

## The impact of vascular diameter ratio on hemodialysis maturation time: Evidence from data mining approaches and thermodynamics law

Mohammad Rezapour<sup>1</sup>, Somayeh Taran<sup>2</sup>, Mahmood Balin Parast<sup>3</sup>  
Morteza Khavanin Zadeh<sup>\*4</sup>

Received: 3 January 2015

Accepted: 18 Feb 2016

Published: 19 April 2016

### Abstract

**Background:** Vascular Access (VA) is an important aspect for blood circulatory in Hemodialysis (HD). Arteriovenous Fistula (AVF) is a suitable procedure to gain VA. Maturation of the AVF is a status of AVF, which can be cannulated for HD. This study aimed to discover the parameters that effectively reduce the duration between VA and start of HD, which symbolizes the maturation time (MT).

**Methods:** Ninety-six patients who underwent AVF creation were selected for this study. The decision tree method was used based on CART/C4.5 algorithm, which is one of the data mining approaches for data classification. Vascular diameter ratio (VDR) coefficient was obtained (VDR=Artery/Vein diameters).

**Results:** We investigated the relationship between the VDR and MT in this study and found that MT is reversely related to VDR in elderly patients, while this relation was direct in younger patients.

**Conclusion:** The analysis revealed a Spearman's correlation coefficient for Vein diameter with MT. MT decreases when diameters of vein and artery are close to one another. This study can help the surgeons to identify high-risk patients who elongate MT for HD.

**Keywords:** Data Mining; Hemodialysis; Maturation Time; Vascular Diameter Ratio; Thermodynamics.

*Cite this article as:* Rezapour M, Taran S, Balin Parast M, Khavanin Zadeh M. The impact of vascular diameter ratio on hemodialysis maturation time: Evidence from data mining approaches and thermodynamics law. *Med J Islam Repub Iran* 2016 (19 April). Vol. 30:359.

### Introduction

Chronic kidney disease (CKD) is a condition in which the kidneys are damaged and cannot filter blood well. In the advanced stage of CKD, known as end stage renal disease (ESRD), kidney functions are reduced very severely. Hemodialysis (HD) treatment is the most common procedure which is performed for ESRD patients, and HD requires permanent vascular access (VA) as an important aspect (1). Furthermore, three main types of VA are used in HD treatment: Arteriovenous fistula (AVF), synthetic arteriovenous graft (AVG), and central venous catheter (CVC)

(2). According to the clinical practice guidelines, AVF is the first choice because of its minor complications, morbidity and mortality compared to AVG and CVC.

Also, AVF has a superior survival rate (estimated at 90% after one year) than other VA types (such as 60% of AVG) (3). AVF is less expensive and remains the gold standard access. Fistula maturation depends on several changes involving the vein such as increased blood flow, increased vein diameter, and increased visibility of the vein (4). Genetic predisposition, low shear stress, increases in transmural pressure, turbulence, differences in compliance between arteries

<sup>1</sup>. PhD candidate, Department of Information Technology Management, Science and Research Branch, Islamic Azad University, Tehran, Iran. mrezapour@srbiau.ac.ir

<sup>2</sup>. Master of Science in Physics, Department of Physics, Zanjan University, Zanjan, Iran. somayeh.taran@gmail.com

<sup>3</sup>. Software Engineering, Computer Engineering Faculty, Shahid Beheshti University, Tehran, Iran. Mahmoodymail@ymail.com

<sup>4</sup>. (**Corresponding author**) Associate Professor of Surgery, Hasheminejad Kidney Center, Iran University of Medical Sciences, Tehran, Iran. khavaninzadeh.m@iums.ac.ir

and veins, and vascular injury of the mobilized segment all contribute to neointimal hyperplasia and adverse vascular remodeling (5).

Reported AVF maturation rate varies widely from 30-90% (6-8). Successful fistula creation results in easy cannulation within adequate blood flow to support dialysis. Protracted hemodialysis via percutaneous catheter may be required while awaiting fistula maturation, and this increases the risk of infection and compromise the central vein patency (9).

