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Global differences in dialysis modality mix: the role of patient characteristics, macroeconomics and renal service indicators

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ABSTRACT

Background. An increase in the dialysis programme expenditure is expected in most countries given the continued rise in the number of people with end-stage renal disease (ESRD) globally. Since chronic peritoneal dialysis (PD) therapy is relatively less expensive compared with haemodialysis (HD) and because there is no survival difference between PD and HD, identifying factors associated with PD use is important.

Methods. Incidence counts for the years 2003–05 were available from 36 countries worldwide. We studied associations of population characteristics, macroeconomic factors and renal service indicators with the percentage of patients on PD at Day 91 after starting dialysis. With linear regression models, we obtained relative risks (RRs) with 95% confidence intervals (CIs).

Results. The median percentage of incident patients on PD was 12% (interquartile range: 7–26%). Determinants independently associated with lower percentages of patients on PD were as follows: patients with diabetic kidney disease (per 5% increase) (RR 0.93; 95% CI 0.89–0.97), health expenditure as % gross domestic product (per 1% increase) (RR 0.93; 95% CI 0.87–0.98), private-for-profit share of HD facilities (per 1% increase) (RR 0.996; 95% CI 0.99–1.00; P = 0.04), costs of PD consumables relative to staffing (per 0.1 increase) (RR 0.97; 95% CI 0.95–0.99).

Conclusions. The factors associated with a lower percentage of patients on PD include higher diabetes prevalence, higher healthcare expenditures, larger share of private-for-profit centres and higher costs of PD consumables relative to staffing. Whether dialysis modality mix can be influenced by changing healthcare organization and funding requires additional studies.

INTRODUCTION

Renal replacement therapy (RRT) is an expensive therapy, accounting for ∼1–2% of healthcare spending in high-income countries [1]. With the rising incidence and prevalence of treated end-stage renal disease (ESRD), expenditures on dialysis will increase putting more pressure on dialysis capacity and health budgets [2–4].

With the exception of highly comorbid patients, there is no clear survival benefit for either haemodialysis (HD) or peritoneal dialysis (PD) [5–11]. In most countries, PD is a cheaper modality than HD, as it has lower overhead costs for buildings, equipment and labour [1, 12, 13]. Studies evaluating potential cost savings from increasing the share of PD have concluded that a higher proportion of patients on PD are associated with substantial annual savings and an increased dialysis capacity. Therefore, a greater share of patients on PD would allow more patients to receive dialysis for the same budget [14–16]. So why does HD account for the lion's share of initial dialysis modality in most countries?

Several investigations have already addressed this question and concluded that the decision to start RRT with either HD or PD is influenced (besides medical superiority in some patient groups) by patient and physician preference and by macroeconomic factors including economic structures at a national or centre level, national wealth and cost differences between the two dialysis modalities [1, 17–26]. Unfortunately, these previous studies have been rather descriptive in nature, have focussed on a very small number of countries or have relied on crude results only. The current international study aims to identify specific medical factors (dialysis population characteristics) and non-medical factors (macroeconomic factors and renal service indicators) that, adjusted for known confounders, are associated with the country-specific percentage of patients on PD at Day 91 after initiating RRT.

METHODS

Data collection

This study is part of the EVEREST study (Explaining the Variation in Epidemiology of RRT through Expert opinion, Secondary data sources and Trends over time), including 46 of the 51 national renal registries worldwide known to have reported validated data on RRT [27]. The EVEREST study started in 2008, aiming to investigate the detailed interplay between economic characteristics of countries and their incidence of RRT, dialysis modality mix and mortality on dialysis [28, 29]. For this analysis focusing on dialysis modality mix, we use country-level data from $n = 36$ renal registries that were able to provide incidence counts stratified by modality type over the time period 2003–05 [Africa (Tunisia), Asia (Israel, Japan, Malaysia, The Republic of Korea, Taiwan, Thailand, Turkey), Australasia (Australia and New Zealand), Europe (Austria, Belgium, Bosnia-Herzegovina, Croatia, Czech Republic, Denmark, Finland, France, FYR of Macedonia, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Romania, Slovenia, Spain, Sweden and UK), North America (Canada and USA) and South America (Chile, Uruguay and Venezuela)]. Macroeconomic indicators were collected from the OECD and WHO; a description of the variable and the source is included in Box 1. The renal service organization indicators were collected using a survey among experts in renal services. All these variables concerned the period 2003–05. A more extensive description of this study is presented elsewhere [27].

