ABSTRACT

Growing elder population and awareness in Turkey force to take some steps to hinder the increase in Chronic Kidney Failures (CKFs) one of the most serious illnesses in Turkey. Stages 1-3 are totally ignored in Turkey and no measures but approximations are taken to prevent further stages instead of accurate screening. Mainly last stages of CKF are tried to be cured by organ translation or dialysis. This study aims to understand the dynamics of CKF and to develop a performance measurement system for successes. To understand the kidney failures and treatments, Markov chains are used to create some models and find transition rates and probabilities. Bayesian networks are the most beneficial methods to estimate the costs and transitions from one stage of CKF to another stage. It is found that there are trends in increasing number of CKFs patients and private sector have been getting more share in the treatment of it. Cost decreasing is ignored and the main costs are supported by governments; hence, private hospitals are more willing to take last stages CKF patients. It is estimated with this trend that just 6,000 patients are expected to be transplanted and 4,484,630,000 $ will be spent country wide for 2021-2022 years for the treatment of just last stages.

Keyword: Chronic Kidney Disease, Markov Chains

INTRODUCTION

The increasing burden of CKF leads to governments to take some precautions. With transition probabilities, the treatment methods and stages are modelled by Bayesian Networks. Absorbing and steady-state probabilities are tried to be drawn. All treatments are compared to find the advantages and disadvantages of each treatment method. Statistical analysis is carried out to find trends of each treatment or possible patients. Data to validate the model are taken from Turkish Community of Nephrology, health ministry and some researches done in that field. Many researches are done in that field but they are lack of seeing all parts of CKF such as causes, stages, effects after treatments, and deaths due to CKF (Chronic Kidney Failure). All of these are in interaction and affect each other. By knowing the probability of one part, other probabilities can be estimated. Even, there are some international standards for some countries, they cannot represent all countries and there has not been an extensive study in Turkey to learn the number dialysis patients and costs but limited ones. Stages 1-3 are totally ignored in Turkey and no measures are taken to prevent further stages. The number of patients died from CKF has increased 19.7% from 2010 to 2012 as shown in Table 1. It means that 1348 more patients died in 2011, which can be explained by the increasing number of CKFs in one year. It is clear that the increased number of patients could not be decreased and the governments are not successful in decreasing the numbers. In 2012, 152 more CKFs
patients died and this can be seen as a success. CKFs have broad complications on the body even dialysed or transplanted.

**TABLE 1 DEATHS DUE TO RENAL FAILURES IN TURKEY (TurkStat, 2013)**

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>2010</th>
<th></th>
<th>2011</th>
<th></th>
<th>2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
<td>Female</td>
<td>Total</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Diseases of the genitourinary system</td>
<td>8725</td>
<td>4551</td>
<td>4174</td>
<td>10091</td>
<td>5260</td>
<td>4831</td>
</tr>
<tr>
<td>Diseases of kidney and urethra</td>
<td>7,842</td>
<td>3,986</td>
<td>3,856</td>
<td>9,196</td>
<td>4,690</td>
<td>4,506</td>
</tr>
<tr>
<td>Glomerular and renal tubulo-interstitial diseases</td>
<td>155</td>
<td>83</td>
<td>72</td>
<td>174</td>
<td>94</td>
<td>80</td>
</tr>
<tr>
<td>Renal failure</td>
<td>7,580</td>
<td>3,854</td>
<td>3,726</td>
<td>8,928</td>
<td>4,544</td>
<td>4,384</td>
</tr>
</tbody>
</table>

By modelling the CKFs, the performance of successes can be seen more clearly. Not avoiding of initial stages of renal failures results in progressing to end stages. Turkey has not been clear national strategy to decrease the CKFs in years with increasing number patients. The causes of CKF are many and by decreasing these causes, the numbers can be decreased. Modelling all dimensions is beneficial to see the load of all factors on human body and costs on governments.

