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Economic impact of a modification of the treatment trajectories of patients with end-stage renal disease

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ORIGINAL ARTICLE

ABSTRACT

Background. This study assumed that some patients currently treated at hospital-based haemodialysis centres can be treated with another renal replacement therapy (RRT) modality without any increase in mortality risk and sought to evaluate the monthly cost impact of replacing hospital-based haemodialysis, for which fees are highest, by different proportions of other modalities.

Methods. We used a deterministic model tool to predict the outcomes and trajectories of hypothetical cohorts of incident adult end-stage renal disease (ESRD) patients for 15 years of RRT (10 different modalities). Our estimates were based on data from 67 258 patients in the REIN registry and 65 662 patients in the French national health insurance information system. Patients were categorized into six subcohorts, stratified for age and diabetes at ESRD onset, and analyses run for each subcohort. We simulated new strategies of care by changing any or all of the following: initial distributions in treatment modalities, transition rates and some costs. Strategies were classified according to their monthly per-patient cost compared to current practices (cost-minimization analysis).

Results. Simulations of the status quo for the next 15 years predicted a per-patient monthly cost of €2684 for a patient aged 18–45 years without diabetes and €7361 for one older than 70 years with diabetes. All of the strategies we analysed had monthly per-patient costs lower than the status quo, except for daily home HD. None impaired expected survival. Savings varied by strategy.

Conclusions. Alternative strategies may well be less expensive than current practices. The decision to implement new strategies must nonetheless consider the number of patients concerned, feasibility of renal care reorganization, and investment costs. It must also take into account the role of patients' choice and the availability of professionals.

Keywords: cost, dialysis, medico-economic evaluation, simulation tool, transplantation

INTRODUCTION

End-stage renal disease (ESRD) is a chronic state that may continue for many years before death. During this time, patients may receive various modalities of renal replacement therapy (RRT) that vary over time, which we describe as a treatment trajectory. This diversity of modalities enables patients to decide with their physicians, in a shared process, the treatment method most suitable to them, according to their willingness to be actively involved in the treatment process and their preferences about home treatment. As in other European countries [1], a variety of dialysis modalities are used [2, 3] in France, and their weight and distribution differ from region to region. This diversity leaves room for choices and modifications in dialysis care strategies, defined as general plans for initial modality and transitions to other modalities.

ESRD is a major challenge for health-care systems around the world, affecting a growing proportion of the population and causing health-care costs to rise. Although transplantation is widely considered the most cost-effective treatment for ESRD [4], most spending goes towards dialysis in many countries, because of organ shortages. The French health insurance system pays dialysis facilities and professionals various fixed fees according to the dialysis modalities they provide. Fees are highest for hospital-based haemodialysis (HD) care, which treats

around 58% of all dialysis patients. This study assumed that some patients currently treated in these units could be treated with another RRT modality without any increase in mortality risk and sought to evaluate the economic impact, in terms of the monthly per-person cost over a 15-year period, of replacing some hospital-based HD care by various other modalities.

MATERIALS AND METHODS

Modelling the strategies of care

Strategies of care were modelled with a previously described statistical tool [5] that predicts course and trajectories of a hypothetical cohort of incident ESRD patients over a 15-year period of RRT (lifetime horizon).

This model is based on transitions between 10 modalities of RRT during 7 time periods ([0–6] months,]6–12] months,]12–18] months,]18–24] months,]24–36] months,]36–60] months, and [60–180] months) and the number of patients in each modality at each time point. The 10 modalities that we considered were defined both by place and technique: haemodialysis (HD) (at home or in three types of facilities: hospital-based and facilities under medical supervision and nurse-assisted self-care units), peritoneal dialysis (PD) (two different techniques, levels of assistance) and transplantation (living or deceased donor). The predicted changes in compartment volumes (that is, in the number of patients in each compartment) between time t and time $t+1$ were estimated by resolving a system of differential equations (continuous-time deterministic structural model).

We estimated the parameters of the model (transition rates between the 10 modalities and between each of these modalities and death) with a multistate model, using data from 67 258 adult patients in the French Renal Epidemiology and Information Network (REIN) registry who received at least one RRT treatment between 2002 and 2010. Each patient was followed until death or the study endpoint on 31 December 2010. The registry includes all ESRD patients on RRT—either dialysis or transplantation—treated in France. Its organizational principles and quality control are described elsewhere [6].

Patients were categorized into six subcohorts, stratified for age at ESRD onset: 18–44 years, 45–69 years and 70 years and over, and diabetes (present or absent at RRT initiation). For each simulation, the mean 15-year restricted lifetime of the cohort was calculated for the simulation period (i.e. 180 months).

Some specific transition rates could not be estimated because current numbers of patients or facilities are too low. See the Supplementary Methods section.

Costs

We used administrative databases of the French national health insurance information system to estimate costs for ESRD patients according to the 10 RRT modalities and the cost of each patient's events (dialysis start, transition between modality of treatment, death).

To estimate those costs, assessed from the health insurance perspective, we identified 65 662 adult ESRD patients with medical costs paid by the French national health insurance system from March 2009 through February 2010. Costs considered included hospital care, medical and paramedical fees for hospital and outpatient care, medical goods (drugs and medical devices), laboratory tests, transport (all of the above for dialysis or transplant but also all comorbidities and other medical complications) and personal autonomy allowances.

These estimates were calculated for the same six subcohorts, stratified for age at ESRD onset and diabetes status at RRT initiation. Those costs were then introduced in our simulation model. Details of the costs used in our simulation are included in the Supplementary Methods section and Supplementary Table S1.