The prevalence of CKD is increasing around the world. In 2010, in the U.S., more than 10% of people, or more than 20 million patients had CKD (10). According to the recent statistics of National Kidney Foundation (NKF), there were 26 million CKD patients in the U.S. in 2012 (11). Also, the rate of ESRD, as a chronic illness, has grown rapidly in the recent years (12). At the end of 2004, ESRD was reported to be prevalent in the world's population of 400,000 including over 300,000 HD patients (13). At the end of 2008, 547,982 U.S. residents were under treatment of ESRD and 382,343 of them received dialysis; of whom, 354,443 were under hemodialysis (14). In the U.S., AVF use increased from 27.9% in 1998 to 55.0% in 2007 (15), showing an increase from 32.4% in 2003 to 57.9% in 2011 (16). Moreover, the durability of AVF is 90% for a year after maturation for dialysis, while this rate is only 60% for AVG (3). This method was used by 91% of the patients in Japan and by 70% and 90% of patients in most European countries (17).

In Iran, the prevalence and incidence of ESRD is 378 per million populations (PMP) and 59 PMP, respectively (18). More than 14,000 patients were treated with chronic HD therapy for ESRD in 2008 in Iran (19). AVF is used by 93.4% of Iranian HD patients (1). This finding exceeds the recommendations by guidelines, 67-91% of patients reported using AVF in many western countries in the recent years (20). We described the risk factors of early

AVF failure, using a Data Mining approach in an earlier study (21). Then we studied predictive data mining techniques to identify these risk factors in the next publications (22,23). The maturation of a fistula (becoming accessible for dialysis) is described as a fistula condition which can be cannulated with two needle probes permanently or routinely and supply the adequate blood flow (min 350-450ml/min) for a successful HD session (3-4 hours) each time (24).

The complicated nature of real-world biomedical data has made it necessary to look beyond traditional biostatistics. This broader field, which includes methods for data pre-processing and visualization, and new methods from machine learning, is called data mining (25). Data mining approaches have developing implications in the health area and aided the clinical data description processing via health systems transactions (26). Data mining is a process in which specific analysis are used to reveal the novel, standard and beneficial models from a great body of data. Data mining is defined as a process of extracting interesting (non-trivial, implicit, previously unknown and potentially useful) patterns or knowledge from huge amount of data (27).

KDD is defined as the non-trivial process of identifying valid, novel, potentially useful and ultimately understandable patterns in data. Data mining is becoming increasingly popular in healthcare, if not increasingly essential, and several factors motivate the use of data mining applications in healthcare including fraud and abuse detection, the ability to transform data and benefiting healthcare providers. These approaches are boosting and their applications have become increasingly essential for healthcare organizations to make decisions based on the analyses of huge amounts of clinical data, which are generated by healthcare transactions (26). Nevertheless, running these techniques on small datasets are useful, and we recently found a study on a small dataset of patients (28) and found another one on smaller datasets, which was published in Nature journal

(29). This study aimed to discover the parameters that are effective in reducing the duration between VA and the start of HD, which symbolizes Maturation Time (MT).

## Methods

### Data

This study was conducted using the medical history of 96 patients who referred to the Hasheminejad Kidney Center for AVF creation during 2006-2007, using cross-sectional method and classification analysis. A checklist was used to collect data on each patient's vein and artery diameter and time of fistula maturation according to their hospital records.

Our criteria for AVF maturation were as follows: (1) Easily palpable superficial vein; (2) Vein relatively straight; (3) Adequate diameter for easy cannulating needles (4mm); (4) Adequate length ( $\geq 10$ cm, for adequate distance between the cannulating needles); (5) Uniform thrill to palpation and auscultation. We evaluated these criteria by the help of nurses, nephrologists or surgeons. In this study, data included demographic characteristics such as age, gender, and past medical history. Moreover, data on the arterial diameter and time course of maturation were collected from the medical records of the enrolled patients and analyzed using the Rapidminer software. Maturation time (MT) was defined as the duration after the surgery up to the time when AVF becomes accessible for HD.

### Statistical Analysis

Descriptive method is one of the data mining approaches, similar to the clustering method, which we used in the previous study to explore the risk factors of early AVF failure in 99 HD patients (22). However, in this study, we used the predictive approach in the processing stage.

Classification is one of the predictive approaches, which classifies data using many methods, and the other is the decision tree (DT); DT consists of three parts: Root, nodes and leafs. Any DT algorithm can produce different numbers of nodes and

leafs, determining deepness and complexity of DT (30).

