ARTICLE ORIGINAL

Estimating the cost of home dialysis in Tunisia: Application of the Activity-based costing methodology

Estimation du coût de la dialyse à domicile en Tunisie: Application de la méthode Activity-based costing

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Abstract

Introduction: In Tunisia, in-centre haemodialysis (ICHD) is the most common type of dialysis. Despite the increasing demand, the number of haemodialysis machines per 100,000 inhabitants is still low. Home Haemodialysis (HHD) is a candidate solution to this problem. Despite its confirmed benefits over ICHD, HHD has not taken place in Tunisia.

Aim: To describe the processes of home dialysis modalities, especially HHD, evaluate their costs, analyse them, in the context of medical practice in public health structures in Tunisia.

Method: The Activity-Based Costing technique was applied: the processes of home dialysis modalities were modelled, the main activity and resource cost drivers identified, and cost equations developed. Based on data from the nephrology department of Sahloul hospital, the cost per session and annual costs for each home dialysis modality were calculated and analyzed.

Results: Home Peritoneal Dialysis, already implemented in Tunisia; presented the lowest annual cost per patient 25344 TND versus 29232 TND for Conventional HHD and 54144 TND for Short-Daily HHD. The cost per session of the Short-Daily HHD (188,8 TND) was comparable to ICHD (180 TND). Consumables presented the most expensive resource for these modalities. Finally, the cost structure of HHD was comparable in Tunisia and France as well as in previous costing studies.

Conclusion : The cost of one session of HHD is estimated to 188,8 TND. The Tunisian ministry of health could adopt a flexible policy to start HHD program by implementing Conventional HHD first.

Keywords: Home renal dialysis, home haemodialysis, Activity-based Costing, Cost analysis, Tunisia.

Résumé

Introduction : En Tunisie, l'hémodialyse en centre (HDC) est le type de dialyse le plus courant. Malgré la demande croissante, le nombre de machines d'hémodialyse pour 100 000 habitants est encore faible. L'hémodialyse à domicile (HDD) est une solution possible à ce problème. Malgré ses avantages confirmés par rapport à l'HDC, l'HDD n'a pas eu lieu en Tunisie.

Objectif : Décrire les processus des modalités de dialyse à domicile, mesurer leurs coûts, et analyser leurs composantes, dans le contexte de la pratique médicale dans les structures publiques de santé, en Tunisie.

Méthode : La méthode Activity-Based Costing a été appliquée en modélisant les processus des modalités de dialyse à domicile, identifiant les inducteurs de coût et développant les équations des coûts. Enfin, les coûts des modalités de dialyse à domicile ont été évalués et analysés.

Résultats : La Dialyse Péritonéale à Domicile, déjà mise en place en Tunisie, a présenté le coût annuel le plus bas par patient : 25344 DT contre 29232 DT pour l'HDD conventionnelle et 54144 DT pour l'HDD quotidienne-courte. En outre, le coût par séance de l'HDD (188,8 DT) était comparable à celui de l'HDC (180 DT). Les consommables représentaient la ressource la plus coûteuse pour ces modalités. Enfin, la structure des coûts de l'HHD était comparable en Tunisie et en France ainsi que dans les études de coûts précédentes.

Conclusion : Une séance d'HDD pourra coûter 188,8 DT. Le ministère de la santé Tunisien pourrait adopter une politique flexible pour démarrer le programme d'HDD en commençant par introduire l'HDD conventionnelle.

Mots clés : Dialyse rénale à domicile, hémodialyse à domicile, activity-based costing, analyse des coûts, Tunisie.

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INTRODUCTION

Worldwide, the prevalence of End Stage Kidney Disease is continuously increasing. Hence, the demand for kidney replacement therapies, predominantly dialysis is growing (1). By 2030, 5.4 million people are estimated to have this disease, with the highest rise in Asia and Africa (1,2). Tunisia is no exception to this global trend. According to 2018 estimates, between 1,200 and 1,300 new cases per year are recorded (3). Given that renal transplantation activity is low (≈118 transplants/year) (4), these cases are submitted to dialysis treatment (3). In-centre haemodialysis (ICHD) is the most common type of dialysis and the only mode of haemodialysis treatment in Tunisia. The prevalence of haemodialysis in Tunisia is 734 per million inhabitants within an average annual increase of 9.6% (5).

Two problems arise with providing dialysis services to patients in Tunisia. On the one hand, there is an increasing demand for dialysis while the capacity of public and private centres is getting more and more saturated. Besides, the number of haemodialysis machines per 1 million inhabitants is 252 with an interregional disparity of 0.28 (6). On the other hand, the cost of treating dialysis patients in Tunisia, exceeded 5% of overall health expenditure (7). To face the increasing demand for dialysis services, especially haemodialysis, while mastering healthcare expenditure, effective and low-cost treatment is needed. Almost all economic evaluations suggest home dialysis, namely Home Haemodialysis (HHD) and Home Peritoneal dialysis (HPD), to be more cost effective than facility dialysis, with some countries adopting a home-first policy to reduce costs (2).

