

# Multidisciplinary cooperative mode led by infusion nurse specialists used to ensure the nursing quality of peripherally inserted central catheters in China: A 5-year retrospective study

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The Journal of Vascular Access  
1–9

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DOI: 10.1177/11297298211033507

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## Abstract

**Objective:** To analyze the effect of multidisciplinary cooperation mode (MCM) led by infusion nurse specialists (INs) on peripherally inserted central catheters (PICC) catheterization and indwelling nursing quality.

**Methods:** Participants' demographic information, catheter types, catheterization approaches, puncture site, tip position, professional title of nurses, success rate of catheterization, consultation rate, detection rate of complications and outcome improvement rate of 6576 outpatients and hospitalized patients with PICC were analyzed retrospectively by a software named “questionnaire stars,” in a large tertiary general hospital in Shanghai, from January 2015 to December 2019. SPSS 26.0 for Windows was used for data collection and description, Chi-square test were used for statistical analysis of enumeration data, and  $p < 0.05$  was statistically significant.

**Results:** According to the catheter types' data, the use rate of three-way valve catheters decreased from 79.9% to 14.5%, while the use rate of three-way valve catheters increased from 12.7% to 51.6%, and the use rate of power injectable and open-ended catheters increased from 7.4% to 33.9%. According to the data of PICC catheterization method, conventional technology decreased significantly from 16.8% to 1.1%, modified Seldinger technique (MST) increased gradually from 26.1% to 51.3%, while ultrasound guided modified Seldinger technique (US and MST) decreased slightly from 57.2% to 47.6%. 7.5% catheter tip ends were malpositioned while nine indwelled PICCs were traced to have tip end malposition. The consultation rate was significantly higher than that before applying MCM led by INs ( $\chi^2 = 151.713$ ,  $p < 0.05$ ). After applying MCM led by INs, the detection rate of complications was significantly higher than before ( $\chi^2 = 5.499$ ,  $p < 0.05$ ), the rate of successful insertion at one time was significantly higher than before ( $\chi^2 = 187.589$ ,  $p < 0.05$ ).

**Conclusion:** After the application of INs-led MCM, progresses have been achieved. The nursing quality of patients' PICC was significantly improved than before.

## Keywords

Multidisciplinary cooperative mode, infusion nurse specialists, nursing quality, peripherally inserted central catheters

Date received: 16 December 2020; accepted: 27 June 2021

## Background

Peripherally inserted central catheters (PICCs) represent common devices for reliable administration of intravenous therapy in different medical settings. Their use has become a routine part of the management of oncologic and non-oncologic patients, for the administration of chemotherapy, total parenteral nutrition, and vasostimulant drug infusion.<sup>1</sup> As a relatively new but rapidly developing type of VAD, PICCs can provide secure and effective venous accesses with minor injury and simple operation for

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medium to long term use and have been widely used in the fields of tumor chemotherapy, parenteral nutrition treatment, irritant drug infusion, long-term intravenous blood transfusion and large area burn, etc.<sup>2-4</sup> PICCs had more catheter dwell days and lower incidence of bloodstream infection than CVCs and PIVCs.<sup>5,6</sup> These catheters facilitate the management of both inpatient and outpatient care and offer flexibility in meeting both short and long term vascular access requirements.<sup>7,8</sup> Furthermore, nurse-led PICC bedside placement is convenient for providers and patients.<sup>9,10</sup>

In 1952, the first attempt was taken to access the central venous system via the superior vena cava.<sup>11</sup> After 70 years of development and change, PICC rapidly developed into an effective catheterization instead of repeated peripheral venipuncture and other central veins.<sup>11</sup> The technique of PICCs was introduced into China in the 1990s.<sup>12</sup> Gradually, the modified Seldinger catheterization technology under the guidance of ultrasound (US and MST) was introduced into China, which greatly improved the success rate of puncture.<sup>13</sup>

In the beginning of the 21st century, the Infusion Therapy Standards of Practice<sup>14</sup> was introduced into China for the first time. As the first echelon, Changhai Hospital has applied the international PICC intravenous infusion standard in its nursing practice. Under more than 20 years of clinical practice and research, PICC catheterization technology are becoming more and more sophisticated. In 2006, Changhai Hospital has established PICC infusion nursing clinic to manage complex PICC cases and provide regular maintenance.