Simulation of strategies

We were able to simulate new strategies of care by changing any or all of the following: initial distribution into treatment modalities, transition rates, and some costs. Each scenario was then compared with the unchanged baseline scenario, the status quo, based on the practices currently observed in the REIN registry. The status quo, thus corresponds to the current transition rates observed between modalities and current initial distribution.

Several alternative strategies were defined for each patient subcohort, based on various modality rates in Europe [1] or in different regions of France [2, 3] and on the opinion of 30 experts [7]. All alternatives were required to be feasible and safe for the patients. Experts' suggestions for such strategy were checked against the database to ensure that they did not result in an increased risk, as in non-inferiority trials. Potential strategies identified included increasing rates of renal transplantation, home dialysis (PD or HD) and modalities that promote autonomy, in contrast to hospital-based HD units. These strategies differed for each of the six patient subcohorts. See Supplementary Methods section and Supplementary Table S2.

Some transition rules also required adaptation. In some PD strategies, to avoid unprepared transfer to hospital-based HD, we also simulated prepared transfer to an HD modality—in facilities under medical supervision for elderly patients, or self-care unit for middle-aged patients, and self-care units or home HD for young patients—in the 2–5 years after PD start. Similarly, in strategies aimed to increase non-hospital-based HD to avoid unprepared transfer to hospital-based HD for elderly patients, we simulated a prepared transition after 5 years to a HD modality in a more medicalized environment, i.e., from self-care units to facilities under medical supervision or from facilities under medical supervision to hospital-based units.

Finally, a more ambitious strategy, combining the development of PD and non-hospital-based HD was also simulated for each subcohort. The details of each strategy for each subcohort of patients are detailed in Supplementary Table S2.

Output

To quantify the impact of these various strategies and take into account the size of each subpopulation concerned, we simulated the various strategies according to the number of incident patients observed in 2011 in the REIN registry.

Strategies were classified according to their monthly per-patient cost relative to the status quo. See also Supplementary Methods section.

The feasibility of each scenario was approached by considering the number of patients starting RRT in each modality of treatment and the number of transitions entering each modality during the period, compared to the status quo. The role of each treatment modality in a given strategy was summarized by the mean time spent in each modality.

RESULTS

The incident patients in 2011 were distributed as follows into the six age/diabetes subcohorts: 18–44 years, 8.6% without diabetes, 1.3% with diabetes; 45–69 years, 22.8% without diabetes, 16.3% with diabetes; and 70 years or older, 29.2% without diabetes and 21.8% with diabetes.

Our simulations over a period of 180 months estimated that the monthly cost per patient according to current practices (status quo) ranged from €2684 for a patient 18–45 years without diabetes to €7361 for a patient aged 70 years or older with diabetes.

As expected, because the experts selected strategies that they considered safe for a given subgroup of patients, overall differences in life expectancy were very small between the strategies: 0–8 months.

In each subcohort of patients, increases in renal transplantation had the greatest impact on monthly costs compared to the status quo. Increasing dialysis alternatives to hospital-based HD had a smaller effect and one that varied notably according to patient subcohort.

Twelve alternative strategies were simulated for the youngest patients (18–44 years) without diabetes (Table 1). Three are based on increased development of renal transplantation, and nine on the development of home dialysis (non-assisted PD or HD). Transfer to HD in self-care units or at home was simulated for some patients still on PD after 2 years. Except for daily home HD, all but one of those strategies, including renal transplantation, had a mean monthly per-patient cost lower than the status quo (−468€ to −27€); daily home HD increased costs by €30/month.

For the young patients (18–44 years) with diabetes, we simulated nine alternative strategies (Table 2), three based on increasing transplantation and six on increasing the share of non-assisted PD or HD in self-care units. Prepared transfer to HD self-care units was simulated for some patients still on PD after 2 years. All those strategies had a monthly per-patient cost lower than the status quo (−€441 to −€38).

Of the 11 alternative strategies simulated for middle-aged patients (45–69 years) without diabetes (Table 3), 3 were based on increased renal transplantation development, and 8 on development of non-assisted PD or HD in self-care units or facilities under medical supervision. Prepared transfer to HD self-care units was simulated for some patients still on PD after 2 years, and prepared transfer to facilities under medical supervision for patients still on HD in a self-care unit after 5 years. Finally, a strategy increasing the rate of patients (8 versus 3%) beginning treatment in facilities under medical supervision rather than hospital-based centres was also simulated. Again, all strategies were less expensive than the status quo (−€466 to −€13 monthly per patient).

For the middle-aged patients (45–69 years) with diabetes, we simulated 11 alternative strategies (Table 4), 1 based on an increase in transplantation from deceased donors, and 10 on the expanding non-assisted PD and HD in facilities under medical supervision. Prepared transfer to HD self-care units was simulated for some patients still on PD after 2 years, and prepared transfer to facilities under medical supervision for some patients still on HD in a self-care unit after 5 years. Finally, the development of local facilities under medical supervision was also simulated, by decreasing transportation costs. Every strategy was less expensive than the status quo (−€361 to −€82 per patient per month).

Among the patients aged 70 years or older, both with and without diabetes, we simulated 11 alternative strategies (Tables 5 and 6). One was based on the increased development of renal transplantation from deceased donors, with perfusion machines, while 10 simulated increased use of assisted PD or HD in facilities under medical supervision. Prepared transfer to these facilities under medical supervision was simulated for some patients still on PD after 2 years, and to hospital-based HD for patients still in facilities under medical supervision after 5 years. Finally, the development of local HD in facilities under medical supervision was also simulated, by decreasing transportation costs. All strategies had lower monthly costs than the status quo, both for patients without (−€959 to −€47) and with diabetes (−€479 to −€47).

