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Research Article

Machine Learning Algorithms as new screening framework for recommendation of Appropriate Vascular Access and Stroke Reduction

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Abstract

Background and Objectives: The central venous catheter (CVC) insertion is a major surgery to provide vascular access (VA) as a requirement for hemodialysis (HD). Recently, the stroke risk has been reported in ESRD patients in addition to other complications. Due to the risk of death after stroke and the problems that accompany it for the individual, others and the community, it is important to examine the risks associated with it in patients. This study investigates the risk of stroke and the factors affecting it following catheter insertion in HD patients in Shahid Hasheminejad Hospital.

Methods: The current study uses a descriptive-quantitative method which is performed in two steps: 1. determining the effective factors for data collection and 2. data analysis. The effective factors were first identified in consultation with the HD physicians and then the data checklist was designed. Subsequently, the records of 468 HD patients over five years were studied, of which 324 were female and 144 were male. The decision tree and statistical tests were used to analyze the data.

Results: Our results showed that, the risk of stroke is up to 84.21% in those patients who do not insert an arteriovenous fistula (AVF) in time and delay until the catheter was inserted, However, there is no significant relationship between the age of HD patients and stroke. A history of high blood pressure or diabetes affects the risk of stroke in addition to catheter insertion.

Conclusion: The results indicate that ESRD patients who cannot have a kidney transplant and are decided to undergo permanent HD should be scheduled for AVF insertion at least three months before the start of HD to avoid reaching the emergency stage and having a catheter inserted and complications from the catheter.

Keywords: Machine Learning Algorithm (MLA), Data Mining, Descriptive Analysis, arteriovenous fistula (AVF), Central venous catheter (CVC), Cerebrovascular Insufficiency, Hypertension, Diabetes Mellitus

Background and Objectives

Currently, 10 to 13% of Americans today suffer from kidney disease. This figure was 10 thousand cases in 1973 and reached 527 thousand in 2008. The number of patients with renal failure was 137 per million in Iran in 1998, but it reached 435 per million 10 years later (2008)[1]. Aghighi et al., showed that the number of end-stage renal disease (ESRD) patients in Iran has increased by more than 130% during the years 1997-1996, which raises the need to pay attention to this disease [2]. A systematic review by Rezapour et al. illustrated incidence of Stroke in Hemodialysis Patients with Central Venous Catheter (CVC)[3], especially in hypertensive diabetic chronic kidney disease (CKD) Patients after CVC placement[4]. Another study suggests that the incidence of ESRD in Iran has increased from 38.5 per million in 1998 to 49.9 in 2000[5]. Statistics show that there were more than 24,000 ESRD patients in Iran in 2008 alone and that this number is increasing[6].

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48% of kidney patients in Iran are currently transplanted, but this figure is 20% of kidney patients worldwide. Besides, the lifespan of a kidney transplant in one year is 80% for patients receiving a kidney from non-relatives, while this figure is 90% for patients receiving a kidney from relatives1. So, a large number of patients use alternative therapy for dialysis. Hemodialysis (HD) is the most common method of dialysis, with more than 2,000,280 patients in the United States using it. This treatment method is used to treat patients with acute and chronic renal stage who need long-term or permanent treatment[7].

However, the use of HD requires vascular access, which occurs in a variety of ways, such as CVC and arteriovenous fistula (AVF) insertion[8-10].

Nowadays, CVC is widely used for vascular access in HD in patients with renal failure[11-14]. However, this method has significant complications and can be used for less time compared to AVF. Two types of silicone catheters are used intermittently and indwelling. Due to the high risk of infection, thrombosis, venous stenosis, and long-term inefficiency, the use of an intermittent catheter is recommended for a maximum of 2-3 weeks[9-15].

Each intravenous cannulation is used temporarily and mostly at the beginning of the HD process or in emergencies[16,17]. More stable cannulation such as AVF should be used if the patient requires long-term HD[18]. Some risks that can be caused by the use of catheters include infection, suture rupture, catheter removal, bleeding, large subcutaneous hematomas, air entering the catheter, air embolism, hemothorax, and pneumothorax[19-21]. A study by Rezapour et al. has showed impact of infection and hypertension on the vascular access surgery (VAS) complications, using data mining[22,23] and Khavaninzadeh et al. have applied decision tree algorithm for identifying the risk factors of early AVF failure in HD patients[24,25]. According to the study performed by Afshar et al., Catheter-related infection and thrombosis are two common complications in HD patients with CVC[26].

