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Original Articles

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Effects of comorbid and demographic factors on dialysis modality choice and related patient survival in Europe

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Abstract

Background. The mean age of patients starting dialysis increased over the years, as has the proportion of patients with diabetes mellitus, ischaemic heart disease, peripheral vascular disease (PVD), cerebrovascular disease (CD) and malignancy. We assessed dialysis modality choice within subgroups of patients with these comorbidities and in different age categories and subsequently evaluated the association between modality choice and patient survival in these subgroups.

Methods. Seven European renal registries participating in the ERA–EDTA Registry provided data from 15 828 incident peritoneal dialysis (PD) and haemodialysis (HD) patients (1998–2006) with available comorbidity data. The likelihood to receive PD rather than HD was assessed with logistic regression and 3-year survival on PD versus HD was evaluated using Cox regression.

Results. Besides large international variations in the likelihood to receive PD, we found that elderly patients and patients with PVD, CD, malignancy and multiple comorbidities were significantly less likely to receive PD than HD. Overall patients starting on PD had survival benefits [adjusted hazard ratio (HR_{adj}) 0.82 (0.75–0.90)], especially patients without comorbidity [HR_{adj} 0.65 (0.53–0.80)] or those with malignancy [HR_{adj} 0.73 (0.56–0.94)]. In males, survival benefits of PD were independent of diabetic status. Conversely, diabetic females tended to have increased mortality risk on PD [HR_{adj} 1.16 (0.93–1.44)], especially if they were >70 years [HR_{adj} 1.55 (1.15–2.08)].

Conclusions. In general, modality choice was consistent with expected survival. However, elderly patients, non-diabetic patients and those with malignancy were less likely to receive PD, even though they had decreased mortality risk on PD. Also, although a survival benefit of PD was found for male patients without comorbidity, HD was just as likely to be the chosen dialysis modality as was PD for these patients.

Keywords: comorbidity; diabetes mellitus; haemodialysis; peritoneal dialysis; survival

Introduction

During the last decades, the mean age of patients starting renal replacement therapy (RRT) has increased substantially [1–3] as has the proportion of those suffering from diabetes mellitus (DM), cardiovascular disease or cerebrovascular disease (CD) or malignancies.

Whether an end-stage renal disease patient will be treated with either haemodialysis (HD) or peritoneal dialysis (PD) at the start of RRT depends on practice patterns that may vary between and within countries due to several factors. Socio-economic factors, reimbursement for and (lack of) access to a particular treatment, time of referral, as well as patient or physician preferences and patient characteristics such as age, gender and primary renal disease all influence modality choice [4–9]. In addition, the presence of comorbidities was demonstrated to play an important role in the choice for a particular type of dialysis [10–12].

Which type of dialysis is considered to be optimal for various patient subgroups remains controversial. An American study evaluated determinants of modality selection and demonstrated that the 'chance' of receiving PD was lower for patients with advancing age but showed no influence of malignancies on modality selection [12]. In contrast, Couchoud *et al.* [13] demonstrated that in France,

PD was more likely to be chosen in elderly patients but less frequently for patients with malignancies.

Many of the previous studies on dialysis modality choice were based on data from just one country and in most cases the USA, where the proportions of patients on PD and HD and patient profiles are different from those of other countries [12,14–19]. Consequently, results of these studies may not be generalizable to non-American populations. In addition, most of these previous studies only adjusted for demographic and comorbid factors in their analyses, while we aim to assess modality choice within subgroups of patients based on age, gender and the presence of DM, CD, cardiovascular disease or malignancy. With this large European registry-based study, we subsequently aimed to evaluate associations between modality choice and patient survival within these subgroups and to link these findings.

Materials and methods

Study population

The ERA–EDTA Registry collects a core data set on RRT patients via national and/or regional renal registries in Europe. This data set includes date of birth, gender, primary renal disease, date of first RRT, history of RRT (including dates and changes of modality) and date and cause of death. Only registries that provided us with additional comorbidity data at the start of dialysis were included in this study, i.e. Austria, Belgium (French-speaking part), Catalonia (Spain), Greece, Norway, Sweden and the UK. Comorbidity data were collected as part of the routine data collection (Sweden) or within the framework of previous studies (Austria, Belgium, Catalonia, Greece, Norway and UK) [20, 21].

We included patients who were $\geq$20 years and started dialysis between 1998 and 2006. Day 91 on dialysis was considered as start of treatment because at that moment, the type of dialysis can be considered as the modality of choice. The comorbidities we studied were DM, ischaemic heart disease (IHD), peripheral vascular disease (PVD), CD and malignancies. Their classification was presented elsewhere [20]. The category DM included both DM as primary renal disease and as comorbidity in addition to another primary renal disease. The comorbidities were coded as being present or absent in the medical history at dialysis initiation. Patients were excluded if data on all five types of comorbidity were missing. However, in the Norwegian data for the study years, no distinction was made between 'missing comorbidity' and 'no comorbidity'; in this case, we assumed patients had no comorbidity.

