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Original research

Inverse effects of anemia and diabetes mellitus on non-cuffed central venous catheters longevity

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Abstract

Patients with End Stage Renal Disease (ESRD) not undergoing transplant require hemodialysis (HD) through a vascular access (VA). It is important to detect risk factors that cause morbidity (thrombosis and infection) of VA. Central Venous Catheters (CVC) are type of VA which has higher cost of care, compared to other methods. In this research, 296 HD patients aged 17 to 88 years were studied by data mining. All catheters inserted in a period of 410 days (from February 2011 to March 2012) and 167 (56%) were male and 129 (44%) were female. Risk factors were assessed extracting reasons of morbidity in non-cuffed catheters. Even though low hemoglobin (Hgb) causes thrombosis in Femoral Vein Catheterization (FVC), but more durability of non-cuffed CVC was observed in patients with low Hgb, which means an inverse effect of Hgb. Diabetes mellitus (DM) and hypertension reduce durability of jugular vein access. Long duration of DM increases durability of non-cuffed CVC. Left jugular has more morbidity than right jugular. Femoral vein (FV) causes low durability and so maximal risk rates. Thrombosis is a major complication of Femoral Vein Catheterization. When this event has been occurred, we will remove thrombosed catheter so that durability of it would be less not more. Catheterization using “femoral” causes low durability and so maximal risk rates. Moreover, although diabetes mellitus (DM) and hypertension are major risk factors for internal jugular vein (IJV) catheterization, but there is an inverse effect of duration of hemoglobin (Hgb) and DM on non-cuffed CVC.

Keywords: Non-cuffed catheter, Anemia, Diabetes mellitus, Vascular access, Data mining

Introduction

Patients with End-Stage Renal Disease (ESRD) not having renal transplant require hemodialysis (HD). A vascular access (VA) procedure is necessary for HD. VA can be obtained by three common surgeries: Arteriovenous Fistula (AVF), Arteriovenous Graft (AVG) or Central Venous Catheter (CVC). Although the most common technique is surgical elevation(insertion) of the AVF [1-2], but CVC represents a good choice, especially when urgent or emergent HD is required either at the time of initiation of renal replacement therapy or when a permanent access becomes dysfunctional [3-4]. In fact, patients with CVCs have greater morbidity and mortality relative to patients with AVF and AVG [5-6], but CVC access remains beneficial in patients where AVF may be impractical [7] and also CVC is used as a short-term bridging access or where vascular anatomy is unsuitable for AVF or AVG creation [8]. CVCs for HD are essentially of two types: (i) non-cuffed non-tunneled, temporary, acute catheters used for short time and immediate VA and (ii) cuffed, chronic, tunneled dialysis catheters for longer use. The non-cuffed CVC lacks a subcutaneous cuff and is used only

for weeks to a month due to the absence of a barrier to infection, while cuffed tunneled catheters have a subcutaneous cuff and can potentially be used for months to years.

The average yearly cost per patient with ESRD was $50,000 in 1995; [9] this increased to $75,000 in 2005 [10] and to $87,945 in 2011 [11]. Many researchers have reported that approximately ¼ of ESRD patient care costs are related to VA procedures [12-13]. The study of Liu, et al [14] showed that VA accounted for 27% of total urgent-start HD costs, with the remaining costs due to dialysis services 42%, and initial hospitalization 31%. Therefore, it is clear that the additional costs of VA and hospitalization exceed more than 58% of the total costs of HD treatment; so in terms of health economics, it is important to reduce morbidity and need for replacing of VA increasing its durability.

Because of hospitalization rates are higher among patients with CVCs than among AVF ones [3], and using CVC has higher costs of care, so that the relative cost per person per year was found to bring an additional $10,000/year in patients with CVC compared to those with AVF or AVG [15]; but there is a disproportionately high use of CVC across some countries. According to the Dialysis Outcomes and Practice Patterns Study (DOPPS), CVC were used as the dominant type of VA for initiation of HD in the US and UK in comparison to countries in Europe and in Japan, within 5 days of their first dialysis treatment [16-17].