Modality mix as outcome measure

The outcome measure representing dialysis modality mix was the percentage of dialysis patients on PD at Day 91 after the initiation of RRT. This day was chosen for the assessment of the dialysis modality of choice as some patients receive HD for a short period, while preparations are made for PD. For the Republic of Korea, Day 30 was used due to the unavailability of Day 91 data.

Potential determinants of modality mix

The selection of potential determinants of modality mix and the development of a theoretical framework for defining our prior rationales (Figure 1) were based on a review of the

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Box 1: Description and source of the macroeconomic factors

Macroeconomic factor	Description	Source
HDI	The United Nations Development Programme HDI combines indicators of life expectancy, education and income to create a validated composite score of a nations state of development.	The Human Development Report team. Human Development Indicators per country.[1]
GDP per capita	Gross domestic product per capita is a measure of national wealth. Data have been collected in USD.	International Monetary Fund (IMF): World Economic Outlook Database, April 2008.[2]
Health expenditure as % GDP	Percentage of gross domestic product (i.e. national wealth) spent on healthcare.	WHO HFA database for EU countries.[3] OECD Health Database for OECD countries.[4] WHOSIS database for non-EU and non-OECD countries.[5]
Public share of healthcare expenditure	Public expenditure as a percentage of total expenditure on healthcare.	WHO HFA database for EU countries.[3] OECD Health Database for OECD countries.[4] World Bank HNP Stats for remaining countries.[6]
Responsiveness index	This is a composite indicator of healthcare system performance developed by the WHO, with elements capturing respect for dignity, confidentiality, autonomy, prompt attention, quality of amenities, access to social support networks and choice of provider.	WHO: The World Health Report 2000 Health Systems: Improving performance. Geneva, Switzerland: World Health Organization; 2000[7].

[1]http://www.hdr.undp.org.
[2]http://www.imf.org/external/pubs/ft/weo/2008/01/weodata/index.aspx.
[3]http://data.euro.who.int/hfadb/.
[4]http://stats.oecd.org/Index.aspx.
[5]http://apps.who.int/gho/indicatorregistry/App_Main/view_indicator.aspx?iid=3104.
[6]http://datatopics.worldbank.org/hnp/topic/health-financing.
[7]http://www.who.int/whr/2000/en/whr00_en.pdf.

literature. We hypothesized that the macroeconomic factors indirectly influenced the proportion of PD patients either by influencing RRT incidence or by influencing the renal service organization. Our prior hypotheses for the determinants are stated in Table 2.

Statistical analyses

First, we obtained descriptive statistics for all countries and calculated medians and interquartile ranges (IQRs) for continuous determinants or the percentages for categorical variables. Thereafter, with linear regression analyses we studied associations between the potential determinants (i.e. patient characteristics, macroeconomic factors and renal service indicators) and the percentage of incident patients on PD. Since this outcome measure can only take positive values and our data were skewed [with several countries having a very low percentage of PD patients (Figure 2)], we log-transformed this measure. After log transformation, all criteria for linear regression analysis were met. The estimated regression coefficients were subsequently converted back to the original scale and could be interpreted as relative risks (RRs).

To evaluate the independence of each association, we constructed multivariable linear regression models for each determinant adjusting for variables that satisfied the criteria for confounding [30]. With a number of 36 observations, we were able to include a maximum of four covariates in each model, i.e. the determinant and the three strongest confounders [31]. We assessed the strength of each confounder by calculating the subsequent change in the estimated coefficient of the determinant after including the confounder in the model. Covariates that caused <10% change in the coefficient of the determinant were not considered as potential confounders. We also excluded confounders that were collinear with the determinant as assessed after examining the tolerance and variance inflation factor [32]. Analyses were performed using SPSS version 16.0 (SPSS Inc., Chicago, Illinois). The P-values <0.05 were considered statistically significant.

Sensitivity analyses

For a sensitivity analysis, we excluded the FYR of Macedonia and Luxembourg as they had very low percentages of PD patients. Since the effects could differ according to the state of economic and social development, models were also analysed separately for high and low human development index (HDI) countries, i.e. above or below the calculated median HDI. Also, we repeated analyses for patients below

Table 1: Characteristics of the study population for all countries and by quartiles of % PD use