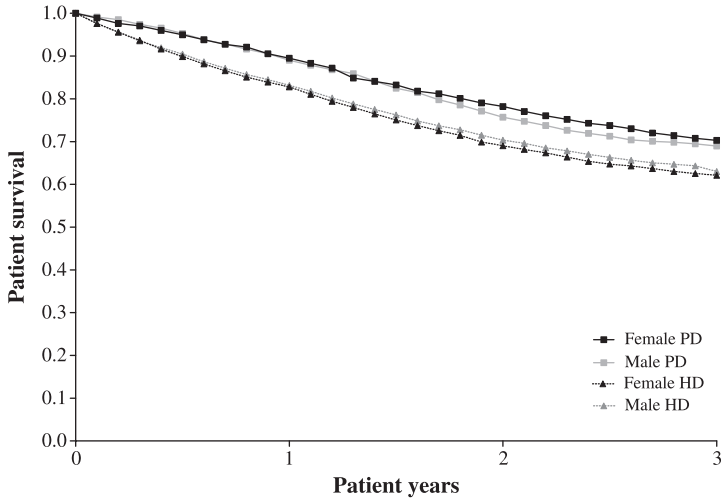
Data analyses

To test whether our study population was representative for the total dialysis population of the participating countries, we compared patient characteristics and 3-year survival of our study population with the results for patients that were excluded due to missing data on comorbidity.

We performed logistic regression analyses to study the likelihood of receiving PD rather than HD. Patients were categorized based on age (i.e. 20–44, 45–59, 60–69 or $\geq$70 years) and on comorbidity count (i.e. none, one, two or three to five comorbidities) to assess whether age and the number of comorbidities influenced the likelihood of receiving PD. Subsequently, we constructed separate multivariate logistic regression models to assess associations between comorbid and demographic factors and dialysis modality choice. These models included those variables that satisfied the criteria for confounding and are presented in the legends of Table 2 [22]. Results from logistic regression analyses are reported as adjusted odds ratios (OR_{adj}) with 95% confidence interval (CI) for the likelihood of receiving PD rather than HD in the total dialysis population.

To assess patient survival (from Day 91) on PD when compared to HD, we performed Kaplan–Meier and Cox proportional-hazard analyses for several subgroups. We restricted our survival analysis to a 3-year survival because otherwise the number of patients at risk during follow-up became too small, i.e. <10–20% of the total study population [23]. The subgroups were defined by comorbidity count, DM, IHD, PVD, CD and malignancy. Follow-up time was censored at recovery of renal function, kidney transplantation, loss of follow-up and at the end of the observation period (31 December 2006). Adjusted hazard ratios (HR_{adj}) with 95% CI for mortality were calculated using confounding variables, which were the same as those in the logistic regression models as presented in the legends of Figure 2. Cells in the survival tables were left empty when <30 events occurred.

As previous studies on survival in dialysis patients showed different results for males and females, diabetics and non-diabetics and different age categories [24], we tested whether there was interaction between the variables sex, age and the separate comorbidities in our models. In the overall logistic regression analysis, we found interaction between age and sex. In addition, interactions were found between DM and age and between DM and sex. Therefore, we stratified our full model and the model used to assess the association between DM and modality choice both for age and sex. In the survival analyses, interaction existed between dialysis modality and sex for patients with PVD or IHD, so stratification for sex was applied



Number of patients at risk (n)

	0	1	2	3
Female PD	1108	784	488	228
Female HD	4645	3031	1886	1311
Male PD	1875	1293	810	403
Male HD	416	4892	3036	2006

Fig. 1. Crude survival curves for PD and HD patients stratified for gender.

in these subgroups. The survival analysis for patients with DM was also stratified for sex based on literature [24].

For subgroups, the analysis was repeated using propensity scores instead of separate covariates as the application of propensity scores requires less degrees of freedom and thereby increases the power of the model [25]. Propensity scores represent either the probability of receiving PD (logistic regression analyses) or of patient survival (Cox regression analyses) for each individual patient based on all confounders in the model.

All analyses were based on the intention-to-treat principle and were performed using SAS 9.1 (1999–2001; SAS Institute Inc., Cary, NC).

