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Association between non-matured arterio-venus fistula and blood pressure in hemodialysis patients

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Abstract

Background: Chronic Kidney Disease (CKD) is a complicated kidney problem causing permanent renal failure in progressive stages. The final stage of CKD is called ESRD in which most accepted management is Hemodialysis (HD). Arterio-Venus Fistula (AVF) is the most practical way of making proper access to the blood circulatory system; however, maturation of the AVF is a challenge, since there are number of variables interfering with the whole process. The purpose of this study was to evaluate potentially modifiable factors associated with Maturation Time (MT) after creation of a Vascular Access (VA).

Methods: In this cross-sectional study, a total of 87 patients referred to the Hasheminejad Kidney Center for AVF creation in 2010 were evaluated. Patients were evaluated before and after the AVF creation and risk factors such as history of blood pressure abnormalities, diabetes and congestive heart failure, as well as the successive development of AVF was studied and finally processed using 'data mining' technology.

Results: The "Decision Trees" indicated the significant impact of the systolic blood pressure (SBP) in the delay of the patient's AVF maturation. Also, prediction of AVF maturation was made with 70.59% of precision in regard to their BP condition.

Conclusion: This study demonstrated that monitoring the SBP is one of the important steps in management of the cardiovascular variables producing any delay in the process of the patient's HD. Also the data mining method can discover the hidden relationship between the patient's medical conditions in order to predict the potential disorders.

Keywords: Data Mining, ArterioVenus fistula, Blood pressure, Hypertension.

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Introduction

According to the Kidney Disease Quality Outcome Initiative (K/DOQI), chronic kidney disease (CKD) is defined as the atrophy of the kidney or failure of renal function (1). The progression of renal disease can be separated into five stages, the criterion of which is glomerular filtration rate (GFR). Patients in the first stage share similar GFR (≥90) to healthy counterparts (kidney damage with normal or increased GFR), making it difficult to identify the disease according to GFR alone. Stage 4, or pre-End-Stage Renal Disease (ESRD), has a GFR level of 15–29 mL/min/1.73 m2 (severely decreased GFR). Finally, ESRD is declared upon the fifth stage when the kidney is completely deprived of its function. If transplantation is not available, it is crucial to undergo dialysis at this point (2). Hemodialysis (HD) process requires a vascular access (VA) which can be perform by three common surgeries: ArterioVenous Fistula (AVF), ArterioVenous graft (AVG) or Central Venous Catheter (CVC) (3).

According to KDOQI HD Adequacy guidelines, the preference of AVF over other forms of access arises from their

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functional advantages because of a lower rate of complications. Fistulae have the lowest rate of thrombosis, and require the fewest interventions, providing longer survival of the access (4). Catheters may cause central vein stenosis, which can adversely affect VA outcomes (5). Our criteria for AVF maturation was: (i) easily palpable superficial vein, (ii) vein relatively straight, (iii) adequate diameter for easy cannulating needles (3-4 mm), (iv) adequate length (≥10 cm, for adequate distance between the cannulating needles), and (v) uniform thrill to palpation and auscultation. We evaluated these criteria by nurses or nephrologists or surgeon (6). AVGs require far more interventions than do AVFs to maintain long-term patency for dialysis. On the average, the annual frequency of intervention (elective angioplasty, thrombectomy, or surgical revision) in mature accesses is approximately four-fold higher for AVGs than for AVFs (7). Also the durability of AVF is about 90% for a year after maturation for the reason of dialysis, while this rate is only 60% for AVG (8).

Clinical guidelines established by the National Kidney Foundation cite these reasons in advocating use of AVFs whenever possible (9). Placement rates for each type of access have changed dramatically over the last 10 years (10), with a decrease in catheter placement rates and an increase in AVF placement rates (11). In 2003, the using rates of AVF has been reported in about 91% in Japan, and between 70% and 90% in most European countries, compared with a dismal 30% in the United States (Fig. 1) (12).

Data from the DOPPS. Note the dismal prevalence rate for native AVF and the high prevalence rate for PTFE grafts in the United States as compared with other industrialized countries. ANZ, Australia and New Zealand; BE, Belgium; CA, Canada; FR, France; GE, Germany; IT, Italy; Jpn, Japan; SP, Spain; SW, Sweden; US, United States (Data as of September, 2003; courtesy Dr. Rajiv Saran, University of Michigan, Ann Arbor, MI.) (12).

