Patient cost estimation for standard treatments (hemodialysis and peritoneal dialysis) of end-stage renal disease

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Abstract

Dialysis treatments represent a significant portion of the total health care expenditures worldwide. In Portugal, the scenario is no different, especially because these treatments are totally financed by the State and almost 90% of the patients with chronic kidney disease are treated in private peripheral dialysis units (PPDU). In 2008, the Portuguese State introduced a model of payment through an aggregate price, which is called the comprehensive price. Since then, some changes in the value paid have occurred.

This work aims to identify and estimate the major costs associated with the provision of dialysis treatments and compare them with the comprehensive price, as well as with other studies in this area. For the development of this methodology, one has defined a standard clinic for each type of dialysis treatment (SCH, for hemodialysis and SCPD, for peritoneal dialysis) and has assessed different parameters taking into consideration the reality of these treatments not only in Portugal but also worldwide. Consequently, one has measured the impact that each of these parameters has in the total cost and the effect that slight changes may have on the final result. Furthermore, one has evaluated the total cost that a patient may represent to a unit, taking into account the average period of each of the treatments.

Keywords: Comprehensive price, Dialysis treatments, Hemodialysis, Peritoneal Dialysis, Cost Estimation, Standard clinic

1 Introduction

Renal failure is a disease that affects millions of people worldwide. Portugal is one of the European countries with the highest number of patients undergoing dialysis treatments. According to the Portuguese Nephrology Society, there are more than 10 000 patients undergoing dialysis treatments in Portugal. This means that more than 200 million euros have to be spent every year due to the amount of treatments performed - in 2013, this value was 252 254 390.70€ (ACSS, 2013). Portugal plays a special role when it comes to dialysis treatments, as it is the only nation in Europe where almost all the dialysis providers are private. Only around 10% of the total number of chronic kidney disease patients are treated in state owned hospital dialysis units (SOHDU), even though there is a total installed capacity of 20% (CEGEA, 2007).

As it is a disease that affects people throughout their lives and patients have to undergo dialysis treatments, on average, three times a week over the years, the Portuguese Health System finances it through an amount of money paid to dialysis units based on an administrative price, which is designated by comprehensive price. Therefore, it is a free treatment for patients and they have no influence on the price paid (EY, 2012). The comprehensive price is defined per week and per patient and covers all the costs that are directly related to a dialysis session. It is now set at €450.68 per patient per week without vascular access and at €470.09 per patient per week with vascular access, which is a surgically created vein (2.ª série — N.º 161 Diário da República, 2011).

The introduction of the comprehensive price was accompanied by an integrated management of the disease, which allowed patients to be treated, supervised and get access to their medication all in the same place (ACSS, 2013). Therefore, dialysis units have to make sure that their patients are being well treated, whilst the money they are receiving is enough to make it possible for them to pay for all the expenses. Hence, there is the need to understand the costs that dialysis units face. In the past years, some

studies were published on the cost structure for dialysis clinics. However, this structure has changed over the recent years. Regarding Portugal, the most significant and important difference between the work mentioned in this paper and previous reports is that the costs with transports - which are no longer part of the comprehensive price – are not considered in this case. Also, changes in the cost structure are taken into account in this report as well as a detailed analysis of all the components that should be considered as part of the structure.

Evaluating the potential cost of a patient throughout time will help clinics to manage their money and see if they are being financed properly for each treatment provided. Taking this into consideration, the purpose of this work is to find the appropriate methodology to assess the cost of a patient undergoing a dialysis treatment, during a defined period of time. A comparison between hemodialysis and peritoneal dialysis treatments is also shown, to assess if there should be a difference in the financing of these different methods of treatment.

2 Literature Review

Kidney transplantation is considered the optimal form of renal replacement therapy as it provides the best prognosis for survival and quality of life. However, due to the increasing number of end-stage renal disease patients and to the shortage of kidney donors, most of the patients suffering from this disease will need some form of dialysis treatment during their lives (Vonesh & Moran, 1998). There are two major types of dialysis treatments: hemodialysis and peritoneal dialysis. The main principle of these treatments is to use an artificial kidney that will help with to remove toxic waste products and to restore the normal levels of body fluid volume and composition.

When it comes to the difference of costs between hemodialysis and peritoneal dialysis, the results may vary significantly across countries. However, in most of the cases, peritoneal dialysis is more affordable as it is mainly performed at home and there is no need for infrastructures and staff available in the sessions (Karopadi et al., 2013). Therefore, taking into consideration the different expenditures in both treatments, hemodialysis has more expenses and associated costs.

Regarding patients on both treatments, the expected cost per life year and the cost per quality-adjusted life year are more favorable for the ones on peritoneal dialysis (Sennfält et al., 2002). Even though a lot of factors seem to be in favor of peritoneal dialysis, the majority of countries worldwide still use hemodialysis as the main end-stage renal disease treatment. A study made by the United States Renal Data System that has data from 42 countries - mainly developed countries – shows that in over 76 percent of the reporting countries at least 80 percent of the patients undergo hemodialysis treatments (USRDS, 2013).

End-Stage Renal Disease is a disease that has a huge amount of costs associated to it and thus it means a high resource demand to every health care system in the world (Just et al., 2008). Consequently, the study of the disease and the economic burden related to it is very important as it can help to develop measures for cost containment without compromising the health condition of the patients. Estimating the quantity of resources (in monetary terms) used in the treatment of a disease is one of the points that cost-of-illness studies take into consideration. Therefore, they represent a useful step in the development of knowledge about the economic burden of a chronic disease (Suhrcke et al., 2006).

Characteristics such as sex, employment status, lifestyle, marital status and comorbid diseases might influence the cost-effectiveness of a treatment as well. In the case of End-Stage Renal Disease, the older the patient and the more comorbid diseases it suffers from, the higher the cost and the more complications the treatment will have. As several studies suggest that peritoneal dialysis treatments have a lower cost than hemodialysis treatments, this can be a potential way of saving costs. Nevertheless, PPDU are driven by the microeconomics of their centers and need to find a way to repay the high investment made in hemodialysis' equipment, infrastructures and personnel. Hence, PPDU want their dialysis stations to be used maximally in order to refund their investments. Therefore, they have an interest to provide as much hemodialysis treatments as they can (De Vecchi et al., 1999).