**THEORETICAL BACKGROUND**

There are six types of treatment for end stage renal disease (ESRD): Haemodialysis (HD) - the cleaning of the blood from waste with three types named as home haemodialysis(HHD), limited care haemodialysis(LCHD), and full care centre haemodialysis(CHD), Kidney transplantation (TX), and Peritoneal dialysis (PD) with two types: continuous ambulatory peritoneal dialysis(CAPD) and continuous cycling peritoneal dialysis(CCPD). Kidney transplantation has the best result according to costs and effects of treatment. Haemodialysis leads to the highest cost per life year gained. (Ardine, 1998) In Turkey, there are three main treatments: HD, PD and TX. The increasing number of patients and their rate for each treatment are explained. Last two stages of CKF are the most serious ones and take more attention due to high amount of urine in blood.

**TABLE 8 AGES AND GENDER DISTRIBUTION OF CHRONIC HD PATIENTS DIED IN 2011(TSN, 2012)**

<table>
<thead>
<tr>
<th>Yaş / Age</th>
<th>Erkek Male</th>
<th>Kadin Female</th>
<th>Toplam Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>0–19</td>
<td>3</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>20–44</td>
<td>128</td>
<td>2.9</td>
<td>85</td>
</tr>
<tr>
<td>45–64</td>
<td>706</td>
<td>16.1</td>
<td>534</td>
</tr>
<tr>
<td>65–74</td>
<td>853</td>
<td>19.4</td>
<td>733</td>
</tr>
<tr>
<td>75+</td>
<td>737</td>
<td>16.8</td>
<td>606</td>
</tr>
</tbody>
</table>

**Total number of deaths**

2427 55.3 1959 44.7 4386 100.0
65-74 ages patients have the highest number of deaths with 36.6%. In generally, as the age increases, more people die representing with 95% deaths from 45+ ages. HD patients represent almost the half of deaths in 2011. More males die in that year than women with 55.3% as shown in Table 2.

Moderate CKF can be reversed or slowed down to go further stages by preventing and treating high blood pressure, diabetes, hyperlipidemi or other illness. (KC, 2013) End-stage kidney diseases cannot meet the functions of kidney and bloods need to be cleaned regularly.

Figure 1 Stages of Kidney disease (KHA, 2013)

It is stated that there are 7,307,315 people in 1-5 stages and 2,369,059 patients are in 3-5 stages in Turkey. (Süleymanlar et al., 2011) It was found that the cost of haemodialysis is 22,759 $ per year for each patient. (Yatkin, 2009) In 2012, 2,901 kidney transplantations were carried out. 2,377 of them were taken from human body and 524 were taken from dead body. 1,155 people died while waiting kidney transplant. 31 kidneys were rejected by receiver. It was found that kidney transplantation have been decreased when compared with previous year. (SP, 2013). End-stage renal disease (ESRD) identified and monitored timely for therapy has increased 4 times since 2000. (Süleymanlar et al., 2011) It was found that 98.2% of people are not aware of their CKF. The cost of HD, PD, TX first year, and TX second year is 22,759 $, 22,350 $, 23,393 $ and 10,028 $ per year in Turkey. In 2004, 830,000,000 $ was spent on CKF and it was 1,218,650,000 $ for 2006. 5% of health budget is spent on CKFs in Turkey. The cost of HD, PD and TX are 52,000 $, 45,000 $ and 18,000 $ respectively per year in USA. 28.3 billion $ was spent on CKF in USA in 2010. (Süleymanlar, 2012) PD is cheaper than HD in USA and in Turkey; these costs seem close to each other. The budget spent in Turkey is far away from USA budget on CKF.

It is found that haemodialysis session was about 169, 86 ₺ (Turkish Lira) for each time. About 2/3 haemodialysis patients have been cured in private hospitals. These costs are mainly supported by government insurance (SGK). It was stated that the government could not take all patients and the role of private hospitals is very important in that illness. Quality of life and living years are crucial parameters for the treatment. In last 15 years, the public share has decreased from 71% to 30 %. Especially after 2004, there is an increasing trend in the share of private hospitals. (DIADER, 2009) In this way, public hospitals stay behind the private sector. Even private hospitals are good at dialysis; they take some extra money besides government payment. Middle class or poor people may not pay that extra payment even though many improvements have been done to close that gap in last 10 years. Over time, private hospitals see the insured patients supported by governments partly as way of getting more profit. The increasing numbers of patients are expected to be treated by governments.
Figure 2 the percentage of public and private institutions haemodialysis patients treated over the years (Tatar, 2012)

