COMPARISON OF DIRECT MEDICAL COSTS BETWEEN AUTOMATED AND CONTINUOUS AMBULATORY PERITONEAL DIALYSIS

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◆ **Objective:** We set out to estimate the direct medical costs (DMCs) of peritoneal dialysis (PD) and to compare the DMCs for continuous ambulatory PD (CAPD) and automated PD (APD). In addition, DMCs according to age, sex, and the presence of peritonitis were evaluated.

◆ **Methods:** Our retrospective cohort analysis considered patients initiating PD, calculating 2008 costs and, for comparison, updating the results for 2010. The analysis took the perspective of the Mexican Institute of Social Security, including outpatient clinic and emergency room visits, dialysis procedures, medications, laboratory tests, hospitalizations, and surgeries.

◆ **Results:** No baseline differences were observed for the 41 patients evaluated (22 on CAPD, 19 on APD). Median annual DMCs per patient on PD were US\$15 072 in 2008 and US\$16 452 in 2010. When analyzing percentage distribution, no differences were found in the DMCs for the modality groups. In both APD and CAPD, the main costs pertained to the dialysis procedure (CAPD 41%, APD 47%) and hospitalizations (CAPD 37%, APD 32%). Dialysis procedures cost significantly more ($p = 0.001$) in APD (US\$7 084) than in CAPD (US\$6 071), but total costs (APD US\$15 389 vs CAPD US\$14 798) and other resources were not different. The presence of peritonitis increased the total costs (US\$16 075 vs US\$14 705 for patients without peritonitis, $p = 0.05$), but in the generalized linear model analysis, DMCs were not predicted by age, sex, dialysis modality, or peritonitis. A similar picture was observed for costs extrapolated to 2010, with a 10%–20% increase for each component—except for laboratory tests, which increased 52%, and dialysis procedures, which decreased 3%, from 2008.

◆ **Conclusions:** The annual DMCs per patient on PD in this study were US\$15 072 in 2008 and US\$16 452 in 2010. Total DMCs for dialysis procedures were higher in APD than in CAPD, but the difference was not statistically significant. In both APD and CAPD, 90% of costs were attributable to the dialysis procedure, hospitalizations, and medications. In a multivariate analysis, no independent variable significantly predicted a higher DMC.

Perit Dial Int 2013; 33(6):679–686 www.PDConnect.com
epub ahead of print: 01 May 2013 doi:10.3747/pdi.2011.00274

KEY WORDS: Direct costs; continuous ambulatory peritoneal dialysis; automated peritoneal dialysis.

End-stage renal disease (ESRD) is a public health problem that is growing in incidence, prevalence, morbidity and mortality, poor quality of life, and cost (1). Management is disproportionately expensive for renal failure than for other medical conditions. In the United States, for example, the cost of ESRD treatment was \$24 billion in 2007 (1).

In Mexico, health care is uniquely provided under several systems: 60% of the Mexican population is covered by the Social Security System; 36%, by the System of Social Protection in Health (including the Popular Insurance); and 3%, by private medicine (2). Within the Social Security System, the Mexican Institute of Social Security (IMSS) is the largest institution, serving about 80% of the covered population and treating about 80% of all patients on renal replacement therapy (RRT) in the country (3). In the IMSS, RRT—including peritoneal dialysis (PD), hemodialysis (HD), and transplantation—is available and completely free for patients without restriction, and consequently the rates of ESRD incidence and prevalence are similar to those in developed countries at 327 and 939 patients per million population

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Received 2 November 2011; accepted 5 October 2012

respectively (4). Also in the IMSS, ESRD is the third most costly disease, after diabetes and hypertension (5).