Recent studies have provided further evidence that while conventional HD in medical centers can extend the life of patients, it can negatively affect the brain, leading to cognitive deficits. One of the major complications reported in patients undergoing intermittent HD catheters is stroke and risk of death[27]. This is reviewed in a review paper submitted to the World Conference on Vascular Access (WoCoVa 2020)[28]. In another study (2019), 37,623 patients were studied between 2000 and 2010, and the risk of ischemic stroke in patients over 35 years of age was concluded[29]. In general, CKD patients are 3-5 times more likely to have a stroke[30].

Shahid Hasheminejad Hospital is a subspecialty hospital in the field of kidney and receives 300 HD patients monthly. The patients are dialyzed 2 to 3 times a week at this center. In this center, CVC and AVF insertion is used for vascular access according to the patient's condition and the physician's discretion. This method is used for vascular access more than AVF for various reasons including lower cost and shorter time and convenience of catheter insertion. Thus, it is very important to investigate the complications of this method. One of the complications reported by recent studies but there is not much evidence to prove it is stroke. So, this study investigates the risk of developing this complication following the use of CVC and also the factors affecting the development of this complication .

One of the important aspects in choosing the vascular access surgery method is the patient's condition in terms of the urgent need for HD. If the patient is in end-stage

renal disease (ESRD), the nephrologist will usually tell him/her to insert an AVF because it takes at least one to several months for the fistula to mature[31-32]. If the patient refuses to have a fistula inserted (because he/she can still live with little kidney function) and delays it until HD is necessary, a catheter must be inserted to save him/her from death. However, this auxiliary catheter has complications that, especially in patients with diabetes and high blood pressure, can progress to stroke. Due to the non-time perform of AVF surgery in patients for any reason, including not accepting by them or their families or reduced hospitalization facilities in certain conditions, such as COVID-19 pandemic and, consequently, a serious reduction in elective surgery[33]. We face a paradox and we do not get out of it in an emergency, and that is: a catheter must be placed to provide access to the patient for dialysis and immediate purification of the patient's blood, and on the other hand we know that this rescue route is a very smooth It is not, but it will carry risks such as stroke for the patient. Therefore, the importance of this study in warning the need for culture in those kidney patients for whom the need for dialysis for any reason has been proven and proven, and by implanting a fistula at the appropriate time, the complications of catheter implantation can be reduced. With reverse engineering, it is easy to see that the prevalence of catheter implantation in patients indicates that there is still a gap in the decision-making process that the patient is not persuaded to accept the venous artery fistula in time and postpone it until the emergency situation. He is forced to undergo a catheter to save him from death .

Methods

Figure (1) shows the steps of the research:

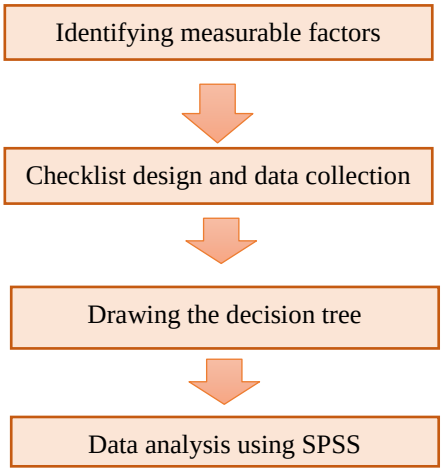

Figure 1. Research stages

Description of the Study Steps

This retrospective study is performed based on the information containing the patient records. Effective and practical factors to achieve the desired goal are identified in consultation with HD physicians in Hasheminejad Hospital. Accordingly, a checklist is designed to collect data. The checklist is designed taking into account the demographic characteristics of patients including sex, age, height, weight, BMI, clinical signs, history of underlying diseases such as breast cancer and epilepsy, history of kidney disease, cystoscopy,

history of hospitalization before catheter insertion, history of hospitalization after catheter insertion, history of smoking, etc. (Table 1).

The case information of 468 HD patients for whom a central venous catheter is inserted based on a designed checklist (Table2).

Table 1. Checklist factors

Group	Factors
Demographic	Age, Gender, Height, Weight, BMI, Care Level
Clinical factors	Menopause, PR, T, RR, high blood pressure, low blood pressure
History of kidney disease treatment	Indwelling catheter, history of kidney transplant
History of underlying diseases	hyperlipidemia, history of cancer, nephrotic syndrome, ischemic heart disease, diabetes, and hypertension
Drugs taken	Atorvastatin, insulin, aspirin, and Plavix
Blood test factors	IHD ،BloodGroupRh ،PIT، Hct ،Hb ،W.B.C ،Magnesium ،potassium ، Sodium ،Phosphorus ،Ca ،Neutrophil ،Lymphocyte ،PT ،INR ،
Complications	CVA ،CHF ،DM ،HTN
History of treatments	Angioplasty, cardiac angiography, renal angiography
Catheterization features	CathSide ،CathTipLoc
Other factors	Duration of preoperative catheterization, Duration of postoperative catheterization, History of smoking, Duration of kidney disease

Input Data

Table (2) provides an overview of the input data.