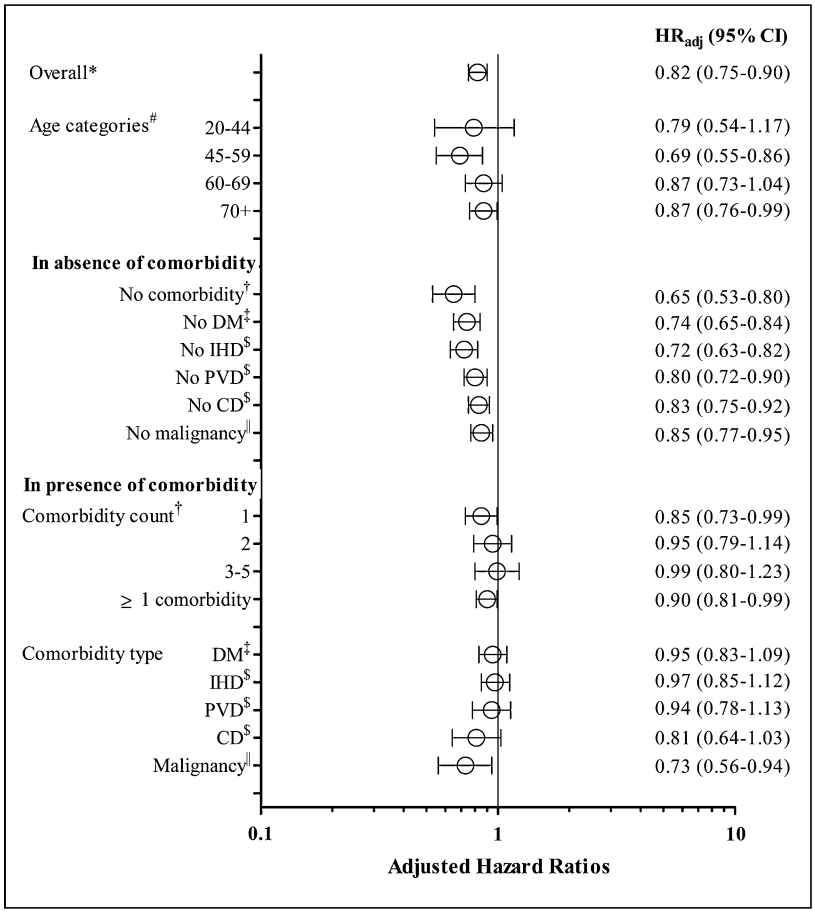
Results

Baseline characteristics

Data on comorbidity were available from 15 828 of 23 101 (69%) patients who started dialysis between 1998 and 2006. Baseline characteristics of the included patients for the total population and for HD and PD patients separately are presented in Table 1. In general, PD patients were younger and had less comorbid conditions as compared to HD patients. When comparing baseline characteristics between included and excluded patients (those without data on comorbidity), their age (63 versus 62 years) and gender (62% males in both groups) were similar, but the proportion of patients on PD was lower in the study population (20 versus 28%). However, country, age and sex adjusted 3-year survival of PD patients versus HD patients was similar in both groups, i.e. HRs_{adj} of 0.82 (95% CI: 0.75–0.89) for the included versus 0.81 (95% CI: 0.72–0.91) for the excluded patients.

Dialysis modality choice

We calculated OR_{adj} for the likelihood to receive PD as compared to HD treatment for several potential risk factors (Table 2). The data showed a strong negative association



Abbreviations: HR; Hazard Ratio, CI; Confidence Interval, DM; diabetes mellitus, IHD; ischaemic heart disease, PVD; peripheral vascular disease, CD; cerebrovascular disease.
Adjustments:
* age, sex, country, DM, IHD, PVD, CD, and malignancy.
# sex, country, DM, IHD, PVD, CD, and malignancy.
† age, sex, and country.
‡ age, sex, country, and malignancy.
$ age, sex, country, DM, and malignancy.
‖ age, sex, country, DM, IHD, PVD, and CD.

Fig. 2. HR_{adj} for the 3-year survival for PD versus HD patients (reference).

between age and the choice for PD. Compared to the youngest age group (20–44 years), patients of ≥70 years were 56% less likely to receive PD as compared to HD treatment (OR_{adj} 0.44; 95% CI: 0.39–0.51). Further analysis stratified for gender showed that this effect was less pronounced in males than in females with OR_{adj} of 0.53 (95% CI: 0.44–0.63) for male patients of ≥70 years and 0.33 (95% CI: 0.27–0.41) for elderly females. There was no association between sex and modality choice (OR_{adj} 1.03; 95% CI: 0.94–1.13).

Patients with three to five comorbidities were 19% less likely (OR_{adj} 0.81; 95% CI: 0.69–0.94) to start on PD compared to patients without comorbidity. Comparing modality choice in patients with and without specific comorbidities, we found a borderline significant association between the presence of DM and the likelihood to receive PD (OR_{adj} 1.09; 95% CI: 1.00–1.20). After stratification for age and gender, diabetic males were 17% (OR_{adj} 1.17; 95% CI: 1.04–1.31) more likely to receive PD compared to non-diabetic males, whereas for females, the presence of DM did not make a difference (OR_{adj} 1.00; 95% CI: 0.86–1.16). In addition, we found that in diabetic patients both the younger (20–44 years) and the older patients (≥70 years) were 32 and 25% more likely to receive PD as compared to non-diabetic patients.

Patients with IHD were as likely to receive PD as HD. Furthermore, patients with PVD, CD or malignancy were significantly less likely to receive PD than patients without these conditions.

Table 2 also illustrates differences in PD treatment between the participating countries. Except for patients in Sweden, patients in the other countries were less likely to receive PD as compared to the UK (reference group). Further analysis by country suggested similar associations between risk factors and modality choice as those presented in Table 2 with two exceptions: Catalonia (Spain) where the presence of multiple comorbidities relatively strongly increased the likelihood of receiving PD and Greece where the likelihood of receiving PD increased with age.

Table 1. Baseline characteristics of the study population at Day 91 on dialysis[a]

	Total *N* (%)	HD *N* (%)	PD *N* (%)	P-value
Incidence of dialysis				
Number of patients (%)[b]	15828	12731 (80)	3097 (20)	
% Males	62	62	63	0.196
Age (years)				
Mean (SD)	63 (15)	64 (15)	58 (16)	<0.05
Age categories (%)[b]				
20–44	2235 (14)	1558 (12)	677 (22)	<0.05
45–59	3702 (23)	2826 (22)	876 (28)	
60–69	3898 (25)	3158 (25)	740 (24)	
70+	5993 (38)	5189 (41)	804 (26)	
Comorbidity count (%)[b]				
0	6240 (40)	4801 (38)	1439 (47)	<0.05
1	4541 (29)	3630 (29)	911 (29)	
2	2888 (18)	2416 (19)	472 (15)	
3–5	2159 (14)	1884 (15)	275 (9)	
Presence of comorbidity (%)				
DM	4931 (31)	3976 (31)	955 (31)	0.670
IHD	4451 (28)	3662 (29)	789 (25)	<0.05
PVD	3928 (25)	3461 (27)	467 (15)	<0.05
CD	2339 (15)	2047 (16)	292 (9)	<0.05
Malignancy	1687 (11)	1458 (11)	229 (7)	<0.05
Country (%)				
Austria	3302 (20)	2989 (23)	313 (10)	<0.05
Belgium (French-speaking)	378 (2)	343 (3)	35 (1)	
Catalonia (Spain)	3294 (20)	3019 (24)	275 (9)	
Greece	1982 (12)	1723 (14)	259 (8)	
Norway	964 (6)	784 (6)	180 (6)	
Sweden	1714 (11)	1143 (9)	571 (18)	
United Kingdom	4194 (26)	2730 (21)	1464 (47)	