DT algorithms are popular because of their applications and easily understandable results; some of DT algorithms are: ID3, C4, CART, C4.5, C5, CHAID, QUEST. In 1993, Quinlan designed the C4.5 algorithm and used the information gain concept to create the tree; C4.5 is recursive and greedy (31).

In this study, we used many DT operators based on CART/C4.5 algorithm, and then selected the DT with novel and usable patterns. Prior to the processing phase, we prepared and categorized the data into four frames. Due to the age distribution of the patients, they were placed into four sub-groups and labeled accordingly: "A20" for 22-37 year olds; "A40" for 41-59 year olds; "A60" for 60-79 year olds; and "A80" for 81-84 year olds. The MT was classified as follows: Class A: 21 days, class B: 23-46 days, and class C: 54-145 days. These classes consisted of 54, 22 and 20 patients, respectively. Lastly, we defined the VDR coefficient as in Equation 1:

(1)  $VDR = \text{Artery Diameter} / \text{Vein Diameter}$

After preparing the data, we executed the decision tree algorithm over the data. The decision tree (DT) is one of the predictive data mining approaches for data classification. The related DT in this analysis is illustrated in Fig. 1.

### Assessment using Physics

Many studies, which were conducted based on the physics laws, examined the impacts of blood flow and vessel characteristics on the arterial diseases. In one of these studies, unsteady stenosis flow was predicted and it was showed that the wall shear stress (WSS) distribution over the time interval was comparable for both non-Newtonian models; Also, according to Laplace's law, the wall stress on an ideal cylinder is directly proportional to its radius and intraluminal pressure. Even though an abdominal aortic aneurysms (AAA) is not

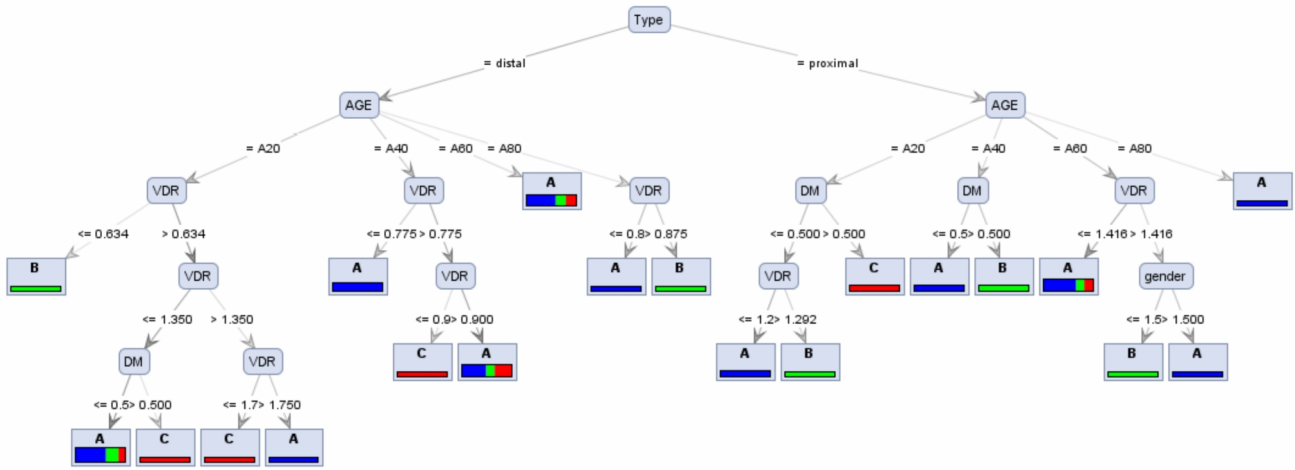


Fig. 1. The Decision Tree of the Classified MT and Its relation with VDR Ratio

an ideal cylinder, Laplace’s law still applies and with an increasing aortic diameter, the internal pressure increases, and so does the risk of rupture. The increase in internal pressure against the aortic walls results in progressive growth of the AAA diameter; and eventually, this pressure may overcome the resistance of the aortic wall resulting in rupture (32). In two other studies, the computational fluid dynamics (CFD) computation was performed assuming that the arterial wall is rigid and the blood is considered a homogeneous Newtonian fluid; These researchers observed a correlation between patient-specific AAA geometric parameters, WSS and hemodynamic loads, and used it as a potential predictor of AAA arterial wall rupture and potential intra luminal thrombus (ILT) formation (33-34).

