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Current approach to venous catheterization in hemodialysis patients and important points

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ABSTRACT

Hemodialysis procedure is commonly performed in hospitals. It is typically conducted due to renal dysfunction, elevated levels of urea and serum creatinine, or excessive volume overload. Additionally, emergency hemodialysis may be implemented in cases of certain poisonings. Emergency hemodialysis procedures are usually performed through a temporary venous catheter. The majority of patients undergoing continuous hemodialysis therapy access dialysis through arteriovenous fistula and permanent hemodialysis catheter. This procedure can be carried out with a very low risk of complications when performed by experienced individuals.

Keywords: Venous catheterization, catheterization, hemodialysis

INTRODUCTION

The prevalence of chronic kidney disease (CKD) is increasing worldwide, driven by the rising rates of obesity, diabetes, extended life expectancy, and the surge in chronic conditions such as hypertension. This trend has led to a growing frequency of hemodialysis (HD) requirements, with HD also being utilized in cases of certain poisonings. While peritoneal dialysis (PD) is common in some countries (such as Mexico), hemodialysis remains more prominent in many others. In our country, there are approximately 80,000 dialysis patients, with around 70,000 receiving HD treatment. The number of HD patients in our country was around 60,000 in 2017, and as of 2023, this figure has exceeded 70,000 (Figure 1). Emergency dialysis treatments, particularly for patients undergoing dialysis for the first time, are predominantly conducted through venous catheterization. The majority of patients undergoing continuous HD therapy receive dialysis through arteriovenous fistula (AVF) and permanent HD catheter (Figure 2). Venous catheterization procedures, when performed by experienced hands, carry a very low risk of complications.[1-4]

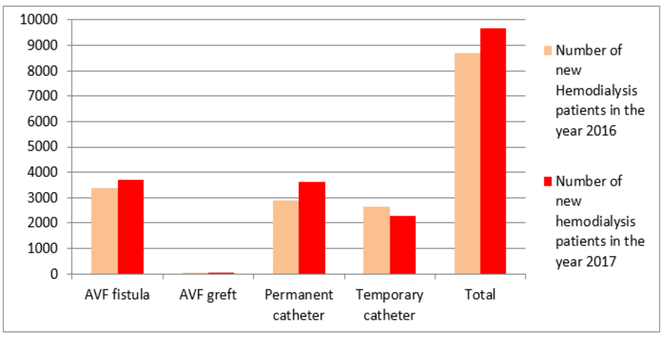

Figure 1. Distribution of new hemodialysis patients based on the currently used vascular access route as of the end of 2016-2017[2]

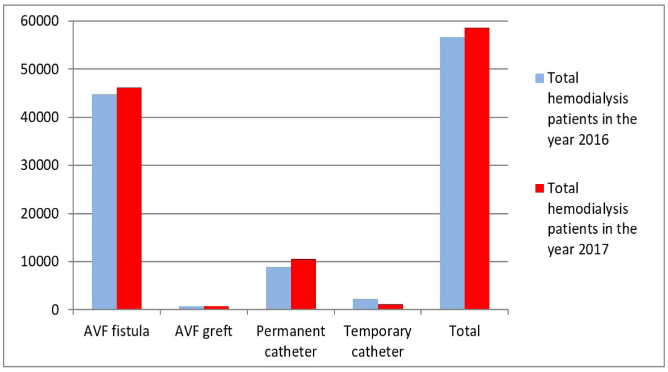

Figure 2. Distribution of hemodialysis patients based on the currently used vascular access route as of the end of 2016-2017[2]

HEMODIALYSIS: WHAT IS IT?

Hemodialysis (HD) is the process of removing various toxic products such as urea, creatinine, potassium, phosphorus, and excess water from the body due to kidney insufficiency. This is achieved through the use of a semi-permeable membrane located outside the body, which cleans the blood.

WHO UNDERGOES HEMODIALYSIS AND HOW IS IT PERFORMED?

