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ORIGINAL ARTICLE

Factors of Autogenous Arterial-Venous Fistula Creation Failure

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ABSTRACT

Background: The effects of chronic renal disease on society are significant. As the most widely employed renal replacement therapy (RRT), hemodialysis generally requires vascular access (VA) to supply the 300–500 mL/min of blood flow necessary for efficient and adequate management. The current gold standard for obtaining a reliable as well as safe VA for Hemodialysis (HD) management is the development of a native Arteriovenous Fistula (AVF). We planned this study to identify the main causes of native A-V fistula maturation failure. Utilizing PubMed, Medscape, and other Medline databases to examine the success rate of arterial-venous fistula development till 2023. Each study that was considered for inclusion was reviewed separately. Those that met the following standards were considered for inclusion: Written in English, published in scholarly journals, and addressing both the early and late causes of failure in a native arterial-venous fistula. Research was simply ignored if it did not meet the predetermined standards. Ethical approval, eligibility requirements, controls, data completeness, and the clarity of assessment measures were all considered in this process. Our concerned study outcomes were gathered by independently abstracting information by utilizing a data collection form from each relevant study.

Conclusions: Most patients had a functioning fistula within 6 weeks of creation. However, a significant proportion of patients experienced complications such as thrombosis, hematoma, and pseudoaneurysm, which can contribute to early or late fistula failure.

Keywords: Renal failure; Dialysis; Vascular access; Arteriovenous fistula.

INTRODUCTION

It is estimated that chronic renal disease is the 19th leading cause of death globally, affecting many of people health lives [1]. Currently, hemodialysis is the most popular form of renal replacement therapy, but it requires a vascular access (VA) to supply the 300–500 mL/min of blood essential for an adequate and effective management [1m2]. The current gold standard for obtaining a safe and dependable VA for Hemodialysis (HD) therapy is the development of a native Arteriovenous Fistula (AVF) [3]. Brescia and Cimino were the first to conduct the surgery in 1966, and in the decades after then, the surgical process has been refined [4]. There are two main categories of factors that lead to the failure of A-V fistula creations: primary or early failure and secondary or late failure. Lack of vascular remodelling (external remodelling and/or venous arterialization) following access development is the primary cause of accesses failing to allow HD treatment. While accesses that have been used successfully for treatment but are afterwards impaired by postmaturation stenosis due to uncontrolled neo-intimal hyperplasia (IH) establishment that is not adequately compensated for by outward remodelling are said to be experiencing secondary failure (inward remodeling) [5]. There are several potential causes of AVF failure, but it is still a subject of debate. Both the mechanical (related to hemodynamics) and biological causes of A-V Fistula failure are considered in the current hypothesis [6]. Patients with diabetes, or hypertension may have a higher chance of AVF failure because to these conditions' effects on the vascular biology [3,6,7]. Changes in wall shear stress (WSS) exerted on the endothelium as a result of the new hemodynamics introduced by the AVF are the primary mechanical factors in AVF remodelling. The pressure drop at the AVF anastomosis is another important factor [6,8]. The aim of the current study was to identify the main causes of native A-V fistula maturation failure to improve the selection of patients.

METHODS

***Data sources*:**

Utilizing PubMed, Medscape, and other Medline databases to examine the success rate of arterial-venous fistula development from January 2000 to June 2023.

***Study selection*:** Each study that was considered for inclusion was reviewed separately. Those that met the following standards were considered for inclusion: Written in English, published in scholarly journals, involving only humans with any number of participants, and addressing both the early and late causes of failure in creating a native arterial-venous fistula.

***Data extraction*:** Research was simply ignored if it did not meet the predetermined standards. Ethical approval, eligibility requirements, controls, data completeness, and the clarity of assessment measures were all considered in this process. Our concerned study outcomes were gathered by independently abstracting information by utilizing a data collection form from each relevant study.

LITERATURE

***Renal failure*:**

Renal failure refers to a condition in which the kidneys are unable to eliminate waste nitrogenous materials from the body's blood [9].