It was found that %33.2 of costs is personal and %28.1 of costs comes from raw materials and supplies expenses. The payment of dialysis is done by governments insurance. In 2010 and 2011, 145 ₺ was paid per session for HD to private hospitals. Furthermore, the cost of per session was 163.5 ₺ for private hospitals, which is higher than session paid by SGK (Tatar, 2012). It is an important finding that the costs paid by governments cannot meet the cost of private hospitals. Even that, the CKFs at private hospitals has increased. The question is that whether the private sector shows higher costs to get more payments from governments or not. From interviews with some health staff, it was empathized that private hospitals are more profit centered organizations and this seem as an obstacle in improving the health sector in Turkey. They provide better service than public hospitals in many ways, but high profit orientation can be managed by some people and others have to go public hospitals. This creates inequality in the treatments of patients in the country while some people get better service than others.

**TABLE 3 AVERAGE UNIT COST ANALYSIS RESULTS (₺) (Tatar, 2012)**

<table>
<thead>
<tr>
<th>Dialysis Centres</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Expense Amount</td>
<td>166,415,560</td>
<td>163,419,945</td>
<td>169,534,935</td>
</tr>
<tr>
<td>Total Number of Patients</td>
<td>7,102</td>
<td>6,861</td>
<td>7,017</td>
</tr>
<tr>
<td>Total Number of Machines</td>
<td>1,818</td>
<td>1,820</td>
<td>1,888</td>
</tr>
<tr>
<td>Total Number of Sessions</td>
<td>1,018,712</td>
<td>996,057</td>
<td>1,036,879</td>
</tr>
<tr>
<td>Average Unit Cost-Patient</td>
<td>23,432,2</td>
<td>23,818,7</td>
<td>24,160,6</td>
</tr>
<tr>
<td>Average Unit Cost-Machine</td>
<td>91,537,7</td>
<td>89,791,2</td>
<td>89,796</td>
</tr>
<tr>
<td>Average Unit Cost-session</td>
<td>163,4</td>
<td>164,1</td>
<td>163,5</td>
</tr>
</tbody>
</table>

*In 2009, 75 centres of cost analysis were conducted, 70 centres were done in 2010 and 2011*

Increasing the availability of different treatments is seen as quality indicators. PD and HD having different pros and cons are two main treatment methods almost in all countries. Providing home treatments options will bring more flexibility. Turkey is behind developed countries at PD. New Zealand provides 56% PD to its patients (Stein, 2002) whereas in Turkey, it is around 10%. HD represents the highest treatment
methods in Turkey. This shows that Turkey is not at good level for providing different types of Treatments. The kidney failure is not a cause but a result. Many health conditions such as Diabetes Mellitus, Ischemic heart disease etc. as shown in Table 4 cause to CKF. Knowing the relationship between them and CKF will make the researches easier. Three years data at different centres were collected by (Tatar, 2012). Diabetes Mellitus needing more kidney functions is the greatest cause of CKF.

**TABLE 4. NEW HAEMODIALYSIS PATIENTS WITH CONCOMITANT DISEASES DURING START-UP (Tatar, 2012)**

<table>
<thead>
<tr>
<th>Diseases</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>2.922</td>
<td>34,8</td>
<td>3.518</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>1.248</td>
<td>14,9</td>
<td>1.647</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>1.020</td>
<td>12,1</td>
<td>1.088</td>
</tr>
<tr>
<td>Chronic lung disease (COPD, etc.)</td>
<td>614</td>
<td>7,3</td>
<td>674</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>490</td>
<td>5,8</td>
<td>597</td>
</tr>
<tr>
<td>Malignancy</td>
<td>400</td>
<td>4,8</td>
<td>525</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>385</td>
<td>4,6</td>
<td>487</td>
</tr>
<tr>
<td>Chronic liver disease</td>
<td>191</td>
<td>2,3</td>
<td>197</td>
</tr>
<tr>
<td>Others</td>
<td>1.134</td>
<td>13,5</td>
<td>1.498</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8.404</strong></td>
<td><strong>100,0</strong></td>
<td><strong>10.231</strong></td>
</tr>
</tbody>
</table>

* Based on the data collected 717 centres in 2008, 811 centres in 2009 and 692 centres in 2010

Even the kidney transplantation is the highest among other organs and increasing over years as seen from Figure 3; it is not at expectable level. Liver and hearts are other crucial organ transplantations and finding them is really difficult. Each person has just one heart or liver and to get one, the organs need to be donated by dying person.