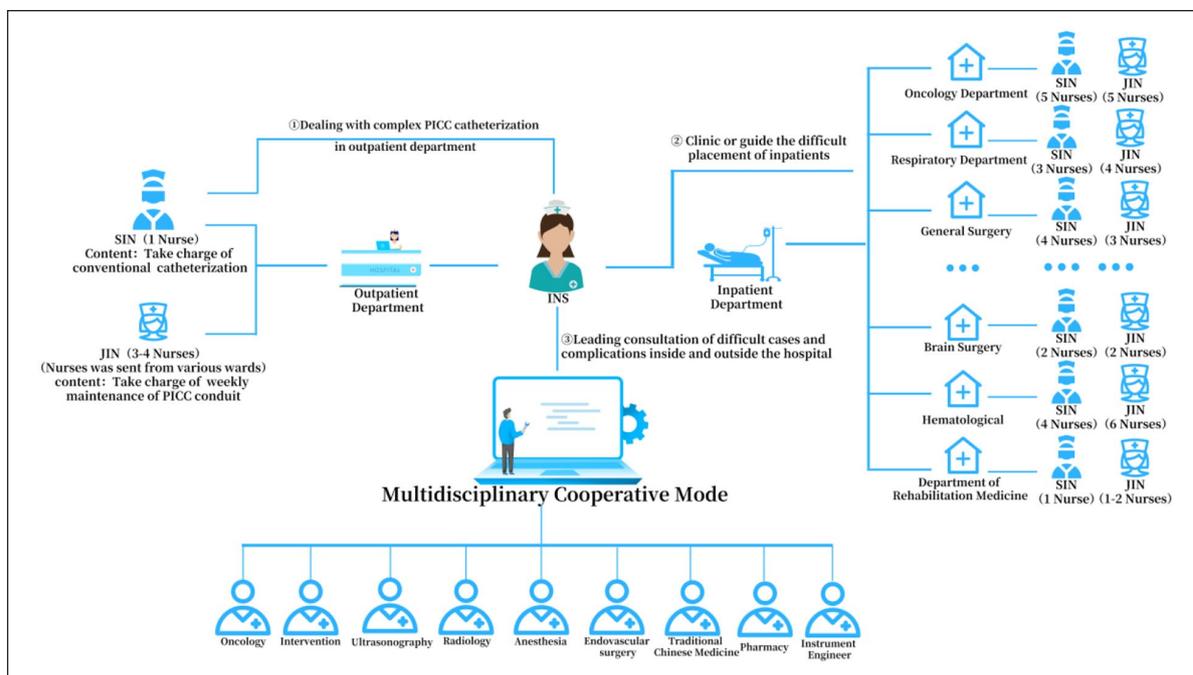
In 2008, the PICC infusion nursing clinic provided consultation for the patient through personal contact. An electronic database was established in 2009 to collect the PICC catheterization information. In 2010, an infusion nurse expert of Changhai hospital was appointed as the vice Chairperson of Infusion Therapy Committee in Shanghai Nurses Association. In 2015, to improve the skill and quality of PICC care, Changhai Hospital established a PICC patient information database. In 2016, the hospital launched a large-scale PICC skill training for senior nurses, which trained a large number of intravenous infusion nursing talents.

In 2017, a new management mode named INS-led multidisciplinary cooperation mode (MCM) was created. There was a three-level nursing staff structure of the infusion nurse board (INB). Infusion Nurse Specialists (INSSs), Senior Infusion Nurses (SINs) and Junior Infusion Nurses (JINs) took different roles and responsibilities. The committee played a key role in qualification recognition, professional promotion, and multidisciplinary consultation network led by INSSs based upon the infusion nursing clinic. In this mode, there were three levels of infusion nurses in the organization, including 10 INSSs, 14 SINs, and 43 JINs in the year of 2017. Each of them played