Epidemiology:

Renal failure has been observed in 1% of patients upon hospital admission, 2-5% of patients while in the hospital, up to 37% of patients treated in ICUs, and 4- 15% of patients following cardiovascular surgery. Estimates place the annual incidence of renal failure at 209 per million people, with 36% of those diagnosed needing some form of renal replacement therapy. Renal failure could be either of acute or chronic type [10].

Dialysis:

Dialysis is the gold standard treatment for renal failure because of its ability to flush the body of waste products and toxins. Dialysis can help people whose kidney function suddenly declines (acute renal injury) or whose kidney function gradually declines over time (chronic kidney disease stage 5). Diffusion (elimination of wastes) and ultrafiltration, two components of dialysis, are used to substitute for kidney function [11].

Hemodialysis:

In hemodialysis, the patient's blood is pumped into the blood compartment of the dialyzer, where it is subjected to a partially permeable membrane to remove waste and hazardous chemicals. Thousands of microscopic synthetic hollow fibres make up the dialyser. The fibre membrane plays the role of a selectively permeable lining. Dialysate moves counterclockwise to the blood's flow. The membrane allows fluid and smaller solutes to pass through, but it prevents the passage of larger molecules (like large proteins or red blood cells) [11].

TYPES OF VASCULAR ACCESS

Temporary vascular access (VA)

When HD is required quickly and a suitable VA is needed immediately, this method of access is employed. Currently, there are two distinct sorts of this kind of access dialysis catheters which are cuffed and tunneled.and dialysis catheters which are non-cuffed and non-tunneled.

The most popular method for acute HD is the use of a non-cuffed, double-lumen, non-tunneled type of HD catheters, which is made of polymers that are rigid at room temperature to aid in insertion but soften at body temperature to reduce the risk of vessel injury and blood vessel laceration. It is possible to place these catheters into the femoral, subclavian or jugular veins [13].

When all other access points to the central vein have been excluded, the femoral vein then can be the last possible option that can be used. Due to the substantial risk of vein stenosis and thrombosis, subclavian catheters are generally not recommended. According to the Kidney Disease Outcomes Quality Initiative (K/DOQI) recommendations, non-cuffed, non-tunneled catheters should be used for dialysis treatments lasting less than one week, whereas cuffed, tunneled catheters should be used for treatments lasting one week or longer [14].

Permanent vascular access (VA):

Patient-specific factors, such as prognosis, co-morbidities, cardiovascular health, and access features, are considered while determining the best VA. The danger of infection and thrombosis, as well as the VA's functional lifespan, are other crucial considerations. There are benefits and drawbacks to every possible surgical anastomosis [15].

Because of its low risk of thrombosis and infection, arteriovenous fistula is the VA of choice. The gold standard for maintaining vascular access for HD is autologous ***arteriovenous fistula (AVF).*** It is best to have a fistula in the upper limbs rather than the lower limbs or anywhere else on the body**.** In accordance with the recommendations of the Kidney Disease Outcomes Quality Initiative, the Brescia-Cimino fistula, i.e. radiocephalic (RC) fistulas, are preferred above brachiocephalic and brachiobasilic AVF and then straight or loop synthetic graft fistulas in either lower or upper arm [16-18].

Creation and technical aspects of arteriovenous fistula:

Dialysis centres work tirelessly to minimise the usage of central venous catheters (CVCs) and maximise the effectiveness of vascular access beginning with the very first hemodialysis session. Despite these efforts, the growth of AVF as a vascular access still faces a hostile situation due to the fact that a rising number of patients, especially older and diabetic patients, lack adequate superficial veins [19].

An organized strategy to optimize the use of autogenous veins in the upper limbs is crucial for vascular access, as autogenous (AVFs) offer superior patency rates, less problems, and lower mortality rates compared to alternative options like AVG or catheters [20].

AVFs are more desirable than AVGs. Compared to grafts, fistulas have lower thrombosis rates, longer access lifespans, require fewer secondary treatments to maintain patency, and are cheaper. Compared to patients who received grafts, those who received fistulas had a decreased incidence of infection, steal syndrome, and symptomatic central venous stenosis. Patients with ESRD who undergo fistula dialysis have a significantly lower mortality rate than those who use graft dialysis. Consequently, fistulas are the favorite vascular access for chronic hemodialysis [21].