HHD does not yet exist in Tunisia. To provide a useful estimate for Tunisian decisionmakers, a socio-economic study on the introduction of HHD is necessary. This paper focuses on the economic aspect: the estimation of the cost of a HHD session and its comparison to the cost of HPD and ICHD (which is already calculated in a previous study (8)). To our knowledge, this is the first time in North Africa that methodological work is done on the evaluation of home dialysis. Our goal is to try to answer the question: “what is the cost of a home dialysis session in Tunisia?”. Therefore, we are conducting a costing study from the healthcare system perspective. It will provide results that are more useful for external users namely the healthcare ministry and government.

METHODS

This study is conducted within the framework of a research project between France and Tunisia entitled: “robust planning of home healthcare”. The socioeconomic partners of this project are the nephrology departments of Tenon hospital (Paris, France) and Sahloul hospital (Sousse, Tunisia). One of the aims of the project is to study the introduction of HHD in Tunisia with our Tunisian socio-economic partner.

The nephrology department at Sahloul Hospital (Sousse, Tunisia) is the fourth university hospital pole. Since 2006, it practices mainly two modes of dialysis: Conventional haemodialysis which is done in the hospital (ICHD) and Peritoneal Dialysis, especially continuous ambulatory peritoneal dialysis (CAPD). The department started also renal transplant programme in 2007. Peritoneal Dialysis, is performed both in-centre (hospital) and at home while haemodialysis only in hospital. In Tunisia, and in Sousse region particularly, ICHD is the most common dialysis mode. It is conducted whether in nephrology departments at public hospitals or in private dialysis centres. While many haemodialysis patients could be treated at home, this could not be done since HHD is not yet implemented. With the nephrology team of Sahloul Hospital, we are interested in identifying the different steps of HHD, activities and resources involved as well as estimating the cost of one session of HHD and comparing it to the cost of existing dialysis modalities.

Activity-Based Costing method was applied to estimate the cost of single HHD and HPD sessions. First, we identified cost objects. Second, we modelled the processes of HHD and HPD and validated them while focusing on main activities and resources. Since HPD exists already in Tunisia, its process was validated with nephrology team in Sahloul Hospital (Sousse, Tunisia). Regarding HHD process, we conducted bibliographic research and discussed with nephrology teams in both hospitals. Especially, the French team helped us with their experience in HHD. That is why the HHD process was validated based on bibliographic research as well as the HHD experience of our second socio-economic partner in this project: Nephrology team in Tenon hospital (Paris, France). Upon this validation, resource cost drivers were defined, and cost equations were developed for each home dialysis modality. Finally, based on these equations, the cost of HHD and HPD session as well as monthly and annual cost were calculated. To do so, we considered data from the nephrology department in Sahloul Hospital (Sousse, Tunisia). These results are presented in section 4. We have noted that the French case study was considered for validating the HHD processes. It was also used for cost benchmarking of Short Daily HHD (the modality adopted in France for HHD) while applying the same cost methodology in Sahloul and Tenon hospitals. The objective was to discuss the differences between organizations regarding the distribution of the total cost per session over activities and/or resources.

The cost objects

For a healthcare service, the cost object is the patient. Hence the number of cost objects was equal to the types of patients to be treated. For HHD, the types of patients depend on HHD modality: conventional (CHHD), Short daily (SDHHD), and nocturnal. CHHD is usually done three times per week, for three to five hours per session. SDHHD requires more frequent access: two/three hours, five to seven days a week. Nocturnal HHD is performed three to six nights a week and between six and ten hours per session while the patient sleeps.

In this paper, we studied the cost of SDHHD and CHHD. Since SDHHD needs lower dialysate flux using dialysate bags, its choice was justified by the poor quality of the water available in Tunisia (9). ICHD practiced in the nephrology department of Sahloul hospital is the conventional haemodialysis. Hence, it is legitimate to study the introduction of CHHD (which needs a water purification system in addition to the haemodialysis machine).

For HPD, both modalities are performed at home under the supervision of the nephrology team in Sahloul hospital. We distinguish Continuous Ambulatory Peritoneal Dialysis (CAPD) performed 2 to 4 times a day, 7 days a week, and Automated Peritoneal Dialysis (APD) performed at night for 8 to 12 hours, 5 to7 nights out a week while using a cycler.

In summary, four cost objects, one for each home dialysis modality, were identified in our study.