Financing methods vary from country to country but in most industrialized countries, dialysis is financed primarily through national or provincial health care systems (Hirth et al., 2008). , there is evidence of different dialysis' reimbursement policies in several countries. On the majority of the countries, there is a higher reimbursement in hospital hemodialysis treatments relatively to other types of treatments. Additionally, peritoneal dialysis treatments tend to receive less funding than hemodialysis treatments (Vanholder et al., 2012).

3 Methodology

The standard clinic is an example of a standard treatment, which results from a survey conducted in several PPDU – the ones that are more important and represent the biggest percentage of providers - and the consideration of a SOHDU environment. A standard clinic results from a health facility where it is possible to undergo a specific type of treatment (in this case, dialysis treatments). Therefore, a standard clinic consists of a set of protocols regarding drugs, equipment and consumables, as well as other specificities that are common to any dialysis provider. The norms related to organizational, operational, human resources and technical requirements are present in the DR (1.ª série — N.º 231 Diário da República, 2013) and in the Chronic Dialysis Best Practices Manual (OM, 2011). Hence, the standard clinics considered in the development of this document result from information gathered from several dialysis units – either private or public -, which took these norms into consideration when building their facilities and providing the treatments to their patients.

In order to define a standard clinic and to account the costs that it faces, one has used the study developed by Ernst & Young (EY, 2012), which took into consideration the most representative PPDU in Portugal that treat 77% of all hemodialysis patients. The methodology developed includes also the characteristics associated with SOHDU. Therefore, in order to establish those characteristics, the model integrates the principles of the study conducted by Deloitte (2008), which assessed the costs incurred at *Hospital de São João* (HSJ) and *Hospitais da Universidade de Coimbra* (HUC).

Apart from the treatment protocol, the costs that each facility incurs - independently from being a PPDU or a SOHDU - are mainly operational costs (especially related with human resources, equipment and consumables) and structural costs.

3.1 Model parameters definition

In order to develop the application of the one needs to define 4 important parameters: the number of treatments per patient per week, the number of patients in a standard unit, the number of days in a patient year and the average period that a patient spends on treatment.

To compute the number of treatments per patient per week, one uses this formula, which gives the weighted average number of sessions (WANS):

$$(1) \qquad WANS = P_P\% \times Ns_P + P_H\% \times Ns_H$$

$P_P\%$: *Percentage of patients undergoing the treatment in PPDUs*
Ns_p: *Number of sessions per patient per week in PPDUs*
$P_H\%$: *Percentage of patients undergoing the treatment in SOHDUs*
Ns_H: *Number of sessions per patient per week in SOHDUs*

In order to compute the average number of sessions per patient per week in SOHDU (Ns_H), we have to analyse the data from the two units considered: HSJ and HUC. To do so, we will apply the following formula:

$$(2) \qquad ANS_{SOHDU} = \frac{Ns_1 * Np_1 + Ns_2 * Np_2}{Np_1 + Np_2}$$

Ns_1 *and* Ns_2: *Number of sessions per patient per week in SOHDU* 1 *and SOHDU* 2
Np_1 *and* Np_2: *Number of patients undergoing the treatment in SOHDU* 1 *and SOHDU* 2

The number of patient-days can be defined as the total number of days between the admission and discharge dates for each patient. Therefore, it is a measure of the average length of stay of a patient at a unit during a year (USC, 2002). In order to compute the number of patient-days, Abreu et al. (2013) defined it using the following formula:

$$(3) \qquad PD = Pat_{years} \times \frac{Ndays_y}{N_p}$$

Pat_{years}: *Number of patient − years*
$Ndays_y$: *Number of days in a year*
N_p: *Number of patients*

As one has access to different studies, one needs to compute the weighted average for the number of patient-days at the SCH and the SCPD. Formula 4 will be used in order to do so:

$$(4) \qquad PD_{SC} = \sum_1^i \%w_i \times PD_i$$

$$(5) \qquad w_i = \frac{Np_i}{TP}$$

TP: *Total number of patients in all units*

The average period of time that a patient spends on treatment needs to be calculated as well, as it will define the average length of time patients spend at the SCH and SCPD before being out of the treatment. To compute the average period of a dialysis treatment, there is the need to know the data related to the number of patients that were undergoing the treatment

in the beginning and in the end of each year. It is also needed to take into consideration that the difference between the values given in the beginning of the year and the ones got at the end of the year is not directly related to the amount of patients that died and, therefore, to the mortality rate. There are four reasons that may lead to the end of a dialysis treatment: it can be either due to death, which is the most common reason, to kidney transplantation, to a change in the type of treatment (either from hemodialysis to peritoneal dialysis or vice-versa), to abandonment of the treatment or due to recovery (Macário, 2013).

The formula used to compute the average period of a dialysis treatment is given by:

(6) $$AN_p = \frac{(Pt(b)+Pt(e))/2}{Pt(o)}$$

(7) $$Pt(o) = Pt(d) + Pt(t) + tP(ct) + Pt(a)$$

$Pt(b)$: *Number of patients undergoing the treatment in the beginning of the year*
$Pt(e)$: *Number of patients undergoing the treatment in the end of the year*
$Pt(o)$: *Number of patients that stopped the treatment during the year*
$Pt(d)$: *Number of patients that died during the year*
$Pt(t)$: *Number of patients that were submitted to a renal transplant during the year*
$Pt(ct)$: *Number of patients that changed the type of treatment during the year*
$Pt(a)$: *Number of patients that recovered or abandoned the treatment during the year*

3.2 Standard Clinic for Hemodialysis: Cost definition

In order to define the standard clinic for the hemodialysis treatment, there are some recommendations given by the Best Practices Manual (OM, 2011) that should be taken into consideration, apart from considering facilities as private or state owned.