**Figure 3 Number of organ transplantation, Turkey, 2006-2010 (TurkStat, 2011)**

**METHODS**

Firstly, the numbers of patients are estimated and then these estimations are analyzed by using Markov chains. Decision analysis tools are used to model causes, results and side effects of CKF. Each of them has different dimensions and the last model can be applied as a part of further study. The real data are used in models but, to find transitions, some approximations are done. Even that, the Markov chains can provide better results than trend analysis. Decision analysis provides proper tools to see the effect of decreasing one probability on other steps. Decisions tools are used to visualize the effects and results. In the first case, the reasons
are connected to the types of treatments (4-5 stage of kidneys mainly). In reality, results are expected to be quantified to see effects of preventive precautions and successes measures.

**Estimation of CKFs Patients**

The data about HD, PD and TX are taken from Turkish Kidney Community public data for 1997-2011 as shown in Figure 3 an estimated value was determined based on data of that community for 2012. Next 10 years are estimated based on trend analysis by using MINITAB statistical tool. In the last years, HD plays an important role for the treatment and increased over years as shown below. The total numbers of CKFs have increased dramatically. Preventive healthcare can decrease the CKFs significantly.

![Figure 3 the number of HD and PD over years.](image)

Transplantation seems the best solution for the treatment of CKF and also has increased over years a shown below. The main problem of TX is not having enough living kidneys and majority of people do not want to give their kidneys after dying even governments make incentives for that. The other methods of developing kidneys from animals or artificial methods have not been improved well to provide kidneys in Turkey. Cultural problems and monetary benefits are still handicaps of TX. Many poor people cannot afford to buy a living kidney, while rich ones are more advantages. Close relatives can give one of their kidneys to organ recipient and they can continue their life healthy. This case is more seen in Turkey since it is more probable that the organ is accepted by recipient.
According to past data, the number of transplantations will increase steadily as shown in Figure 5 with actual, fitted and estimated data. Data are estimated by using $y(t)=-51+274*t$ formula. However, it is still very low when compared with dramatic increase in CKFs. The governments are aware the need of TXs, but it is difficult to get alive kidneys. Even though, some people are willing to give one of their kidneys to a close relative, the awareness is still low and thousands of patients estimated to be around 20,000 are waiting for TX. Otherwise they will take dialysis for the rest of their life. It is expected that the estimated trend will be changed and decreased by the public awareness and government’s supports. Just 6,000 patients are expected to be transplanted in 2022 and this is far below expectations.

By using trend analysis, the forecasted number of PD and HD will be doubled in next 10 years as shown in Figure 6. The estimation may be greater than current estimates when the growing number of old people is considered in the next years. Past data are used to estimate the trend and other parameters are taken into account. The number of people taking PD is low even it is cheaper than HD. One way of decreasing costs is to increase the proportion of PD in hospitals.
In the last years, increased number of kidney failures has taken the attention of governments and they try to decrease the dramatic increase otherwise, they need to increase the budget of kidney failures estimated to be now around 5% of total health expenditures. If it goes in this manner, the budget is expected to be doubled. 100,000 people as shown in Figure 7 with CKF are an alarming number for a country and this number cannot be cared in long run without enough technical and monetary support. The expected quality of life these people will be decreased greatly and the benefits given by them will decrease negatively to the community. Increasing number of old people will not have just CKF, but also side effects such as blood pressure, diabetes, anaemia etc. The effective planning of governments will play a critical role in CKF. How to decrease that trend is an important consideration. One way is to make people aware of CKF by preventive measures. Another way is to take some healthcare programs by screening. Diet of people, exercise and family history are factors that will help to decrease that trend. In Turkey, last stages (4-5) are taken into consideration mainly and people at those stages are cared mainly in private hospitals. There is a Turkish Kidney Community to register the number of CKFs besides health ministers. They make great efforts to increase the public awareness and academic studies. It is an alarming situation since the Turkish population does not increase as much as of that rate. Even though, there is a great effort about kidneys, there are not enough studies about root analyzing of that trend. The cost of a patient is very high and this is supported by governments. Hence, they will give more budgets to that field instead of other serious illnesses.
Modelling Treatments Methods