special roles in the organization. In the hospital, there were two main practice places for them. In the infusion therapy clinic, JINs are responsible for the weekly maintenance of the PICC, SINs are responsible for PICC insertion, and INSSs are in charge of complicated insertion cases and complication consultation. On the ward of Oncology, Respiratory, General surgery, where patients usually have chemotherapy or long term infusion therapy, JINs are responsible for routine maintenance and medication delivery, as well as catheterization under the guidance of SINs. SINs are responsible for catheter puncture independently, routine catheter quality control and on-site group consultation when difficult and complicated cases are encountered. On the ward, each department will train all kinds of nurses according to the demand of PICCs indwelling, for example, in Oncology, Hematology and Respiratory departments, the number of patients with PICC is large, so these wards are generally equipped with 3-5 SINs and 4-6 JINs. However, in the department with fewer PICC patients, the number of infusion nurses will be relatively fewer (shown in Figure 1).

The hospital founded an INS-led committee of infusion therapy, which established a multidisciplinary consultation network. In this network, there were many specialized physicians or surgeons participated in the infusion therapy practice, who were in the disciplines of Oncology, Interventional Therapy, Ultrasonography, Radiology, Anesthesia, Endovascular surgery, Traditional Chinese Medicine, Pharmacy, Medical Engineering, etc. In outpatient clinics and inpatient wards, when JINs find complications or suspicious complications during catheter indwelling and maintenance, or SINs find complications during catheterization. They report to INSSs and contact relevant specialists to start multidisciplinary cooperative mechanism and solve complex problems.

The infusion nurses who were selected from different departments are trained in the hospital. Every year, the hospital organized the training of JINs, and took the theoretical assessment for the infusion nurses who need to be promoted. Nurses with longer than 3 years of work experience or primary professional title can voluntarily apply for JINs' training program, and they would have puncture qualification after passing the assessment. In order to achieve a higher quality of puncture and weekly care of PICCs in the hospital, JINs are responsible for puncture and maintenance in the clinical department. In addition, JINs are also responsible for the maintenance of PICCs in the infusion nursing clinic on a regular basis. Due to the large number of JINs while less numbers of ultrasound equipment, the hospital cannot guarantee that ultrasound devices are equipped in each department, so JINs can only use MST method for puncture. However, when JINs successfully punctured 100 cases of PICCs and passed the theoretical examination, they could be promoted to SINs. The hospital will provide ultrasound devices for the



**Figure 1.** INS-led multidisciplinary cooperative mode for PICC care.

departments where SIN is located. SINS can perform the US and MST in the departments.

Since the application of MCM 3 years ago, the infusion quality of the hospital has been improved. The purpose of this paper is to retrospectively analyze the detection and outcome improvement rate of complications after applying the INS-led MCM during past 5 years.

## Methods

### Study design

This study was a descriptive study which retrospectively analyzed the PICC insertion and administration data in a single large tertiary medical center, comparing the data of 2015–2016 before to the data of 2018–2019 after application of MCM, in Shanghai, the second largest city in China. In order to avoid data ambiguity caused by the establishment of the mode in 2017, the data of 2017 is excluded. All the patients had the PICC indwelled in the hospital, which is also the PICC inserting skill training base of Shanghai Nurses Association. This study collected the effect and efficacy indicators of applying this multidisciplinary mode, including the type of catheters, catheterization method, abnormal catheter tip position, incidence of various complications, consultation rate, and improvement rate.

### Definitions

PICC related complications reported in this paper include: phlebitis, blood oozing and fluid exudation, catheter-related

blood stream infection (CRBSI), catheter-related thrombosis (CRT), malpositioned catheter, catheter occlusion, catheter rupture or extravasation, medical adhesive-related skin injury (MARS). These are defined as follows:

Phlebitis is one of the most common complications after PICC catheterization. Phlebitis usually occurs 48–72 h after puncture, showing redness, swelling, heat and pain around the puncture point, redness, and induration of the skin along the vein. According to the etiology, phlebitis is divided into mechanical, bacterial, chemical, and thrombotic phlebitis, of which the most common is mechanical phlebitis.<sup>15</sup>

Blood oozing and fluid exudation at the puncture point refers to the exudation of blood or fluid from the puncture site along the catheter after PICC catheterization. Most of the bleeding occurred 12–24 h after puncture and lasted for 3–5 days, which was often related to patients' own disease and nutritional status, blood coagulation function, local infection, nurse puncture, and maintenance techniques and patient health education.