The costs that a unit has with drugs represent a significant percentage of its total costs. The drug protocol was analysed in general terms, taking into consideration the list of drugs included in the comprehensive price. The price of each drug was provided by two private units that provide dialysis treatments and that did not authorize the revelation of the source. These costs were assessed according to the prices they pay to the suppliers.

In some cases, the number of drugs taken is not well defined. Hence, in order to compute the annual consumption of drugs, one needs to consider the sample provided in Deloitte (2008) and to get the estimated value for the daily dosage, which will be used after to assess the current costs. The following formula helps to compute the proportion of drugs taken per day (daily dosage):

(8) $$DD = \frac{Cons_{ys}}{D_s} \times \frac{1}{N_{ps}}$$

$Cons_{ys}$: *Annual Consumption of the sample*
D_s: *Number of days considered in the sample*

To calculate the consumption per type of drug per year in the SCH, one uses the information got from the previous formula and applies the following one:

(9) $$Cons_y = DD \times D_y \times N_p$$

DD: *Daily dosage proportion of drugs*
D_y: *Number of days considered in a year*

In order to compute the annual costs of the different classes of drugs, it is necessary to assess the annual costs for each drug and then sum the values for the ones that belong to the same class. The computations needed are present in the following formula:

(10) $$AC_{class} = \sum_{i=1}^{d} C_{drugy} = \sum_{i=1}^{d} Cons_{yi} \times U_{pi}$$

C_{drugy}: *Annual Costs for drugs belonging to a specific class*
d: *Total number of drugs that belong to a given class*
U_{pi}: *Unit price*

The total annual costs are then given by:

(11) $$TAC = \sum_{i=1}^{d} AC_{classi}$$

Finally, to assess the cost per patient per day, it is necessary to use the subsequent formula:

(12) $$C_{pd} = \frac{TAC}{PD} \times \frac{1}{N_p}$$

There is a list of auxiliary diagnostic and therapeutic means that are required for hemodialysis patients with a given periodicity and that are included in the comprehensive price. These auxiliary diagnostic and therapeutic means can have a different periodicity, depending on their final goal and need. The values for the cost of each auxiliary diagnostic and therapeutic mean were taken from DR (1.ª série — N.º 20 Diário da República, 2014).

In some cases the periodicity may not be well defined, as some ADTM may be needed at a casual basis. When that is the case, one needs to consider the sample provided in Deloitte (2008) in order to assess the value for the annual periodicity. The following formula allows the computation of the periodicity in those cases:

(13) $$P_t = \frac{AC_S}{U_{ps}} \times \frac{1}{N_{pts}}$$

AC_s: *Annual Cost of the sample*
N_{pts}: *Number of patients undergoing a hemodialysis treatment in the sample*

In order to compute the annual costs of the different ADTM areas, it is necessary to assess the annual costs for each ADTM and then sum the values for the ones that belong to the same area. The computations needed are present in the following formula:

(14) $$AC_{area} = \sum C_{ADTMi} = \sum_{i=1}^{m} P_{ti} \times U_{pi} \times N_p$$

The number of personnel working at a unit is established by the Portuguese legislation (1.ª série — N.º 231 Diário da República, 2013) and guided by the Best Practices Manual (OM, 2011). To compute the number of total hours of work per week for a type of professional, one uses the following formula:

(15) $$N_{hours} = \frac{N_p}{K} \times h$$

K: *Constant that represents the ratio of patients per weekly hour of work*
h: *Number of weekly hours of work taking into consideration K*

The cost per hour of each professional does not depend solely on his salary as there are other expenses that the company is charged for. Besides the monthly salary, one needs to consider also the one-twelfth for the Christmas and Holiday bonuses, the contributions for Social Security, the insurance against accidents at work, the food allowance and extra costs such as training expenses and medical assistance. Hence, to compute the costs per hour, one uses the given formula:

(16) $$\mathrm{C_h} = \frac{\left(\sum_{i=1}^{4} \mathrm{GS} * \%\mathrm{t_i} * \frac{\mathrm{N_{mb}}}{\mathrm{N_m}}\right) + \mathrm{FA}}{\mathrm{Nwd}} \times \frac{1}{\mathrm{Nhd}}$$

GS: *Gross salary*
$\%t_i$: *Tax applied*
N_m: *Number of months in a year*
N_{mb}: *Number of months considering bonuses*
N_{wd}: *Number of working days in a month*
N_{hd}: *Number of working hours per defined by legislation*

Then, to compute the annual costs per professional, one uses the following formula:

(17) $$\mathrm{AC_p} = \mathrm{N_{hours}} \times \mathrm{C_h} \times \mathrm{w} \times \mathrm{N_m}$$

w: *Number of weeks in a month*

The indicative number of professionals for each profession is given by:

(18) $$\mathrm{N_{prof}} = \frac{\mathrm{N_{hours}}}{\mathrm{N_{hd}}}$$

These formulas will allow estimating the costs that each type of professionals represent to the standard unit SCH, related to the salaries they receive and the number of hours they work.

The consumables play an important role in a dialysis treatment. To compute the annual consumption we need to evaluate the number of times each consumable is needed per year as some are used every dialysis session, but others have a different periodicity. Given this, considering the average number of sessions per patient per year, it is possible to compute the annual consumption of each consumable. The prices of each consumable were supplied by a PPDU that belongs to one of the biggest hemodialysis providers in Portugal but whose source will be kept confidential. To compute the annual consumption, one uses the following formula:

(19) $$Cons_y = Cons_s \times S_y \times N_p$$

$Cons_s$: *Consumption per session of each consumable*
S_y: *Number of hemodialysis sessions per year*

Finally, to calculate the total costs, one uses the result for the annual consumption and the unit price of each consumable:

(20) $$AC_{consumable} = Cons_y \times U_p$$

Lastly, after knowing the annual costs and considering the number of patients that undergo the treatment at the SCH and the average number of days of treatment, it is possible to compute the cost per patient per day using formula (12).