The AVFs constitutes 2 main types; Radial-dependent fistula (radiocephalic fistula) (figure 1) is referred to as the Brescia-Cimino fistula. Brachial-dependent fistula is either the brachiocephalic fistula (figure 2) at or slightly below the elbow level, or brachiobasilic fistula [fistula between the brachial artery and basilic vein in transposition (figure 3)] [22,23].

Brachiobasilic (BBAVF) was introduced by Dagher [24]who showed positive outcomes in terms of both patency and access-related complications. When comparing the basilic vein to the cephalic vein, the basilic vein is often longer and has a thicker wall. Even after numerous blood draws and an intravenous catheter insertion, this vein has remained in relatively good condition. Despite these potential benefits, chronic hemodialysis patients still require a translocation of the basilic vein for cannulation.

Elazeem Saleh et al. [25] compared brachiobasilic (BBAVF) to distal forearm radiocephalic (RCAVF) as the primary access for regular hemodialysis in individuals with metabolic syndrome. After a year, the patency rate was about 90% among patients in the BBAVF group, compared to 30% of patients in the RCAVF group. Among patients who received BBAVF, the rate of primary access failure was 6.7%, while it was only 3.3% among those who received RCAVF. Furthermore, 10% of those with BBAVF and 70% of those with RCAVF had secondary access failure. By counting the number of criteria and the rate of AV fistula failure, we found that patients who met both the 4th and 5th criteria for the metabolic syndrome had a considerably lower RCAVF patency.

Arteriovenous fistula configuration:

All of the different AVF configurations underwent the same surgical procedures, which all involved end-to-side anastomoses using running 6 polypropylene (Prolene) sutures. When constructing a BCAVF or BBAVF, the biggest vein was typically selected for arteriovenous anastomosis. Transverse or longitudinal skin incisions were performed 5 cm above the wrist to expose the radial artery and cephalic vein for RCAVFs. Using a radial artery anastomosis, the distal cephalic vein was mobilised after transection . The incision for BCAVFs was made transversely, 2 cm below the elbow crease. The lacertus fibrosus was opened transversely, and the subcutaneous cephalic and cubital veins were dissected. The cephalic vein was then anastomosed with the dissected brachial artery . A brachiocubital AVF was created in rare occasions. In this procedure, the perforating vein was used to connect to the brachial artery instead of the cephalic vein. Every single BBAVF was a straightforward, single-step operation. Upper arm basilic vein was transected as far distally as possible after dissection through an interrupted medial cutaneous incision. An incision 2.5 cm above the elbow crease transversely opened the skin to expose the brachial artery for dissection. An anterolateral subcutaneous tunnel was created, and the basilic vein was threaded through it to be anastomosed (7-10 mm) to the brachial artery [26].

Tertiary vascular access:

The choice of which tertiary VA surgery is best for a given patient is contingent on both the patient's unique anatomical characteristics and the surgeon's level of expertise and training. These can be categorised into three groups with progressively higher levels of danger and complexity, and should be dealt with in the following order of importance: Upper limb, chest wall, and lower limb autogenous vein transposition make up Group 1. The lowest limbs were of group 2. An arterio-arterial loop in the upper or lower extremity is an example of an uncommon VA procedure, in group three VA was spanning the diaphragm [27].

Endo-AVF creation using Wavelinq and Ellipsys:

When there are sufficient blood vessels, the gold standard is still a radiocephalic arteriovenous fistula (AVF). For patients with insufficient arteries for distal AVF construction, the next best option is to generate an AVF in the proximal forearm between the proximal radial artery (PRA) and the perforating vein of the elbow (PVE). 1 Recently, a less invasive approach has been devised that permits the percutaneous establishment of such a fistula. Similar to surgical PRA-AVFs, the main difference in vessel size requirements is a smaller distance between the PRA and PVE, 1.5 mm instead of 2 mm. Verifying healthy distal blood flow in the ulnar artery and palmar arch is necessary before using the PRA as an inflow for surgery or percutaneous access [28].

Using a combination of heat, pressure, and tissue fusion, the PRA and PVE are permanently anastomosed with the Ellipsys Vascular Access System. A survey on 232 patients found that the average Ellipsys treatment took 15 minutes (range: 7-35 minutes), with 99 percent of patients experiencing technical success [29].

