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Integration of Field Ⅱ and SiteRite5 In Vascular Ultrasound Improves One-Time Success Rate of Peripherally Inserted Central Catheter

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Abstract
Medical ultrasound has been used in clinical diagnosis for decades. In recent decades, vascular stenosis or aneurysm caused by cardiovascular and cerebrovascular diseases caused growing number of deaths, and early detection of those diseases drawn increased attention. In the present study, we used the Doppler method to simulate the distribution of axial blood flow velocity in vessels with varying degrees of stenosis. Then we propose a Field Ⅱ simulation model of ultrasonic RF signal for varying degrees of vascular stenosis. The experimental results show that the ultrasonic RF signal generated by Field Ⅱ and its estimated velocity profile are concordant with the theoretical results, which shows that the simulation model of ultrasonic radiofrequency signal with narrow blood vessel established by the Field II is effective and is practical in clinical settings, such as assessing the processing methodologies and feature extraction algorithms of ultrasonic signals for blood flow. With the assitance of Field II simulation, the SiteRite5 vascular ultrasound system and the micro-catheter sheath technique were used to puncture the upper arm PICC. The patients with vascular disease were divided into two groups: observation group and comparison group. The upper arm PICC for patients in the observation group were assisted by American Bart SiteRite5 system to monitor the blood vessels and performed by micro-catheter sheath technique. In comparison group, blood vessel line PICC. The one-time success rate of total puncture, and the recovery rate of the in-observation group was significantly improved compared with comparison, and the incidence of complication was accordingly reduced.
Keywords: Field Ⅱ simulation; blood flow velocity distribution; SiteRite5 ultrasonic guidance instrument; micro-catheter sheath technology

1. Introduction

Real-time monitor and measurement of blood flow and internal pressure in the blood vessels is of vital importance for hemodynamic studies[1]. Therefore, simulation of synthetic ultrasonic signals in blood vessels is helpful in clinical diagnosis of cardiovascular and cerebrovascualr diseases[2]. Recently, many studies are devoted to the acquisition of computer ultrasound images in the blood flow distribution model of diseased blood vessels. Among these, Doppler method is widely used to analyze the distribution of blood flow velocity in simulated stenosis [3]. Though multiple studies were conducted to analyze blood flow images synthesized with ultrasonic RF signals in normal blood vessels, the studies of ultrasonic signals in vessels with varying degrees of stenosis to assess the blood flow velocity and distribution is rarely reported.

The physical structure of the blood vessels is very complex. Unlike isotropic cylindrical lumen, it is difficult to apply particular algorithms to analyze mechanical properties of blood vessels. For convenience of analysis, the early blood vessel velocity distribution model usually takes the blood vessels as a homogeneous cylindrical tube, using finite element method to analyze the normal the blood flow distribution. Based on medical imaging and anatomical statistics obtained by lesion vascular blood flow distribution model, physicians

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have more confidence in diagnosis of cardiovascular and cerebrovascular diseases.

Due to the deposition of cholesterol and lipid substances adhered to the wall of the blood vessels, the vessel surface is often uneven and has irregularitieswhich makes the establishment of homogeneous narraow vascular model difficult. Taken into consideration, the researchers often approximate the narrow wall of the vascular wall of the ideal geometric shape, such as concentric, rectangular, conical and cosine-shaped, in which the cosine-shaped stenosis of the vascular blood flow model is more widely used.

For the concentric annular stenosis of blood vessels, Zhang Yu and colleauges used the iterative method to calculate the vortices-flow function of the blood flow control equation to obtain the velocity distribution of the intravascular constant flow [4]. The power spectral density of the intravascular flow rate is obtained by the correlation between the blood flow velocity distribution and the power spectral density, and the ultrasonic Doppler signal of the narrow blood vessel is obtained by the cosine signal superposition method. In a concentric annular stenosis model, the transition from a normal vessel to a stenosis vessel is discontinuous, which different from reality and thus nor practical.

Oung [5] and colleagues used the finite element analysis method to solve the Navier-Stokes equations and obtain a rectangular narrowed blood vessel velocity distribution. In this study, the disease blood vessel regarded as a rigid blood vessel with 50% stenosis. In the non-axisymmetric rectangular stenosis model, the information parameters of the blood flow signal in the tube were derived from the Navis-Tox equation. The blood flow velocity profile obtained from the blood flow information data.