Khavanin Zadeh, et al [18] reported VA types in their HD patients were using to be 68.2% with AVF, 26.3% with non-cuffed CVC, 4% with AVG and 1.5% with cuffed CVC; but they found that in their patients the mean survival time of VA was: 144.52 months (for AVF), 32.43 months (for AVG), 7.3 months (for cuffed CVC) and 3.7 months (for non-cuffed CVC).

There are different opinions about comparison of subclavian vein catheterization (SVC) with femoral vein catheterization (FVC) for HD. Although some researchers had found access related hospitalizations were lower and the number of out-patient dialyses performed were higher with SVC than FVC [19], and whenever in some studies it is explained that risk of thrombosis is lower in the internal jugular vein (IJV), slightly higher in the SVC, and still higher in the FVC [20], some other studies have illustrated infections are most common in the FVC region due to the proximity of the perineum, whilst the SVC probably causes less infection than the IJV [21]. Moreover, Hryszko, et al. concluded that catheterization of the IJV is associated with longer catheter survival when compared to the FVC; they have concluded HD catheters should be placed, if possible, in IJV to prevent their premature malfunction [22]. Because the right IJV (RJV) has a much wider diameter and runs more superficially than the left IJV (LJV), a right-sided approach is more acceptable than a left-sided one for CVC insertion via the IJV [23]. According to study of Santoro, et al [3], efficiency of the IJV catheterization for different purposes has been emphasized in several studies, therefore right and left jugular IJV, represents the choice for CVC insertion for several reasons; So, followed by the FVC as second, and SVC as third, because of the higher risk of thrombosis.

The aim of our present study was to analyze the risk factors influencing non-cuffed catheter durability in VA surgery and those affecting morbidity (consisting infection, thrombosis). Use of data mining approaches is boosting their applications and have become increasingly essential for healthcare organizations to make decisions based on the analysis the huge amounts of clinical data generated aside healthcare services [24-27]. Nevertheless, running these techniques on low volume datasets is useful, and there are novel extracted knowledge performing by other studies on small datasets of patients [28-31] and [33-42].

Materials and Methods

The longevity and events related to non-cuffed catheter in HD patients were investigated, retrospectively. In our collected data, there are 296 ESRD patients, aged 17 to 88 years. Details of their non-cuffed CVC were recorded, including variables such as diabetes mellitus (DM), hypertension (HTN), Hemoglobin (Hgb), removal causes (thrombosis, infection, use of other VA such as AVF). All catheters inserted for HD at the Hasheminejad Kidney Center (HKC), where a tertiary center and patients is are referred here from different hospitals.

During following up period –which is 410 days (from February 2011 to March 2012) – the during time ("duration") is calculated between catheter insertion date and removal date.

We aimed to detect known risk factors of CVC, using three approaches of data mining: at first we

studied data by summarizing, next by running decision tree on the data and finally reviewing the attributes of clusters extracted from data. For preprocessing data, two steps were taken; (I) the duration of catheter survival divided into four categories based on "Duration" as Table 1. (II) The second step is the final condition of the catheter which is recorded as "Status": "worked", "thrombosis", or "infection". Then processing analyses were performed running two data miner tools: (i) Rapidminer and (ii) the library Rattle Version 3.4.1 of open-source software R [32], without any finance goals with these software.

Results

In our collected data, we had 296 ESRD patients aged 17 to 88 years evaluated; 167 participants (56%) were male and 129 (44%) were female. Summarizing data by the "Cross Tab" method, given the "Status" of patients' surgeries, the following results were extracted (Table 2).

These results indicate that the "morbidity rate" (which is defined as by adding frequencies of infection and thrombosis together) for LJV, FVC and RJV is 22.22%, 15.38% and 10.52% respectively. Therefore, "LJV" method carries this important, potential drawback.

Considering "Durability" as the target variable in our analyses, we have the results as shown in Table 3 which explain that "FVC has more risk rather than LJV".

From Table 3, it is clear that the "Excellent" durability is states are totally in RJV catheters, whereas most failures in non-cuffed CVC are with FVC; so FVC method has less survival rate and entails higher patients. In view of the detectable risk regions from Figure 1, we defined four labels for Hemoglobin (Hgb): "under 8", [8-10), [10-11], "after 11".

Then we measured the frequency of the non-cuffed CVC survival for each defined Hgb-label, which is presented as Figure 2. Figure 2 describes that the rate for "Up to 15 days" increases when Hgb is under 8, so we find this relation in non-cuffed catheterization: "when Hemoglobin (Hgb) is high → the risk of Longevity is Low".