MT is low when diameters of vein and artery are close. The laws of physics confirm this fact in joining two pipes at global cases. To prove this, we considered the condition in which two pipes with different diameters joined together. For each mean velocity,  $v_1$  in a smaller pipe will have a velocity of  $v_2$  in a bigger pipe that is represented by cohesion equation; so far in compress flow all force on control volume horizontal side is constant. In a real situation, for severe turbulences of fluids valid in outside space of control volume, just be restored few of kinetic energy of fluids of basic flow the pressure then this kinetic en-

ergy be loss the internal energy and transition heat. In these calculations, we supposed that the restoration of pressure in this space was zero and the pressure of valid across this region is equal to  $p_1$ . The equation of linear momentum for control volume is obtained by (2):

$$p_1 A_2 - p_2 A_2 = \rho v_2^2 A_2 - \rho v_1^2 A_1 \quad (2)$$

by replacing  $v_1$  with  $v_2(A_2/A_1)$  in continuity equation (3):

$$\frac{p_2 - p_1}{\rho} = v_2^2 \left(1 - \frac{A_2}{A_1}\right) \quad (3)$$

To determine the head loss, we assumed the first law of thermodynamics (FLT) for control volume and used the basic definition of the head (4):

$$\frac{v_1^2}{2} + \frac{p_1}{\rho} = \frac{v_2^2}{2} + \frac{p_2}{\rho} + h_1 \quad (4)$$

We obtained  $(P_1 - P_2)/\rho$  from the equation 4 and the sentence in the equation 3. Therefore, we obtained  $h_1$  as (5):

$$h_1 = \frac{v_2^2}{2} \left(1 - \frac{A_2}{A_1}\right)^2 = \frac{v_2^2}{2} \left[1 - \left(\frac{D_1}{D_2}\right)^2\right]^2 \quad (5)$$

We observed that (35) when pipes diameters were different, the formal friction coefficient is as (6):

$$K = \frac{[1 - (D_1/D_2)^2]^2}{(D_1/D_2)^4} = \left[\left(\frac{D_2}{D_1}\right)^2 - 1\right]^2 = \left[1 - \left(\frac{D_2}{D_1}\right)^2\right]^2 \quad (6)$$

Finally equation 6 shows that whatever the sections of the tubes (or vessels diameters) be much different, the friction force

will increase, causing a rise in the temperature, and so arterial wall rupture will be followed.

**Results**

Fifty-six male (58.3%) and 40 female (41.7%) patients participated in this study. The mean±SD age of all patients was 54.7±17.01 years and the mean±SD of arterial and vein diameter was 2.6±1.10 and 2.4±0.79 millimeter, respectively. The mean±SD AVF maturation time (MT) for all the patients was 36.5±35.30 days.

However, in six men (6.25% of the patients) aged over 80 years, VDR was bigger than 1 and no relation was found between vascular diameters and MT, but in the rest of the patients (90 person=93.75%

of the patients) with  $VDR \leq 1$ , a considerable reduction was observed in MT. The average numbers of the input and output (I/O) parameters are shown in Table 1.

As demonstrated in Figure 1, we observed that “class A” is an after condition “ $VDR > 1.5$ ” and “ $VDR > 1.75$ ” in two leafs of the tree, and these leafs have only two patients, while in all other leafs with “class A” VDR was close to 1. This means that MT is low when vein’s diameter is closer to diameter of (either brachial or radial) artery in AVF creation.

As illustrated in Table 2, a significant relationship was found between the MT and the vein diameter. Moreover, the vascular diameter ratio (VDR) coefficient had meaningful relations with diabetes mellitus (DM).