Akbar [6] and colleagues used the analytical method and the perturbation method to calculate the velocity distribution of blood vessels in the conical stenosis, which was specifically related to the velocity distribution of Jeffrey blood and Reiner-Revlin blood. Subsequently, they analyzed the heat mass conversion of Reiner-Rivlin blood and discussed the delay on the flow of Jeffrey fluid.

Fang [7] and colleagues used finite element analysis method to calculate the blood flow control equation to obtain cosine-shaped stenosis blood flow velocity distribution. This computer simulation model can generate ultrasound Doppler signals for vessels with varying degrees of stenosis and under different blood flow conditions, though the computation is more complex. Wang et al calculated the pulsating velocity distribution in the blood vessels of the cosine-shaped stenosis by calculating the blood flow control equation via Fourier series expansion. The computer model mainly uses the mathematical analysis method to solve the blood flow velocity distribution. Compared with the above hydrodynamic method, computational model combined with methmatical analysis is more computationally cost-effective.

These simulation models only consider the flow of blood flow in rigid blood vessels with ideal cosine and narrow shape, and the blood flow signals in the tube are analyzed and simulated [8]. These cosine-shaped stenotic vascular models are no longer suitable for use when the stenotic plaque shape changes, although it is still more widely used because of its proximity to the actual situation.

In the end, this paper uses the Field II toolkit to generate ultrasonic RF signal of bloodstream in the narrow blood vessels in the bloodstream and obtain the ultrasonic RF flow velocity distribution. Then proposed an ultrasound RF signal simulation model to reflect the flow distribution within vessels with different degrees of stenosis. The specific process is to use the ultrasonic velocity measurement equipment to detect the axial blood flow velocity in the normal blood vessels, then use the tube flow velocity to solve the Navier-Stakes equation to calculate the pressure of the blood flow in the narrow blood vessel gradient and oscillation velocity distribution.

Currently, there is a tacit consensus that: ultrasound technology used to guide PICC can significantly improve the one-time success rate of one-time placement, but the most studies compared ultrasound guiddance and blind puncture, comparison of different ultrasound technology applied to PICC n were lacking. CDFI technique was used in PICC vascular screening and combined with SiteRite5 vascular ultrasound guidance system by 262 cases of clinical case analysis. The effect of SiteRite5 ultrasound-guided puncture in PICC was analyzed. By contrast, CDFI was used for PICC vascular screening, and SiteRite5 ultrasound-guided puncture was used to reduce PICC catheter-related thrombus and mechanical vein.

2. Experimental principle

2.1 Field II simulation method

2.1.1 Ultrasonic beam forming

The beam has two types: transmitting beam and receiving beam. The formation of a transmitting beam can improve the sound pressure in a particular direction and reduce the reception artifacts. The control of beam forming is to delay the excitation time of each channel, which ensures that the emission sound at the focal position is superimposed with the phase, and the sound pressure reaches the maximum. According to the probe on the array to the target point of the distance difference, you can calculate the ultrasonic wave propagation time [9].

$$\tau_n = \frac{\sqrt{r^2+x^2}+\sqrt{r^2+(x_n-x)^2}}{c} \quad (1)$$

Where x is the distance between the center of the firing aperture and the nth element, x is the lateral distance between the emission focus and the center of the emission array, c is the speed of sound, r is the vertical distance between the emission focus and the probe, the space of the element and the image position. The relationship is shown in Fig.1. A launch cycle can only launch a sound wave, generally in accordance with the location of the calculation of each element channel transmission delay. Therefore, a launch cycle is equal to emission delay.

