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The Relationship Between Hypertension and the Occurrence of Aneurysms in AV Shunts in CKD Stage V Patients at RSU Kertha Usadha Singaraja

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Abstract Chronic Kidney Disease (CKD) stage V patients rely on hemodialysis using arteriovenous (AV) shunts for treatment. However, aneurysms frequently occur as complications, threatening the efficacy of therapy. Hypertension, a prevalent condition in CKD patients, increases the risk of aneurysm formation through sustained high pressure on blood vessel walls. This study investigates the relationship between hypertension and aneurysm occurrence in AV shunts among CKD stage V patients. Method : This cross-sectional observational study was conducted at RSU Kertha Usadha Singaraja, involving 40 CKD stage V patients undergoing hemodialysis. Data collection included medical record reviews, blood pressure measurements, and physical examination for aneurysm detection. The association between hypertension and aneurysm incidence was analyzed using the Chi-square test. Result : Among the 40 participants, 27.5% had aneurysms, with a significant association between uncontrolled hypertension and aneurysm occurrence ($p = 0.013$). Patients with uncontrolled blood pressure were more likely to develop aneurysms (45%) compared to those with controlled blood pressure (10%). The findings underline the importance of blood pressure management in mitigating aneurysm risk. Conclussion : Uncontrolled hypertension significantly contributes to aneurysm formation in AV shunts among CKD stage V patients. Effective blood pressure management is essential to reduce vascular complications, ensuring better outcomes and sustainability of hemodialysis therapy.

Keywords: Chronic Kidney Disease, AV Shunt, Hypertension, Aneurysm, Hemodialysis, Vascular Complications.

INTRODUCTION

Chronic Kidney Disease (CKD) is a growing global health concern, particularly in elderly populations and individuals with comorbidities such as hypertension and diabetes mellitus. In CKD stage 5, patients require renal replacement therapy, one of which is hemodialysis through vascular access such as an arteriovenous (AV) shunt. AV shunt access plays a crucial role in patient survival as it facilitates adequate blood flow for the dialysis process. However, complications frequently arise

with this access, including aneurysms, which can threaten the effectiveness of therapy and the health of the patients.(1)

Hypertension is one of the main risk factors for vascular complications, including aneurysms in AV shunts. Uncontrolled high blood pressure can increase pressure on the blood vessel walls, thereby weakening the structure of the arterial and venous walls and increasing the risk of aneurysm formation. In CKD patients, hypertension is often difficult to control due to hemodynamic changes resulting from decreased kidney function. This exacerbates existing vascular damage risks, especially in AV shunts, which serve as the primary access for hemodialysis. (2)

This study aims to analyze the relationship between hypertension and the occurrence of aneurysms in AV shunt access among CKD stage 5 patients undergoing hemodialysis. It is hoped that this research will provide a deeper understanding of the impact of blood pressure control on vascular access complications. By understanding this relationship, better preventive and management measures can be developed to reduce the risk of aneurysms in patients dependent on AV shunts, thereby improving their quality of life and extending the sustainability of hemodialysis therapy.

METHOD

The study utilized an observational analytical design with a cross-sectional approach to examine the relationship between hypertension and the occurrence of aneurysms in AV shunts among CKD stage 5 patients undergoing hemodialysis at RSU Kertha Usadha Singaraja. The sample size consisted of 40 patients, determined using purposive sampling based on inclusion criteria such as a confirmed diagnosis of CKD stage 5, regular hemodialysis sessions, and the presence of an AV shunt. Data were collected through medical record reviews, blood pressure measurements, and ultrasound examinations to identify aneurysm occurrence. The data were analyzed statistically using univariate and bivariate analyses, with the Chi-square test employed to evaluate the association between hypertension and aneurysm incidence.

RESULTS AND DISCUSSION

This study analyzed data from 40 participants to evaluate the relationship between blood pressure control and the presence of aneurysms, alongside other relevant characteristics. The majority of participants (72.5%) were above 50 years old, while the remaining 27.5% were below 50. Blood pressure control was evenly distributed, with 50% having uncontrolled and 50% having controlled blood pressure. Aneurysms were present in 27.5% of participants, while 72.5% showed no signs of aneurysms. Regarding hemoglobin levels, 52.5% of participants had levels above 9 g/dL, and 47.5% had levels below this threshold. Serum creatinine levels were predominantly high, with 80% of participants exceeding 10 mg/dL and only 20% below. Additionally, 42.5% of participants had comorbid conditions, while 57.5% had none. Gender distribution showed a higher proportion of females (62.5%) compared to males (37.5%).