By redirecting blood flow , the Ellipsys AVF reduces pressure and turbulence in both veins and provides valuable additional undisturbed cannulation length. Patient satisfaction is high because the operation leaves no surgical scar, causes minimal postoperative pain, and may be done in an outpatient setting (figures 4, 5, 6 and 7) [30].

ARTERIOVENOUS FISTULA MONITORING

Clinical monitoring:

Every time a patient receives dialysis, he or she should have a full physical examination and clinical monitoring of the arteriovenous access. Physical signs such as persistent arm swelling, the existence of collateral veins, prolonged bleeding after needle removal, or altered features of pulse or thrill in the outflow vein or graft have all been linked to arteriovenous access dysfunction [31].

Noninvasive monitoring of AVF

One of the techniques used for AVF investigation is **Doppler ultrasound**, which is a great and sensitive modality for hemodialysis access evaluation both before and after surgery**.** Measuring access blood flow and treating hemodynamically severe stenosis are both advised for AVF surveillance. The number of subsequent invasive operations can be drastically cut down with ultrasonography imaging. It's useful for gauging the AVF's structure and performance (blood flow volume). It identifies the specifics of the issue at hand, such as its location and severity, and facilitates the preparation for either endovascular or open surgical treatment [32].

A single longitudinal scan of the vessel is sufficient for measuring the vessel diameter and mean flow velocity required for computing flow volume. At first, a suitably enlarged B-mode picture used to determine the vessel diameter. The time/velocity curve is used to determine the average flow rate once the pulsed Doppler module has been turned on and the PRF has been adjusted to remove artefacts. By measuring both parameters in a single scan, you may rest assured that your measurements were taken at the same location in the blood artery. Further computations are unnecessary once the two measurements have been made: Most current ultrasound machines include computation techniques that can automatically determine the AVF flow volume [33].

Invasive monitoring:

The most reliable method for determining if an access is patent is **digital subtraction angiography (DSA)**. Because of its compatibility with endovascular treatment, DSA is not any more invasive than needle puncture for dialysis. On the other hand, DSA subjects the patient to ionizing radiation and iodinated contrast chemicals, which can worsen renal function or trigger an allergic reaction**.** [34].

Evaluation of failed access fistulas and grafts is now possible with **contrast-enhanced magnetic resonance angiography (CE-MRA).** With CE-MRA, the entire vascular tree of an access can be mapped out using angiography without the need of harmful ionizing radiation. The lack of a guided access mechanism for CE-MRAs is a significant barrier [34].

Haemodialysis vascular access issues can often be diagnosed with the help of **multi-slice computed tomographic angiography (MSCTA).** It is more cost-effective than digital subtraction angiography (DSA) and has largely replaced DSA for imaging haemodialysis vascular access, with useful results that can be used to guide AVF revision or angioplasty [34].

Arteriovenous fistula complications:

Stenosis, lymphedema, heart failure, infections, steal syndrome, aneurysms, and thrombosis as well as ischemic neuropathy are considered the most serious consequences associated with fistulae in HD. Among HD patients, neointimal hyperplasia is the leading cause of vascular access failure. [35].

Treatment of stenotic lesions inside the access with PTA for isolated stenoses and coil embolization and ligation to remove competing branch veins have both been shown to be effective [36].

Eighty-three percent of nonmaturing fistulas were successfully treated by Nassar et al. [38] who used balloon angioplasty of focal stenoses and coil embolization of accessory veins, but They concluded that 16.8% of the fistulas were hopeless due to outflow obstruction or because the venous outflow channel was too deep, convoluted, or structured.

Long-segment arterial angioplasty of the radial artery to 4 mm in diameter was shown to facilitate maturation in 96% of patients with failed Brescia-Cimino fistulas in a study by Turmel-Rodrigues et al. [38] Early detection of neointimal hyperplasia is crucial for preventing further hemodynamic alterations after HD, such as reduced blood flow via the AVF, increased venous pressure, and prolonged bleeding. One such limitation is the difficulty in achieving sufficient local concentrations of antiproliferative drugs without generating systemic toxicity, which in turn has an effect on the efficacy of the treatment. DNA damage from radiation is thought to reduce the number of endothelial cells and macrophages that can divide to replenish injured tissue. Radiation can have a devastating effect on the body's newest blood vessels. In 42% of patients with restenosis, intracoronary gamma radiation was successful. The application of beta radiation yielded the same outcomes.