In case of IJV (Right or Left), the situation is the same as above, but preexisting DM and HTN increase failure of non-cuffed catheters (Figures 3 and 4).

But using FVC, this failure exists in most Hgb levels (Figure 5).

Despite the above finding that "low Hemoglobin (Hgb)" has a direct correlation with "durability" of non-cuffed CVC, but about FVC, we found that "thrombosis" may still occur commonly even when Hemoglobin (Hgb) was low (Figure 6):

Although, "diabetes mellitus" (DM) is usually a risk factor in VA surgery – as we clearly showed in another study [33] - in case of non-cuffed CVC we have surprisingly detected some inverse effects of history of DM in our present analyses; Firstly, such as inverse relation is mentioned in Figures 7-8. When "DM-Duration" is longer → there is highest likelihood for catheter longevity.

As an explanation for Figure 7, "DM-Duration" expresses the history of diabetes by year; so the diagram depicted in this figure shows that diabetic patients with more than 20 years DM, have had an "excellent" (most survival) CVC, compared with other categories of diabetic patients.

Discussion

The sample size of present study (296 ESRD patients) was one of our study limitation. Another of our research which published recently by one Nature journal, [28] was performed on other 480 ESRD patients and it was found that there is an adverse relation between positive history of HTN and AVF maturation, such that hypertensive HD patients have significantly lower risk of AVF failure. The focus of this study is on CVCs, and results reveal inverse effects originated from DM and low Hgb on the survival of this VA type.

According to our rates of infection/thrombosis for non-cuffed CVC, in general, LJV has higher morbidity rate than RJV and FVC has medium risk. But using FVC results in low durability; also DM and HTN decrease durability of IJV. Low Hgb has direct ratio with durability of non-cuffed CVC, but in FVC, the "thrombosis" morbidity may be aggravated when Hgb is low. High "DM-Duration" increases durability of non-cuffed CVC, which entails less costs of this surgery. There are different opinions about comparison of subclavian vein catheterization (SVC) with femoral vein catheterization (FVC) for HD. Raja, et al. [19] reported that related hospitalizations were lower and the number of out-patient dialyses performed were higher with SVC than FVC.

Table 1. Defined labels for duration of catheter survival in preprocessing phase

Duration of catheter survival	Defined label
Up to 2 weeks	"Up to 15 days"
From 2 WEEK to 60 days	"15-60 Days"
61-120 days	"2-4 months"
More than 4 months	"Excellent"

Table 2. The frequency of "morbidities in VA types"; LJV has high morbidity rate (In each table cell, the upper digit represents the number of occurrences and the lower digit shows its frequency)

Status Vein	Infection	Thrombosis	Worked	Total	Morbidity Rate
Right Jugular	3 (1.21%)	23 (9.31%)	221 (89.48%)	247 (84%)	10.52%
Left Jugular	3 (8.33%)	5 (13.89%)	28 (77.78%)	36 (12%)	22.22%
Femoral	1 (7.69%)	1 (7.69%)	11 (84.62%)	13 (4%)	15.38%
Total	7 (2.4%)	29 (9.8%)	260 (87.8%)	296 (100%)	

Table 3. Cross Tab of VA, by target variable "Duration"; the most duration, namely "excellent" exists in RJV and FVC has lowest durability

Durability Vein	Up to 15 days	15-60 Days	2-4 months	Excellent	Total
Right Jugular	90 (0.364)	106 (0.429)	43 (0.174)	8 (0.032)	247 (0.834)
Left Jugular	8 (0.222)	21 (0.583)	7 (0.194)	0 (0.000)	36 (0.122)
Femoral	11 (0.846)	2 (0.154)	0 (0.000)	0 (0.000)	13 (0.044)
Total	109 (0.368)	129 (0.436)	50 (0.169)	8 (0.027)	296