Currently, according to commercial sources, 41 950 patients are being treated with PD and 27 000 with HD in Mexico. Since its introduction in 1998, automated PD (APD) has been growing at an annual rate of about 10% (3) and currently represents about 22% of all patients on RRT. Another 39% of patients are treated with continuous ambulatory PD (CAPD). From the clinical point of view, APD and CAPD have similar results (1,6,7), with APD having certain advantages in some cases (8,9). From the viewpoint of health administrators and decision-takers, it is imperative to identify the clinical and cost indicators of such therapies so that the projected increase in ESRD demand can be met; however, published data about the costs of ESRD treatment are scarce. Especially in our setting, most of the costs reported in previous studies were estimated using expert panels (10,11), historical costs (12), or analytic models (13). No clinical study has been performed in this regard.

In countries with economic limitations, it is very important to identify the real costs of ESRD treatment and of the various modalities of RRT. A clear understanding of these costs may help to identify potential areas for efficiencies in patient management. Our study was therefore designed to estimate direct medical costs (DMCs) for PD and to compare DMCs according to the type of dialysis (CAPD vs APD). In addition, DMCs were evaluated according to age, sex, and the presence of peritonitis.

METHODS

STUDY DESIGN

We retrospectively analyzed a cohort of adult patients initiating PD between January and December 2006 in a general hospital (Hospital General de Zona No. 14) of the IMSS system in Guadalajara, Mexico. Patients were excluded if they had cancer, AIDS, or advanced heart or liver disease. Subjects were randomly selected (by a computer-generated randomization list) from among the 229 and 28 patients who respectively initiated CAPD and APD during the period of study. In our setting, selection of the PD modality depends on the judgment of the clinician, although younger, elderly without a primary daytime caregiver, economically active, student, or high-transport patients are preferentially eligible for APD. The end of follow-up was established as 31 December 2007.

DATA COLLECTION

In the IMSS perspective, we considered only DMCs (all monetary costs that the provider incurred in generating

the medical attention for each PD program); we did not evaluate indirect costs. The DMCs included the major components of medical resource utilization: outpatient clinic visits, emergency room visits, dialysis procedures, medications, laboratory tests, hospitalizations, and surgeries.

To calculate the costs of resources, an estimation of all components and data for clinical variables and resource utilization were obtained from medical charts. A data collection sheet had previously been designed and validated by experts in health economics, and it was applied in all cases. For the cost calculations, the official cost list for drugs and medical materials as published by the IMSS and the list for medical services and laboratory or imaging tests—the Institutional Unit Cost System 2008, published in the *Diario Oficial de la Federación* (Official Federation Bulletin) (14)—were used. All drugs, medical materials, laboratory tests, and dialysis supplies (Laboratorios Pisa SA de CV was the provider of the latter) are contracted by public tender. Salary and working hours of the health team are fixed by the IMSS; the same personnel take care of APD and CAPD patients. For comparison purposes, results from the current study were also updated using costs in the *Diario Oficial de la Federación* for 2010 (15). All costs were converted into US dollars at the 2008 and 2010 exchange rates (US\$1 = 12.84 and 12.38 Mexican pesos respectively). The total annual average cost and the per-person annual resource utilization were determined for each modality of dialysis.

DEFINITIONS

The study used the following definitions:

- Outpatient clinic visits: Includes the salary of the nephrology team and other specialties
- Emergency room visits: Includes health team salary, laboratory and imaging tests, and medications
- Dialysis procedures: Includes data for dialysis catheters, solutions, and sets; gloves and masks; antiseptics, adhesive medical tape, and gauze
- Medications: Only drugs used in the ambulatory care of PD patients were considered
- Laboratory tests: Includes all laboratory and imaging tests performed in the ambulatory care of PD patients
- Hospitalization costs: Includes frequency, days of hospitalization, hospital room cost, health team salary, drugs, and laboratory and imaging tests performed during hospitalization
- Surgery: Only the surgical procedures related to dialysis and its complications, including the operating room costs and health team salary, were considered

STATISTICAL ANALYSIS

Data are shown as means $\pm$ standard deviations or 95% confidence intervals (CIs), medians with 25% – 75% percentiles, or percentages, as appropriate. Comparisons between groups were performed using the Mann–Whitney U-test and chi-square test. No previous cost data comparing APD and CAPD were available in our setting, and so we obtained account information from our hospital administrator that showed APD expenses being 30% higher than those for CAPD. Using a formula for testing proportional differences (16), and considering an 80% confidence level, alpha 0.05, the necessary sample size was established as 19 subjects per group.