CONCLUSIONS

Our study showed that the majority of patients in the study population had a functioning fistula within 6 weeks of creation. However, a significant proportion of patients experienced complications such as thrombosis, hematoma, and pseudoaneurysm, which can contribute to early or late fistula failure. The data also indicates that the majority of patients in the study population had a proximal brachiocephalic fistula created for vascular access. Type of shunt have no significant impact on the time of functional maturation. Strategies for preventing arterial-venous fistula failure are proposed in this review, including the following: early identification of risk factors of VAF (such as preoperative vascular conditions, age, sex, ethnicity, and clinical backgrounds); early failure detection through monitoring and surveillance of vascular access, particularly at frequent stenotic sites; and early intervention in the event of a failure.

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FIGURE LEGENDS

Figure (1): Illustration shows configuration of radiocephalic fistula. Juxtaanastomotic segment is variably defined as first 2–5 cm of outflow vein adjacent to arteriovenous anastomosis

Figure (2): Illustration depicts anatomy of brachiocephalic fistula. Cephalic arch is most central portion of cephalic vein

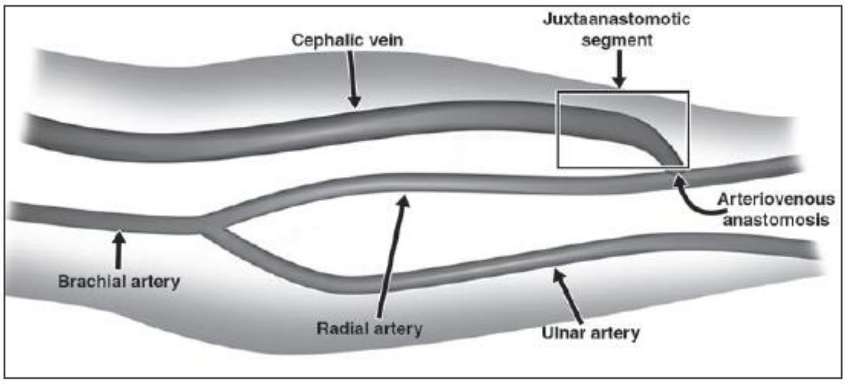
Figure (3): Illustration shows normal anatomy of brachial artery–to– transposed basilic vein (BTB) fistula. Proximal swing segment is most frequent site of stenosis in BTB fistulas

Figure (4): Puncture of proximal radial artery (PRA) through the deep communicating vein at the level of the antecubital fossa. A guidewire should be placed to secure the connection between the artery and vein for the subsequent steps of the procedure.

Figure (5): A, Ellipsys catheter advanced into the artery in an open position with the tip of the device in the artery and the base of the device remaining in the vein, B: Gentle traction is applied to the device to ensure the device has captured the arterial wall-the operator should feel the resistance when the artery is seen secured adjacent to the vein.

Figure (6): The device is closed and activated. Thermal energy and pressure will cut and fuse the anastomosis between the proximal radial artery and deep communicating vein.

Figure (7): The anastomosis between the proximal radial artery and deep communicating vein is completed.



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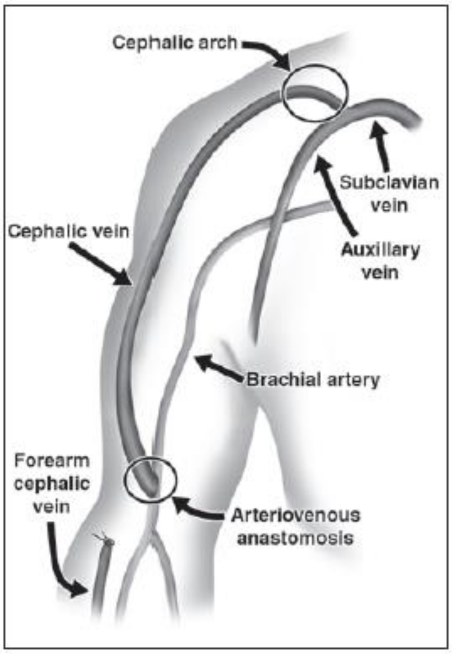