The AVF using rate has reported to be 93.4% in Iran (13). In the USA, AVF use increased from 27.9% in 1998 to 55.0% in 2007 (14) and shows an increase from 32.4% in 2003 to 57.9% in 2011 (15) and has grown up into 61% in 2013 (16). Finally, according the report Fiscal Year (FY) 2014 (16), increasing the rate of AVF access for ESRD patients improves the quality of HD treatment, while decreasing unnecessary complications and hospitalizations. Since FY 2009, CMS has increased AVF access by over 6 percent, exceeding recent targets (Table 1).

The AVF is the preferred type of vascular access because thrombosis rates, infection rates, access-related expenditures, and total health care expenditures all are lower for patients with fistulas than for those with either synthetic AVG or CVC; However, the advantages of fistulas are counterbalanced by the substantially higher proportion of fistulas than grafts that are never able to be used for dialysis because of failure to mature adequately to support effective HD (17). A much higher likelihood of fistula non-maturation, ranging between 20% and 60% (18) and recent studies have reported 20-50% of the fistulas failed to maturation (19). There are several variables interfering with the time takes for an AVF to develop to become accessible for HD, which all together can be divided into four groups (20): first, demographic factors, such as; age, race, economic condition and geographic region (21), second, diagnostic exams and evaluations before surgery, such as, ultrasound results to examine the ArterioVenus system and regional vascular anatomy (22), third, measuring the physiological variables during surgery, such as fistula blood flow and dimensions of arteries and veins (23), and the last group is rehabilitative exercises and post operation cares (24).

The NKF-KDOQI guidelines provides an evidence based on clinical measurements that a reciprocal relationship exists between the blood pressure (BP) and CKD, in which, BP is a cause and a consequence for

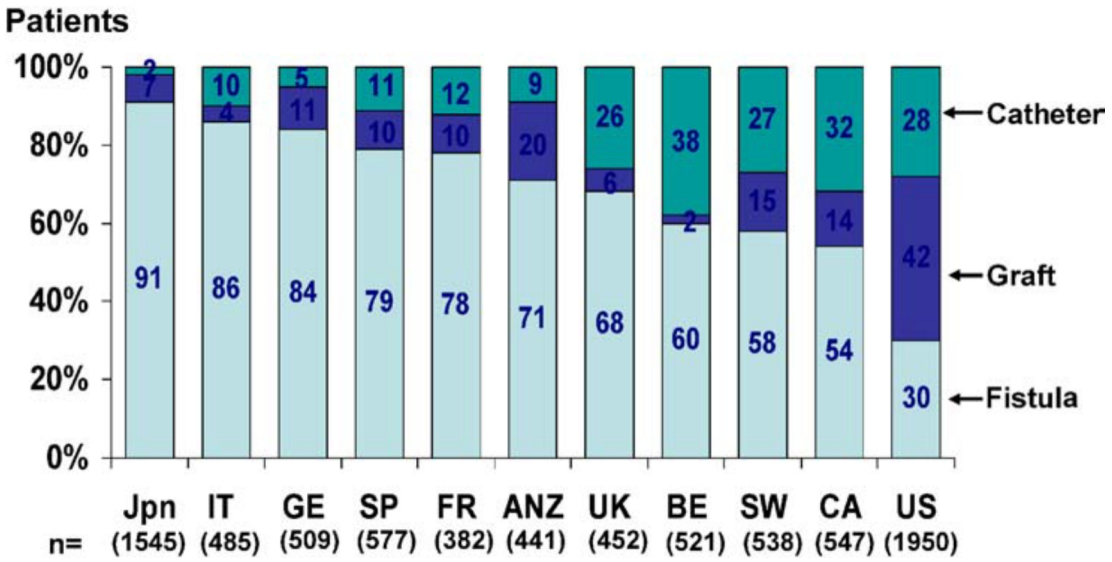


Fig. 1.Data from the DOPPS. Note the dismal prevalence rate for native AVF and the high prevalence rate for PTFE grafts in the United States as compared with other industrialized countries. ANZ, Australia and New Zealand; BE, Belgium; CA, Canada; FR, France; GE, Germany; IT, Italy; Jpn, Japan; SP, Spain; SW, Sweden; US, United States (Data as of September, 2003; courtesy Dr. Rajiv Saran, University of Michigan, Ann Arbor, MI.) (12).

CKD. Likewise, it has suggested the determination of the relation between the levels of BP against time in ESRD patients (25). Therefore, having information about the factors which have impact on the maturation time (MT) after AVF creation, can help in screening and choosing the right patients for the procedure and thus offering better diagnostic services and treatments and finally expediting the healing and maturation period after AVF creation as well as minimizing the side effects and eventually preparing the patient for HD (26, 27). For this reason, this study is prepared to investigate the impact of BP conditions on the period in which takes the AVF to develop for HD in ESRD patients. Also, studies the interference of other variables such as age, diabetes and cardiac failures with the process.