Besides the costs related to the treatment, there are other expenses that have to be considered. In order to compute the rent, it is necessary to take into account the area of the SCH, as well as the price of the rent. According to Paiva (2002) in each dialysis station there should be space for a nurse, for mobility and for privacy so one should consider an area of 7.84m^2 for each station. Also, according to the same author it is necessary to consider an area of 18m^2 for the reception. A study conducted by the NHS, suggests that 16.5m^2 are occupied by the room for medical appointments and 12m^2 are occupied by a room for other treatments rather than the hemodialysis session (NHS, 1996). Also, according to Kronborg (2010), a dialysis unit has to have changing rooms, offices and

other appurtenant facilities. Therefore, to assess the total area of a unit, one uses the subsequent formula:

(21) $TA_{unit} = A_{otherfac} + TA_{stations}$

Finally, to compute the total rent paid by the unit in a year (AC_{rent}), one uses the following formula:

(22) $AC_{rent} = TA_{unit} \times P_{sm} \times 12$

As stated by Gomes, costs with building maintenance and unexpected corrective interventions represent between 2 to 5% of the total costs (Gomes, 1992). Therefore, to compute the costs with the building maintenance one is going to consider a percentage of the rent as shown in the following formula:

(23) $OC_{maint} = 5\% \times AC_{rent}$

Costs with security and insurance also have to be considered. To assess the costs with security, one has evaluated the prices for the central of fire detection and intrusion control. After having these values, one has to consider the depreciation rate for other machines and appliances, which is 14.28%. Besides the cost with the centrals, there is also a monthly fixed cost with the security company. The values assessed for both the centrals and its installation were the ones that were assessed from a contract with Prosegur. The following formula allows the computation of the annual costs with security:

(24) $AC_{security} = C_{sc} \times D_r + N_m \times M_{fee}$

C_{sc}: *Costs with the security central*
D_r: *Depreciation rate*
M_{fee}: *Monthly fee paid to the security company*

After contacting a specialist from an insurance company named Seguro Plus, one had access to the costs that a clinic might face with insurance. These costs include a fixed value (called the company's civil responsibility) and a variable value that depends on the materials and furnishings that the SCH has and is computed considering a specific constant of $\frac{1.5}{1000}$ (called the multi-risks component). The following formula represents the annual cost with insurance:

(25) $OC_{insurance} = FV + \frac{1.5}{1000} \times VV_{mat}$

VV_{mat}: *Variable value related with the materials and furnishings of the SCH*

Costs such as the ones with work material and the administrative costs are related to the number of personnel working at the unit. As for the expenses with meals, communication, waste and other medical products, these are related with the number of patients treated at the SCH Therefore, in order to compute them, one needs to take into consideration the proportion between the number of professionals operating in the clinics from the EY (2012) and the costs for each of the items and do the same for the number of patients. However, in order to analyse the annual costs of the sample, it was necessary to bring them to their present value, considering the consumer price index (i). Therefore, one needs to compute the average inflation rate using the following formula:

(26) $i_a = \prod_{j=1}^{n} (1 + i)^j$

So, to calculate the costs that are related to the number of professionals and patients working at the clinic, one uses these formulas:

(27) $OC_{pp} = \frac{C_{si} * N_{pp}}{N_{pps}}$

(28) $C_{si} = C_s \times (1 + i_a)^n$

C_{si}: *Annual costs in the sample, taking into consideration the inflation rate*
N_{pp}: *Number of professionals or patients at the clinic*
N_{profs}: *Number of professionals or patients in the sample*

The hygienic products expenses depend on both the number of patients and professionals. As for the accounting expenses, one has looked at the structure of the total costs with services related to auditing, factoring and consultancy present at the Annual report of a Health Care Entity (JMS, 2014). Given their total expenses and the amount spent with auditing, it is possible to conclude that 32.5% of the total costs are related to it. Therefore, to assess the accounting costs for the SCH one will take into consideration the values provided by EY (2012) and use the following formula:

(29) $OC_{account} = 32.5\% \times C_{si}$

Hemodialysis patients are exposed to between 300 and 400 litres of hemodialysis fluids per week during their sessions (Canaud & Mion, 1996). Given this, the units have to be aware that it will have a great impact in their costs, not only because of the amount of water used in each hemodialysis session but also because of its indispensable treatment. To compute the annual cots with water, one uses the following formula:

(30) $AC_{wat} = ACons_{wat} \times U_p = Cons_w \times w \times N_m \times N_p \times U_p$

$Cons_w$: *Consumption of water per week*
w: *Number of weeks in a month*

As for the electricity, one needs to consider the main devices that consume energy in the clinic, which include the hemodialysis machines, illumination, air conditioning, computers and television. The total annual costs are then given by a fixed and a variable component. Therefore, these two items need to be considered when assessing the values:

(31) $TC_E = P_{day} \times N_y + P_{kWh} \times \sum_{i=1}^{n} E \times N_m$

P_{day}: $Fixed\ price\ per\ day$
N_{days}: $Number\ of\ days\ in\ a\ year$
P_{kWh}: $Price\ per\ kWh$
C_E: $Annual\ consumption\ of\ energy$

In order to be able to provide the treatment at the same time to a number of patients, the SCH has to have more than one set of hemodialysis equipment, which is constituted by the machine and a chair. Besides this, given that the quality of the water used to dilute the concentrated dialysate fluid is of an extreme importance as it is going to be in contact with the patient's blood, one needs to consider the costs incurred with a water treatment system (Canaud & Mion, 1996). The cost per equipment was provided by a confidential source. The depreciation rates (D_r) considered for each type of equipment are the ones stated in the DR (1.ª série — N.º 178 Diário da República, 2009). With this information it is then possible to estimate the annual costs for each type of equipment. To assess the annual costs that the SCH incurs with the equipment one uses:

(32) $AC_{equip} = Q \times U_p \times D_r$

Hemodialysis equipment maintenance is extremely important to certify that the treatment is being well-provided as studies show that the efficiency of a dialysis machine helps to assure a proper dialysis adequacy and that efficiency is related with a constant monitoring of the machines (Azar, 2009). As was stated by Singer et al. (1994) maintenance costs represent 10% per annum of the total value paid for the equipment. The following formula makes it possible to compute the annual costs:

(33) $AC_{maint} = U_p \times 10\% \times Q$

After estimating all these costs, it is possible to construct the costs structure for the unit. The structural costs include general management, information technologies and back-office areas such as finance, legal and human resources management issues (EY, 2012). Hence, as stated by Baboolal et al. (2007), structural costs represent 14.8% of the total costs, including interest expenses. In fact, the analysis of the EY (2012) shows that structural costs and financial costs account for around 16% of the total costs which is close to Baboolal et al.'s evaluation. Therefore, in order to assess the total costs and, consequently, the structural costs, one uses the following formula:

(34) $TC_{SCH} = OC + SC = OC + 14.8\% \times TC_{SCH}$

OC: $Operating\ Costs$
SC: $Structural\ Costs$

3.3 Standard Clinic for Peritoneal Dialysis: Cost definition

When it comes to peritoneal dialysis, the scenario is different. This type of treatment is performed at home by independent users but they still need to go to the SOHDU periodically.

Although there are differences in the drugs taken in a peritoneal dialysis treatment in comparison to hemodialysis, these are not very significant so the costs that the SCPD has with drugs represent a big portion of its total costs as well. In order to compute the cost per patient, one considers the drug protocol for this treatment and afterwards uses the same methodology as for the SCH.

In what concerns the ADTM, the needs of peritoneal dialysis patients are very similar to the needs of hemodialysis patients. Therefore, the cost structure and its values will be identical and assessed as mentioned in section 3.2.

With the purpose of providing the services defined in this scenario, the clinic needs to have different personnel working there. However, as peritoneal dialysis treatments are mainly performed at home, there is no need to have such a wide number of staff at a unit. Although the number of Human Resources needed to work at the company is smaller, the cost structure is computed in the same way as for the SCH.

Once again, the consumables play an important role in a dialysis treatment. This time, the consumables needed are very different from the ones used in hemodialysis treatments. In the standard protocol for a SOHDU, the consumables' structure is defined so it is possible to estimate the consumption per type of consumable considering the values from Deloitte (2008). The values got for the price of each consumable were assessed through the product catalogue of one of the biggest manufacturers, which is Baxter (2012). However, as these prices are in US dollars and are from 2012, it is necessary to consider the inflation rate in the USA for the years 2013 and 2014 and use the exchange rate from US dollar to Euro. Therefore, to compute the current price in euros

($P_€$) for each consumable, one uses formula (26) to compute the inflation rate between 2013 and 2014 and then the following formula:

(35) $$P_€ = P_\$ \times (1 + i_a) \times e_r$$

e_r: $Exchange\ rate\ from\ USD\ to\ EUR$

After assessing the unit price for each consumable, one computes the annual costs using the same methodology as for the SCH.

Also for the SCPD, besides the costs related to the treatment, there are other expenses that have to be considered. In order to compute the rent, one uses the same approach as for the SCH but this time does not consider the space needed for the dialysis stations. The same applies to the maintenance costs, which will be smaller in this case because of a difference in the size of the unit. The cost structure for expenditures with security, insurance, communications, waste and other medical products will be similar in this case, as one is considering the same amount of patients in both units. However, expenses with work material, hygiene products and administrative costs will be different. To compute these costs one uses the same formulas (26), (27), (28) and (29) as before. In this case there are no patient meals as the treatments are performed at home.

In the case of peritoneal dialysis, costs with electricity and water are reduced as the treatment is performed at home so there are no dialysis machines and water treatment related costs. Although the final values will be lower, to compute the annual cost with water and electricity, one uses the same methodology as before.

As there are no costs with equipment and with its maintenance, one can now compute the total operating costs for the SCPD. To compute the total costs, it's necessary to use formula (34), considering the same structure as before as stated by Baboolal et al. (2007).

3.4 Formulas for result analysis

In order to make it possible to analyse and compare the results and given the fact that the comprehensive price is a price per week, one needs to consider the cost per patient per week of treatment. As the number of patient days is not the same as the number of days in a year either for the SCH as for the SCPD, one can use the following formula to assess the number of days of treatment in a week (considering 52 weeks in a year:

(36) $$N_{DPw} = \frac{N_{pd}}{52}$$

This value and the costs per patient per day, make it possible to assess the cost per patient per week, through the given formula:

(37) $$C_{pw} = N_{DPw} \times C_{pd}$$

To compare the obtained result with other studies, one needs to put all the values in the same units. Therefore, it is necessary to compute the present value of the annual costs per patient, meaning that one needs to assess the yearly consumer price index since the date the study was released to the present. As in some cases, the annual costs are not available in euros it is mandatory to consider the current exchange rate between currencies.

Taking into consideration the average period of treatment, one can measure the total cost that each patient represents for the clinics. Considering that the annual costs will increase with the inflation rate, one can evaluate the cost for each year. Then, to compute the present value of the overall treatment, it's necessary to take into account the discount rate for the health sector, which is r=5% (Ferreira, 2013) and use formula (38). The constant *n* depends on the type of treatment that is being considered. For hemodialysis treatments, *n* corresponds to the average period of treatment for this type of treatment and the same applies to peritoneal dialysis.

(38) $$PV_{CPT} = \sum_{i=1}^{avt} \frac{TC_n}{(1+r)^n}$$

avt: $Average\ period\ of\ treatment$
TC_n: $Total\ Costs\ in\ year\ n$

4 Application and Data Analysis

4.1 Values for the model parameters

After applying the methodology defined in 3.1 and taking into consideration the characteristics of the EY (2012) and the Deloitte (2008) units, one has assessed the values present in Table 1. These values will allow the definition of the cost structure for both the SCH and the SCPD.