DISCUSSION

This study evaluated the change in monthly costs of various strategies of ESRD patient care from the national health insurance perspective, in six subcohorts of patients. All the strategies we analysed aimed to develop feasible and safe alternatives to hospital-based HD, for which fees are highest. Unsurprisingly, therefore, all but daily home HD reduced monthly per-patient costs below those of the status quo. The amount of the savings varied between strategies and between subcohorts.

As other studies report [4, 8], expanding renal transplantation reduced monthly per-patient costs in each patient subcohorts by amounts ranging from €250 to €950. Nonetheless, in view of the existing organ shortage and insufficient rate of development of living donors in France, we must consider alternative dialysis strategies. In each subcohort of patients, the largest potential savings were seen in ambitious strategies that combined substantial increases in PD and in non-hospital-based HD. They would require quite sizable changes in practices: increased rates of incident patients starting with PD from the current 10–15% up to 25–35% and reduction of the total time spent in hospital-based HD units by 25 to 35%. The feasibility of these changes is debatable. Although studies of patients' opinions indicate that up to 30% say they would be willing to use PD, the current PD figures are not encouraging [9–14]. Nephrologists' opinions are extremely important to

Table 1. Based on a simulation covering a total of 180 months, impact of various dialysis strategies on the monthly per-patient costs and on the initial distribution at RRT start, the total time spent in each modality, the number of transitions and the mean lifetime for patients aged 18–44 years without diabetes

Cohort = 823 incident patients	Status quo	Renal TR, all donors	Renal TR, deceased donor	Renal TR, living donor	Combined: CAPD, APD and home HD	Non-assisted CAPD, transfer to self-care unit	Non-assisted CAPD, transfer to home HD	Non-assisted APD	Non-assisted APD, transfer to home HD	Non-assisted CAPD	Non-assisted APD, transfer to self-care unit	Home HD	Daily home HD
Cost/months (euros) for 1 patient	2684	2216	2233	2443	2584	2618	2618	2619	2623	2625	2624	2656	2714
Comparison with status quo (euros/months)		−468	−451	−240	−100	−66	−65	−64	−61	−59	−60	−27	30
Initial distribution at RRT start (%)													
Hospital-based HD	**61.7**	**61.7**	**61.7**	**61.7**	**42.4**	**46.1**	**46.1**	**46.4**	**46.4**	**46.1**	**46.4**	**61.7**	**61.7**
Assisted automated PD	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Non-assisted automated PD	7.7	7.7	7.7	7.7	19.2	7.7	7.7	23.0	23.0	7.7	23.0	7.7	7.7
Assisted continuous PD	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Non-assisted continuous PD	5.2	5.2	5.2	5.2	13.1	20.9	20.9	5.2	5.2	20.9	5.2	5.2	5.2
HD self-care unit	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
HD home	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Facility under medical supervision	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Renal graft deceased donor	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Renal graft living donor	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Distribution of the total time spent in each modality (%)													
Hospital-based HD	**11.3**	**7.6**	**7.7**	**9.5**	**9.0**	**10.0**	**9.9**	**10.1**	**9.9**	**10.2**	**9.9**	**10.6**	**10.6**
Assisted automated PD	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Non-assisted automated PD	1.5	0.9	0.9	1.2	2.3	1.9	1.9	3.2	2.7	2.0	2.5	1.5	1.5
Assisted continuous PD	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Non-assisted continuous PD	0.8	0.5	0.6	0.7	1.2	1.8	1.9	0.8	0.8	2.4	0.8	0.8	0.8
HD self-care unit	12.8	6.2	6.4	9.4	12.4	12.2	11.4	11.4	11.3	11.5	12.7	12.2	12.2
HD home	0.7	0.3	0.3	0.5	1.4	0.6	1.4	0.6	1.7	0.6	0.6	1.7	1.7
Facility under medical supervision	2.7	1.4	1.4	2.1	2.3	2.5	2.5	2.5	2.4	2.5	2.4	2.6	2.6
Renal graft deceased donor	61.3	71.5	73.2	60.9	62.1	61.8	61.8	62.1	61.9	61.6	61.8	61.6	61.6
Renal graft living donor	8.6	11.4	9.3	15.6	9.0	9.0	8.9	8.9	8.9	8.9	8.9	8.7	8.7

Continued

Table 1. Continued

Cohort = 823 incident patients	Status quo	Renal TR, all donors	Renal TR, deceased donor	Renal TR, living donor	Combined: CAPD, APD and home HD	Non-assisted CAPD, transfer to self-care unit	Non-assisted CAPD, transfer to home HD	Non-assisted APD	Non-assisted APD, transfer to home HD	Non-assisted CAPD	Non-assisted APD, transfer to self-care unit	Home HD	Daily home HD
Number of transitions entering each modality (per 823 patients)													
Hospital-based HD	**788**	**742**	**743**	**764**	**644**	**676**	**675**	**683**	**674**	**684**	**676**	**787**	**787**
Assisted automated PD	19	18	18	18	21	20	20	20	20	20	20	19	19
Non-assisted automated PD	111	104	104	107	218	143	144	235	234	149	234	110	110
Assisted continuous PD	15	14	14	15	15	16	16	15	15	16	15	15	15
Non-assisted continuous PD	63	61	61	62	127	191	192	65	64	192	63	63	63
HD self-care unit	514	435	439	473	507	490	459	462	460	462	512	502	502
HD home	29	22	22	26	63	26	54	26	66	27	26	79	79
Facility under medical supervision	146	113	114	129	127	135	134	134	132	135	133	141	141
Renal graft deceased donor	720	824	842	714	732	725	726	728	729	721	727	724	724
Renal graft living donor	82	108	88	150	86	85	84	85	84	84	84	82	82
Number of deaths (per 823 patients)	156	120	122	135	146	151	151	150	149	154	149	153	153
Restricted mean lifetime (months)	161.9	166.2	165.9	164.3	163.6	162.7	162.7	163	163.1	162.3	163	162.3	162.3

Shaded values correspond to the modalities of treatment impacted by the given strategy. Bold values correspond to hospital-based HD.