The chronic kidney failure can be represented by Markov chains in five stages: W (Well), D(Death), PD, HD and TX. Trend analysis provides beneficial results but it lacks of state exchanges. Hence, a Bayesian Model is developed to estimate the movement from each state to another state. Death is an absorbing state and at the end, each stage will end in it. One weakness of that model, states probabilities are drawn from available data collected of Health Minister and Turkish Nephrology Community. 4-5 stages of CKF are considered in that model and other stages are considered as “well”. It is known that great number of people is not aware of CKF and they are accepted as CKF patients in 1-3 stages. To estimate the real cost of CKF, the rate of flow from one state to another state should be known to distribute the probabilities to each state. Later, next years of CKFs can be estimated and costs can be determined. In this model, the transfer rate from PD and HD is costly beneficial. Death occurs at highest expense. HD has the highest number of patients and can be absorbed by TX or death. However, TX cannot be completely successful and the kidney can be rejected by patient body or may have other complications. The strength of that model is that transition matrix can give every kind of information like cost estimation, number of kidney failures at each stage, transition from each state. Patients at HD and PD with last stages can be cured to states (1-3 stages). It would be easily to see that movement and well state is a desirable state with high gaining score. Expected costs due to not being good can be estimated over years and the success of that illness cures can be measured more clearly. In Turkey, dialysis brings huge costs and the estimations will play an important role to hinder the increase and rise expected quality of life by going to W and TX states. Death is the worst case and has highest cost even not quantified properly in real life. The cost is mainly calculated based on cares done at hospitals. However, the success of preventing the death can be pictured. TX is seen the best way to get better if a suitable kidney can be found.
Figure 8: Possible Markov chains for CKF.

TM1 (Transition Matrix) shows all probabilities from one state to another state. To calculate further stages and to estimate number of people having CKF, this matrix is helpful.

\[
\begin{align*}
TM1 &= a_{i1} + a_{i2} + a_{i3} + a_{i4} + a_{i5} = 1 \\
\text{If the state space } S &= \{0, 1, \ldots, m-1\} \text{ then } \sum_j p_{ij} = 1 \quad \forall \ i \\
\text{and } p_{ij} &\geq 0 \quad \forall \ i, j.
\end{align*}
\]

In TM2, W state is taken out and 4 states are used to calculate number of people in next year. W state stands for the greatest probability and represents (1-3) stages of CKF, at which the patients do not need dialysis. However, W state is not analyzed even the further stages are more dangerous in Turkey.

\[
\begin{align*}
TM2 &= a_{i1} + a_{i2} + a_{i3} + a_{i4} = 1 \\
\text{To find the probabilities of TM2, the data of Health Minister are used. Some of them are approximate based data on hand.}
\end{align*}
\]

\[
\begin{align*}
\text{States} & \quad HD \quad PD \quad TX \quad D \\
HD &= a_{11} \quad a_{12} \quad a_{13} \quad a_{14} \quad a_{15} \\
PD &= a_{21} \quad a_{22} \quad a_{23} \quad a_{24} \quad a_{25} \\
TX &= a_{31} \quad a_{32} \quad a_{33} \quad a_{34} \quad a_{35} \\
D &= 0 \quad 0 \quad 0 \quad 0 \quad 1
\end{align*}
\]

\[
\begin{align*}
\text{States} & \quad HD \quad PD \quad TX \quad D \\
HD &= 0.8597 \quad 0.0787 \quad 0.046 \quad 0.0156 \\
PD &= 0.87 \quad 0.132 \quad 0.02 \quad 0.022 \\
TX &= 0.02 \quad 0.03 \quad 0.85 \quad 0.1 \\
D &= 0 \quad 0 \quad 0 \quad 1
\end{align*}
\]