Data mining is a process in extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) patterns or knowledge from huge amount of data. (28) The outcome of Data Mining technologies are to provide benefits to healthcare organization for grouping the patients having similar type of diseases or health issues so that healthcare organization provides them effective treatments; This analysis of health data improves the healthcare by enhancing the performance of patient management tasks. (29) These approaches have developing implication in the health area and have aided the clinical data description processing via transaction of health systems (30).

Methods

In this cross-sectional and prospective study, the medical history of 87 patients who referred to the Hasheminejad Kidney Center for AVF creation in 2010 were analyzed. For all of the patients, the surgery was performed within the radio-cephalic area by one surgeon. Patients' participation was under total awareness and consent. The patient's information were recorded including personal descriptions such as age and gender, medical history before AVF creation, monitoring during operation (the operation region) and potential risk factors such as BP, diabetes and cardiac failures. MT was considered as the time between the AVF creation and accessibility. The AVF accessibility was indicated by the length of the straight superficial vein (should be

Table 1. Increase percentage of dialysis patients with AVF as their vascular access for HD. (11)

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
Target	54%	57%	58%	60.5%	61%	61%
Result	54%	56.8%	59.8%	Nov 30, 2013[1]	Nov 30, 2013	Nov 28, 2014
Status	Target Met	Target Not Met but Improved	Target Exceeded	Pending	Pending	Pending

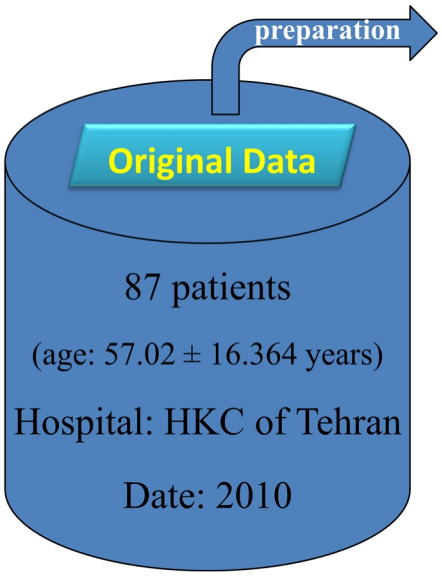
[1]Reporting on this target is delayed until November 2013.

about 10cm), palpable with proper diameter (about 4mm) and having continues and uniform thrill and continues bruit in auscultation (20). In this way, the fistulas maturation times were recorded for a successful HD and then the data were processed with the data mining method. 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 by routine and supply the adequate blood flow (min 350-450 ml/min) for a successful HD session (3-4 hours) each time (31).

One of the data mining approaches is "descriptive method", which a subdivision of that called clustering, was used in our previous study to explore the early failure of the inserted AVF in 99 patients (32). Another approach is "predictive method" which we have implemented in our recent researches on 193 HD patients (33, 34).

In this study we use the "predictive approaches" in processing stage. The data mining was performed by "Rapid Miner", before starting the data processing. For this reason, the data were randomly sampled by "Bootstrapping" algorism (70 samples). Later, the "Decision Trees" (DT) were extracted, representing the impacts of different variables on AVF maturation. There were quite a few trees which were extracted by this method, however, only those were chosen for our two groups of data, which according to the 'compatibility rules of the trees' had better consistency with the Medical Instruction Criteria (8, 22).

To improve processing, instead of entering all the data into the software, we have defined these groups for age and maturation time (MT). This definition is regarding the average age of the patients and their MT range. Before the processing, we had 'data preparation' and categorize the data into



	Method I	Method II	Defining Maturation Time (MT) Lables
	Considering two subgroups, regarding the average age of patients	Classifying into three subgroups, according min-max of ages range	
GROUP 1	"below-57"	19-49 years	A: 3-4 weeks
GROUP 2	"above 57"	50-64 years	B: 5-7 weeks
GROUP 3	----	65-83 years	C: 8-10 weeks

Fig. 2.Infographic of our research-flow

Table 2. Extracted rules from decision in Figure 3

```
If Systolic <= 105  Then "class C" {A=0, C=7, B=0}
If Systolic > 105 Then
  If IHD = no  then "class A" {A=27, C=7, B=5}
  If IHD = yes then
    If  Diastolic <= 75  then "class A" {A=4, C=0, B=0}
    If  Diastolic > 75 then
      If   DM = no  then "class C" {A=0, C=2, B=1}
      If   DM = yes then "class B" {A=2, C=0, B=15}
```

