Staff	N	Payment	CPPP		N	Payment	CPPP	
Doctors	0.75	44,611.3	492.0		1.00	44,611.3	619.6	
Nurses	1.50	27,993.3	617.5		2.00	27,993.3	777.6	
Nursing assistants	0.00	19,059.5	0.0		0.00	19,059.5	0.0	
Head of Department	0.10	58,890.2	86.6		0.10	58,890.2	81.8	
Head of nurses	0.20	35,092.8	103.2		0.20	35,092.8	97.5	
Secretary	0.10	21,051.8	31.0		0.10	21,051.8	29.2	
Total			**1,330.3**				**1,605.7**	
Catheter	**N**	**CpU**	**Total**		**N**	**CpU**	**Total**	
Ultrasound	33	998.6	32,951.2		29	998.5	28,957.1	
Laparoscopic	2	1,684.1	3,368.1		0	1,684.1	0.0	
Complications	**N(D)**	**CpU**	**Total**	**Average**	**N(D)**	**CpU**	**Total**	**Average**
Admissions	3(15)	555.0	8,325.0	122.4	5(30)	555.00	16,650.0	231.3
Other		128.0	8,704.6			128.01	9,216.6	
Total			**17,029.6**	**250.4**			**25,866.6**	**359.3**
Pharmacy	**CPPP**		**Total**		**CPPP**		**Total**	
	519.4		35,320.0		490.6		35,320.0	
Laboratory	**N**	**CpU**	**Total**	**PPP**	**N**	**CpU**	**Total**	**PPP**
Blood test	5	134.8	663.8		2	134.8	269.5	
Microbiology	4	29.2	116.8		4	29.2	116.8	
Total			**53,757.4**	**790.6**			**27,813.6**	**386.3**
Structure	**CPS**	**CPPP**	**Total**		**CPS**	**CPPP**	**Total**	
Blood test	2.0	741.7	50,435.6		2.03	741.7	53,402.4	

CAPD=Continuous ambulatory peritoneal dialysis; APD=Automated peritoneal dialysis; CPS=Cost per session; CPPP=Cost per prevalent patient year; CpU=Cost per unit; N0 Number; D=Days

For PD, the cost per session (cps) was 54.86 € and 67.14 € in years 2017 and 2018, respectively. This means an increase of 12.28 (22.4%) € (table 3). Interestingly, the rate of icodextrin usage was the really very similar in 2017 (22 %) and in 2018 (23%), p=0.8344. However, the rate of bicarbonate usage was significantly higher in 2018 (90.5%) than in 2017 (72%), P=0.0410. The total cps of the CHDC in 2017 and 2018 was 228.5 € each, respectively. The cost is itemized in **Table 4**.

The cps of HDH was 332.7 € and 474.7 € in 2017 and 2018, respectively. Such increase was mainly due to the greater number of OLHDF sessions in 2018 (1,142 that represented a 41% of the HD sessions) than in 2017 (915 that represented only the 20% of the HD sessions). Nevertheless, for HDH, it can be observed a reduction in 9,974.14 € in 2018 as compared with 2017 per prevalent patient. The costs were broken down in **Table 5**.

Regarding complications, independently of the technique, the highest cost was associated with hospital admissions. The cost attributable to complications was much lower with PD (average cost per prevalent patient/year 250.4 and 359.3 in 2017 and 2018, respectively) than with CHDC (average cost per prevalent patient/year 2,131.2 and 2,486.4 in 2017 and 2018, respectively) or with HDH (average cost per prevalent patient/year 1,844.0 and 3,770.7 in 2017 and 2018, respectively).

DISCUSSION

This study collected and analyzed costs relating to materials; pharmacy; personnel (doctors, nurses and nurse assistants); administrative and hospitalization fees; hospitalizations due

to complications; patient transportation; as well as other incidentals, to establish economic parameters.

Table 4. Overview of the cost (in euros) associated with hemodialysis in arranged centers (HDAC) in years 2017 and 2018.

