



Recommendation and consensus

# Expert consensus on the establishment and maintenance of native arteriovenous fistula

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## Abstract

Vascular access is the lifeline of hemodialysis patients. There are great differences in the establishment and use of vascular access in different countries and regions around the world. We believe that on the basis of good evaluation and planning, it is recommended that hemodialysis patients choose native arteriovenous fistula first. In view of the new progress of vascular access views domestic and international at home and abroad in recent years, we organized experts to recommend the establishment and maintenance of arteriovenous fistula (AVF) for the Chinese population, including preoperative evaluation and planning of the establishment of AVF, AVF surgery, perioperative drug intervention measures and postoperative maintenance, and put forward suggestions for future research directions. The recommendations in this consensus are general and clinicians need to make treatment decisions based on the actual situation.

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**Keywords:** Hemodialysis; Vascular access; Arteriovenous fistula; Consensus

Vascular access is the lifeline of hemodialysis (HD) patients. Vascular access requires careful evaluation and planning by the medical staff and adequate training and education of the patients, allowing them to participate in the maintenance and management of vascular access.<sup>1–3</sup> Currently, there are considerable differences in the establishment and use of vascular access across different countries and regions worldwide.<sup>4–9</sup> The Dialysis Outcomes and Practice Patterns Study

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(DOPPS) showed that from 1996 to 2015 (DOPPS 1–5), the parts (forearm and upper arm) where arteriovenous fistula (AVF) is located in different countries and regions have changed to varying degrees, and there are huge international differences in the time to maturity and the first puncture of AVF. The proportion of AVF located in the forearm in Japan has remained above 93%. Although the proportion of AVF in the forearm in Europe has shown a downward trend, it is still the most common site. In the United States (US), as demonstrated in the DOPPS Phase 3 and thereafter, there has been a reversal manifested by decline in the proportion of AVF in the forearm and increase in the proportion in the upper arm.<sup>5</sup> The median time until first successful use of AVF is 10 days in Japan, 46 days in Europe, and 82 days in the US. However, the lifespan of AVF is the longest in Japan.<sup>4</sup> Thus, there are differences among regions and populations regarding the establishment, use, and maintenance of vascular access.

The 2019 Kidney Disease Outcomes Quality Initiative (KDOQI) released a new version of the vascular access guidelines (hereinafter referred to as KDOQI guidelines). For most patients requiring HD, AVF is still recommended as a priority. See section 2.13 and 2.14 of the KDOQI guidelines for the detailed statements.<sup>3</sup> AVF for vascular access in dialysis patients has obvious advantages in terms of the quality of life, complications, and primary and secondary patency rates. After considering China's national condition and population; results of domestic surveys and scholars' opinions<sup>10–14</sup>; and at the same time, based on the recommendations of the 2015 Japan Society for Dialysis Therapy (JSDT) Vascular Access Guidelines, 2018 Vascular Access Guidelines of The European Society for Vascular Surgery (ESVS), 2019 KDOQI Guidelines, and other vascular access guidelines, we recommend AVF as the preferred option for HD patients after adequate evaluation and planning. At present, there has been great progress in the field of HD in mainland China, which ranks first in the world in the number of HD patients, and the number is still growing rapidly. In 2014 and 2019, mainland China successively published two editions of a consensus on vascular access, which has played a positive role in the development of domestic vascular access. Postoperative maturity of AVF is affected by multiple factors such as gender, age, diabetes, vascular diameter, as well as its expandability and surgical skills.<sup>4,5,15–21</sup> There are still several opinions on the establishment and maintenance of AVF that have not yet reached a consensus. Some treatments still lack adequate support based on evidence-based medicine. In addition, the KDOQI guidelines have changed from

recommending the concept of “internal fistula first” to “patient first.” Therefore, we aimed to establish a new consensus on AVF establishment and maintenance.

The literature search for this consensus included the following: (1) English literature databases: Medline, Embase, Web of Science, Cochrane Library, Ovid; (2) Chinese literature databases: Chinese Medical Current Content (CMCC), Wanfang Data Resource System (WANFANG DATA), Chinese Science and Technology Journal Full-text Database (VIP), China Evidence-Based Medicine/Cochrane Central Database (CEBM/CCD), China Journal Full-text Database (CJFD), China Biology Medicine disc (CBM), China National Knowledge Infrastructure (CNKI); and (3) Main search terms: end stage renal disease (ESRD), end-stage kidney disease, chronic kidney disease (CKD), HD, vascular access, arteriovenous fistula, AVF, guidelines, China, Chinese, consensus, nursing.

Evidence evaluation: In view of the insufficient number of domestic AVF studies and small number of relevant research samples, the recommendation level was divided into three levels, evidence level was divided into three levels (Table 1), and recommendations were made based on the preoperative assessment and planning for AVF, surgical implementation, post-operative intervention and nursing, and other chapters. We also discuss the corresponding evidence and finally propose future research directions. The recommendations in this consensus are general and not specific regimens. Medical staff should perform individualized operations based on the needs of patients and conditions of the medical institutions they are located in.

Table 1  
Expert consensus rating/evidence level for the establishment and maintenance of autologous arteriovenous fistula.

Rating	Meaning/methodological evidence supporting the evidence
Recommendation level	
Level 1	Definitely effective, implementable, and safe for evaluation or diagnosis and treatment
Level 2	The effectiveness for treatment is controversial, and more evidence is required
Unrated	Expert opinions
Evidence level	
A	Evidence comes from multiple randomized controlled trials or systematic reviews and meta-analyses
B	Evidence comes from a single randomized controlled trial or a large sample non-randomized study, multiple observational studies, a subgroup of randomized controlled trials, or post-event analysis and other support
C	Evidence comes from small sample studies, retrospective studies, or expert opinions

## Consensus content

### 1. Preoperative assessment and planning for establishment of AVF

1.1. Knowledge, education, and informed communication on AVF, which allow patients to understand the principles behind various vascular access methods and the possible risks/pros and cons, in order to ensure their greatest understanding and participation. (2B)

1.2. Before surgery, the general condition of the patient should be assessed, history of vascular access and invasive operations of the blood vessels should be obtained, contraindications should be excluded, physical examination should be performed, and the relevant blood vessels should be evaluated. (1A)

1.3. Routine Doppler ultrasonography should be used to check the blood vessels related to the operation before surgery. Information on the internal diameter of the arteries and veins, length of the puncturable blood vessels, route and trajectory of the blood vessels, branched veins, and venous valves should be extracted. Patients with a history of complicated vascular access or suspected central venous disease revealed using physical examination require further angiography. The angiography method can be selected from modalities such as digital subtraction angiography (DSA), computed tomography angiography (CTA), and magnetic resonance angiography (MRA), depending on the resources of the medical institution where the surgeon is based and the patient's general condition. (1B)

1.4. Preoperative inner diameter of the radial artery and cephalic vein (after tourniquet binding)  $\geq 2.0$  mm may be considered an indication for surgery and further evaluation should be performed; if the preoperative inner diameter of the radial artery and cephalic vein (after tourniquet binding)  $< 2.0$  mm, surgery should be carefully considered; if the preoperative inner diameter of the radial artery and cephalic vein (after tourniquet binding)  $< 1.5$  mm, surgery should be avoided or other blood vessels (surgical methods) should be selected as far as possible. (Unrated)