CRBSI refers to the presence of tenderness, redness, swelling, fever, chills, and other symptoms at the puncture site within 48 h of indwelling or removal of the catheter, with or without leukocytosis, positive bacteria or fungi in peripheral venous blood culture, or pathogens with the same kinds and drug sensitivity results from catheter segment and peripheral blood.<sup>16,17</sup>

CRT is one of the more common and serious complications.<sup>18,19</sup> The main manifestations are swelling and pain in the upper limb or shoulder and neck on the side of the tube, pitting edema in the affected limb, high skin temperature,

exposure or dilatation of superficial veins in the affected limb. Studies have shown that,<sup>20,21</sup> the incidence of PICC related venous thrombus is 2.3%–3.9%. In addition, the formation of CRT can lead to catheter leakage of infusate. If there is a fibrin sheath, nurses can use a guide wire to support or use a dilator to expand the skin and blood vessels.

Malpositioned catheter is one of the inevitable complications of PICC with an incidence of 10%,<sup>22</sup> which is often related to thoracic cavity tumor, vascular variation, and improper posture. The common malpositioned is the internal jugular vein and axillary vein, and the patient shows pain and swelling in the upper limb, upper arm, or neck. The patient feels pain during infusion. If the catheter is malpositioned, it should be regulated in time, and finally confirmed by photography.

Patients with PICCs have a 7% risk of developing occlusion. The risk becomes higher as the retention days of catheter becomes longer.<sup>23</sup> Catheter occlusion is usually caused by a blood clot or chemical blockage. The clinical manifestations of catheter occlusion are as follows: difficult infusion, inability to draw blood or slow blood flow, inability to flush the catheter, precipitate or blood clots can be seen in the catheter, continuous high pressure alarm of infusion pump, and tumor patients are more likely to have catheter occlusion.

The incidence of PICC catheter rupture or extravasation was 2.0%–3.5%, which happened during catheter insertion, high-pressure flushing, or removal. If the extracorporeal catheter rupture is not treated in time, the broken catheter will retract into the blood vessel, and cause pulmonary embolism, which eventually leads to life-threatening.<sup>24,25</sup>

MARSI is one of the common complications after PICC,<sup>26</sup> mainly characterized by redness of the puncture point and surrounding skin, papules, accompanied by itching, and in severe cases, blisters and exudates. The factors related to MARSI in PICC patients include, skin moisture and sweating, correct maintenance methods. It affects the quality of life of patients.<sup>27</sup>

### Data collection

The data record of MCM application during PICCs insertion and indwelling, mainly relied on the support of an information system called Wen Juan Xing. This system mainly aimed at the data collection and statistical analysis of the inserting, indwelling, complications referring, and removal of PICCs. By scanning the quick response (QR) code of Wen Juan Xing in the WeChat software, which was developed in 2014, infusion nurses can extract the questionnaire and fill in it according to the actual situation of the practice by their mobile phones.

When the PICC was placed, the data were collected through the QR code, which included the main purpose of

catheterization, catheter type, lumen diameter, inserting method, expected insertion length, actual insertion length, external length, arm circumference 10 cm above cubital crease, tip position of the catheter, nurses' qualification, and professional title. When there was any complication happened, the data which included the puncture site, time consumption of catheterization, complication description, infusion medications, types of complication, and treatments of complication were collected, meanwhile, the photos or images of related symptoms were uploaded. If consultation was needed, JINs or SINs would fill in the complications consultation form and send it to INNs, which including consultation purpose, brief disease and medical history, the consultation expert's information. After consultation was taken, the diagnosis, expert's opinions, and treatment options were recorded by the information system. Before and after the removal of the PICC, the information of whether the catheter is normal or integrated was also needed to report to the system.

### Statistical analysis

In this study, we collected data of 4 years which contained totally 6576 participants. Qualitative variables are described by the number of cases and percentage. Comparisons of qualitative variables were performed using Chi-square test.  $P < 0.05$  was considered statistically significant, and all the significance tests were two-tailed. Data analysis was performed using SPSS software (Version 26.0).