\[
\begin{align*}
A_i &\text{ represents the distribution of CKF to each state to add the number of new CKF in next year. It will add new comers.}
\end{align*}
\]

\[
\begin{align*}
\text{States} & \quad HD \quad PD \quad TX \quad D \\
HD &= 0.859 \quad 0 \quad 0 \quad 0 \\
PD &= 0 \quad 0.093 \quad 0 \quad 0 \\
TX &= 0 \quad 0 \quad 0.046 \quad 0 \\
D &= 0 \quad 0 \quad 0 \quad 0.001
\end{align*}
\]
\( X_{t+1} = X_t \cdot TM + N_{t+1} \cdot A_i \) formula used to estimate next year from previous year data.

\( X_{t+1} = \text{Number of patients at } (t+1) \)

\( X_t = \text{Number of patients at } t \)

\( N_{t+1} = \text{Number of new patients at } (t+1) \)

\[
\begin{array}{cccccc|cccccc}
\text{States} & HD & PD & TX & D & \text{States} & HD & PD & TX & D \\
\hline
HD & a11 & a12 & a13 & a14 & HD & 0.859 & 0 & 0 & 0 \\
PD & a21 & a22 & a23 & a24 + N_{t+1} & PD & 0 & 0.093 & 0 & 0 \\
TX & a31 & a32 & a33 & a34 & TX & 0 & 0 & 0.046 & 0 \\
D & 0 & 0 & 0 & 1 & D & 0 & 0 & 0 & 0.001 \\
\end{array}
\]

\[
X_{2013} = \begin{bmatrix}
58104 \\
6814 \\
3238 \\
1008
\end{bmatrix} +
\begin{bmatrix}
4186 \\
4186 \\
4186 \\
4186
\end{bmatrix} = \begin{bmatrix}
59541 \\
5970 \\
3001 \\
1092
\end{bmatrix}
\]

69604 people will have CKF in 2013 based Bayesian Network. 68156 patients are found in trend analyzing. It is clear that Markov Chain provides better data to be used in cost calculations and planning.

There are 5 stages of kidney failure and each stage has different priorities. First three stages are not so serious and people can sustain their life normally. But, last two stages are serious and needed to be treated regularly to make the blood clean from urine. These five stages can be represented by Bayesian networks as Markov chains as shown below. End-stage CKF is the most dangerous stage and people need dialysis for their remaining life or a new kidney. The mathematical representation will provide a good background to decrease the End-stage CKF. If the necessary precautions are taken then the rate of flow to end-stage CKF will decrease. First 4 stages can be revisable but there is no way to reverse the last stage. Most of people die from the last stage and fourth stage can be also dangerous with severe complications. One of the important topics of healthcare is preventive healthcare and CKFs can be visualized with causes. The change in each probability or rate will change the further stages. If there are enough kidneys, then many people at end stage will not die. Each stage has different evaluation and the most expensive stage is the last one. It brings great cost over health budget of public. The success of that model is based on minimization the last stages. Hence, sufficient support of governments and people play crucial role. The current situation is horrendous since it is estimated that around 7 million people in Turkey have a kidney stage and 96% of them are not aware of that. In this study, it is aimed to see the success factors of CKF and quantified the results. The key success of the model is to stay at first three stages.
This model is a more complex, but it represents the whole states of kidney illness. Death is here again is the absorbing state and if the whole stages are well documented, the matrix will provide beneficial results of transitions to see how the health program is effective in Turkey. There are approximate data that 7.2 million people have CKF. Around 60,000 people take dialysis. Most of deaths occur at 5th stage. The matrix gives the proportion of each stage and can be used in Markov processes to make mathematical calculations. As it is stated before, there are data just for last two stages of CKF in Turkey. To see the success of preventive healthcare management, this model can be used to measure performance criteria. Going lower stages brings more advantages to decrease the costs and increase the expected quality of life. Due to not having enough collected data for that model, none mathematical calculations are carried out, but it expected to be part of further study.