Table 1. The Average Numbers of the I/O Parameters

Parameter	Number of Patients	%	Range	Mean	SD
All of patients	96	100			
Males	56	58.3			
Females	40	41.7			
VDR>1 (Artery>Vein)	39	37.5			
VDR≤1 (Artery≤Vein)	58	60.41			
MT: class A	54		21 days		
MT: class B	22		23-46 days		
MT: class C	20		54-145 days		
Age			22-84 years	54.75	17.01
Maturation Time			21-145 days	36.52	35.30
Arterial Diameter			1-5 millimeter	2.56	1.1
Vein Diameter			1-4 millimeter	2.4	0.79

Table 2. Correlations among the Associated Factors by Spearman's rho Analysis

		Gender	DM	arteryD	veinD	MT	VDR
Gender	Correlation Coefficient	1.000					
	Sig. (1-tailed)	.					
	N	96					
DM	Correlation Coefficient	.099	1.000				
	Sig. (1-tailed)	.181	.				
	N	86	86				
Artery D	Correlation Coefficient	-.128	.300**	1.000			
	Sig. (1-tailed)	.108	.003	.			
	N	96	86	96			
Vein D	Correlation Coefficient	-.226*	.251**	.754**	1.000		
	Sig. (1-tailed)	.013	.010	.000	.		
	N	96	86	96	96		
MT	Correlation Coefficient	.063	.082	.088	.129	1.000	
	Sig. (1-tailed)	.271	.227	.196	.106	.	
	N	96	86	96	96	96	
VDR	Correlation Coefficient	.087	.138	.593**	-.038	.001	1.000
	Sig. (1-tailed)	.201	.103	.000	.355	.494	.
	N	96	86	96	96	96	96

\*. Correlation is significant at the 0.05 level (1-tailed).

\*\* Correlation is significant at the 0.01 level (1-tailed).

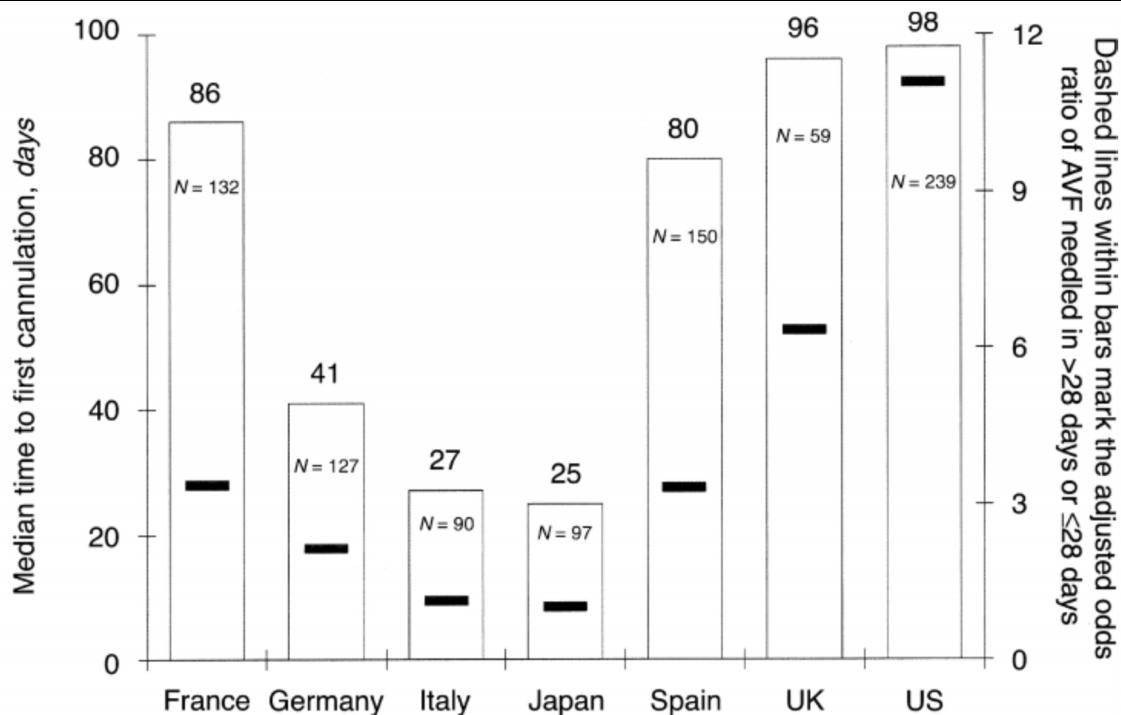


Fig. 2. The Median Time to First Cannulation of A-V Fistulae by Country (bars), and Adjusted Odds Ratio of an A-V Fistula being Cannulated  $\leq 28$  days versus  $>28$  days after Creation Relative to Japan (dashed line within bar) (36)

## Discussion

There is much discrepancy between MT in various reports. In NKF-K/DOQI guidelines, the average time for fistula maturation is reported to be 1 to 4 months. Also, the median time to first fistula cannulation differed between countries, ranging from 28 days in Japan and Italy to 96 and 98 days in transplantation in UK and US, respectively (36) (Fig. 2).

