Influence of various types of hemodialysis arteriovenous fistula on cardiac function: Review article

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Abstract

Background: Cardiovascular diseases are the most common cause of high mortality in hemodialysis patients. These patients undergoing maintenance hemodialysis through arteriovenous fistula (AVF) develop both structural and functional cardiovascular abnormalities.

Aim of the review: Highlight the potential influence of AVFs on cardiac function, which may contribute to its timely detection and allow measures to be taken that might prevent its serious complications.

Methods: We have searched literatures in American National Center for Biotechnology Information (NCBI), PubMed, Google scholar, Egyptian bank of knowledge and science direct.

Conclusion: Patients with AVFs should be followed regularly with echocardiographic studies to detect any cardiac complications as early as possible.

Keywords: Arteriovenous fistula; Hemodialysis; Renal failure; Cardiac effect.

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1. Arteriovenous fistula

It is a direct surgical anastomosis between an artery and a vein made to maintain hemodialysis; it is well known that native arteriovenous fistula (AVF) is the preferred choice for vascular access (VA), as it has much lower incidence of thrombosis and infection when compared to central venous catheter and arteriovenous grafts. But unfortunately it affects the hemodynamic state by shifting the blood directly into the venous side, which in turn may affect the heart in several ways **(Santoro et al., 2014).**

1.1. Radiocephalic arteriovenous fistula

As recommended by the American Kidney Disease Outcomes Quality Initiative (KDOQI) radiocephalic fistula (RC-AVF) is the first choice for vascular access in hemodialysis **(Gilmore, 2006)**, as regarding the steal syndrome RC-AVF has the lowest incidence among other types of AVFs **(Mickley, 2008).** Unfortunately, RC-AVF has very poor maturation rate **(Tordoir et al., 2003)**, with one study showing that up to two thirds of radiocephalic fistulas failed to mature **(Miller et al., 2014).** Also, the creation of distal AVFs saves another option of proximal AVFs to be created later **(Bode and Tordoir, 2013).**

1.2. Brachiocephalic arteriovenous fistula

It is only required in case of failure of distal AVFs. Brachiocephalic arteriovenous fistulas (BC-AVF) have a very good maturation rate mostly because of the wide caliber of the cephalic vein, which gets anastomosed to the brachial artery 1 cm above the elbow joint in end to side way **(Koksoy et al., 2009).**

1.4. Brachiobasilic arteriovenous fistula

Also, it is only required when there is no more option for more distal AVFs, it is surgically created by making subcutaneous tunnel for basilic vein transposition superficially to be suitable for dialysis cannulation. Also being deep, keep the vein safe from repetitive needling which in turn prevents the fibrotic deformation, brachiobasilic AVF (BB-AVF) has lower thrombosis and infection incidence when compared to lower limb vascular access or AVG **(Lazarides et al., 2008).**

2. Effects of AVFs on the cardiac function

There are immediate reactions post AVF creation, including decreased vascular resistance which help to increase cardiac output by 10–20% of the baseline. Intravascular volume increases after 1 week of AVF creation, resulting in increased inferior vena cava diameter, and left atrial volume **(MacRae et al., 2006).**

It ought to be certain that the exact impacts of AVFs on cardiac functions can't be thoroughly elucidated as chronic kidney disease (CKD) patients who are in need for hemodialysis have, in almost every case, salt and water retention which leads to volume overload. Arterial sclerosis, hypertension, as well as chronic anemia, can lead to pressure overload which causes a secondary increase in cardiac output. In addition, those patients can have significant pre-existing cardiac disease. However, those immediate impacts of AVF on cardiovascular system favoring that AVF may affect certain cardiac functions **(Elfekky et al., 2020).**

2.1. AVFs and congestive heart failure (CHF):

The majority of studies believe that most patients with end stage renal disease (ESRD) endure AVFs, and they have low incidence of high output CHF **(Unal et al., 2010).** This belief depends on the observation that studies on CHF in hemodialysis patients is confined to small series and case reports **(Dixon et al., 2002)** and it is uncommon to take surgical measures (AVF banding or surgical ligation) because of cardiac complications caused by AVF. Dixon et al. in a cohort study of 204 patients, found that the incidence of AVF banding was only 2.6%. In contrary, some studies suggest that it is not rare for high output CHF to be found in hemodialysis patients with AVFs **(MacRae et al., 2006).** These authors rely on that when cardiac deterioration occurs; the role of AVF in the worsening of cardiac functions is often overlooked because it is often assigned to the other risk factors that are highly common in hemodialysis patients. This often occurs in patients with long-term functioning AVFs, although it took 10 years after AVF creation for AVF-related worsening CHF to be noticed **(Alkhouli et al., 2015).**