Table 2. Based on a simulation covering a total of 180 months, impact of various dialysis strategies on the monthly per-patient costs and on the initial distribution at RRT start, total time spent in each modality, number of transitions and mean lifetime for patients aged 18–44 years with diabetes

Cohort = 123 incident patients	Status quo	Renal TR, all donor	Renal TR, deceased donor	Combined: CAPD, APD and self-care unit	Renal TR, living donor	Self-care unit	Non-assisted CAPD, transfer to self-care unit	Non-assisted CAPD	Non-assisted APD	Non-assisted APD, transfer to self-care unit
Cost/months (euros) for 1 patient	4494	4053	4103	4215	4377	4299	4404	4409	4452	4456
Comparison with status quo (euros/months)		−441	−392	−279	−117	−195	−90	−85	−42	−38
Initial distribution at RRT start (%)										
Hospital-based HD	**67.4**	**67.4**	**67.4**	**46.2**	**67.4**	**67.4**	**56.5**	**56.5**	**57.1**	**57.1**
Assisted automated PD	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Non-assisted automated PD	3.5	3.5	3.5	13.8	3.5	3.5	3.5	3.5	13.8	13.8
Assisted continuous PD	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Non-assisted continuous PD	3.6	3.6	3.6	14.6	3.6	3.6	14.6	14.6	3.6	3.6
HD self-care unit	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
HD home	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Facility under medical supervision	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Renal graft deceased donor	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Renal graft living donor	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Distribution of the total time spent in each modality (%)										
Hospital-based HD	**23.4**	**18.3**	**18.9**	**15.7**	**21.8**	**17.5**	**21.5**	**21.7**	**22.0**	**21.9**
Assisted automated PD	0.6	0.5	0.5	0.8	0.6	0.5	0.7	0.7	0.7	0.7
Non-assisted automated PD	0.9	0.7	0.7	2.4	0.9	0.9	1.3	1.3	2.5	2.2
Assisted continuous PD	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Non-assisted continuous PD	0.5	0.4	0.4	1.2	0.5	0.5	1.2	1.4	0.6	0.6
HD self-care unit	9.9	7.1	7.2	14.7	9.3	16.2	9.5	9.2	9.3	10.0
HD home	0.7	0.5	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Facility under medical supervision	3.4	2.5	2.6	2.4	3.2	2.6	3.2	3.2	3.3	3.3
Renal graft deceased donor	59.4	66.4	68.1	61.0	58.8	59.9	60.7	60.7	59.9	59.5
Renal graft living donor	0.9	3.3	0.8	1.0	3.9	1.1	0.9	0.9	0.9	0.9
Number of transitions entering each modality (per 123 patients)										
Hospital-based HD	**135**		**135**	**120**	**135**	**141**	**124**	**125**	**126**	**126**
Assisted automated PD	2	2	2	3	2	2	3	3	3	3
Non-assisted automated PD	9	9	8	25	9	8	12	12	21	21
Assisted continuous PD	3	2	2	2	3	2	3	3	3	3
Non-assisted continuous PD	7	7	7	21	7	7	21	21	8	8
HD self-care unit	47	43	43	72	46	80	46	44	44	48
HD home	3	135	3	3	3	3	3	3	3	3
Facility under medical supervision	28	3	25	26	27	28	26	26	26	27
Renal graft deceased donor	90	24	104	96	90	95	92	92	91	91

Continued

Table 2. Continued

Cohort = 123 incident patients	Status quo	Renal TR, all donor	Renal TR, deceased donor	Combined: CAPD, APD and self-care unit	Renal TR, living donor	Self-care unit	Non-assisted CAPD, transfer to self-care unit	Non-assisted CAPD	Non-assisted APD	Non-assisted APD, transfer to self-care unit
Renal graft living donor	2	102	2	2	6	2	2	2	2	2
Number of deaths (per 123 patients)	60	53	54	56	58	56	59	59	59	59
Restricted mean lifetime (months)	130.8	138.3	137.3	135.4	132.8	135.4	131.6	131.4	130.8	130.9

Shaded values correspond to the modalities of treatment impacted by the given strategy. Bold values correspond to hospital-based HD.

patient decisions, and private sector nephrologists appear to consider PD optimal for considerably fewer patients than either public- or nonprofit-sector nephrologists do [9]. Early information and a structured organization for adequate patient education and support during treatment at home must be planned. In addition, increasing the number of patients in self-care units and facilities under medical supervision requires extensive development of both patient and professional education and a major reorganization of renal care [13, 15, 16].

Comparison of our results with those of other studies is difficult because most cost analyses have compared modalities directly, rather than strategies of care that integrate patient trajectories over a long time period. Most studies have concluded that PD is a cost-effective alternative [17–19]. Those studies have generally analysed all modalities of each technique (PD or HD) together, without considering the costs of transportation, or separating out the different age groups, or considering expansion of transplantation.