		PD quartile 1[A], 0–7.2%	PD quartile 2[B], 7.2–11.9%	PD quartile 3[C], 11.9–26.0%	PD quartile 4[D], 26–49.2%
	Median (IQR)[a] all countries (*n* = 36)	Median (IQR)[a] *n* = 9	Median (IQR)[a] *n* = 9	Median (IQR)[a] *n* = 9	Median (IQR)[a] *n* = 9
Incident RRT patients characteristics					
Percentage of dialysis population aged 65+ years (%)	49.8 (41.3–55.8)	43.2 (36.0–64.6)	48.5 (34.7–51.7)	54.9 (41.5–61.0)	49.8 (44.1–53.8)
Percentage diabetes as primary renal disease (%)	29.0 (21.3–37.5)	30.0 (21.2–37.0)	33.2 (25.7–43.4)	23.2 (16.7–32.7)	24.9 (17.8–37.8)
Macroeconomic factors					
HDI	0.94 (0.85–0.95)	0.87 (0.79–0.94)	0.90 (0.83–0.94)	0.95 (0.87–0.96)	0.95 (0.94–0.96)
GDP per capita (per 1000 USD)	23.9 (5.9–35.0)	5.99 (2.55–33.6)	14.9 (4.6–27.3)	29.0 (12.6–33.2)	35.3 (27.8–41.5)
Health expenditure as % GDP (%)	8.5 (7.3–9.7)	7.8 (5.58–8.3)	8.7 (5.5–10.0)	8.6 (7.5–9.8)	9.0 (7.8–9.2)
Public share of healthcare expenditure (%)	76.0 (62.0–82.0)	78.0 (56.5–89.5)	48.0 (44.3–76.8)	72.0 (70.5–82.0)	78.0 (66.0–84.5)
Responsiveness Index	6.7 (5.8–6.9)	5.81 (5.08–7.05)	6.1 (5.5–6.7)	6.7 (5.8–6.9)	6.8 (6.6–6.9)
Renal service indicators					
The private-for-profit share of HD facilities (%)	23.3 (0.0–47.9)	48.0 (0–76.9)	36 (23.3–62.5)	20.0 (1.0–45.5)	0 (0–19)
Number of nephrologists WTE (pmp)	11.6 (7.3–20.2)	7.42 (4.99–17.90)	20.1 (8.4–32.5)	11.7 (10.1–25.1)	11.1 (7.3–15.8)
Number of incident patients per WTE nephrologist	10.3 (7.5–18.3)	11.9 (9.7–26.9)	8.0 (3.5–18.1)	8.6 (4.5–15.2)	9.5 (7.1–17.5)
Number of dialysis centres (pmp)	9.0 (5.9–13.1)	11.8 (7.6–14.2)	11.5 (8.3–15.3)	9.1 (5.4–15.5)	3.9 (3.4–8.6)
Transplant availability[b]	14.8 (6.3–22.6)	4.7 (1.5–8.7)	12.3 (6.5–19.3)	15.5 (8.4–70.5)	22.2 (18.7–37.2)
Cost of PD consumables relative to GDP per capita (per patient per year as a proportion of GDP per capita)	0.86 (0.51–1.14)	1.16 (0.73–1.72)	0.98 (0.50–1.05)	0.76 (0.53–1.16)	0.68 (0.31–1.08)
Cost of PD consumables relative to staffing (per patient per year as a proportion of senior nurse annual salary)	0.57 (0.33–0.96)	1.13 (0.45–1.54)	0.70 (0.45–1.05)	0.42 (0.33–0.69)	0.37 (0.15–0.58)
Cost of senior nurse (annual salary as a proportion of GDP per capita)	1.48 (1.16–1.83)	1.24 (1.10–1.52)	1.16 (0.98–1.53)	1.47 (1.20–2.21)	1.84 (1.65–2.11)

Salary of salaried nephrologist (per year as a proportion of GDP per capita)	2.99 (2.01–4.34)	2.30 (1.49–3.10)	2.67 (1.71–3.33)	3.35 (1.84–5.74)	4.07 (3.14–5.61)
HD facility reimbursement method					
Activity based	72.2%	66.7%	78%	100%	44%
Global budget only	25.0%	33.3%	22%	0%	44%
Other (n = 1; not specified)	2.8%	0%	0%	0%	11%
HD facility reimbursement rate (per year as a proportion of GDP per capita)	1.22 (0.87–1.85)	1.21 (0.97–1.59)	1.02 (0.75–1.97)	1.60 (1.09–1.97)	1.42 (0.72–1.84)
PD facility reimbursement rate (per year as a proportion of GDP per capita)	1.00 (0.69–1.36)	1.51 (0.53–1.79)	0.71 (0.13–0.95)	1.04 (0.79–1.34)	1.04 (0.88–1.31)
Reimbursement rate for HD relative to PD	1.27 (0.93–1.67)	0.83 (0.74–1.00)	1.33 (0.93–2.40)	1.54 (1.32–1.77)	1.26 (0.78–1.58)

A: Bosnia-Herzegovina, Chile, Czech Republic, FYR of Macedonia, Germany, Japan, Luxembourg, Thailand, Tunisia. B: Austria, Croatia, Greece, Malaysia, Slovenia, Taiwan, USA, Uruguay, Venezuela. C: Belgium, Canada, France, Israel, Italy, Norway, Romania, Spain, Turkey. D: Australia, Denmark, Finland, Iceland, Netherlands, New-Zealand, Republic of Korea, Sweden, UK. GDP per capita, gross domestic product per capita; WTE, whole time equivalent; pmp, per million population.

