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Nurses' knowledge of peripherally inserted central catheter maintenance and its influencing factors in Hunan province, China: a cross-sectional survey

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ABSTRACT

Objectives The aim of this study was to assess the level of knowledge on peripherally inserted central catheter (PICC) maintenance among nurses in China and to analyze related factors influencing the knowledge.

Design A cross-sectional survey.

Setting 91 hospitals that have introduced PICC maintenance technique in Hunan Province, China, including country hospitals, municipal hospital, and provincial hospitals.

Participants 4110 registered nurses engaged in clinical work related to intravenous infusion.

Primary and secondary outcome measures Nurses' knowledge of PICC maintenance was measured by the score of an anonymous, self-reported questionnaire**.**

Results The mean score of PICC maintenance among 4110 nurses was 72.86±14.86. 83.5% of them got a score of 60 or above, and 34.1% of them had a good grade with a score of 80 or above. The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01). The Generalized Linear Model showed that the factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting and whether PICC maintenance training was obtained before.

Conclusions In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China. Special attention should be given to male nurses and those who are under 25 years old, with junior professional title, working in county hospitals, and never obtained any PICC maintenance training previously. In addition, relevant training and education should be more targeted based on the barriers that were found in this study, such as the replacement of dressing and infusion connectors.

Keywords: peripherally inserted central catheter (PICC), maintenance, knowledge, nurses, influencing factor

ARTICLE SUMMARY

Strengths and limitations of this study

1. We designed the questionnaire based on an extensive review of literature and expert consultation.
2. Our findings could provide a valuable reference for nursing managers and providers of PICC maintenance training.
3. The sample size of this study was very large, which ensured the statistical power to draw the conclusion.
4. The cross-sectional design and convenience sampling method may cause nonresponse and selection biases and make our results not representative.
5. The survey was based on self-reported data.

INTRODUCTION

The peripherally inserted central venous catheter (PICC) is an intravenous device[1] inserted into the central veins via the peripheral veins[2-5] (e.g., basilic vein[2], antecubital vein[2], cephalic vein[3], brachial vein[3], and femoral vein[4,5]), which are commonly used for prolonged intravenous therapy, blood and nutrition administrations, and frequent blood sampling[4-10]. Although the PICC is regarded as a safe, efficient and cost-effective intravenous device due to long indwelling time, less vascular damage without repeated puncture, and convenient insertion and removal without the necessity for general anesthesia or deep cutting and suturing of wounds[2,3,9-11], its complications cannot be ignored, including thrombosis[4,5,12-14], catheter exit site infection[4], bloodstream infections[12,13,15], accidental dislodgement[5,11,12], malposition[11], occlusion[4,5,11,12,16], leakage[12], breakage[5,12], phlebitis[12], and cardiac tamponade[15]. A systematic review[17] showed that about 30% of PICC failed before the completion of treatment because of complications, which would delay drug administration and blood sampling, increase the financial burden on patients and reduce their satisfaction, even deplete patients' useable veins for future treatment and can obstruct vessels long-term. And for cancer patients, the delays to chemotherapy cycles would reduce treatment efficacy and can affect subsequent survival. Researches[18-21] reported that appropriate PICC maintenance may offset the risk of such harms and maximize the safety of PICC. As the provider of PICC maintenance, the nurses' PICC maintenance knowledge and skill directly affect the quality of care, clinical outcomes, and patients' safety[8,22]. Although gaps between the evidence of PICC maintenance and its knowledge and practice among nurses were reported[3,8], little was known for nurses in Hunan province, China. Thus, the purpose of this cross-sectional study was to investigate nurses' knowledge of PICC maintenance. We also aim to characterize and identify some factors influencing nurses' knowledge, which may provide information on decision making and quality-improvement efforts related to PICC.

METHODS

Study setting and participants

To investigate nurses' knowledge of PICC maintenance, we conducted a web-based cross-sectional survey of nurses across 91 hospitals that participate in the PICC maintenance service network in Hunan province, China. The PICC maintenance service network is a province-wide PICC maintenance alliance led by the intravenous infusion(IV) team of Xiangya Hospital, Central South University, aiming to allow patients in the intermission of treatment to choose the nearest site to maintain their PICC instead of returning to where their PICC was placed, thus making PICC maintenance more convenient and economical. Xiangya Hospital is a university-affiliated hospital with 3,620 beds and a training base for PICC specialist nurses in Hunan Province. Since 2015, the IV team of Xiangya Hospital has started construction of the PICC maintenance network. They disseminated PICC related theoretical knowledge and strategies of complications management through intravenous therapy classes and provided training in catheterization and maintenance procedures. Each hospital voluntarily sent nurses to Xiangya hospital to study and

joined the PICC maintenance service network. Up to now, 103 maintenance sites have been involved. Each maintenance site has an IV team that is responsible for intravenous nursing training, quality control, and consultation. And each IV team has a liaison who is responsible for communicating with the IV team in other hospitals.

Participants were enrolled through a convenience sampling method. In order to achieve the required sample size, which is determined by the criterion that the sample size should be 5-10 times the number of questionnaire items, we contacted the liaisons at each site and enquired whether they can help us to carry out the survey. In this study, the questionnaire contained 56 items (50 items of knowledge questionnaire and 6 items of demographic information questionnaire). Thus, the sample size should be 280-560. And in consideration of nonresponse and invalid response, the sample size should be increased by 20%, which was 336-672. At 91 eligible sites where the liaisons were willing to help us, the registered nurses who engaged in clinical work related to intravenous infusion, had more than 1 year of work experience, were willing to participate in the research after informed consent, and can correctly understand the contents of the questionnaire were included. Exclusion criteria were nurses who were taking psychotropic substances due to mental or psychological illness, and nurses who were absent from work due to illness, maternity leave or other reasons.

Survey instrument

In this study, the survey instrument was a self-designed questionnaire based on an extensive review of literature[3,8,18,23-25], including the Infusion Therapy Standards of Practice[23] released by Infusion Nursing Society, the Nursing Practice Standards for Intravenous Therapy[24] issued by the National Health Commission of the people's Republic of China in 2013, and so on. In addition, 5 experts in intravenous therapy were consulted to assess the questionnaire's validity, and the pretest was carried out to make sure the questionnaire could be understood easily. The questionnaire included 50 items in total covering 5 dimensions of PICC maintenance knowledge, including tube flushing and locking (12 items), replacement of dressings and infusion connectors (8 items), complication management (19 items), health education (6 items), and catheter removal (5 items). All items were single choice questions. The correct answer was assigned a point of 2, otherwise 0, with the full score of 100. The higher the score is, the higher the PICC maintenance knowledge level is. The Cronbach's alpha coefficient of this questionnaire was 0.873, and the content validity index (CVI) was 0.915, indicating that the questionnaire had good internal consistency reliability and validity.

In addition, we collected the data of potential factors influencing PICC maintenance knowledge by self-designed demographic information questionnaire, including gender, age, professional title, education level, work setting, and whether PICC maintenance training was obtained before.

Implementation

First, we provided unified training on our inclusion criteria, exclusion criteria, and how to fill out the questionnaire for 91 liaisons who were willing to help us by telephone and sent them a cover letter explaining the rationale and purpose of the

survey along with the survey link. Then, the liaisons obtained approval from the head nurses in their facilities, selected the participants according to our inclusion and exclusion criteria with the help of the head nurses and provided unified training on how to fill out the questionnaire for the head nurses. Next, the liaisons sent the electronic link to the head nurses through WeChat, and the head nurses sent the link to their Ward WeChat Group and organized the targeted nurses to fill out the questionnaire after their informed consent. All eligible nurses were informed that participation in this study was voluntary, they can withdraw from the study at any time for any reason. And the questionnaire would be answered anonymously based on their own knowledge and understanding of PICC maintenance.

In addition, the participants were assured that their information would only be used for research, that their data would be kept confidentially, and that their scores of the questionnaire would not have any influence on their career and promotion due to their boss could not see their score. The survey was administered at 91 PICC maintenance sites at the same time from August 2017 and kept open for 4 weeks. During the 4-week period, 2 e-mail reminders were sent to the liaisons to encourage participation.

Statistical analysis

Descriptive statistic was used to summarize participants' characteristics and the knowledge score of PICC maintenance. The Kruskal-Wallis H test was used to compare the correct rate in different dimensions. The knowledge score among nurses with different characteristics was compared using the Wilcoxon rank-sum test for two-group comparison and the Kruskal-Wallis H test for multiple comparisons. The generalized linear model was used to identify the demographic factors influencing PICC maintenance knowledge. All analyses were performed using SPSS V.22.0, and two-tailed $P<0.05$ was considered statistically significant.

RESULTS

Participant characteristics

In this study, 4110 valid questionnaires were recovered. Among 4110 respondents, most were women (98.6%). The largest age group was 25-34(51.6%) followed by those aged under 25(30.9%). The majority (75.6%) had a junior professional title. All of them worked in secondary and above hospitals with 29.9% in county hospitals, 46.9% in municipal hospitals, and 23.2% in provincial hospitals. Less than half (44.6%) reported having received PICC maintenance training previously. (table 1)

Table 1 Demographic characteristics of respondents(n=4110)

Characteristic	Frequency	Percentage (%)
Gender		
Male	58	1.4
Female	4052	98.6
Age, years		
＜25	1268	30.9
25-34	2120	51.6
35-44	597	14.5
≥45	125	3.0
Professional title		
Nurse	1554	37.8
Senior nurse	1555	37.8
Supervisor nurse	848	20.6
Co-chief nurse	153	3.7
Education level		
Technical secondary school	49	1.2
Junior college	1906	46.4
Undergraduate	2130	51.8
Postgraduate	25	0.6
Work setting		
County hospital	1228	29.9
Municipal hospital	1929	46.9
Provincial hospital	953	23.2
Whether PICC maintenance training was obtained before?		
No	2277	55.4
Yes	1833	44.6

PICC，peripherally inserted central catheter.

Table 2 Score and distribution of PICC maintenance knowledge among the 4110 included nurses

Dimensions	Score ($\bar{x}\pm s$)	Grade of the total score*			
		Failed, N (%)	Passed, N (%)	Good, N (%)	Total, N (%)
Tube flushing and sealing	18.30±3.67	-	-	-	-
Replacement of films and infusion connectors	8.28±3.83	-	-	-	-
Complication management	26.93±7.13	-	-	-	-
Health education	11.28±1.51	-	-	-	-
Catheter removal	8.06±2.13	-	-	-	-
Overall PICC maintenance knowledge	72.86±14.86	679 (16.5)	2030 (49.4)	1401 (34.1)	4110 (100.0)

*Grade of the total score: The total score was divided into four grades. Failed represents the score under 60; Passed represents the score from 60 to 79; Good represents a score of 80 or above.

PICC, peripherally inserted central catheter; N, Number.

Table 3 Statistics and distribution of item correct rate for different dimensions (n=4110)

Dimensions	Number of items by correct rate, N (%)				Total, N (%)	Correct rate ($\bar{x}\pm s$)
	<30%	≥30%,<60%	≥60%,<90%	≥90%		
Tube flushing and locking	1(8.3)	1(8.3)	5(41.7)	5(41.7)	12(100.0)	0.76±0.222
Replacement of dressings and infusion connectors	2(25.0)	3(37.5)	3(37.5)	0(0.0)	8(100.0)	0.52±0.248
Complication management	0(0.0)	4(21.1)	13(68.4)	2(10.5)	19(100.0)	0.71±0.167
Health education	0(0.0)	0(0.0)	1(16.7)	5(83.3)	6(100.0)	0.94±0.052
Catheter removal	0(0.0)	0(0.0)	3(60.0)	2(40.0)	5(100.0)	0.81±0.117
Kruskal-Wallis H	17.721					
P value	0.001**					

**: P<0.01

N, Number.

Table 4 PICC maintenance knowledge score by characteristics(n=4110)

Characteristics	Score ($\bar{x}\pm s$)	Z/H	P value
Gender		-3.280[a]	0.001**
Male	64.55±17.84		
Female	72.98±14.78		
Age, years		314.543[b]	0.000**
<25	66.53±16.99		
25-34	74.98±12.86		
35-44	78.03±12.39		
≥45	76.29±13.33		
Professional Title		357.421[b]	0.000**
Nurse	67.42±16.61		
Senior Nurse	74.70±12.84		
Supervisor Nurse	78.27±11.89		
Co-chief Nurse	79.40±11.54		
Education level		204.807[b]	0.000**
Technical Secondary School	65.55±16.84		
Junior College	69.35±16.58		
Undergraduate	76.15±12.19		
Postgraduate	74.00±14.15		
Work setting		79.721[b]	0.000**
County Hospital	70.33±14.51		
Municipal Hospital	74.28±14.72		
Provincial Hospital	73.24±15.19		
Whether PICC maintenance training was obtained before?		-17.850[a]	0.000**
No	69.41±14.84		
Yes	77.14±13.73		

[a]: Z value ; [b]: H value ; **: P < 0.01

PICC, peripherally inserted central catheter.