Increasing non-assisted PD among young patients without diabetes would have a relatively low impact because these patients will finally spend up to 70% of the 15-year period considered with a functioning graft. Indeed, any change in dialysis strategies would affect their total cost very little. For example, the savings from moderately increased home HD (from 36 to 79 patients) would increase total time spent in this modality (from 0.7% to only 1.7%). A more ambitious strategy might have a greater impact. The availability of new machines with low dialysate flow allowing daily HD at home might change current practices, but their outcomes and costs have not yet been evaluated [20] and thus could not be included in our simulations. In any case, our simulations found daily home HD was more expensive than the status quo.

In young patients with diabetes and middle-aged patients without it, expanding HD in self-care units would save more money than expanding non-assisted PD. Similarly, for middle-aged patients with diabetes and all elderly patients, increasing HD in facilities under medical supervision would be more economical than expanding PD. In all of these subcohorts, increasing the number of patients starting with PD would have only a moderate impact on the total time spent in hospital-based HD, because of the limited time observed on PD. Patients who do not receive a graft will eventually require transfer to HD. Because the French system pays for nursing assistance for home PD, this modality is available for elderly patients at a cost lower than hospital-based HD. The cost for a stable prevalent patient in non-assisted automated PD is approximately the same as for patients in self-care units, but higher than for non-assisted continuous ambulatory PD (€3.7 k) (see Supplementary Table S1). On the contrary, a patient in a facility under medical supervision has a lower cost than a patient at home with assisted PD.

The strength of our model is that it makes it possible to simulate the course of treatment of a cohort of incident patients and to quantify the impact of various changes on monthly costs. The model inputs are based on nationwide French databases and representative of current clinical practices. An important strength of our approach is that it was designed to have no negative effect on the patient's life expectancy, as verified by the life expectancy results it produced. Nonetheless, the interpretation of this study must consider some of the limitations and methodological choice underlying the analysis. The first limitation to consider is that this study is based on observational data. Indication bias may be present, since the case mix is related to the choice of a given modality. Stratifying the analysis by age and diabetes and defining feasible alternatives for each subcohort should have moderated this potential bias. Secondly, the global cost estimates for ESRD patients include costs associated with comorbidities and complications. Therefore, the extent to which these results are transferable to other countries with quite different case-mixes and care strategies is debatable. Third, the mathematical model chosen is a deterministic model that assumes the transition rates are independent of each other. The impacts analysed depend on the modifications of transition rates, calibrated according to practices observed in other countries or in various regions of France. No confidence intervals were estimated for the outcomes. Fourth, conservative management was not analysed, because data about it are unavailable in France [21]. Fifth, quality of life data were not available for the 10 treatment modalities, and we therefore could not perform a cost-utility analysis. Finally, the perspective adopted was that of the national health insurance fund, rather than a collective perspective. Thus, total costs paid by providers (hospitals and dialysis facilities) were not considered because they were not available in the databases we used. Some strategies may be economical for the health insurance fund but not for these providers, since their profitability may depend on the reimbursement system and on external constraints including geography and patient volume.

In conclusion, alternative strategies may be less expensive than current practices without any increase in mortality risk.

Table 3. Based on a simulation covering a total of 180 months, impact of various dialysis strategies on the monthly per-patient costs and on the initial distribution at RRT start, the total time spent in each modality, the number of transitions and the mean lifetime for patients aged 45–69 years without diabetes

Cohort = 2193 incident patients	Status quo	Renal TR, all donor	Renal TR, deceased donor	Combined: CAPD, APD and self-care unit	Renal TR, living donor	Self-care unit	Self-care unit, transfer to facility under medical supervision	Non-assisted CAPD, transfer to a self-care unit	Non-assisted CAPD	Non-assisted APD	Non-assisted APD, transfer to a self-care unit	Direct start in a facility under medical supervision
Cost/months (euros) for 1 patient	3684	3218	3291	3404	3513	3490	3499	3575	3581	3588	3595	3671
Comparison with status quo (euros/months)		−466	−394	−280	−171	−195	−185	−110	−104	−97	−90	−13
Initial distribution at RRT start (%)												
Hospital-based HD	**72.1**	**45.4**	**45.4**	**45.4**	**45.4**	**72.1**	**72.1**	**57.2**	**57.2**	**60.4**	**60.4**	**66.7**
Assisted automated PD	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Non-assisted automated PD	3.9	15.6	15.6	15.6	15.6	3.9	3.9	3.9	3.9	15.6	15.6	3.9
Assisted continuous PD	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Non-assisted continuous PD	5.0	19.9	19.9	19.9	19.9	5.0	5.0	19.9	19.9	5.0	5.0	5.0
HD self-care unit	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
HD home	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Facility under medical supervision	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	8.1
Renal graft deceased donor	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Renal graft living donor	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Distribution of the total time spent in each modality (%)												
Hospital-based HD	**23.6**	**19.1**	**19.8**	**15.2**	**21.9**	**18.2**	**18.2**	**20.8**	**21.2**	**21.4**	**21.2**	**22.7**
Assisted automated PD	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3
Non-assisted automated PD	1.5	1.0	1.1	3.3	1.3	1.4	1.4	2.2	2.4	4.0	3.0	1.5
Assisted continuous PD	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.6	0.5	0.5	0.5
Non-assisted continuous PD	1.1	0.9	0.9	2.4	1.0	1.1	1.1	2.5	3.5	1.2	1.2	1.1
HD self-care unit	15.1	10.8	11.3	20.4	13.7	20.5	19.4	15.1	13.4	13.6	15.3	14.8
HD home	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Facility under medical supervision	5.9	4.4	4.6	4.4	5.3	4.9	5.9	5.4	5.3	5.4	5.5	7.2
Renal graft deceased donor	49.3	56.6	59.0	50.7	48.5	50.8	50.8	50.3	50.4	50.7	50.3	49.3
Renal graft living donor	2.3	6.4	2.4	2.5	7.4	2.3	2.3	2.4	2.5	2.4	2.4	2.4