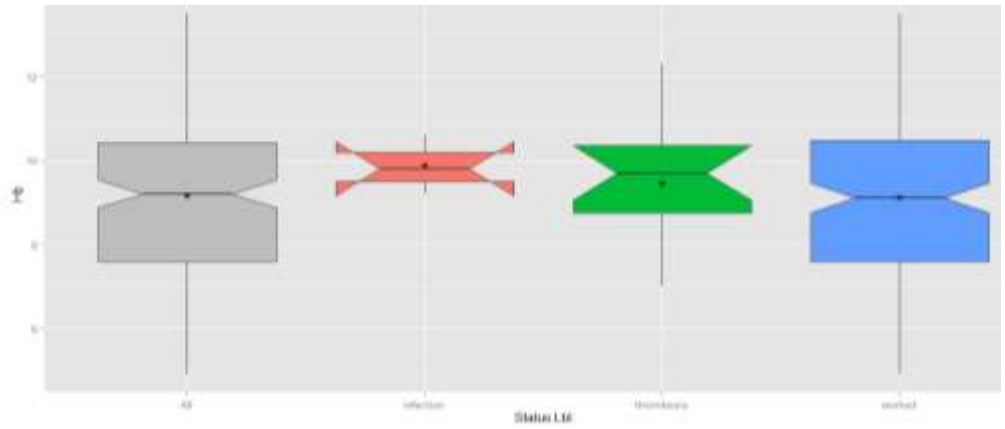

Figure 1. Distribution of hemoglobin (Hgb) in each functional status of non-cuffed CVCs

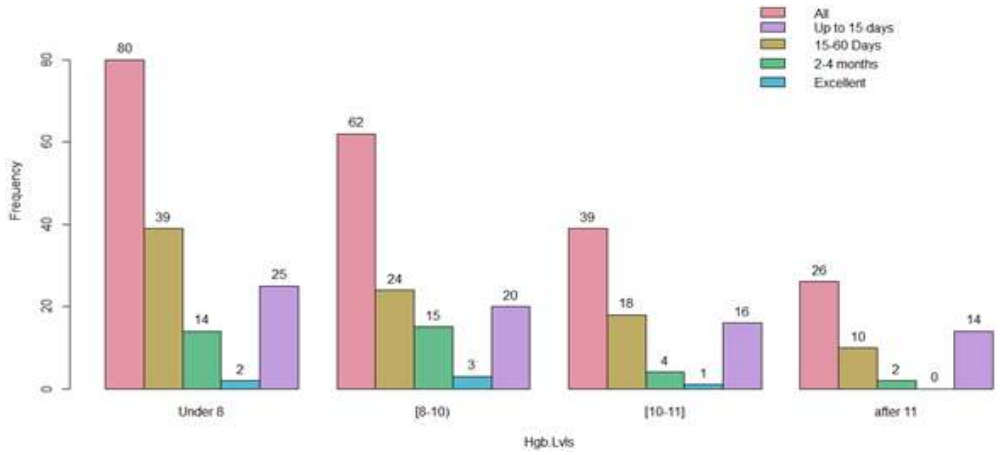

Figure 2. The survival of non-cuffed catheterization in Hgb levels

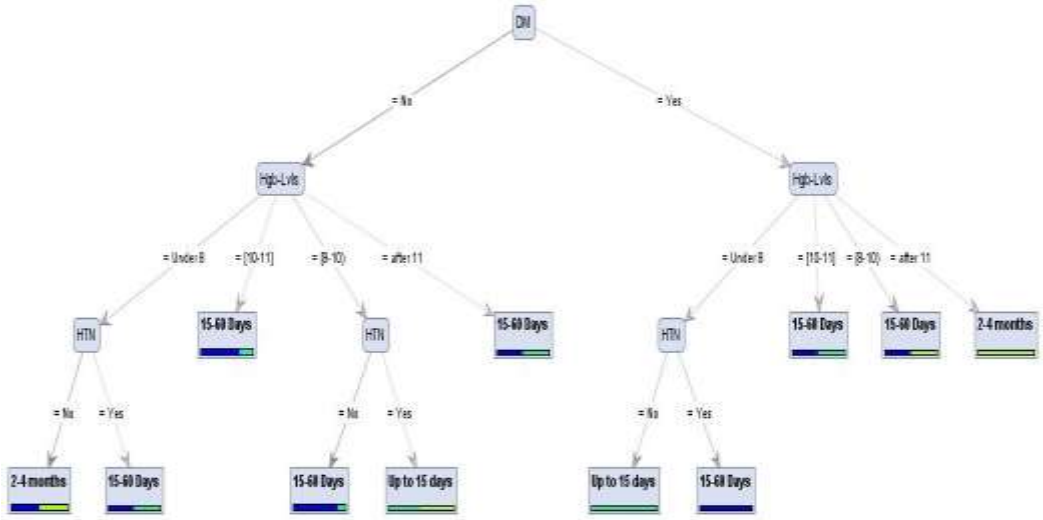

Figure 3. Effects of "Diabetes Mellitus" (DM) and Hypertension (HTN) on decreasing longevity of non-cuffed LJV catheter