Table 2. Input data concluding HD patients

Population	468 Iranian hemodialysis patients
Vascular access time	October 2013 - October 2018
cuffed tunneled CVC	368 individuals
non-cuffed CVC	100 individuals
Ages	12 – 86 (mean age, 54.85) years
Gender	324 females and 144 males

Pearson's correlation coefficient is used to determine the degree of correlation between the factors. The decision tree is used to find the roots of the relationships between the factors more accurately. The data are analyzed using SPSS software.

Findings

The state of direct or inverse correlation between variables is first determined by calculating Pearson's correlation coefficient. However, this type of analysis

gives an overview of the correlations between the variables as shown in Table 3.

Table 3. Correlations (Pearson's rho)

		CVA	**Atorvastatin**	**Insulin**	**Aspiri**	**CABG**	**DM**	**HTN**	**Shaldon**	**Hystere**
CVA	Pearson	1	**.094***	**.137****	**.126****	**.165****	**.175****	**.169****	**.130****	**.099***
	Sig. (2-tailed)		.042	.003	.006	.000	.000	.000	.005	.033
	N	468	468	468	468	468	468	468	468	468
Atorvastatin	Pearson	.094*	1	.234**	.322**	.167**	.294**	.347**	.143**	.025
	Sig. (2-tailed)	.042		.000	.000	.000	.000	.000	.002	.583
	N	468	468	468	468	468	468	468	468	468
Insulin	Pearson	.137**	.234**	1	.170**	.189**	.545**	.326**	.052	.191**
	Sig. (2-tailed)	.003	.000		.000	.000	.000	.000	.262	.000
	N	468	468	468	468	468	468	468	468	468
Aspirin	Pearson	.126**	.322**	.170**	1	.244**	.274**	.278**	.251**	.076
	Sig. (2-tailed)	.006	.000	.000		.000	.000	.000	.000	.101
	N	468	468	468	468	468	468	468	468	468
CABG	Pearson	.165**	.167**	.189**	.244**	1	.273**	.081	.114*	.092*
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.079	.014	.047
	N	468	468	468	468	468	468	468	468	468
DM	Pearson	.175**	.294**	.545**	.274**	.273**	1	.520**	.204**	.157**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.001
	N	468	468	468	468	468	468	468	468	468
HTN	Pearson	.169**	.347**	.326**	.278**	.081	.520**	1	.194**	.069
	Sig. (2-tailed)	.000	.000	.000	.000	.079	.000		.000	.137
	N	468	468	468	468	468	468	468	468	468
Shaldon Catheter	Pearson	.130**	.143**	.052	.251**	.114*	.204**	.194**	1	.121**
	Sig. (2-tailed)	.005	.002	.262	.000	.014	.000	.000		.009
	N	468	468	468	468	468	468	468	468	468
~~Hysterectomy~~	~~Pearson~~	.099*	.025	.191**	.076	.092*	.157**	.069	.121**	1
	~~Sig. (2-tailed)~~	.033	.583	.000	.101	.047	.001	.137	.009	
	~~N~~	468	468	468	468	468	468	468	468	468

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Some of the variables listed in Table 3, such as drugs taken or injected, can be controlled, but some, such as a history of diabetes (DM), a history of high blood pressure (Htn), gender (Gender), and history of intermittent catheter insertion (Shaldon Catheter) cannot be controlled.

Since data analysis methods, especially data mining, can help to extract the correlation between data more accurately[34-39], it is not enough to simply calculate the correlation between variables, and the decision tree algorithm is executed to find the correlation between the above variables (Figure 2).