Process modelling and resources identification

This step aimed at identifying and modelling the main activities in HHD, APD and CAPD as well as the resources involved. The breakdown of activities was important for the subsequent development of cost equations and allocation of resources.

The process of HHD does not exist yet in Tunisia. For this reason, data for modelling the HHD process were based on i) a bibliographic study of HHD in other countries which had already implemented it (10,11), ii) the observation of the course of ICHD sessions at 'Sahloul' hospital and HPD sessions and iii) interviews with the nephrologists and medical staff engaged in the project along with staff from nephrology department of Tenon Hospital (Paris, France). The different HHD and HPD processes were validated with nephrology teams in Tenon and Sahloul hospitals, respectively.

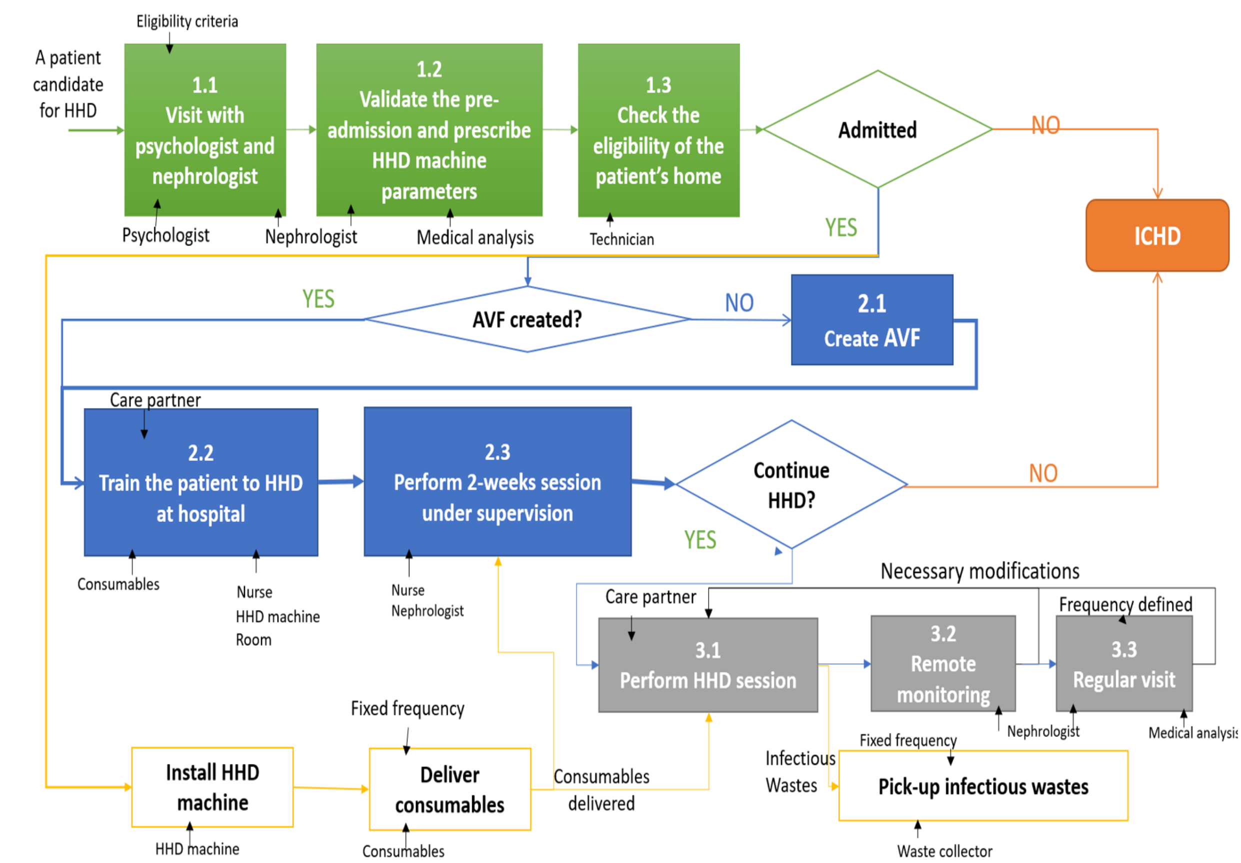
The stakeholders in Home Dialysis modalities are the patient and his/her care partner, the nephrology department, and the provider of HHD machine/ APD cycler and consumables. The process of home dialysis consists of three common phases and support activities which are detailed in Table 1.