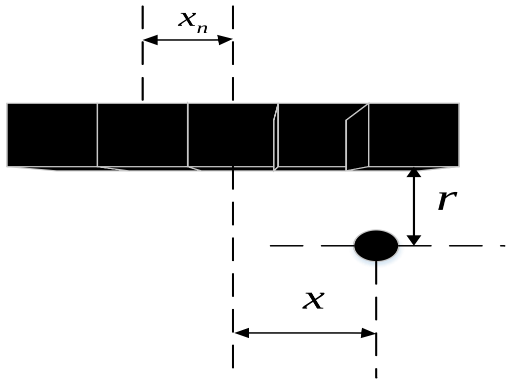

Figure 1. **The relative position between element and image position**

The receiving beam forming enables the echo signals of each channel to receive the target point to be added in phase [10]. When the focus is received, the echo signal arrives at the time of each element, and the phase is changed. Therefore, the signal of each array needs to be adjusted and summed by time. Similarly, according to Fig.1 and the formula 1 to calculate the target point of the echo to reach the array displacement. Unlike the transmitted beam forming, the receive beam can be continuously focused in the distance direction, which requires that the delay time difference of each array be changed with the reception depth. In addition to the main control of each element channel delay time, another important measure is the atomization. For example, the use of Gaussian function of the channel weighting, specifically for each channel excitation intensity is not the same, the receiving channel echo signal gain is different. As with the focus, the transmitter only needs a set of atomization parameters, but it need to change with the depth.

2.1.2 Field II environment

The core of the package includes a C program and a number of M files, taking Matlab as the operating platform. C program is mainly used to complete the calculation of data storage and management. M files have three types, field-prefix files are used to complete the initialization package [11]; xdc-prefix files are used to define and construct the ultrasonic transducer characteristics, such as considering the need for array transducer or convex surface change, the number of elements needed to activate the transducer, the focus and the atomization, etc. The M files prefixed with calc are used to perform the operations associated with the calculation. The definition, function and specific usage of the relevant functions involved in the Field II toolkit are described in the reference manual. The basic structure of the toolkit is shown in Fig.2:

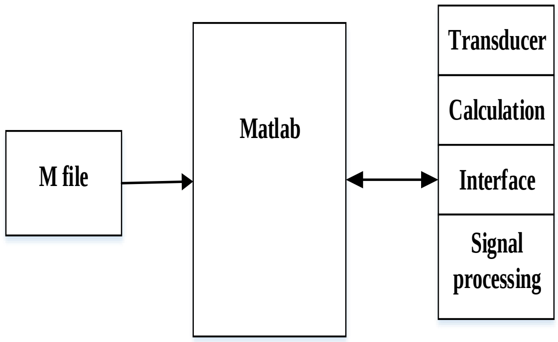

Figure 2. **The basic structure of the Field II toolkit**

2.1.3 Field II simulation method

Field II uses the spatial impulse response method proposed by Tupholme and Stepanishen [12] to calculate the sound field of the ultrasonic wave. According to the linear system theory, when the ultrasonic transducer is excited by the Diracδ function, the emitted ultrasonic sound field of space with a certain time is obtained by the spatial impulse response. For any type of excitation, it is only necessary to convolve the spatial impulse response and the excitation signal to compute the sound field. For example, the result of the continuous wave signal excitation is the Fourier transform of the spatial impulse response at a given frequency [13].

It can also simulate any linear imaging, and the simulation of the human body tissue image is very realistic. The spatial impulse response is equal to the received response of the spherical wave emitted by the point source. The received spatial impulse response and the emitter function are convoluted to receive the response [14], and the echo voltage is obtained according to the electromechanical transfer function of the sensor signal. Field II is able to compute the spatial impulse response of the atomization transducer, which is difficult to do with other methods. It divides the transducer surface into many squares, and the sensor's response is equal to the sum of the squares, so it can simulate any geometric sensor [15].

Field II program uses the time series to achieve focus, each focus area corresponds to a focus position and a point in time, dynamic focus, the focus with time (depth) changes. Set the focus parameter and use focus to set the reference position. The focus time is calculated as follows:

$$t_i = \frac{1}{c}\sqrt{(x_c-x_f)^2+(y_c-y_f)^2+(z_c-z_f)^2} - \sqrt{(x_i-x_f)^2+(y_i-y_f)^2+(z_i-z_f)^2} \quad (2)$$

(x_f, y_f, z_f) is the focal position, (x_c, y_c, z_c) is the center reference position of the sensor, (x_i, y_i, z_i) is the central position of the element, and $c$is the speed of sound.