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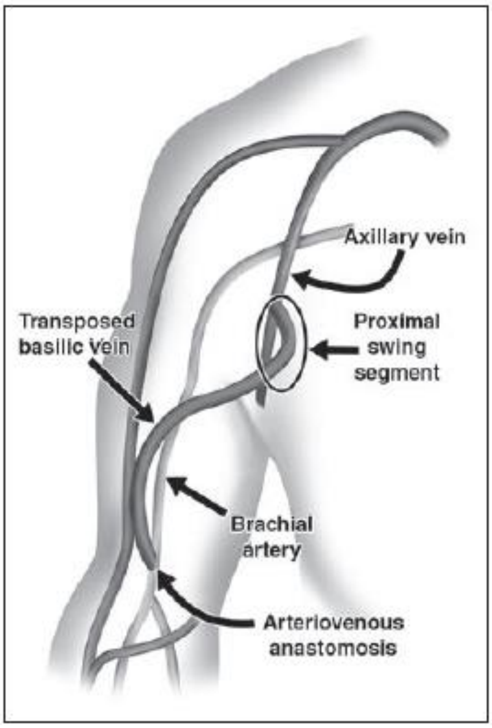

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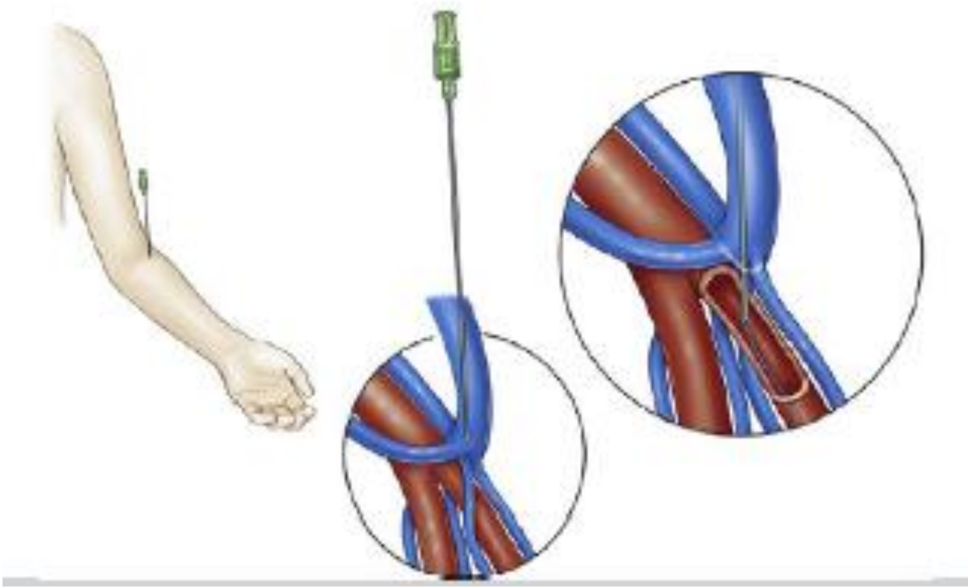