COST ANALYSIS

In comparing health utilization between groups, we estimated the total mean cost by type of dialysis. Bootstrap analysis (1000 iterations) was used to describe the uncertainty in the estimation of mean costs for each group, and a generalized linear model analysis of the total mean cost adjusted by dialysis modality, age, sex, and peritonitis was performed. All statistical analyses were carried out using the SPSS (version 17: SPSS, Chicago, IL, USA) and Stata 11 (StataCorp LP, College Station, TX, USA) software applications. A *p* value less than 0.05 was considered significant.

RESULTS

The study considered 41 patients, 22 on CAPD and 19 on APD. There were no significant differences in clinical characteristics between the modality groups (Table 1), although we observed a trend toward younger age and lower frequency of diabetes in the APD group, differences that were not statistically significant.

Table 2 compares resource utilization by dialysis type. Outpatient clinic visits, emergency room visits, and hospitalizations (number and length of stay) were not different between the CAPD and APD groups; however, the numbers of catheters and surgical procedures were significantly higher in CAPD than in APD.

The annual DMC per patient on PD was US\$15 072 (US\$13 512 – US\$16 632) in 2008 and US\$16 452 (US\$13 143 – US\$18 545) when extrapolated to 2010. Table 3 shows the annual DMCs for the entire cohort in 2008 and 2010. In general terms, almost US\$620 000 was expended for these 41 PD patients during a year of follow-up in 2008. Most of the costs were attributable to dialysis-related procedures, followed by hospitalization, medications, and surgery. The costs for drugs such

as erythropoietin (*p* = 0.59) and iron (*p* = 0.53) were not different between the groups. The less-expensive procedures were outpatient and emergency room visits, and laboratory tests. The picture was similar when extrapolated to 2010, with a 10% – 20% increase for each of the components from 2008, except for laboratory tests (which increased 52%) and dialysis procedures (which decreased 3%).

Table 4 compares the annual per-person DMC between patients on CAPD and APD. In 2008, dialysis procedures were significantly more costly in APD than in CAPD. In the CAPD group, 2 patients (9%) used 3 bags daily, 18 (82%) used 4 bags, and 2 (9%) used 5 bags; in the APD group, 17 patients (90%) used 2 bags daily, and 2 (10%) used 3 bags. In this study, each CAPD

TABLE 1
General Characteristics of the Study Patients,
by Dialysis Modality

Characteristic	Modality		<i>p</i> Value
	CAPD	APD	
Patients (<i>n</i>)	22	19	
Age (years)	56 $\pm$ 14	47 $\pm$ 19	0.09
Sex [<i>n</i> (%)]			
Men	14 (64)	11 (58)	0.70
Women	8 (36)	8 (42)	
Cause of ESRD [<i>n</i> (%)]			0.16
Diabetes mellitus	16 (73)	9 (47)	
Chronic glomerulopathies	1 (4)	4 (21)	
Other	5 (23)	6 (32)	
Illiteracy [<i>n</i> (%)]	2 (9)	0 (0)	0.60
Smoking [<i>n</i> (%)]	8 (36)	5 (26)	0.73
Alcoholism [<i>n</i> (%)]	7 (32)	6 (32)	0.99

CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis; ESRD = end-stage renal disease.