[a]Percentages in the case of categorical variables.

[b]Data available for 23 countries.

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and above 65 years of age. Finally, we adjusted models for the percentage of diabetes as primary renal disease and transplant availability by including these as additional confounders in the original models. This was considered worthwhile on the grounds that countries with a high transplantation rate may be more likely to start patients on PD (because they know that the patient is likely to be transplanted before the technique becomes less effective). Transplant availability was defined as the total number of kidney transplants performed in 2004, divided by the number of prevalent dialysis patients (data from 23 countries).

RESULTS

Baseline country characteristics

The median percentage of incident patients on PD at Day 91 after the initiation of RRT was 12% (IQR 7–26%), with values ranging from 0% for Luxembourg and 2% for FYR Macedonia to 49% in New Zealand (Figure 2). The baseline characteristics of our study population are presented in Table 1, for all countries combined and by quartiles of % PD use, while complete data per country are shown in Supplementary data, Table S1. Large differences in gross domestic product (GDP) per capita were found between countries, ranging from <2600 USD in Thailand, Bosnia-Herzegovina and FYR of Macedonia to >45 000 USD in Iceland, Norway and Luxembourg (Table 1). The private-for-profit share of HD facilities was 0% in ten countries, while it was >75% in five (Supplementary data, Table S1).

DETERMINANTS OF MODALITY CHOICE

Theoretical framework

We developed a theoretical framework (Figure 1) to select the potential determinants of interest out of all incident patient characteristics, macroeconomic factors and the renal service indicators and for defining our prior rationales (Table 2).

Incident patient characteristics

The results of the linear regression analyses are presented in Table 3. In the crude analyses, none of the incident patient characteristics were associated with the percentage of patients on PD at Day 91. After adjustment for the responsiveness index, relative costs of PD consumables as % GDP per capita and costs of PD consumables relative to staffing, we found that diabetes is relevant for predicting the PD share: each 5% increase in the percentage of RRT patients with diabetic nephropathy was significantly associated with a 7% decrease of the percentage of patients on PD at Day 91 [RR 0.93; 95% confidence interval (CI) 0.89–0.97; P = 0.001].

Macroeconomic factors

Only GDP per capita was associated with the percentage of patients starting on PD in the crude analyses: for each 1000 USD increase in GDP per capita, the percentage of patients

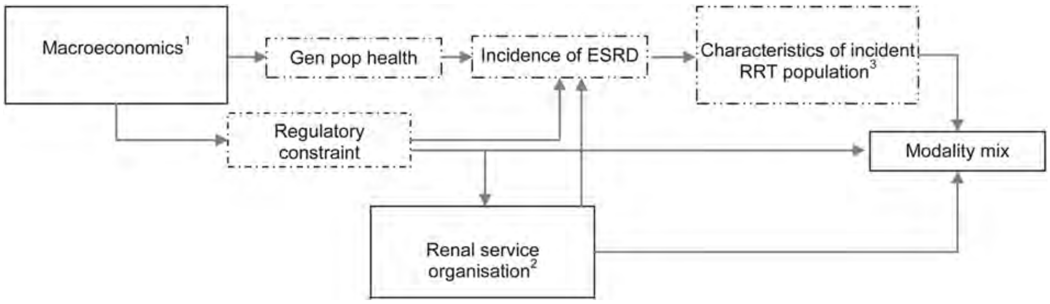

FIGURE 1: Theoretical framework and the classification of the determinants. Determinants included in the models; (i) GDP per capita, Health expenditure as % GDP, public share of healthcare expenditure; (ii) the private-for-profit share of HD facilities, number of dialysis centres pmp, cost of PD consumables relative to staffing, reimbursement rate for HD relative to PD; (iii) percentage of dialysis population aged 65 + years, percentage diabetes as primary renal disease.

starting on PD increased by 1%. However, the impact of GDP per capita is complex: the above association lost its significance after adjusting for the private-for-profit share of HD facilities, relative costs of PD consumables and relative staffing costs of a senior nurse. Multivariable analyses revealed at the same time an independent relationship between the percentage of GDP per capita spent on healthcare and PD use: each 1% increase was associated with a 7% lower percentage of patients starting on PD (RR 0.93; 95% CI 0.87–0.98; P = 0.013).