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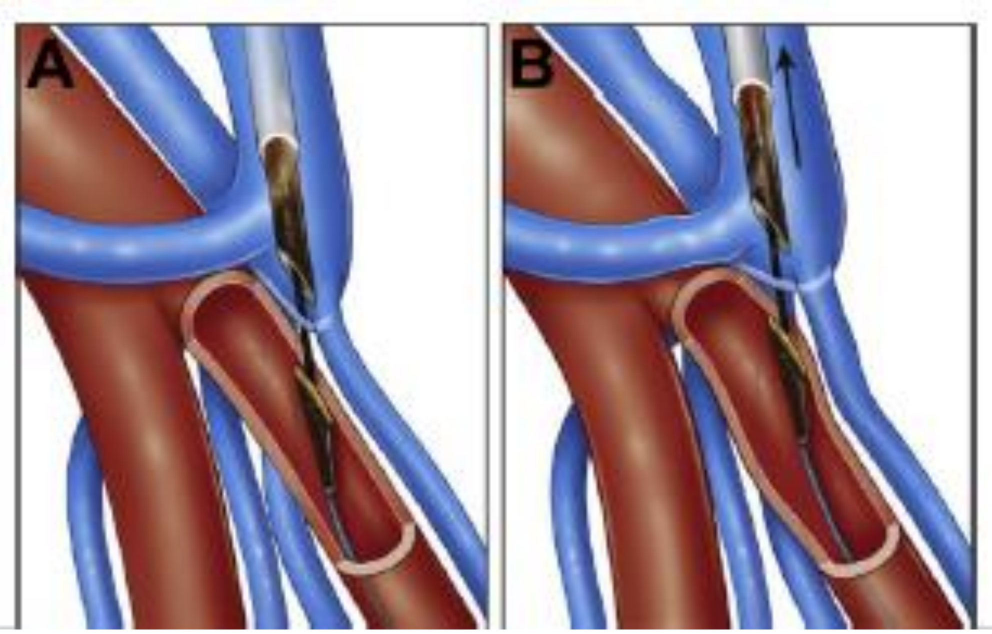

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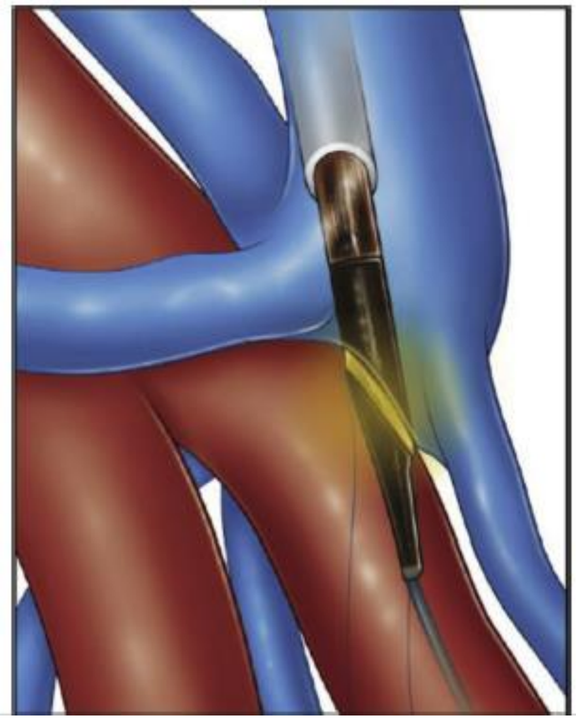

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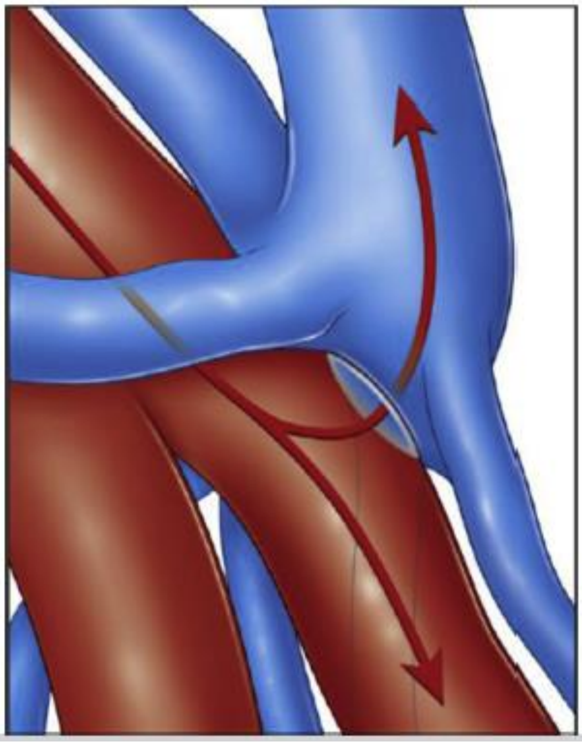

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