[a]P-values for HD versus PD patients. SD, standard deviation.
[b]Percentages are row-percentages.

Patient survival

Mean follow-up time was 1.6 years, with a maximum of 3 years. In this period, 6110 patients (38.6%) died and 6641 patients (42.0%) were alive and on dialysis at the end of the observation period, 1.6% was lost to follow-up and 17.9% received a kidney transplant (17.7% of the HD patients and 17.9% of the PD patients). During the study, 8% of the patients switched from their dialysis modality, i.e. 25% of the PD patients switched to HD and 4% of the HD patients switched to PD. Switches from PD to HD occurred more often with higher age and in the presence of comorbidity. Crude survival curves for male and female patients treated with HD or PD are presented in Figure 1.

Using Cox regression models, we calculated crude and HR_{adj} for the 3-year survival for PD compared to HD patients (Figure 2). Overall, we found that initiating dialysis on PD resulted in a survival benefit with an HR_{adj} of 0.82 (95% CI: 0.75–0.90). When examining patients without comorbidity, the risk of death on PD versus HD was even lower (HR_{adj} 0.65; 95% CI: 0.53–0.80); but with increasing number of comorbidities, the survival benefit disappeared. When studying patient survival by presence or absence of comorbidities, those patients without a specific comorbidity and patients with a malignancy had survival benefits starting on PD as compared to HD. Patients with DM, IHD, PVD or CD had no statistically significant survival benefits on PD as compared to HD.

In patients with IHD and PVD, we observed interaction between dialysis modality and sex. Moreover, interactions of DM with age and sex were described in the literature. We performed stratified survival analyses in these groups accordingly (Figure 3). After stratification for sex, the survival advantages of PD remained in males but not in females in the presence of comorbidities. For patients with three to five comorbidities, we found an HR_{adj} of 0.81 (95% CI 0.62–1.06) for males, whereas for females, the HR_{adj} was 1.53 (95% CI 1.06–2.22). After additional stratification for age, we found that females in the highest age category (≥70 years) already had an increased HR_{adj} when at least one comorbidity was present [HR_{adj} 1.28 (1.00–1.62; $P = 0.046$)]. In patients with PVD, females tended to have worse survival outcomes on PD, whereas males tended to have better survival on PD with HRs_{adj} of 1.27 (95% CI: 0.94–1.72; $P = 0.12$) and 0.81 (95% CI: 0.64–1.02; $P = 0.08$), respectively. Similar results were found for patients with IHD and DM. After additional stratification for age, the data showed that the increased risk of death in diabetic

Table 2. Crude OR and OR_{adj} for the likelihood of receiving PD treatment when compared to receiving HD treatment (reference)

	Crude OR (95% CI)	OR_{adj} (95% CI)
Age[a]		
20–44	1.00	1.00
45–59	0.71 (0.63–0.80)	0.79 (0.69–0.90)
60–69	0.54 (0.48-0.61)	0.68 (0.59-0.78)
70+	0.36 (0.32–0.40)	0.44 (0.39–0.51)
Sex[b]		
Female	1.00	1.00
Male	1.06 (0.97–1.14)	1.03 (0.94–1.13)
Comorbidity count[c]		
0	1.00	1.00
1	0.84 (0.76–0.92)	0.95 (0.86–1.05)
2	0.65 (0.58–0.73)	0.91 (0.80–1.03)
3–5	0.49 (0.42-0.56)	0.81 (0.69-0.94)
≥1 comorbidity	0.70 (0.64–0.76)	0.89 (0.81–0.97)
Presence of comorbidity		
No DM	1.00	1.00
DM[d]	0.98 (0.90–1.07)	1.09 (1.00–1.20)
No IHD	1.00	1.00
IHD[e]	0.79 (0.73–0.87)	0.98 (0.88–1.09)
No PVD	1.00	1.00
PVD[e]	0.47 (0.42–0.52)	0.72 (0.64–0.81)
No CD	1.00	1.00
CD[e]	0.52 (0.46–0.60)	0.68 (0.59–0.79)
No malignancy	1.00	1.00
Malignancy[f]	0.62 (0.54–0.72)	0.64 (0.55–0.75)
Country[g]		
United Kingdom	1.00	1.00
Austria	0.20 (0.17–0.22)	0.22 (0.19–0.26)
Belgium (French-speaking)	0.19 (0.13–0.27)	0.22 (0.15–0.31)
Catalonia (Spain)	0.17 (0.15–0.20)	0.18 (0.16–0.21)
Greece	0.28 (0.24–0.32)	0.30 (0.26–0.35)
Norway	0.43 (0.36–0.51)	0.44 (0.37–0.53)
Sweden	0.93 (0.83–1.05)	0.97 (0.86–1.10)

Adjustments: [a] country, sex, primary renal disease, DM, IHD, PVD, CD and malignancy.
[b]Country, age, primary renal disease, DM, IHD, PVD, CD and malignancy.
[c]Age, sex, and country.
[d]Age, sex, country and malignancy.
[e]Age, sex, country, DM and malignancy.
[f]Age, sex, country, DM, IHD, PVD and CD.
[g]Age, sex, primary renal disease, DM, IHD, PVD, CD and malignancy.

females on PD was only present in patients ≥70 years of age (HR_{adj}: 1.55; 95% CI: 1.15–2.08). For male patients with DM on PD, such age trend in risk of death was not found. Propensity score adjustment provided similar results.