Renal service indicators

In crude analyses, three determinants were associated with a lower percentage of patients starting on PD: the private-for-profit share of HD facilities, the costs of PD consumables relative to staffing and the number of HD centres per million population (pmp). The private-for-profit share of HD facilities and the costs of PD consumables relative to staffing remained statistically significant in the multivariable analyses. For the private-for-profit share of HD facilities, each 1% increase was associated with a 0.4% decrease in PD use (RR 0.996; 95% CI 0.99–1.00, P = 0.04). After adjusting for HDI and GDP per capita, every 0.1 increase in the costs of PD consumables relative to staffing resulted in a 3% decrease in the percentage of patients on PD at Day 91, (RR 0.97; 95% CI 0.95–0.99; P = 0.015).

Explained variance

There were four determinants for which we found independent associations with the percentage of patients on PD: the percentage of incident patients with diabetes as primary renal disease, the percentage of GDP per capita spent on healthcare, the private-for-profit share of HD facilities and the costs of PD consumables relative to staffing. Together they explained 69% of the variance in PD use across countries.

SENSITIVITY ANALYSES

After excluding those countries with a very low PD use (i.e. FYR of Macedonia and Luxembourg) from the analyses, the results remained similar. Nor did the results differ after examining the low and high HDI countries separately, examining the European and non-European countries separately or after adjusting the original models for transplant availability and the percentage of diabetes as primary renal disease.

DISCUSSION

In this study examining 36 countries worldwide, we were able to study for the first time independent associations between PD use and incident dialysis characteristics, macroeconomic factors and renal service indicators. We showed that a higher percentage of incident patients with diabetes as primary renal disease, a higher percentage of GDP per capita spent on healthcare, a higher share of private-for-profit centres and higher costs of PD consumables relative to staffing were independently associated with a lower percentage of patients starting on PD.

We found an association between the percentage of patients with diabetic nephropathy and the percentage of patients on PD. Most studies reported poorer outcomes on PD when compared with HD for patients with diabetic kidney disease [33–36]. The presence of a negative association between the percentage of incident patients with diabetic kidney disease and the percentage receiving PD on Day 91, therefore, may reflect clinical practices aimed at avoiding PD in patients with diabetic nephropathy. Alternatively, diabetic kidney disease may act as a surrogate for other comorbidities [37, 38]. However, a study by Mehrotra *et al.* reported decreased PD use in the USA from 11% in 1996–97 to 7% in 2002–03. This decline was independent of age, comorbidity burden and body size of the incident dialysis population. Adjusting for case-mix and laboratory data did not change their results [39], suggesting that other factors like macroeconomic factors and renal service indicators may influence the incidence of PD.

There are two possible explanations for the association between the high healthcare expenditure as a percentage of GDP per capita and the lower percentage of patients on PD. As shown in the theoretical framework (Figure 1), one possible pathway involves regulatory constraints. As an example of such constraints, countries spending more on healthcare may

Table 2: A priori hypotheses for the models included in the study

Model	Determinant	A priori hypothesis
Incident patients characteristics		
A	Percentage of dialysis population aged 65+ years	Increasing age is associated with lower rates of PD use in some countries [59, 60] and higher rates in others [53]. As more countries tend to provide HD to their elderly patients, we hypothesized that the percentage of PD patients will be lower when the percentage of patients >65 is higher.
B	Percentage diabetes as primary renal disease	Patients with diabetes mellitus have worse survival on PD when compared with HD so percentage of PD patients is hypothesized to decrease with a larger share of patients with diabetes mellitus. In addition, DM may be considered as a surrogate for comorbidity?
Macroeconomic indicators		
C	GDP per capita	Patients in richer countries may have better education systems, housing and medical supplies to enable HD. GDP per capita has been shown to be associated with the rate of diffusion of medical technologies, including HD [46].
D	Health expenditure as % GDP	Countries spending a smaller proportion of GDP on healthcare are likely to have more control over introduction and expansion of new and expensive technologies [61]. Increasing healthcare expenditure may then result in less control over expansion of HD facilities and less patients may be treated with PD.
E	Public share of healthcare expenditure	The proportion of total healthcare spending that is public (i. e. from taxes or compulsory social insurance) has been suggested to be a proxy for the level of regulatory constraint on adopting and expanding new medical technologies. Countries where the public sector purchases most medical goods may more easily implement cost–control strategies Constraint on expansion of HD facilities may have increased the rate of PD use [46].
Renal service indicators		
F	The private-for-profit share of HD facilities	PD utilization is lower in private-for-profit centres. With a higher share of private-for-profit centres, a lower percentage of PD patients can be expected [42, 62].
G	Number of dialysis centres pmp	In systems with more freedom to set up new services, there will be more HD capacity with an economic need to maximize the use of that capacity rather than promote PD [1].
H	Cost of PD consumables relative to staffing[a] (per patient per year as proportion of senior nurse annual salary)	Countries in which imported dialysis consumables are relatively more expensive than staffing costs (e.g. eastern Europe) will have lower rates of PD utilization [45].
I	Reimbursement rate for HD relative to PD[b]	PD is less expensive to provide than HD in developed countries (see H).If the difference in reimbursement for HD and PD is larger, then providing HD is more preferable than providing PD [45].