## Results

### Demographic data and descriptive results

From January 2015 to December 2019, a total number of 6576 patients had PICC line. Totally, there were 4985 (75.81%) power injectable and 1591 (24.19%) non power injectable PICC lines. Three hundred eighty-three (5.82%) PICCs were placed by general catheterization, 2718 (41.33%) PICCs were placed by MST and 3475 (52.84%) PICCs were placed by MST and US. There were 3350 males and 3226 females, whose age ranged from 10 to 96 years old. 4130/6576 (62.80%) used the INS-led MCM during the year of 2018 and 2019, while 2246/6576 (34.15%) used the regular mode in the year of 2015 and 2016.

Before the INS-led MCM applied, the proportion of cases per JINs was 999/2446 (40.84%), and it increased to 2161/4130 (52.32%) when the INS-led MCM applied; the number of cases per SINs decreased from 1275/2446 (52.13%) to 1727/4130 (41.82%); the number of cases per INNs decreased from 172/2446 (7.03%) to 242/4130 (5.86%). The insertion vessels being chosen followed the ZIM method to prevent catheter related thrombosis (CRT).<sup>28</sup> The proportion of basilic vein selected decreased

**Table 1.** Demographic data of patients.

Patients' characteristics	2015		2016		2018		2019	
	<i>n</i> = 1216		<i>n</i> = 1230		<i>n</i> = 1867		<i>n</i> = 2263	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Gender								
Male	652	53.6	632	51.4	844	45.2	1222	54.0
Female	564	46.4	598	48.6	1023	54.8	1041	46.0
Age (year)								
≤29	73	6.0	49	4.0	84	4.5	75	3.3
30–39	97	8.0	80	6.5	120	6.4	203	9.0
40–49	236	19.4	199	16.2	314	16.8	276	12.2
50–59	371	30.5	335	27.2	452	24.2	564	24.9
60–69	331	27.2	421	34.2	654	35.0	674	29.8
≥70	108	8.9	146	11.9	243	13.0	471	20.8
Cases per each level of qualifications								
JIN	434	35.7	565	45.9	754	40.4	1407	62.2
SIN	700	57.6	575	46.7	995	53.3	732	32.3
INS	82	6.7	90	7.3	118	6.3	124	5.5
Via vein								
Basilic vein	1109	91.2	1133	92.1	1667	89.3	2054	90.8
Cephalic vein	39	3.2	29	2.4	71	3.8	161	7.1
Median vein	48	3.9	66	5.4	87	4.7	37	1.6
Brachial vein	20	1.6	2	0.2	34	1.8	11	0.5
Axillary vein	0	0	0	0	8	0.4	0	0

from 2242/2446 (91.66%) to 3721/4130 (90.10%), and median vein selected decreased from 114/2446 (4.66%) to 124/4130 (3.00%), while cephalic vein selected increased from 68/2446 (2.78%) to 232/4130 (5.62%), and brachial vein selected increased from 22/2446 (0.90%) to 45/4130 (1.09%). The proportion of axillary vein puncture increased from 0/2446 (0%) to 8/4130 (0.19%) (Shown in Table 1).

According to the data, there were mainly three types of catheter applied in the hospital over the years, the proportion of three-way valve (non power injectable) PICC catheter decreased year by year from 79.9% to 14.5%, while the number of three-way valve solo PICC and open-ended Power PICC increased year by year, the proportion of three-way valve solo PICC increased from 12.7% to 51.6%, the proportion of power injectable and open-ended PICC increased from 7.4% to 33.9% (Shown in Figure 2). Because the three-way valve (non power injectable) PICC catheter is easy to break, which is not suitable for injecting contrast medium, power injectable PICC catheters has become the main trend today.

