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Risk Factors And Complications of Arteriovenous Fistula In Patients on Cronic Hemodialysis

Damir N. Peličić[1,2]

[1] Clinical Center of Montenegro, Podgorica, Montenegro
[2] Faculty of Medicine, University of Montenegro, Podgorica, Montenegro

SUMMARY

Introduction: Arteriovenous fistula (AVF) is a surgical connection created between an adjacent artery and vein in patients undergoing chronic hemodialysis, The aim is to divert arterial blood into a vein, which becomes arterialized due to the newly established hemodynamics. AVF is widely recommended as the preferred vascular access for hemodialysis (HD), due to long-term therapy of patients with end-stage renal disease and significantly fewer complications compared to other vascular access options, such as Central Venous Catheter (CVC). However, despite the lower complication rate, AVF can still be associated with intraoperative, early, and late postoperative complications.
Methodology: Recent scientific publications were thoroughly reviewed through PubMed, Scopus, SCI Index and other reference databases with a focus on risk factors and complications of arteriovenous fistula in patients on a chronic HD program.
Topic: The most common AVF complications include: stenosis caused by hemodynamic and functional changes that cause narrowing of the blood vessel lumen by more than 50% and occurs on both the arterial and venous sides of the AV fistula. Thrombosis, which is the complete cessation of blood flow in the AVF venous segment proximal to the AV anastomosis. Aneurysm is a local expansion of a vein resulting from strong blood flow through the site of narrowing. Then the infection of the anastomosis that occurs due to careless and non-aseptic puncturing of the AVF and other complications of the AV fistula, such as pseudoaneurysm, hematoma, peripheral ischemia and heart complications.
Conclusion: Thrombosis and stenosis are among the most common late complications of AVFs. This paper highlights the significance of AVFs as a permanent vascular access for hemodialysis and reviews the various complications and their associated risk factors. Scientific evidence from the literature emphasizes that proper and consistent AVF puncture technique can significantly delay the onset of these complications, underlining the importance of careful preoperative and ongoing management.

Keywords: Chronic Kidney Disease, Hemodialysis, Thrombosis, Aneurysm

INTRODUCTION

Chronic kidney disease (CKD) is defined as permanent and irreversible kidney function damage, characterized by a reduced glomerular filtration rate persisting for three months or more along with a sustaineddecline in glomerular filtration capacity [1,2]. In the terminal stage of CKF, there are three modalities for renal function replacement: HD, Peritoneal Di-

Corresponding author:
Associate in teaching Damir N. Peličić, PhD
Specialist in Health Care
Clinical Centre of Montenegro, Ljubljanska bb, 81000 Podgorica, Montenegro
E-mail: damir.pelicic@t-com.me

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alysis (PD), and Kidney Transplantation (KTx) [3]. To access treatment for patients on HD, it is necessary to create certain prerequisites, including providing adequate vascular access, which can be temporary CVC or permanent vascular access AVF and Arteriovenous Graft (AVG). AVF is recommended as the preferred vascular access option for HD due to its suitability for chronic hemodialysis patients and significantly fewer complications compared to other vascular access types such as CVC [4]. However, despite the lower complication rate, AVF may still be associated with intraoperative, early, and late postoperative complications [5]. This paper provides an overview of the importance of AVF as a permanent blood access for HD along with its associated complications and the risk factors contributing to their development.

METHODOLOGY

In our article, we reviewed recent scientific original publications and meta-analyses, which we thoroughly studied through PubMed, Scopus, SCI Index and other reference databases with a focus on risk factors and complications of arteriovenous fistula in patients on a chronic HD program. The keywords we used to search for scientific articles were related to: Chronic renal failure, complications, Arteriovenous fistula, hemodialysis, central venous catheter, thrombosis, aneurysm, risk factors and others.