Table 1 - Model Parameters

Parameter	Hemodialysis	Peritoneal dialysis
Number of treatments per patient per week	3.15	7
Number of patients	120	120
Number of patient days in a year	296.19	295.73
Average period of treatment	5.49	2.94

4.2 Results analysis

After applying the methodology to each of the cost items for both the SCH and the SCPD, one got the results present in Table 2. It is possible to see that, contrarily to what was mentioned in the literature review, the costs for peritoneal dialysis are higher than the costs for hemodialysis. This is mainly given by the high price of the consumables for the SCPD. In order to make the costs per patient per day comparable to the comprehensive price and to compare and evaluate the results available in other studies, one needs to consider the cost per patient per week, using formulas (36) and (37). In the case of the SCH, the patient week has 5.696 days and the total cost per patient per week is 410.75€. For the SCPD, the patient week has 5.687 days and the total cost per patient per week is 715.69€.

Table 2 - Total Cost Structure for the SCH and the SCPD

	SCH			**SCPD**		
	Annual Cost (€) (A)	**Percentage of the total costs (B)**	**Cost per patient per day (€) (C)**	**Annual Cost (€) (A)**	**Percentage of the total costs (B)**	**Cost per patient per day (€) (C)**
Operational and general costs [1]						
Drugs [2]	773 651.84	30.18%	21.77	526 736.25	11.79%	14.84
ADTM [3]	115 747.97	4.52%	3.26	114 998.95	2.57%	3.24
Human Resources [4]	358 185.60	13.97%	10.08	249 500.16	5.59%	7.03
Consumables [5]	658 215.79	25.68%	18.52	2 833 167.05	63.44%	79.84
Other costs [6]	113 468.06	4.43%	3.19	75 665.54	1.69%	2.13
Water and electricity [7]	32 631.23	1.27%	0.92	3 949.04	0.09%	0.11
Maintenance [8]	53 000	2.07%	1.49	-	-	-
Operating costs without amortization/ depreciation [9]	2 104 900.49	82.12%	59.22	3 804 016.59	85.18%	107.19
Amortization/Depreciation [10]	78 831.60	3.08%	2.22	999.60	0.02%	0.03
Operating costs [11]	2 183 732.09	85.20%	61.44	3 805 016.59	85.20%	107.22
Structural costs [12]	379 333.74	14.80%	10.67	660 965.32	14.80%	18.63
Total costs [13]	2 563 065.83	100%	72.112	4 465 981.91	100%	125.846

After comparing the annual and weekly costs per patient for the SCH with the ones obtained in other studies and the comprehensive price (Tables 1 and 2 from Annex 1) one can conclude that the weekly cost per patient assessed throughout using the methodology described is lower than the results got in other countries and in different years. This can be explained by the fact that one is comparing countries with different costs of living, which has a repercussion in the cost structure, and that one has considered the inflation rate to assess the current costs (in 2014) but as not considered possible changes in costs that may have occurred over the years. However, the result got using this methodology is similar to the ones got in other units in Portugal. To assess these costs, one has considered the Portuguese consumer price indexes over the last years to extrapolate them to the year 2014. Hence, it is possible to see that all the costs measured are below the comprehensive price. Nevertheless, it is important to note that this comprehensive price has not changed since it was applied (in 2012), so in the future it is most likely that the inflation rate will force the weekly cost per patient to exceed the comprehensive price value. Therefore, this should be taken into consideration by the SNS, as it may have to be adapted eventually.

As for the annual and weekly costs per patient for the SCPD (present in Tables 3 and 4 from Annex 1), one can conclude that the weekly cost per patient assessed throughout the development of this study is similar to some of the results got in other countries and in different years. However, there are some discrepancies in comparison with other results. Once again, one has considered the inflation rate to assess the current costs (in 2014) but as not considered possible changes in costs that may have occurred over the years. Comparing with the values got for the Portuguese units, all the weekly costs are above the comprehensive price. Therefore, one can state that peritoneal dialysis ends up being more expensive for the unit than hemodialysis. However, literature review

has showed that peritoneal dialysis treatments are perceived as being cheaper than hemodialysis treatments, something that wasn't assessed during the development of this report and also in Deloitte (2008). Although the structural costs and part of the operating costs are cheaper in the case of peritoneal dialysis, it is shown that in the end this treatment was more expensive. This is mainly due to the fact that consumables represent 63.44% of the total costs and are very costly for this type of treatment. The values got from Baxter (2012) were very expensive, especially taking into consideration that a patient needs to use the solution bags and other consumables more than once a day. However, one should take into consideration that SOHDU and PPDU can usually negotiate these prices when ordering massive quantities and hence, pay less for these consumables. A way to surpass this issue is to review the policy for these items and, as mentioned, make an effort to negotiate this price in order for it to be as low as possible.

After conducting a sensitivity analysis for the SCH, considering changes of ±10% and ±20% in the annual cost with drugs and consumables, it is possible to conclude that these don't have a significant impact in the final value (see Tables 5 and 6 from Annex 2). These percentage changes do not translate into big fluctuations in the total annual costs, which are relatively insensitive to changes in the price of drugs and the price of consumables. However, as expected, one can conclude that a change in the cost of drugs has more impact in the final expenses than a change in the costs with consumables.

After making the same alterations in the total annual costs for the SCPD (present in Tables 7 and 8 from Annex 2), one can conclude that these changes translate into a significant difference in the total annual costs, in the case of consumables. This behaviour was expected as the weight that the consumables have on the total annual costs is significant (it represents 63.44% of the total costs). As for the changes in the costs with drugs, these will not have a significant impact in the final expenses.