To simplify the model and due to data on hand, some stages are combined 1-3 stages and 4-5 stages are taken the main attention of optimization. The whole Turkey population is sampled and 7.2 people have CKF in that model.
This matrix can be used to estimate the number of patients and transitions in next year’s. These estimates can be used to make more accurate costing.

\[
\begin{bmatrix}
  a_{11} & a_{12} & a_{13} & a_{14} \\
  a_{21} & a_{22} & a_{23} & a_{24} \\
  a_{31} & a_{32} & a_{33} & a_{34} \\
  D & 0 & 0 & 0 & 1
\end{bmatrix}
\]

\[a_{11} + a_{12} + a_{13} + a_{14} = 1\]

\[
\begin{bmatrix}
  0.9 & 0.066 & 0.0339 & 0.0001 \\
  0.25 & 0.67 & 0.07 & 0.01 \\
  0.05 & 0.03 & 0.9 & 0.02 \\
  0 & 0 & 0 & 1
\end{bmatrix}
\]

\[P_2 : 1 - 3 \quad 0.25 \quad 0.67 \quad 0.05 \quad 0 \] * \[1 - 3 \quad 0.25 \quad 0.67 \quad 0.07 \quad 0.01 \]

\[4 - 5 \quad 0.05 \quad 0.03 \quad 0.9 \quad 0 \]

\[a_{11} \quad a_{22} \quad a_{33} \quad a_{12} \quad a_{21} \quad a_{32} \quad a_{31} \]

Figure 11: Three states Markov chain of treatments

In TM3, the death state is taken out of model and the model has three states, HD can be divided in 3 types (HD1, HD2, and HD3) and PD (PD1 and PD2) can be divided into two sub states. This model will have more advantages to find long run steady-state probabilities since there is no absorbing state. The rate at each stage can be found to be used in long term in order to measure performances and finding expected probabilities. If one patient takes TX and in next state, the kidney will be accepted with 90% while there is 10% of being unsuccessful and in that case, the transplanted kidney will be wasted. Even long run probabilities provide not realistic results, they can be used to see the dynamics of model and compare with actual model with absorbing state.
\[
\begin{pmatrix}
1 & 0 & 0 & 0.859 & 0.109 & 0.031 & \pi_1 \\
0 & 1 & 0 & -0.850 & 0.0937 & 0.056 & \pi_2=0 & \pi_1 + \pi_2 + \pi_3 = 1 \\
0 & 0 & 1 & 0.085 & 0.015 & 0.90 & \pi_3
\end{pmatrix}
\]

\[\Pi \sim [\pi_1, \pi_2, \pi_3] = [0.640, 0.081, 0.249],\] In the long run, all estimates can be done just from these three probabilities.

### Decision Analysis of CKF

Based on type of treatment, expected cost of a dialysis per two years can be found since TX has costs of two years. The expected cost for each patient was found to be 44846.3 $ per two years as seen in Figure 12. This result is high due to mainly preferring HD (86%) in Turkey. HD is the most expensive type of treatment. 100,000 patients will have the cost 4,484,630,000 $ per two years of 2021-2022 which is very high and this amount is almost five times of the total costs of current spending on CKF. Analyzing reasons of CKF can help to decrease the costs by eliminating the roots. Diabetes Mellitus is the most common reason of CKF and preventive healthcare measures can prevent diabetes in many ways. Others reasons do not have strong effect on kidneys and the most serious one is Diabetes Mellitus. Patients with Diabetes Mellitus can be screened and the change in its numbers will decrease the costs.

The model below shows the results of each decision when it is know that all cases are in stage five. That means all patients will take a kind of treatment. In two years evaluation, TX is seen as the cheapest method and lower than average cost. The second best option is periton dialysis but the usage of it per day may hinder people to use it. It should be considered the costs of reasons are not considered. Moreover, the reason will also effect the decision of treatments. Combining costs of reasons with stage costs can provide more accurate and benefical results. Each patient may have different reasons causing CKF and the average of them can be used in costing. In Figure 13, when all patients are known at stage 5, the costs for each treatment is shown.