RRT, renal replacement therapy; GDP, gross domestic product; HD, haemodialysis; PD, peritoneal dialysis.
[a]PD consumables for one patient for 1 year, i.e. the amount a dialysis facility pays a pharmaceutical company, NOT what the dialysis facility is reimbursed for PD. Consumable costs should include dialysate fluid and lines but exclude drugs, staff costs, transport and overhead costs of running a hospital.
[b]The amount given should exclude reimbursement for transport to and from dialysis, medication (erythropoiesis-stimulating agents and bone/phosphate medication), vascular access. The amount should include any reimbursement of the nephrologist even if this occurs separately (i.e. direct to the nephrologist).

have fewer restrictions on adopting expensive technologies like HD, whereas when capital investment restrictions limit the expansion of in-centre HD infrastructure, home-based therapies like PD and home-HD are promoted [1]. Another possible explanation is that differences in access to treatment may be responsible for the influence of macroeconomic factors through the incidence of RRT (Figure 1). Previously, we showed that countries spending more on healthcare have higher ESRD treatment rates [28]; these higher take-on rates are likely to indicate that treatment is being offered to older, frailer, more comorbid patients who will be less suitable for PD [37, 38]. Additionally, physician preference may affect the proportion of patients on HD or PD [40].

We found an independent association between private-for-profit share of HD facilities and dialysis modality. This may be a direct influence of the renal service indicator on dialysis modality mix or it may be that it is acting through the characteristics of the dialysis patients (Figure 1). As suggested by Castledine *et al.*, in a for-profit facility, the need to fill spaces can be considered as a main factor against PD use [41]. Additionally, several studies have shown that after adjusting for several patient characteristics, the percentage of patients on PD is lower in private-for-profit dialysis centres than in not-for-profit centres [21, 42–44].

We also found that an increase in the costs of PD consumables relative to staffing costs of a senior nurse resulted in a decreased percentage of patients starting on PD. This link has long been recognized and reflects the relative importance of staffing and consumables to the cost of providing HD and PD, particularly as PD consumables were for many years almost exclusively manufactured in high-income countries [1, 12, 13, 45].

For two determinants, we found a statistically significant association in the crude analyses that did not reach significance in the multivariable analyses: GDP per capita and the number of dialysis centres pmp. This stresses the importance of adjusting for country-specific factors like macroeconomic factors and renal service indicators and further exploring the working mechanisms of suggested associations. Our prior rationale for including GDP per capita in the analyses was that patients in richer countries may have a better transport infrastructure, readier access to medical supplies to enable HD and a higher diffusion rate of HD [46]. After adjusting for the private-for-profit share of HD facilities and either the relative costs of PD consumables or the relative staffing costs of a senior nurse, our results did not support this hypothesis. As several studies suggested, other factors like patient preference, pre-dialysis educational deficits (i.e. if not all modalities are explained sufficiently to the patients), physician preference and HD capacity, may prevail above the social/housing situation of the patient [24, 47]. Considering the number of HD facilities pmp in a country, our prior hypothesis had been that a high number of HD centres may reflect less control by the health department or government on the expansion of HD facilities (and thus improved access to HD) leading to a lower percentage of patients treated with PD [1]. This association may be absent because other factors are prevailing such as the existing dialysis capacity, the attitudes of physicians towards PD [1, 40] or, as shown in this analysis, the private-for-profit share of HD facilities.