As kidney function declines, the levels of toxic products such as urea, as well as various electrolytes like potassium and phosphorus, become uncontrollable. Conditions such as uremia, hyperkalemia, and hypervolemia can lead to severe complications and, if left untreated for an extended period, may result in death. While the primary goal in acute kidney failure is to address these complications, the objective in chronic kidney failure is to reintegrate the individual into daily social and work life.[3-5]

In the process of HD, the fundamental technique involves passing the patient's blood through an external filter to eliminate toxic substances. Simultaneously, the depleted electrolytes are replenished before returning the blood back into the body. Essential components such as proteins and shaped elements of blood, including vital elements like electrolytes and water, are retained in the blood, while toxins and excess water are removed through micro-pores. The HD solution also possesses a replacement feature, normalizing the electrolyte and water balance. During treatment, anticoagulants such as heparin may be administered to prevent blood clotting.[4-7]

VASCULAR ACCESS ROUTE

To transport blood from the body to the machine and back to the patient, a vascular access route is essential. The choice of vascular access route depends on the urgency of the HD requirement. Catheters, associated with both infectious and non-infectious complications, contribute to increased morbidity and mortality. In cases of urgent HD need arising from acute kidney failure (AKF) or chronic kidney disease (CKD), catheters are the initial preference. The ability to initiate HD treatment immediately upon catheter insertion is the reason for this preference, eliminating the need for waiting. Further planning is made based on the clinical course.

If the anticipated duration of HD need is short-term (a few weeks), a temporary catheter may suffice. If a prolonged need for this treatment is foreseen, an arteriovenous fistula (AVF), also known as AVF, is planned as soon as possible. This topic is explained in more detail under the relevant heading. If there is an obstacle to creating an AVF, a "permanent tunneled catheter" can be placed after a temporary catheter. Moreover, if the need for such access is foreseeable from the beginning, placing a permanent catheter instead of a temporary one in a single procedure may be more appropriate.[1-4,6,8]

CATHETER

A central catheter is a type of central venous vascular access route with one end located outside the body and the other advanced towards the cardiac cavities.[3,8]

While this vascular access route has various applications, this discussion will primarily focus on its use in HD.

Catheter Usage

The use of catheters comes with both advantages and disadvantages (Table 1, 2).[1-3,4-8]

Table 1. Advantages of catheter usage
No maturation time is required, as in shunts (arteriovenous fistula).
Cost-effective.
Applicable in every center and easily implemented.
Offers numerous anatomical options.
Depending on the type, can be used for weeks to years.
Catheter blockage is often a correctable condition.

Table 2. Disadvantages of catheter usage
Increased risk of catheter thrombosis or thrombotic occlusion in the vessel where it is placed.
Short lifespan of temporary catheters.
Directly accessing central vascular structures increases the risk of infection and sepsis.
Complicates hygiene practices.
Disrupts patient comfort.

Catheter Types

There are two different types of catheters based on duration of use: permanent and temporary. If the planned duration of use is between a few days and a few weeks, temporary catheters are initially preferred. However, even within this period, especially to prevent complications such as infection, it may be necessary to remove the catheter every 72 hours and replace it with a new one from a different site. This practice becomes even more crucial in areas with high vulnerability and increased incidence of resistant infections, such as intensive care units. A temporary catheter enters the central vein just below the skin entry point and reaches the heart. On the other hand, a permanent catheter, after entering the skin, is advanced a certain distance (usually around 10 cm) under the skin before entering the central vein and reaching the heart. These catheters are referred to as tunnelled catheters because a tunnel-like space is formed as they progress under the skin. Additionally, to firmly anchor in the area where it will remain for an extended period, there is Dacron felt outside the catheter, and this felt ensures adhesion to the surrounding tissue a few days later. It should be noted that due to catheter dysfunction and dysfunction-related issues, approximately 52% of tunnelled HD catheters need to be removed within one year. Therefore, if vascular access is required for more than three weeks, a tunnelled catheter should be preferred.[4-8]

Catheter Placement

Different techniques are used for catheter placement for each central vein except for the external jugular vein, which is superficial. Almost all central venous catheters are placed deep below the fascia. Therefore, vascular tracing is done by creating reference points using the vein trajectory, surrounding muscles, and the artery. Prior to the procedure, the patient's cardiac rhythm is monitored with electrocardiogram (ECG) leads, blood pressure is monitored with a cuff placed near the central area, and oxygen saturation is monitored with a pulse oximeter. The area is sterilized with betadine, covered with a sterile drape with small holes, and local anesthetic is applied. Before starting the procedure, it is confirmed that the patient does not have bleeding diathesis and has not used any medication that may disrupt hemostasis. For this purpose, the intrinsic pathway (aPTT), extrinsic pathway (PT/INR), and platelet count are checked with a complete blood count. In very specific cases, catheter placement may be performed despite unfavorable conditions, but this situation carries significant risks and should be managed with awareness of potential complications. Particularly in such cases, performing the procedure under ultrasound guidance can reduce complications. In the standard method, a small amount of saline is drawn into a syringe first. A puncture needle is attached to the tip, and the air is expelled. The needle is advanced toward the target point with negative pressure created in the syringe.