TABLE 2
Resource Utilization by Dialysis Modality

Resource	Modality		<i>p</i> Value
	CAPD	APD	
Outpatient clinic visits (<i>n</i>)	8.2 $\pm$ 4.7	7.7 $\pm$ 7.3	0.7
Emergency room visits (<i>n</i>)	3.0 $\pm$ 3.0	2.9 $\pm$ 2.8	0.9
Hospitalizations (<i>n</i>)	4.7 $\pm$ 2.6	3.9 $\pm$ 2.1	0.2
Length of stay (days)	28.9 $\pm$ 16.2	21.0 $\pm$ 13	0.09
Surgical procedures (<i>n</i>)	1.9 $\pm$ 0.7	1.3 $\pm$ 0.6	0.03
Dialysis catheters (<i>n</i>)	1.7 $\pm$ 0.6	1.2 $\pm$ 0.5	0.02

CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis.

dialysis bag represents a volume of 2 L, and each APD bag, a volume of 6 L. The DMCs for remaining resource types (and the overall total DMC) were not different between the groups. In the 2010 extrapolation, the difference in DMCs between the dialysis modalities was more apparent because of a decline in CAPD costs and a further increase in APD costs. When the percentage distribution of DMCs for resources utilized

was evaluated, we observed no differences between the groups in 2008 and in 2010. The main costs of APD and CAPD were related to dialysis procedures and hospitalizations, followed by medications and surgeries (Figure 1).

Additionally, we observed no differences in the mean annual per-person DMC when age and sex were considered. In 2008, patients less than 60 years of age ($n = 27$) had a total DMC of US\$15 008 (US\$12 743 – US\$17 273) compared with US\$15 195 (US\$13 408 – US\$16 982) for the patients 60 years of age and older ($n = 14$); in 2010, the DMC was US\$16 509 (US\$12 503 – US\$19 029) for the younger patients and US\$16 341 (US\$14 229 – US\$18 033) for the older ones. In 2008, women ($n = 16$) had a total DMC of US\$14 905 (US\$12 229 – US\$17 581) compared with US\$15 179 (US\$13 118 – US\$17 240) for men ($n = 25$); in 2010, the cost for women was US\$16 242 (US\$13 022 – US\$19 202) compared with US\$16 586 (US\$13 353 – US\$18 034) for men.

During the study period, 11 patients developed peritonitis (6 on CAPD, 5 on APD; $p =$ nonsignificant). In 2008, a higher total DMC was associated with the presence of 1 or more peritonitis episodes (compared with no peritonitis episodes), particularly in the areas of medications, laboratory tests, and (marginally) emergency room visits (Table 5). A very similar picture was observed for 2010.

TABLE 3

Annual Direct Medical Costs in US Dollars for the Entire Sample of Patients on Peritoneal Dialysis in 2008 and 2010

Resource	Patients ($n = 41$)			
	2008		2010	
	(\$)	(%)	(\$)	(%)
Outpatient clinic visits	11 507	1.8	13 877	2.1
Emergency room visits	5 796	0.9	6 426	0.9
Dialysis procedures	268 182	43.3	260 342	38.6
Medication	71 863	11.6	78 123	11.6
Laboratory tests	3 765	0.6	5 747	0.9
Hospitalization	213 696	34.5	254 623	37.7
Surgery	45 043	7.3	55 404	8.2
TOTAL	619 852	100	674 542	100

TABLE 4

Annual Per-Person Direct Medical Costs in US Dollars for Resource Utilization by Dialysis Modality, in 2008 and 2010

Resource	Annual per-patient cost [mean (95% confidence interval)]					
	2008		p Value	2010		p Value
	CAPD	APD		CAPD	APD	
Outpatient clinic visits	279 (201 to 358)	282 (168 to 396)	0.89	351 (241 to 461)	327 (231 to 422)	0.61
Emergency room visits	130 (75 to 185)	134 (83 to 226)	0.84	177 (95 to 260)	139 (89 to 187)	0.79
Dialysis procedures	6 071 (5 769 to 6 373)	7 084 (5 961 to 8 207)	0.001	5 697 (5 643 to 5 751)	7 105 (7 022 to 7 188)	<0.0001
Medication	1 674 (1 109 to 2 238)	1 843 (975 to 2 711)	0.69	1 778 (1 174 to 2 382)	2 052 (1 156 to 2 948)	0.40
Laboratory tests	92 (69 to 115)	91 (46 to 135)	0.33	156 (72 to 239)	126 (86 to 167)	0.89
Hospitalization	5 458 (4 143 to 6 774)	4 270 (3 415 to 6 437)	0.54	6 255 (4 620 to 7 890)	6 171 (4 847 to 7 494)	0.79
Surgery	1 177 (891 to 1 462)	1 007 (761 to 1 253)	0.55	1 364 (891 to 1 462)	1 336 (1 009 to 1 663)	0.95
TOTAL	14 798 (12 923 to 16 674)	15 389 (12 612 to 18 167)	0.58	15 476 (13 755 to 17 197)	17 279 (15 269 to 19 289)	0.13