1.5. Elderly patients with CKD who have no obvious contraindications to AVF can routinely undergo preoperative assessment and planning, followed by AVF surgery; however, the inner diameter of the blood vessel is generally required to be  $\geq 2.5$  mm. (2B)

### 2. AVF surgery

2.1. A multidisciplinary team (MDT) should be established for vascular access. Team members should include nephrologists or HD physicians, vascular surgeons, sonographers, radiologists, and HD specialist

nurses. The team members should collaborate based on the division of work to improve the success rate of AVF. (Unrated)

2.2. It is feasible and beneficial to use nerve block anesthesia for AVF surgery. (2B)

2.3. Physicians who are skilled in the operation can independently perform AVF surgery. (1A)

2.4. It is recommended that end-to-side anastomosis be adopted for AVF vascular anastomosis in the distal forearm, while end-to-side and side-to-side methods may be used for an upper arm AVF vascular anastomosis. Additionally, individualized operations should be performed based on the patient's vascular conditions and the surgeons' experience. (2C)

2.5 NO-Touch technology is feasible for vascular anastomosis in AVF. (Unrated)

### 3. Perioperative drug intervention measures

3.1. Antiplatelet drugs (including aspirin and clopidogrel), statins, and fish oil are not routinely recommended during the perioperative period for AVF. (2B)

3.2. Beraprost can be selectively used after AVF surgery. (2B)

### 4. Postoperative maintenance

4.1. Routine health education should be provided after AVF surgery to improve the self-management ability of patients. Appropriate physical exercises should be recommended after AVF surgery. (1B)

4.2. Successful puncture after AVF and meeting the needs of HD are considered maturation of AVF. The use of plastic cannula for puncture after AVF surgery is beneficial for the maintenance of internal fistula, especially in the early stage of internal fistula use. (2C)

4.3. After the use of mature AVF, regular Doppler ultrasound examinations are reasonable. (Unrated)

4.4. The specialized training of HD nurses should be strengthened, AVF patients should undergo routine physical examination before each puncture, and further intervention should be provided when abnormalities are found, which is conducive to AVF maintenance. (1C)

## Description of the consensus

### 1. Preoperative assessment and planning for the establishment of AVF

1.1. Knowledge, education, and informed communication on AVF, which allow patients to understand the principles behind various vascular access methods and the possible risks/pros and cons,

**in order to obtain their greatest understanding and participation. (2B)**

Maintenance HD is a long-term and regular treatment. It is crucial for patients to have sufficient knowledge and actively participate in the management. In this regard, Japanese guidelines make detailed recommendations,<sup>1</sup> including explaining the necessity, work principles, and daily precautions of vascular access to patients and their families. Furthermore, the patient's understanding level is confirmed during the explanation process. A domestic multi-center study on the current status of AVF knowledge and related factors surveyed eight hospitals in Shanghai and enrolled 430 patients. The study showed that 53% of HD patients had a low level of AVF-related knowledge and only 18.6% patients had attended lectures on internal fistula.<sup>22</sup>

As vascular access is unfamiliar to new dialysis patients, a health education plan needs to be developed, which can be shown to patients in various ways such as maps and videos. Provided that the privacy of other patients is not infringed, protection against infections is ensured, and if the medical resources permit, patients can be allowed to visit the dialysis treatment area and develop a more intuitive understanding of HD and vascular access. Allowing patients to make their own choices based on their own vascular conditions, coexisting diseases, personal preferences, and other comprehensive factors is in line with the concept of “patient first”.<sup>3,23,24</sup> In fact, this consensus does not require much evidence, and we recommend it based on clinical common sense.

Good communication is conducive to the diagnosis and treatment of diseases and is also of considerable value in reducing medical expenses.<sup>25</sup> Communication should include patients and their family members. Under normal circumstances, HD patients require the support of family members to face the issue together. This is consistent both at home and abroad.

**1.2. Before surgery, the general condition of the patient should be assessed, history of vascular access and invasive operations of the blood vessels should be obtained, contraindications should be excluded, physical examination should be performed, and the relevant blood vessels should be evaluated. (1A)**

Before AVF surgery, history of kidney disease and coexisting diseases must be fully clarified, especially the history of invasive procedures closely related to the operation, including central venous catheterization (CVC), indwelling needles, peripherally inserted central catheters, pacemaker implantation, and history of

surgical trauma. A study retrospectively analyzed 53 patients with a history of vascular access, including CVC and internal fistula surgery, or chest varices and other positive signs revealed using physical examination; among them, 21 patients underwent multiple AVF operations, and the failure rate was very high.<sup>26</sup>

Physical examination has been recommended by Italian scholars as the primary measure for vascular assessment before AVF.<sup>27</sup> A study in South Korea even claimed that patients with satisfactory results of routine physical examination demonstrated better AVF outcomes.<sup>28</sup> Before AVF surgery, the skin condition of the upper limb selected for the operation, the front of the chest, and thickness of the subcutaneous tissue should be checked. Additionally, bilateral upper limb arteries should be examined and compared for abnormal pulsation, along with performing the Allen test and comparing the blood pressure of the upper limbs. The veins (whether the upper arm veins are missing), length of puncturable blood vessels, inner diameter and depth of the blood vessels, position of the collateral veins, and distance from the artery should be examined, in addition to determining the expansibility of the veins after tourniquet binding. Physical examination is the most basic, economical, and effective method and should be routinely performed before every AVF operation.

**1.3. Routine Doppler ultrasonography should be performed to check the blood vessels related to the operation before surgery. Information on the internal diameter of the arteries and veins, length of puncturable blood vessels, route and trajectory of the blood vessels, branched veins, and venous valves should be extracted. Patients with a history of complicated vascular access or suspected central venous disease revealed using physical examination require further angiography. The angiography method can be selected from modalities such as DSA, CTA, and MRA, according to the resources of the medical institution where the surgeon is based and the patient's general condition. (1B)**

Physical examination, as a preliminary screening for evaluating the blood vessels, has certain limitations.<sup>26,29</sup> For example, while visual inspection and palpation can help to identify more venous conditions, they cannot accurately assess the inner diameter of the artery or determine factors such as the speed of blood flow, and whether vascular calcification or plaques are present, which are of great significance in determining whether the internal fistula is mature.<sup>16,18,21</sup> Doppler ultrasound can verify the reliability of physical examination and provide more information about vascular

access. A domestic retrospective cohort study analyzed 353 first-time AVF cases. The inner diameters of the arteries and veins were measured on ultrasound, and it was found that compared with 1/4 of the group with the highest arterial diameter, 1/4 of the group with the lowest inner diameter of the artery demonstrated an increased risk of immature events (more than 34%).<sup>30</sup> An Austrian retrospective study included 331 patients, of which 114 were in the conventional Doppler ultrasound group and 217 were in the physical examination alone group. The results showed that the primary AVF patency rate was higher (62% vs. 26%), the AVF intervention rate was significantly lower after surgery (25.4% vs. 59.4%), and patient costs were significantly reduced in the conventional Doppler ultrasound group than in the physical examination alone group.<sup>31</sup> In a Japanese study, conventional preoperative Doppler ultrasonography was performed on 139 AVF patients with an average follow-up of 2 years. The average patency period was  $448.6 \pm 271.3$  days. The 1-year and 2-year patency rates were 64.0% and 51.2%, respectively. It was concluded that preoperative ultrasound examination of the diameter of the radial artery can predict the AVF patency rate.<sup>16</sup> In an earlier study in the US, which included patients who underwent ultrasound for preoperative positioning, the proportion of those who received AVF surgery increased from 34% to 64%, while that of useable internal fistulas increased from 16% to 34%. Researchers believe that conventional preoperative Doppler ultrasonography before AVF surgery is beneficial for improving the surgery rate and success rate of AVF.<sup>32</sup>