Some complications may arise at this stage. Attempting to enter one of the veins around the thorax, especially when air is aspirated into the syringe, may indicate entry into the thoracic cavity. Pneumothorax is very rare when the needle is rapidly withdrawn with negative pressure, as long as there is no injury to the lungs. Alternatively, entering one of the arteries adjacent to the target vein in any region may result in bright-colored and pressurized blood. In both cases, the needle is immediately withdrawn, and pressure is applied to the relevant area for about 5 minutes. Then, the procedure continues. It should be kept in mind, especially in patients with COPD or respiratory distress at that moment, with low oxygen saturation, that arterial blood color may be dark like venous blood, and there may be a false vascular puncture. Similarly, considering the patient profile, patients with poor cardiac function, low ejection fraction, and inadequate blood pressure, pulse, and circulation may also have pressureless arterial blood, leading to a potential false vascular puncture. Once the relevant vein is punctured correctly, the needle is advanced without any movement, and the guide wire is threaded from the needle into the vein and then towards the heart. In a patient without cardiac risk, the ECG trace is monitored from the monitor as the guide wire is advanced to the heart, and the change in heart rhythm at the moment the guide wire touches the atrial tissue is considered an indicator that the guide wire has reached the heart. However, especially for elderly patients with rhythm problems, such verification is a significant risk and may not be necessary.[1,2,4-8]

Venous Selection for Hemodialysis Catheterization

Choosing the appropriate vein for intervention is crucial, taking into account the individual patient's condition, as each venous access site has various advantages and disadvantages. The most commonly preferred veins include:[4-8]

1. Vena jugularis interna (Internal jugular vein)
2. Vena subclavia (Subclavian vein)
3. Vena jugularis externa (External jugular vein)
4. Vena femoralis (Femoral Vein)

1. Vena jugularis interna: This is the most commonly chosen route for short-term central venous catheterization. The relatively lower complication rate and the wide diameter of the vein make it a primary choice. It runs within the carotid sheath in the neck, passing anteriorly and laterally to the carotid artery. It joins the subclavian vein at the level of the clavicle, forming the brachiocephalic vein that enters the thorax. The patient lies supine with arms secured at the sides, and the head is slightly turned in the opposite direction during the procedure. The Trendelenburg position (head down) is useful to protect the brain from potential air embolism during the procedure and to increase venous filling, thereby expanding the vein diameter. In cases of insufficient venous filling, additional volume replacement from another peripheral vascular access may be performed. The Valsalva maneuver or maintaining a brief inspiratory hold on a mechanical ventilator can increase venous filling. Gentle rotation of the head in the opposite direction of the puncture site can ease the procedure but excessive rotation may increase the risk of arterial puncture. The puncture site is usually the apex of the triangle formed by the clavicular and sternal heads of the sternocleidomastoid muscle. Palpate the carotid artery at the level of the cricoid cartilage, then puncture the skin at a 30-40 degree angle towards the nipple, maintaining slight negative pressure in the syringe. Generally, the vein is accessed at a depth of 2-3 cm; going deeper increases the risk of complications.[4-8]

2. Vena subclavia: It is chosen when catheter placement in the neck veins, the primary preference area, is not feasible. While the advantage lies in the wide diameter of the vein, entering the thorax increases the risk of complications such as pneumothorax/hemothorax and arterial injury, and their repair can be challenging. Subclavian vein catheters have the highest risk of stenosis (30-50%), a concern that is particularly significant in patients with bleeding diathesis. It is a continuation of the axillary vein. The subclavian vein is located in the lower part of the supraclavicular triangle, between the posterior edge of the sternocleidomastoid muscle, the middle of the clavicle, and the anterior surface of the trapezius muscle. It joins the internal jugular vein behind the sternoclavicular joint and extends below the first rib, passing beneath and in front of the artery. The pleura is immediately below the vein. The patient lies supine with arms secured at the sides, and the head is slightly turned in the opposite direction during the procedure. The Trendelenburg position (head down) is important to protect the brain from potential air embolism during the procedure and to increase venous filling, expanding the vein diameter and volume. In cases of insufficient venous filling, additional volume replacement from another peripheral vascular access may be performed. The Valsalva maneuver or maintaining a brief inspiratory hold on a mechanical ventilator can increase venous filling. Puncture is made 1 cm below and lateral to the midpoint of the clavicle, directed towards the sternal notch. If the needle tip touches the clavicle, it is slightly withdrawn and redirected to go deeper. The needle tip should not pass the sternal alignment. Generally, the vein is accessed at a depth of 2-3 cm; going deeper increases the risk of complications.[4,5,7,8]