Table 5 Generalized linear model of the factors influencing PICC maintenance knowledge

Factors	B	SE	95% Wald CI Lower	95% Wald CI Upper	Wald χ^2	P value
Gender						
Female	0.082	0.0269	0.029	0.135	9.255	0.002**
Male	Reference					
Age, years						
＜25	-0.054	0.0235	-0.1	-0.007	5.186	0.023*
25-34	-0.003	0.0214	-0.045	0.039	0.014	0.906
35-44	0.009	0.0202	-0.03	0.049	0.212	0.645
≥45	Reference					
Professional title						
Nurse	-0.074	0.0231	-0.119	-0.029	10.281	0.001**
Senior nurse	-0.035	0.0208	-0.076	0.006	2.813	0.094
Supervisor nurse	-0.002	0.0187	-0.039	0.035	0.013	0.909
Co-chief nurse						
Education level						
Technical secondary school	-0.062	0.0504	-0.161	0.036	1.529	0.216
Junior college	0.009	0.0413	-0.072	0.09	0.049	0.824
Undergraduate	0.035	0.041	-0.045	0.116	0.74	0.390
Postgraduate	Reference					
Work setting						
County hospital	-0.028	0.009	-0.046	-0.01	9.768	0.002**
Municipal hospital	0.013	0.0081	-0.003	0.029	2.587	0.108
Provincial hospital	Reference					
Whether PICC maintenance training was obtained before?						
No	-0.075	0.0066	-0.088	-0.062	128.321	0.000**
Yes	Reference					

**: P＜0.01; *:P<0.05

The independent variables in the generalized liner model were coaded as the following: Gender(Femal=0, Male=1), Age(<25=1,25-34=2,35-44=3,≥45=4), Professional title(Nurse=1, Senior nurse=2, Supervisor nurse=3, Co-chief nurse=4), Education level(Technical secondary school=1, Junior college=2, Undergraduate=3, Postgraduate=4), Work setting(County hospital=1, Municipal hospital=2, Provincial hospital=3), Whether PICC maintenance training was obtained before? (No=0, Yes=1)

PICC, peripherally inserted central catheter.

Nurses' knowledge of PICC maintenance

The mean score of PICC maintenance among 4110 nurses was 72.86±14.86. According to the scoring system, 83.5% of them passed the exam with a score of 60 or above, and 34.1% of them had a good grade with a score of 80 or above. Table 2 showed the scores of each dimension and the overall questionnaire, and the distribution of total score.

The correct rate in different dimensions

For dimension "Tube flushing and locking", among 12 items, 2 items (16.6%) were answered with a correct rate below 60%, these for dimension "Replacement of dressings and infusion connectors" and "Complication management" were 5 out of 8 (62.5%) and 4 out of 19(21.1%). While for dimension "Health education" and "Catheter removal", all items were answered with a correct rate of 60% or above (table 3). The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01).

Comparison of knowledge score among nurses with different characteristics

As shown in table 4, statistical differences were found in PICC maintenance knowledge score among nurses with different gender, age, professional title, education level and work setting (all P <0.01). And the difference of knowledge score between nurses who had received PICC maintenance training before and those who hadn't obtained training was statistically significant (P <0.01). The highest score (higher level of PICC maintenance knowledge) was found among nurses who were female, aged from 35 to 44 years old, with the professional title of co-chief nurse and the education level of undergraduate, and working in municipal Hospitals, and those who had received PICC maintenance training before(table 4).

Multivariate analysis of nurses' PICC maintenance knowledge

The generalized linear model was chosen for multivariate analysis due to the abnormal distribution of the dependent variable, the knowledge score. The independent variables included the nurses' gender, age, professional title, education level, and work setting, and whether the PICC maintenance training had been received before. The gamma distribution was chosen as the distribution of the dependent variable, and the logarithmic function was chosen as the link function. As shown in table 5, five factors were entered the generalized linear model. Female nurses (B=0.082, P<0.01) got higher PICC maintenance knowledge score than male nurses. Nurses under 25 years old(B= -0.054, P<0.05), with a professional title of nurse (B=-0.074, P<0.01), working in county hospitals(B=-0.028, P<0.01), and hadn't received PICC maintenance training previously (B=-0.075, P<0.01) reported a lower level of PICC maintenance knowledge compared with those aged 45 years old or above, with a professional title of co-chief nurse, working in provincial hospitals, and had received PICC maintenance training before.

DISCUSSION

This study demonstrated that the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China, with a mean score of 72.86±14.86. 83.5% of nurses passed the exam with a score of 60 or above and 34.1% of them had

a good grade with a score of 80 or above, which were lower than those (88.9% and 47.2%) reported by Wu et al[26]. This difference may result from the difference in the demographic data of the subjects. The subjects in our study involved nurses of Grade Ⅱ hospitals and Grade Ⅲ hospitals, while the nurses in Wu et al's study all came from Grade III Level A hospitals, making them have more opportunities to learn new technologies including PICC maintenance. The gap of PICC maintenance knowledge between nurses in Hunan province, China and those in other regions deserves the attention of nursing managers, and appropriate strategies need to be taken to increase their knowledge.

Nurses' levels of mastery toward different dimensions were different, with the maximum correct rate of health education (90.94±0.052), followed by catheter removal (0.81±0.117), tube flushing and locking (0.76±0.222), and complication management (0.71±0.167). And the correct rate of replacement of dressings and infusion connectors was the minimum (0.52±0.248) among 5 dimensions. The correct rate of health education ranking the first may be due to its uniqueness. Unlike other dimensions, health education is often the transfer of knowledge without clinical operation. On the one hand, its form is simple and easy to master. On the other hand, nurses need to inform the patients of the precautions related to PICC in their daily life again and again, which also leaves them a deep impression. The dimension with the minimum correct rate was replacement of dressings and infusion connectors, inconsistent with Oliveira et al's[3] finding that the criteria related to the dressing of PICC and the change of administration sets showed a moderate to high compliance. In addition, Sharpe et al's [8]research also showed that a majority of nurses can perform well in the PICC dressings change. The difference between our finding and those of others is probably because that the replacement of dressings and infusion connectors is relatively simple, so the nurses often operate it according to their clinical experience, neglecting the learning toward the standardized theoretical knowledge. The gap of mastery degree toward dressings and infusion connectors between nurses in Hunan province, China and those in other regions (e.g., Sao Paulo, Brazil [3]) is evident. Thus, this is a barrier that needs to be taken into consideration for nursing education and training in clinical practice. Other dimensions, such as catheter removal, tube flushing and locking, and complication management, although showing a medium to high level of mastery, should not be ignored during training as they also directly affect patients' safety.

The factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting and Whether PICC maintenance training was obtained before. Female nurses got higher PICC maintenance knowledge score than male nurses, and nurses under 25 years old reported a lower level of PICC maintenance knowledge compared with those aged 45 years old or above. We did not find similar findings in other studies. In China, male nurses mainly work in the psychiatry department, the emergency department, the operating room and the orthopedics department due to their career advantages, such as good physical constitution, strong psychological endurance, excellent emergency response capacity, and the ability of rational thinking and logical reasoning[27]. The patients need PICC

insertion and maintenance in such departments are relatively less, so the male nurses have less opportunity to study and conduct PICC maintenance. This may be an explanation of the higher score of female nurses. As for the finding of age, the reason may be related to the work experience. However, Chopra et al's[22] research showed there was no statistical difference in vascular nurses' knowledge based on years of experiences, which they thought was due to the small sample size. Thus, the reason for this need to be further explored.

Our study demonstrated that nurses with a professional title of the nurse got lower PICC maintenance knowledge score than those with a professional title of the co-chief nurse. This is not surprising as nurses with senior professional title usually have more study and communication opportunities, making them acquire more knowledge of specialized nursing. In addition, nurses with senior professional title often undertake clinical teaching work, benefiting themselves as well when teaching interns and nurses with a junior professional title about PICC maintenance.

The most significant finding is that nurses working in county hospitals reported a lower level of PICC maintenance knowledge compared with those working in provincial hospitals. In china, county hospitals are mainly secondary hospitals, which are responsible for providing comprehensive health services, medical education and conducting research on a regional basis, while provincial hospitals are mainly tertiary hospitals, which are responsible for providing specialist health services, perform a bigger role with regard to medical education and scientific research and serve as medical hubs providing care to multiple regions. Specialized nursing techniques such as PICC catheterization and maintenance are first carried out by tertiary hospitals. An increasing number of secondary hospitals have provided PICC maintenance service due to the increased use of PICCs in recent years. To the best of our knowledge, this study is the first to compare nurses' PICC maintenance knowledge among hospitals at different levels. In consideration of the gap of nurses' PICC maintenance knowledge between county hospitals and provincial hospitals, attention must be given to narrow the gap and provide homogenized nursing for patients with PICC.

Our study also showed that nurses hadn't received PICC maintenance training previously reported a lower level of PICC maintenance knowledge compared with those had received training before, indicating that training is an effective way to enhance nurses' knowledge of PICC maintenance, consistent with Roslien et al's [28]and Purran et al' [29]researches. Through systematic and standardized PICC training[30], nurses can acquire basic knowledge of vascular anatomy, ultrasound and radiographic, PICC catheterization and maintenance standard procedures, various emergency response processing and complication management processes, effectively decreasing the catheter-related complications and improving patients' safety.

Care and troubleshooting of PICCs are essential practice of all bedside nurses, our study would help nursing managers to accurately identify problems in PICC maintenance among nurses, so as to develop some problem-focused strategies to increase nurses' PICC maintenance knowledge and practice, thereby helping to provide better and homogenized services for patients, including providing more study and communication chances to nurses with junior professional title, providing more

free standardized PICC maintenance training for nurses in county hospitals to narrow the knowledge gap between them and the nurses in provincial hospitals, and so on. In addition, our study would be helpful for the providers of PICC maintenance training and education. The trainers and educators could design the training program based on the barriers found in our study, which would make their training program more targeted.

Our study has some limitations. First, despite a large sample size, our study was a cross-sectional survey and was conducted using a convenience sampling method. Thus, nonresponse and selection biases may be a threat to our conclusion. Second, we investigated nurses in hospitals that have introduced PICC maintenance technique, our finding may therefore not be representative of the knowledge level of all nurses in Hunan province, China, but reflect the group with a higher level of PICC maintenance knowledge. Thus, a similar survey aimed at nurses in the hospitals that haven't introduced PICC maintenance technique yet needs to be conducted in the future. Third, although the quality control procedure was used throughout the data collection and entry, we have no way to avoid the potential information bias in view of the survey was based on self-reported data. Last, as mentioned in the first half of the discussion, some general information that may be factors influencing the nurses' PICC maintenance knowledge had not been collected, such as departments and years of experience, which affected our conclusion to some extent.

CONCLUSIONS

In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China, and this was mainly influenced by their gender, age, professional title, work setting, and that whether the PICC maintenance training would be obtained before. Special attention should be given to male nurses and those who are under 25 years old, with junior professional title, working in county hospitals, and never obtained any PICC maintenance training previously. In addition, relevant training and education should be more targeted base on the barriers that were found in this study, such as the replacement of dressing and infusion connectors.

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Author Contributions BBX, JHZ, and SYT contributed to the study conception and design, and questionnaire development. BBX and JHZ contributed to data collection, analysis, and interpretation, and manuscript drafting. BBX, JMH, and MDM contributed to the literature search and data collection. BBX and ZHG contributed to data collection and management. All authors contributed to manuscript drafting and revising, and approved the final version.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	n/a,

		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	n/a,
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5,6
		(b) Give reasons for non-participation at each stage	n/a, the questionnaire link was sent to the WeChat group, and the targeted nurses filled out it based on their willing. Thus, we cannot collect the information of non-participation.
		(c) Consider use of a flow diagram	n/a, we didn't use the flow diagram in our manuscript.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5,6
		(b) Indicate number of participants with missing data for each variable of interest	n/a, the questionnaire cannot be submitted if it was not be filled completely, so there were no missing values in the returned questionnaire.
Outcome data	15*	Report numbers of outcome events or summary measures	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9,10
		(*b*) Report category boundaries when continuous variables were categorized	7,8,10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	10,11,12,
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or	13

		imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13-14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Nurses' knowledge of peripherally inserted central catheter maintenance and its influencing factors in Hunan province, China: a cross-sectional survey

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Nurses' knowledge of peripherally inserted central catheter maintenance and its influencing factors in Hunan province, China: a cross-sectional survey

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ABSTRACT

Objectives The aim of this study was to assess the level of knowledge on peripherally inserted central catheter (PICC) maintenance among nurses in China and to analyze related factors influencing the knowledge.

Design A cross-sectional survey.

Setting 91 hospitals that have introduced PICC maintenance technology in Hunan Province, China, including county hospitals, municipal hospitals, and provincial hospitals.

Participants 4110 registered nurses engaged in clinical work related to intravenous infusion.

Primary and secondary outcome measures Nurses' knowledge of PICC maintenance was measured by the score of an anonymous, self-reported questionnaire**.**

Results The mean score of PICC maintenance among 4110 nurses was 72.86±14.86. 83.5% of them got a score of 60 or above, and 34.1% of them had a good grade with a score of 80 or above. The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01). The Generalized Linear Model showed that the factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting and whether PICC maintenance training was obtained before.

Conclusions In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China. Multiple steps should be taken to improve their PICC maintenance knowledge, including disseminating PICC maintenance knowledge in multiple ways, such as courses, lectures, seminars and new media, giving special attention to populations who did poorly in this survey, and providing targeted education for nurses based on what they didn't do well, such as the replacement of dressing and needle free connectors. In addition, the quality of the nurses' practical performance should be measured in the future.

