk of EPS is generally low in the first 3–5 years after PD initiation[88]. Key risk factors for EPS include PD vintage, recurrent peritonitis, PD fluids (for example, the use of a dialysate with a high glucose concentration, an acetate buffer or a bio-incompatible dialysis fluid) and medications (for example, the use of β-blockers or calcineurin inhibitors)[91]. Of note, the risk of EPS might be higher in kidney transplant recipients who used to receive PD than in patients who are still on PD and who have not received a transplant[92]. It is unclear whether this risk is related to the transplant procedure, reduced clearance of fibrin due to the cessation of peritoneal lavage following transplantation, or the known pro-fibrotic effects of calcineurin inhibitors[92].

Mechanical complications. Approximately 40% of PD patients are estimated to develop mechanical complications[93]. Fluid leaks (including hydrothorax or pleuroperitoneal leaks) occur when PD solution leaks out of the peritoneal cavity[94]. These leaks happen with varying incidence according to differences in practice, population demographics and catheter types[95,96]. For example, the reported incidence of acute pleural effusion in patients receiving PD varies from 1.6 to 10%[97] and women are affected more commonly than men[98]. Bowel obstruction is also a rare complication of PD that is most commonly seen in patients with EPS or previous history of abdominal surgery complicated by adhesions[99]. Catheter malpositioning could also affect optimal treatment delivery owing to inflow or outflow dysfunction. Notably, mechanical complications of PD are linked to patient and treatment outcomes as they can affect the timely initiation and sustainability of PD therapy.

Cognitive function. Cognitive dysfunction, including executive, memory, attention, information processing, language and visuospatial skill dysfunction, is common in patients receiving dialysis owing to multiple factors such as uraemia, electrolyte imbalance, comorbidity burden, homeostatic shifts with dialysis therapy, and vascular ischaemic changes that affect the brain[100]. The burden of cognitive dysfunction is estimated to be 3–5-fold higher in patients receiving dialysis than in the general population, and executive function is the domain that is most commonly affected[101]. Interestingly, PD is linked to better cognitive function than HD, particularly in the first few years of dialysis initiation, which has been attributed to it lower intensiveness, enhanced clearance of uraemic toxins and better anaemia control. Cognitive dysfunction is associated with increased risks of hospitalization, poor QOL, dialysis withdrawal and mortality[101]. In children, even subtle cognitive concerns can present barriers to learning, social functioning and overall QOL if not appropriately recognized or addressed.

Global patient-reported PD outcomes

Patient-reported outcomes give an indication of patient perceptions of how they function or feel, typically in relation to QOL or symptoms[102]. These outcomes are being increasingly incorporated into routine clinical care.

Life participation. Similar to other patients with kidney failure, patients receiving PD want to be able to live well, maintain their social roles and functioning, live as normal a life as possible, and maintain a sense of control over their health and wellbeing[103]. However, the daily and frequent nature of PD exchanges, as well as the increased risk of infections can limit the ability of these patients to participate in various life activities (for example, work, travel or recreation). Life participation, which is a SONG-PD core outcome[21], is not uniformly assessed or reported across PD studies. A systematic review identified 42 different measures used for assessment of life participation, of which 36% were specifically designed to assess life participation and 64% assessed broader constructs, which suggests that these measures vary in their characteristics, content and validation[24].