Category	**Presentage (n = 40)**
Age	
Above 50 years	29 (72.5%)
Below 50 years	11 (27.5%)
Gender	
Male	15 (37.5%)
Female	25 (62.5%)

Blood Preasurre	
Uncontrolled hipertension	20 (50.0%)
Controlled hipertension	20 (50.0%)
Aneurysm	
Present	11 (27.5%)
Absent	29 (72.5%)
Hemoglobin	
Above 9 mg/dl	21 (52.5%)
Below 9 mg/dl	19 (47.5%)
Serum creatinin	
Above 10 mg/dl	17 (42.5%)
Below 10 mg/dl	23 (57.5%)
Comorbidities	
Present	17 (42.5%)
Absent	23 (57.5%)

Table 1. Characteristic data

A chi-square test was conducted to assess the association between blood pressure control and the presence of aneurysms. The results revealed a statistically significant relationship, with a Pearson chi-square value of 6.144 (df = 1, p = 0.013). Participants with uncontrolled blood pressure were significantly more likely to have aneurysms compared to those with controlled blood pressure. Specifically, 45% of participants with uncontrolled blood pressure had aneurysms, whereas only 10% of those with controlled blood pressure showed similar findings. These results emphasize the critical role of effective blood pressure management in reducing the risk of aneurysms and underline the importance of targeted interventions to address this modifiable risk factor.

Discussion

The causes of aneurysms remain poorly understood. Pseudoaneurysms can originate from the anastomosis, often resulting from blood leakage outside the vessel lumen during surgery due to technical issues or later as a result of infection. Puncturing an arteriovenous fistula (AVF) or arteriovenous graft (AVG), whether for routine dialysis needling or other procedures, may lead to prolonged bleeding and the development of pseudoaneurysms. This risk is especially significant in AVGs if the needling site is overly concentrated. (3)

The underlying causes of true aneurysms in AVFs remain uncertain. Repeated needling creates numerous small fibrous scars on the vessel wall, which may enlarge over time, leading to localized aneurysmal regions. Even in areas untouched by needling, aneurysmal dilation can develop, driven by the high blood flow through the vessel that generates abnormal shear stress. This stress encourages outward remodelling and gradual dilation, significantly increasing the vessel's diameter. Histological studies of resected fistula aneurysms reveal extensive collagen infiltration, vessel wall thickening, and disrupted architecture. Stenoses, which intensify abnormal haemodynamics, are often linked to aneurysm formation. Aneurysms may develop downstream of a stenosis due to heightened transmural pressure or altered flow dynamics. Conversely, upstream of a stenosis, significant changes in flow patterns can trigger pathological remodelling of the vessel. (4)

The characteristics of the vessel wall may play a role, with some individuals having a predisposition to aneurysm formation. Similar patterns are observed in other aneurysms linked to

connective tissue disorders, and an increased incidence of aneurysm formation in vascular access (VA) has been noted in conditions like Alport's syndrome. Certain diseases, such as adult polycystic kidney disease, which is associated with intracerebral aneurysms, have also been linked to increased AVF diameters. Pregnancy, although less commonly reported, has been associated with aneurysms, including splenic artery aneurysms. However, its impact on VA remains undocumented, likely due to its rarity. Studies have explored additional factors that may contribute to a heightened risk of aneurysm development, with one study suggesting a reduced incidence of aneurysm formation when using buttonhole cannulation techniques. In prosthetic grafts, repeated localized punctures often lead to pseudoaneurysms, although true aneurysms can also develop at the arterial inflow site. (5)

The progression of VA aneurysms is typically benign, with most patients remaining stable and symptom-free, without compromising the functionality of the access or the dialysis process. Many individuals can undergo haemodialysis for years using large, tortuous AVFs that meet the criteria for aneurysms without encountering significant issues. Such stable aneurysms can be monitored over time, starting with baseline measurements and followed by routine clinical and ultrasound surveillance. Ultrasound evaluation should include both transverse and longitudinal measurements, along with assessments of blood flow and the presence of thrombus. Additionally, the inflow and outflow vessels should be examined, and wall characteristics such as thickness or signs of infection should be evaluated. (6)