2.2 SiteRite5 vascular ultrasound guided instrument and PICC puncture technique

2.2.1 SiteRite5 Vascular Ultrasound Guiding Instrument

The design of SiteRite5 ultrasound guided instrument for catheter is delicate. Ultrasound-guided PICC puncture is the use of a guide system equipped with a blood guide system to puncture the selected veins, which can detect and evaluate the patient's upper arm blood vessels, while the overall assessment of the blood vessels in the shape of the possible obstruction and unpredictable narrow. Under the guidance of the use of MST technology line PICC catheter to solve the invisible blood vessels that cannot touch the puncture, and this method in the elbow above the catheter puncture reduced the mechanical phlebitis, catheter-related infection and venous thrombosis [16]. In the United States, the use of ultrasound guidance technology for the upper arm of the hospital has become a professional hospital nurses into the catheter gold standard, currently only a small number of domestic hospitals use.

2.2.2 PICC puncture technology

PICC catheterization has a higher success rate than other catheterization methods and maintains a long retention time (up to 1 year). PICC has less intravenous valve and is easy to place. Puncture site is relative independent to daily activities,and the forearm is more flat, which help to fix catheter and prevent it from falling off. Studies showed that PICC catheterization has less complications [17]. PICC catheters are soft and have high elasticity hydrophilic silicone or polyurethane tubing, which diminishes tissue damage during puncture implantation process on the vascular wall. Moreover, in patients with cancer, PICC catheter can reduce the toxicity of chemotherapy drugs on vascular tissue. Through the PICC catheter directly into the central vein, which reduces the drug toxicity on peripheral veins, and avoid chemotherapy drugs penetrating into blood vessels [18]. The aforementioned advantages of PICC overwhelms conventional method.

3. Experimental process

3.1 Ultrasonic Doppler flow signal simulation

For use of ultrasonic Doppler methods in simulation of blood flows in varying degrees of cosine-shaped blood vessels, Mo and Cobbold proposed the following formula [19]:

$$z(t) = \sum_{m=1}^{M} a_m \, exp[j(2\pi f_m t + \varphi_m)] \quad (3)$$

In equation 3, $\varphi_m$is a random phase that satisfies the hook distribution on [0,2π]. The variables φ_m represents the randomness of the Doppler flow signal, $a_m$is the sine of the Rayleigh amplitude distribution.

The pressure grades and axial velocity distribution of the blood in normal blood vessels can be calculated by the above formula, and the flow velocity is calculated by substituting the pressure gradient at the center of the lesion axis and the transformation of blood pressure gradient and velocity is shown in Fig.3 and Fig.4.

As shown below, the blood pressure in the normal blood vessels increases and decreases with the systole and diastole of the heart, but the oscillation of pressure gradients in late is caused by the elasticity of the vessel wall. The pressure gradient and velocity distribution of the blood flow in stenotic vessel were simulated and analyzed.

3.1.1 Simulation of blood pressure gradient

Calculating the pressure gradient distribution of the oscillating blood flow in stenotic vessels is a prerequisite for obtaining the velocity of the blood flow. Therefore, it is necessary to assess the accuracy of the pressure gradient calculationApplying the known blood pressure gradient to formulus, the pressure gradient in vessels of varying degrees of stenosis can be generated.