This finding that the use of vein with larger stream diameters was associated with greater success rate is consistent with the following studies. These studies examined preoperative venous diameter and AVF adequacy for dialysis (37,38). Wong et al. (37) found no differences in the average venous diameter at the wrist between failed and adequate AVF, but reported that all AVF would fail if the diameter was 1.6 mm or less. Another study reported that 16% of AVF were adequate with a vein diameter of 2 mm or less compared to 76% of those  $>2$  mm (39).

Using Spearman's correlation analysis (Table 1), we found that the maturation time of fistula (MT), was correlated with

vein diameter. However, no correlation was observed between MT and diameter of the arteries in the previous research (9).

No correlation was found between MT and gender of the patients. Moreover, as there were only six patients over 80 years of age (label A80), no statistically significant relation was found between them. This study may help to identify those patients with higher risks for elongated vascular accessibility for the HD. Moreover, future studies should be conducted with larger sample sizes to evaluate these factors and other ones that can decrease the period of fistula maturation.

## Conclusion

Based on the results of this study, we concluded that in most patients, maturation time (MT) decreased when diameters of the vascular vein and artery were close to one another. In addition, the analysis revealed a Spearman's correlation coefficient for vein diameter with MT. The VDR ratio showed that in elderly patients, MT was reversely related to VDR (arterial  $>$  venous diameter), while this relation was direct in younger

patients (arterial<venous diameter). Moreover, VDR had a notable role (Table 1) in diabetic patients. Thus, we recommend that more studies be conducted on this subject in the future. Based on our observation, a surgeon could choose a vein with a diameter closer to either brachial or radial artery in AVF creation.

#### Disclosure

None of the authors and co-authors of this paper have any direct or indirect financial relation with the commercial identity, "Rapidminer" mentioned in this paper.

#### Conflict of interest

The authors declare no competing interests.