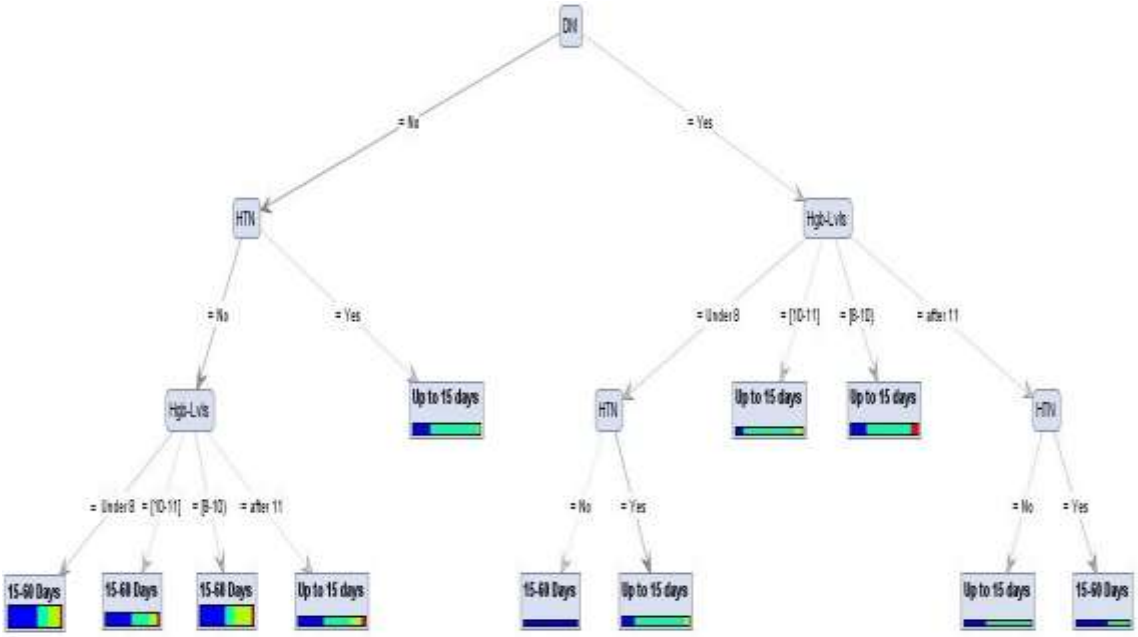

Figure 4. Effect of DM or HTN on decreasing longevity of RJV non-cuffed catheter

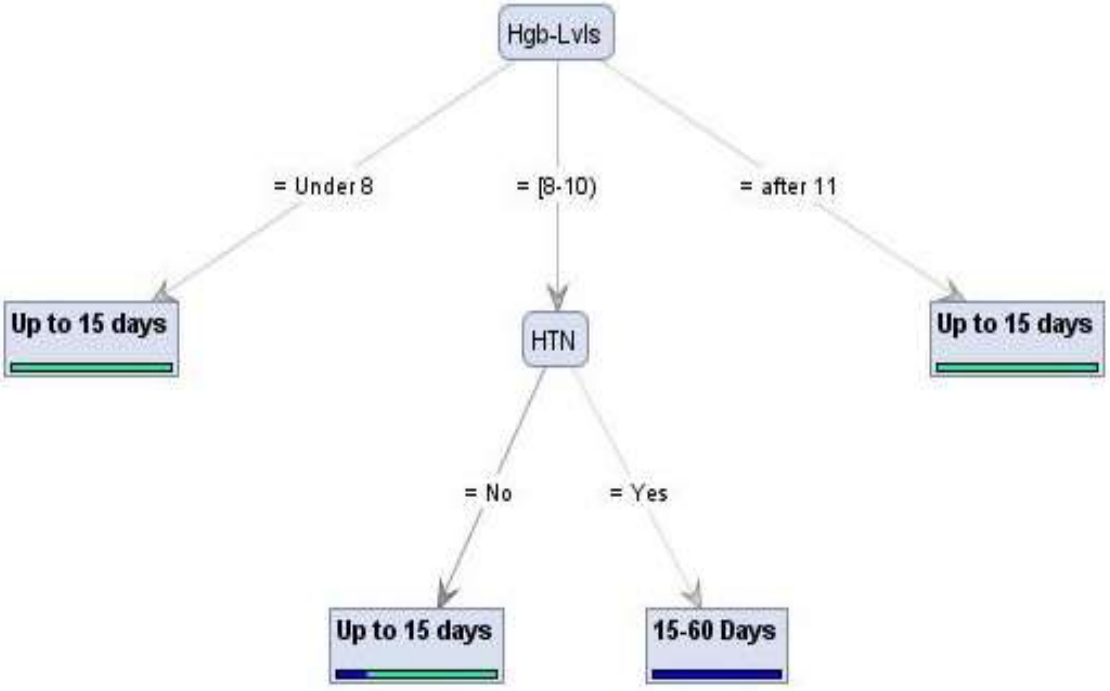

Figure 5. Risk of early failure ("Up to 15 days") is high, using femoral vein

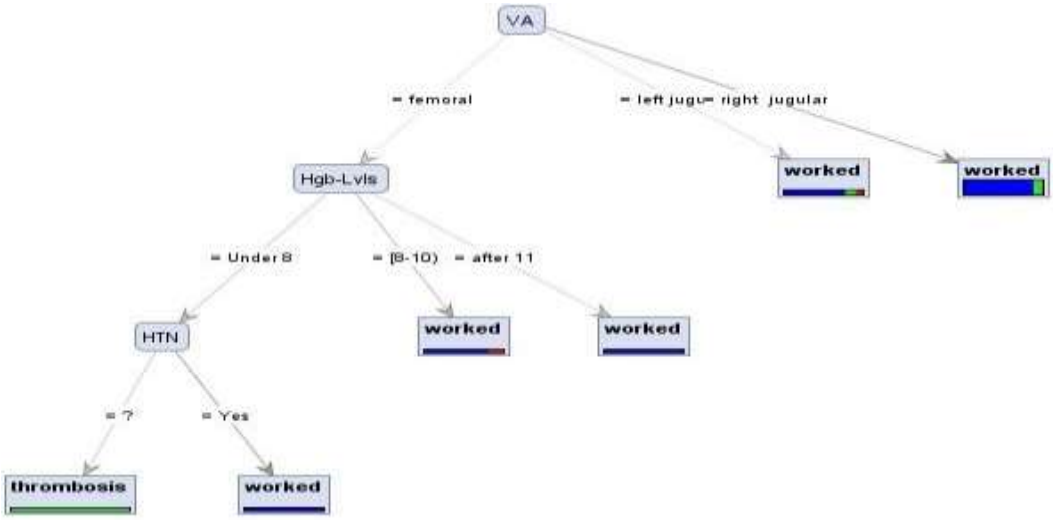

Figure 6. Occurring "thrombosis" morbidity when Hgb is low, using FVC

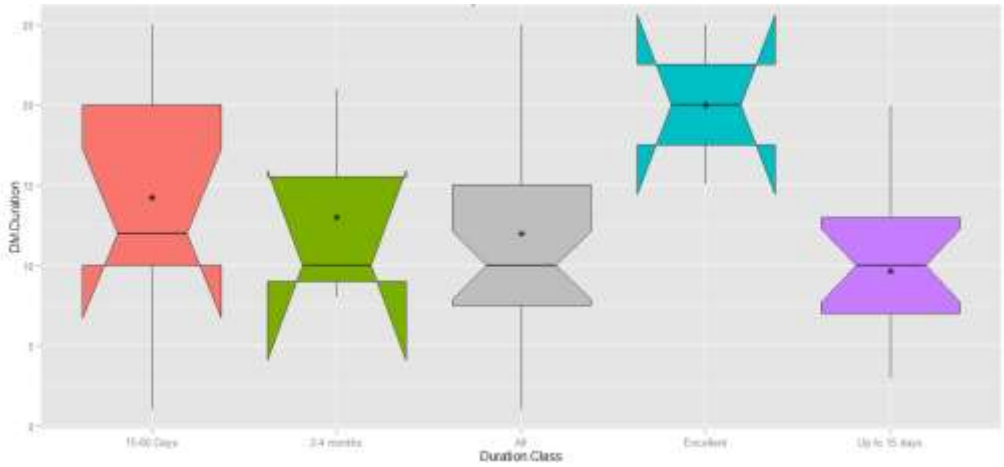

Figure 7. Most survival ("Excellent") when "DM- duration" be high!

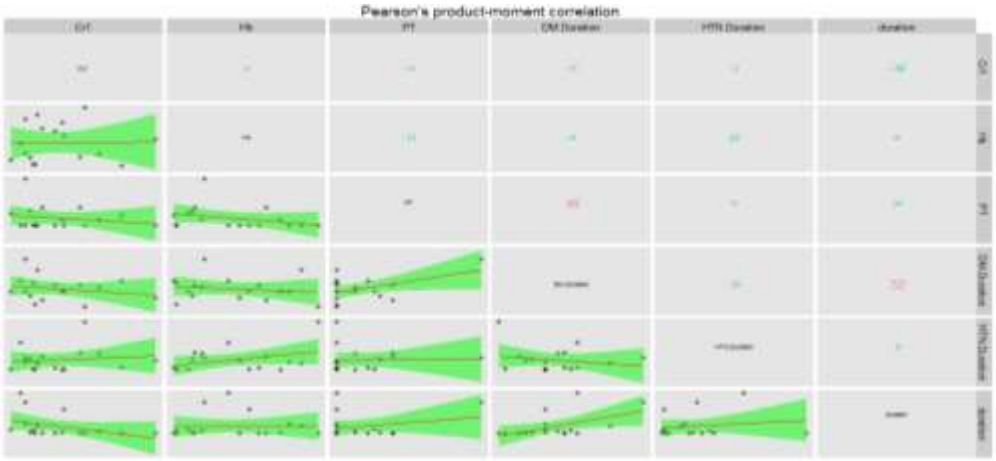

Figure 8. Positive correlation between "DM-duration" and "duration" of non-cuffed CVC!

Whenever Merrer, et al. [20] have shown that risk of thrombosis is lower in the internal jugular vein (IJV), slightly higher in the SVC, and still higher in the FVC; the study of McGee DC and Gould MK [21], illustrated infections are more common in the FVC region possibly due to the proximity of the perineum, whilst the SVC probably causes less infection than the IJV. Moreover, in another study it