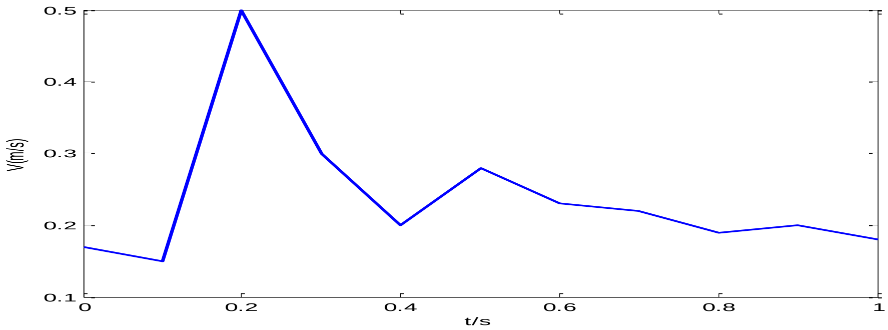

Figure 3. **Blood flow velocity at tube axis of normal blood vessel**

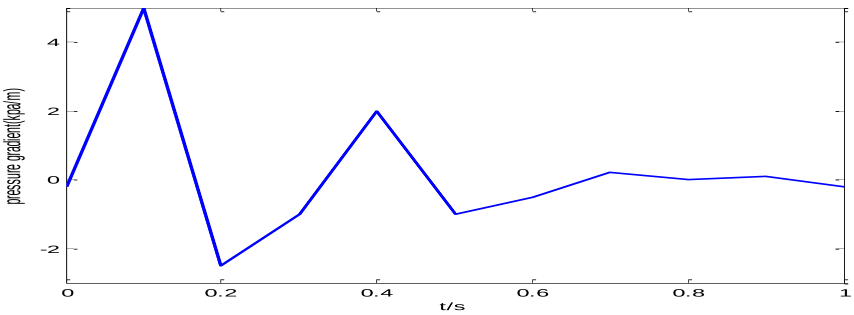

Figure 4. **Blood pressure gradient of normal blood vessel**

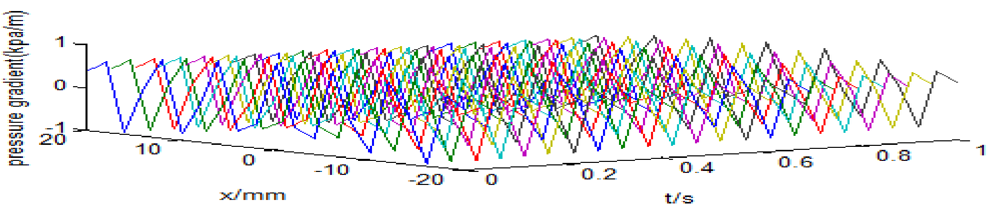

Figure 5. **50% stenosis intravascular flow velocity**

With 20% stenosis, the pressure gradient curve at different axial positions and time points is almost the same as that of normal blood vessels. With the increasing degree of stenosis, the pressure gradient values along different axial positions increase rapidly, especially at the axial position. The pressure values of blood flow in different degrees of stenosis are consistent with normal blood vessels over time and exhibit an axisymmetric pattern related to the tube axis. This is consistent with the results of clinical trials.

3.1.2 Simulation of blood flow velocity

Theoretically, the steady flow of blood is manifested as laminar flow. As shown in Fig.8, the length of the arrow indicates the size of the blood flow velocity and $\Delta v$is the difference in blood flow velocity when the distance between the vessels isΔL. The velocity of the laminar flow can be calculated by the following formula:

$$v = \frac{P_1 - P_2}{4\eta L}(R^2 - r^2) \qquad (4)$$

$R$is the radius of the vessel,$r$is the vertical distance from the center of the tube axis, and $P_1 - P_2$is the pressure different between two ends spanning a distance L. According to the formula, the laminar velocity profile is approximate to a parabolic distribution, the velocity in the middle axial middle of the vessel is larger than that close to vessel wall.

From the below figure we can see that the velocity of steady blood flow in the stenotic vessels complies to Poiseuille's formula. The velocity profile of the blood flow does not change with the time, and the velocity across the vessel section suggests parabola distribution, which means the velocity is larger in axis than that close to the wall. The velocity of blood flow in the stenotic vessel is higher than that in the normal blood vessel and increase with the degree of stenosis.

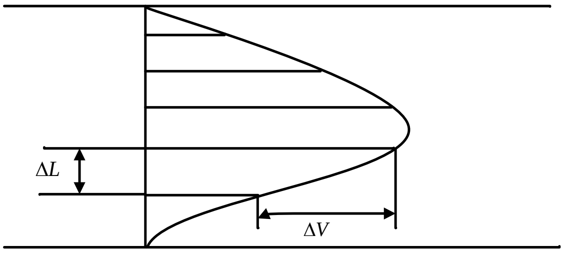

Figure 6. **Laminar velocity profile**

3.2 Clinical trials

3.2.1 Case selection conditions

Those patients were chosen for PICC catheterization: histological and cytologic examination confirmed as lung cancer; Karnofsky performance status (KPS) score above 70 scores; Functions of liver\ kidney, and marrows are normal, and blood routine examination showed no abnormalities. Patients are excluded when they have contraindications to PICC puncture,phlebitis, thrombosis, repeated puncture , or bleeding tendency [20]. Both written informed consent and risk statement of PICC catheterization were obtained from all included patients.