TOPIC

An arteriovenous fistula (AVF) is a surgically created connection between an adjacent artery and vein in patients undergoing hemodialysis (HD), designed to divert arterial blood into the venous system, which becomes arterialized due to the resulting hemodynamic changes [6-8]. The global incidence of CKD is increasing rapidly, along with the prevalence of patients on HD. Among patients with CKD, HD is the most commonly usedform of dialysis, commonly used 89% of the dialysis population, while PD accounts for the remaining 11% [9-12]. The indication for creating AVF is in patients with an endogenous creatinine clearance ≤ 20 mL/min/1.73 m^2. An internal diameter of the radial artery ≥ 2.0 mm, internal diameter of the cephalic vein ≥ 2.5 mm, blood flow velocity through the radial artery (VmaxS) ≥ 50 cm/s, and blood flow through the radial artery (Qa.radialis) ≥ 40 mL/min ensure proper maturation of the distal radio-cephalic AVF. Maturation is considered adequate when, four to five weeks postoperatively, the cephalic vein diameter reaches ≥ 4.0 mm and blood flow exceeds 500 mL/min, indicating readiness for AVF puncture In terms of HD treatment efficiency, guidelines suggest that AVFs should support a blood flow velocity of 100–350 cm/s and a blood flow rate of 500–1000 mL/min to ensure effective dialysis delivery [13]. AVF is essentially an anastomosis between the radial artery and cephalic vein (known as Brescia-Cimino fistula). Under constant arterial blood pressure, the venous part of the fistula undergoes dilation (6–10 mm) and thickening, a process called „maturation". This maturation process should last at least a month, ideally 3 to 4 months after the surgical procedure performed by a vascular surgeon, except in patients with type 2 diabetes, the elderly, and patients with cardiovascular insufficiency or other chronic diseases [1-3]. Early and appropriate planning of vascular access ensures good access, preventing complications associated with CVC and other HD complications [14,15]. AVF is the standard and best vascular access for HD patients. In some patients with inadequate blood vessels, a proximal arteriovenous fistula may need to be created, or an AVG may be implanted. Literature suggests that such a procedure is practiced in patients without other options for creating vascular access. In the dialysis center of the Clinical Center of Montenegro, the number of AVF is about 80 percent compared to CVC [16]. The growing prevalence of end-stage CKD has led to a sharp increase in the number of HD patients due to longer life expectancy.. AVF is the optimal blood access for HD due to its longevity, lower rates of infection and thrombosis, and greater safety compared to AVG or CVC [17-19]. The most common AVF complications by frequency of occurrence in patients on HD (Table 1.).

Thrombosis AVF

The most common complications of AVF include stenosis caused by hemodynamic and functional changes that result in a narrowing of the vessel lumen by more than 50%. It is important to emphasize that stenosis can precede AVF thrombosis and occurs on both the arterial and venous sides of the AV fistula [20,21].

Table 1. The most common AVF complications by frequency of occurrence in patients on HD

The most common AVF complications by frequency of occurrence in patients on HD	Some of the risk factors for AVF complications
Thrombosis AVF	Stenosis, hypercoagulability and narrowing of blood flow due to access occlusion with too tight bandages or clamps during the hemostasis period, heart failure, hypotension, etc.
Aneurysm AVF	Increased venous pressure due to central venous stenosis, repeated punctures at the same puncture site, infections, etc.
Infection AVF	Inexpert puncture and failure to adhere to aseptic measures, inadequate hygiene and patient care, etc.

Thrombosis results in the complete cessation of blood circulation in the venous segment of the AVF, proximal to the AV anastomosis[20,21]. Regarding complications associated with vascular access for HD, thrombosis, along with stenosis, is among the most common late complications of AVF, with an incidence ranging from 17% to 25% [20,21]. According to the literature , significant predictors for the development of thrombosis in the first AVF in HD patients were a body mass index > 25 kg/m², blood pressure > 140/90 mmHg, and an age category of 45-59 years [21,22]. The most common cause of vascular access failure is thrombosis [23-27]. The three primary causes of AVF failure or thrombosis are: inadequate venous outflow (stenosis), inadequate arterial blood inflow, and medical factors, including heart failure and reduced hypotension [23-27]. A study by Miller et al. suggests that thrombosis is the most common complication in the female population, which they explain by the poor development of blood vessels in women, unlike the male population [28].