	2017				2018			
Price	**PPS**		**Total**		**PPS**		**Total**	
Conventional	200.2		4,369,983.7		200.2		4,369,983.7	
OLHDF	227.7		1,141,965.65		227.7		1,141,965.7	
Complications	N	CpU	Total[a]	CPP[b]	N	CpU	Total[a]	CPP[b]
Admissions[c]	480	555.0	266,400.0	2,131.2	560	555.0	310,800.0	2,486.4
Access thromboses								
Angioplasty	0	0	0	0	2	2,500.0	5,000.0	
Other	0	0	0	0	19	1,550.0	25,650.0	
CPS	0	0	0	0	2	600.0	1,200.0	
Total			**58.3**				**122.33**	
			266.400.0				**342,650.0**	
Access[d]	**N**	**CpU**	**Total**		**N**	**CpU**	**Total**	
IAVF								
Placement	0	957.0	0		0	957.0	0	
Reparation	0	957.0	0		0	957.0	0	
CVC	0	470.3	0		0	470.3	0	
PC	0	4,736.0	0		24	4,736.0	113,664.0	
Transport	N	CPS	CPP/Y	Total	N	CPS	CPP/Y	Total
Hospital transportation	39,000.0	31.9	4,968.8	621,101.8	39,000.0	31.9	4,968.8	621,101.8

aCost per request
bAveraged
cNumber of days
dVascular Access
PPS=Price per session; N=Number of patients; CpU=Cost per unit; CPS=Cost per session; IAVF=Internal arteriovenous fistula; CVC=Central venous catheter; PC=Permanent catheter

Table 5. Overview of the cost (in euros) associated with hemodialysis in Josep Trueta Hospital (HDH) in years 2017 and 2018.

	2017				2018			
Cost	**CPS**		**Total**		**CPS**		**Total**	
Conventional	52.9		193,453.3		52.9		87,736.2	
OLHDF	71.6		65,597.0		71.6		81,870.8	
Equipment	**N**	**CPS**	**CPP/Y**	**CPE**	**N**	**CPS**	**CPP/Y**	**CPE**
HD monitors		2.5	386.0			2.5	386.0	

Other								
Infrastructure	**m^2**	**CPS**	**CPP/Y**	**CPm^2**	**m^2**	**CPS**	**CPP/Y**	**CPm^2**
Dialysis room								
Changing room								
Other		2,225.1	14.3			2,225.1	14.3	
Staff	**N**	**Income**	**CPS**	**Total**	**N**	**Income**	**CPS**	**Total**
Doctors	2.0	44,611.3	4.4	89,222.6	2.0	44,611.3	4.7	89,222.6
Nurses	16.0	27,993.3	22.2	447,892.2	16.0	27,993.3	23.5	447,892.2
Nursing assistants	1.0	19,059.5	0.94	19,059.5	1.5	19,059.5	1.5	28,589.2
Head of	0.5	58,890.2	1.5	29,445.1	0.5	58,890.2	1.6	29,445.1
Department	0.7	35,092.8	1.2	23,161.3	0.7	35,092.8	1.2	23,161.3
Head of nurses	0.5	21,051.8	0.52	10,525.9	0.5	21,051.8	0.55	10,525.9
Secretary			**30.7**				**33.0**	
Total				**19,977.6**				**18,495.2**
PPP								
Access[d]	**N**	**CpU**	**CPS**	**Total**	**N**	**CpU**	**CPS**	**Total**
IAVF								
Placement	18	957.0		17,226.0	26	957.0		22,011.0
Reparation	10	957.0		9,570.0	6	957.0		5,742.0
CVC	5	470.3		2,351.3	12	470.3		5,643.1
PC	23	4,736.0		108,928.0	31	4.736.0		146,816.0
Total			**30.2**	**138,075.3**			**63.3**	**180,212.1**
Laboratory	**N**	**CpU**	**Total**	**PPP**	**N**	**CpU**	**Total**	**PPP**
Blood test	10	134.8		1,347,5	10	134.8		1.347,5
Microbiology	1	29.3		29,2	1	29.3		29,2
Total			**42,677.7**				**46,807.8**	
CPS				**8.8**				**8.8**
Complications	**N**	**CpU**	**Total[a]**	**CPP[b]**	**N**	**CpU**	**Total[a]**	**CPP[b]**
Admissions[c]	103	555,0	57,165.0	1,854.0	231	555.0	128,205.0	3,770.7
Access thromboses	4	458,0	1,348.0		4	2,500.0	10,000.0	
Angioplasty		337,0			9	1,350.0	12,150.0	
Other		778,5			8	600.0	20,400.0	
Admissions[d]	427	555.0	236,985.0		52	555.0	28,860.0	
CPS			**18.1**				**61.0**	
Total			**294,150**				**199,615.0**	
Transport	**N**	**CPS**	**CPP/Y**	**Total**	**N**	**CPS**	**CPP/Y**	**Total**