In recent years, studies on preoperative Doppler ultrasonography for internal fistulas had different sample sizes and were mostly retrospective analyses, with the quality of evidence generally low. Ultrasonic examination can give accurate information regarding the internal diameter of the arteries and veins, length of the puncturable blood vessels, route and trajectory of the blood vessels, condition of the communicating branches of the superficial and deep veins, and make up for the defects of physical examination, which can help to avoid blindly performing operations. We have already emphasized that vascular access requires reasonable planning and maintenance by the medical staff, which promotes long-term patient survival. Therefore, we believe that both preoperative physical examination and Doppler ultrasound should be routinely performed.

Patients with a history of complicated vascular access or suspected central venous disease based on physical examination require further angiography. The three guidelines, including the Japanese vascular

access guidelines, European vascular access guidelines, and the KDOQI guidelines, make recommendations regarding this. Considering the invasiveness, potential risks, and other factors involved in a venography operation, this consensus does not recommend conventional angiography for new dialysis patients with a simple medical history and no positive (central venous) lesions detected using physical examination; however, patients with a history of multiple CVCs, pacemaker implantation, trauma to the upper limb, neck or chest, or major surgery, especially when central venous disease is suspected, need to undergo angiography after physical examination and ultrasound evaluation. Modalities such as DSA, CTA, or MRA can be selected for angiography depending on the resources available in the medical institution where the surgeon is based. They can be used to perform vascular tracing of the parameters, such as the inner diameter and route or trajectory of the blood vessels related to the scheduled fistulation. The above-mentioned angiography methods have their respective advantages and disadvantages for AVF assessment, and this consensus does not make specific recommendations.

**1.4. Preoperative inner diameter of the radial artery and cephalic vein (after tourniquet binding)  $\geq 2.0$  mm can be considered an indication for surgery and further evaluation should be performed; if the preoperative inner diameter of the radial artery and cephalic vein (after tourniquet binding)  $< 2.0$  mm, surgery should be carefully considered; if the preoperative inner diameter of the radial artery and cephalic vein (after tourniquet binding)  $< 1.5$  mm, surgery should be avoided or other blood vessels (surgical methods) should be selected as far as possible. (Unrated)**

Although the inner diameter of the blood vessel is very important for AVF maturation, there are several studies with differing opinions on the minimum required inner diameter of the blood vessel for surgery. Both the European vascular access guidelines and KDOQI guidelines point out that if the inner diameter of the radial artery or cephalic vein is  $< 2.0$  mm, the surgical site should be carefully evaluated or reselected. The Japanese vascular access guidelines specify that the minimum internal diameter of the radial artery should be between 1.5 and 2.0 mm, and the minimum internal diameter of the vein (after tourniquet binding) should be between 1.6 and 2.5 mm. If it is below the above range, the success rate will be low.

In recent years, several studies have investigated the relationship between the inner diameter of the blood vessel and the maturity of AVF. A Canadian study

pointed out that an inner diameter of the radial artery  $\geq 2.1$  mm and inner diameter of the vein (after tourniquet binding)  $\geq 3.0$  mm are independent predictors of AVF maturity and patency.<sup>33</sup> A South Korean study claimed that an inner diameter of the vein (after tourniquet binding)  $< 2.5$  mm was an independent risk factor for AVF failure.<sup>34</sup> A study from Singapore found that the average preoperative vein size of the mature AVF was  $3.2 \pm 1.1$  mm, while the average vein size of unsuccessful AVF was  $2.8 \pm 0.9$  mm.<sup>17</sup> A British study showed that an inner diameter of the radial artery  $> 1.6$  mm and an inner diameter of the vein (after tourniquet binding)  $> 1.5$  mm can predict AVF maturity. It has also been suggested that AVF surgery with an inner diameter of the vein  $< 1.5$  mm should not be tried.<sup>18</sup>

The expert group discussed and made the recommendations according to the characteristics and actual situation of the population in China. Nevertheless, the clinicians need to implement them comprehensively based on the general condition of the patients and experience of the surgeons.

**1.5. Elderly patients with CKD who have no obvious contraindications to AVF, can routinely undergo preoperative assessment and planning, followed by AVF surgery, provided the inner diameter of the blood vessel is  $\geq 2.5$  mm. (2B)**

Although aging may affect the maturity and patency of AVF, AVF can still be created in elderly patients with CKD after detailed evaluation. A US study analyzed the AVF data of patients over 67 years of age in the kidney disease database and found no significant difference in the primary and secondary patency rates between patients aged 67–77 years and those aged  $\geq 77$  years after AVF maturity.<sup>35</sup> A Canadian study enrolled 525 elderly dialysis patients who were stratified according to age into  $< 65$ , 65–75, and  $> 75$  years and observed for AVF maturity and patency for 3 years. The results showed that the incidence rates of AVF maturity, primary patency, complications, or need for intervention among the three age groups were not different. Although there was a slight decrease in the secondary patency rate in patients aged  $> 75$  years, the researchers suggested that advanced age alone should not be used as an exclusion criterion for AVF creation.<sup>36</sup> An Australian study retrospectively analyzed 77 HD patients over 80 years of age. Among them, 65 patients had AVF and 12 had CVC. The results revealed that the cumulative survival rate of AVF patients at 12 and 24 months was 82% and 72%, respectively, while the 12-month survival rate of CVC patients was 45% ( $P < 0.001$ ). The primary patency rates of AVF patients who received follow-up at 6, 12,

and 24 months were 58%, 39%, and 31%, respectively. Therefore, although AVF has a lower patency rate and higher intervention rate in older patients than in younger patients, in selected elderly patients, AVF is more suitable for long-term vascular access for HD than CVC, and age itself, in particular, should not be an exclusion criterion for AVF surgery.<sup>37</sup>