Table 1. Processes of home dialysis modalities

Activities/ processes		HHD	APD	CAPD
Admission		Validate the eligibility of the patient to HHD (based on physical and/or psychological criteria) and the adaptability of his/her home		
Training	Pre-training	Create an Arteriovenous Fistula (AVF)	Place Catheter	
	Duration (weeks)	3 to 8	2	
	Preparing Home	Install HHD machine and deliver consumables. For CHHD, a purification water system is also needed.	Install cycler Deliver consumables	No cycler is needed
	Training at home	First session with nephrologist and nurse home visit. 2-weeks sessions, nurse reachable by phone in case of problems	Nurse home visit for the first session	
Performing Home Dialysis sessions		Daily dialysis sessions Regular visits (monthly, quarterly, and annual check-ups)		
	Remote monitoring: to ensure the safety of home dialysis patients, it is essential to keep a continuous monitoring to cope with occurring medical problems. Home dialysis machines are connected directly through a tablet to the nephrology staff, so all the messages and alarms triggered during the dialysis sessions as well as all the detected parameters are sent in real time to the nephrologist.			
	Remote data sent from HHD machine include ultrafiltration rate, weight, blood pressure and medications	Remote data sent from the cycler involve treatment time, ultrafiltration total, compliance		---
Support activities		Deliver consumables Pick up infectious wastes		

HHD : home haemodialysis
APD : Automated peritoneal dialysis
CAPD: Continuous Ambulatory Peritoneal Dialysis

To model the processes of Home Dialysis modalities, we used the Structured Analysis and Design Technique (SADT) diagram (12). The global process of HHD using SADT is illustrated in Figure 1. The process related to APD/CAPD is equivalent to HHD process subject to some modifications: replacing HHD by APD/CAPD, HHD machine by Peritoneal Dialysis cycler for APD (with eliminating the activity "install the cycler for CAPD") and create Arteriovenous Fistula by place Peritoneal Dialysis catheter.



HHD : home haemodialysis / ICHD: In centre Haemodialysis
AVF: Arteriovenous Fistula

Figure 1. The process of organizing and performing HHD (including CHHD and SDHHD, A purification water system is needed for home sessions in CHHD)

Identification of resource drivers

Resources involved in home dialysis include the physical areas, human resource as well as machines, consumables, and vehicles.

For human resources (nephrologist, psychologist, nurses, technicians, drivers), time was chosen as a resource driver. The human resource's salary is proportional to the number of their working hours. The activity consumes the nephrologist's time, so it is more natural to assign its cost according to the time spent on the activity.

Physical areas in our study stand for training rooms for patients in the nephrology department. The surface was chosen as a resource driver.

For measuring fuel used to transport nurses/ technicians from the hospital to the patient's home and vice versa, two resource drivers could be considered: the journey time spent on transportation, and the daily distance travelled (in kilometres). Since it was easier to estimate the number of hours spent doing this activity, the first resource driver was chosen.

Development of cost equations

Table 2 presents resource drivers as well as cost equations for each resource used by each activity for HHD. Cost equations for APD and CAPD were developed in the same way. To develop these equations, several hypotheses were defined and discussed with nephrology team in

Sahloul hospital (Sousse, Tunisia), since it is our partner in this project, as follows:

• At the beginning of HHD program, the nephrology department in Sahloul hospital (Sousse, Tunisia) would not consider additional human resources (i.e., nephrologists and nurses). A part of existing resources has already been trained to HHD by the head of the nephrology department. Hence, no implementation costs for HHD related to additional human resources were considered.

• Tangible assets such as, physical structures and vehicles are depreciated as they have been used by the hospital for more than 20 years. Hence their depreciation cost is zero (13).

• The cost of Arteriovenous fistula creation, Catheter placement (C2.1 (activity 2.1)) as well as medical analysis were already calculated by the hospital.

• The cost of the activity “deliver consumables” was included in the consumables’ price.

• Consumables for HHD involved: the blood lines set, the dialysate bag, the anticoagulant, needles and syringes and the dialyzer.

• Consumables for HPD involved: the tubing, dialysate bag, drainage bag and catheter.

• By analogy with HPD, 2 hours was the estimated time needed to visit 8 patients (by nurses).

• No time was attributed to remote monitoring. The nephrologist will not spend time on follow-up, he will intervene only if he/she receives an alarm indicating the occurrence of HHD/APD incidents. Still, the probability of alarms is negligible. Thus, the remote monitoring activity was eliminated.

• The pick-up of infectious wastes was not considered for the cost calculation. The collection of wastes from patient’s homes and its transfer to the hospital were ensured by the deliverer of consumables once per month which was included in the consumables’ price. Then these wastes were collected from the hospital along with the other wastes. The hospital’s wastes collector picks-up all these wastes together.

• Morbidity and modality switching costs (from home to in-centre dialysis) were not considered.

• The average number of years of treatment for dialysis patient was estimated to the average service life of the dialysis machine. From information of the major haemodialysis machine manufacturer, a haemodialysis machine lasts 10-12 years in average (14). Therefore, we considered a primary average number of years of treatment equivalent to 12 years. After this period, the machine should be changed or repaired.