Hospital transportation	9,146	31.9	4,968.8	154,033.3	5,602	31.9	4,968.1	168,939.7
Water	**C/S(l)**	**CPm^3**	**CPS**	**Total**	**C/S(l)**	**CPm^3**	**CPS**	**Total**
Consumption	150.0	3.0	0.45	2,057.9	150.0	3.0	0.45	1,260.5
Pharmacy	N	CPS	Total		N	CPS	Total	
	34	8.6	39,287.0		34	14.0	39,2897.0	

[a]*Cost per request*
[b]*Averaged*
[c]*Number of days*
[d]*Patients admitted in other hospitals*
CPE= Cost per equipment

The results of this study suggested that on average, the costs associated with HD are greater than those of PD. When comparing total costs (including those of dialysis sessions, complications-hospital admissions, and patient transportation) of PD versus HD (combining both CHDC and HDH) it can be observed that HD resulted in an extra charge per prevalent patient/year of 31,631.8 € in 2017 and 29,013.0 € in 2018.

It should be pointed out that, within hemodialyzed patients, the cost is greater among those treated in CHDC (52,837.2 € and 53,937.3 € in 2017 and 2018, respectively) than among those treated in the Josep Trueta Hospital (49,079.0€ and 39,104.8 € in 2017 and 2018, respectively).

Regarding those HDH patients there was a saving costs of 191,893.9 € between 2017 and 2018. This cost saving was due to the reduction in the incidence of complications, for being precise, the decrease in the number of days of hospitalization in a hospital different than Josep Trueta Hospital. When comparing our results with the current literature, it can be observed that with the exception of the Berger et al study [23] that reported a total cost significantly greater than ours for HD (232,934.9 €) and for PD (161,433.9 €) (values calculated according the current exchange rate), our results are in line with the published literature (**Table 6**).

Table 6. Overview of the total cost associated with peritoneal dialysis (PD) and hemodialysis (HD) in different studies.

Study	Country	Currency	HD	PD	Year of publication
Salonen et al. [14]	Finland	US $	54,140	45,262[a]	2003
Baboolal et al. [15]	UK	£	35,023[c, d]	15,570[a, b]	2008
Berger et al. [23]	USA	US $	263,001[e]	182,292[e]	2009
Villa et al. [5]	Spain	€	37,968[f]	25,826[f]	2011
de Abreu et al. [24]	Brazil	US $	28,570[f]	27,158[f]	2013
Vaccaro et al. [25]	Italy	€	38,656.6[f, g]	26,835.9[f, g]	2017
Conde-Olasagasti et al. [16]	Spain	€	48,021[f]	48,703[f]	2017
Koukou et al. [26]	Greek	€	48,230.4[i]	39,051.6[i]	2017
Wong et al. [27]	Hong-Kong	HK$	380,490.5[j, k]	99,631.5[j, k]	2019
Zhang et al. [28]	China	CNY	94,760.5[l]	80,762.9[l]	2020
Current study	Spain	€	51,421.7[f, m]	21,124.0[f, m]	N.A.

[a]*Continuous ambulatory peritoneal dialysis (CAPD).*
[b]*Cost of automated peritoneal dialysis (APD): 21,655 £.*

[c]*Hospital based HD.*
[d]*Cost of satellite-unit-based HD: 32 669 £.*
[e]*Total cost per patient, including health costs, inpatient costs, other services for outpatient office visits and other costs.*
[f]*Weighted average for Hospital HD and incenter HD or APD and CAPD, as appropriate.*
[g]*Total cost per prevalent patient year was calculated multiplying the average cost per week per 52 weeks per year.*
[h]*Weighted average for 2012 and 2013.*
[i]*Total cost per prevalent patient year was calculated multiplying the average cost per month per 12 months per year.*
[j]*Weighted average for the first and second year of treatment.*
[k]*Equivalent cost in euros 2019: 42,940.4€ and 11,243.9€ for HD and PD, respectively.*
[l]*Direct medical costs.*
[m]*Weighted average for 2017 and 2018*

The higher costs associated with HD treatment comparing with PD treatment is not surprising [5,14-16,20,23-28]. In the HDH patients' group, the cost of hospital staff (doctors, nurses and nurse assistants) represented the greatest weight on the total costs (487,450.7 € and 436,198.7 € in 2017 and 2018, respectively). In fact, personnel costs were a 32.0% and a 32.8% of the total cost associated with HDH in 2017 and 2018, respectively. These results did no differ from those reported by Vaccaro & Sopranzi in 2017 [25], who showed that personnel associated costs had the greatest impact on the direct costs of HD.