Obligatory dimensions refer to factors necessary for day-to-day living (for example, paid work, education, ability to perform household tasks), whereas non-obligatory dimensions refer to factors such as leisure activities. Although both dimensions are often reported together, the obligatory components are more likely to be reported than non-obligatory dimensions (for example, socializing and recreation)[104–107]. For instance, the SONG-PD group found that 76% of studies reported both dimensions; an additional 14% and 10% of studies reported obligatory and non-obligatory dimensions, respectively[24]. Patients receiving PD often have a better employment status than those treated with HD[106–110], probably because they need to spend less time in a treatment facility. One study reported that PD was associated with a 4% increased probability of employment, 6% reduced probability of disability pension requirement and increased work income compared with HD[111]. However, studies from low-resource settings where maintenance PD is infrequently utilized showed much lower employment for PD patients compared with those receiving HD[104]. These regions might already be affected by low levels of employment in the general population and the reported unwillingness of employers to provide space for PD fluid storage or to provide time allowances for PD exchanges might further prevent patients receiving PD from access to employment[104]. There are no differences in non-obligatory dimensions, such as travel and recreation, between patients treated with HD and those treated with PD[105]. The ChinaQ study randomly assigned 725 patients across China to PD or HD and found that the burden of kidney disease on the PD group was non-inferior to that of the HD group[112]. However, studies comparing QOL between patients receiving HD or PD have tended to show better QOL in PD than in HD[108–110]. This difference might result from greater lifestyle flexibility, better ability to perform exchanges at home (or in a comfortable place that imposes less restriction), and better dietary flexibility in patients receiving PD[110].

PD-related pain. Abdominal pain, which is a SONG-PD middle-tier outcome[21], can occur during either the inflow or outflow phase of PD, particularly at PD initiation. Inflow pain often resolves with time on PD and is related to the acidic pH of conventional PD solutions and/or PD fluid turbulence during inflow[113]. In a systematic review, inflow pain was reduced by the use of PD solutions with neutral pH and low glucose degradation products (GDPs)[114]. Outflow pain near the end of the outflow phase, also known as drain pain, is related to suction on abdominal viscera or the peritoneum by the catheter tip. This type of pain is usually improved with tidal PD therapy, in which only part of the intraperitoneal fluid is exchanged to avoid the complete emptying of the peritoneal cavity. In a Canadian study that involved 375 patients receiving PD from six centres, 72 (19%) patients were administered tidal therapy, which specifically reduced drain pain[115]. Some studies have linked older age and abnormal bone mineral metabolism with PD-associated pain[116].

Gastrointestinal symptoms. Most patients receiving PD experience gastrointestinal symptoms, including constipation (14.2–0.3%), indigestion (32.7%), early satiety (41.6%) and gastroesophageal reflux (30.7–93.1%)[117]. Compared with patients receiving HD, constipation is less common among patients treated with PD owing to higher dietary fibre and potassium intake, more liberal fluid consumption, more active lifestyle and lower use of phosphate binders and ion exchange resins[118–120]. Nonetheless, constipation is associated with higher risks of catheter malfunction, peritonitis and technique failure, which demands a proactive treatment approach[118]. Early satiety, postprandial pain and anorexia[117,121,122] are more common in patients treated with PD owing to delayed gastric emptying[123], which seems to be related to dialysate composition rather than intraperitoneal volume or pressure[124]. In particular, icodextrin and bicarbonate-based solutions reduce gastric hypomotility compared with glucose or lactate-based solutions[123,124].

Fatigue. Fatigue affects between 42 and 89% of patients on dialysis[125,126] and can lead to substantial social, mental and physical disability[125,127] (FIG. 2). This outcome was identified as critically important in SONG-PD, mainly owing to its effect on life participation and carer burden[21]. Fatigue in patients treated with PD has been associated with older age[128,129], female sex[128,129], higher BMI[127,129], unemployment status[129], low physical activity[130], anaemia and use of erythropoiesis-stimulating agents (ESAs)[128,130,131], sleep disturbances[126], poorer dialysis adequacy[132], expression of serum markers of chronic inflammation and poor nutrition[132], and early dropout[133]. An ongoing multicentre, adaptive RCT will test whether 12 weeks of structured exercise can reduce fatigue in 400 patients receiving PD or HD[134].