Table 2. Resource drivers and Cost equations for each resource in each activity and process phase and the cost equation of one HHD session

PHASE	Activity	Resource involved	Resource driver	Cost equation/ resource	Cost of activity	Cost Of the phase
1	**1.1: Consultation with psychologist and nephrologist**	Psychologist	Mean Time spent (hours) per patient *	$CP = \text{Salary} \times \frac{\text{Mean Time spent (hours) per patient}}{\text{number of working hours per month}}$ [E1]	$C_{1.1} = CP + CN_1$	
		Nephrologist		*CN1* [E1]		
	1.2: Validate the pre-admission and prescribe HHD parameters	Medical analysis	Type of analysis	*CA: Cost of the analysis*		
		Nephrologist	*	*CN2* [E1]	$C_{1.2} = CA + CN_2$	$C_{Admission} = C_{1.1} + C_{1.2} + C_{1.3}$
	1.3 Validate the Home of the patient	Technician	Time spent on the visit	*CT* [E1]		
		Driver	**= travel time per patient + visit time	*CD1* [E1]		
		Fuel	Travel time per patient	$CF_1 = Cost\ of\ Fuel\ consumption\ per\ hour \times\ Travel\ time\ per\ patient$ [E2]	$C_{1.3} = CT + CD_1 + CF_1$	
		Vehicle	**	*0*		

Table 2. Resource drivers and Cost equations for each resource in each activity and process phase and the cost equation of one HHD session (suite)

PHASE	Activity	Resource involved	Resource driver	Cost equation/ resource	Cost of activity	Cost Of the phase
2	**2.2 Training at the hospital**	Nurse	Mean Time spent (hours)	CNu1 [E1]	$C_{2.2} = CNu_1 + CCons_{Train1} + CM_{Train}$	$C_{Training} = C_{2.1} + C_{2.2} + C_{2.3}$
		HHD machine	Total number of training sessions	$CM_{Train} = \frac{\text{Number of training sessions / patient} \times \text{Depreciation cost of the machine}}{\text{total number of training sessions per year}}$		
		Room	Square meters	Depreciation cost=0		
		Dialysate bag, Cassette, Lines, specific needles, syringes, KIT, anticoagulant)	Number of consumable units used in a session***	Cost for one session = Number of units × Purchasing cost [E3a]	Let CCons1= [E3a]+ [E3b]	
		One bottle of Betadine Antiseptic Gargle serves for 20 sessions		Cost for one training session = 1/20 * purchasing cost [E3b]	$CCons_{Train1} = CCons_1 \times$ total number of training sessions per patient [E3]	
	2.3 Perform 2-Weeks HHD sessions under supervision	Consumable	***	$CCons_{Train2}$ [E3]	$C_{2.3} = CNu_2 + CN_3 + CCons_{Train2} + CD_2 + CF_2$	
		Nephrologist	**	CN_3 [E1]		
		Nurse		CNu_2 [E1]		
		Driver		CD_2[E1]		
		Fuel	Travel time	CF_2 [E2]		
3	**3.1 Perform HHD sessions**	Consumables	***	$CCons_{total} = CCons_1 \times$ total Number of sessions for 12 years	$C_{3.1} = CCons_{total}$	$C_{HHD} = C_{3.1} + C_{3.2}$
	3.3 Regular visits	Medical analysis	Type of the analysis and frequency	Annual analysis: CA_1 Trimestral analysis: CA_2 Monthly Analysis CA_3 $CA_{total} = \text{Number of treatment years} \times (CA_1 + 3 \times CA_2 + 12 \times CA_3)$	$C_{3.2} = CN_4 + CA_{total}$	
		Nephrologist	*	$CN_4 = 12 \times \text{Number of treatment years} \times CN_1$		
Install HHD machine		HHD machine	Price	*CM: Price of the machine*		**CM**

$$\text{Cost for one HHD session} = \frac{C_{Admission} + C_{Training} + C_{HHD} + CM}{\text{total Number of sessions for average number of years of treatment}}$$

HHD	*Home Haemodialysis*
$C_{Admission}$	*Cost of the admission phase*
$C_{Training}$	*Cost of the training phase*
C_{HHD}	*Cost of performing a dialysis session*
CM	*Cost of installing and purchasing the haemodialysis machine*
CN	*Cost of nephrologist*
CP	*Cost of Psychologist*
CNu	*Cost of nurse*
CA	*Cost of analysis*
CT	*Cost of Technician*
CF	*Cost of Fuel*
CD	*Cost of Driver*
$CCons_{Train}$	*Cost of Consumables during the training phase*
CM_{Train}	*Cost of the machine during the training phase*