In contrast to the conclusions of a narrative review [23], our comparison at a country level showed no association between the total reimbursement rate for HD relative to PD and the percentage of patients on PD. It may be that there is only an association between reimbursement and dialysis modality when reimbursement directly affects the income of those most involved in decision-making, i.e. the nephrologists, but this is often not the case [48, 49]. In addition, reimbursements may not be a major determinant of dialysis modality distribution. This is supported by the findings of Mendelssohn, who reported no major shift in modality distribution when home dialysis fees were raised by the Ontario government in 1998 [50]. Nevertheless, this may be different in countries with a large proportion of private-for-profit

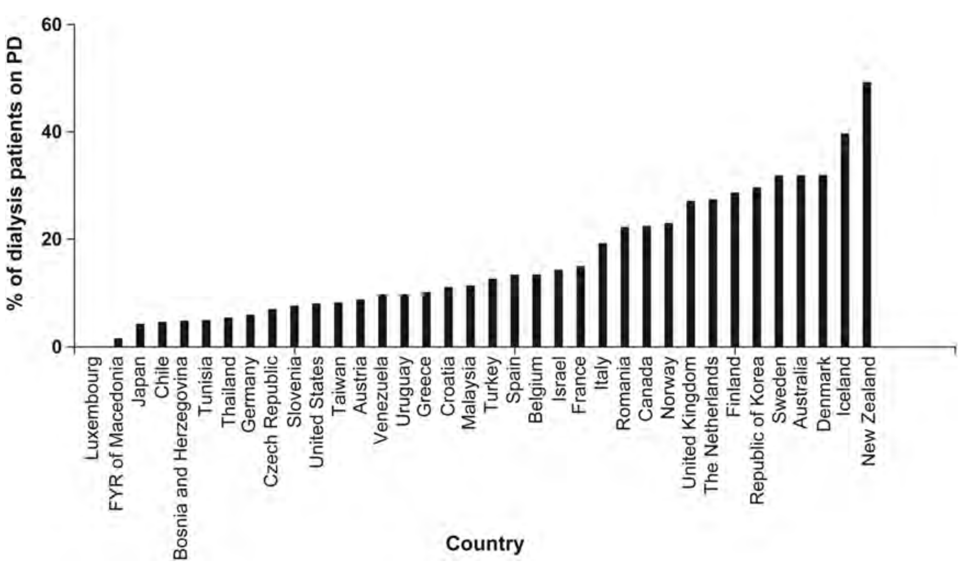

FIGURE 2: Distribution of the percentage of dialysis patients starting on PD at Day 91.

centres where financial incentives may be effective in influencing the dialysis modality distribution.

When examining the crude data for countries with high rates of PD use as shown in the Supplementary data, Table S1, we expected that determinants with significant positive associations would have higher values in the countries with lower PD use and vice versa. This did not turn out to be the case for all countries or all statistically significant determinants. We therefore speculate that each country may have its own prevailing factors that overrule all other factors. First of all, the two dialysis modalities may not be available and affordable, at least in part as a result of specific policies of the government [51]. Such policies were not captured by our survey. For example, in some countries elderly and frailer patients are provided with assisted PD, whereas in many other countries HD would be the preferred dialysis treatment for these

Table 3: Results of the univariable and multivariable analyses with proportion of dialysis patients on PD as the outcome variable

		Univariable model			Multivariable model	
Model	Variable of interest	RR (95% CI)	P-value	Adjusted for confounder	RR (95% CI)	P-value
Incident patient characteristics						
A	Percentage of dialysis population aged 65+ (per 1% ↑)	1.00 (0.99–1.01)	0.663	4, 5, 9[a]	1.00 (0.99–1.01)	0.880
B	Percentage diabetes as primary renal disease (per 5% ↑)	0.98 (0.93–1.03)	0.407	4, 6, 9[b]	0.93 (0.89–0.97)	0.001
Macroeconomic indicators						
C	GDP per capita (per 1000 USD ↑)	1.01 (1.01–1.02)	0.001	3, 6, 7	1.00 (1.00–1.01)	0.702
D	Health expenditure as % GDP (per 1% ↑)	1.02 (0.97–1.08)	0.456	1, 2, 4[c]	0.93 (0.87–0.98)	0.013
E	Public share of healthcare expenditure (per 1% ↑)	1.00 (1.00–1.01)	0.223	1, 2, 3	1.00 (0.99–1.00)	0.378
Renal service indicators						
F	The private-for-profit share of HD facilities (per 1% ↑)	0.99 (0.99–1.00)	0.004	1, 2	0.996 (0.99–1.00)	0.040
G	Number of dialysis centres pmp (per 1.0 ↑)	0.98 (0.96–0.99)	0.012	3	0.98 (0.97–1.00)	0.100
H	Cost of PD consumables relative to staffing (per 0.1 ↑) (per patient per year as a proportion of senior nurse annual salary)	0.96 (0.94–0.98)	0.000	1, 2	0.97 (0.95–0.99)	0.015
I	Reimbursement rate for HD relative to PD					
	Reimbursement PD ≤ HD	1 (reference)			1 (reference)	
	Reimbursement PD > HD	0.81 (0.64–1.02)	0.067	2	0.86 (0.70–1.06)	0.144