Depression. In an international cohort of 3,227 patients treated with PD, the prevalence of depression ranged from 28 to 40%; lowest in the USA, and highest in Japan and the UK[135]. Concerningly, an inverse relationship was observed between screen-positive and physician-diagnosed depression, highlighting problems of under-recognition and under-treatment[135]. Patients with kidney disease are affected by a multitude of complex inter-relational factors that can lead to the development of

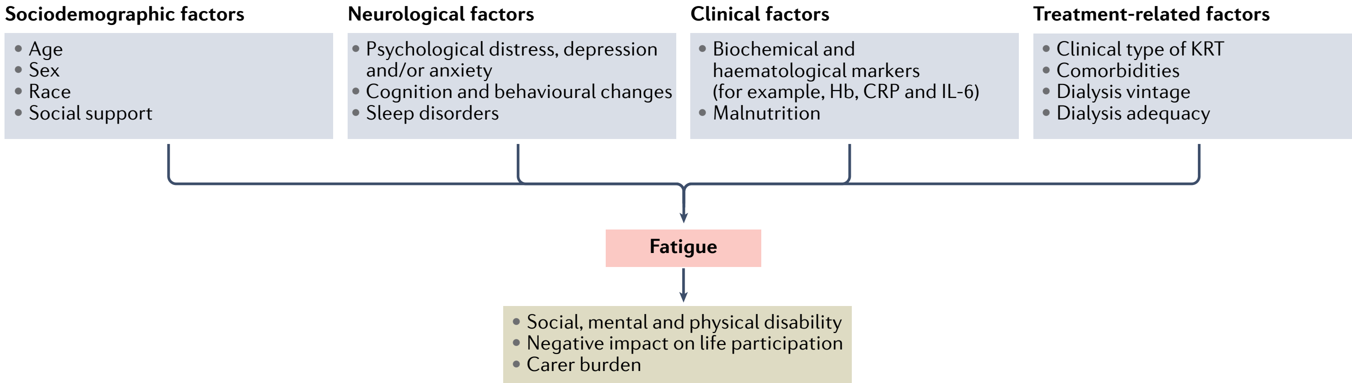

Fig. 2 | **Correlates of fatigue in kidney failure.** The onset of fatigue in patients with kidney failure is multidimensional and multifactorial, with bidirectional and circular associations leading to substantial social, mental and physical disability. CRP, C-reactive protein; Hb, haemoglobin; KRT, kidney replacement therapy. Adapted with permission from Artom et al.[125], Elsevier.

depression[136,137] (Supplementary Figure 1). Lower functional status, younger age and cognitive impairment are especially common among PD patients with depression[135]. The evidence linking depression with mortality or HD transfer is inconclusive[138–140] but several studies have highlighted its effect on QOL and peritonitis risk[135,138].

Anxiety. Anxiety, which is defined as an emotional state in which a person experiences intense fear, uncertainty and apprehension towards a situation or event that is anticipated[141], is reported in 24–43% of patients treated with PD[139,142], particularly in men and patients with diabetes[139], and is independently associated with death and HD transfer[142]. Fear of adverse events, social isolation, perceived financial stress from dialysis costs, caregiver burden and fear of HD transfer are important contributors to the development of chronic anxiety in these patients[143]. Ensuring appropriate patient selection for PD, providing comprehensive and early pre-dialysis education, and supporting patients with a multidisciplinary network are crucial measures for minimizing anxiety in this population[143].

Cramps. Cramps are characterized by sudden, involuntary, painful and prolonged muscular contractions[117,121,122]. Although cramps are probably under-recognized in PD, a 2012 study revealed that 73% of patients on PD for ≥3 months experienced cramping, which is comparable with what is observed in HD[144]. Both modalities share common factors implicated in dialysis-associated cramps, including plasma volume contraction, metabolic alkalosis, hypotension, hyponatraemia, carnitine deficiency and hypomagnesaemia[145,146].

Pruritus. More than half of all patients receiving PD (52.1–62.6%) experience pruritus[147,148], which is characterized by an itching sensation with variable spatial distribution (usually affecting large, discontinuous areas of skin) and without evident skin alterations that is exacerbated at night[149]. Pruritus is associated with impaired QOL domains, particularly sleep, mood and social functioning[150], and increased risks of death and HD transfer[151]. Although the pathogenesis of pruritus remains largely unknown, it is no longer thought to be purely histamine-mediated but rather to result from a complex crosstalk between dermal mast cells, epidermal keratinocytes, T helper 1 lymphocytes and nerve fibres[152].