RESULTS

Cost calculations were conducted based on cost equations and data from the nephrology department in Sahloul hospital (Sousse, Tunisia). These data are presented in Figure 2. First, we calculated the cost of one session of HHD (i.e., SDHHD and CHHD) and HPD (i.e., APD and CAPD) as well as their annual cost. Second, we conducted cost analysis by determining the contribution of each activity and resource in the total cost of each home dialysis modality. Finally, we conducted cost benchmarking. The results related to these experiments are illustrated in Figure 3. Figure 3 contains four graphics: a, b c and d (which we refer to as Figure 3a, Figure 3b, Figure 3c and Figure 3d respectively)

Figure 3a shows the costs per session and per year of home dialysis modalities. One session of: SDHHD costs 188 TND, CHHD 203 TND, CAPD 74 TND and APD 88 TND. We added in this graphic the costs related to ICHD to compare them to those of home dialysis. This graphic demonstrates that HPD was less costly than HHD modalities. In fact, HPD modalities were already well established in Tunisia. We pointed out that although CHHD presented the highest cost per session; its yearly costs were not only lower than SDHHD (54144), but also comparable to HPD (25344 TND for HPD versus 29232 for CHHD). This could be explained by the frequency of CHHD compared to SDHHD.

Figure 3b and 3c illustrate the contribution of each activity and each resource in the cost of one session of each home dialysis modality, respectively. It showed that consumables were the most important resource and that the activity of “performing home dialysis sessions” was more expensive than the other ones for home dialysis modalities. In fact, this activity consumed basically the most expensive resource “consumables”. Based on this analysis, the high cost of HHD could be explained by the economy of scale applied to HPD for consumables (i.e., the cost of HHD (consumables) will be reduced if the number of HHD patients increases) and the absence of dialysis machine for CAPD and the lower price of APD cycler.

Data for Home Dialysis modalities

	CHHD	SDHHD	APD	CAPD
Frequency	3/week	6/week	5 to 7/week	2 to 4 times/ day; 7 days a week 1 session = 1 day
Duration (h)	3→ 5	2	8 to 10	0,5 → 4
Number of sessions per month	12	24	20 → 28 => in average 24	in average 30
Needed machines	Home HD machine + Purification water system	The low flow dialysate machine (the Nx Stage System One®).	PD Cycler (Baxter)	-

Data for Human resources

Human resource	Salary (TND)	Total working hours per month
Nephrologist/ Psychologist	2000	144
Nurse/ technician	700	176
Driver	800	

1TND ≈ 0,3 euros

Data for medical analysis and surgeries

Type of analysis/ frequency	Activity	Cost (TND)
Standard	Admission	174,100
Monthly analysis	Perform home dialysis sessions	79,200
Trimestral analysis		221,920
Yearly analysis		174,100
Create AVF		700
Place Catheter		800

HHD : home haemodialysis / SDHHD : short daily HHD / CHHD : conventional HHD
ICHD : In-centre haemodialysis
APD : Automated peritoneal dialysis / CAPD: Continuous Ambulatory Peritoneal Dialysis

Figure 2. Tables of data related to home dialysis modalities, human resources, medical analysis and surgeries from the nephrology department in Sahloul Hospital (Sousse, Tunisia).