Linking initial dialysis modality choice to patient survival

Finally, we linked initial dialysis modality choice to related patient survival. For this purpose, we calculated the OR_{adj} for modality choice within each subgroup where the patient survival on PD and HD was statistically significantly different, as depicted in Figure 2. In most cases, the OR_{adj} for initial modality choice was in line with patient survival, i.e. if there was a survival advantage on PD, patients were more likely to receive PD as initial dialysis modality and vice versa (data not shown).

However, there were some discrepancies in that particular patient groups had survival benefits on PD, whereas they were less likely to receive PD. In patients of ≥70 years, there was a survival advantage on PD (HR_{adj} 0.87; 95% CI: 0.76–0.99), whereas the likelihood of choosing PD was lower (OR_{adj} 0.57; 95% CI: 0.52–0.63). Also, patients without DM were less likely to receive PD (OR_{adj} 0.91; 95% CI: 0.82–0.98), whereas their survival on PD was better (HR_{adj} 0.74; 95% CI: 0.65–0.84). Finally, in patients with a malignancy, the likelihood of choosing PD was lower (OR_{adj} 0.64; 95% CI: 0.55–0.75) but their survival on PD was better (HR_{adj} 0.73; 95% CI: 0.56–0.94).

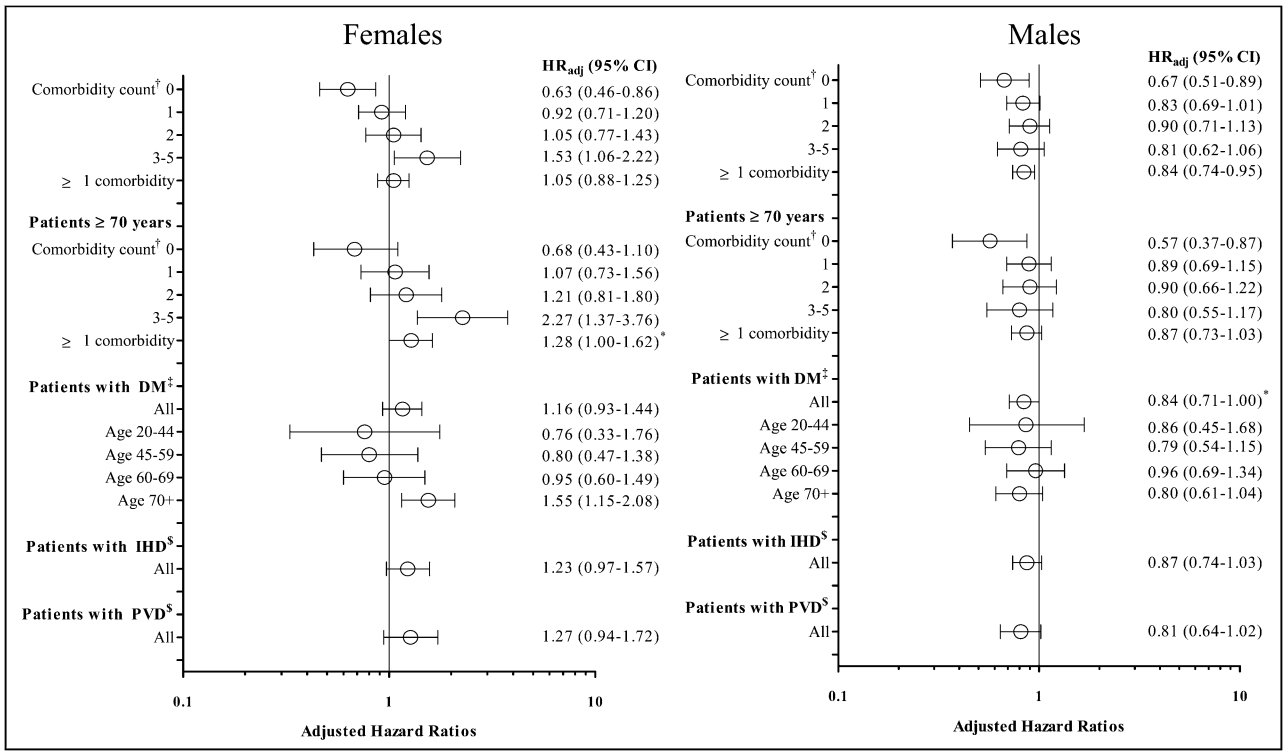
A discrepancy was also found for male patients without any comorbidity. These patients were as likely to receive either HD or PD as their initial dialysis modality (OR_{adj} 1.04; 95% CI: 0.93–1.17), while a survival benefit when starting on PD was found (HR_{adj} 0.67; 95% CI: 0.51–0.89).