Continued

Table 3. Continued

Cohort = 2193 incident patients	Status quo	Renal TR, all donor	Renal TR, deceased donor	Combined: CAPD, APD and self-care unit	Renal TR, living donor	Self-care unit	Self-care unit, transfer to facility under medical supervision	Non-assisted CAPD, transfer to a self-care unit	Non-assisted CAPD	Non-assisted APD	Non-assisted APD, transfer to a self-care unit	Direct start in a facility under medical supervision
Number of transitions entering each modality (per 2193 patients)												
Hospital-based HD	**2227**	**2153**	**2166**	**1826**	**2199**	**2320**	**2321**	**1959**	**1974**	**2022**	**2016**	**2142**
Assisted automated PD	36	34	34	41	35	35	35	41	44	42	37	36
Non-assisted automated PD	153	149	149	495	152	151	151	239	251	412	411	152
Assisted continuous PD	59	55	56	66	57	58	58	66	76	61	60	58
Non-assisted continuous PD	153	150	151	492	152	151	151	483	484	167	164	152
HD self-care unit	948	889	899	1307	928	1348	1358	965	848	867	976	938
HD home	27	24	25	22	26	24	25	25	26	25	25	26
Facility under medical supervision	429	382	389	380	413	416	496	400	393	401	409	534
Renal graft deceased donor	1042	1223	1262	1151	1040	1135	1130	1083	1069	1085	1081	1049
Renal graft living donor	43	120	45	49	130	44	44	45	46	45	45	43
Number of deaths (per 2193 patients)	1365	1243	1264	1269	1320	1292	1297	1337	1352	1342	1337	1357
Restricted mean lifetime (months)	110.4	117.5	116.2	118.9	113	116.5	116.4	112.6	111.5	112.2	112.7	111.3

Shaded values correspond to the modalities of treatment impacted by the given strategy. Bold values correspond to hospital-based HD.

Table 4. Based on a simulation covering a total of 180 months, impact of various dialysis strategies on the monthly per-patient costs and on the initial distribution at RRT start, the total time spent in each modality, the number of transitions and the mean lifetime for patients aged 45–69 years with diabetes

Cohort = 1565 incident patients	Status quo	Combined: CAPD, APD and local facility under medical supervision	Combined: CAPD, APD and facility under medical supervision	Renal TR, deceased donor	Local facility under medical supervision	Facility under medical supervision	Local facility under medical supervision, transfer to hospital-based HD	Facility under medical supervision, transfer to hospital-based HD	Non-assisted CAPD	Non-assisted APD	Non-assisted APD, transfer to facility under medical supervision	Non-assisted CAPD, transfer to facility under medical supervision
Cost/months (euros) for 1 patient	6076	5716	5749	5788	5843	5875	5882	5911	5986	5989	5993	5994
Comparison with status quo (euros/months)		−361	−327	−288	−234	−201	−195	−165	−90	−88	−84	−82
Initial distribution at RRT start (%)												
Hospital-based HD	**81.7**	**66.1**	**66.1**	**81.7**	**81.7**	**81.7**	**81.7**	**81.7**	**73.0**	**74.8**	**74.8**	**73.0**
Assisted automated PD	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Non-assisted automated PD	2.3	9.2	9.2	2.3	2.3	2.3	2.3	2.3	2.3	9.2	9.2	2.3
Assisted continuous PD	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Non-assisted continuous PD	4.4	13.1	13.1	4.4	4.4	4.4	4.4	4.4	13.1	4.4	4.4	13.1
HD self-care unit	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
HD home	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Facility under medical supervision	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Renal graft deceased donor	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Renal graft living donor	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Distribution of the total time spent in each modality (%)												
Hospital-based HD	**48.2**	**36.3**	**36.3**	**44.9**	**39.9**	**39.9**	**41.5**	**41.5**	**45.9**	**45.9**	**45.6**	**45.5**
Assisted automated PD	0.4	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.5	0.5
Non-assisted automated PD	1.4	2.9	2.9	1.2	1.3	1.3	1.3	1.3	1.9	3.6	2.7	1.8
Assisted continuous PD	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	1.2	1.0	1.0	1.1
Non-assisted continuous PD	1.7	3.3	3.3	1.6	1.6	1.6	1.6	1.6	4.2	1.9	1.8	3.3
HD self-care unit	13.6	11.9	11.9	12.0	13.0	13.0	13.0	13.0	12.9	12.9	12.9	12.9
HD home	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Facility under medical supervision	9.9	19.1	19.1	8.9	18.5	18.5	16.9	16.9	9.5	9.5	11.0	10.9
Renal graft deceased donor	22.7	23.9	23.9	29.0	23.2	23.2	23.2	23.2	22.9	23.5	23.3	22.9
Renal graft living donor	0.9	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Number of transitions entering each modality (per 1565 patients)												
Hospital-based HD	**1752**	**1712**	**1712**	**1751**	**1909**	**1909**	**1956**	**1956**	**1650**	**1670**	**1675**	**1657**
Assisted automated PD	26	35	35	25	26	26	26	26	30	34	31	30
Non-assisted automated PD	70	206	206	70	70	70	70	70	100	180	180	96
Assisted continuous PD	58	66	66	57	58	58	58	58	68	59	58	65
Non-assisted continuous PD	101	243	243	100	100	100	101	101	240	112	106	240
HD self-care unit	445	418	418	440	453	453	450	450	420	425	431	425
HD home	7	6	6	7	7	7	7	7	7	7	7	7
Facility under medical supervision	348	696	696	340	673	673	675	675	333	336	388	382
Renal graft deceased donor	290	327	327	373	316	316	312	312	291	300	302	294
Renal graft living donor	9	9	9	9	10	10	10	10	9	9	9	9
Number of deaths (per 1565 patients)	1362	1336	1336	1333	1341	1341	1348	1348	1364	1360	1356	1359
Restricted mean lifetime (months)	75.2	80.1	80.1	78.1	79.5	79.5	79.0	79.0	74.9	75.5	76.2	75.6