A South Korean study on the impact of age on AVF maturity and patency rate included 130 elderly (age  $\geq 70$  years) and 293 young patients. Successful AVF puncture performed twice was defined as mature. The elderly and young groups had inner diameters of the cephalic vein of 2.6 and 2.8 mm ( $P = 0.02$ ) and maturity rates of 83.6% and 94.3% ( $P = 0.01$ ), respectively; the overall patency rates in the elderly group were 73.1% and 57.1% at 6 and 12 months, respectively, and those in the young group were 86.7% and 77.7%, respectively ( $P = 0.009$ ). The AVF maturity and patency rates in the elderly group were lower than those in the young group. It has been suggested that more stringent standards should be adopted for AVF in elderly patients, especially for the inner diameter of blood vessels.<sup>38</sup> A US study included 136 patients who underwent a total of 146 AVF operations. The patients were aged 18–91 years, with a median age of 68 years. The demographic characteristics and risk factors of the patients, as well as the location of internal fistulas and venous diameter, were analyzed. It was observed that when the inner diameter of the vein exceeded 2.5 mm, the overall AVF maturity rate was 72%. The researchers also found that the only significant predictor of AVF failure was body mass index (BMI)  $> 29.5$ . Accordingly, it has been postulated that age, sex, and fistula location should not be used as conditions to limit the implementation of AVF surgery in patients with a blood vessel diameter exceeding 2.5 mm.<sup>39</sup>

The number of elderly patients requiring HD is increasing year by year. Compared with CVC and arteriovenous graft (AVG), the advantages of AVF in elderly patients have been controversial, especially after the update of the KDOQI guidelines, and the views of some domestic scholars have fluctuated. As pointed out above, there are many factors that can affect the maturity and patency of AVF, and age may be one of them. In patients with risk factors, the surgeon needs to perform a more detailed assessment before making a decision on whether to operate. The expert group believes that the selection of the vascular access method needs to be individualized. Based on the current experience and documentary evidence, it is recommended that elderly patients with CKD can undergo routine

preoperative evaluation and planning and subsequently undergo AVF surgery if the vascular diameter is  $\geq 2.5$  mm. For patients whose blood vessel inner diameter is  $< 2.5$  mm, it is necessary to evaluate the factors influencing AVF maturity and patency more carefully, and accordingly consider or choose AVG/CVC.

**Future research directions:** 1. Research on the application of Doppler ultrasound by doctors specializing in vascular access. 2. Prospective comparative studies on Doppler ultrasound and physical examination. 3. The feasibility of AVF in the Chinese elderly population with CKD.

## 2. AVF surgery

**2.1. A MDT should be established for vascular access. Team members should include nephrologists or HD physicians, vascular surgeons, sonographers, radiologists, and HD specialist nurses, and the team members should collaborate based on the division of work in order to improve the success rate of AVF. (Unrated)**

A MDT analyzes, discusses, and thinks about the disease, puts forward opinions on diagnosis and treatment after comprehensively considering various factors, and develops detailed and personalized diagnosis and treatment regimens for patients. The establishment of vascular access in HD patients requires procedures such as preoperative evaluation and planning, intraoperative collaboration, and postoperative maintenance. The above procedures are very important for AVF. If any aspect is not handled properly, AVF may fail. The KDOQI guidelines recommend using a MDT to implement education, coordination, and management of all aspects of AVF patients depending on the available resources and feasibility.

The Vascular Access Working Group of the Canadian Society of Nephrology recommends that the vascular access MDT should include vascular access nurses (vascular access coordinators), nephrologists, surgeons, radiologists, and even patients and family members and should make a detailed division of labor among the members; the final goal is to successfully establish personalized vascular access with the patient as the center.<sup>40</sup> A study in Canada included 609 patients in the preliminary (2004–2005), early (2006–2008), and late (2009–2011) stages of the establishment of a multidisciplinary vascular access group. Compared with the preliminary stage, the internal fistula implementation rates in the early and late stages increased by 40% and 30%, respectively.<sup>41</sup> A Dutch study enrolled 228 patients from October 2005 to October 2015 and performed 231 native AVF operations. The results revealed that diabetes

and internal diameter of the cephalic vein are independent factors that affect the maturity of the internal fistula, and a meticulous preoperative inspection and monitoring program of the MDT is very important for obtaining better patency.<sup>21</sup>

A study showed that MDT working based on the division of labor in the vascular access group has a definite impact on the successful establishment of AVF and reduces medical costs.<sup>7</sup> Although vascular access MDTs are being established and operated in some large general hospitals in China, it may still be difficult to promote them in the primary hospitals. This consensus is recommended as an expert opinion.

**2.2. It is feasible and beneficial to use nerve block anesthesia for AVF surgery. (2B)**

The KDOQI guidelines have not made any recommendations on the anesthesia method for AVF, but the European vascular access guidelines have indicated that nerve block anesthesia should be preferred over local anesthesia as it may improve the patency of vascular access. The “Clinical Practice Guidelines for Perioperative and Postoperative Care of Arteriovenous Fistulas (AVF and AVG) for Adult Hemodialysis” (hereinafter referred to as the European nursing guide) formulated by the European Renal Best Practice (ERBP) Vascular Access Working Group also makes this recommendation.<sup>42</sup> Although many studies on the benefits of nerve block anesthesia in AVF have been published at home and abroad, the included sample size was small and quality of evidence was generally low. A Japanese study retrospectively analyzed the expansion of the inner diameter of the basilic vein from  $3.0 \pm 1.1$  mm before anesthesia to  $4.1 \pm 1.2$  mm after anesthesia under nerve block anesthesia ( $P < 0.001$ ).<sup>43</sup> A US study performed AVF on 65 patients under nerve block anesthesia and found that the inner diameters of the forearm cephalic vein and median elbow cephalic vein increased by 0.96 mm ( $P < 0.01$ ) and 0.5 mm ( $P = 0.04$ ) after nerve block anesthesia, respectively.<sup>44</sup> Another US study compared the prognosis of AVF with vascular inner diameter  $\leq 2.4$  mm under nerve block anesthesia and AVF with vascular inner diameter  $\geq 2.5$  mm under traditional anesthesia (not specified in the original text) and reported no significant difference in AVF primary patency and re-intervention rates between the two groups and part of AVG could be converted to AVF.<sup>45</sup> A meta-analysis included four randomized controlled trials (RCT) containing 286 patients and compared the prognosis of AVF with nerve block anesthesia and local (infiltration) anesthesia. It was found that compared with local

anesthesia, there was a reduction in the AVF failure rate under nerve block anesthesia.<sup>46</sup>

A British study compared the effects of local anesthesia and nerve block anesthesia on AVF patency. The 126 patients enrolled were divided into local (n = 63) and nerve block (n = 63) anesthesia groups and followed up for 3 months. The results showed that the primary patency of the nerve block anesthesia group (53 cases, 84%) was higher than that of the local anesthesia group (39 cases, 62%) (odds ratio [OR] = 3.3, 95% confidence interval [CI]: 1.4–7.6,  $P = 0.005$ ). It was proposed that this may be related to the significant increase in the vessel inner diameter and arterial blood flow after nerve block anesthesia. Therefore, they recommended that nerve block anesthesia should be used for AVF surgery.<sup>47</sup> There have also been some small sample size studies in China that have concluded that AVF can benefit from nerve block anesthesia, which are not referenced here. Based on the current research status at home and abroad, the expert group believes that AVF under nerve block anesthesia is feasible and may be beneficial, and therefore makes this recommendation.