#### References

1. Khavanin Zadeh M, Omrani Z, Najmi N. Prevalence and survival of Hemodialysis Vascular Access in End-Stage Renal Disease (ESRD) patients of Tehran, Iran', *Annals of Iranian Medicine* 2006;3(8):37-40.
2. Vachharajani Tushar J. Dialysis Vascular Access Selection in Elderly Patients, *US Nephrology* 2011;6(2):128-130.
3. Fluck R, Kumwenda M. UK Renal Association Clinical Practice Guidelines for Vascular Access, 2008–2011, 2011; Final Version. Available at: [www.renal.org/Libraries/Guidelines/Vascular\\_Access\\_for\\_Haemodialysis\\_-\\_FINAL\\_VERSION\\_05\\_January\\_2011.sflb.ashx](http://www.renal.org/Libraries/Guidelines/Vascular_Access_for_Haemodialysis_-_FINAL_VERSION_05_January_2011.sflb.ashx)
4. VA (Vascular Access 2006 Work Group). Clinical practice guidelines for vascular access, *Am J Kidney Dis* 2006;48(1):S176-S247.
5. Spergel LM, Ravani P, Roy-Chaudhury P, Asif A, Besarab A. Surgical salvage of the autogenous arteriovenous fistula (AVF), *J Nephrol* 2007;20(4):388-398.
6. Hakaim AG, Nalbandian M, Scott T. Superior maturation and patency of primary brachiocephalic and transposed basilic vein arteriovenous fistulae in patients with diabetes, *Journal of Vascular Surgery* 1998;27(1):154-157.
7. Silva Jr MB, Hobson II RW, Pappas PJ, Jamil Z, Araki CT, Goldberg MC, et al. A Strategy for increasing the use of Autogenous Hemodialysis Access Procedure: impact of perioperative noninvasive evaluation, *Journal of Vascular Surgery* 1998;27:302-370.
8. Mendes RR, Farber MA, Marston WA, Dinwiddie LC, Keagy BA, Burnham SJ. Prediction of wrist arteriovenous fistula maturation with preoperative vein mapping with ultrasonography, *Journal of Vascular Surgery* 2002;36(3):460-463.
9. Khavanin Zadeh M, Gholipour F, Naderpour Z, Porfakharan M. relationship between vessel diameter and time to maturation of arteriovenous fistula for hemodialysis access, *International Journal of Nephrology*, 2012. doi:10.1155/2012/942950.
10. CDC (Centers for Disease Control and Prevention). National chronic kidney disease fact sheet: general information and national estimates on chronic kidney disease in the United States, Atlanta, GA: U.S. Department of Health and Human Services (HHS) 2010.
11. NKF (National Kidney Foundation). The Facts About Chronic Kidney Disease (CKD), NKF, 30 East 33rd Street, New York, NY 10016, 2012; web site: [www.kidney.org/kidneydisease/ckd/index.cfm](http://www.kidney.org/kidneydisease/ckd/index.cfm)
12. Rambod M, Rafii F. Perceived Social Support and Quality of Life in Iranian Hemodialysis Patients, *Journal of Nursing Scholarship* 2010;42(3):242-249.
13. Smeltzer SC, Bare BG, Hinkle JL, Cheever KH. *Medical surgical nursing* (11th ed.). Philadelphia: Lippincott Williams & Wilkins, 2008.
14. USRDS., Annual Data Report. United States Renal Data System Web site, USRDS End-Stage Renal Disease Incident and Prevalent Quarterly, 2010; Update is available at: [www.usrds.org/qr/default.html](http://www.usrds.org/qr/default.html) (Accessed November 8, 2010).
15. NKUDIC, Kidney Disease Statistics for the United States, National Kidney and Urologic Diseases Information Clearinghouse, NIH Publication June 2012;12-3895.
16. FFBI, The Gold Standard, 2011; Available from URL: [http://www.networkofnewengland.org/FistulaFirst/FF\\_GoldStandard\\_06-11.pdf](http://www.networkofnewengland.org/FistulaFirst/FF_GoldStandard_06-11.pdf)
17. Roy-Chaudhury P, Kelly BS, Melhem M. Vascular Access in Hemodialysis: Issues, Management, and Emerging Concepts, Elsevier Inc. *Cardiol Clin* 2005;(23):249-273.
18. Mahdavi-Mazdeh M, Heidary-Rouchi A, Aghighi M, Rajolani H. Organ and Tissue Transplantation in Iran, *Saudi J Kidney Dis Transpl* 2008;19:127-31.
19. Aghighi M, Heidary Rouchi A, Zamyadi M, Mahdavi-Mazdeh M, Rajolani H, Ahrabi S, et al. Dialysis in Iran. *Iranian Journal of Kidney Diseases* 2008;2(1):11-15.
20. Ethier J, Mendelssohn DC, Elder SJ, Hasegawa T, Akizawa T, Akiba T, et al. Vascular access use and outcomes: an international perspective from the Dialysis Outcomes and Practice Patterns Study, *Nephrol Dial Transplant* 2008;23:3219-26.
21. Sepehri MM, Khavaninzadeh M, Rezapour M, Teimourpour B. A Data Mining Approach to Fistula Surgery Failure Analysis in Hemodialysis Patients,