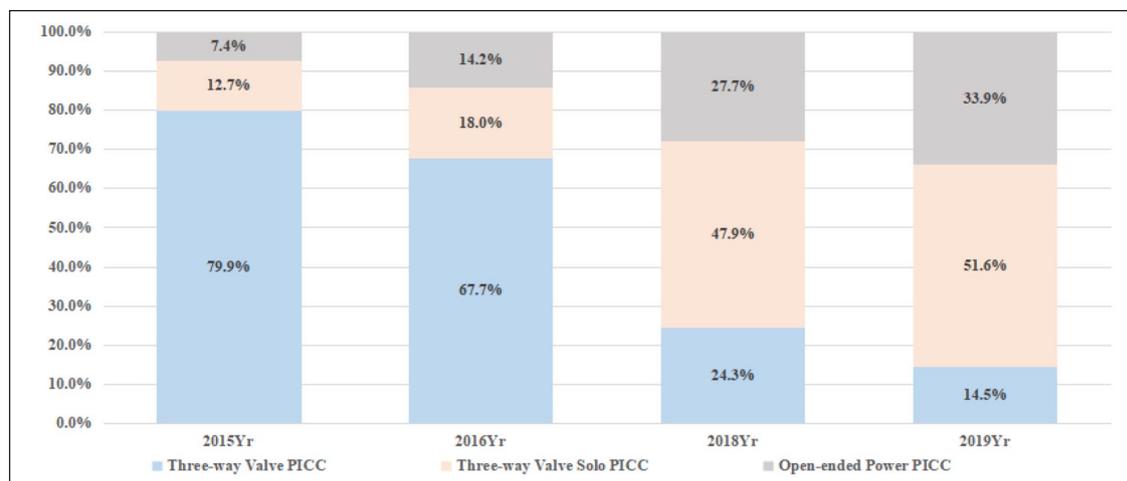
Three approaches of catheterization were used, which were routine catheterization method, modified Seldinger technique (MST) and ultrasound guided modified Seldinger technique (US and MST). After the application of MCM, the proportion of routine catheterization method decreased from 16.8% to 1.1%, MST increased from 26.1% to 51.3%, US and MST decreased slightly, from 57.2 to 47.6% (Shown in Figure 3). The routine

catheterization method is a large invasive approach which has the shortcomings of bleeding, painful, etc. So, nowadays, it has been replaced by MST or US and MST. Because the successful insertion cases are one of recognition standards of JINs following the MCM, more and more candidates have the chance to do MST than before.

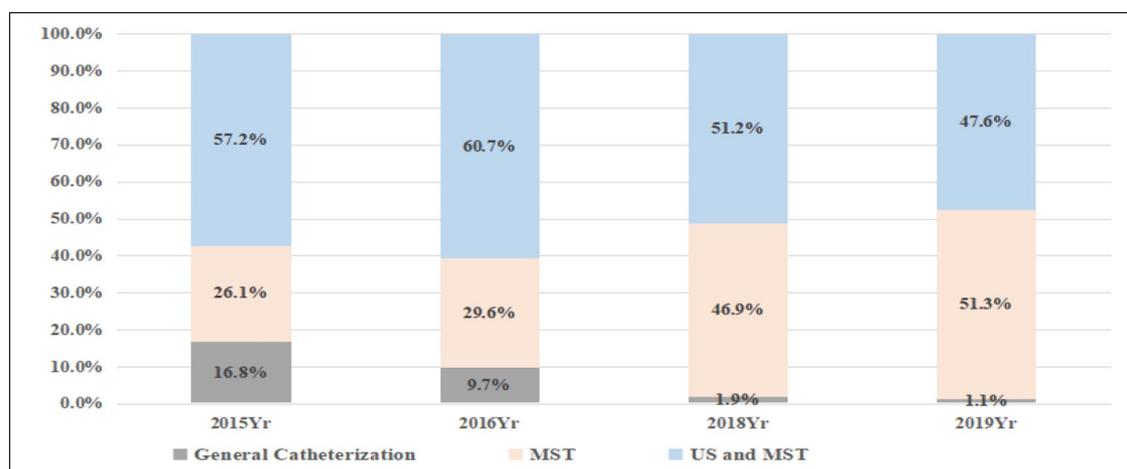
The tip ends of 6083 (92.5%) PICCs were positioned to the desired location where was the lower one third of the superior vena cava (SVC). Meanwhile, the tip ends of 493 (7.5%) PICCs were malpositioned during insertion, among which, 235 cases were located in the internal jugular vein, 178 cases in the upper segment of SVC, 53 cases in subclavian vein, 13 cases in axillary vein, 14 cases in the right atrium or other locations. Most of the catheter tip malposition happened in the internal jugular vein and upper segment of SVC, the constituent ratio of different kinds of malposition in each year were shown in Figure 4.