Discussion

The primary aim of this study was to identify potential risk factors that influence modality choice in the dialysis population. We found that increasing age was associated with a lower likelihood to receive PD, especially in female patients. In addition, we found that patients with PVD, CD, malignancies or multiple comorbidities were less likely to receive PD than HD. However, the presence of DM was, especially in males, associated with a higher likelihood of receiving PD. There was no significant difference in receiving either PD or HD in patients with IHD and in male patients without any comorbidity.

In contrast to US data, the association between types of comorbidity and dialysis modality choice in Europe has been assessed in only a few studies. Couchoud *et al.* studied the variability in case mix and PD selection in several French districts. In their study population of patients >75 years of age, they demonstrated that receiving treatment with PD was associated with older age, congestive heart failure and severe behavioural disorders but not with any type of vascular disease (of the heart, brain or peripheral vessels). Patients with malignancy or DM less often received PD than HD as initial treatment [13, 15], while in our study, we demonstrated that older age and the presence of PVD and CD were negatively associated with the likelihood of receiving PD. This is in line with our findings suggesting different modality choice policies between countries, which, as outlined in the introduction, may be due to a variety of reasons.

The presence of IHD did not affect treatment modality choice, which may be explained by the fact that IHD can be a contraindication for both dialysis modalities. In such cases, nephrologists may need to choose the lesser of two evils [10, 11]. In addition, nephrologists might be more interested in the presence of congestive heart failure, but unfortunately such data were unavailable in this study. When deciding between PD and HD, nephrologists may take potential treatment effects into account as well. PD may result in a more atherogenic profile, which may accelerate pre-existing coronary artery disease or contribute to atherosclerotic cardiovascular comorbidity and mortality [26]. This might explain why patients with PVD or CD at



* *p=0.05;* Abbreviations: HR; Hazard Ratio, CI; Confidence Interval, DM; diabetes mellitus, IHD; ischaemic heart disease, PVD; peripheral vascular disease

Adjustments:

† age, sex, and country.

‡ age, sex, country, and malignancy.

$ age, sex, country, DM, and malignancy.

‖ age, sex, country, DM, IHD, PVD, and CD.

Fig. 3. HR$_{adj}$ for the 3-year survival on PD versus HD in subgroups that were based on existing statistical interaction.

the start of RRT were less likely to receive PD. However, the differential effects of PD and HD on arterial stiffness, vascular function, oxidative stress and inflammation, and myocardial structure and function need to be evaluated more extensively [27].

For diabetic patients, both modalities may have drawbacks. Diabetic patients often suffer from calcific atherosclerosis, which may lead to inadequate arterial inflow and problems with the vascular access during HD treatment [28, 29]. On the other hand, the glucose load during PD treatment could worsen the metabolic status and contribute to an increased risk of atherosclerotic complications [30]. In addition, it is suggested that diabetic patients have a high peritoneal transport rate, which is associated with loss of ultrafiltration [28, 31] and an increased risk of morbidity, technique failure and death [31, 32]. However, the impact of high peritoneal transport rates on mortality remains controversial.

The second aim of this study was to assess patient survival in subgroups of patients. Overall, we found survival benefits for patients starting on PD, but effects of dialysis modality on survival were different for males and females in different comorbidity categories. Male patients showed better survival rates on PD, even in the presence of comorbidity. In contrast, survival benefits in females were only found for those with no or few comorbidity: female patients with three to five comorbidities as well as females in the highest age category with at least one comorbidity showed increased risks of death when starting on PD. However, this latter finding is most likely due to the effect in elderly diabetic females for whom we found a 55% higher risk of death when starting on PD as compared to HD.

Some previous studies comparing survival between HD and PD patients suggested that patient survival is similar for patients on HD and PD [17, 24,33–35], while others argued that one modality provides better results than the other [19,36–40]. In agreement with our results, McDonald *et al.* suggested that age and the presence of comorbidities *per se* are important factors influencing the association between treatment modality and survival [17]. In this study, we were able to show that this is indeed the case for specific comorbidities.

In a study among prevalent patients in the 1990s, Bloembergen *et al.* found higher mortality risks associated with PD in patients >55 years of age. Increased mortality risks were present in both diabetic and non-diabetic patients and in both males and females, although they turned out to be more pronounced in diabetics and females [24].

Our European study in incident patients now only shows an excess mortality risk in diabetic females $\geq$ 70 years of age.

When studying modality choice in relation to survival, we may conclude that in most subgroups, the likelihood to receive PD was in line with expected survival, or in other words, patients who were most likely to receive PD treatment had the best expected survival if treated with that modality. However, there were a few discrepancies. Firstly, elderly patients (age $\geq$ 70 years), non-diabetic patients and those with malignancy were less likely to receive PD, although we found survival benefits on PD for these three groups. In addition, in healthy patients, i.e. those without any comorbidity, we found survival benefits on PD for both males and females. However, results from our logistic regression analysis showed that females were indeed more likely to receive PD, but for males HD was just as likely to be the chosen method of treatment as was PD. These discrepancies may be due to different factors. Nephrologists may let other medical factors prevail above increased mortality risk, they may have needed to choose for PD (e.g. because the patient's heart condition was too poor to tolerate HD) or they may have been unaware of the expected patient survival on PD in these specific subgroups. In addition, modality choice may be based on practical and social considerations. For example, elderly or poorly patients will often choose HD because they regularly have difficulties to cope with or to perform home-based therapies. Nevertheless, these contrasting results emphasize the need for more extensive research on dialysis modality choice and outcome within these specific subgroups of patients.