Restless legs syndrome. Restless legs syndrome (RLS) is a clinical diagnosis based on an urge to move the legs, often accompanied by an uncomfortable sensation at rest, that improves with activity and worsens in the evening or at night[153]. Using a broad definition, RLS was identified in >50% of patients receiving dialysis[154], whereas using the stricter International Restless Legs Syndrome Study Group (IRLSSG) diagnostic criteria yielded a prevalence of 10–20%[154]. RLS prevalence did not differ between PD and HD[155].

Sexual function. Sexual dysfunction is common in chronic kidney disease (CKD) and correlates inversely with estimated glomerular filtration rate[156]. In a systematic review of 50 observational studies of sexual dysfunction in CKD populations, 16 studies (429 patients) included PD patients[157]. Most studies focused solely on men and specifically on erectile dysfunction[157]. The pooled analysis showed that the prevalence of erectile dysfunction in patients treated with PD was 64%[157], compared with 79% in patients receiving HD and 59% in kidney transplant recipients (heterogeneity $P=0.2$)[157].

Sleep quality. Sleep disorders are common in patients receiving dialysis, can affect QOL substantially, and are associated with fatigue and depression[158]. Several studies have reported sleep quality outcomes in patients treated with PD, but they used variable measurement methods. The Pittsburgh Sleep Quality Index (PSQI), which is a standardized self-administered sleep questionnaire, was used in 6 studies[159–165] (Supplementary Table 1). The mean prevalences of poor sleep quality, defined by PSQI >5 ($n=3$) and PSQI ≥5 ($n=3$), were 69.37%% and 81%, respectively (Supplementary Table 1). Whether sleep quality differs between patients undergoing PD and those on HD remains uncertain, although two small studies[165] ($n=102$ and 124) did not report appreciable differences[159,162].

Global surrogate PD outcomes

Surrogate outcomes are biological or physiological parameters used in the prediction of risk of hard adverse clinical events, such as kidney failure, CVD and mortality, or clinical benefits, such as reduction in the risk of adverse health outcomes, based on epidemiological (for example, co-morbidities such as anaemia), therapeutic (for example, blood pressure treatment) or pathophysiological evidence (for example, inflammatory markers such as serum C-reactive protein) that may or may not be validated[166]. In this section, we review key surrogate outcomes of relevance in predicting risk of adverse health outcomes in patients on PD. Hard endpoints such as CVD events or mortality take longer to reach, and thus surrogate measures are important intermediate measures of risk of prognostic and therapeutic significance.

Residual kidney function. Residual kidney function (RKF) is vital for patients treated with PD because it is strongly associated with improved survival and technique survival[167]. In general, PD is thought to preserve RKF better than HD because it does not commonly induce intradialytic hypotension and/or hypovolaemia[168]. Other PD-specific interventions associated with better RKF preservation include the use of solutions with neutral pH and low GDPs[169], and incremental PD[170]; these interventions seem to be beneficial owing to reduced exposure to GDP and glucose, which can be nephrotoxic with attendant fibrotic changes and loss of kidney function[171]. The status of RKF at PD initiation varies across countries; in PDOPPS, the median 24-h urine volume ranged from 0.4 l (Thailand; interquartile range 0.08–0.8) to 1.2 l (UK; IQR 0.71–1.77)[15]. The rate of RKF decline reportedly decreases after PD initiation (-2.69 ± 0.18 ml/min/1.73 m^2/year) compared with the pre-dialysis rate (-4.09 ± 0.33 ml/min/1.73 m^2/year, $P < 0.001$)[172].

Fluid volume status. Volume overload in PD is associated with accelerated RKF decline, HD transfer and mortality[173–175]. The use of hypertonic solutions and automated PD was not associated with significant volume reductions in the Patient Outcomes in Dialysis-Peritoneal Dialysis study, which involved 1,054 incident patients from 135 centres in 28 countries (3-year follow-up)[174]. Based on the findings of a 2018 Cochrane systematic review[114], the ISPD Guidelines make a strong level 1 A recommendation that use of neutral pH, low GDP ('biocompatible') PD solutions improves preservation of RKF and urine output[176]. These guidelines also strongly recommend (level B1) that icodextrin should be considered as an alternative to hypertonic solutions to maintain euvolaemia in patients with inadequate ultrafiltration. Compared with clinical assessment alone, the use of bioimpedance devices does not improve guidance of fluid management and PD prescription significantly[173,177].