3. Vena jugularis externa: Especially in cases of short-term and urgent central venous catheterization needs, when catheter placement in the internal jugular vein or subclavian vein is not possible for any reason, and there is a visibly prominent external jugular vein structure, it may be preferred. Although not always prominent in every patient, it is easily visible and palpable in a position accessible in the neck, leading to fewer complications associated with puncture. However, even if successful vein puncture and advancement of the guidewire are possible, the course, diameter, and valvular structure of the vein may not allow the catheter to advance. It descends down from the mandible, crossing the sternocleidomastoid muscle, and joins the subclavian vein at the level of the clavicle. Similar to the internal jugular vein, the patient lies supine with arms secured at the sides, and the head is slightly turned in the opposite direction during the procedure. The position is given to facilitate easy visualization and palpation, and the puncture is performed as if opening a peripheral vascular access, with the guidewire and then the catheter advanced. The Trendelenburg position (head down) is important to protect the brain from potential air embolism during the procedure and to increase venous filling, expanding the vein diameter and volume. In cases of insufficient venous filling, additional volume replacement from another peripheral vascular access may be performed.

The Valsalva maneuver or maintaining a brief inspiratory hold on a mechanical ventilator can increase venous filling. While a slight rotation of the head in the opposite direction of the puncture site can ease the procedure, excessive rotation may increase the likelihood of arterial puncture.[4-8]

4. Vena femoralis: It may be preferred, especially in cases of short-term and urgent central venous catheterization needs, when catheter placement in the internal jugular vein or subclavian vein is not possible for any reason. Since it is adjacent to the easily palpable femoral artery, complications associated with puncture are minimized. However, prolonged use poses a risk of deep vein thrombosis and can be a significant source of infection due to the difficulty in keeping the area clean at all times. Additionally, in mobilized patients, the catheter in this region can easily become obstructed when folded in a sitting position. Located just distal to the inguinal ligament, in the femoral triangle area, it is in proximity to the medial side of the femoral artery. The patient lies supine, and the vein is punctured at an angle of 20-30 degrees to the skin, just distal to the inguinal ligament and immediately medial to the femoral artery. Puncture is performed as if opening a peripheral vascular access, guided by palpation, and then the guidewire and catheter are advanced. If the needle is advanced too laterally, arterial puncture may occur. Inappropriately lateral entries can lead to femoral nerve damage. Achieving adequate hygiene, especially due to proximity to the genital area, is often challenging and carries a much higher risk of infection. Therefore, long-term use is not recommended.[4-8]

Catheter Complications

Improper catheter placement has the potential to cause life-threatening complications, including pneumothorax, arterial puncture, bleeding, and central circulation infections associated with vital structures.[1,3,4]

During catheter placement, the following complications may arise:

1. Arterial/venous injury
2. Bleeding
3. Pneumothorax
4. Emboli
5. Cardiac arrhythmias
6. Obstruction

During hemodialysis:

1. Collapse
2. Obstruction
3. Bleeding
4. Emboli
5. Cardiac arrhythmias
6. Hypotension

Late Complications:

1. Infection: Treatment of catheter-related bacteremia often necessitates the removal of the catheter in most patients.[6-7]

2. Catheter thrombosis: While vascular wall injury typically occurs during catheter placement, any manipulation or repositioning of the catheter can lead to further injury. This triggers turbulent blood flow around the catheter, stimulating coagulation and inflammatory cascades, resulting in thrombosis.[7,8]

3. Stenosis in central vein: Stenosis in the central vein is one of the most common complications, occurring in around 40% of patients undergoing HD despite all precautions. The development of collateral veins can compensate for the narrowing, allowing asymptomatic patients without venous return problems to be monitored. However, if the return is impaired and venous hypertension develops, percutaneous transluminal angioplasty is the preferred treatment method.