After analysing these results, it is possible to conclude that the total annual costs are relatively insensitive to changes in the price of drugs but are sensitive to changes in the price of consumables. Therefore, one can state that by altering the price of consumables, manufacturers have a great power over their clients and, consequently, over the Portuguese state, which is the entity paying for these treatments. Therefore, negotiating better prices with suppliers would allow making peritoneal dialysis a less expensive treatment.

Considering the average period of treatment, one can measure the total cost that each patient represents for the clinic using formula (38) and considering the Eurostat Forecast for the Consumer Price Index in Portugal. In the case of hemodialysis treatments, the present value of the total costs that the SCH incurs with a patient during the average period of treatment is 112 470.79€. In the case of peritoneal dialysis treatments, the present value of the total costs that the SCPD incurs with a patient during the average period of treatment is 102 906.45€.

5 Conclusions

Dialysis treatments represent a big portion of the Portuguese State expenditures with the Health sector.

Given the importance of the expenses with hemodialysis and peritoneal dialysis treatments, one has developed this work to assess the real expenses that a unit has with its patients and with all the materials and features that it needs to be able to provide these treatments. In order to do so, it was necessary to evaluate all cost components and measure its importance and values to assess a final result. One has concluded that clinics have to consider different costly items when evaluating their income statements and that some of the operational and structural costs have a huge impact in the final results.

By the analysis of the results, it is possible to see that, in the case of hemodialysis treatments, the comprehensive price is well applicable to Portugal, as the costs show a lower weekly cost per patient than the comprehensive price, giving leeway for the clinics to provide the treatments correctly. However, in the case of peritoneal dialysis, it is perceptible that the weekly costs per patient are much higher than the comprehensive price, mainly due to the negative impact that the price of consumables has on the expenditures. In this case, the comprehensive price should be reviewed to meet the actual needs of providers. Also, hemodialysis and peritoneal dialysis should be financed differently, according to the cost structure of each treatment. Although peritoneal dialysis treatment has a huge potential, it is not being used at its best due to the high costs that clinics have with it.

6 References

Abreu, M. M., Walker, D. R., Sesso, R. C., & Ferraz, M. B. (2013). A Cost Evaluation of Peritoneal Dialysis and Hemodialysis in the Treatment of End-Stage Renal Disease in São Paulo, Brazil (Vol. 33): International Society for Peritoneal Dialysis.

ACSS. (2013). Hemodiálise 2011-2013 *Relatório de Acompanhamento de Actividade*: Departamento de Gestão e Financiamento de Prestações de Saúde.

Azar, A. T. (2009). The influence of maintenance quality of hemodialysis machines on hemodialysis efficiency *Saudi Journal of Kidney Diseases and Transplantation* (Vol. 20, pp. 49).

Baboolal, K., McEwan, P., Sondhi, S., Spiewanowski, P., Wechowski, J., & Wilson, K. (2007). The cost of renal dialysis in a UK setting - a multicentre study.

Baxter. (2012). Price List and Product Catalog.

Canaud, B. J. M., & Mion, C. M. (1996). Water Treatment for Contemporary Hemodialysis (Vol. Replacement of Renal Function by Dialysis).

CEGEA. (2007). Estrutura de Mercado e Performance nos Serviços de Hemodiálise em Portugal: Universidade Católica Portuguesa.

Deloitte. (2008). Estudo de custeio de cuidados de diálise em centros de elevada diferenciação em Nefrologia: Administração Central do Sistema de Saúde.

Diário da República, s. N. (2009). *Tabela 1 - Taxas específicas*.

Diário da República, s. N. (2011). *Despacho n.º 10569/2011*.

Diário da República, s. N. (2013). *Portaria n.º 347/2013*.

Diário da República, s. N. (2014). *Portaria n.º 20/2014*.

Dratwa, M. (2008). Cost of home assistance for peritoneal dialysis: Results of a European survey *Kidney International*.

EY. (2012). Panorama da IRCT em Portugal: Ernst & Young.

Ferreira, L. N. d. N. e. (2013). Avaliação Económica no Sector da Saúde.

Gomes, J. (1992). Metodologia para a Manutenção e Exploração de Edifícios *Dissertação para obtenção do grau de mestre em construção*: Instituto Superior Técnico.

Grün, R. P., Constantinovici, N., Normand, C., & Lamping, D. L. (2003). Costs of dialysis for elderly people in the UK *Nephrol. Dial. Transplant. (2003)*.
Hirth, R. A., Greer, S. L., Albert, J. M., Young, E. W., & Piette, J. D. (2008). Out-Of-Pocket Spending And Medication Adherence Among Dialysis Patients In Twelve Countries: Health Affairs.

JMS. (2014). Relatório e Contas: José de Mello Saúde.

Just, P. M., Riella, M. C., Tschosik, E.A., Noe, L. L., Bhattacharyya, S. K., Charro, F. (2008) Economic evaluations of dialysis treatments modalities.

Karopadi, A. N., Mason, G., Rettore, E., & Ronco, C. (2013). Cost of Peritoneal Dialysis and Haemodialysis Across the World *Nephrology Dialysis Transplantation, Oxford Journals*.

Komenda, P., Gavaghan, M. B., Garfield, S. S., Poret, A. W., & Sood, M. M. (2011). An economic assessment model for in-center, conventional home, and more frequent home hemodialysis *Kidney International*.

Kronborg, C., Kjaer, T., & Bech, M. (2010). Cost analysis of establishing dialysis facilities for the treatment of chronic renal failure in Greenland.

Macário, F. (2013). Relatório Gabinete de Registo da SPN - Tratamento Substitutivo Renal da Doença Renal Crónica Estadio V em Portugal: Sociedade Portuguesa de Nefrologia.

NHS. (1996). Satellite Dialysis Unit *Health Building Note 53*: National Health Service.

OM. (2011). Manual de Boas Práticas de Diálise Crónica. In C. d. E. d. Nefrologia (Ed.): Ordem dos Médicos.