- IEEE - ICBME 2011 proceeding, 2011; pp. 21-26. is available at: [ieeexplore.ieee.org/xpl/freeabs\\_all.jsp?arnumber=6168546](http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=6168546)
22. Rezapour M, Khavanin Zadeh M, Sepehri MM. Implementation of Predictive Data Mining Techniques for Identifying Risk Factors of Early AVF Failure in Hemodialysis Patients, *Computational and Mathematical Methods in Medicine*, 2013; 8 pages. Is available at: <http://dx.doi.org/10.1155/2013/830745> and <http://www.ncbi.nlm.nih.gov/pubmed/23861725>
23. Khavanin Zadeh M, Rezapour M, Sepehri M. M. Data Mining Performance in Identifying the Risk Factors of Early Arteriovenous Fistula Failure in Hemodialysis Patients, *International Journal of Hospital Research (IJHR)* 2013;2(1):49-54. Is available at: <http://ijhr.iums.ac.ir/index.php/ijhr/article/view/52/116>
24. Dixon BS. Why don't fistulas mature? *Kidney Int* 2006 Aug 2;70:1413-1422.
25. Lucas P. Bayesian Analysis Pattern Analysis and Data Mining in Health Care, Radboud Univ Nijmegen, Netherlands, *Current Opinion in Critical Care* 2004 10:399-403.
26. Koh HC, Tan G. Data Mining Applications in Healthcare, *Journal of Healthcare Information Management* 2005;19(2):65.
27. Han J, Kamber M. *Data Mining Concepts and Techniques*, Morgan Kaufmann Publishers, 2006.
28. Rezapour M, Khavanin Zadeh M, Association between non-matured arteriovenous fistula and blood pressure in hemodialysis patients. *Med J Islam Repub Iran* 2014 8 December;28(144). Is available at: [http://mjiri.iums.ac.ir/browse.php?a\\_id=2569&sid=1&slc\\_lang=en](http://mjiri.iums.ac.ir/browse.php?a_id=2569&sid=1&slc_lang=en)
29. Su X, Hu J, Huang S, Ning K. Rapid comparison and correlation analysis among massive number of microbial community samples based on MDV data model. 2014; *Scientific reports* 4, <http://www.nature.com/srep/2014/140917/srep06393/full/srep06393.html>.
30. Khavanin Zadeh M, Rezapour M, Khavanin Zadeh E, Balin Parast M, Rezapour H. The Relationship between Risk Factors of Hemodialysis Patients and Arterio Venous Fistula Maturation at Hasheminezhad Hospital, *Iranian Journal of Surgery* 2015;22(4):54-64. Is available at: [http://www.ijs.ir/library/upload/article/af\\_44473325%20Hemodialysis-Dr.Khavaninzadeh%201830.pdf](http://www.ijs.ir/library/upload/article/af_44473325%20Hemodialysis-Dr.Khavaninzadeh%201830.pdf)
31. Alborzi M, Khanbababaei M, Pourzarandi M I. Using clustering techniques and genetic algorithm in decision trees optimization for credit scoring of customers of banks, *Jour Management Future Research* 2012;1(1):15-34. Is available at: [http://jmfr.srbiau.ac.ir/pdf\\_5175\\_73f7d20b0b59d9a0c641395de6c451b4.html](http://jmfr.srbiau.ac.ir/pdf_5175_73f7d20b0b59d9a0c641395de6c451b4.html)
32. Siau W, Ng EY, Mazumdar J. Unsteady stenosis flow prediction: a comparative study of non-Newtonian models with operator splitting scheme, *Medical Engineering & Physics* Volume 2000 May;22(4): 265-277.
33. Vorp DA. Biomechanics of abdominal aortic aneurysm', *Journal of Biomechanics* 2007;40(9): 1887-1902.
34. Soudah E, Ng EY, Loong TH, Bordone M, Pua U, Narayanan S. CFD modelling of abdominal aortic aneurysm on hemodynamic loads using a realistic geometry with CT, *Computational and Mathematical Methods in Medicine* 2013, <http://dx.doi.org/10.1155/2013/472564>
35. Shames IH, Shames IH. *Mechanics of Fluids*, 1923; 4th ed Boston: McGraw-Hill, 2003.
36. Rayner HC, Pisoni RL, Gillespie BW, Goodkin DA, Akiba T, Akizawa T, et al. Creation, cannulation and survival of arteriovenous fistulae: data from the Dialysis Outcomes and Practice Patterns Study. *Kidney international* 2003;63(1):323-330.
37. Wong V, Ward R, Taylor J, Selvakumar S, How TV, Bakran A. Factors associated with early failure of arteriovenous fistulae for haemodialysis access, *European Journal of Vascular and Endovascular Surgery* 1996;12(2):207-213.
38. Brimble KS, Rabbat CG, Treleaven DJ, Ingram AJ. Utility of ultrasonographic venous assessment prior to forearm arteriovenous fistula creation, *Clinical Nephrology* 2002;58(2):122-128.
39. Ferring M, Henderson J, Wilmsink A, Smith S. Vascular ultrasound for the pre-operative evaluation prior to arteriovenous fistula formation for haemodialysis: review of the evidence. *Nephrology Dialysis Transplantation* 2008;23(6):1809-1815.