### **2.3. Physicians who are skilled in the operation can independently perform AVF surgery. (1A)**

Among the factors that affect the success rate of AVF, the skill of the surgeon is crucial. A British study retrospectively analyzed 195 cases of AVF surgery, among which 153 were performed by experienced surgeons and 42 by junior surgeons. The median follow-up time for both groups was 22 months. The surgical success rates of the two groups were 94.2% and 81%, respectively ( $P < 0.01$ ). The researchers suggested that AVF surgery should be performed by experienced physicians, or at least under their supervision.<sup>48</sup> Similarly, a US study retrospectively analyzed 29,034 internal fistula operations, including 22,541 (78%) AVF and 6493 (22%) AVG. The results showed that for every 10 surgeries among the doctor's cumulative surgeries, the failure rate of vascular access decreased by 5% ( $P = 0.007$ ).<sup>49</sup> Another study retrospectively analyzed 467,827 operations performed by 4959 surgeons, and the results revealed that the cumulative amount of surgeries performed by surgeons is closely related to the success rate of AVF.<sup>50</sup> A domestic study retrospectively analyzed 42 HD patients who had failed multiple AVF operations in external hospitals within 3 years. The results indicated that the failure of the operations was largely caused by improper arterial selection and anastomosis techniques.<sup>51</sup>

The American Association for Vascular Surgery stipulates that vascular surgery residency training

should include instructions on conducting vascular laboratory tests and interpreting the results. Trainees should be familiar with vascular laboratory equipment, testing protocols, and ultrasound imaging of the vascular anatomy and should be able to classify the severity of the disease based on the examination results.<sup>52</sup> A meta-analysis included 16 clinical trials involving 9438 patients who underwent internal fistula surgery. Although the results did not find a significant difference in the primary patency rate between surgeries performed by primary physicians and experienced physicians (the complexity of the surgery might be different), the final recommendation was still that junior physicians should accumulate experience through appropriate training and perform surgical operations under the guidance of experienced physicians and without harming the interests of patients.<sup>53</sup>

In summary, junior doctors should receive training, and gradually perform operations under the leadership of experienced doctors. Another finding of the above-mentioned study was that doctors of different specialties performed internal fistula operations, including 13,110 cases of vascular surgery (45.2%), 9398 cases (32.3%) of general surgery, 2313 cases (8%) of thoracic surgery, 1517 cases (5.2%) of other specialized operations, and 2696 cases (9.3%) of unknown specialized operations. Researchers believe that the specialty of the surgeon is not related to the possibility of vascular access failure.<sup>49</sup> Therefore, the expert group believes that AVF surgeons can be from departments of vascular surgery, general surgery, urology, nephrology, and others,<sup>49,54–57</sup> which is also in line with the actual situation in China. Individualized care should be implemented according to the actual medical resources of each unit, and we will not make specific recommendations.

### **2.4. It is recommended that end-to-side anastomosis be adopted for AVF vascular anastomosis in the distal forearm, while end-to-side and side-to-side methods can be adopted for an upper arm AVF vascular anastomosis, and individualized operations should be performed according to the patient's vascular conditions and experience of the surgeon. (2C)**

The KDOQI guidelines have not made any recommendations on the preferred AVF vascular anastomosis method. However, the Japanese guidelines recommend venous end-arterial side as the AVF vascular anastomosis method. The European nursing guide points out that the pros and cons of side-to-side anastomosis for AVF are similar to those of end-to-side anastomosis. There have been several controversies regarding the



vascular anastomosis method. The expert group believes that the distal AVF should preserve the integrity of the radial artery and reserve a distal arterial approach for later percutaneous transluminal angioplasty (PTA) antegrade puncture. The venous end-arterial side anastomosis method is recommended for distal AVF. For mid-to-high AVF, selection can be made according to the specific vascular conditions of the patient and expected puncture range, and anastomosis methods such as venous end-arterial side and venous side-arterial side can be adopted. In fact, the specific method of vascular anastomosis needs to be chosen according to the vascular inner diameter, puncturable vessel length, AVF vascular outflow tract, nursing technology, and other comprehensive factors. This consensus will not elaborate too much on this issue.

### **2.5. No-touch technology is feasible for vascular anastomosis in AVF. (Unrated)**

Since the establishment of AVF surgery, clinicians and scholars have continuously improved and explored new technologies and methods, aiming to improve the maturity and patency of AVF. There are reports on the successful application of No-touch technology in AVF surgery at home and abroad. No-touch technology is a vein acquisition technology that preserves the fat and connective tissue around the vein (preserving the fat or venous pedicle and other venous wall nourishing tissues). It was first applied in coronary artery bypass surgery and has achieved good results.<sup>58</sup> However, the number of studies on AVF surgery using the No-touch technology is limited, sample size is small, and the evidence is of low quality. Therefore, it was not adopted by this consensus. However, the No-touch technology is widely used in coronary artery bypass graft surgery, and some members of the expert group also routinely implement it in AVF surgery. The technology is simple and easy to implement. Therefore, we believe that No-touch technology is feasible for AVF vascular anastomosis.

**Future research directions:** 1. MDT operation mode. 2. Application of No-touch technology in AVF surgery. 3. The difference in prognosis between different vascular anastomosis directions (acute angle and obtuse angle).

## **3. Perioperative drug intervention measures**

### **3.1. Antiplatelet drugs (including aspirin and clopidogrel), statins, and fish oil are not routinely used during the perioperative period for AVF. (2B)**

As mentioned above, factors affecting AVF maturity may be multifaceted, including factors such as

epidemiology, preoperative evaluation, surgical technique, and postoperative care. Scholars have been working hard to find methods that are conducive to the maturation of internal fistulas, such as the administration of drugs during the perioperative period. However, increasing evidence shows that most perioperative medications are not ideal for AVF maturation and prevention of complications. The European vascular access guidelines and KDOQI guidelines do not recommend the routine use of antiplatelet drugs (including aspirin and clopidogrel), statins, and fish oil. The effects of these drugs are not precise, and the risks outweigh the possibility of benefits.<sup>2,3</sup>

A prospective study in South Korea enrolled 881 patients with HD using internal fistulas (including AVF and AVG), among which 241 (27.4%) patients took aspirin. The median follow-up time was 30 months. During the follow-up, 180 patients (20.4%) experienced the main outcome event (vascular access failure). Multivariate analysis showed that the hazard ratio (HR) for the incidence of vascular access failure among aspirin users was 0.89 (95% CI: 0.62–1.27,  $P = 0.51$ ). Taking aspirin had no protective effect on internal fistulas (including AVF and AVG).<sup>59</sup> A prospective, double-blind, randomized controlled trial in Australia included 567 adult CKD patients, who were divided into the fish oil group (fish oil vs. placebo) and aspirin group (aspirin vs. placebo). The results showed that within 12 months after AVF surgery, the use of fish oil did not reduce the primary failure rate of AVF (hazard ratio [HR] = 0.85, 95% CI: 0.65–1.12,  $P = 0.25$ ). The time to primary failure of AVF among the participants taking aspirin and placebo was similar (HR = 1.01, 95% CI: 0.69–1.47,  $P = 0.98$ ). Neither fish oil nor aspirin significantly prolonged the time to AVF abandonment. Similarly, the use of fish oil (HR = 0.92, 95% CI: 0.69–1.21,  $P = 0.53$ ) or aspirin (HR = 1.01, 95% CI: 0.73–1.42,  $P = 0.94$ ) did not change the time to primary failure or time to abandonment of AVF.<sup>60</sup> A domestic prospective cohort study<sup>61</sup> included 406 HD patients with an observation period of 5 years. The patients were divided into aspirin (100 mg/d) group and non-aspirin group. The main results comprised all-cause death, cardiovascular events, hemorrhage, and ischemic stroke. It was revealed that the cumulative survival rate of the aspirin group was not significantly different from that of the non-aspirin group ( $P = 0.061$ ).<sup>61</sup> Although this study was basically unrelated to AVF, there was no benefit of using aspirin among the patients as a whole.