Shaded values correspond to the modalities of treatment impacted by the given strategy. Bold values correspond to hospital-based HD.

Table 5. Based on a simulation covering a total of 180 months, impact of various dialysis strategies on the monthly per-patient costs and on the initial distribution at RRT start, the total time spent in each modality, the number of transitions and the mean lifetime for patients aged 70 years or older without diabetes

Cohort = 2809 incident patients	Status quo	Renal TR, deceased donor	Combined: CAPD, APD and local facility under medical supervision	Combined: CAPD, APD and facility under medical supervision	Local facility under medical supervision	Facility under medical supervision	Local facility under medical supervision, transfer to hospital-based HD	Facility under medical supervision, transfer to hospital-based HD	Assisted CAPD, transfer to facility under medical supervision	Assisted CAPD	Assisted APD, transfer to facility under medical supervision	Assisted APD
Cost/months (euros) for 1 patient	6271	5312	5800	5845	5896	5941	5945	5986	6029	6160	6208	6225
Comparison with status quo (euros/months)		−959	−471	−427	−376	−331	−326	−285	−242	−111	−63	−47
Initial distribution at RRT start (%)												
Hospital-based HD	**79.9**	**79.9**	**57.5**	**57.5**	**79.9**	**79.9**	**79.9**	**79.9**	**64.9**	**64.9**	**72.5**	**72.5**
Assisted automated PD	1.9	1.9	9.3	9.3	1.9	1.9	1.9	1.9	1.9	1.9	9.3	9.3
Non-assisted automated PD	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Assisted continuous PD	10.0	10.0	24.9	24.9	10.0	10.0	10.0	10.0	24.9	24.9	10.0	10.0
Non-assisted continuous PD	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
HD self-care unit	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
HD home	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Facility under medical supervision	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Renal graft deceased donor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Renal graft living donor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distribution of the total time spent in each modality (%)												
Hospital-based HD	**62.3**	**50.3**	**39.9**	**39.9**	**46.4**	**46.4**	**48.7**	**48.7**	**55.1**	**55.9**	**58.5**	**59.0**
Assisted automated PD	1.4	1.1	3.6	3.6	1.2	1.2	1.2	1.2	1.8	1.9	3.3	4.7
Non-assisted automated PD	1.0	0.7	1.4	1.4	0.9	0.9	0.9	0.9	1.2	1.3	1.3	1.4
Assisted continuous PD	5.5	4.7	10.2	10.2	4.8	4.8	4.9	4.9	10.2	12.7	5.7	5.9
Non-assisted continuous PD	1.4	1.2	1.5	1.5	1.2	1.2	1.3	1.3	1.6	1.8	1.4	1.5
HD self-care unit	13.3	8.6	10.6	10.6	12.0	12.0	12.1	12.1	12.1	12.3	12.6	12.7
HD home	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Facility under medical supervision	11.5	8.3	29.4	29.4	29.9	29.9	27.3	27.3	14.7	10.7	13.7	11.2
Renal graft deceased donor	3.2	24.9	3.1	3.1	3.3	3.3	3.3	3.3	3.0	3.1	3.2	3.3
Renal graft living donor	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2

Number of transitions entering each modality (per 2809 patients)												
Hospital-based HD	**2695**	**2718**	**2248**	**2248**	**3032**	**3032**	**3109**	**3109**	**2362**	**2317**	**2543**	**2523**
Assisted automated PD	92	90	326	326	91	91	91	91	116	121	301	303
Non-assisted automated PD	51	49	75	75	52	52	52	52	62	63	63	73
Assisted continuous PD	342	339	774	774	338	338	338	338	760	762	356	365
Non-assisted continuous PD	80	89	93	93	79	79	79	79	90	98	81	83
HD self-care unit	406	393	356	356	416	416	415	415	369	362	390	385
HD home	3	3	3	3	3	3	3	3	3	3	3	3
Facility under medical supervision	369	344	1010	1010	1059	1059	1062	1062	468	330	442	355
Renal graft deceased donor	44	376	47	47	51	51	50	50	42	41	44	44
Renal graft living donor	2	2	3	3	3	3	3	3	2	2	2	2
Number of deaths (per 2809 patients)	2744	2639	2721	2721	2717	2717	2732	2732	2741	2750	2741	2745
Restricted mean lifetime (months)	45.2	52.1	49.1	49.1	51.0	51.0	50.3	50.3	45.9	43.6	45.6	44.8

Shaded values correspond to the modalities of treatment impacted by the given strategy. Bold values correspond to hospital-based HD.