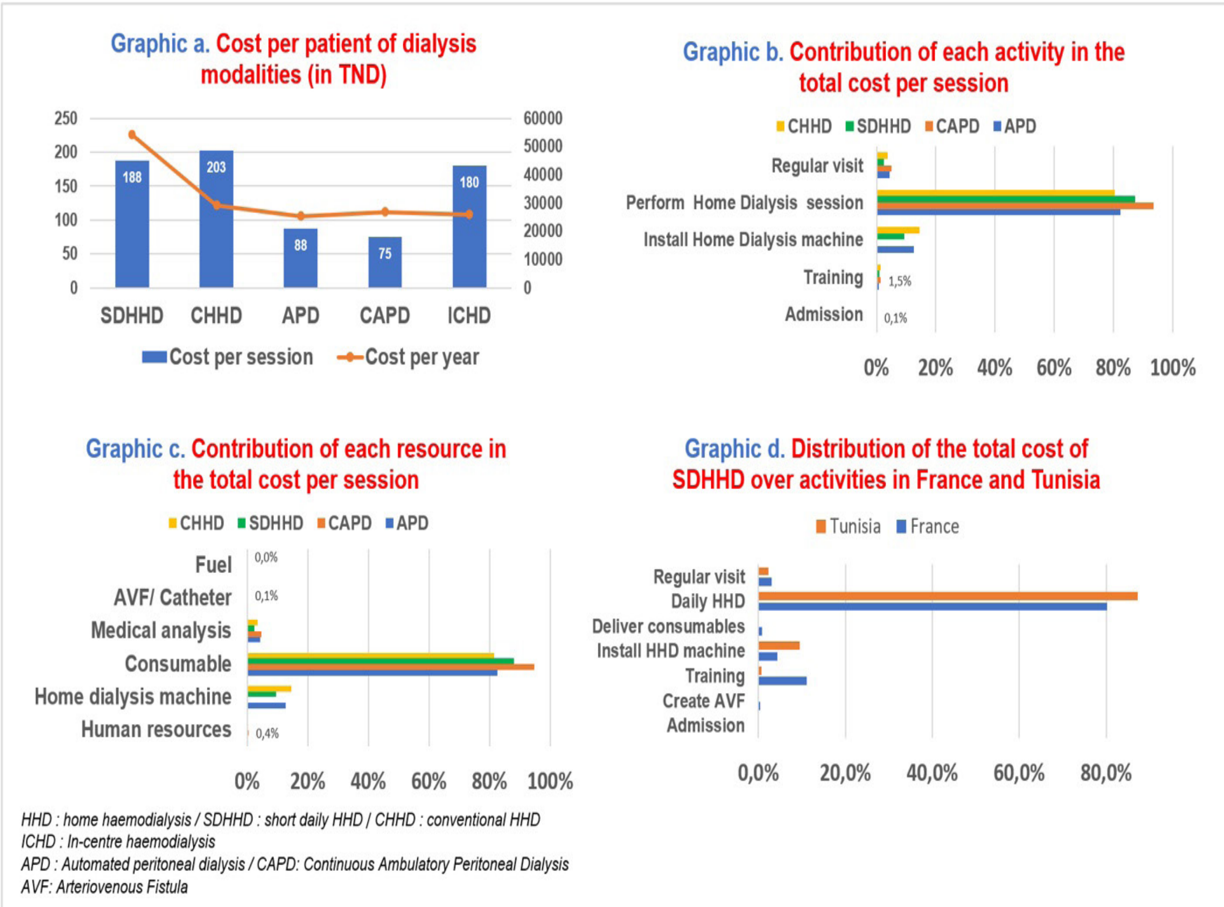


Figure 3. Results related to the estimation of the cost of home dialysis modalities and their comparison (graphic a), the analysis of these costs (graphics b. and c). and cost benchmarking (graphic d)

DISCUSSION

Derived from data in published studies on HHD and interviews with nephrologists from Tenon (Paris, France) and Sahloul (Sousse, Tunisia) Hospitals, we have generated an activity-based-costing model for HHD and HPD from the healthcare payer's perspective. The model details their activities and resources and develops cost equations for each resource/activity and phase. Furthermore, the generated HHD model has been validated based on previous costing models and by the nephrology team in Tenon hospital (Paris, France).

Costs of home dialysis modes were the subject of different research papers especially in high income countries. A recent literature review of Economic Evaluations of Dialysis Modalities (2) showed that there is a lack of costing data in nephrology, particularly in low- and low-middle income countries (like Tunisia). The cost of dialysis in low- and middle-income countries has been reviewed up to 2013 by Mushi et al. (15). This study reviewed mainly the cost of ICHD, and peritoneal dialysis. Home dialysis modalities were not discussed. Authors pointed out that the number of studies on the economics of dialysis in low and middle-income countries is still limited and that further research is needed to determine the cost of dialysis based on a standard methodology grounded on existing economic guidelines. This research tried to fill this gap. To our knowledge, this is the first time in North and Sub-Saharan Africa that methodological work has been done on the evaluation of home dialysis.

Our model allows the determination of the cost of HHD and HPD session per patient and can be considered as a generic model after the comparison with previous published studies and reviews on the economic assessment of newly established and existing home dialysis modalities (2,10,11,15-20). The main difference between our study and the others is that our model is developed and applied for a non-established HHD delivery system (Tunisia) and validated on existing system (France).