Aneurysm AVF

An aneurysm is defined as a localized dilation of a vein due to strong blood flow through the narrowed area. Infection of the anastomosis occurs due to improper and non-aseptic puncturing of the AVF, and other complications of surgical AVF include pseudoaneurysms, hematomas, peripheral ischemia, and cardiovascular complications [20,21]. A study by Jankovic A et al.'s involving 181 HD patients found that150 were eligible for inclusion in the study. Aneurysmal changes were found in 90 (60%) patients, with most having two or more aneurysms at one AVF flow site [29]. Patients with poorly controlled long-term diabetes mellitus on HD have a 5.8 times higher risk of developing AVF aneurysms compared to others. The study also reported a higher incidence of aneurysms in patients who had been on high-flow dialysis membranes for a longer period and with higher blood flow rates [29]. Between August 2010 and August 2013 in the United States, the use of AVF increased from 63% to 68%, while CVC usage decreased from 19% to 15% [30]. Aneurysms are now recognized as one of the most common and severe complications vascular access for HD [31]. Dilatation of more than three times the original diameter of the natural blood vessel is considered an aneurysm, confirmed by ultrasound scanning [32]. Literature suggests that long-term patency of AVF is the most relevant factor for the treatment of patients with end-stage kidney failure on HD [33]. Al-Thani H et al.'s study suggests that the overall mortality rate from all causes related to AVF was 37.5%, with the leading causes of death being sepsis/pneumonia (60%), myocardial infarction, and heart failure (40%). These findings underscore the high morbidity and mortality associated with AVF aneurysms in HD patients [34]. Hang F et al.'s study, which aimed to investigate risk factors for AVF dysfunction, concluded that sex, body weight, and phosphorus levels were independent risk factors for AVF dysfunction [35]. They found that AVF dysfunction was significantly associated with several risk factors, including body weight, phosphorus levels, and sex. Therefore, weight loss or oral phosphate binders can significantly improve the long-term success of AVF [35]. Zhang et al., in a comprehensive meta-analysis involving 27 studies (including 24 cohort studies, two case-control studies, and one cross-sectional study), identified the following as independent risk factors for AVF thrombosis: advanced age, female sex, elevated C-reactive protein (CRP) levels, distal fistula location, hypertension, low levels of $CD34^{+}KDR^{+}$ cells, and erythropoietin use [36]. A study by Erkut B et al., who followed 412 HD patients with AVF implantation over a 10-year period, suggests that vascular access occlusion leads to significant morbidity in HD patients. Age, sex, diabetes mellitus, malignancy, tobacco smoking, heparin use after one HD treatment,

previous placement of a dialysis CVC, number of HD therapy treatments, and AVF location may be associated with primary AVF survival. The authors of some studies concluded that risk factors affecting primary AVF patency were diabetes mellitus ($p = 0.0001$), number of hemodialysis sessions > or =3 per week ($p < 0.0005$), presence of malignancy ($p < 0.0005$), previous dialysis CVC ($p < 0.0007$), and post-HD ($p < 0.0007$) [33].

Infection AVF

Infection is associated with CVC and other HD complications [14,15]. The literature suggests that CVC and AVG infections are more common than AVF infections [37]. In a study by Liu et al., there were 2119 patients from a HD center in the China National Kidney Data System between January 1, 2010, and October 10, 2023. Multivariate analysis showed that a high comorbidity score from blood access complications for HD was a risk factor for death, of which infection was a significant factor [38]. An insufficiently mature or developed AVF may increase the infection rate and mortality in hemodialysis patients [39]. AVF infections are less common than CVC infections by as much as 90% in HD patients [40]. The literature suggests that incompetent AVF cannulation by nurses is associated with an increased risk of infection in HD patients [41].

Risk factors and complications of AVF

Heart failure is the most prevalent cardiovascular disease associated with CKD and represents a high risk for cardiovascular mortality in patients with HD. Heart failure is particularly high risk during the period of AVF maturation due to the pronounced hemodynamic changes associated with the large increase in blood flow, as well as in the first 120 days after initiating HD. Studies suggest that AVF creation in the high-flow brachial artery should be avoided because this is the highest risk of worsening cardiac function in the patient [42]. Some studies suggest that the AVF maturation process should last from 6 to 16 weeks, and it is important to note that in patients with uncontrolled and long-term diabetes and elderly patients, this AVF maturation process can last up to 6 months [43,44]. A meta-analysis by Almasri et al. found that patients with diabetes and advanced vascular complications, such as atherosclerosis, have a shorter duration of AVF patency than other patients on HD [45]. The establishment of a well-functioning AVF in patients on a chronic HD is essential, as it reduces reliance on central venous catheters (CVCs) [46-50]. Individual factors such as comorbidities, AVF anatomy, remaining dialysis access options, and patient preferences should be considered when planning a surgical approach for HD [49]. Loss of AVF patency in patients on HD significantly leads to a greater number of intraoperative and postoperative complications and is significantly associated with a number of modifiable risk factors, the early recognition and elimination of which risk factors can improve AVF functioning and extend its exploitation time [51]. Preventive interventions in AVF reduce the incidence of complications and improve blood flow in the AVF. In this way, they reduce negative emotions in HD patients such as anxiety and depression, and significantly improve the patient's quality of life, thereby increasing patient satisfaction with care [52].