A meta-analysis on the use of drug adjuvant therapy to increase the patency of AVF (including AVF and

AVG) included 15 clinical trials involving 2230 patients who received internal fistula surgery. The adjuvant drugs used in the clinical trials were aspirin and ticlopidine, dipyridamole combined with aspirin, warfarin, fish oil, clopidogrel, thiopyrazolone, and recombinant human type I pancreatic elastase (PRT-201). The authors compared studies on aspirin and placebo, those on ticlopidine and placebo, those on fish oil and placebo, and those on clopidogrel and placebo and discovered that there was insufficient evidence to determine whether there was a difference between the effects of placebo and other treatments (such as aspirin, fish oil, clopidogrel, PRT-201, dipyridamole, dipyridamole plus aspirin, warfarin, and thiopyrazolone) on the patency of AVF.<sup>62</sup> Another meta-analysis evaluating the value of statins in AVF included one RCT and six randomized controlled studies with 20,246 HD patients in total, of which 9847 received statins and 10,399 received placebo. The AVF failure rate of patients receiving statin therapy was similar to that of the control group (pooled risk ratio [RR] = 0.89; 95% CI 0.70–1.12,  $P = 0.32$ ). In addition, a sub-combination analysis showed that statin therapy did not relieve AVF failure in participants from the same ethnic background or in trials of similar sample size.<sup>63</sup>

In view of the current research and recommendations of the international guidelines,<sup>2,3,42,64</sup> the expert group does not recommend the routine use of antiplatelet drugs (including aspirin and clopidogrel), statins, and fish oil during the perioperative period of AVF.

### 3.2. Beraprost can be selectively used after AVF surgery. (2B)

Beraprost is an analog of prostacyclin, which acts by binding to the prostacyclin receptors on the cell membrane. After activation of the prostacyclin receptors on the cell membrane of platelets and vascular smooth muscle cells, it increases the action of adenylate cyclase in the cell, prevents the influx of  $Ca^{2+}$  and production of thromboxane  $A_2$ , and produces antiplatelet and vasodilator effects. It is widely used in peripheral vascular disease, pulmonary hypertension, kidney disease, and other diseases and has a good therapeutic effect.<sup>65,66</sup> Studies have shown that neointimal hyperplasia after vascular injury is related to the transfer of smooth muscle cells from the media to the intima. Beraprost sodium can activate the downstream Epac/Rap1 pathway by activating cyclic adenosine monophosphate (cAMP) in the smooth muscle cells, inhibit changes in the actin cytoskeleton, reduce the transfer of smooth muscle cells, and reduce intimal hyperplasia.<sup>67</sup> This provides a theoretical basis for its application in AVF.

We reviewed nine studies on the application of beraprost sodium in maintenance HD patients after AVF surgery (Supplementary Table 1).<sup>68–75</sup> A prospective study in South Korea found that the use of beraprost sodium in maintenance HD patients significantly improved the 2-year patency rate of vascular access and prolonged the patency time. Multivariate analysis demonstrated that the use of beraprost sodium can reduce the risk of loss of vascular access by 42% (HR = 0.580, 95% CI: 0.068–0.982,  $P = 0.047$ ), while aspirin has no benefit for vascular access.<sup>68</sup> Domestic research has shown that beraprost sodium can significantly increase the vascular internal diameter and blood flow of AVF, reduce the occurrence of thrombotic events, and increase the postoperative maturity and long-term patency rates. In elderly patients or patients with diabetes, beraprost sodium also has beneficial effects on the maturation and long-term patency of internal fistulas. Compared with the commonly used antiplatelet drug clopidogrel, beraprost sodium can significantly reduce the risk of thrombosis within 1 month after surgery (HR = 0.33, 95% CI: 0.18–0.56), and delay the time to thrombosis. Sequential treatment with alprostadil and beraprost sodium can shorten the time to fistula maturation and increase the blood flow of fistula. In addition, the combined application of beraprost sodium and clopidogrel or infrared therapy can increase fistula maturation after AVF surgery.<sup>71</sup>

Taking into account factors such as the low quality of evidence in the available studies on such drugs, we believe that beraprost can be used routinely or selectively (for example, in patients with risk factors that affect the maturity of AVF internal fistula) after AVF surgery.

Consequently, although several factors can affect AVF maturity, detailed preoperative evaluation and skilled surgical technique are paramount. The impact of drugs (including antiplatelet drugs, fish oils, statins, and beraprost) on AVF is currently inconclusive,<sup>1,62,76–81</sup> and the expert group believes that they can be selectively administered as an auxiliary measure, although individualized assessment of indications and contraindications should be conducted for patients with multiple coexisting diseases.

**Future research directions:** 1. Studies on the benefits of adjuvant drugs in high-risk groups of AVF patients with complications. 2. Randomized, controlled, multi-center prospective studies on adjuvant drugs in the Chinese population.

## 4. Postoperative maintenance

### 4.1. Routine health education should be provided after AVF surgery to improve the self-management

**ability of patients. Appropriate physical exercises should be recommended after AVF surgery. (1B)**

Generally speaking, health education is the main channel for patients to obtain knowledge about disease diagnosis and treatment. HD patients need information such as precautions and maintenance measures required for vascular access. Some studies have proposed that it is particularly important for hospitals with a low AVF implementation rate and high AVF failure rate to educate all members of the MDT (including patients, family members, nursing staff, and family doctors) and implement optimized nursing plans.<sup>82–84</sup> In order to increase the understanding and interest in AVF, medical staff should strive to continuously educate all participants in patient care.<sup>85–87</sup> This point has been discussed and emphasized a lot in the Japanese guidelines.

A Turkish study enrolled 32 HD patients, collected patient data in a scale format, and obtained AVF nursing knowledge and anxiety scores before and after education and found that the scores of nursing knowledge and anxiety before education were low and high, respectively, while those of patient care knowledge and anxiety after education increased and decreased, respectively, and the above results were statistically significant ( $P < 0.001$ ).<sup>88</sup> Another Turkish study conducted an AVF nursing knowledge questionnaire survey on 335 HD patients and reported that the patients had the most knowledge of the rules of “do not measure blood pressure” and “do not draw blood from the fistula side arm” on the limbs on the fistula side and were less familiar with the rules of “use blood vessels in the arm without internal fistula for intravenous treatment” and “what situations will cause hypotension” (the rules in the country or the researchers’ unit, which may not necessarily have universal applicability). Researchers believe that the development of self-care behaviors is a means of reconciling the lifestyle with the current health conditions.<sup>89</sup> HD patients and their families should be provided with planned self-care training, and nurses should provide repeated health education to patients who lack relevant knowledge.