Blood pressure. The prevalence of hypertension in patients treated with PD varies from 29 to 88% in different studies[178,179]. When PD is started, blood pressure control is frequently better than in patients starting HD owing to better volume control homeostasis and reduced haemodynamic shifts compared with HD, although this difference is often not maintained over time[180]. Similar to several HD studies[181], a USRDS study found a non-linear relationship between blood pressure and survival in patients treated with PD[182]. Specifically, a systolic pressure <111 mmHg was associated with increased mortality, whereas hospitalization duration was shorter in patients with a systolic pressure >120 mmHg[182]. However, this protective effect was not observed in another study[183]. These discrepant findings might be explained by the heterogeneous nature of the population across the two studies. Although no high-certainty evidence exists, guidelines recommend that patients receiving PD with blood pressure >140/90 mmHg should be treated to maintain their BP <140/90 mmHg[58]. Of note, hypertension in patients treated with PD is mechanistically linked to salt and water retention[184]; therefore, volume status should be optimized before starting or increasing anti-hypertensive medications[58,185].

CKD mineral and bone disorder. CKD mineral and bone disorder refers to any one or a combination of abnormalities of mineral metabolism (calcium, phosphorus, vitamin D, parathyroid hormone (PTH)), bone metabolism (kidney osteodystrophy, alkaline phosphatase) and/or vascular calcification[186]. These complications increase the risk of fractures, CVD and mortality in patients receiving dialysis[187–189]. Despite physiological differences in mineral metabolism between patients treated with PD and those treated with HD[190], most studies have focused on HD populations, with relatively few studies including PD patients[191–193].

Anaemia. Anaemia is a common multifactorial complication in patients with kidney failure driven, for example, by low erythropoietin production, iron deficiency and inflammation. Untreated or inadequately treated anaemia can lead to reduced QOL and increased risk of CVD and health care utilization[194]. Patients treated with PD often need to use fewer ESAs to treat anaemia than patients receiving HD (71.4% versus 96.9%, respectively, $n = 274{,}784$; US data)[195]. These differences have been attributed to better RKF preservation in patients receiving PD, who are also at a lower risk of blood loss than patients receiving HD. The prevalence of ESA-requiring anaemia varies geographically (for example, 82% in Hong Kong versus 96% in Thailand)[196]. However, the true extent of variation is incompletely understood, especially in LICs and LMICs, where haemoglobin is often never measured (LICs, 1/5 countries (20%); LMICs, 4/17 (24%))[4]. Of note, hypoxia-inducible factor inhibitors (for example, roxadustat) can improve anaemia and other clinical parameters, including decline of RKF, in patients receiving PD[197].

Other outcomes

Additional socio-economic (non-clinical) factors that affect the day-to-day lives of people receiving PD, as well as their families, caregivers and friends, should also be considered.

Effects on family and friends. The regular dialysis sessions and responsibilities associated with PD can be overwhelming and can extend naturally to family, friends and caregivers of patients[198,199]. Thus, minimizing patient and caregiver fatigue to improve QOL, increase patients' adoption of PD and decrease HD transfer is important[200]. In a PDOPPS cohort ($n = 2{,}760$), "space taken up by PD supplies" was the most commonly cited disadvantage of PD and had the strongest association with HD transfer (hazard ratio 1.28; 95% confidence interval 1.07–1.53)[201]. Developing approaches that enable the reduction of total PD fluid storage requirements would be prudent to overcome this barrier to PD adoption and improve PD patient experience[201]. Moreover, advances in technology could decrease the burden of PD care at home. In one study, patients and their care partners favoured remote PD management to troubleshoot problems and decrease clinic visits[202].