Only nine PICCs were traced to have tip end malposition during the catheter indwelled period. It may because that, PICC nurses spent much time in patient health education, so patients were avoid to take strenuous exercises and do hyperextension of upper limbs. MARS, catheter rupture, catheter obstruction, phlebitis, CRT, CRBSI were detected by the MCM application (Shown in Figure 5).

When facing the complex situations or complications, we worked out the countermeasures together by the MCM. Patients can get timely evaluation and treatment in the early stage of complications during periodical catheter



**Figure 2.** Distribution of catheter types.



**Figure 3.** Different puncture approaches of PICCs.

maintenance. The MCM improved the detection rate of complications, promoted early intervention of complications, which would improve the comfort of patients wearing PICC catheters.

### *Comparison of the consultation, complication detection, and successful insertion rate*

The average incidence of complications during the insertion and indwell was 1.48%, the consultation rate of complex inserting situation and complications was 5.73%, and the improvement of complications was 100%; the rate of successful insertion at one time was 66.45%. The MCM was introduced to the hospital in 2017. The consultation rate was 0.73%, the complication detection rate was 1.02% and the rate of successful insertion at one time was 56.09% before the application of MCM. The consultation rate was 8.45%, the complication detection rate was 1.74% and the rate of successful insertion at one time was 72.59% after

using MCM. Chi-square test showed that, after the application of MCM, the consultation rate, the complication detection rate and the rate of successful insertion at one time were significantly higher than before the application of MCM ( $p < 0.05$ ) (Shown in Table 2).

### **Discussion and summary**

After the implementation of MCM, the detection rate of PICC complications has significantly increased. Not only the cure rate has been improved, but also a number of classical treatment cases have been summarized, and a series of standardized treatment processes have been formed in the hospital. The INSS-led MCM applied in the PICC nursing practice in Shanghai has showed to be an ideal mode, which can timely translate the new knowledge and practice guidelines into infusion therapy practice. Personalized training programs were designed according to their levels of ability for specialized infusion nurses. The three levels of INSS-led

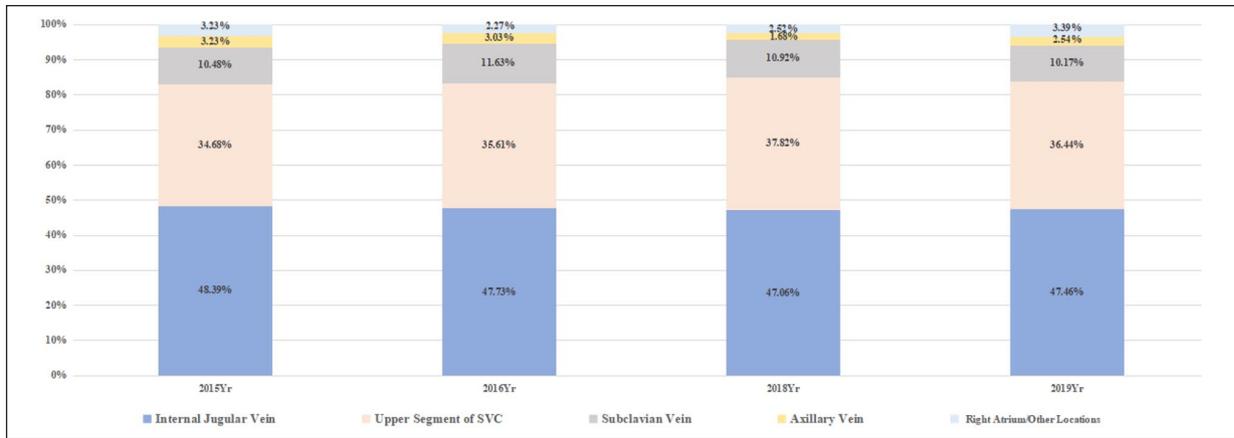


Figure 4. Constituent ratio of different catheter tip malpositions.