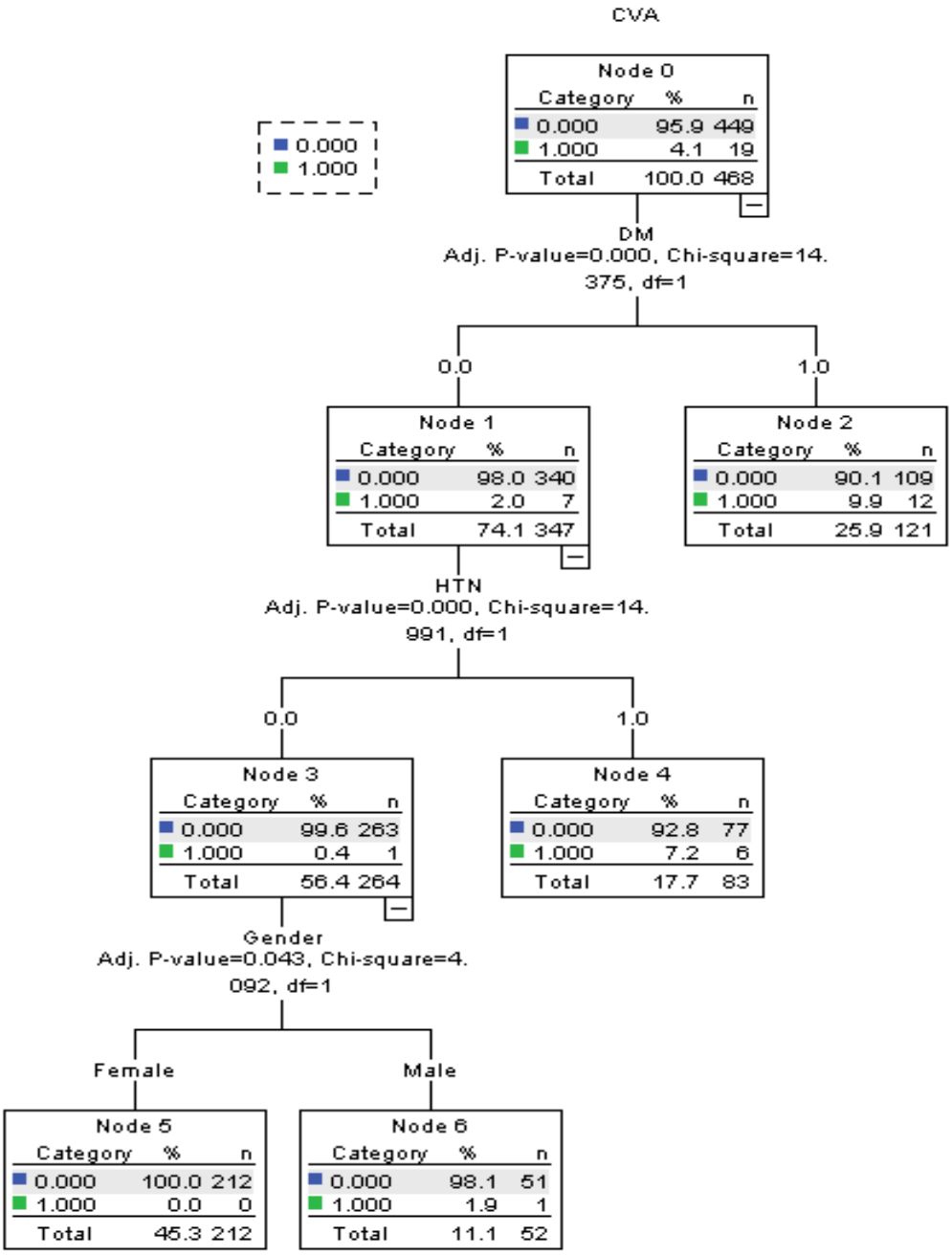

Figure 2. The decision tree to find the correlation between the variables

Although simply measuring the accuracy of the classification method does not mean accepting the final output of the algorithm, and adapting it to the literature mentioned in the introduction is essential, this calculation technically helps to ensure the efficiency of the decision tree. The accuracy of the decision tree is provided in Table 4. More than 98% of the prediction accuracy is reported in this tree.

Table 4. Confusion Matrix for Classification Assesment

Observed	Predicted		
	0	1	Percent Correct
0 (449)	438	11	97.5%
1 (19)	0	19	100.0%
Overall Percentage	100.0%	100.0%	98.75%
Growing Method: CHAID Dependent Variable: CVA			

Conclusion

Although there is a correlation between diabetes and high blood pressure with stroke, as shown in Table 3, the decision tree in Figure 2 indicates that this effect is demonstrated in some patients and stroke occurs for 12 patients with diabetes and 6 patients with high blood pressure, respectively. Moreover, according to Table 5, out of 19 cases of CVC insertion, 16 patients had a stroke (CVA). In these patients, the following factors have a higher share in the incidence of stroke, respectively:

Intermittent catheter insertion and non-timely AVF insertion + history of diabetes and high blood pressure the risk of stroke.

The above equation, on the one hand, is a generalized form of the characteristics mentioned in other studies alone, such as a direct effect on diabetic patients and their ischemic stroke[40], and on the other hand, is a specific condition examined in HD patients and the risk of stroke in them. It is concluded that EDRD patients, who cannot have a kidney transplant and are diagnosed with HD by a nephrologist, should be instructed so that their vascular access is through an AVF, thus preventing them from reaching the emergency stage and having to insert a catheter so that at least the possible problems of the catheter insertion are not added to their other problems.

Conflict of Interest

The authors declare that there are no conflicts of interest. None of the authors have any financial relation with the software tools, used in this study.

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