![Figure 12: Reasoning the CKF](image.png)
The model below is an extended form and includes all probabilities. In the model, the survival of age is simulated. The probabilities are estimated and living five years is given 10 favour points and for TX, 20 favour points is given due to living more years. Less than 5 years is the half of living 5 years for PD and HD. It is found that TX is more beneficial when age is considered. When the total number of patients is considered, the HD brings more utility and costs. Thus, the optimal treatment methods will HD in decision node by favour points. However, the psychological effects of utility will more depend on treatment type and when the HD and PD are compared; the curve of the model supports PD. When the dying cause is considered, we want to decrease the numbers of cancer. Thus, TX method is not favourable due to high risk of having cancer and costs. This model can provide valuable data when the costs, probabilities and other related data are available for big hospitals, cities and country over years to see the burden of each treatment. The weakness of model below is that not having all exact data and but even that, the model provides accurate strategies. Stages can be divided in two sections and 1-3 stages can be seen as a different chance note while there is no need of treatment. This node can be directly connected to utility node. Stages 4-5 node can be connected to decision and utility node.
As seen from models above, there is not a best model and each decision has drawbacks and advantages. Even, TX is best method to overcome CKF, the high rate of cancer can prevent many patients to take that method. The efforts for HD and PD are high and you have to take treatments many times per week, in this case, TX is seen as the best treatment. PD is more flexible and psychological effects may be decreased if done at home, in this case PD is more favourable. The profit oriented centres may prefer more profitable method HD and the numbers of private hospitals are high in Turkey, thus HD can be seen as the best method for them. When the health minister wants to decrease the overall costs, in this case TX will be beneficial for country or PD.

CONCLUSION

The Markov chain method provides more accurate results to estimate the number of CKFs over years and transitions are considered to get more correct estimates for costs. It is seen from models that the cost of TX is far below HD when 5 years period is considered in Turkey. The best treatment rate is TX to extend the life period of a patient and HD and PD provides temporal treatments. TX provides just 50% function of original kidney and HD and PD provides around 10%. Nothing can substitute the quality of original kidney. Home haemodialysis options are expected to be increased in Turkey especially for working people. Peritoneal dialysis is another option to provide more flexibility with daily sessions. End-stage renal disease needs haemodialysis but the 3-4 stages may also need haemodialysis if the complications are so severe.

The best treatment is to prevent CKF by concentrating on more reasons before end stages. Otherwise the cost is increasing incrementally as seen from models. Family history with blood pressure and diabetes can be screened to prevent CKF. Making sports is another two important preventive parameters. 20,000 people are waiting for kidney transplantations in Turkey. TX is an important field that Turkey needs to increase the percent in CKFs. Developed countries are more successful than Turkey in that. Living kidney is the best option for treatment but, cadaveric kidneys can be also helpful. Turkey is expected to make more investments in the field of researches in TX. Sexual difficulties affecting the majority of male and female of dialysis patients are also expected to be investigated. Other important life activities can be analyzed and the life quality in these fields can be increased. Psychological effects are expected to be decreased. Dialysis is not compulsory but it extends the life of people.

The increased number of private sector in CKFs has monopolized the health sector in that field and the governments supported public hospitals is expected to take more active role and provide different types of treatments such home haemodialysis. Even the costs are taken by governments; the quality of life for patients is very low when utility function is considered in the model for each patient. Private hospitals are profit oriented centres and they will try to optimize their profit by giving more HD, the hidden costs to governments and country cannot be seen. The best treatment is preventive healthcare and the preventive measures can be made more in the future to decrease the increased trend of CKFs patients. The benefit of decreasing each patient to 4-5 stages is between 16,000-24,000 ₺ per year to the country. Expect life of quality per year will be higher. In this case, both parties will get more benefits. An organized country wide health venture to decrease CKFs is a necessary way to fight against that illness. After stages 4-5, it is difficult to turn back stages and the strategy is to increase the probabilities at well stages, this will provide more beneficial results in transition matrixes over years. The last model can be as further study to be validated with Markov chains. These models can bring great beneficial results for hospitals and related communities to make right plans.
REFERENCES