High flow within a vascular access for hemodialysis develops progressively over time. As an AVF matures, the increased flow in the artery and vein causes dilation, reducing resistance within the circuit. This high-flow state alters hemodynamics and promotes intimal hyperplasia, which leads to venous stenosis. Venous stenosis raises venous pressure, contributes to aneurysm formation, reduces blood flow rates, and increases the risk of venous thrombosis. These complications necessitate multiple interventions to maintain access patency and may eventually result in access failure. Excessive flow in an AVF can also lead to abnormal growth of the access and impose cardiac strain. In brachiocephalic fistulas (BCFs), all blood flow is directed through the cephalic arch unless there are communicating veins linking to the basilic system. Flows as high as 2,000 mL/min can reach the axillary vein, and a flow exceeding 1,000 mL/min is a predictor of cephalic arch stenosis (CAS). BCFs are characterized by a significant increase in cross-sectional area and blood flow, with a mean flow rate of 1,983 ± 1,199 mL/min, compared to lower arm AVFs. (7)

Research has demonstrated that wall shear stress (WSS) is crucial in regulating endothelial cell function. Normal endothelial function, characterized by anti-inflammatory and antineointimal hyperplasia properties, is associated with high, laminar WSS. However, in high-flow conditions, regions of low flow can develop in vessel curves, such as in the cephalic arch. These areas of low flow lead to disturbed WSS, which is linked to vascular endothelial dysfunction, promoting neointimal hyperplasia and increasing the risk of cephalic arch stenosis (CAS). Neointimal hyperplasia inversely correlates with WSS and is influenced by flow patterns. Physiologically, after creating an arteriovenous fistula, high flows initially raise pressure and WSS, facilitating AVF maturation. Over time, low shear stress zones, known as recirculation zones, emerge in the curved areas of the arch, causing endothelial cell dysfunction and leading to CAS. As venous stenosis worsens, flow becomes restricted, and pressures rise. CAS perpetuates a cycle of high pressure, which results in tortuous veins and aneurysm formation. Over time, these extreme conditions create a complex interaction between biological factors driving outward remodeling and physical forces of wall tension, ultimately resulting in the formation of a mega-fistula. (8)

Cardiovascular disease remains the leading cause of mortality among patients with end-stage renal disease (ESRD). Hemodialysis patients exhibit both traditional risk factors, including diabetes, peripheral vascular disease, and hypertension, as well as nontraditional ones, such as elevated inflammatory markers, homocysteine levels, anemia, hyperparathyroidism, endothelial dysfunction, and abnormal lipoprotein B. These factors collectively contribute to higher cardiovascular mortality

rates. Research indicates that cardiac output increases by approximately 15% as early as the seventh day after AVF creation. This elevated cardiac output is associated with high AVF flow, potentially resulting in long-term complications like high-output heart failure, characterized by increased left ventricular end-diastolic volume and pulmonary hypertension. (9)

The K/DOQI guidelines recommend that asymptomatic aneurysms do not require intervention and should instead be managed by avoiding cannulation of the affected areas. Best practices for preventing aneurysms include careful cannulation techniques such as the rope-and-ladder or area cannulation method once the AVF has matured. The management of AVF aneurysms is guided by clinical signs and symptoms, the condition of the overlying skin, ease of cannulation, and the AVF's functionality, rather than the aneurysm's size. Venography can help delineate the aneurysm's anatomy and detect upstream venous stenosis, such as cephalic arch stenosis (CAS). (10)

The primary indication for intervention is clinical presentation. Bleeding from an AV aneurysm, which can be severe and life-threatening, may occur spontaneously, after hemodialysis needle removal, or due to trauma. Risk factors for bleeding include thinning or erosion of the skin over the aneurysm, rapid aneurysm expansion, anticoagulation therapy, prolonged bleeding time after needle removal, and increased intra-access pressure. In cases of active, prolonged bleeding accompanied by these signs, immediate surgical intervention is crucial. (10)