Keywords: peripherally inserted central catheter (PICC), maintenance, knowledge, nurses, influencing factor

ARTICLE SUMMARY

Strengths and limitations of this study

1. We designed the questionnaire based on an extensive review of literature, and experts who are PICC specialist nurses and hold the position of head of the nursing department or head nurse were consulted.
2. Our findings could provide a valuable reference for nursing managers and providers of PICC maintenance training.
3. The sample size of this study was very large, which ensured the statistical power to draw the conclusion.
4. The cross-sectional design and convenience sampling method may cause nonresponse and selection biases and make our results not representative.
5. The survey was based on self-reported data.

INTRODUCTION

The peripherally inserted central venous catheter (PICC) is an intravenous device[1] inserted into the central veins via the peripheral veins[2-5] (e.g., basilic vein[2], antecubital vein[2], cephalic vein[3], brachial vein[3], and femoral vein[4,5]), which are commonly used for prolonged intravenous therapy, blood and nutrition administrations, and frequent blood sampling[4-10]. It is regarded as a safe, efficient and cost-effective intravenous device due to long indwelling time, less vascular damage without repeated puncture, and convenient insertion and removal without the necessity for general anesthesia or deep cutting and suturing of wounds[2,3,9-11]. However, its complications cannot be ignored, including thrombosis[4,5,12-14], catheter exit site infections[4], bloodstream infections[12,13,15], accidental dislodgement[5,11,12], malposition[11], occlusion[4,5,11,12,16], leakage[12], breakage[5,12], phlebitis[12], and cardiac tamponade[15]. A systematic review[17] showed that about 30% of PICC failed before the completion of treatment because of complications, which would delay drug administration and blood sampling, increase the financial burden on patients and reduce their satisfaction, even deplete patients' useable veins for future treatment and can obstruct vessels long-term. This would have a greater impact on cancer patients, since the delays to chemotherapy cycles would reduce treatment efficacy and can affect subsequent survival. Researches[18-21] reported that appropriate PICC maintenance may offset the risk of such harms and maximize the safety of PICC. As the provider of PICC maintenance, the nurses' PICC maintenance knowledge and skills directly affect the quality of care, clinical outcomes, and patients' safety[8,22]. Although gaps between the evidence of PICC maintenance and its knowledge and practice among nurses were reported[3,8], little was known for nurses in Hunan province, China. Thus, the purpose of this cross-sectional study was to investigate nurses' knowledge of PICC maintenance. We also aim to characterize and identify some factors influencing nurses' knowledge, which may provide information on decision making and quality-improvement efforts related to PICC.

METHODS

Study setting

To investigate nurses' knowledge of PICC maintenance, we conducted a web-based cross-sectional survey of nurses in 91 hospitals, including county hospitals, municipal hospitals, and provincial hospitals. County hospitals are hospitals located in counties and under the control of county governments, which provide comprehensive health services and medical education to residents in counties, villages, and towns. They are generally Grade Ⅱ hospitals. Municipal hospitals are hospitals constructed and administered by municipal governments. They are located in cities and provide comprehensive health services, emergency and critical medical services, and specialist health services to residents from different counties, and perform a bigger role in medical education and conduct research on a regional basis. They are mainly Grade Ⅲ hospitals, but municipal hospitals that are too small and don't have enough beds (less than 500) are Grade Ⅱ hospitals. Provincial hospitals are hospitals under the jurisdiction of provincial governments. They are usually located in the provincial

capital and play an important role in scientific research and teaching, serve as medical hubs providing care to multiple regions. They are mainly Grade Ⅲ level A hospitals.

All included hospitals are members of the PICC maintenance service network in Hunan province, China. The PICC maintenance service network is a province-wide PICC maintenance alliance led by the intravenous infusion(IV) team of Xiangya Hospital, Central South University, aiming to allow patients in the intermission of treatment to choose the nearest site to maintain their PICCs instead of returning to where their PICCs was placed, thus making PICC maintenance more convenient and economical. Xiangya Hospital is a university-affiliated hospital with 3,620 beds and a training base for PICC specialist nurses in Hunan Province. The IV team of Xiangya Hospital began to construct the PICC maintenance network in 2015. To date, 103 maintenance sites have been involved. Each maintenance site has an IV team that is responsible for intravenous nursing training, quality control, and consultation, and each IV team has a liaison who is responsible for communicating with the IV team in other hospitals.

Participants

Participants were enrolled through a non-random, convenience sampling method. First, we contacted the liaisons in every PICC maintenance site and enquired whether they can help us to carry out the survey. Then, in sites where the liaisons were willing to help us, the registered nurses who engaged in clinical work related to intravenous infusion, had more than 1 year of work experience, were willing to participate in the research after informed consent, and can correctly understand the content of the questionnaire were included. Exclusion criteria were nurses who were taking psychotropic substances due to mental or psychological illness, and nurses who were absent from work due to illness, maternity leave or other reasons.

The sample size was calculated according to the formula for the sample size for the mean, which is as follow:

$$n = \frac{z_{\alpha/2}^2 \sigma^2}{\delta^2}$$

$Z_{\alpha/2}$ is the abscissa of the normal curve that cuts off an area α at the tails; σ is the population standard derivation, which could be replaced by the sample standard deviation; δ is the margin of error, the value of which is generally 10%-60% of the standard deviation. In this study, α=0.05, $Z_{\alpha/2}$=1.96, σ=14.602 (determined by the pre-survey), δ=1.4602 (10%*σ). Thus, the sample size n=384. In consideration of nonresponse and invalid response, the sample size should be increased by 20%, which was 461.

Survey instrument

In this study, the survey instrument was a self-designed questionnaire based on an extensive review of literature[8,18,23-25], mainly including the Infusion Therapy Standards of Practice[23] released by Infusion Nursing Society and the Nursing Practice Standards for Intravenous Therapy[24] issued by the National Health Commission of the people's Republic of China in 2013. In addition, five experts who are PICC specialist nurses and hold the position of head of the nursing department or head nurse were

consulted to assess the questionnaire's validity, and the pretest was carried out to make sure the questionnaire could be understood easily. The questionnaire included 50 items in total covering 5 dimensions of PICC maintenance knowledge, including PICC flushing and locking (12 items), replacement of dressings and needle free connectors (8 items), complication management (19 items), health education (6 items), and catheter removal (5 items). All items were single choice questions. The correct answer was assigned a point of 2, otherwise 0, with a full score of 100. The higher the score is, the higher the PICC maintenance knowledge level is. The Cronbach's alpha coefficient of this questionnaire was 0.873, and the content validity index (CVI) was 0.915, indicating that the questionnaire had good internal consistency reliability and validity.

In addition, we collected the data of potential factors influencing PICC maintenance knowledge by self-designed demographic information questionnaire, including gender, age, professional title, education level, work setting, and whether PICC maintenance training was obtained before.

Implementation

This survey was divided into two stages: the recruitment of PICC maintenance sites and the participants, and the implementation of the investigation.

In June 2017, we recruited 91 PICC maintenance sites, where the liaisons were willing to help us to carry out the survey. After the recruitment of PICC maintenance sites, we provided unified training on our inclusion criteria and exclusion criteria for these liaisons by telephone. The recruitment of participants was implemented by these liaisons in July 2017. Specific steps were as follows: first, the liaisons explained the purpose of the survey to the head nurses in their facilities, for the purpose of obtaining approval and support; then, the liaisons selected the potential participants according to our inclusion and exclusion criteria with the help of the head nurses; finally, the participants were included after their informed consent. All eligible nurses were informed that participation in this study was voluntary, they can withdraw from the study at any time for any reason, and the questionnaire would be answered anonymously based on their own knowledge and understanding of PICC maintenance. Moreover, they were assured that their information would only be used for research, that their data would be kept confidentially, and that their scores of the questionnaire would not have any influence on their career and promotion due to their employers could not see their scores.

The investigation was implemented by the liaisons and the head nurses who supported our study. First, we sent the electronic survey link to the liaisons by email and provided unified training on how to fill out the questionnaires by phone. Then, the liaisons sent the link to the head nurses in their facilities through WeChat and told them how to fill it out. Finally, the head nurses sent the link to their Ward WeChat Group and organized the eligible nurses to fill out the questionnaires. The investigation was administered at 91 PICC maintenance sites at the same time from August 2017 and kept open for 4 weeks. During the 4-week period, 2 e-mail reminders were sent to the liaisons to encourage participation.

Statistical analysis

Descriptive statistics were used to summarize participants' characteristics and the knowledge score of PICC maintenance. The Kruskal-Wallis H test was used to compare the correct rate in different dimensions. The knowledge score among nurses with different characteristics was compared using the Wilcoxon rank-sum test for two-group comparison and the Kruskal-Wallis H test for multiple comparisons. The generalized linear model was used for multivariate analysis to identify the demographic factors influencing PICC maintenance knowledge, because the dependent variable (the knowledge score) was not normally distributed. The gamma distribution was chosen as the distribution of the dependent variable, and the logarithmic function was chosen as the link function. All analyses were performed using SPSS V.22.0, and two-tailed $P<0.05$ was considered statistically significant.

Patient and Public Involvement

No patient involved

RESULTS

Participant characteristics

In this study, a total of 6524 nurses were eligible to fill out the questionnaires, and 4110 of those completed it, with a response rate of 63.0%. Among 4110 respondents, the majority were women (98.6%). The largest age group was 25-34(51.6%) followed by those aged under 25(30.9%). The majority (75.6%) had a junior professional title. All of them worked in secondary and above hospitals with 29.9% in county hospitals, 46.9% in municipal hospitals, and 23.2% in provincial hospitals. Less than half (44.6%) reported having received PICC maintenance training previously. (table 1)

Table 1 Demographic characteristics of respondents(n=4110)

Characteristic	Frequency	Percentage (%)
Gender		
Male	58	1.4
Female	4052	98.6
Age, years		
＜25	1268	30.9
25-34	2120	51.6
35-44	597	14.5
≥45	125	3.0
Professional title		
Nurse	1554	37.8
Senior nurse	1555	37.8
Supervisor nurse	848	20.6
Co-chief nurse	153	3.7
Education level		
Technical secondary school	49	1.2
Junior college	1906	46.4
Undergraduate	2130	51.8
Postgraduate	25	0.6
Work setting		
County hospital	1228	29.9
Municipal hospital	1929	46.9
Provincial hospital	953	23.2
Whether PICC maintenance training was obtained before?		
No	2277	55.4
Yes	1833	44.6

PICC，peripherally inserted central catheter.

Table 2 Score and distribution of PICC maintenance knowledge among the 4110 included nurses

Dimensions	Score ($\bar{x}\pm s$)	Grade of the total score*			
		Failed, N (%)	Passed, N (%)	Good, N (%)	Total, N (%)
PICC flushing and sealing	18.30±3.67	-	-	-	-
Replacement of films and needle free connectors	8.28±3.83	-	-	-	-
Complication management	26.93±7.13	-	-	-	-
Health education	11.28±1.51	-	-	-	-
Catheter removal	8.06±2.13	-	-	-	-
Overall PICC maintenance knowledge	72.86±14.86	679 (16.5)	2030 (49.4)	1401 (34.1)	4110 (100.0)

*Grade of the total score: The total score was divided into four grades. Failed represents the score under 60; Passed represents the score from 60 to 79; Good represents a score of 80 or above.

PICC, peripherally inserted central catheter; N, Number.

Table 3 Statistics and distribution of item correct rate for different dimensions (n=4110)

Dimensions	Number of items by correct rate, N (%)				Total, N (%)	Correct rate ($\bar{x}\pm s$)
	<30%	≥30%,<60%	≥60%,<90%	≥90%		
PICC flushing and locking	1(8.3)	1(8.3)	5(41.7)	5(41.7)	12(100.0)	0.76±0.222
Replacement of dressings and needle free connectors	2(25.0)	3(37.5)	3(37.5)	0(0.0)	8(100.0)	0.52±0.248
Complication management	0(0.0)	4(21.1)	13(68.4)	2(10.5)	19(100.0)	0.71±0.167
Health education	0(0.0)	0(0.0)	1(16.7)	5(83.3)	6(100.0)	0.94±0.052
Catheter removal	0(0.0)	0(0.0)	3(60.0)	2(40.0)	5(100.0)	0.81±0.117
Kruskal-Wallis H	17.721					
P value	0.001**					

**: P<0.01

N, Number.

Table 4 PICC maintenance knowledge score by characteristics(n=4110)

Characteristics	Score ($\bar{x}\pm s$)	Z/H	P value
Gender		-3.280[a]	0.001[**]
Male	64.55±17.84		
Female	72.98±14.78		
Age, years		314.543[b]	P<0.001
<25	66.53±16.99		
25-34	74.98±12.86		
35-44	78.03±12.39		
≥45	76.29±13.33		
Professional Title		357.421[b]	P<0.001
Nurse	67.42±16.61		
Senior Nurse	74.70±12.84		
Supervisor Nurse	78.27±11.89		
Co-chief Nurse	79.40±11.54		
Education level		204.807[b]	P<0.001
Technical Secondary School	65.55±16.84		
Junior College	69.35±16.58		
Undergraduate	76.15±12.19		
Postgraduate	74.00±14.15		
Work setting		79.721[b]	P<0.001
County Hospital	70.33±14.51		
Municipal Hospital	74.28±14.72		
Provincial Hospital	73.24±15.19		
Whether PICC maintenance training was obtained before?		-17.850[a]	P<0.001
No	69.41±14.84		
Yes	77.14±13.73		

[a]: Z value ; [b]: H value ; [**]: P < 0.01

PICC, peripherally inserted central catheter.