CI, confidence interval; GDP, gross domestic product; USD, United States dollar; HD, haemodialysis; PD, peritoneal dialysis.
Only three strongest confounders were included in the models; other confounders were [a]7, [b]5, [c]7 & 9.
Potential confounders.
(1) HDI.
(2) GDP per capita.
(3) Private-for-profit share of HD facilities.
(4) Responsiveness index.
(5) Number of dialysis centres.
(6) Relative costs of PD consumables (per patient per year as a proportion of GDP per capita).
(7) Relative staffing costs of senior nurse.
(8) Salary of salaried nephrologist (per year as a proportion of GDP per capita).
(9) Cost of PD consumables relative to staffing (per patient per year as proportion of senior nurse annual salary).

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patients. In the presence of such policies, nephrologists may apply different patient selection criteria because of the specific benefits and drawbacks of this type of PD [52, 53]. Another relevant factor may be the (dialysis) population density. If the population density is extremely low, patients live far from each other as well as from the centres, which makes it likely that the preferred dialysis modality will be PD; this has been shown by O'Hare *et al*. Although they found that centres in small remote rural areas were least likely to support PD and other home-based treatments, small remote rural areas appeared to have higher percentages of PD use on Day 90 when compared with urban areas, i.e. 17% versus 11% [54]. As there is no consensus on the definition of an urban area—each country has its own definition—we could not use this measure for our analysis. In addition to the examples mentioned above, there may be other determinants that explain why the independently associated factors will not always follow the expected pattern in all countries.

This study has a number of strengths. For the first time, we were able to study independent associations between PD use and incident dialysis characteristics, macroeconomic factors and renal service indicators, including all countries worldwide that had validated registry and macroeconomic data. The sensitivity analyses suggest that our findings are quite robust. However, when interpreting the results of this study, several limitations should be kept in mind. Information on several factors potentially associated with dialysis modality selection was lacking, among others educational deficits, physician bias, social mores and cultural habits and urbanization [24]. Moreover, we were not able to include extensive data on medical characteristics of the incident dialysis population other than the proportion of patients with diabetes mellitus as primary renal disease and the proportion of patients aged ≥65 years. Nevertheless, the explained variance of the four factors with statistically significant results in multivariable models was high at 69%. The percentage of patients with diabetes as primary renal disease was only available for the RRT instead of the dialysis population. We considered this a good approximation for the incident dialysis population as in most countries the pre-emptive transplantation rate is very low [55]. As only countries with renal registries and modality mix data could be included in analyses, the results may not be generalizable to all countries, particularly developing countries. Although with the countries as included in our study, we had a high geographical coverage, the absence of some expected associations may reflect the heterogeneity of our group of countries ($n = 36$). Further, as each country could only contribute a single observation for each of the variables, it is important to recognize the risk of both type 2 error and ecological fallacy as we cannot be certain that the associations we found at the population level also apply at the individual patient level. Finally, our data concerned the period 2003–05, while some countries may have experienced changes in health policy, or other factors may have affected modality mix since the period of study. For example, Jain *et al.* showed that PD use from 1997 to 2008 declined by 5.3% in developed countries but did not change in developing countries [56]. Additionally, recent initiatives in the USA and the UK have set out to improve the utilization of home dialysis (including PD) through a number of incentives, some of which are financial [57, 58].

In conclusion, a higher proportion of patients with diabetes mellitus as primary renal disease, increased healthcare expenditure as a percentage of GDP per capita, higher private-for-profit share of HD facilities and higher costs of PD consumables relative to staffing costs were all associated with a lower percentage of patients on PD at Day 91. While each country has its own prevailing factors influencing PD use, knowledge of the determinants of the percentage of patients on PD may be helpful in scenarios where the dialysis capacity needs to be expanded. Although the characteristics of the incident dialysis populations are clearly not modifiable without restricting access to treatment, the role of the three 'non-medical' factors suggests that it may be possible to influence the dialysis modality choice through healthcare organization and funding.

SUPPLEMENTARY DATA

Supplementary data are available online at http://ndt.oxfordjournals.org.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have had no involvements that might raise the question of bias in the work reported or in the conclusions, implications or opinions stated. The results presented in this paper have not been published previously in whole or part, except in abstract format.

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