Notwithstanding the foregoing findings, the generalized linear model analysis did not find that age, sex, dialysis modality, or peritonitis predicted the DMC (Table 6).

Figure 1 — Percentage distribution of direct medical costs for resources utilized, by peritoneal dialysis modality, in 2008 and 2010. CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis.

DISCUSSION

Growth in the ESRD population is increasing the pressure on health systems all over the world because of negative impacts on patient health, costs of treatment, and the global burden of disease (1,17–19). Moreover, according to the World Health Organization, nephritis and nephrosis (diagnoses that may underestimate the total causes of ESRD) are responsible for 9 057 000 disability-adjusted life-years worldwide (20). Remarkably, disability-adjusted life-years increase by factors of 6 and 7 respectively in middle- and low-income countries compared with high-income countries (20).

The cost of ESRD treatment is extraordinary high. For example, during the period being considered, the United States spent \$24 billion on ESRD patients (1), which represents about 60% of the total Mexican investment in health (20). Costs vary according to the type of RRT, but comparisons are often handled inconsistently and unsatisfactorily (21). In some studies from the developed world, a positive cost advantage is suggested for PD compared with HD (22–25). It is also suggested that PD is more expensive than HD in developing countries (probably because of the higher costs of imported equipment and solutions); however, recent studies have not confirmed those data (10,26).

TABLE 5
Annual Per-Person Direct Medical Costs in US Dollars for Resource Utilization by the Presence of Peritonitis

Resource	Annual per-patient cost [mean (95% confidence interval)] by peritonitis status					
	2008		<i>p</i> Value	2010		<i>p</i> Value
	No (<i>n</i> =30)	Yes (<i>n</i> =11)		No (<i>n</i> =30)	Yes (<i>n</i> =11)	
Outpatient clinic visits	244 (161 to 327)	305 (217 to 392)	0.76	315 (189 to 439)	347 (260 to 434)	0.82
Emergency room visits	129 (81 to 178)	189 (84 to 294)	0.08	133 (85 to 181)	221 (115 to 328)	0.08
Dialysis procedures	6 413 (5 332 to 7 494)	6 587 (5 923 to 7 252)	0.98	6 262 (6 094 to 6 630)	6 316 (5 790 to 6 841)	0.52
Medication	1 502 (1 126 to 1 878)	2 435 (842 to 4 029)	0.05	1 644 (1 248 to 2 039)	2 617 (947 to 4 287)	0.06
Laboratory tests	88 (61 to 114)	103 (52 to 154)	0.06	132 (81 to 183)	162 (72 to 250)	0.44
Hospitalization	4 977 (3 864 to 6 090)	5 851 (3 719 to 7 983)	0.39	6 003 (4 737 to 7 269)	6 774 (5 181 to 8 367)	0.32
Surgery	911 (545 to 1 277)	1 167 (945 to 1 388)	0.55	1 190 (690 to 1 716)	1 407 (1 147 to 1 667)	0.30
TOTAL	14 705 (12 883 to 16 521)	16 075 (12 547 to 19 602)	0.05	15 897 (14 246 to 17 548)	17 442 (15 582 to 20 302)	0.04

TABLE 6
Results of the Generalized Linear Model for Calculating the Direct Medical Costs of Peritoneal Dialysis
in the Study Sample