3.2.2 Experimental grouping

The subjects were divided into two groups: 153 cases in the observation group and 109 cases in the comparison group. There was no significant difference in the sex, age and disease composition between the two groups.

For the observation group, SiteRite5 ultrasonic guided device was use to assist PICC catheterization, following screening by CDFI. Patients lied in the cathetering bed; the lobe side that would receive puncture laid. The coupling agent probe was applied into the sterile probe plastic set, and then fixed with sterile rubber ring [21]. The puncture device is placed on the vein and the needle is inserted into the pinhole of the needle guide. Stop the needle when piercing the blood vessel. After needle became stable and blood reflux, slowly and gently put catheter into the blood vessels and left with a predefined length of catheter in the vessel. Procesures will be taken to prevent the access of catheter into the neck vein, and the location of catheter head was determined under X-ray.

The comparison group: PICC insertion was performed by the conventional (routine) method through direct vein visualization and palpation of the vein. In the study group, before PICC insertion, subjects' antecubital areas of both upper limbs were investigated through static sonography, and PICC insertion was performed by a researcher who was familiar with this method and had a certificate for PICC insertion through sonography. [22]. Firstly, after target vein entrance localization on the device monitor, the overlying skin was marked by a marker. Next, the target point was disinfected and the primary needle was inserted in a place relatively lower than the marked point. Other stages and all equipments used in both groups were quite identical. Other steps were same with observation group [23]. Catheter-related thrombosis refers to the formation of clot caused by catherization [24].

4. Results analysis

SPSS17.0 statistical software was used for data analysis; numerical data was presented as mean ± standard deviation (x ± s). Student's test was conducted to measure the difference between observation group and comparison. Finally, a total of 262 patients completed the experiment. The demographical and clinical parameters of both groups were listed in Table 1. The one-time success rate of PICC in both groups are all 100%, while the incidence of thrombosis and mechanical phlebitis were both significantly reduced in observation group (Fig. 7), suggesting that the meassures taken in observation group was effective.

The incidence of mechanical phlebitis was 8.9% in the comparison group and 10.4% in the local hematoma. The incidence of local phlebitis was 0. The rate of local hematoma was 1.4%, and the difference was statistically significant (P<0.01, Fig.8).

Table 1. **Comparison of general information of patients**

Influencing factors	Comparison group	Observation group	P value
Average age	50.1±11.3	52.2±10.4	0.142
Bowel cancer	8	14	
Breast cancer	27	35	
Lung cancer	25	15	
Cervical cancer	7	14	
Liver cancer	11	23	
Leukemia	10	11	
Ovarian cancer	5	15	0.124

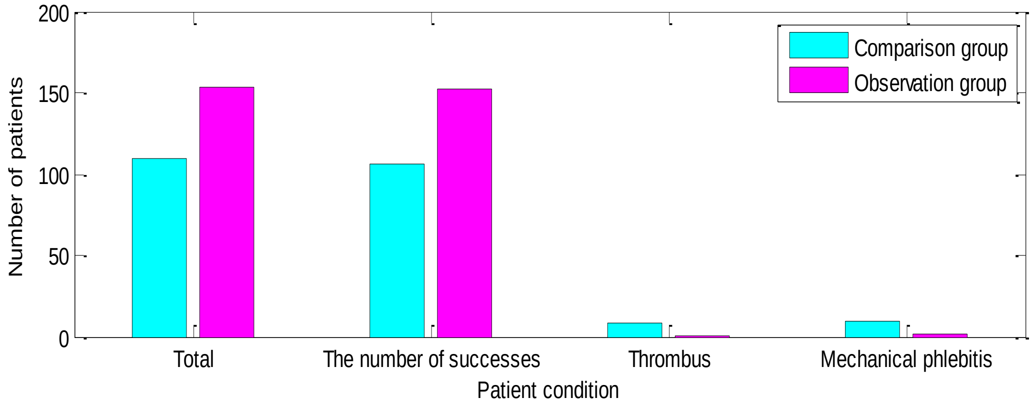

Figure 7. **Comparison of one-time success rate, thrombosis, and mechanical phlebitis**