Table 5 Generalized linear model of the factors influencing PICC maintenance knowledge

Factors	B	SE	95% Wald CI Lower	95% Wald CI Upper	Wald χ^2	P value
Gender						
Female	0.082	0.0269	0.029	0.135	9.255	0.002**
Male	Reference					
Age, years						
＜25	-0.054	0.0235	-0.1	-0.007	5.186	0.023*
25-34	-0.003	0.0214	-0.045	0.039	0.014	0.906
35-44	0.009	0.0202	-0.03	0.049	0.212	0.645
≥45	Reference					
Professional title						
Nurse	-0.074	0.0231	-0.119	-0.029	10.281	0.001**
Senior nurse	-0.035	0.0208	-0.076	0.006	2.813	0.094
Supervisor nurse	-0.002	0.0187	-0.039	0.035	0.013	0.909
Co-chief nurse						
Education level						
Technical secondary school	-0.062	0.0504	-0.161	0.036	1.529	0.216
Junior college	0.009	0.0413	-0.072	0.09	0.049	0.824
Undergraduate	0.035	0.041	-0.045	0.116	0.74	0.390
Postgraduate	Reference					
Work setting						
County hospital	-0.028	0.009	-0.046	-0.01	9.768	0.002**
Municipal hospital	0.013	0.0081	-0.003	0.029	2.587	0.108
Provincial hospital	Reference					
Whether PICC maintenance training was obtained before?						
No	-0.075	0.0066	-0.088	-0.062	128.321	P<0.001
Yes	Reference					

**: P＜0.01; *:P<0.05

The independent variables in the generalized liner model were coadded as the following: Gender(Female =0, Male=1), Age(<25=1,25-34=2,35-44=3,≥45=4), Professional title(Nurse=1, Senior nurse=2, Supervisor nurse=3, Co-chief nurse=4), Education level(Technical secondary school=1, Junior college=2, Undergraduate=3, Postgraduate=4), Work setting(County hospital=1, Municipal hospital=2, Provincial hospital=3), Whether PICC maintenance training was obtained before? (No=0, Yes=1)

PICC, peripherally inserted central catheter.

Nurses' knowledge of PICC maintenance

The mean score of PICC maintenance among 4110 nurses was 72.86±14.86. According to the scoring system, 83.5% of them passed the exam with a score of 60 or above, and 34.1% of them had a good grade with a score of 80 or above. Table 2 showed the scores of each dimension and the overall questionnaire, and the distribution of total score.

The correct rate in different dimensions

For dimension "PICC flushing and locking", among 12 items, 2 items (16.6%) were answered with a correct rate below 60%, these for dimension "Replacement of dressings and needle free connectors" and "Complication management" were 5 out of 8 (62.5%) and 4 out of 19(21.1%). While for dimension "Health education" and "Catheter removal", all items were answered with a correct rate of 60% or above (table 3). The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01).

Comparison of knowledge score among nurses with different characteristics

As shown in table 4, statistical differences were found in PICC maintenance knowledge score among nurses with different gender, age, professional title, education level and work setting (all P <0.01). And the difference of knowledge score between nurses who had received PICC maintenance training before and those who hadn't obtained training was statistically significant (P <0.01). The highest score (higher level of PICC maintenance knowledge) was found among nurses who were female, aged from 35 to 44 years old, with the professional title of co-chief nurse and the education level of undergraduate, and working in municipal Hospitals, and those who had received PICC maintenance training before(table 4).

Multivariate analysis of nurses' PICC maintenance knowledge

Multivariate analysis showed that female nurses (B=0.082, P<0.01) got a higher PICC maintenance knowledge score than male nurses. Nurses under 25 years old(B= -0.054, P<0.05), with a professional title of nurse (B=-0.074, P<0.01), working in county hospitals(B=-0.028, P<0.01), and hadn't received PICC maintenance training previously (B=-0.075, P<0.01) reported a lower level of PICC maintenance knowledge compared with those aged 45 years old or above, with a professional title of co-chief nurse, working in provincial hospitals, and had received PICC maintenance training before. (table 5)

DISCUSSION

This study demonstrated that the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China, with a mean score of 72.86±14.86. 83.5% of nurses passed the exam with a score of 60 or above and 34.1% of them had a good grade with a score of 80 or above, which were lower than those (88.9% and 47.2%) reported by Wu et al[26]. This difference may result from the difference in the demographic data of the subjects. The subjects in our study involved nurses of Grade Ⅱ hospitals and Grade Ⅲ hospitals, while the nurses in Wu et al's study all came from Grade III Level A hospitals, making them have more opportunities to learn new technologies including PICC maintenance. The gap of PICC maintenance knowledge

between nurses in Hunan province, China and those in other regions deserves the attention of nursing managers, and appropriate strategies need to be taken to increase their knowledge.

Nurses' levels of mastery toward different dimensions were different, with the maximum correct rate of health education (90.94±0.052), followed by catheter removal (0.81±0.117), PICC flushing and locking (0.76±0.222), and complication management (0.71±0.167). And the correct rate of replacement of dressings and needle free connectors was the minimum (0.52±0.248) among 5 dimensions. The correct rate of health education ranking the first may be due to its uniqueness. Unlike other dimensions, health education is often the transfer of knowledge without clinical operation, which is simple and easy to master. Moreover, nurses need to repeat the knowledge again and again when educating the patients with PICC, which would strengthen their memory of the knowledge. The dimension with the minimum correct rate was replacement of dressings and needle free connectors, inconsistent with Oliveira et al's[3] finding that the criteria related to the dressing of PICC and the change of administration sets showed a moderate to high compliance. In addition, Sharpe et al's [8]research also showed that a majority of nurses can perform well in the PICC dressings change. The difference between our findings and those of others is probably because that the replacement of dressings and needle free connectors is relatively simple, so the nurses often operate it according to their clinical experience, neglecting the learning toward the standardized theoretical knowledge. The gap of mastery degree toward dressings and needle free connectors between nurses in Hunan province, China and those in other regions (e.g., Sao Paulo, Brazil [3]) is evident. Thus, this is a barrier that needs to be taken into consideration for nursing education and training in clinical practice. Other dimensions, such as catheter removal, PICC flushing and locking, and complication management, although showing a medium to high level of mastery, should not be ignored during training as they also directly affect patients' safety.

The factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting, and whether PICC maintenance training was obtained before. Female nurses got higher PICC maintenance knowledge scores than male nurses, and nurses under 25 years old reported a lower level of PICC maintenance knowledge compared with those aged 45 years old or above. We did not find similar findings in other studies. Since the number of male nurses responding to the questionnaire is so low (1.4%), it is unnecessary to speculate as to why they did so poorly. As for the finding of age, the reason may be related to the work experience. However, Chopra et al's[22] research showed there was no statistical difference in vascular nurses' knowledge based on years of experiences, which they thought was due to the small sample size. Thus, the reason for this need to be further explored.

Our study demonstrated that nurses with a professional title of the nurse got a lower PICC maintenance knowledge score than those with a professional title of the co-chief nurse. This is not surprising as nurses with senior professional titles usually have more study and communication opportunities, making them acquire more knowledge of specialized nursing. In addition, nurses with senior professional titles often

undertake clinical teaching work, benefiting themselves as well when teaching interns and nurses with a junior professional title about PICC maintenance.

The most significant finding is that nurses working in county hospitals reported a lower level of PICC maintenance knowledge compared with those working in provincial hospitals. This may be because that the PICC maintenance technology is young in county hospitals. In China, specialized nursing technologies such as PICC catheterization and maintenance are first carried out by provincial hospitals, then promoted to municipal hospitals. An increasing number of county hospitals have introduced PICC maintenance technology due to the increased use of PICCs in recent years. To the best of our knowledge, this study is the first to compare nurses' PICC maintenance knowledge among hospitals at different levels. In consideration of the gap of nurses' PICC maintenance knowledge between county hospitals and provincial hospitals, attention must be given to narrow the gap and provide homogenized nursing for patients with PICC.

Our study also showed that nurses hadn't received PICC maintenance training previously reported a lower level of PICC maintenance knowledge compared with those had received training before, indicating that training is an effective way to enhance nurses' knowledge of PICC maintenance, consistent with Roslien et al's [27]and Purran et al' [28]researches. Through systematic and standardized PICC training[29], nurses can acquire basic knowledge of vascular anatomy, ultrasound and radiographic, PICC catheterization and maintenance standard procedures, various emergency response processing and complication management processes, effectively decreasing catheter-related complications and improving patients' safety.

Our study has some limitations. First, despite a large sample size, our study was a cross-sectional survey and was conducted using a convenience sampling method. Thus, nonresponse and selection biases may be a threat to our conclusion. Second, we investigated nurses in hospitals that have introduced PICC maintenance technology, our finding may therefore not be representative of the knowledge level of all nurses in Hunan province, China, but reflect the group with a higher level of PICC maintenance knowledge. Thus, a similar survey aimed at nurses in the hospitals that haven't introduced PICC maintenance technology yet needs to be conducted in the future. Third, although the quality control procedure was used throughout the data collection and entry, we have no way to avoid the potential information bias in view of the survey was based on self-reported data. Last, as mentioned in the first half of the discussion, some general information that may be factors influencing the nurses' PICC maintenance knowledge had not been collected, such as years of experience, which affected our conclusion to some extent.

CONCLUSIONS

In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China, and this was mainly influenced by their gender, age, professional title, work setting, and that whether the PICC maintenance training would be obtained before. However, considering that the theoretical knowledge of PICC maintenance, especially in the form of guidelines, is freely available to the

nurses, and has been used to educate the nurses by the IV team of Xiangya Hospital within the PICC maintenance network, there is room for the improvement of PICC maintenance knowledge of nurses at all professional levels and in all work settings. To improve the nurses' PICC maintenance knowledge, the next steps include disseminating PICC maintenance knowledge in multiple ways, such as courses, lectures, seminars and new media, giving special attention to populations who did poorly in this survey, and providing targeted education for nurses based on what they didn't do well, such as the replacement of dressing and needle free connectors.

In addition, since the quality of the nurses' practical performance of PICC maintenance has a more direct impact on improving PICC related outcomes, the study that measures nurse's practical performance should be conducted in the future. It can be measured directly by observation at bedside according to the standardized PICC maintenance order sets and checklist. It can also be measured indirectly by the PICC indwelling time, the incidence of PICC-related complications, and patients' satisfaction, and more measurement methods need to be explored.

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Author Contributions BBX, JHZ, and SYT contributed to the study conception and design, and questionnaire development. BBX and JHZ contributed to data collection, analysis, and interpretation, and manuscript drafting. BBX, JMH, and MDM contributed to the literature search and data collection. BBX and ZHG contributed to data collection and management. All authors contributed to manuscript drafting and revising, and approved the final version.

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Competing interests None declared.

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Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Extra data can be extracted by emailing the first author BBX.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	n/a,

		(*d*) If applicable, describe analytical methods taking account of sampling strategy	4
		(*e*) Describe any sensitivity analyses	n/a,
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	n/a, the questionnaire link was sent to the WeChat group, and the targeted nurses filled it out based on their willing. Thus, we cannot collect the information of non-participation.
		(c) Consider use of a flow diagram	n/a, we didn't use the flow diagram in our manuscript.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	n/a, the questionnaire cannot be submitted if it was not be filled completely, so there were no missing values in the returned questionnaire.
Outcome data	15*	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11
		(*b*) Report category boundaries when continuous variables were categorized	11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	11,12,13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or	13

		imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12,13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13,14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Nurses' knowledge of peripherally inserted central catheter maintenance and its influencing factors in Hunan province, China: a cross-sectional survey

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Keywords:	peripherally inserted central catheter (PICC), maintenance, nurses, knowledge, influencing factor

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Nurses' knowledge of peripherally inserted central catheter maintenance and its influencing factors in Hunan province, China: a cross-sectional survey

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ABSTRACT

Objectives The aim of this study was to assess the level of knowledge on peripherally inserted central catheter (PICC) maintenance among nurses in China and to analyze related factors influencing the knowledge.

Design A cross-sectional survey.

Setting 91 hospitals that have introduced PICC maintenance technology in Hunan Province, China, including county hospitals, municipal hospitals, and provincial hospitals.

Participants 4,110 registered nurses engaged in clinical work related to intravenous infusion.

Primary and secondary outcome measures Nurses' knowledge of PICC maintenance was measured by the score of an anonymous, self-reported questionnaire**.**

Results The mean score of PICC maintenance among 4,110 nurses was 72.86±14.86. 83.5% of them got a score of 60 or above, and 34.1% of them had a good grade with a score of 80 or above. The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01). The Generalized Linear Model showed that the factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting and whether PICC maintenance training was obtained before.