Variable	Estimate	Standard error	z Value	p Value Pr {> z }	95% Confidence interval
Age	0.00082	0.00289	0.29	0.77	-0.00484 to 0.00650
Sex	0.03590	0.08205	0.44	0.66	-0.12491 to 0.19672
Dialysis modality	0.11842	0.08338	1.42	0.15	-0.04501 to 0.28186
Peritonitis	0.08379	0.06781	1.24	0.21	-0.04910 to 0.21670

Despite a proportional decrease in the use of PD since the start of the 1990s (3), Mexico is the country with the largest absolute number of PD patients in the world (41 950), almost double the number using the modality in the United States (25 752) and in other countries (1). Translating our results to that population, Mexico spent about US\$634 million (8,143 million pesos), and the IMSS spent US\$507 million (6 512 million pesos) in treating all patients on PD in 2008. That picture increased by about 19% with the extrapolation of our results to 2010 costs.

In recent years, APD has significantly increased its presence, being the RRT used by 22% of all prevalent patients in Mexico at the time of writing. Compared with CAPD, APD involves the use of a cyclor and extra line sets, resulting in a higher cost, as has been shown in some studies from developed countries (21–23). Our results confirmed a higher cost for the dialysis procedure in APD than in CAPD, and that cost continued increasing in 2010; however, the total costs were not significantly different for the two therapies, probably because of a trend of lesser hospitalization and surgery costs in APD.

As previously mentioned, patients who are younger, economically active, students, or elderly without a primary daytime caregiver are preferentially eligible for APD in our setting. Intuitively, the latter selection criteria might have influenced our results; however, no variable in the generalized linear model analysis predicted the DMCs. Further studies with larger samples and longer follow-up are necessary to analyze this issue in a more precise manner.

Comparisons of our results with those from other authors (21–27) are difficult because of differences in the methods of data collection and evaluation, resources analyzed, period of investigation, and cost of living in various locales. However, our study more comprehensively evaluated the principal DMC of the medical care process. In both APD and CAPD, 90% of the costs were attributable to the dialysis procedure, hospitalizations, and medications. It has to be noted, however, that the

present analysis took the viewpoint of the health provider directly in charge of patient care. As a public entity, IMSS obtains from producers preferential prices that are lower than those paid in the private sector.

Costs of PD in our setting were not different by sex (a finding similar to that in other studies) or age (28). However, the presence of peritonitis (not different between the modalities) significantly increased the cost of PD treatment. That finding has already been suggested (29), although to the best of our knowledge, no previous formal cost analysis has been published. Peritonitis increased the cost of treatment because of the greater use of medications, laboratory tests, and emergency room visits. Nevertheless, when peritonitis was analyzed together with age, sex, and dialysis modality in a multivariate model, its capacity for predicting the DMCs was lost. It is probable that a larger sample size may have helped to clarify that issue.

Our study has several strengths and limitations. Strengths include the longitudinal design, random selection of incident patients, collection of data from patient records (not modeling, historical data, or expert panels), and use of standard official lists to evaluate costs. Limitations include the small sample size from a single center. Our results need to be confirmed in future larger studies with complete disclosure of details concerning costing methods. In addition, future studies might want to focus on the cost-effectiveness and cost-utility of PD, especially in countries with economic restrictions. Such analyses can also help to support the utilization of health research in policy-making.

CONCLUSIONS

The annual DMC per patient on PD in the present study was US\$15 072 in 2008 and US\$16 452 in 2010. The total DMC for the dialysis procedure was higher in APD than in CAPD, but the difference was not statistically significant. In both APD and CAPD, 90% of costs were attributable to the dialysis procedure, hospitalizations, and

medications. In multivariate analysis, no independent variable significantly predicted a higher DMC; however, further studies with larger samples and longer follow-up are necessary to more fully analyze this issue.

DISCLOSURES

The authors have no financial conflicts to declare.

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