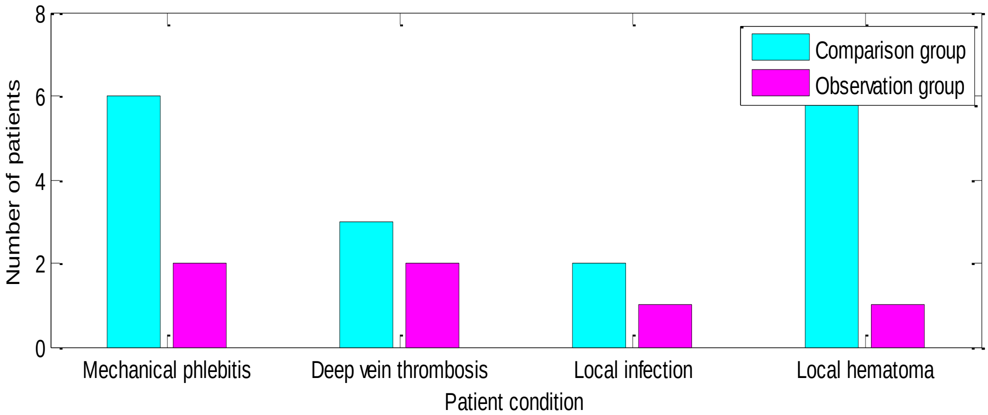

Figure 8. **Comparison of the incidence of complications in both groups**

The scores of pain in the comparison group were significantly higher than those in the observation group (P <0.01, Table 2).

Table 2. **Comparison of pain between the two groups when punctured**

Group	**<3'**	**3-4'**	**>4'**
Comparison group	34	52.2±10.4	0.142
Observation group	64	8	5
x^2	27.29	8.43	19.02
P	<0.01	<0.01	<0.01

Currently, there are some challenges in PICC catheterization.PICC catheter is mostly blindly inserted, exposure of puncture site to nursing staff may increase the risk of infectionsPeripheral vascular conditions is usually not ideal for vascular puncture as it may be easy to cause damage of intima and deep vein thrombosis, as well as other complications [25]. Therefore, establishment of a safe and efficient intravenous PICC has become an important nursing problem. The use of SiteRite5 ultrasound guidance and micro-catheter sheath technology PICC can effectively improve the success rate of puncture. SiteRite5 vascular ultrasound guidance system explore the blood vessels subcutaneous 0.5-0.6 cm, evaluating the thickness and direction, which help with decisions on where, when and how to perform catheterization[26]. The status of deep veins in the upper arm, needle walking and locations can be visualized and traced under guidance, which avoids problems caused by blind insertion, and improves the one-time success rate of a puncture. Application of vascular ultrasound probe further improves the success rate of puncture. The one-time success rate of observation group was 97.2%, and the total success rate was 100%, significantly higher than comparison group that was under normal ultrasound guidance (P<0.01).

Mechanical phlebitis is one of the most common clinical complications after PICC catheterization. Intraoperative catheter sheath is easy to damage the intima [27]. Studies showed that the postoperative are 2- to 10-fold prone to phlebitis [28]. Earlyprevention and treatment is expected reduce the patient's pain, prolong the catheterization time [29], and ensure that patients are sustained with adequate therapeutic substances. SiteRite5 vascular ultrasound function clearly shows the cross-section and direction of blood vessels, allowing operators to choose proper types of catheters. It reduced the type of catheter mismatch that would lead to phlebitis and thrombosis. Furthermore, it can effectively reduce the occurrence of mechanical phlebitis and other complications [230]. Using the SiteRite5 ultrasound guided and micro-catheter sheath technique, PICC was punctured with 20-21 needle. The puncture needle (14-16) under the guidance of ordinary ultrasound was small, and the micro sheath kit had little damage to the tissue. Therefore, the incidence of mechanical phlebitis, local hematoma is eliminated. In addition, SiteRite5 ultrasound guidance system is equipped with a sterile coupling agent and 1.5 m long sterile probe hood, effectively reducing the incidence of infection.