Conclusions In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China. Multiple steps should be taken to improve their PICC maintenance knowledge, including disseminating PICC maintenance knowledge in multiple ways, such as courses, lectures, seminars, and new media, giving special attention to populations who did poorly in this survey, and providing targeted education for nurses based on what they didn't do well, such as the replacement of dressing and needle free connectors. In addition, the quality of the nurses' practical performance could be measured in the future.

Keywords: peripherally inserted central catheter (PICC), maintenance, knowledge, nurses, influencing factor

ARTICLE SUMMARY

Strengths and limitations of this study

1. We designed the questionnaire based on an extensive review of literature, and consultation with experts who are PICC specialist nurses and hold the position of head of the nursing department or head nurse.
2. Our findings could provide a valuable reference for nursing managers and providers of PICC maintenance training.
3. The sample size of this study was very large, which ensured the statistical power to support the conclusion.
4. The cross-sectional design and convenience sampling method may cause nonresponse and selection biases and make our results not representative.
5. The survey was based on self-reported data.

INTRODUCTION

The peripherally inserted central venous catheter (PICC) is an intravenous device[1] inserted into the central veins via the peripheral veins[2-5] (e.g., basilic vein[2], antecubital vein[2], cephalic vein[3], brachial vein[3], and femoral vein[4,5]), which are commonly used for prolonged intravenous therapy, blood and nutrition administrations, and frequent blood sampling[4-10]. It is regarded as a safe, efficient and cost-effective intravenous device due to long indwelling time, less vascular damage without repeated puncture, and convenient insertion and removal without the necessity for general anesthesia or deep cutting and suturing of wounds[2,3,9-11]. However, its complications cannot be ignored, including thrombosis[4,5,12-14], catheter exit site infections[4], bloodstream infections[12,13,15], accidental dislodgement[5,11,12], malposition[11], occlusion[4,5,11,12,16], leakage[12], breakage[5,12], phlebitis[12], and cardiac tamponade[15]. A systematic review[17] showed that about 30% of PICC failed before the completion of treatment because of complications, which would delay drug administration and blood sampling, increase the financial burden on patients and reduce their satisfaction, even deplete patients' useable veins for future treatment and can obstruct vessels long-term. This could have a greater impact on cancer patients, since the delays to chemotherapy cycles might reduce treatment efficacy and can affect subsequent survival. Researches[18-21] reported that appropriate PICC maintenance may offset the risk of such harms and maximize the safety of PICC. As the provider of PICC maintenance, the nurses' PICC maintenance knowledge and skills directly affect the quality of care, clinical outcomes, and patients' safety[8,22]. Although gaps between the evidence of PICC maintenance and its knowledge and practice among nurses were reported[3,8], little was known for nurses in Hunan province, China. Thus, the purpose of this cross-sectional study was to investigate nurses' knowledge of PICC maintenance. We also aim to characterize and identify some factors influencing nurses' knowledge, which may provide information on decision making and quality-improvement efforts related to PICC.

METHODS

Study setting

To investigate nurses' knowledge of PICC maintenance, we conducted a web-based cross-sectional survey of nurses in 91 hospitals, including county hospitals, municipal hospitals, and provincial hospitals. County hospitals are hospitals located in counties and under the control of county governments, which provide comprehensive health services and medical education to residents in counties, villages, and towns, they are generally Grade Ⅱ hospitals. Municipal hospitals are hospitals constructed and administered by municipal governments. They are located in cities and provide comprehensive health services, emergency and critical medical services, and specialist health services to residents from different counties, and perform a bigger role in medical education and conduct research on a regional basis. They are mainly Grade Ⅲ hospitals, however municipal hospitals that are too small and don't have enough beds (less than 500) are Grade Ⅱ hospitals. Provincial hospitals are hospitals under the jurisdiction of provincial governments. They are usually located in the provincial capital and play an important role in scientific research and teaching, serve

as medical hubs providing care to multiple regions. They are mainly Grade Ⅲ level A hospitals.

All included hospitals are members of the PICC maintenance service network in Hunan province, China. The PICC maintenance service network is a province-wide PICC maintenance alliance led by the intravenous infusion(IV) team of Xiangya Hospital, Central South University, aiming to allow patients in the intermission of treatment to choose the nearest site to maintain their PICCs instead of returning to where their PICCs was placed, thus making PICC maintenance more convenient and economical. Xiangya Hospital is a university-affiliated hospital with 3,620 beds and a training base for PICC specialist nurses in Hunan Province. The IV team of Xiangya Hospital began to construct the PICC maintenance network in 2015. To date, 103 maintenance sites have been involved. Each maintenance site has an IV team that is responsible for intravenous nursing training (peripheral venous catheter training, central venous catheter training, PICC training, and PORT training), quality control, and consultation, and each IV team has a liaison who is responsible for communicating with the IV team in other hospitals.

Participants

Participants were enrolled through a non-random, convenience sampling method. First, we contacted the liaisons in every PICC maintenance site and enquired whether they can help us to carry out the survey. Then, in sites where the liaisons were willing to help us, the registered nurses who engaged in clinical work related to intravenous infusion, had more than one year of work experience, were willing to participate in the research after informed consent, and can correctly understand the content of the questionnaire were included. Exclusion criteria were nurses who were taking psychotropic substances due to mental or psychological illness, and nurses who were absent from work due to illness, maternity leave or other reasons.

The sample size was calculated according to the formula for the sample size for the mean, which is as follow:

$$n = \frac{z_{\alpha/2}^2 \sigma^2}{\delta^2}$$

$Z_{\alpha/2}$ is the abscissa of the normal curve that cuts off an area α at the tails; σ is the population standard derivation, which could be replaced by the sample standard deviation; δ is the margin of error, the value of which is generally 10%-60% of the standard deviation. In this study, α=0.05, $Z_{\alpha/2}$=1.96, σ=14.602 (determined by the pre-survey), δ=1.4602 (10%*σ). Thus, the sample size n=384. In consideration of nonresponse and invalid response, the sample size should be increased by 20%, which was 461.

Survey instrument

In this study, the survey instrument was a self-designed questionnaire based on an extensive review of literature[8,18,23-25], mainly including the Infusion Therapy Standards of Practice[23] released by Infusion Nursing Society and the Nursing Practice Standards for Intravenous Therapy[24] issued by the National Health Commission of the people's Republic of China in 2013. In addition, five experts who are PICC specialist

nurses and hold the position of head of the nursing department or head nurse were consulted to assess the questionnaire's validity, and the pretest was carried out to make sure the questionnaire could be understood easily. The questionnaire included 50 items in total covering five dimensions of PICC maintenance knowledge, including PICC flushing and locking (12 items), replacement of dressings and needle free connectors (eight items), complication management (19 items), health education (six items), and catheter removal (five items). All items were single choice questions. The correct answer was assigned a point of two, otherwise zero, with a full score of 100. The higher the score is, the higher the PICC maintenance knowledge level is. The Cronbach's alpha coefficient of this questionnaire was 0.873, and the content validity index (CVI) was 0.915, indicating that the questionnaire had good internal consistency reliability and validity.

In addition, we collected the data of potential factors influencing PICC maintenance knowledge by self-designed demographic information questionnaire, including gender, age, professional title, education level, work setting, and whether PICC maintenance training was obtained before.

Implementation

This survey was divided into two stages: the recruitment of PICC maintenance sites and the participants, and the implementation of the investigation.

In June 2017, we recruited 91 PICC maintenance sites out of 103 eligible sites, After the recruitment of PICC maintenance sites, we provided unified training on our inclusion criteria and exclusion criteria for these liaisons by telephone. The recruitment of participants was implemented by these liaisons in July 2017. Specific steps were as follows: first, the liaisons explained the purpose of the survey to the head nurses in their facilities, for the purpose of obtaining approval and support; then, the liaisons selected the potential participants according to our inclusion and exclusion criteria with the help of the head nurses; finally, the participants were included after their informed consent. All eligible nurses were informed that participation in this study was voluntary, they can withdraw from the study at any time for any reason, and the questionnaire would be answered anonymously based on their own knowledge and understanding of PICC maintenance. Moreover, they were assured that their information would only be used for research, that their data would be kept confidentially, and that their scores of the questionnaire would not have any influence on their career and promotion as their employers could not see their scores.

The investigation was implemented by the liaisons and the head nurses who supported our study. First, we sent the electronic survey link to the liaisons by email and provided unified training on how to fill out the questionnaires by phone. Then, the liaisons sent the link to the head nurses in their facilities through WeChat and told them how to fill it out. Finally, the head nurses sent the link to their Ward WeChat Group and organized the eligible nurses to fill out the questionnaires. The investigation was administered at 91 PICC maintenance sites at the same time from August 2017 and kept open for four weeks. During the 4-week period, two e-mail reminders were sent to the liaisons to encourage participation.

Statistical analysis

Descriptive statistics were used to summarize participants' characteristics and the knowledge score of PICC maintenance. The Kruskal-Wallis H test was used to compare the correct rate in different dimensions. The knowledge score among nurses with different characteristics was compared using the Wilcoxon rank-sum test for two-group comparison and the Kruskal-Wallis H test for multiple comparisons. The generalized linear model was used for multivariate analysis to identify the demographic factors influencing PICC maintenance knowledge, because the dependent variable (the knowledge score) was not normally distributed. The gamma distribution was chosen as the distribution of the dependent variable, and the logarithmic function was chosen as the link function. All analyses were performed using SPSS V.22.0, and two-tailed $P<0.05$ was considered statistically significant.

Patient and Public Involvement

No patient involved

RESULTS

Participant characteristics

In this study, a total of 6,524 nurses were eligible to fill out the questionnaires, and 4,110 of those completed it, with a response rate of 63.0%. Among 4,110 respondents, the majority were women (98.6%). The largest age group was 25-34(51.6%) followed by those aged under 25(30.9%). The majority (75.6%) had a junior professional title. All of them worked in secondary and above hospitals with 29.9% in county hospitals, 46.9% in municipal hospitals, and 23.2% in provincial hospitals. Less than half (44.6%) reported having received PICC maintenance training previously. (table 1)

Table 1 Demographic characteristics of respondents(n=4110)

Characteristic	Frequency	Percentage (%)
Gender		
Male	58	1.4
Female	4052	98.6
Age, years		
＜25	1268	30.9
25-34	2120	51.6
35-44	597	14.5
≥45	125	3.0
Professional title		
Nurse	1554	37.8
Senior nurse	1555	37.8
Supervisor nurse	848	20.6
Co-chief nurse	153	3.7
Education level		
Technical secondary school	49	1.2
Junior college	1906	46.4
Undergraduate	2130	51.8
Postgraduate	25	0.6
Work setting		
County hospital	1228	29.9
Municipal hospital	1929	46.9
Provincial hospital	953	23.2
Whether PICC maintenance training was obtained before?		
No	2277	55.4
Yes	1833	44.6

PICC，peripherally inserted central catheter.

Table 2 Score and distribution of PICC maintenance knowledge among the 4110 included nurses

Dimensions	Score ($\bar{x}$±s)	Grade of the total score*			
		Failed, N (%)	Passed, N (%)	Good, N (%)	Total, N (%)
PICC flushing and sealing	18.30±3.67	-	-	-	-
Replacement of dressing and needle free connectors	8.28±3.83	-	-	-	-
Complication management	26.93±7.13	-	-	-	-
Health education	11.28±1.51	-	-	-	-
Catheter removal	8.06±2.13	-	-	-	-
Overall PICC maintenance knowledge	72.86±14.86	679 (16.5)	2030 (49.4)	1401 (34.1)	4110 (100.0)

*Grade of the total score: The total score was divided into four grades. Failed represents the score under 60; Passed represents the score from 60 to 79; Good represents a score of 80 or above.

PICC, peripherally inserted central catheter; N, Number.

Table 3 Statistics and distribution of item correct rate for different dimensions (n=4110)

Dimensions	Number of items by correct rate, N (%)				Total, N (%)	Correct rate ($\bar{x}$±s)
	＜30%	≥30%,＜60%	≥60%,＜90%	≥90%		
PICC flushing and locking	1(8.3)	1(8.3)	5(41.7)	5(41.7)	12(100.0)	0.76±0.222
Replacement of dressings and needle free connectors	2(25.0)	3(37.5)	3(37.5)	0(0.0)	8(100.0)	0.52±0.248
Complication management	0(0.0)	4(21.1)	13(68.4)	2(10.5)	19(100.0)	0.71±0.167
Health education	0(0.0)	0(0.0)	1(16.7)	5(83.3)	6(100.0)	0.94±0.052
Catheter removal	0(0.0)	0(0.0)	3(60.0)	2(40.0)	5(100.0)	0.81±0.117
Kruskal-Wallis H	17.721					
P value	0.001**					

**: P＜0.01

N, Number.