2.2. AVFs and pulmonary hypertension:

Pulmonary hypertension (PH) is an elevated pulmonary arterial pressure above 25 mmHg caused by narrowing and obliteration of lung vessels lumen. It is confirmed by right heart catheterization **(Babadjanov et al., 2016).**

Regarding PH, one study found highly significant difference between patients with peritoneal dialysis (PD) and those with hemodialysis via AVFs, as the hemodialysis group had much higher PH than the PD group (P-value < 0.001) **(Paneni et al., 2010).** Several other studies came up with similar results when they compared between patients undergoing hemodialysis through AVF and those who receive PD, regarding the incidence of PH, patients with AVF had much higher rate of PH **(Fabbian et al., 2010).**

Although the main mechanism in development of PH in hemodialysis patients tend to be the volume overload caused by AVF, the ability of an AVF as a single factor to cause PH has been questioned **(Unal et al., 2010).** Usually the pulmonary circuit has the capability to accommodate significant volume overloads before it decompensates as it has an enormous capacity. Hence, it has been suggested that there is some degree of pulmonary vascular dysfunction in those patients who develop PH after AVF creation, which results in inability of the pulmonary system to accommodate the elevated cardiac output (CO) caused by AVF. This assumption depends on two findings: (1) Patients without significant co-morbidities or kidney disease don't develop symptoms of heart failure or PH except after a long time with traumatic AVFs. (2) Kidney transplantation for ESRD patients can return pulmonary artery pressure to normal **(Chaudry et al., 2010).**

2.3. AVFs and left ventricular hypertrophy:

The cardiac remodeling phenomenon has been well described and supported by various authors. Creation of an AVF is thought to cause ventricular wall hypertrophy by triggering myocyte changes through increasing venous return, preload and cardiac output (**Alkhouli et al., 2015**). Yet, it is still questionable how far is the effect of AVF on the left ventricle (LV) **(Cortesi et al., 2018).**

CKD and ESRD patients have high incidence of LV wall changes, including dilatation and hypertrophy, one study on ESRD patient, found the majority of them to have LV hypertrophy (LVH), and about the third to have wall dilatation **(Glassock et al., 2009).**

Myocardial hypertrophy is accompanied by decreased capillary density, which leads to marked increase in oxygen demands in comparison with its supplies, leading to ischemia**,** which in turn leads to interstitial fibrosis as it increases accumulation of extracellular collagen and increases the rate of myocardial cell apoptosis, ending in LV stiffness, impaired LV diastolic filling, increased filling pressure, and diastolic dysfunction **(Cerasola et al., 2011).** Myocardial fibrosis aggravates ischemia, and markedly increases the incidence of arrhythmias and sudden cardiac arrest **(Segall et al., 2014)**

There are many ways the AVF can cause LVH, mainly the increased afterload and preload which in turn lead to increase in the rate and force of contractility resulting in compensating changes of the ventricular wall ending in LVH **(Cortesi et al., 2018).** Various degrees and combinations of preload and afterload factors usually coexist with a synergistic or additive effect, explaining why there is mixed pattern of LVH (cocenteric and eccentric hypertrophy), as increased afterload caused by hypertension and arterial stiffness may result in the concentric type, also increased preload caused by volume overload or anemia (ESRD patients) may result in the eccentric type **(Pitoulis and Terracciano, 2020).**

2.4. AVFs and right ventricular dysfunction:

One of the most dangerous impacts that may found in patients undergoing hemodialysis via AVFs is heart failure. The risk of heart failure in those patients markedly increases because of the neurohumeral reflexes and hemodynamic changes caused by shunting blood through AVF. These hemodynamic changes (especially increased preload) significantly affect the right side of the heart, leading to right sided heart failure **(Beigi et al., 2009).** Recent study which conducted on 81 individuals who are on dialysis through AVFs, has found high incidence of right sided heart failure in ESRD patients with AVF as it was found in 15 patients of the study population. Postoperative decrease in right ventricular longitudinal strain (RVLS) free wall <-19% was identified as the best predicting factor for right sided heart failure with a cut off value of −14.2% **(Gumus and Saricaoglu, 2020)**.

Conclusion:

Since recent studies have demonstrated that AVF have several undesirable effects on cardiac dimensions and functions and these AVFs can be modified surgically either by ligation or limitation of the blood flow through them, patients with AVFs should be followed regularly with echocardiographic studies to detect these effects as early as possible and take measures to manage them and prevent their serious complications.

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