Finances. The cost of providing KRT remains an important barrier to care access for patients with kidney failure in many parts of the world[203,204]. According to data available from 87 countries, the average annual cost of maintenance PD was 20,524 international dollars (equivalent to the value of US dollars in 2016) per ppy[205]. However, costs varied widely within countries and by World Bank income group. Using the same data, the cost ratio of HD to PD was >1 (that is, PD was less expensive) in 59% of countries[205]. More than half of HICs (65%) and upper-middle-income countries (62%) had a cost ratio >1 but 39% of LMICs had similar HD to PD costs (that is, ratios ~1)[205]. No data were available for LICs. Other studies also found that PD was less costly than HD[206,207]. Low-cost PD equipment (either through low-cost manufacturing or import) is needed to increase dialysis uptake in LICs[5,204].

PD outcomes in vulnerable populations

Certain population subgroups might be particularly disadvantaged because of their biological characteristics and social circumstances, including literacy, economic status, living conditions and access to health insurance and health care. This section focuses on the variability and impact of PD outcomes in vulnerable population subgroups, such as children and adolescents, women and Indigenous peoples.

Children. PD is often selected as the initial KRT modality in the paediatric population, usually as a bridge to transplantation[208]. Urgent start of PD for AKI is also often used in children, especially in low-resource regions, as this may be the only form of dialysis available[209]. PD was leveraged as a KRT modality for paediatric AKI, more commonly in LMICs than in HICs. Acute PD for AKI is often started using improvised catheters and home-made fluid[210]. In the majority of cases, patients recover from AKI but when they do not, chronic PD must be introduced. Survival on PD is higher in children than in adults. A USRDS analysis reported 5-year survival of 76% and 85% in patients treated with PD aged 0–9 and 10–14 years, respectively[208]. Survival amongst infants on PD is 4-fold lower than among older children[211]. According to the North American Pediatric Renal Trials and Collaborative Studies data, patients who started PD in infancy had a 3-year survival probability of 74.6%, compared with 96.2% for those who started at an age >12 years[212]. Notably, infant survival was significantly better from 2000 to 2012 than from 1990 to 1999 (REF.[213]). In Italy, younger children (0–5 years) also had poorer survival and technique survival than older children (5–15 years)[214].

Apart from age, survival on PD also varies geographically. In the International Pediatric Peritoneal Dialysis Network Registry (2,956 children, mean age 7.6 years), the 3-year probability of death varied between 2% (North America) and 9% (Eastern Europe)[215]. Mortality was higher in LICs, and about half of the variance was explained by country income category[215]. In a report from India, the 3-year survival amongst 66 children started on PD was only 30%, with peritonitis being the main cause of death[216]. Unlike in HICs, where children are usually treated with automated PD overnight to facilitate school attendance and play during the day, most children in LICs are treated with manual exchanges.

Growth is another important concern in children on PD and is affected by nutrition and RKF; the use of recombinant growth hormone might be required to ensure adequate growth[217]. Higher fill volumes, fewer peritonitis episodes and the use of biocompatible fluids were associated with improved growth in small studies[211].

Women. Men outnumber women by 2:1 in the dialysis population[218]. However, data on sex differences in the characteristics, treatment and outcomes of PD are scarce. According to data from the Andalusian SICATA Registry, women on PD had similar overall mortality (adjusted HR 0.91, 95% CI 0.72–1.15), higher infection-specific mortality (adjusted HR 1.76, 95% CI 1.03–3.01) and similar cardiovascular mortality (adjusted HR 0.76, 95% CI 0.52–1.09) compared with men[219]. In another study from Australia involving 506 patients, female sex doubled the peritonitis risk (OR 1.91 95% CI 1.2–3.01)[220].

Data on the impact of sex on technique failure are inconsistent. A lower risk of technique failure was reported in females receiving PD in Germany (HR 0.66, CI 0.506–0.89, $P = 0.005$)[221], the USA (HR 0.78, 95% CI 0.64–0.95)[222], and Australia and New Zealand (HR for males 1.13, CI 1.06–1.20)[223]; however, other studies failed to find any sex differences in technique failure[224].