is found that catheterization of the IJV is associated with longer catheter survival when compared to the FVC and it is concluded that HD catheters should be placed, if possible, in IJV to prevent their premature malfunction [22].

High durability of CVCs is studied by other researches but with different results; Silva et al found that DM was no factor independently associated with increased CVC infection risk [43]. Another study has mentioned that for CVC, female gender, DM (type I and II) and late referral were associated with increased frequency in the incident cohort, both female gender and type I diabetes mellitus had a significantly increased likelihood of catheter use in the incident cohort. In addition, type II diabetes mellitus patients also had a significantly increased likelihood of catheter use [44].

Our investigations found that diabetic patients with more than 20 years DM, have had an excellent (most survival) CVC; Continuing this research study provides important information on the longevity of non-cuffed CVCs.

Detecting the risk factors of non-cuffed CVC insertion can prevent HD patients from some morbidities and subsequently. Catheterization using “femoral” causes low durability and so maximal risk rates. Moreover, although diabetes mellitus (DM) and hypertension are major risk factors for IJV Catheterization, but there is an inverse effect of duration of hemoglobin (Hgb) and DM on non-cuffed CVC, such that there exist more durable non-cuffed CVC in some of diabetic patients and in some patients with low Hgb.

Author contribution

All authors contributed equally and approved the final version of the manuscript.

Conflict of Interest

Authors declare that they have no competing interests. None of authors have any financial relation with the commercial tools – such as Rapidminer, R and Rattle - mentioned in this paper.

Ethical declaration

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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