Table 4 PICC maintenance knowledge score by characteristics(n=4110)

Characteristics	Score ($\bar{x}\pm s$)	Z/H	P value
Gender		-3.280[a]	0.001[**]
Male	64.55±17.84		
Female	72.98±14.78		
Age, years		314.543[b]	P<0.001
<25	66.53±16.99		
25-34	74.98±12.86		
35-44	78.03±12.39		
≥45	76.29±13.33		
Professional Title		357.421[b]	P<0.001
Nurse	67.42±16.61		
Senior Nurse	74.70±12.84		
Supervisor Nurse	78.27±11.89		
Co-chief Nurse	79.40±11.54		
Education level		204.807[b]	P<0.001
Technical Secondary School	65.55±16.84		
Junior College	69.35±16.58		
Undergraduate	76.15±12.19		
Postgraduate	74.00±14.15		
Work setting		79.721[b]	P<0.001
County Hospital	70.33±14.51		
Municipal Hospital	74.28±14.72		
Provincial Hospital	73.24±15.19		
Whether PICC maintenance training was obtained before?		-17.850[a]	P<0.001
No	69.41±14.84		
Yes	77.14±13.73		

[a]: Z value ; [b]: H value ; [**]: P < 0.01

PICC, peripherally inserted central catheter.

Table 5 Generalized linear model of the factors influencing PICC maintenance knowledge

Factors	B	SE	95% Wald CI Lower	95% Wald CI Upper	Wald χ^2	P value
Gender						
Female	0.082	0.0269	0.029	0.135	9.255	0.002**
Male	Reference					
Age, years						
＜25	-0.054	0.0235	-0.1	-0.007	5.186	0.023*
25-34	-0.003	0.0214	-0.045	0.039	0.014	0.906
35-44	0.009	0.0202	-0.03	0.049	0.212	0.645
≥45	Reference					
Professional title						
Nurse	-0.074	0.0231	-0.119	-0.029	10.281	0.001**
Senior nurse	-0.035	0.0208	-0.076	0.006	2.813	0.094
Supervisor nurse	-0.002	0.0187	-0.039	0.035	0.013	0.909
Co-chief nurse						
Education level						
Technical secondary school	-0.062	0.0504	-0.161	0.036	1.529	0.216
Junior college	0.009	0.0413	-0.072	0.09	0.049	0.824
Undergraduate	0.035	0.041	-0.045	0.116	0.74	0.390
Postgraduate	Reference					
Work setting						
County hospital	-0.028	0.009	-0.046	-0.01	9.768	0.002**
Municipal hospital	0.013	0.0081	-0.003	0.029	2.587	0.108
Provincial hospital	Reference					
Whether PICC maintenance training was obtained before?						
No	-0.075	0.0066	-0.088	-0.062	128.321	P<0.001
Yes	Reference					

**: P＜0.01; *:P<0.05

The independent variables in the generalized liner model were coadded as the following: Gender(Female =0, Male=1), Age(<25=1,25-34=2,35-44=3,≥45=4), Professional title(Nurse=1, Senior nurse=2, Supervisor nurse=3, Co-chief nurse=4), Education level(Technical secondary school=1, Junior college=2, Undergraduate=3, Postgraduate=4), Work setting(County hospital=1, Municipal hospital=2, Provincial hospital=3), Whether PICC maintenance training was obtained before? (No=0, Yes=1)

PICC, peripherally inserted central catheter.

Nurses' knowledge of PICC maintenance

The mean score of PICC maintenance among 4,110 nurses was 72.86±14.86. According to the scoring system, 83.5% of them passed the exam with a score of 60 or above, and 34.1% of them had a good grade with a score of 80 or above. Table 2 showed the scores of each dimension and the overall questionnaire, and the distribution of total score.

The correct rate in different dimensions

For dimension "PICC flushing and locking", among 12 items, two items (16.6%) were answered with a correct rate below 60%, these for dimension "Replacement of dressings and needle free connectors" and "Complication management" were five out of eight (62.5%) and four out of 19(21.1%). While for dimension "Health education" and "Catheter removal", all items were answered with a correct rate of 60% or above (table 3). The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01).

Comparison of knowledge score among nurses with different characteristics

As shown in table 4, statistical differences were found in PICC maintenance knowledge score among nurses with different gender, age, professional title, education level and work setting (all P <0.01). And the difference of knowledge score between nurses who had received PICC maintenance training before and those who hadn't obtained training was statistically significant (P <0.01). The highest score (higher level of PICC maintenance knowledge) was found among nurses who were female, aged from 35 to 44 years old, with the professional title of co-chief nurse and the education level of undergraduate, and working in municipal Hospitals, and those who had received PICC maintenance training before(table 4).

Multivariate analysis of nurses' PICC maintenance knowledge

Multivariate analysis showed that female nurses (B=0.082, P<0.01) got a higher PICC maintenance knowledge score than male nurses. Nurses under 25 years old(B= -0.054, P<0.05), with a professional title of nurse (B=-0.074, P<0.01), working in county hospitals(B=-0.028, P<0.01), and hadn't received PICC maintenance training previously (B=-0.075, P<0.01) reported a lower level of PICC maintenance knowledge compared with those aged 45 years old or above, with a professional title of co-chief nurse, working in provincial hospitals, and had received PICC maintenance training before. (table 5)

DISCUSSION

This study demonstrated that the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China, with a mean score of 72.86±14.86. 83.5% of nurses passed the exam with a score of 60 or above and 34.1% of them had a good grade with a score of 80 or above, which were lower than those (88.9% and 47.2%) reported by Wu et al[26]. This difference may result from the difference in the demographic data of the subjects. The subjects in our study involved nurses of Grade Ⅱ hospitals and Grade Ⅲ hospitals, while the nurses in Wu et al's study all came from Grade III Level A hospitals, making them have more opportunities to learn new technologies including PICC maintenance. The gap of PICC maintenance knowledge

between nurses in Hunan province, China and those in other regions deserves the attention of nursing managers, and appropriate strategies need to be taken to increase their knowledge.

Nurses' levels of mastery toward different dimensions were different, with the maximum correct rate of health education (90.94±0.052), followed by catheter removal (0.81±0.117), PICC flushing and locking (0.76±0.222), and complication management (0.71±0.167). And the correct rate of replacement of dressings and needle free connectors was the minimum (0.52±0.248) among five dimensions. The correct rate of health education ranking the first may be due to its uniqueness. Unlike other dimensions, health education is often the transfer of knowledge without clinical operation, which is simple and easy to master. Moreover, nurses need to repeat the knowledge again and again when educating the patients with PICC, which would strengthen their memory of the knowledge. The dimension with the minimum correct rate was replacement of dressings and needle free connectors, inconsistent with Oliveira et al's[3] finding that the criteria related to the dressing of PICC and the change of administration sets showed a moderate to high compliance. In addition, Sharpe et al's [8]research also showed that a majority of nurses can perform well in the PICC dressings change. The difference between our findings and those of others is probably because that the replacement of dressings and needle free connectors is relatively simple, so the nurses often operate it according to their clinical experience, neglecting the learning toward the standardized theoretical knowledge. The gap of mastery degree toward dressings and needle free connectors between nurses in Hunan province, China and those in other regions (e.g., Sao Paulo, Brazil [3]) is evident. Thus, this is a barrier that needs to be taken into consideration for nursing education and training in clinical practice. Other dimensions, such as catheter removal, PICC flushing and locking, and complication management, although showing a medium to high level of mastery, should not be ignored during training as they also directly affect patients' safety.

The factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting, and whether PICC maintenance training was obtained before. Female nurses got higher PICC maintenance knowledge scores than male nurses, and nurses under 25 years old reported a lower level of PICC maintenance knowledge compared with those aged 45 years old or above. We did not find similar findings in other studies. Since the number of male nurses responding to the questionnaire is so low (1.4%), it is unnecessary to speculate as to why they did so poorly. As for the finding of age, the reason may be related to the work experience. However, Chopra et al's[22] research showed there was no statistical difference in vascular nurses' knowledge based on years of experiences, which they thought was due to the small sample size. Thus, the reason for this need to be further explored.

Our study demonstrated that nurses with a professional title of the nurse got a lower PICC maintenance knowledge score than those with a professional title of the co-chief nurse. This is not surprising as nurses with senior professional titles usually have more study and communication opportunities, making them acquire more knowledge of specialized nursing. In addition, nurses with senior professional titles often

undertake clinical teaching work, benefiting themselves as well when teaching interns and nurses with a junior professional title about PICC maintenance.

The most significant finding is that nurses working in county hospitals reported a lower level of PICC maintenance knowledge compared with those working in provincial hospitals. This may be because that the PICC maintenance technology is young in county hospitals. In China, specialized nursing technologies such as PICC catheterization and maintenance are first carried out by provincial hospitals, then promoted to municipal hospitals. An increasing number of county hospitals have introduced PICC maintenance technology due to the increased use of PICCs in recent years.

To the best of our knowledge, this study is the first to compare nurses' PICC maintenance knowledge among hospitals at different levels. In consideration of the gap of nurses' PICC maintenance knowledge between county hospitals and provincial hospitals, attention must be given to narrow the gap and provide homogenized nursing for patients with PICC.

Our study also showed that nurses hadn't received PICC maintenance training previously reported a lower level of PICC maintenance knowledge compared with those had received training before, indicating that training is an effective way to enhance nurses' knowledge of PICC maintenance, consistent with Roslien et al's [27]and Purran et al' [28]researches. Through systematic and standardized PICC training[29], nurses can acquire basic knowledge of vascular anatomy, ultrasound and radiographic, PICC catheterization and maintenance standard procedures, various emergency response processing and complication management processes, effectively decreasing catheter-related complications and improving patients' safety.

Our study has some limitations. First, despite a large sample size, our study was a cross-sectional survey and was conducted using a convenience sampling method. Thus, nonresponse and selection biases may be a threat to our conclusion. Second, we investigated nurses in hospitals that have introduced PICC maintenance technology, our finding may therefore not be representative of the knowledge level of all nurses in Hunan province, China, but reflect the group with a higher level of PICC maintenance knowledge. Thus, a similar survey aimed at nurses in the hospitals that haven't introduced PICC maintenance technology yet needs to be conducted in the future. Third, although the quality control procedure was used throughout the data collection and entry, we have no way to avoid the potential information bias in view of the survey was based on self-reported data. Last, as mentioned in the first half of the discussion, some general information that may be factors influencing the nurses' PICC maintenance knowledge had not been collected, such as years of experience, which affected our conclusion to some extent.

CONCLUSIONS

In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China, and this was mainly influenced by their gender, age, professional title, work setting, and that whether the PICC maintenance training would be obtained before. However, considering that the theoretical knowledge of

PICC maintenance, especially in the form of guidelines, is freely available to nurses, and has been used to educate nurses by the IV team of Xiangya Hospital within the PICC maintenance network, there is room for the improvement of PICC maintenance knowledge of nurses at all professional levels and in all work settings. To improve the nurses' PICC maintenance knowledge, the next steps include disseminating PICC maintenance knowledge in multiple ways, such as courses, lectures, seminars and new media, giving special attention to populations who did poorly in this survey, and providing targeted education for nurses based on what they didn't do well, such as the replacement of dressing and needle free connectors.

In addition, since the quality of the nurses' practical performance of PICC maintenance has a more direct impact on improving PICC related outcomes, the study that measures nurse's practical performance should be conducted in the future. It can be measured directly by observation at bedside according to the standardized PICC maintenance order sets and checklist. It can also be measured indirectly by the PICC indwelling time, the incidence of PICC-related complications, and patients' satisfaction, and more measurement methods need to be explored.

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Author Contributions BBX, JHZ, and SYT contributed to the study conception and design, and questionnaire development. BBX and JHZ contributed to data collection, analysis, and interpretation, and manuscript drafting. BBX, JMH, and MDM contributed to the literature search and data collection. BBX and ZHG contributed to data collection and management. All authors contributed to manuscript drafting and revising, and approved the final version.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study was approved by the IRB of behavioral and nursing research in School of Nursing of CSU (No 2017038).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Extra data can be extracted by emailing the first author BBX.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	n/a,

		(*d*) If applicable, describe analytical methods taking account of sampling strategy	4
		(*e*) Describe any sensitivity analyses	n/a,
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	n/a, the questionnaire link was sent to the WeChat group, and the targeted nurses filled it out based on their willing. Thus, we cannot collect the information of non-participation.
		(c) Consider use of a flow diagram	n/a, we didn't use the flow diagram in our manuscript.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	n/a, the questionnaire cannot be submitted if it was not be filled completely, so there were no missing values in the returned questionnaire.
Outcome data	15*	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11
		(*b*) Report category boundaries when continuous variables were categorized	11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	11,12,13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or	13

		imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12,13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13,14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Nurses' knowledge of peripherally inserted central catheter maintenance and its influencing factors in Hunan province, China: a cross-sectional survey

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Nurses' knowledge of peripherally inserted central catheter maintenance and its influencing factors in Hunan province, China: a cross-sectional survey

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ABSTRACT

Objectives The present study aimed to assess the level of knowledge on peripherally inserted central catheter (PICC) maintenance among nurses in China and to analyze the related factors influencing this variable.

Design A cross-sectional survey.

Setting Ninety-one hospitals at three different levels in Hunan Province, China: county hospitals, municipal hospitals, and provincial hospitals.

Participants A total of 4,110 registered nurses engaged in clinical work related to intravenous infusion.

Primary and secondary outcome measures Nurses' knowledge of PICC maintenance was measured by the score of an anonymous, self-reported questionnaire**.**

Results The mean score of PICC maintenance among 4,110 nurses was 72.86±14.86. 83.5% of the participants exhibited a score of 60 or above, and 34.1% of them exhibited a good grade with a score of 80 or above. The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01). The generalized linear model indicated that the factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting and previous history of PICC maintenance training.