Pregnancy, although uncommon, presents a unique challenge for women on PD. In a review of 222 pregnancies in 208 women receiving dialysis (14 on PD)[225], the rate of successful live births was similar in women on HD to those on PD (79%). Four of the 14 patients treated with PD developed peritonitis. Of note, bloody effluent is a harbinger of serious complications — 2 out of 3 pregnancies complicated by haemoperitoneum eventually resulted in miscarriage.

Indigenous peoples. The burden of kidney failure is greatly increased in Indigenous peoples, most of whom live in remote locations. Although PD offers several advantages in this context, such as proximity to family and community support, reduced travel times and elimination of the need to relocate, the use and outcomes of PD in Indigenous populations are highly variable and often poor. Compared with non-Indigenous populations, the proportion of patients starting KRT with PD in 2009 was considerably lower in Australian Aboriginal and Torres Strait Islander peoples (18% versus 25%) and New Zealand Māori (31% versus 41%)[226]. In Canada, Indigenous people with kidney disease were half as likely to be on PD as white patients (OR 0.51, 95% CI 0.40–0.65)[227]. A number of factors, including low socioeconomic status, literacy, colonialism and geography (for example, living in remote or rural communities), are associated with lower rates of PD use in Indigenous populations compared with non-Indigenous populations.

Clinical outcomes are also generally poorer in Indigenous patients[228]. Data from Australia and New Zealand revealed higher mortality amongst Indigenous than amongst non-Indigenous patients receiving PD (HR 1.23, 95% CI 1.01–1.50; $P < 0.05$), after adjustment for patient demographics, comorbidities and peritoneal solute transport characteristics[229]. Indigenous patients also had higher peritonitis rates (1.14 versus 0.71 episodes per year, $P < 0.001$), shorter time to first peritonitis episode (9.9 versus 19.3 months; $P < 0.001$) and a higher level of technique failure (HR 1.30, 95% CI 1.15–1.47; $P < 0.001$) than non-Indigenous patients[230]. Similarly, Canadian Aboriginal patients had a non-significantly increased risk of technique failure (HR, 1.46; 95% CI, 0.95 to 2.23; $P = 0.08$) and comparable overall mortality[227]. Some evidence suggests that PD outcomes in Indigenous people are influenced by their location, with higher rates of peritonitis, technique failure and mortality reportedly associated with remote residence[231]. Importantly, 79% of Indigenous Australian patients who started PD between 1995 and 2008 lived remotely[231]. The relatively poor outcomes in these populations have been attributed to non-medical factors, such as poverty, unemployment, crowded living situations and lack of availability of speciality care.

Older patients. As a result of global increases in life expectancies, the number of older people (≥65 years old) commencing dialysis is growing[232]. Despite the potential advantages of PD listed in the introduction of this review, older patients face several potential barriers to accessing PD, including frequent late presentation, comorbidities, frailty, functional dependence, impaired dexterity, impaired visual acuity and reduced cognitive function[233,234]. A systematic review and meta-analysis of 14 non-randomized studies from 13 countries in Europe, Asia, Latin America and Oceania between 2000 and 2021 reported that (with low-certainty evidence) PD in older patients might be associated with higher mortality (relative risk (RR) 2.45, 95% CI 1.36–4.40, $P = 0.003$, $I^2 = 97\%$) and more frequent peritonitis (RR 1.56, 95% CI 1.18–2.07, $P = 0.002$, $I^2 = 76\%$); differences in technique survival between older and younger patients were minimal or absent (RR 0.95, 95% CI 0.86–1.05, $P = 0.32$, $I^2 = 86\%$)[233].

The use of assisted PD, whereby a carer performs PD for the patient, could potentially circumvent barriers to PD in older patients. However, in a systematic review of 34 non-randomized studies involving 46,597 participants from 20 jurisdictions, the relative efficacy and safety of assisted PD were uncertain, owing to highly variable study quality and markedly heterogeneous reported outcomes[235]. Similarly, a 2021 narrative review concluded that a difference in QOL, mortality or hospitalization between patients on assisted PD and those on facility HD was uncertain, after adjusting for the fact that patients receiving assisted PD were older and more frail[236]. Of note, assisted PD was significantly cheaper than facility HD in Canada and Western Europe[236].