A domestic study included 16 new AVF patients. The patients received ball grip training after the operation. The items were completed by MDT, and the team members included physiotherapists. The initial examination revealed that the overall accuracy rate of patients was only 55% (including the time, strength, frequency, etc. of the ball grip). Nine new AVF patients were included in the evaluation period, and the overall accuracy rate of the patients after health education rose

to 93%.<sup>90</sup> A domestic randomized controlled trial randomly divided 86 HD patients with AVF into a control group and an experimental group. The experimental group performed 6-pound dumbbell exercises on the non-dialysis days for 3 months, and the control group performed ball grip exercises. The changes in the AVF outflow tract venous blood flow from the beginning of the study to 3 months were observed. The results showed that the venous blood flow in the AVF outflow tract in the dumbbell group was significantly higher than that in the control group. The average difference between the two groups was 359.50 (111.90–829.05) mL/min ( $P = 0.001$ ). It was concluded that arm exercise training is essential for AVF dialysis patients. Dumbbell exercise is an economical and effective intervention that can maintain the function of AVF, especially in patients who may have reduced blood flow and have no indications for PTA.<sup>91</sup>

The European nursing guidelines indicated that allowing patients to prepare for HD more actively can improve their self-management ability, improve the sense of gain, and even prognosis. The guidelines state that simple exercises (such as pinching hands) are unlikely to produce any harmful results. In fact, no exercise-controlled trials have reported any important adverse events. The guidelines recommend a standardized exercise plan be developed and hand and arm exercises that can improve the maturation of AVF in adult patients with ESRD be included. The European and Spanish vascular access guidelines also make similar recommendations.<sup>2,92</sup>

There are limitations of the above study, and we do not have enough evidence to prove that arm movements promote the maturation of AVF; however, this is a common practice at home and abroad. Limb exercises are simple, economical, highly maneuverable, and allow patients to participate more.<sup>42,93–96</sup> In the absence of major adverse events (impacts), the expert group recommends routine physical exercises after AVF surgery. As for the timing of exercise, this consensus consulted the recommendations of the European nursing guidelines and believes that the fingers and upper arms can be moved after the surgery if there is no obvious bleeding from the surgical incision. If the incision is oozing blood, it should be handled properly and the range and frequency of activities should be reduced. One to three days after the operation and once the patient's pain is tolerable and the general condition stable, the limbs on the surgical side can be used to perform daily activities such as dressing and eating. After the stitches are removed, strengthening exercises

can be started, and the exercise intensity should be gradually changed from weak to strong. Individualized management should be implemented according to the patient's specific condition.

**4.2. Successful puncture after AVF and meeting the needs of HD are considered mature AVF use. The use of plastic cannula for puncture after AVF surgery is beneficial for the maintenance of internal fistula, especially in the early stage of internal fistula use. (2C)**

There is a lack of uniform criteria for the maturity of AVF. The 2006 version of the KDOQI vascular access guidelines proclaim that AVF maturation should meet the “6S” standard, that is, vessel inner diameter >6 mm, internal fistula blood flow >600 mL/min, internal fistula vessel depth from the skin <6 mm, and puncture should be easy. According to the characteristics of Chinese people, the consensus on vascular access in China sets the standard as vascular inner diameter >5 mm, internal fistula blood flow >500 mL/min, internal fistula blood vessel depth from the skin <6 mm, and the need for three sessions of dialysis per week should be met. The Japanese guidelines have not made any specific recommendations for AVF maturation and point out that after a period of time (usually more than 10 days) following AVF surgery, the inner diameter and length of the internal fistula vessel will increase, it can be touched on the body surface, and puncture can be performed for HD. The 2019 version of the KDOQI vascular access guidelines abandoned the previous criteria and recommends that the maturity of AVF should be mainly based on clinical judgment, rather than relying too much on auxiliary examinations. Based on the above guidelines, the expert group believes that successful puncture after AVF surgery and meeting the needs of HD can be considered as maturity.

After mature AVF is used for HD, complications such as thrombosis, stenosis, and aneurysm may occur at any time, and puncture injury is an important underlying reason.<sup>42,97–100</sup> Patient-centered HD must consider patients' preferences and feelings about the treatment. A Canadian study on dialysis patients' satisfaction and perspectives on complications associated with vascular access-related interventions reported that patients with plastic cannulas can perform activities such as eating food or using mobile phones relatively freely and do not need to be fully immobilized. They also do not worry too much about adverse effects that might be caused, especially to the puncture points at the joints, by involuntary movements of the limbs during rest, which reduces the patient's fear, and

improves the movement of the patient's limbs on the AVF side along with comfort during dialysis treatment.<sup>101</sup> Several other domestic studies have come to the same conclusions.<sup>102–104</sup>

There has been controversy about the earliest suitable puncture time after internal fistula surgery. As mentioned previously, the DOPPS study reported differences in the time to first puncture of AVF among different countries. Japan has the earliest time to first puncture, and its AVF lifespan is the longest. An analysis could not rule out that this might be related to the wide application of plastic cannulas in Japan.<sup>105</sup> A domestic study on the early application of plastic cannulas included 122 patients undergoing AVF who were divided into the early (time to first puncture < 10 days) and late (time to first puncture  $\geq$  10 days) puncture group. The results showed that the median time to first puncture was 6 days. There was no significant difference in the primary ( $P = 0.643$ ) or secondary ( $P = 0.453$ ) patency rates between the groups. After adjusting for influencing factors such as age, sex, and diabetes, there was no significant difference between early and late puncture in terms of primary (HR = 1.21, 95% CI: 0.71–2.05) or secondary (HR = 0.46, 95% CI: 0.08–2.77) patency. Researchers believe that early AVF puncture (<10 days after creation) using an plastic cannula does not affect the patency rate, and it is possible to perform AVF puncture before 10 days to reduce the use of CVC.<sup>106</sup>

A single-center, prospective, randomized clinical trial in South Korea studied 16 HD patients, and all patients had AVG vascular access. They randomly divided eight cases in the metal needle group and eight cases in the plastic cannula group. The researchers measured the arterial and venous pressures before the continuous dynamic pump at five different blood pump flow rates (150, 200, 250, 300, 350 mL/min). The results showed that the negative pressure and venous pressure before the arterial pump in patients with plastic cannulas were lower than in those with metal needles, and the differences were significant ( $P < 0.001$ ). It was suggested that the arterial and venous pressures of the plastic cannula at the set blood pump flow rate are more stable than those of the metal needle.<sup>107</sup> Although this research focused on AVG, we think that there is still some reference significance. An Italian scholar's meta-analysis included 23 studies on plastic cannulas. After analyzing the structure and operation process of the plastic cannula, the scholar reported that the fistula trocar is highly superior in terms of biocompatibility, safety, comfort, and other aspects. Although there is a lack of relevant research, in view of the massive use of

HD in Japan and other countries, the use of fistula trocars is still recognized.<sup>108</sup>

Although there are still some studies or opinions that support the application of plastic cannulas, the overall number of studies is limited, the samples are small, and the observation parameters are not comprehensive.<sup>109–112</sup> For HD patients undergoing early AVF puncture and with poor vascular conditions, a plastic cannula may be used. In summary, considering the current status of HD in China, the expert group believes that the fistula trocar can be routinely used for AVF puncture, especially for early puncture after AVF maturity.