Conclusions In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China. Multiple steps should be taken to improve the nurses' PICC maintenance knowledge, including disseminating PICC maintenance knowledge in multiple ways, such as courses, lectures, seminars, and new media. Particular attention should be given to populations who responded poorly in this survey, and targeted education for nurses should be distributed based on their performance on specific dimensions, such as the replacement of dressing and needle free connectors. In addition, the quality of the nurses' practical performance could be measured in the future.

Keywords: peripherally inserted central catheter (PICC), maintenance, knowledge, nurses, influencing factor

ARTICLE SUMMARY

Strengths and limitations of this study

1. The present study is the first to compare nurses' PICC maintenance knowledge among hospitals at different levels in China.
2. We designed the questionnaire based on an extensive review of literature and consultation with experts who are PICC specialist nurses and hold the position of head of the nursing department or head nurse.
3. The sample size of the study was very large, which ensured the statistical power to support the conclusions.
4. The cross-sectional design and convenience sampling method may cause nonresponse and selection biases and limit the reproducibility of the results.
5. The survey was based on self-reported data.

INTRODUCTION

The peripherally inserted central venous catheter (PICC) is an intravenous device[1] inserted into the central veins via the peripheral veins[2-5] (e.g., basilic vein[2], antecubital vein[2], cephalic vein[3], brachial vein[3], and femoral vein[4,5]), which are commonly used for prolonged intravenous therapy, blood and nutrition administrations, and frequent blood sampling[4-10]. It is regarded as a safe, efficient and cost-effective intravenous device due to long indwelling time, reduced vascular damage without repeated puncture, and convenient insertion and removal without the necessity for general anesthesia or deep cutting and suturing of the wounds[2,3,9-11]. However, its complications cannot be ignored, including thrombosis[4,5,12-14], catheter exit site infections[4], bloodstream infections[12,13,15], accidental dislodgement[5,11,12], malposition[11], occlusion[4,5,11,12,16], leakage[12], breakage[5,12], phlebitis[12], and cardiac tamponade[15]. A systematic review[17] indicated that approximately 30% of PICC failed before the completion of treatment because of complications, which would delay drug administration and blood sampling, increase the financial burden on patients and reduce their satisfaction. It was also shown that PICC-related complications can deplete patients' useable veins for future treatment and can cause long-term vessel obstruction. This could have a greater impact on cancer patients, since the delays to chemotherapy cycles might reduce treatment efficacy and could affect subsequent survival. Previous studies[18-21] reported that appropriate PICC maintenance may offset the risk of such harms and maximize the safety of PICCs. The nurses' PICC maintenance knowledge and skills directly affect the quality of care, clinical outcomes and patient safety[8,22]. Although gaps have been reported between the evidence of PICC maintenance and the knowledge and practice of nurses[3,8], little is known regarding nurses in Hunan province, China. Therefore, the purpose of the present cross-sectional study was to investigate the nurses' knowledge of PICC maintenance. We also aimed to characterize and identify some factors influencing nurses' knowledge, which may provide information on decision making and quality-improvement efforts associated with PICC.

METHODS

Study setting

To investigate the nurses' knowledge of PICC maintenance, we conducted a web-based cross-sectional survey of nurses in 91 hospitals at three different levels: county hospitals, municipal hospitals, and provincial hospitals. County hospitals are hospitals located in counties that are under the control of county governments and provide comprehensive health services and medical education to residents in counties, villages, and towns. They are generally Grade Ⅱ hospitals. Municipal hospitals are hospitals constructed and administered by municipal governments. They are located in cities and provide comprehensive health services, emergency and critical medical services, and specialist health services to residents from different counties. They also perform a wider role in medical education and conduct research on a regional basis. They are mainly Grade Ⅲ hospitals. However, municipal hospitals that are too small and do not contain sufficient beds (less than 500) are Grade Ⅱ hospitals. Provincial

hospitals are hospitals under the jurisdiction of provincial governments. They are usually located in the provincial capital and play an important role in scientific research and teaching. They serve as medical hubs providing care to multiple regions. They are mainly Grade Ⅲ level A hospitals.

All included hospitals are members of the PICC maintenance service network in Hunan province, China. The PICC maintenance service network is a province-wide PICC maintenance alliance led by the intravenous infusion (IV) team of the Xiangya Hospital, Central South University. This network aims to allow patients in the intermission of treatment to select the nearest site to maintain their PICCs instead of returning to the original site where the PICC was placed. This ensures that PICC maintenance is more convenient and cost-effective. The Xiangya Hospital is a university-affiliated hospital with 3,620 beds and a training base for PICC specialist nurses in Hunan Province. The IV team of the Xiangya Hospital began to construct the PICC maintenance network in 2015. To date, 103 maintenance sites have been involved. Each maintenance site has an IV team that is responsible for intravenous nursing training (peripheral venous catheter training, central venous catheter training, PICC training, and PORT training), quality control, and consultation. Each IV team includes a liaison who is responsible for communicating with the IV team in other hospitals.

Participants

Participants were enrolled through a non-random, convenience sampling method. Initially, we contacted the liaisons in every PICC maintenance site and enquired whether they could aid us to carry out the survey. Subsequently, in sites where the liaisons were willing to aid us, registered nurses (RNs) who engaged in clinical work related to intravenous infusion were included. The inclusion criteria were as follows: RNs with more than one year of work experience; RNs who were willing to participate in the research after informed consent; and RNs who can correctly understand the content of the questionnaire. The exclusion criteria were RNs who were receiving psychotropic substances due to mental or psychological illness and RNs who were absent from work due to illness, maternity leave or other reasons.

The sample size was calculated according to the following formula:

$$n = \frac{z_{\alpha/2}^2 \sigma^2}{\delta^2}$$

$Z_{\alpha/2}$ is the abscissa of the normal curve that cuts off an area α at the tails; σ is the population standard derivation, which could be replaced by the sample standard deviation; δ is the margin of error, the value of which is generally 10-60% of the standard deviation. In the present study, these factors were calculated as follows: α=0.05, $Z_{\alpha/2}$=1.96, σ=14.602 (determined by the pre-survey), δ=1.4602 (10%*σ). Therefore, the sample size was estimated to n=384. If nonresponse and invalid response subjects were considered, the sample size was increased by 20%, corresponding to 461.

Survey instrument

In the present study, the survey instrument was a self-designed questionnaire based on an extensive review of literature[8,18,23-25], mainly including the Infusion Therapy Standards of Practice[23] released by the Infusion Nursing Society and the Nursing Practice Standards for Intravenous Therapy[24] issued by the National Health Commission of the people's Republic of China in 2013. Besides, five experts who were PICC specialist nurses and held the position of head of the nursing department or head nurse were consulted to assess the questionnaire's validity. A pretest was carried out to ensure that the questionnaire could be understood easily. The questionnaire included 50 items in total covering five dimensions of PICC maintenance knowledge, including PICC flushing and locking (12 items), replacement of dressings and needle free connectors (eight items), complication management (19 items), health education (six items), and catheter removal (five items). All items were single choice questions. The correct answer was assigned a point of two, otherwise zero was inserted, with a full score of 100. The higher the score, the higher the PICC maintenance knowledge level. The Cronbach's alpha coefficient of this questionnaire was 0.873, and the content validity index (CVI) was 0.915, indicating that the questionnaire had good internal consistency reliability and validity.

In addition, we collected the data of potential factors influencing PICC maintenance knowledge by a self-designed demographic information questionnaire. These included gender, age, professional title, education level, work setting, and previous history of PICC maintenance training.

Implementation

This survey was divided into the two following stages: The recruitment of PICC maintenance sites and the participants and the implementation of the investigation.

In June 2017, we recruited 91 PICC maintenance sites out of 103 eligible sites. After the recruitment of PICC maintenance sites, we provided unified training on our inclusion and exclusion criteria for these liaisons by telephone. The recruitment of the participants was implemented by these liaisons in July 2017. The specific steps used were as follows: Initially, the liaisons explained the purpose of the survey to the head nurses in their facilities to obtain approval and support. Subsequently, the liaisons selected the potential participants according to the study inclusion and exclusion criteria with the help of the head nurses. Finally, the participants were included following their informed consent. All eligible nurses were informed that participation in this study was voluntary. They could withdraw from the study at any time for any reason, and the questionnaire would be answered anonymously based on their own knowledge and understanding of PICC maintenance. Moreover, they were assured that their information would only be used for research, their data would be kept confidential, and their scores of the questionnaire would not have any influence on their career and promotion as their employers could not see their scores.

The investigation was implemented by the liaisons and the head nurses who supported our study. First, we sent the electronic survey link to the liaisons by email and provided unified training on how to fill out the questionnaires by phone. Then the liaisons sent the link to the head nurses in their facilities through WeChat and told

them how to fill it out. Finally, the head nurses sent the link to their Ward WeChat Group, organized the eligible nurses to fill out the questionnaires and aided the completion of the survey. The investigation was administered at 91 PICC maintenance sites at the same time from August 2017 and was kept open for four weeks. During the 4-week period, two e-mail reminders were sent to the liaisons to encourage participation.

Statistical analysis

Descriptive statistics were used to summarize participant characteristics and the knowledge score of PICC maintenance. The Kruskal-Wallis H test was used to compare the correct rate in different dimensions. The knowledge score among nurses with different characteristics was compared using the Wilcoxon rank-sum test for the two-group comparison and the Kruskal-Wallis H test was used for multiple comparisons. The generalized linear model was used for multivariate analysis to identify the demographic factors influencing PICC maintenance knowledge, since the dependent variable (the knowledge score) was not normally distributed. The gamma distribution was selected as the distribution of the dependent variable and the logarithmic function was selected as the link function. All analyses were performed using SPSS V.22.0 and a two-tailed $P < 0.05$ value was considered statistically significant.

Patient and Public Involvement

No patient involved

RESULTS

Participant characteristics

In the present study, a total of 6,524 nurses were eligible to fill out the questionnaires, and 4,110 of these completed them with a response rate of 63.0%. Among 4,110 respondents, the majority were women (98.6%). The largest age group ranged between 25 and 34(51.6%) followed by those aged under 25(30.9%). The majority (75.6%) exhibited a junior professional title. All of them worked in secondary and above hospitals with 29.9% in county hospitals, 46.9% in municipal hospitals and 23.2% in provincial hospitals. Less than half of the subjects (44.6%) reported having received PICC maintenance training previously. (table 1)

Table 1 Demographic characteristics of respondents (n=4,110)

Characteristic	Frequency	Percentage (%)
Gender		
Male	58	1.4
Female	4,052	98.6
Age, years		
＜25	1,268	30.9
25-34	2,120	51.6
35-44	597	14.5
≥45	125	3.0
Professional title		
Nurse	1,554	37.8
Senior nurse	1,555	37.8
Supervisor nurse	848	20.6
Co-chief nurse	153	3.7
Education level		
Technical secondary school	49	1.2
Junior college	1,906	46.4
Undergraduate	2,130	51.8
Postgraduate	25	0.6
Work setting		
County hospital	1,228	29.9
Municipal hospital	1,929	46.9
Provincial hospital	953	23.2
Whether PICC maintenance training was obtained before?		
No	2,277	55.4
Yes	1,833	44.6

PICC，peripherally inserted central catheter.

Table 2 Score and distribution of PICC maintenance knowledge among the 4,110 included nurses

Dimensions	Score ($\bar{x}$±s)	Grade of the total score*			
		Failed, N (%)	Passed, N (%)	Good, N (%)	Total, N (%)
PICC flushing and sealing	18.30±3.67	-	-	-	-
Replacement of dressing and needle free connectors	8.28±3.83	-	-	-	-
Complication management	26.93±7.13	-	-	-	-
Health education	11.28±1.51	-	-	-	-
Catheter removal	8.06±2.13	-	-	-	-
Overall PICC maintenance knowledge	72.86±14.86	679 (16.5)	2030 (49.4)	1401 (34.1)	4110 (100.0)

*Grade of the total score: The total score was divided into three grades. Failed represents the score under 60; Passed represents the score from 60 to 79; Good represents a score of 80 or above.

PICC, peripherally inserted central catheter; N, Number.

Table 3 Statistics and distribution of item correct rate for different dimensions (n=4,110)

Dimensions	Number of items by correct rate, N (%)				Total, N (%)	Correct rate ($\bar{x}$±s)
	＜30%	≥30%,＜60%	≥60%,＜90%	≥90%		
PICC flushing and locking	1(8.3)	1(8.3)	5(41.7)	5(41.7)	12(100.0)	0.76±0.222
Replacement of dressings and needle free connectors	2(25.0)	3(37.5)	3(37.5)	0(0.0)	8(100.0)	0.52±0.248
Complication management	0(0.0)	4(21.1)	13(68.4)	2(10.5)	19(100.0)	0.71±0.167
Health education	0(0.0)	0(0.0)	1(16.7)	5(83.3)	6(100.0)	0.94±0.052
Catheter removal	0(0.0)	0(0.0)	3(60.0)	2(40.0)	5(100.0)	0.81±0.117
Kruskal-Wallis H	17.721					
P value	0.001**					

**: P＜0.01

N, Number.