A major strength of this study is that it is based on a large population of incident dialysis patients from well-established national and regional renal registries with high data quality. With this study, we were able to compare modality choice and related patient survival within several subgroups in a number of European countries. There were, however, some limitations. As one study has shown, the comparison of outcomes by randomizing patients for HD or PD is not feasible [41]. A randomized trial, however, is the only study design to avoid confounding by indication, which occurs when physicians select patients for one type of modality for a specific reason. In this study, we lacked information on other potentially important comorbidities like congestive heart failure and on clinical parameters like residual renal function, laboratory values and medication, which made adjustment for these factors impossible. Finally, in the survival analyses, we censored patients who received a kidney transplant. As we can assume that these patients were the healthiest patients with high survival rates, censoring them might have resulted in an underestimation of the patient survival. Our study focused on survival within the first 3 years on RRT. This may have biased the results in favour of PD since previous studies demonstrated survival benefits to be dependent on the amount of time on RRT [17, 42].

In conclusion, based on data from seven European renal registries, we demonstrated that patients with older age, comorbidities such as PVD, CD and malignancy, multiple comorbidities and those living in particular countries are less likely to receive PD as dialysis treatment. Survival benefits on PD were shown for all patients without specific comorbidities. In male patients, survival advantages were independent of the presence of comorbidity, whereas female patients on PD are suggested to have increased risks of death in the presence of comorbidity, especially the elderly females with DM. Overall, we can conclude that modality choice was consistent with demonstrated survival benefits. However, for patients of $\geq$70 years, non-diabetic patients and those with malignancy, treatment modality choice did not match the expected survival as these patients were less likely to receive PD, while they showed a better survival on PD. Also for male patients without comorbidity, results were not in line with each other; these patients were as likely to receive HD and PD, whereas a survival advantage on PD was found. Further investigation is required to identify explanations why these specific patient groups are not more likely to receive PD and whether the overall survival would improve if more of these patients would be treated with PD.

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References

1. ERA-EDTA Registry. *ERA-EDTA Registry 1998 Annual Report*. Amsterdam: Academic Medical Center; 2003
2. Stel VS, Kramer A, Zoccali C *et al.* The 2006 ERA-EDTA Registry annual report: a precis. *J Nephrol* 2009; 22: 1–12
3. U.S.Renal Data System U. *2008 Annual Data Report: Atlas of End-Stage Renal Disease in the United States*. Bethesda, MD: National Institutes of Health, National Institute of Diabetes and Digestive Kidney Diseases, 2008
4. Thamer M, Hwang W, Fink NE *et al.* US nephrologists' recommendation of dialysis modality: results of a national survey. *Am J Kidney Dis* 2000; 36: 1155–1165
5. Bass EB, Wills S, Fink NE *et al.* How strong are patients' preferences in choices between dialysis modalities and doses? *Am J Kidney Dis* 2004; 44: 695–705
6. Groome PA, Hutchinson TA, Prichard SS. ESRD treatment modality selection: which factors are important in the decision? *Adv Perit Dial* 1991; 7: 54–56
7. Just PM, de Charro FT, Tschosik EA *et al.* Reimbursement and economic factors influencing dialysis modality choice around the world. *Nephrol Dial Transplant* 2008; 23: 2365–2373
8. Lameire N, van Biesen W. The pattern of referral of patients with end-stage renal disease to the nephrologist—a European survey. *Nephrol Dial Transplant* 1999; 14 (Suppl 6): 16–23
9. Bouvier N, Durand PY, Testa A *et al.* Regional discrepancies in peritoneal dialysis utilization in France: the role of the nephrologist's opinion about peritoneal dialysis. *Nephrol Dial Transplant* 2009; 24: 1293–1297
10. Jager KJ, Korevaar JC, Dekker FW *et al.* The effect of contraindications and patient preference on dialysis modality selection in ESRD patients in The Netherlands. *Am J Kidney Dis* 2004; 43: 891–899
11. Miskulin DC, Meyer KB, Athienites NV *et al.* Comorbidity and other factors associated with modality selection in incident dialysis