#### **4.3. After the use of mature AVF, regular Doppler ultrasound examinations are reasonable. (Unrated)**

A physical examination during the perioperative period of AVF is extremely important, as we have discussed multiple times in the previous sections. After AVF surgery, vascular stenosis, aneurysm, thrombosis, and limb swelling are the most common complications, which seriously affect HD. The development of most complications is a chronic process or has a basis in chronic disease. Early physical examinations often do not elicit positive signs. However, Doppler ultrasound is non-invasive, relatively convenient, and reasonable as a regular postoperative re-examination. The European vascular access guidelines recommend Doppler ultrasound assessment of AVF every 3 months. The expert consensus on vascular access in China also makes detailed recommendations.<sup>113,114</sup>

A Japanese study included 2184 HD patients with AVF vascular access. Doppler ultrasound was used to measure the brachial artery blood flow (Qa: mL/min), arterial blood flow resistance index (RI), and internal fistula vessel inner diameter (RD: mm). The endpoint was a vascular access event (VE) that required vascular intervention or vascular surgery. The results were as follows: Average Qa:  $772.8 \pm 441.4$  mL/min; RI:  $0.56 \pm 0.1$ ; RD:  $2.37 \pm 1.0$  mm. The best Qa cutoff point was 581.5 mL/min, RI cutoff point was 0.56, and RD cutoff point was 1.85 mm. Patients with Qa < 581.5 mL/min were more likely to develop VEs than patients with Qa > 581.5 mL/min ( $P < 0.001$ ).<sup>115</sup> Doppler ultrasound is a simple method to predict the risk of thrombus and AVF dysfunction among HD patients. A Spanish study that included 207 patients and lasted for 3 years aimed to compare the application of blood flow (QA)-based monitoring with traditional monitoring (arteriovenous pressure, urea clearance

index, etc.) in AVF. The participating patients were randomly assigned to the control group (traditional monitoring,  $n = 104$ ) and the QA group (using Doppler ultrasound to monitor blood flow in every quarter,  $n = 103$ ). The criteria for intervention were: QA reduction by 25%, QA < 500 mL/min, or significant stenosis with abnormal hemodynamics. The results showed that the thrombosis rate of the QA group was significantly lower than that of the control group (0.025 thrombus/patient/year, 0.086 thrombus/patient/year, respectively;  $P = 0.007$ ). There was a significant improvement in the thrombus-free (HR = 0.30, 95% CI: 0.11–0.82,  $P = 0.011$ ) and secondary (HR = 0.49, 95% CI, 0.26–0.93,  $P = 0.030$ ) patency rate of the QA group, although there was no difference in the primary patency rate between the two groups (HR = 0.98, 95% CI, 0.57–1.61,  $P = 0.935$ ). In the control group, more CVCs were required and more patients were hospitalized due to vascular access ( $P = 0.034/P = 0.029$ ). Researchers believe that QA-based Doppler ultrasound monitoring and intervention can reduce the incidence of thrombosis, is cost-effective, and can improve AVF thrombotic events and secondary patency rate.<sup>116</sup>

While there are studies that support regular Doppler ultrasonography after AVF maturation,<sup>117,118</sup> some other studies have reached different conclusions.<sup>119</sup> Although the KDOQI guidelines have conservative recommendations for regular Doppler ultrasound examinations, this consensus expert group considers that based on the relatively backward status of China's overall HD level and in order to promote the development of vascular access-related fields, we recommend regular Doppler ultrasound examinations for AVF. The examination includes measurement of the internal diameter of the blood vessel (inflow tract, fistula, and outflow tract), vascular intima, blood flow, and assessment of the puncture site.

#### **4.4. The specialized training of HD nurses should be strengthened, routine physical examinations should be performed on AVF patients before each puncture, and further intervention should be provided when abnormalities are found, which is conducive to AVF maintenance. (1C)**

As medical knowledge and ideas change with each passing day, it is necessary to strengthen the specialized training of HD nurses to provide more optimized care for patients. According to the KDOQI guidelines, regular training and supervision of new nurses is essential. The European vascular access guidelines recommend training of nurses as well as vascular

access specialist nurses or coordinators. A domestic study conducted an AVF-related knowledge questionnaire survey (with a total score of 17) among 182 nurses in a city. The average total score of the surveyed nurses was  $6.00 \pm 2.25$ , and low- and high-level nurses accounted for 53% and 47%, respectively. The researchers suggested that education and training programs should be established to improve the level of professional knowledge of the dialysis nurses on internal fistula.<sup>120</sup>

An effective physical examination can assess the AVF blood vessel and blood flow. For example, a palpable tremor at the elbow and above can be one of the signs of good internal fistula function.<sup>121</sup> The positive significance of the AVF physical examination is affirmative, but in view of the differences in the experience of the medical staff performing the physical examination, the results or conclusions of the physical examination may be inconsistent.<sup>122–127</sup> Some scholars in the US found a lack of knowledge regarding physical examination of the internal fistula among clinical medical staff, including ignorance of the concepts, methods, and implementation of the physical examination. Correct and timely physical examination can lead to early detection and management of problems. Failure to perform physical examination or inaccurate physical examination often leads to complications such as insufficient blood flow in HD, hematoma formation, and aneurysm development.<sup>128</sup> Domestic scholars have emphasized that HD nurses should use physical methods of visual inspection, palpation, and auscultation to evaluate and monitor the blood vessels, which can detect common problems related to HD access in a timely manner and is beneficial for further evaluation and treatment by physicians.<sup>129,130</sup> Some scholars in the US have reported that the examination of vascular access can be taught to general nephrologists, dialysis technicians, and nurses working in HD wards. Moreover, educating patients to evaluate their own internal fistulas has also been proven to help prolong the use of internal fistulas.<sup>131</sup>

Although there is insufficient strong evidence supporting the benefits of routine physical examination, major guidelines have made recommendations on routine physical examination before AVF puncture. The physical examination includes visual inspection, palpation, and auscultation. The contents of visual inspection include checking the AVF skin integrity, presence of local redness, bleeding (petechia, ecchymosis, etc.), aneurysm (integrity, inner diameter, and tourniquet test), and swelling of the limbs. Palpation includes assessment of the pulse, blood vessel elasticity

and tension, and the degree of tremor. The contents of auscultation mainly include characteristics such as vascular murmurs and changes in their intensity. Physical examination is economical, fast, and convenient and generally does not cause harm to the patients. Based on the above reasons and clinical practice considerations, the expert group recommends it.

**Future research directions:** 1. The form, content, and methods of health education. 2. Research on medical expenses of plastic cannula.

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## Conflicts of interest

None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cdtm.2021.05.002>.

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