CONCLUSION

Arteriovenous fistula (AVF) remains the gold standard for vascular access in hemodialysis (HD). However, non-functioning AVFs, due to the aforementioned complications, often necessitate the use of central venous catheters (CVCs), which are associated with significantly higher morbidity and mortality rates in patients undergoing chronic HD. The successful and timely placement of AVF is a key indicator for preventing complications in HD patients. The importance of a well-created AVF in patients on a chronic HD program, then a well-cared-for AVF by nurses results in reduced hospitalizations, fewer emergency dialysis procedures, and reduced CVC use, which suggests that such models could potentially significantly reduce overall health care costs. A review of scientific evidence in the relevant scientific literature on preoperative management of this vascular access has determined that long-term and correct puncturing of AVF in HD, along with proper aseptic and antiseptic measures, prevents and significantly delays the occurrence of AVF complications, reduce patient mortality, and enhance the overall quality of life for individuals receiving chronic HD.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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Faktori rizika i komplikacije arteriovenske fistule kod bolesnika na hroničnom programu hemodijalize

Damir N. Pelčić[1,2]

[1] Klinički centar Crne Gore, Podgorica, Crna Gora
[2] Medicinski fakultet, Univerziteta Crne Gore, Podgorica, Crna Gora

KRATAK SADRŽAJ

Uvod: Arteriovenska fistula (AVF) je hirurška procedura gde se spoj koji se izvodi kod bolesnika na hroničnom programu hemodijalize, između susjedne arterije i vene, s ciljem preusmjeravanja arterijske krvi u vensku krv, koja se arterijalizira u venu zahvaljujući novorazvijenoj hemodinamici. AVF se preporučuje kao najpoželjna opcija vaskularnog pristupa za hemodijalizu (HD), zbog dugogodišnje terapije kod bolesnika sa terminalnom bubrežnom insuficijencijom i znatno manjeg broja komplikacija u poređenju sa drugim tipovima vaskularnog pristupa, kao što je Centralni Venski Kateter (CVC). Međutim, uprkos nižoj stopi komplikacija, AVF još uvek može biti povezana s intraoperativnim, ranim i kasnim postoperativnim komplikacijama.
Metodologija: Najnovije naučne publikacije temeljno su pregledane putem PubMed-a, Scopusa, SCI Indexa i drugih referentnih naučnih baza, s fokusom na faktore rizika i komplikacije AVF kod bolesnika na hroničnom programu HD.
Tema: Najčešće komplikacije kod AVF su: stenoza izazvana hemodinamskim i funkcionalnim promenama koje uzrokuju suženje lumena krvnog suda veće od 50 % i javlja se i na arterijskoj i na venskoj strani AV fistule. Kod tromboze je potpuni prestanak cirkulacije krvi u venskom segmentu AVF proksimalnije od AV anastomoze. Aneurizma je lokalno proširenje vene kao posledica jakog strujanja krvi kroz mesto suženja. Zatim Infekcija anastomoze koja se javlja zbog nepažljivog i neaseptičnog punktiranja AVF i ostale komplikacije AV fistule, kao što su pseudoaneurizma, hematom, periferna ishemija i komplikacije na srcu.
Zaključak: Može se reći da je tromboza, uz stenozu, među najčešćim kasnim komplikacijama AVF. U ovom radu smo dali osvrt na značaj AVF kao stalnog krvnog pristupa za HD i na komplikacije AVF, kao i na potencijalne faktore rizika koji do njih dovode. Pregledom naučnih dokaza u relevantnoj literaturi, o preoperativnom zbrinjavanju ovog vaskularnog pristupa utvrđeno je da dugotrajna i pravilna punkcija AVF-a sprečava i značajno odgađa nastanak komplikacija AVF-a.

Ključne reči: hronična bubrežna slabost, hemodijaliza, tromboza, aneurizma

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