Table 3. Extracted rules from decision in Figure 4

```
If  Systolic <= 105  Then "class C" {A=0, C=7, B=0} else
If  Systolic > 105
  If  IHD = no then
    If  Systolic <= 122.500  then
      If  AGE = [19-49] then "class A" {A=2, C=0, B=0} else
      If  AGE = [50-64] then "class C" {A=0, C=2, B=0} else
      If  AGE = [65-83] then "class A" {A=4, C=3, B=0}
    If  Systolic > 122.500 then "class A" {A=21, C=2, B=5}
  If  IHD = yes then
    If  Diastolic <= 75 then "class A" {A=4, C=0, B=0} else
    If  Diastolic > 75 then
      If DM = no then "class C" {A=0, C=2, B=1} else
      If DM = yes then "class B" {A=2, C=0, B=15}
```

two frames: considering the average age of the patients which is 57 years, we had two subgroups: “below-57” and “above 57”. Another group-related subgroups are: 19-49, 50-64 and 65-83 years, labeled accordingly. The MT has also been classified as follow: class A: 3-4 weeks, class B: 5-7 weeks and class C: 8-10 weeks. There was only one case of 16 weeks MT, which we considered it as class C (Fig. 2).

Results

The medical characteristics of 87 patients (including 61 (70%) male and 26 (30%) female) diagnosed with CKD, was studied. The mean (±SD) age of patients in this study was 57.0 (± 16.36) years. The tree related to the first group is illustrated in Figure 3. This tree is a continuous type of DT known as Classification and Regression Trees (CART). (35) For clarificationof findings (A, B and C) in figures 3 and 4, see previous paragraph; the words “Systolic” and “Diastolic” are literally the systolic blood pressure (SBP) and diastolic blood pressure (DBP), accordingly. Also the labels A, B and C are shown in blue, red and green colors.

Table 2 displays the compatible laws with this tree, which indicates that the patient’s gender does not have any impact on the MT of AVFs. On the other side, the systolic blood pressure (SBP) is differentially an important factor (Table 2).

While, the extracted knowledge from the second group tree indicates that the SBP and DBP have significant impact on the MT. For the systolic BPs above 105-122.5mmHg, the maturation accomplished better in groups one and three than patients with ages 50-64 years. Those groups’ matu-

Table 4. The accuracy rate of MT prediction

Accuracy rate: 70.59%	true A	true C	true B	Class precision
pred. A	6	2	1	66.67%
pred. C	0	4	2	66.67%
pred. B	0	0	2	100.00%
class recall	100.00%	66.67%	40.00%	

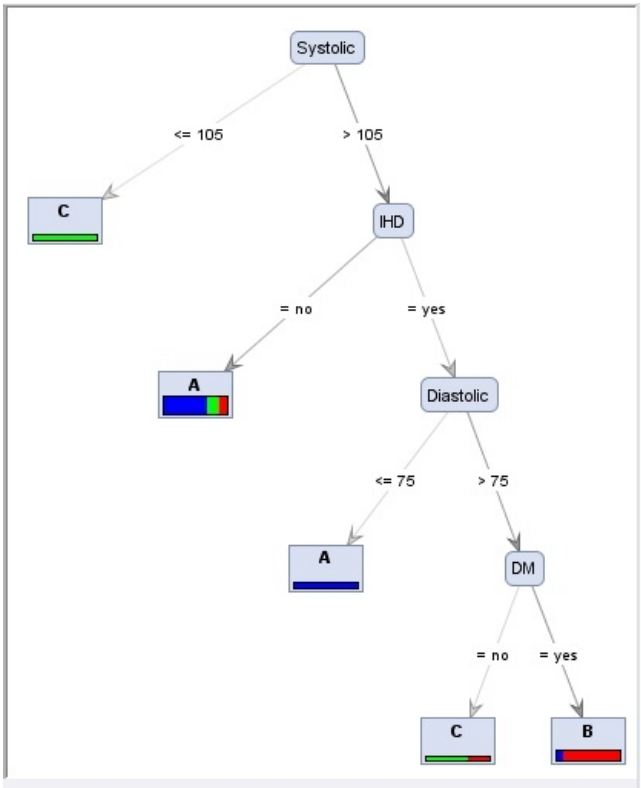


Fig. 3.The decision tree diagram displaying the data mining for 70 patients using the first method