Table 4 PICC maintenance knowledge score by characteristics (n=4,110)

Characteristics	Score ($\bar{x}\pm s$)	Z/H	P value
Gender		-3.280[a]	0.001[**]
Male	64.55±17.84		
Female	72.98±14.78		
Age, years		314.543[b]	P<0.001
<25	66.53±16.99		
25-34	74.98±12.86		
35-44	78.03±12.39		
≥45	76.29±13.33		
Professional Title		357.421[b]	P<0.001
Nurse	67.42±16.61		
Senior Nurse	74.70±12.84		
Supervisor Nurse	78.27±11.89		
Co-chief Nurse	79.40±11.54		
Education level		204.807[b]	P<0.001
Technical Secondary School	65.55±16.84		
Junior College	69.35±16.58		
Undergraduate	76.15±12.19		
Postgraduate	74.00±14.15		
Work setting		79.721[b]	P<0.001
County Hospital	70.33±14.51		
Municipal Hospital	74.28±14.72		
Provincial Hospital	73.24±15.19		
Whether PICC maintenance training was obtained before?		-17.850[a]	P<0.001
No	69.41±14.84		
Yes	77.14±13.73		

[a]: Z value ; [b]: H value ; [**]: P < 0.01

PICC, peripherally inserted central catheter.

Table 5 Generalized linear model of the factors influencing PICC maintenance knowledge

Factors	B	SE	95% Wald CI Lower	95% Wald CI Upper	Wald χ^2	P value
Gender						
Female	0.082	0.0269	0.029	0.135	9.255	0.002**
Male	Reference					
Age, years						
＜25	-0.054	0.0235	-0.1	-0.007	5.186	0.023*
25-34	-0.003	0.0214	-0.045	0.039	0.014	0.906
35-44	0.009	0.0202	-0.03	0.049	0.212	0.645
≥45	Reference					
Professional title						
Nurse	-0.074	0.0231	-0.119	-0.029	10.281	0.001**
Senior nurse	-0.035	0.0208	-0.076	0.006	2.813	0.094
Supervisor nurse	-0.002	0.0187	-0.039	0.035	0.013	0.909
Co-chief nurse						
Education level						
Technical secondary school	-0.062	0.0504	-0.161	0.036	1.529	0.216
Junior college	0.009	0.0413	-0.072	0.09	0.049	0.824
Undergraduate	0.035	0.041	-0.045	0.116	0.74	0.390
Postgraduate	Reference					
Work setting						
County hospital	-0.028	0.009	-0.046	-0.01	9.768	0.002**
Municipal hospital	0.013	0.0081	-0.003	0.029	2.587	0.108
Provincial hospital	Reference					
Whether PICC maintenance training was obtained before?						
No	-0.075	0.0066	-0.088	-0.062	128.321	P<0.001
Yes	Reference					

**: P＜0.01; *:P<0.05

The independent variables in the generalized linear model were coadded as follows: Gender (Female =0, Male=1), Age (<25=1,25-34=2,35-44=3,≥45=4), Professional title (Nurse=1, Senior nurse=2, Supervisor nurse=3, Co-chief nurse=4), Education level (Technical secondary school=1, Junior college=2, Undergraduate=3, Postgraduate=4), Work setting (County hospital=1, Municipal hospital=2, Provincial hospital=3), Whether PICC maintenance training was obtained before？(No=0, Yes=1)

PICC, peripherally inserted central catheter.

Knowledge of PICC maintenance

The mean score of PICC maintenance among 4,110 nurses was 72.86±14.86. According to the scoring system, 83.5% of them passed the exam with a score of 60 or above and 34.1% of them exhibited a good grade with a score of 80 or above. Table 2 indicated the scores of each dimension and the overall questionnaire and the distribution of the total score.

The correct rate in different dimensions

For dimension "PICC flushing and locking", among 12 items, two items (16.6%) were answered with a correct rate below 60%. The number of items with the correct rate below 60% for dimension "Replacement of dressings and needle free connectors" and "Complication management" was five out of eight (62.5%) and four out of 19 (21.1%), respectively. While for dimension "Health education" and "Catheter removal", all items were answered with a correct rate of 60% or above (table 3). The difference in the correct rate among different dimensions was statistically significant (H=17.721, P<0.01).

Comparison of knowledge score among nurses with different characteristics

As shown in table 4, statistical differences were found in PICC maintenance knowledge score among nurses with different gender, age, professional title, education level and work setting (all P <0.01). The difference in the knowledge score between nurses who had received PICC maintenance training previously and those who had not obtained training was statistically significant (P <0.01). The highest score (higher level of PICC maintenance knowledge) was noted among nurses who were female, aged between 35 and 44 years old with the professional title of co-chief nurse and the education level of undergraduate. In addition, the highest scores were also observed for subjects working in municipal hospitals and those who had received PICC maintenance training previously (table 4).

Multivariate analysis of PICC maintenance knowledge

Multivariate analysis showed that female nurses (B=0.082, P<0.01) exhibited a higher PICC maintenance knowledge score than male nurses. A lower level of PICC maintenance knowledge was noted for nurses under 25 years of age (B=-0.054, P<0.05), those with a professional title of nurse (B=-0.074, P<0.01), those working in county hospitals (B=-0.028, P<0.01) and those who had not received PICC maintenance training previously (B=-0.075, P<0.01) compared with the nurses aged 45 years old or above, those with a professional title of co-chief nurse, those working in provincial hospitals and those who had received PICC maintenance training before, respectively (table 5)

DISCUSSION

The present study demonstrated that the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, with a mean score of 72.86±14.86. 83.5% of nurses passed the exam with a score of 60 or above and 34.1% of them exhibited a good grade with a score of 80 or above, which was lower than that (88.9% and 47.2%) previously reported by Wu et al[26]. This difference may result from the difference in the demographic data of the subjects. The subjects of the present study

involved nurses of Grade Ⅱ hospitals and Grade Ⅲ hospitals, while the nurses in the study by Wu et al were all from Grade III Level A hospitals. This enabled the latter to have more opportunities to learn new technologies including PICC maintenance. The gap of PICC maintenance knowledge between nurses in Hunan province and those in other regions requires the attention of nursing managers, and appropriate strategies should be taken to increase their knowledge.

The nurses' level of mastery toward different dimensions was different, with the maximum correct rate of health education (90.94±0.052), followed by catheter removal (0.81±0.117), PICC flushing and locking (0.76±0.222), and complication management (0.71±0.167). The correct rate of replacement of dressings and needle free connectors was the minimum (0.52±0.248) among the five dimensions. The correct rate of health education that ranked the first may be due to its uniqueness. Unlike other dimensions, health education is usually considered the transfer of knowledge without clinical operation, which is simple and easy to master. Moreover, the nurses have to repeat the knowledge again and again when educating the patients with PICC, which will strengthen their memory of the knowledge. The dimension with the minimum correct rate was the replacement of dressings and needle free connectors, which was inconsistent with that reported by Oliveira et al[3]. This study reported that the criteria associated with the dressing of PICC and the change of administration sets indicated a moderate to high compliance. Sharpe et al [8] also reported that a majority of nurses could perform well in the PICC dressings change. The difference between our findings and those of others is probably attributed to the simple way of the replacement of dressings and needle free connectors, a way that the nurses often operate according to their clinical experience, neglecting the learning toward the standardized theoretical knowledge. The gap in the mastery level toward the replacement of dressings and needle free connectors between nurses in Hunan province and those in other regions (e.g., Sao Paulo, Brazil[3]) is evident. Therefore, this is a barrier that needs to be taken into consideration for nursing education and training in clinical practice. Other dimensions, such as catheter removal, PICC flushing and locking, and complication management, which exhibited a medium to high level of mastery, should not be ignored during training as they also directly affect patient safety.

The factors influencing the nurses' PICC maintenance knowledge included gender, age, professional title, work setting, and previous history of PICC maintenance training. Female nurses exhibited higher PICC maintenance knowledge scores than male nurses, whereas nurses under 25 years old reported a lower level of PICC maintenance knowledge compared with those aged 45 years old or above. We did not find similar findings in other studies. Since the number of male nurses responding to the questionnaire was considerably low (1.4%), it was unnecessary to speculate the reason for this poor performance. With regard to the contribution of the parameter age, the reason for these observations may be related to the work experience. However, Chopra et al[22] demonstrated no statistical difference in the knowledge of vascular nurses based on years of experience, which was possibly attributed to the small sample size. Therefore, the reason for this required further exploration.

The present study demonstrated that nurses with a professional nurse title exhibited a lower PICC maintenance knowledge score than those with a professional co-chief nurse title. This is not surprising as nurses with senior professional titles usually possess a higher number of study and communication opportunities, which enables them to acquire additional knowledge on specialized nursing. In addition, nurses with senior professional titles often undertake clinical teaching work and gain experience when teaching interns PICC maintenance.

The most significant finding of the present study was that nurses working in county hospitals reported a lower level of PICC maintenance knowledge compared with those working in provincial hospitals. This may be due to the recent introduction of PICC maintenance technology in county hospitals. In China, specialized nursing technologies, such as PICC catheterization and maintenance, are initially carried out by provincial hospitals and are subsequently promoted to municipal hospitals. An increasing number of county hospitals have introduced PICC maintenance technology due to the increased use of PICCs in recent years.

To the best of our knowledge, this study is the first to compare nurses' PICC maintenance knowledge among hospitals at different levels. In consideration of the gap in the PICC maintenance knowledge between county hospitals and provincial hospitals, particular attention must be made to narrow the gap and to provide consolidated nursing for patients with PICC.

The present study further showed that nurses who had not received PICC maintenance training previously reported a lower level of PICC maintenance knowledge compared with those who received previous training, indicating that training is an effective way to enhance nurses' knowledge of PICC maintenance, which was consistent with the results reported by Roslien et al[27]and Purran et al[28]. Through systematic and standardized PICC training[29], nurses can acquire basic knowledge of vascular anatomy, ultrasound and radiographic data evaluation skills, PICC catheterization and maintenance standard procedures, and various emergency response and complication management processes, which could effectively decrease catheter-related complications and improve patient safety.

The present study has some limitations. Firstly, despite using a large sample size, the study design included a cross-sectional survey and was conducted using a convenience sampling method. Therefore, nonresponse and selection biases may be a threat to our conclusion. Secondly, we investigated nurses in hospitals that had introduced PICC maintenance technology. Therefore, the findings may not be representative of the knowledge level of all nurses in Hunan province but to reflect the group with a higher level of PICC maintenance knowledge. A similar survey should be designed in the future to aim at nurses in hospitals that have not introduced PICC maintenance technology. In addition, although the quality control procedure was used throughout the data collection and entry, potential information bias may have occurred in view of the survey based on self-reported data. Finally, as mentioned in the first half of the discussion, some general information that may include factors influencing the nurses' PICC maintenance knowledge were not collected, such as years of experience. This affected our conclusion to some extent.

CONCLUSIONS

In conclusion, the knowledge of PICC maintenance was at a medium level among nurses in Hunan province, China, and this was mainly influenced by their gender, age, professional title, work setting, and previous history of PICC maintenance training. However, it is important to note that the theoretical knowledge of PICC maintenance, notably in the form of guidelines, is freely available to nurses and has been used to educate nurses by the IV team of the Xiangya Hospital within the PICC maintenance network. Therefore, the PICC maintenance knowledge of the nurses at all professional levels in all work settings could be improved. To improve the nurses' PICC maintenance knowledge, certain steps must be implemented including dissemination of the PICC maintenance knowledge in multiple ways, such as courses, lectures, seminars, and new media. Particular attention must be provided to populations who responded poorly in this survey, and targeted education for nurses should also be distributed based on their performance on specific dimensions, such as the replacement of dressing and needle free connectors.

In addition, since the quality of the nurses' practical performance of PICC maintenance has a more direct impact on improving PICC related outcomes, a study that measures nurse's practical performance should be conducted in the future. It can be measured directly by observation at bedside according to the standardized PICC maintenance order sets and checklist. It can also be measured indirectly by the PICC indwelling time, the incidence of PICC-related complications, and patient satisfaction. Finally, additional measurement methods could be explored in future studies.

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Author Contributions BBX, JHZ, and SYT contributed to the study conception and design, and questionnaire development. BBX and JHZ contributed to data collection, analysis, interpretation, and manuscript drafting. BBX, JMH, and MDM contributed to the literature search and data collection. BBX and ZHG contributed to data collection and management. All authors contributed to manuscript drafting and revising and approved the final version.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study was approved by the IRB of behavioral and nursing research in School of Nursing of CSU (No 2017038).

Provenance and peer review Not commissioned; externally peer reviewed.
Data sharing statement Extra data can be extracted by emailing the first author BBX.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	n/a,

		(*d*) If applicable, describe analytical methods taking account of sampling strategy	4
		(*e*) Describe any sensitivity analyses	n/a,
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	n/a, the questionnaire link was sent to the WeChat group, and the targeted nurses filled it out based on their willing. Thus, we cannot collect the information of non-participation.
		(c) Consider use of a flow diagram	n/a, we didn't use the flow diagram in our manuscript.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	n/a, the questionnaire cannot be submitted if it was not be filled completely, so there were no missing values in the returned questionnaire.
Outcome data	15*	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11
		(*b*) Report category boundaries when continuous variables were categorized	11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	11,12,13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or	13

		imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12,13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13,14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.