Although in agreement with Vaccaro & Sopranzi [25] the cost of hospital staff for PD was significantly lower representing a 6.5% and a 7.4% of the total costs of PD in 2017 and 2018, respectively, these figures are lower than those reported by them [25]. The cost associated with dialysis, either HD or PD, was slightly greater than that reported by Wong et al. [27], especially for PD, which resulted to be an 87.8% more expensive in our study, while HD resulted to be a 19.8% more expensive in ours.

When comparing the results of this study with those published in a Spanish setting, we also found that costs associated with HD are higher than those of PD [5,16]. Villa et al. [5] reported a total cost of 37,968 € and 25,826 € for HD and PD, respectively, in 2010 year. When we update the prices by using the CPI it results in an increase of the 8.6% between December 2010 and December 2018 [29]. With this rate of variation, the updated costs of Villa et al. are 41,233.2 € and 28,047.0 € for the HD and PD, respectively. The weighted average costs for HD (HDH and CHDC) and for PD (CAPD and APD) in 2017 and 2018 in our study were 51,412.1 € and 21,124.0 €, respectively. These results actually mean that costs associate with HD in our study were greater than those reported by Villa et al., being the costs of PD lower [5].

When comparing our results (weighted average costs for 2017 and 2018 years) with those of Conde-Olasagasti et al. [16] (without CPI update), we found that while the cost of HD (both HDH and CHDC) was similar, the cost of the PD was 27,580 € lower in our study. This might be explained by a more efficient ratio of nurse/patient and by a low rate of complications.

The selection of a dialysis modality critically depends on disease progression at the time of referral to Nephrology. Early detection certainly bears on the variety of treatment options. Although patient outcomes with PD are comparable to or better than those with HD, and PD results in lower costs, not all the patients are candidates to initiate a RRT with PD. Some patients do not start on PD due to clinical reasons [30], but other ones due to patient-related challenges, including limited health literacy, cognitive decline, depression, comorbidities, cultural differences, etc. [31].

As the majority of patients could choose either PD or HD, it is extremely important to engage patient in dialysis modality decision [32]. A greater involvement and education of patients, caregivers and hospital personnel (doctors, nurses and nurse assistants) will help in the decision-making process for choosing the dialysis modality that best fits for each patient, which, therefore, will significantly improve clinical and HRQoL outcomes [33]. As mentioned in the introduction section, the dialysis provision is covered by the NHS resulting in a huge cost for the Public Administration. From the NHS perspective not only the clinical criteria but also the economic one matters when selecting therapeutic strategies. From a public budget holder perspective, the results of the current study suggested that treating 2.4 PD (weighted average for APD and CAPD) patients equates to providing dialysis to only one patient on HD (weighted average for HDH and CHDC), which in terms of cost is relevant for the sustainability of the NHS.

This fact may also have played a role in the relatively high rate of patients on PD found in our study (30.4% and 31.2% in 2017 and 2018, respectively) as compared with the figures published by Li et al. [11] or by the Spanish Renal Registry: 2017 report [12], which found that only an 11.0% and a 5.2% of the prevalent dialysis patients, respectively, were on PD. These findings may lead to the hypothesis that the health care financing model of a country or a region might have a significant influence on the RRT modality selection [5].

Finally, total cost of patient transportation per prevalent patient/year was 4,968.1 € for 2017 and 2018 each, respectively. These results are in line with those reported by Villa et al. [5] (5,515.8€, when updating the prices by using the CPI [29], but they were a 41.4% lower than those reported by Conde Olasagasti et al. [16]. Such a difference might be mainly due to the huge difference in surface area between Gerona (5,910 km2) and Toledo (15,369 km2).

This study has limitations that should be taken into account when interpreting its results. The first one is its single center design. The costs of dialysis may only reflect the reality of Catalonia and more specifically, that in Gerona province. Although the methodology could be easily replicated in other regions, the important dispersion regarding healthcare budgets, healthcare expenditure per capita, prices and the specific body that holds each budget line, in other words, the concrete funding model for dialysis treatments, among the autonomous communities (and even between hospitals) would probably deliver different results in terms of dialysis costs.

The second limitation is the fact that we have used an "intent-to-treat" approach for cost calculation. Therefore, transfers between modalities definitively imply costs that may make difficult to allocate each of the modalities. Despite these limitations, this study provides a detailed cost analysis of both HD and PD, from the perspective of the Public Healthcare Administration as budget holder. This study suggested that total costs were lower on PD compared to HD, either HDH or CHDC, and that they were lower for HD in the Josep Trueta Hospital than the contracted out-patient HD center. Additionally, it should be highlighted the relatively high rate of patients on PD. Further studies, preferably prospective cost-effectiveness analysis should be performed to elucidate the most cost-effective RRT strategy.

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