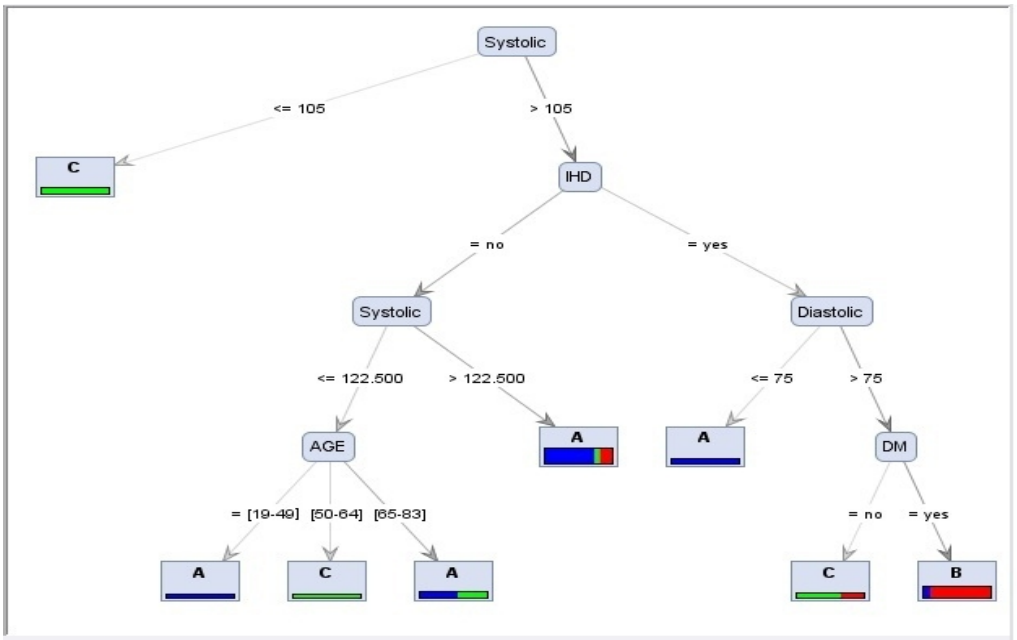


Fig. 4. The Decision tree on 70 patients classified on the basis of age into three subset of 19 to 49 years (with labels [19-49]), 50 to 64 years (with labels [50-64]) and 65 to 83 years (with labels [65-83])

ration times were classified in the class A (Fig. 4, Table 3).

So far, few patients were randomly selected and the system trained the rules extracted from their attributes. At the next step of the data mining process, the quality of the MT was predicted on the remaining patients who were not selected in sampling stage. We have 17 patients who were not sampled in the training phase. The precision of this prediction was measured by the "Performance algorithm". The related pre-

cision was 70.59% (Table 4).

Discussion

One study have evaluated potentially modifiable factors associated with dialysis access patency using statistical methods (36) and they have indicated the role of maturation period blood pressure as a risk factor.

In this study we evaluated medical characteristics of the patients diagnosed with CKD. We divided patients information into two main groups based on their ages and the data mining was performed on both groups, followed by checking the compatibility of the study with the standard medical guidelines. Outcome of this process was two 'decision trees'. This method of study indicated that the gender has not any specific impact on the time needed for the fistula to mature and on the other hand, clearly displayed the significant impact of the patient's systolic (SBP) and diastolic (DBP) blood pressure on the AVF MT. Moreover, the effects of other factors – such as Ischemic Heart Disease (IHD) and Diabetes Mellitus (DM) has been analyzed in formulas (1):

$$SBP > IHD > DBP > DM > Age \quad (1)$$

In addition to the descriptive results, the AVF MT was evaluated with the 70.59% of precision in 17 patients whose data were not sampled in this investigation. Regarding the high impact of the SBP and DBP in the AVF MT, it is very important to constantly monitor this variable in the CKD patients before and during the AVF creation procedure and likewise, considering this variable in the patient's medical plans for a successful HD.

Conclusion

Association of the blood pressure with the fistula maturation time, may play an important role in vascular access patency. The results of this study are not only important in improving the physicians and surgeon's knowledge of the time of the accessibility of the inserted fistulas, also, improves the medical care provided to the patients.

This study also demonstrated that with the use of the data mining it is not only possible to uncover the unknown relations between the medical characteristics related to the disease with the patient's general condition, but also to predict the medical conditions related to the disease in future patients. Thus, the knowledge extracted from the data mining method is considerably helpful in making medical decisions and predicting the patient's condition related to his treatment in similar situations.

Limitations of this study were limited number of patients and lack of evaluation of other factors which may have effects on maturation process.

Conflict of interest

The authors declare no competing interests.

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