Paiva, C. (2002). Estudo sobre unidades de hemodiálise. In D.-G. d. I. e. E. d. Saúde (Ed.): Ministério da Saúde.

Saran, K. A. & Sabry, A. (2012). The cost of hemodialysis in a large hemodialysis center, *Saudi Journal of Kidney Diseases and Transplantation 2012*

Sennfält, K., Magnusson, M., & Carlsson, P. (2002). Comparison of Hemodialysis and Peritoneal Dialysis - A Cost-Utility Analysis. Sweden: International Society for Peritoneal Dialysis.

Singer, M., Myers, S., Hall, G., Cohen, S. L., & Armstrong, R. F. (1994). The cost of intensive care: a comparison on one unit between 1988 and 1991. *Intensive care medicine, 20*(8), 542-549.

Suhrcke, M., Nugent, R. A., Stuckler, D., & Rocco, L. (2006). Chronic Disease: An Economic Perspective. In L. O. H. Alliance (Ed.).

USC. (2002). Glossary of Healthcare Terms Used by OSHPD Hospital and Healthcare Data Programs: University of Southern California.

USRDS. (2013). USRDS 2013 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States (N. I. o. D. a. D. a. K. Diseases, Trans.). In U. S. R. D. System (Ed.): National Institutes of Health.

Vanholder, R., Davenport, A., Hannedouche, T., Kooman, J., Kribben, A., Lameire, N. (2012). Reimbursement of Dialysis: A Comparison of Seven Countries.

Vonesh, E. F., & Moran, J. (1998). Mortality in End-Stage Renal Disease: A Reassessment of Differences between Patients Treated with Hemodialysis and Peritoneal Dialysis.

Annex I

Table 1 - SCH: Comparison of annual and weekly costs per patient

Study	SCH (€)	Baboolal et al. (2008) (€)	%	Saran and Sabry (2012) (€)	%	Grün et al. (2003) (€)	%	Komenda et al. (2011) (€)	%
Annual cost per patient	21 358.88	47 763.76		38 205.07		42 305.73		36 252.11	
Weekly cost per patient	410.75	918.54	+123.6	734.72	+78.9	813.58	+98.1	697.16	+69.7

Table 2 - SCH: Comparison of annual and weekly costs per patient, considering Portuguese examples

Study	SCH (€)	Comprehensive Price (€)	%	EY (2012) (€)	%	HSJ (Deloitte, 2008) (€)	%	HUC (Deloitte, 2008) (€)	%
Annual cost per patient	21 358.88	23 435.36		22 343.35		20 928.39		21 169.67	
Weekly cost per patient	410.75	450.68	+9.7	429.68	+4.6	402.47	-2.02	407.11	-0.9

Table 3 - SCPD: Comparison of annual and weekly costs per patient

Study	SCPD (€)	Baboolal et al. (2008) (€)	%	Dratwa (2008) (€)	%	Grün et al. (2003) (€)	%
Annual cost per patient	37 216.52	25 441.33		25 423.88		38 163.99	
Weekly cost per patient	715.69	607.20	-15.2	488.91	-31.7	733.91	+2.5

Table 4 – SCPD: Comparison of annual and weekly costs per patient, considering Portuguese examples

Study	SCPD (€)	Comprehensive Price (€)	%	HSJ (Deloitte, 2008) (€)	%	HUC (Deloitte, 2008) (€)	%
Annual cost per patient	37 216.52	23 435.36		35 800.68		25 704.6	
Weekly cost per patient	715.69	450.68	-37.0	688.46	-3.8	494.31	-30.9

Annex II

Table 5 - SCH: sensitivity analysis for the costs with drugs

	SCH	**-10% AC_{drugs}**	**+10% AC_{drugs}**	**-20% AC_{drugs}**	**+20% AC_{drugs}**
Annual Cost Drugs (€)	773 651.84	696 286.66	851 017.02	618 921.47	928 382.21
Total Annual Costs (€)	2 563 065.83	2 472 261.63	2 653 870.04	2 381 457.42	2 744 674.25
% change in the annual cost		-3.54	+3.54	-7.09	+7.09
Weekly cost per patient (€)	410.75	396.20	425.30	381.65	439.85

Table 6 - SCH: sensitivity analysis for the costs with consumables

	SCH	**-10% AC_{cons}**	**+10% AC_{cons}**	**-20% AC_{cons}**	**+20% AC_{cons}**
Annual Cost Consumables (€)	658 215.79	592 394.21	724 037.37	526 572.63	789 858.95
Total Annual Costs (€)	2 563 065.83	2 485 810.46	2 640 321.21	2 408 555.08	2 717 576.58
% change in the annual cost		-3.01	+3.01	-6.03	+6.03
Weekly cost per patient (€)	410.75	398.37	423.13	385.99	435.51

Table 7 - SCPD: sensitivity analysis for the costs with consumables

	SCH	**-10% AC_{cons}**	**+10% AC_{cons}**	**-20% AC_{cons}**	**+20% AC_{cons}**
Annual Cost Consumables (€)	2 833 167.05	2 549 850.35	3 116 483.76	2 266 533.64	3 399 800.46
Total Annual Costs (€)	4 465 981.91	4 133 450.57	4 798 513.26	3 800 919.23	5 131 044.60
% change in the annual cost		-7.45	+7.45	-14.89	+14.89
Weekly cost per patient (€)	715.69	662.40	768.98	609.11	822.27

Table 8 - SCPD: sensitivity analysis for the costs with consumables

	SCH	**-10% AC_{drugs}**	**+10% AC_{drugs}**	**-20% AC_{drugs}**	**+20% AC_{drugs}**
Annual Cost Drugs (€)	526 736.25	474 062.63	579 409.88	421 389.00	632 083.50
Total Annual Costs (€)	4 465 981.91	4 404 158.41	4 257 805.42	4 342 334.91	4 589 628.92
% change in the annual cost		-1.38	1.38	-2.77	+2.77
Weekly cost per patient (€)	715.69	705.78	725.60	695.87	735.50