Table 6. Based on a simulation covering a total of 180 months, impact of various dialysis strategies on the monthly per-patient costs and on the initial distribution at RRT start, the total time spent in each modality, the number of transitions and the mean lifetime for patients aged 70 years or older with diabetes

Cohort = 2096 incident patients	Status quo	Renal TR, deceased donor	Combined: CAPD, APD and local facility under medical supervision	Combined: CAPD, APD and facility under medical supervision	Local facility under medical supervision	Facility under medical supervision	Local facility under medical supervision, transfer to Hospital-based HD	Facility under medical supervision, transfer to hospital-based HD	Assisted CAPD, transfer to facility under medical supervision	Assisted CAPD	Assisted APD, transfer to facility under medical supervision	Assisted APD
Cost/months (euros) for 1 patient	7361	6882	6917	6949	7015	7051	7053	7086	7222	7243	7304	7314
Comparison with status quo (euros/months)		−479	−444	−412	−346	−310	−308	−275	−139	−119	−58	−47
Initial distribution at RRT start (%)												
Hospital-based HD	**81.9**	**81.9**	**60.0**	**60.0**	**81.9**	**81.9**	**81.9**	**81.9**	**66.4**	**66.4**	**75.5**	**75.5**
Assisted automated PD	1.6	1.6	8.0	8.0	1.6	1.6	1.6	1.6	1.6	1.6	8.0	8.0
Non-assisted automated PD	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Assisted continuous PD	10.3	10.3	25.8	25.8	10.3	10.3	10.3	10.3	25.8	25.8	10.3	10.3
Non-assisted continuous PD	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
HD self-care unit	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
HD home	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Facility under medical supervision	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Renal graft deceased donor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renal graft living donor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distribution of the total time spent in each modality (%)												
Hospital-based HD	**71.4**	**64.9**	**50.9**	**50.9**	**59.3**	**59.3**	**60.7**	**60.7**	**63.2**	**63.4**	**68.2**	**68.3**
Assisted automated PD	1.4	1.3	4.3	4.3	1.2	1.2	1.3	1.3	1.7	1.8	3.0	4.3
Non-assisted automated PD	0.7	0.7	1.1	1.1	0.6	0.6	0.6	0.6	0.9	0.9	0.9	1.0
Assisted continuous PD	6.7	6.3	14.2	14.2	6.2	6.2	6.2	6.2	12.9	15.4	7.1	7.2
Non-assisted continuous PD	1.0	0.9	1.2	1.2	0.9	0.9	0.9	0.9	1.2	1.3	1.0	1.0
HD self-care unit	8.8	7.5	7.3	7.3	8.3	8.3	8.3	8.3	7.8	8.0	8.4	8.5
HD home	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Facility under medical supervision	8.8	7.2	19.6	19.6	22.0	22.0	20.5	20.5	11.3	8.1	10.2	8.5
Renal graft deceased donor	1.1	11.1	1.1	1.1	1.3	1.3	1.3	1.3	1.0	1.0	1.1	1.1
Renal graft living donor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Number of transitions entering each modality (per 2096 patients)												
Hospital-based HD	**2023**	**2024**	**1811**	**1811**	**2280**	**2280**	**2245**	**2245**	**1774**	**1734**	**1924**	**1913**
Assisted automated PD	61	61	214	214	61	61	61	61	75	78	197	199
Non-assisted automated PD	27	27	45	45	27	27	27	27	33	34	35	39
Assisted continuous PD	268	267	606	606	267	267	267	267	590	590	281	285

Non-assisted continuous PD	42	42	56	56	42	42	42	42	51	54	44	45
HD self-care unit	220	217	189	189	225	225	224	224	196	195	212	211
HD home	4	4	4	4	4	4	4	4	3	3	4	4
Facility under medical supervision	241	235	548	548	637	637	635	635	311	214	278	230
Renal graft deceased donor	11	109	11	11	13	13	13	13	10	9	10	10
Renal graft living donor	0	0	0	0	0	0	0	0	0	0	0	0
Number of deaths (per 2096 patients)	2079	2045	2077	2077	2076	2076	2075	2075	2079	2080	2079	2079
Restricted mean lifetime (months)	39.6	42.1	40.8	40.8	42.8	42.8	42.6	42.6	39.4	38.4	39.6	39.3

Shaded values correspond to the modalities of treatment impacted by the given strategy. Bold values correspond to hospital-based HD.

Deciding to implement new strategies, however, requires consideration of the number of patients concerned, feasibility in terms of renal care reorganization, investment costs, and finally their capacity to adapt care to patients' needs. All those changes must take into account patients' choices and the availability of professionals.

SUPPLEMENTARY DATA

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

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CONFLICTS OF INTEREST STATEMENT

None declared.

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ORIGINAL ARTICLE

Comparative outcomes of predominant facility-level use of ferumoxytol versus other intravenous iron formulations in incident hemodialysis patients

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ABSTRACT

Background. Ferumoxytol was first approved for clinical use in 2009 solely based on data from trial comparisons with oral iron on biochemical anemia efficacy end points. To compare the rates of important patient outcomes (infection, cardiovascular events and death) between facilities predominantly using ferumoxytol versus iron sucrose (IS) or ferric gluconate (FG) in patients with end-stage renal disease (ESRD)-initiating hemodialysis (HD).

Methods. Using the United States Renal Data System, we identified all HD facilities that switched (almost) all patients from IS/FG to ferumoxytol (July 2009–December 2011). Each switching facility was matched with three facilities that continued IS/FG use. All incident ESRD patients subsequently initiating HD in these centers were studied and assigned their facility exposure. They were followed for all-cause mortality,