patients: the CHOICE Study. Choices for Healthy Outcomes in Caring for End-Stage Renal Disease. *Am J Kidney Dis* 2002; 39: 324–336
12. Stack AG. Determinants of modality selection among incident US dialysis patients: results from a national study. *J Am Soc Nephrol* 2002; 13: 1279–1287
13. Couchoud C, Savoye E, Frimat L *et al.* Variability in case mix and peritoneal dialysis selection in fifty-nine French districts. *Perit Dial Int* 2008; 28: 509–517
14. Chung SH, Noh H, Ha H *et al.* Optimal use of peritoneal dialysis in patients with diabetes. *Perit Dial Int* 2009; 29 (Suppl 2): S132–S134
15. Couchoud C, Moranne O, Frimat L *et al.* Associations between comorbidities, treatment choice and outcome in the elderly with end-stage renal disease. *Nephrol Dial Transplant* 2007; 22: 3246–3254
16. Ganesh SK, Hulbert-Shearon T, Port FK *et al.* Mortality differences by dialysis modality among incident ESRD patients with and without coronary artery disease. *J Am Soc Nephrol* 2003; 14: 415–424
17. McDonald SP, Marshall MR, Johnson DW *et al.* Relationship between dialysis modality and mortality. *J Am Soc Nephrol* 2009; 20: 155–163
18. Stack AG, Molony DA, Rahman NS *et al.* Impact of dialysis modality on survival of new ESRD patients with congestive heart failure in the United States. *Kidney Int* 2003; 64: 1071–1079
19. Vonesh EF, Snyder JJ, Foley RN *et al.* The differential impact of risk factors on mortality in hemodialysis and peritoneal dialysis. *Kidney Int* 2004; 66: 2389–2401
20. Stel VS, van Dijk PC, van Manen JG *et al.* Prevalence of co-morbidity in different European RRT populations and its effect on access to renal transplantation. *Nephrol Dial Transplant* 2005; 20: 2803–2811
21. Stel VS, Dekker FW, Ansell D *et al.* Residual renal function at the start of dialysis and clinical outcomes. *Nephrol Dial Transplant* 2009; 24: 3175–3182
22. Jager KJ, Zoccali C, Macleod A *et al.* Confounding: what it is and how to deal with it. *Kidney Int* 2008; 73: 256–260
23. Jager KJ, van Dijk PC, Zoccali C *et al.* The analysis of survival data: the Kaplan-Meier method. *Kidney Int* 2008; 74: 560–565
24. Bloembergen WE, Port FK, Mauger EA *et al.* A comparison of mortality between patients treated with hemodialysis and peritoneal dialysis. *J Am Soc Nephrol* 1995; 6: 177–183
25. Fitzmaurice G. Confounding: propensity score adjustment. *Nutrition* 2006; 22: 1214–1216
26. Babazono T, Miyamae M, Tomonaga O *et al.* Cardiovascular risk factors in diabetic patients undergoing continuous ambulatory peritoneal dialysis. *Adv Perit Dial* 1996; 12: 120–125
27. Fassett RG, Driver R, Healy H *et al.* Comparison of markers of oxidative stress, inflammation and arterial stiffness between incident hemodialysis and peritoneal dialysis patients–an observational study. *BMC Nephrol* 2009; 10: 8
28. Locatelli F, Pozzoni P, Del Vecchio L. Renal replacement therapy in patients with diabetes and end-stage renal disease. *J Am Soc Nephrol* 2004; 15 (Suppl 1): S25–S29
29. Schlieper G, Kruger T, Djuric Z *et al.* Vascular access calcification predicts mortality in hemodialysis patients. *Kidney Int* 2008; 74: 1582–1587
30. Wu HY, Hung KY, Huang JW *et al.* Initial glucose load predicts technique survival in patients on chronic peritoneal dialysis. *Am J Nephrol* 2008; 28: 765–771
31. Rumpsfeld M, McDonald SP, Johnson DW. Higher peritoneal transport status is associated with higher mortality and technique failure in the Australian and New Zealand peritoneal dialysis patient populations. *J Am Soc Nephrol* 2006; 17: 271–278
32. Churchill DN, Thorpe KE, Nolph KD *et al.* Increased peritoneal membrane transport is associated with decreased patient and technique survival for continuous peritoneal dialysis patients. The Canada-USA (CANUSA) Peritoneal Dialysis Study Group. *J Am Soc Nephrol* 1998; 9: 1285–1292
33. Collins AJ, Hao W, Xia H *et al.* Mortality risks of peritoneal dialysis and hemodialysis. *Am J Kidney Dis* 1999; 34: 1065–1074
34. Fenton SS, Schaubel DE, Desmeules M *et al.* Hemodialysis versus peritoneal dialysis: a comparison of adjusted mortality rates. *Am J Kidney Dis* 1997; 30: 334–342
35. Liem YS, Wong JB, Hunink MG *et al.* Comparison of hemodialysis and peritoneal dialysis survival in The Netherlands. *Kidney Int* 2007; 71: 153–158
36. Lee CC, Sun CY, Wu MS. Long-term modality-related mortality analysis in incident dialysis patients. *Perit Dial Int* 2009; 29: 182–190
37. Sanabria M, Munoz J, Trillos C *et al.* Dialysis outcomes in Colombia (DOC) study: a comparison of patient survival on peritoneal dialysis vs hemodialysis in Colombia. *Kidney Int Suppl* 2008; 108: S165–S172
38. Termorshuizen F, Korevaar JC, Dekker FW *et al.* Hemodialysis and peritoneal dialysis: comparison of adjusted mortality rates according to the duration of dialysis: analysis of The Netherlands Cooperative Study on the Adequacy of Dialysis 2. *J Am Soc Nephrol* 2003; 14: 2851–2860
39. Vonesh EF, Moran J. Mortality in end-stage renal disease: a reassessment of differences between patients treated with hemodialysis and peritoneal dialysis. *J Am Soc Nephrol* 1999; 10: 354–365
40. Xue JL, Everson SE, Constantini EG *et al.* Peritoneal and hemodialysis: II. Mortality risk associated with initial patient characteristics. *Kidney Int* 2002; 61: 741–746
41. Korevaar JC, Feith GW, Dekker FW *et al.* Effect of starting with hemodialysis compared with peritoneal dialysis in patients new on dialysis treatment: a randomized controlled trial. *Kidney Int* 2003; 64: 2222–2228
42. Heaf JG, Lokkegaard H, Madsen M. Initial survival advantage of peritoneal dialysis relative to haemodialysis. *Nephrol Dial Transplant* 2002; 17: 112–117

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