Centre effects and PD outcomes

Despite improvements in PD care over the years, consistent and unacceptable variation in outcomes between different PD centres within various countries remains[29,237]. Although these differences have been previously attributed to heterogeneity in patient-related factors, emerging evidence suggests that variations in PD centre characteristics have a much greater role.

An ANZDATA registry study that included 54,773 patients with kidney failure reported 0–87% variation in the uptake of home dialysis ($n = 24{,}399$; 88.4% PD) across 76 centres[238]. Centre-level predictors of low uptake included small centre size, a small proportion of patients with permanent HD access at dialysis initiation and low weekly facility HD hours, defined in the study as ≤12.6 h of time spent on HD. The variation in odds of home dialysis uptake in this Australian study across centres was associated with centre-level characteristics (24%) and not patient-level characteristics[238]. This dominant effect of centre-level characteristics was observed for several PD outcomes, including peritonitis occurrence[239], peritonitis outcomes[34] and technique survival[240]. Other studies from France have reported similar results that support the important effects of centre-level characteristics on PD outcomes[237]. Centre-level characteristics consistently associated with better PD outcomes include a high proportion of PD patients in the centre, which is a marker of greater clinical experience with PD[34,240] and alignment of centre practices with ISPD guideline recommendations (for example, the use of empiric antibiotic therapy against both Gram-positive and Gram-negative organisms in patients with peritonitis)[34]. These results highlight the importance of implementing interventions at a centre level to ensure that practices follow standardized, evidence-informed policy.

Prescribing high-quality goal-directed PD

In 2020, the ISPD published practice recommendations for prescribing high-quality goal-directed PD[176]. These recommendations represented a paradigm shift from the conventional, non-evidence-based and potentially harmful practice of prescribing PD to achieve so-called 'dialysis adequacy' based primarily on the unvalidated and imprecise surrogate measure of small solute clearance. This approach potentially led to greater PD-related burden and complications without clear evidence supporting its benefit. Instead, the new guidelines advocate a tailored, shared decision-making model. Such a PD plan should be developed by the person receiving PD in collaboration with their care team to ensure the delivery of high-quality PD that helps the patient to achieve their expressed, personal goals of care, and is informed by careful assessment of (in descending order of priority) patient-reported outcome measures (such as QOL and symptom burden), clinical measures (such as fluid status) and, to a much lesser extent, surrogate measures (such as RKF, bone mineral disorder parameters, nutritional indices, peritoneal membrane function and small solute clearance) (Supplementary Figure 2). Of note, the guidelines indicate that small solute clearance measurement should not, in and of itself, influence PD prescription. The ISPD guidelines advocate for a quality cycle in which there is iterative evaluation of whether or not a patient's goals of care are being met, taking into consideration a number of hierarchical PD outcome measures (Supplementary Figure 2).

Conclusions

PD remains an important treatment modality but its adoption as a treatment modality for kidney failure varies widely across the world. The median global prevalence of PD has been estimated at 38.1 pmp but varied over 5,000-fold from as low as 0.1 pmp in Egypt to 531 pmp in Hong Kong. Interestingly, the majority of patients on PD resided in only four countries — China, USA, Mexico and Thailand.

The association of PD with better clinical and patient-reported outcomes compared with HD is well established. These benefits include better preservation of RKF, enhanced patient satisfaction, improved QOL, better kidney transplantation outcomes (in transplant recipients), a delayed need for vascular access (especially in small children), enhanced anaemia management and lower risk of blood-borne and respiratory virus infections, including the novel SARS-CoV-2. Of note, the nephrology community has worked assiduously to improve dialysis outcomes, such that over the last decade PD outcomes have been improving in many parts of the globe, However, significant variability in the epidemiology of these outcomes still exists across regions and countries, largely driven by patient-, centre- and system-level inequities, and differences in practice culture and resource allocation to PD. Enactment of strategies for improvement and monitoring of outcomes via enhanced standardization, monitoring and reporting, as well as implementation of CQI initiatives and novel interventions, including incremental PD, the use of biocompatible PD solutions and remote PD monitoring, are all crucial to improving PD outcomes.

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