Using the SiteRite5 ultrasound guided and micro-catheter sheath technology, the puncture needle is more subtle than the ordinary ultrasound-guided puncture needle, which potentially reduce pain for the patients. In addition, the avoidance of joints as puncture points reduces the patient's physical activity during the traction of the pipeline. The impact on patients with daily life is small, which can reduce the patient's discomfort [31-34].

The use of SiteRite5 ultrasound guidance and micro-embolization sheath technology still need to pay attention to the problem: (1) the use of ultrasound guidance and micro-catheter sheath technology on the upper arm PICC catheter is expensive, and medical source in China is limited, which makes the inpatient registration unaccessible. This shortage of medical nursing makes the implementation of conventional puncture is difficult to apply new technologies. (2) The use of ultrasound guided and micro-catheter sheath technology PICC enables the insertion of micro-cannula sheath into the upper arm when expansion surgery is needed, without causing too much pain for the patients (pain score of 2-4 minutes). (3) The use of ultrasound guidance and micro-catheter sheath technology PICC, to carry infusion in winter has some problems. Such situation will requires infusion extension tube, but therefore increase the cost of treatment. (4) the procedures should be taken with extra care, especially when there is no independent walking veins, veins parallel to arteries may be chosen, and the precision of location and precise puncturing is required to prevent the ectopic access of PICC into arteries.

Overall, within 153 patients in observational group, only 2 cases have phlebitis, 2 cases have deep vein thrombosis, while in comparison group, the incidence of phlebitis and thrombosis are respectively 6 and 3. The incidence of local infection in observation group is also lower than comparison group (1:2), so is incidence of local hematoma (1:6). In pain assessment, observation group demonstrated significant improvement, where the majority of the patients have pain score below 3, yet the comparison group have most patients with 3-4 (Chi-square test, p<0.01).

5. Conclusion

In this paper, we discuss some representative constricted vascular models established by researchers both at home and abroad in recent years, and briefly introduce the concentric annular, rectangular, conical and cosine stenosis vascular models. We study and analyze the cosine-shaped stenosis model. First, we use the Doppler speedometer to measure the maximum blood flow velocity at the upstream (no stenosis) of the local stenosis. Probe speedometer until the blood flow velocity waveform can be steadily presented. Then, based on the blood flow velocity measured at the normal blood vessel segment, the blood flow control equation about the pressure gradient in the local cosine stenosis plaque in the blood vessel was derived. Finally, the blood flow velocity gradient was used to calculate the velocity distribution in blood vessels with varying degrees of stenosis.

Although success rate of PICC has been achieved, the extension of life of catheter, decrease of incidence of PICC complications are still the forefront issues yet to be addressed. More prospective studies are warranted to explore the mechanism underlying PICC complications.

The CDFI technique was applied to the vascular screening before PICC catheterization, combined with SiteRite5 ultrasound-guided puncture to achieve the complementarity: CDFI makes a comprehensive and accurate assessment of vascular conditions to determine the pre-puncture vein, catheter model, and positioning puncture points. SiteRite5 ultrasound guided catheterization successfully expand the scope of the use of CDFI, and substantially reduce the incidence of PICC complications.

The present study demonstrated that the combincation of blood flow velocity analysis based on Field II simulation and SiteRite5 ultrasound guidance could help precise positioning and provide informative parameters for nursing personel to consider, thereby eliminating the PICC complications and improving one-time success rate. With no significant difference in clinical parameters, patients received SiteRite 5 ultrasound guided PICC and blind PICC showed significant difference in the incidence of thrombosis, philebitis, local infections and hematoma. In addition, pain assessment suggested that patients receiving SiteRite5 ultrasound guided PICC have less pain than comparison group, indicating precise positioning of puncture probe and timely and informative visualization of blood vessels could reduce suffering of patients during PICC catheterization.

Despite aforementioned advantages of SiteRite5 guided PICC catheterization demonstrated in the present study, there are still some limitations regarding study design. The establishment of stenotic blood vessels is simple that is not adequate to reflect the real-world blood fluid during circulation. Fluctuations due to other parameters cannot be included in this model; For instance, respiratory and heartbeat may also have impact on blood flow, but this model only takes the stenosis into considerations. Ultrasound guidance and micro-catheter sheath PICC have presented a plethora of promises, the use of this technology in other operational settings and corresponding risk management need further investigation. Only in this way can the nursing quality be improved [10].

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