Our findings regarding the HHD cost structure are consistent with the previous studies especially (10,11) those analysing the cost per patient of ICHD and frequent HHD (nocturnal and short daily) in Canada, Australia, and in the UK. First, consumables present the higher cost. The cost of HHD machine comes in the second place. Furthermore, the comparison of the cost structure of SDHHD in France (the HHD modality adopted in Tenon Hospital (Paris France)) and in Sahloul hospital (Sousse,Tunisia), illustrated in Figure 3d, suggested that the distribution of the total cost over activities was comparable in both countries. Therefore, the Tunisian case was validated. Also, the activity "performing HHD sessions" is costlier higher in the Tunisian case. This could be explained by a higher cost in consumables. In fact, the Tunisian case is in the process of implementation. Therefore, we did not consider the economy of scale offered by the supplier contrary to the French case. The activity "Install SDHHD machine" costs more in Tunisia. It is a low flow dialysate machine (the Nx Stage System One®). The cost of the machine was higher in Tunisia because it was imported, and the Tunisian dinar was devalued against the euro. Finally, the activities which resource driver was the human resource (nurse, doctor ...) were more expensive in France than in Tunisia. This was the case of both activities "training" and "regular visit" since human resources were more costly in high-income countries (like France). This finding is also valid for Canada, UK and Australia (12). In addition, in (12), authors considered the recruitment of medical staff for HHD only which is not our case. Overall, Tunisia is a country with developing economies where labour costs are often lower than countries with more developed economies. Hence, the cost of materials remains the major driver of dialysis costs due to high import costs on the equipment and consumables, which was pointed out by (12, 16).

The comparison of the cost of HHD to ICHD in previous studies suggested that it is difficult to conclude which modality is costlier within each country because of the lack of generalizability between studies and countries (17,18). In our case, ICHD costs per session 180 TND (8) against 188,8 for SDHHD and 203 for CHHD. However, the annual costs of ICHD and CHHD are lower than SDHHD because of the difference in the frequency of dialysis sessions. The higher costs of SDHHD compared to CHHD are explained by the higher consumable usage due to dialysis frequency (11).

However, overall, there is a consensus that HHD was associated with lower costs and better outcomes compared with facility haemodialysis. Beaudry et al. (18) explained that "Home modalities have lower overall maintenance costs, and beyond a short time horizon, they are more cost efficient when including incremental training expenses". Walker et al. (19) showed that HHD is a cost-effective treatment and allows more equitable distribution of good health outcomes for individuals with early-stage kidney disease.

Our activity-based costing model has several limitations. First, as it was developed for a non-established HHD program and validated on a French case study, data were based on average and approximative values. Second, we did not consider implementation costs related to additional human resources as we supposed that the launch of HHD program could be done with existing nurses and nephrologists already trained to HHD. The cost of exiting HHD program or switching to another dialysis modality were not included. Third, we provided estimates that account for public health care costs related specifically to HHD modality directly. We also assumed that all patients underwent successful Arteriovenous Fistula creation and that morbidity and modality switching costs (from home to in-centre dialysis) are not considered. Finally, we did not provide comparison in terms of environmental impacts (cost of energy, water, and wastes) which is an important issue nowadays (21,22). Despite this, we believe that our work has two main contributions. On the one hand, our model is transparent enough so that decisionmakers could vary specific costs to fit any payer model. It details the link between resources, activities, and patients, managers can therefore reduce the service cost by diminishing spending on non-value activities: acting on resources or increasing the output, those resources produce. Therefore, it provides not only more accurate estimate of service cost, but also a useful tool to optimize cost. On the other hand, and most importantly, we derived meaningful managerial insights about the introduction of HHD in Tunisia. The Tunisian ministry of health could adopt a flexible policy to start HHD program by implementing CHHD first (as described by Piccoli et al. (23), as its annual cost was comparable to HPD and could be further minimized by considering economy of scale for consumables. Finally, the choice of introducing a dialysis modality must not only rely on medical and economic reasons (e.g., cost and cost-effectiveness), but many other types of criteria must also be considered, namely, social (e.g., quality of life), organizational (e.g., liberating hospitals capacity), and environmental (e.g., CO2 emissions, energy, and water consumption (22)) criteria. Hence a multi-criteria decision-making approach could be developed and used to guide wisely the choice of dialysis mode in Tunisia while integrating the environmental perspective.

In summary, one session of Short-Daily HHD was estimated to 188 TND, Conventional HHD to 203 TND, CAPD to 74 TND and APD to 88TND. Hence, the cost per session of HHD modalities was higher than HPD modalities and was comparable to ICHD (180 TND). The analysis of these costs showed a similarity in the cost structures for all home dialysis modalities. Especially, consumables presented the most expensive resource. The non-consideration of the economy of scale for consumables, especially for HHD (the not yet established modalities), as well as the devaluation of the Tunisian Dinar explained the difference between the costs of HHD and HPD. Finally, we showed that the annual cost of CHHD is comparable to HPD that is already practiced in Tunisia. Knowing that these costs could be further minimized after applying economy of scale to consumables for CHHD, the Tunisian ministry of health could adopt a flexible policy to start HHD program by implementing CHHD first. The introduction of HHD in Tunisia will contribute to liberating the capacity of nephrology departments to treat more patients needing in-centre dialysis while providing the others with home dialysis. This will allow to respond more equitably to the increasing demand for dialysis, especially for early-stage kidney disease patients.

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