4. Perforation

Catheter Obstruction and Treatment

For the HD machine to perform adequately, the device usually requires a blood flow rate of 300-500 ml/min to come into the machine, and after the procedure, it should be able to be given back to the patient.[8,9] In hemofiltration devices, although this need drops to levels around 100 ml/min, it is still important that the vascular access pathway operates at full capacity. When there is a decrease in inflow or outflow to the device, the machines usually give warnings. The possibility of the catheter being folded should be considered first in this situation. Both the catheter itself and all connections should be checked. Catheter clamps can easily cause folding in this area due to constant compression. Also, considering the possibility of thrombosis, prophylactic heparin administration during the procedure can be preventive for such occlusion.[9,10] Additionally, after flushing the catheter line with sterile saline at the end of the procedure, the space inside the catheter line is filled with a diluted solution in temporary catheters and with pure heparin in permanent catheters. The volume of the relevant space is indicated on the catheter. It should be remembered that filling the catheter line only with the amount of heparin indicated on the catheter, without giving any heparin to the patient, is essential. For example, giving 2 ml of heparin to a space indicating 1.7 ml means administering 0.3 ml (1500 units) of heparin to the patient, which can lead to bleeding, especially in a patient with bleeding diathesis. It is crucial to precisely fill the catheter line with the amount of heparin written on the catheter using a precise measurement. If the catheter is blocked for any reason, several maneuvers can be attempted to salvage the situation. A classic sign is the absence of both blood coming in and going out through the catheter. Using the thinnest possible syringe (2 cc or even an insulin syringe), pressure is applied to the catheter with a solution diluted to 1/10 with heparin. Since the syringe tip can pop out of place during this pressure, the connection point should be held firmly. Using a syringe with a screw tip is even more secure. The highest possible pressure is achieved with the thinnest syringe. Moreover, since only a small volume of 1-2 cc is delivered to the vessel during the opening of the blockage, vascular damage is prevented. Although some thrombus may fall into the vessel during the clearance of the blockage, this amount is usually small enough not to cause a problem. Nevertheless, to prevent possible complications, heparinization of the patient is recommended. If thrombosis cannot be removed despite all these efforts, the catheter is replaced with a new one.[8-11]

Another significant reason is the rapid blockage of catheter holes due to contact with the vessel or atrium walls during rapid suction. The HD machine creates a vacuum at the catheter tip, pulling tissue towards itself along with blood, similar to an electric vacuum cleaner. If the region where the catheter tip is located is not in a wide space or there is not enough fluid in the area, the walls near the catheter holes are pulled towards the catheter, instantly blocking itself, stopping the blood flow, and locking the system. The classic sign of this problem is that when blood is slowly withdrawn from the catheter with a syringe, it flows smoothly, but when withdrawn rapidly, it gets blocked. Before intervening in the catheter, several basic techniques can be tried to still operate the system. Firstly, changing the patient's position or making them cough may resolve the situation. The patient may be hypovolemic, and venous filling can be increased by placing them in the Trendelenburg position or using the Valsalva maneuver. Excessive fluid removal from the patient during dialysis can also cause hypovolemia. The system working very well at the beginning of dialysis but inadequate flow towards the end is a typical sign of this condition. Hypotension, a common complication during HD, can also indicate preload reduction due to hypovolemia. In this case, fluid removal can be stopped, and fluid replacement (including blood products if necessary) can be considered.[4-7,9,11]

If the problem of flow inadequacy cannot be corrected with these maneuvers in the dialysis room, a chest X-ray can provide important information regarding the location of the catheter. Especially for catheters placed in the chest or neck area, the tip must have reached the atrial space. As the venous diameters and venous filling are not very high at this level, when the system creates a vacuum, venous structures can collapse, and the system can lock. If the catheter is too advanced and touches the heart valves or bends in the atrium, the system can also collapse. If the catheter is too inside, it can be pulled out a bit surgically or with controlled small manipulations. However, the opposite is dangerous and difficult. That is, pushing the catheter from the outside to advance it to reach the atrial space is both difficult due to the catheter's softness and its partial adherence to the surrounding tissues, and it brings an additional risk of sepsis by inserting a catheter region that cannot be completely sterilized into the vessel. Generally, in this case, the catheter is replaced with a new one. As a convenience, a guidewire can be inserted into the old catheter, the catheter can be withdrawn, and then a new catheter can be placed over the same guidewire. However, this method also carries an additional risk for sepsis as the sterility of the area cannot be guaranteed during this procedure. Another problem we can see with chest X-ray is the folding of especially tunneled permanent catheters inside the body. Often this folding is at the level just before entering the vessel in the tunnel. Sometimes this folding can be corrected by manipulating the skin from the outside, but many times surgical manipulation or sometimes replacement of the catheter is needed.[7-11]