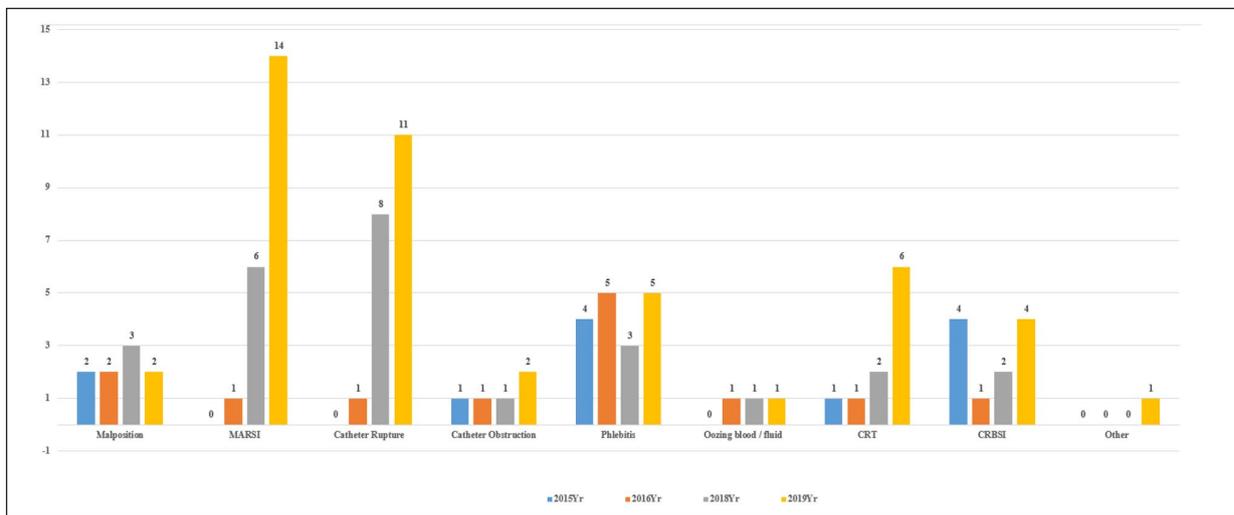


Figure 5. Distribution of PICC catheter related complications.

MCM could pay a continuous attention on patients care quality about PICC using. Many complications became preventable, and they can be found quickly by weekly maintenance care when developed. With the coordination of INSSs, multiple experts in related disciplines can provide their intelligence in resolving complication problems.

Based on the hierarchical training structure of MCM, many young nurses entered into the INB. When they were getting higher skilled care, the outcomes of insertion and maintenance improved. Also, forums and workshops were held every month, all the infusion nurses set together to discuss representative cases and complication measurement, guidelines of infusion were reviewed, the practice of infusion nurses were getting better.

### Conclusion

The INSSs-led MCM is a systematic and scientific mode of PICC nurses' practice and training, which can promote its

quality in the future. Due to the cost of ultrasound equipment, it was not able to be utilized for all PICC line placements, however, in this study, we found MST was adopted at a higher level. As using ultrasound is noted to improve insertion success rate and allows infusion nurses to measure the diameter of the vessel and potentially reduce thrombosis, we hope in the future all nurses can 100% use the US and MST technique to insert the PICC lines. ECG has also been adopted for tip confirmation for PICC line placements in other countries. China has not had widespread adoption of ECG due to the limited number of products with ECG on the market and the limited training for using ECG for nurses. We look forward to using ECG when placing the catheter, as this may decrease malposition during placement. Overall, with this new INSSs-led MCM application, our facility has increased the usage of MST placement on patients. In addition, as JINs move up the clinical ladder and become SINs, they will have the ability of utilizing ultrasound.

**Table 2.** Comparison of the consultation, complication detection and successful insertion at one time before and after MCM.

Group	n	Consultations		Complication detection		Successful insertion	
		n	%	n	%	n	%
Post-MCM	4130	349	8.45	72	1.74	2998	72.59
Pre-MCM	2446	28	0.73	25	1.02	1372	56.09
$\chi^2$		151.713		5.499		187.589	
p		0.000**		0.019*		0.000**	

\* $p < 0.05$ ; \*\* $p < 0.01$ .

### Acknowledgements

We would like to thank the infusion nurse team of Changhai Hospital for collecting all the data in this paper, thank associate professor Wu Jing of Nursing School for her great work in language editing. Thank all the patients who trusted us to give them PICC insertion and indwelling care, and shared their truthful feeling with us.

### Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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