Impaired dialysis associated with aneurysms is often due to reduced arterial inflow or venous outflow stenosis, requiring targeted treatment for the underlying lesion. Angioplasty is typically recommended to address low flow; however, when there is a risk of bleeding associated with stenosis, an open surgical approach or the use of a covered stent, with or without angioplasty, is advised. High-flow AVFs that contribute to high-output heart failure may benefit from aneurysmorrhaphy. Various surgical techniques for aneurysm treatment have been described, but the lack of randomized controlled trials makes it challenging to compare their effectiveness. (11)

In ESRD patients with a history of congestive heart failure or progressive left ventricular hypertrophy, regular measurement of vascular access flow is essential. Monthly access flow assessments can be performed in clinical settings using the saline ultrasound dilution method, facilitated by devices such as the Transonic Hemodialysis Monitor HDO2 (Transonic Systems Inc., Ithaca, NY, USA). Although intradialytic cardiac output measurements were not included in this study, the transonic device provides valuable longitudinal data that can aid in identifying and mitigating risks of high-output AVF and cardiac failure. The ultrasound dilution technique effectively measures access flow (exceeding 2 L/min) and cardiac output (greater than 5 L/min). A ratio of access flow to cardiac output exceeding 25% is associated with a higher risk of high-output cardiac failure. When elevated access flow is linked to complications such as CAS, high-output heart failure, or steal syndrome, it requires careful decision-making and efforts to preserve the AVF. Banding has proven to be a successful method for reducing flow and addressing steal syndrome in high-flow AVFs. High-flow AVFs are a prevalent clinical challenge, though their definition remains inconsistent. They undoubtedly contribute to cardiac risks and access complications. Prospective studies are necessary to track volumetric flow in AVF access and its impact on cardiac dysfunction. Defining and optimizing blood flow is critical to preventing long-term complications associated with AVF access. (12)

The findings of this study provide important insights into the relationship between hypertension and the occurrence of aneurysms in arteriovenous (AV) shunts among CKD stage 5 patients undergoing hemodialysis. The results highlight the significant role of blood pressure control in mitigating the risk of vascular complications, particularly aneurysms, in this population.

The chi-square analysis revealed a statistically significant association between blood pressure control and the presence of aneurysms ($p = 0.013$). Participants with uncontrolled hypertension were significantly more likely to develop aneurysms in their AV shunts compared to those with controlled blood pressure. This finding aligns with existing literature that identifies hypertension as a major risk

factor for vascular complications. Uncontrolled blood pressure increases the hemodynamic stress on the vessel walls, leading to structural weakening and predisposition to aneurysm formation. The results of this study are consistent with prior research that underscores the impact of hypertension on vascular health. Studies have demonstrated that sustained high blood pressure exacerbates endothelial dysfunction and promotes arterial remodeling, both of which are critical factors in aneurysm pathogenesis. Moreover, in CKD patients, the interplay of hypertension with uremia-related vascular changes further amplifies these risks, making this population particularly vulnerable.

The findings emphasize the need for rigorous blood pressure management as part of the comprehensive care for CKD stage 5 patients with AV shunts. Effective hypertension control not only reduces the risk of aneurysm formation but also extends the durability and functionality of AV shunt access, ultimately improving the quality of life and dialysis outcomes for patients. Regular monitoring, patient education, and tailored pharmacological interventions are critical components of this strategy.

While the study provides valuable insights, certain limitations must be acknowledged. The cross-sectional design precludes the determination of causality between hypertension and aneurysm occurrence. Additionally, the relatively small sample size may limit the generalizability of the findings to broader populations. Future studies with larger sample sizes and prospective designs are needed to validate these results and explore underlying mechanisms further.Building on these findings, future research should investigate the long-term effects of blood pressure control on the prevention of aneurysm-related complications in CKD patients. Moreover, exploring the role of adjunct therapies, such as vascular protective agents, may provide additional avenues for mitigating risks associated with AV shunt aneurysms.

CONCLUSION

This study underscores the critical role of hypertension control in reducing the risk of aneurysms in AV shunts among CKD stage 5 patients. These findings highlight the importance of integrating effective blood pressure management into routine care for this vulnerable population. Addressing modifiable risk factors such as hypertension holds promise for improving patient outcomes and ensuring the sustainability of hemodialysis therapy.

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