Catheter Care

Every invasive procedure carries various risks. Therefore, reducing the need for the same process to be repeated is crucial. Appropriate care and usage techniques from the moment of placement extend the catheter's lifespan. This care and dressing changes should be performed by trained healthcare personnel.[7-11]

- The entry site of the catheter should be checked before and after each hemodialysis session. Temporary catheters are held in place with stitches, and if these stitches have become loose or broken, they should be repaired, and if necessary, new stitches should be applied. Permanent catheters, on the other hand, are held in place from a few days onwards by the adherence of the Dacron cuff around them to the skin. Until this adhesion is achieved, a stitch also helps keep the catheter in place. If the stitches holding the catheter in place have broken or been damaged without sufficient adhesion, they should be repaired or new stitches should be applied. The cuff of the catheter must be within the skin. If the cuff is visibly protruding (malposition), it should be referred to a center that can correct the situation through surgical intervention. In such a center, the cuff can be pushed a bit under the skin as much as possible in sterile conditions, or a cut can be made in the skin to bury the cuff, and then it can be covered or a new catheter can be placed.
- Before and after each hemodialysis session, the catheter site and catheter caps should be sterilized with a solution (2% chlorhexidine or 10% povidone iodine or 70% alcohol) and covered with a sterile gauze after the procedure.
- During bathing, the catheter site should be covered with a waterproof drape that completely covers the entire catheter. Applying a small amount of antibacterial ointment around the catheter entry hole can contribute to protection by providing a liquid seal feature.

PERMANENT CENTRAL VENOUS PORTS

This is a method commonly used to administer agents sequentially to the patient that could potentially damage the vascular lumen. The most frequent application is for the administration of chemotherapeutic agents. One end of the catheter is placed in a central vein with high blood flow, similar to HD catheters, allowing the medication to quickly dilute in the blood. Unlike HD catheters, the other end does not exit the body; it is subcutaneous and not visible from the outside. This significantly reduces the risk of infection. The other end is left in the body as a small reservoir. The silicone surface is left in the front for needle puncture. It can remain in the body for months to years. Using a special needle, the silicone membrane is pierced to access the reservoir, and the needle is removed at the end of the treatment. Another difference from HD catheters is that the catheters that continue as a reservoir have much smaller diameters. This reduces the risk of causing venous stenosis.[7-11]

CONCLUSION

The need for venous catheterization is increasing due to various reasons, especially in hemodialysis patients. When performed with certain principles and in experienced hands for appropriate indications, the risk of this procedure is minimal.

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Vats HS. Complications of catheters: tunneled and nontunneled. *Adv Chronic Kidney Dis*. 2012;19(3):188-194.
2. Türk Nefroloji Derneği Registry Raporları. http://www.nefroloji.org.tr/icerik.php?gid=88 Accessed December 11, 2018.
3. Miller LM, MacRae JM, Kiaii M, et al. Hemodialysis tunneled catheter noninfectious complications. *Can J Kidney Health Dis*. 2016; 3:2054358116669130.
4. Shingarev R, Barker-Finkel J, Allon M. Natural history of tunneled dialysis catheters placed for hemodialysis initiation. *J Vasc Interv Radiol*. 2013;24(9):1289-1294.
5. Osman OO, El-Magzoub AR, Elamin S. Prevalence and risk factors of central venous stenosis among prevalent hemodialysis patients, a single center experience. *Arab J Nephrol Transplant*. 2014;7(1):45-47.
6. US Renal Data System: USRDS 2012 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States, Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2012.
7. Chan MR. Hemodialysis central venous catheter dysfunction. *Semin Dial*. 2008;21(6):516-521.
8. Vascular Access Work Group. Clinical practice guidelines for vascular access. *Am J Kidney Dis*. 2006;48(Supplement 1):S248-S273.
9. Moran JE, Ash SR. Locking solutions for hemodialysis catheters; heparin and citrate—a position paper by ASDIN. *Semin Dial*. 2008;21(5):490-492.
10. NKF-K/DOQI Clinical Practice Guidelines UpDate 2000. *Am J Kidney Dis*. 2001;37(1):S137-S181.
11. Yamamoto Y, Orii T, Yoshimura M, Kitahara H, Karasawa Y. Is there any correlation between venipuncture sites and complications of central venous port placement in the chest wall? *Int J Surg Open*. 2018;14:15-18.