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Evidence-based summary of preventive care for central venous access device-related thrombosis in hospitalized children

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Abstract

Purpose This study aims to summarize the latest and best evidence on central venous access device-related thrombosis (CRT) in hospitalized children, which provides theoretical support for standardizing the preventive care practice of CRT in hospitalized children.

Methods Relevant guidelines, systematic reviews and expert consensuses were reviewed through ten guideline websites, six professional association websites and seven databases. The literature evaluation was conducted, and the best evidence from qualified studies was extracted and summarized. Furthermore, the best evidence was summarized through expert consultation and localized for the preventive care practice of CRT in hospitalized children in China.

Results A total of 14 topics and 68 best evidence were collected, including personnel qualification and quality management, pediatric patient selection, risk assessment, central venous access device (CVAD) selection and use, tip position, catheter maintenance, basic prevention, drug prevention, imaging examination, health education, nursing records, follow-up, CVAD removal and others.

Conclusion In this study, the best evidence based on evidence-based nursing was summarized, and expert consultation was adopted to localize the best evidence collected. It is of great significance to standardize the clinical practice of pediatric nurses and ensure the effectiveness of CRT preventive care for hospitalized children, thus guaranteeing the safety of hospitalized children with CVAD catheterization.

Keywords Central venous access device-related thrombosis, Hospitalized children, Evidence-based nursing, Evidence summary, Expert consultation

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What is known

- CVAD is considered as the most significant risk factor of VTE in hospitalized children.
- Asymptomatic CRTs are reported to be more common than symptomatic CRTs and have a significantly increased risk of death.
- To the best of our knowledge, no clinical practice guidelines on CRT preventive care for children have been issued in China.

What is new

- The best evidence on the preventive care of CRT in hospitalized children could be used to provide pediatric nurses with an evidence-based reference in clinical practice.
- Evidence-based guidelines, systematic reviews and expert consensus endorsed by several authoritative academic resources were included by scientific methods to provide the best theoretical basis and technical standards for pediatric nurses to strengthen the risk prevention and management of CRT in hospitalized children, and guarantees the safety of children with tubes.

Introduction

The statistics indicate that about 25% of hospitalized children have received the central venous access device (CVAD) for treatment [1]. The employment of CVAD has strongly improved the quality of treatment and nursing care for hospitalized children. However, CVAD remains the most significant risk factor of venous thromboembolism (VTE) in hospitalized children, with almost 90% of neonatal VTE and more than 60% of non-neonatal VTE associated with CVAD [2]. The VTE caused by CVAD is also known as central venous access device-related thrombosis (CRT), and the incidence of CRT has increased obviously in recent years [3]. Prospective studies from China [4], Austria [5], Spain [6], and the United States [7] show that the incidence of CRT in hospitalized children is 25.7%, 27.78%, 33.21%, and 43.53%, respectively; the studies from Canada indicate that the incidence of CRT in children receiving total parenteral nutrition (TPN) is as high as 66.67% [8].

The CRT may be symptomatic for patients, with symptoms and signs related to inflammation or vascular obstruction, such as swelling and pain of arm/neck/head, vein dilation, skin pigmentation, extremity numbness, and CVAD dysfunction can lead to difficulties or even failure in venous blood collection or intravenous medication [9]. When the lower extremities are involved in CRT, acute life-threatening complications represented by deep venous thrombosis (DVT) and pulmonary embolism (PE) can occur, and its sequela includes recurrent thrombosis, postphlebitic syndrome, and complications of anticoagulant therapy [10]. The incidence of the long-term complications like post-thrombotic syndrome (PTS) and loss of limb function are also possible [11]. However, some CRT may be completely asymptomatic and only can be detected only by imaging techniques. Asymptomatic CRTs are reported to be more common than symptomatic CRTs and have a significantly increased risk of death [9]. There is a strong association between asymptomatic CRT and catheter complications like occlusion and infection related to CVAD [12]. These complications can not only increase medical costs but also prolong the hospital stay of patients and worsen the conditions requiring urgent systemic treatment or CVAD removal [13].

In essence, CRT is a response to the placement of foreign bodies (i.e. the CVAD) in blood vessels [3]. Nevertheless, clinical staff can take rational and objective approaches to prevent thrombosis based on a full understanding of CRT. Clinical nurses play a key role in the prevention of VTE by assessing, delineating risks, collecting information, providing advice and implementing preventive care for patients [14]. As a special type of VTE, CRT is closely related to the implanted CVAD in terms of etiology. However, the role of CVAD in clinical use should also be considered in the treatment [3]. Due to improper awareness and management of CRT, the psychological burden on healthcare workers, children and their families may be increased, leading to over-diagnosis and over-prevention. As a result, the application of CVAD is also hindered to some extent.

Evidence-based clinical practice guidelines are of great significance for standardizing the clinical work of nurses and providing patients with rational nursing care [15]. Currently, research on clinical practice guidelines related to VTE prevention for patients has received wide attention. It is found that guidelines specifically aimed at health care providers, especially nurses, for CRT preventive care in hospitalized children are limited. The only clinical practice guideline that recommends the use of a long-term central venous catheter (CVC) in children with hematologic oncology focuses on the treatment of occlusions and thrombosis associated with CVC, rather than CRT preventive care [13]. However, considering the actual situation of China's medical environment, the willingness of the children's families, and the favorable and hindering factors for pediatric nurses to use evidence-based evidence, whether the norms and standards involved in the foreign guidelines are applicable to China remains to be further explored. Moreover, no clinical practice guidelines on CRT preventive care for children have been issued in China. Therefore, this study summarizes the best evidence of the preventive care of CRT in hospitalized children based on evidence-based nursing and localizes the collected evidence by expert

consultation methods, so as to provide scientific CRT prevention for hospitalized children.

Methods

The study has been enrolled in PROSPERO under the registration number of CRD42021265475.

Retrieval strategy

In this study, search terms of "venous thromboembolism, venous thrombosis, totally implantable venous access port, central venous catheters, peripherally inserted central catheter, central venous access device" were employed to retrieve the following guidelines and professional association websites: ① guideline websites: Guidelines International Network (GIN), Registered Nurses' Association of Ontario (RNAO), National Guideline Clearinghouse (NGC), National Institute for Health and Clinical Excellence (NICE), Joanna Briggs Institutem (JBI), Scottish Intercollegiate Guidelines Network (SIGN), New Zealand Guidelines Group (NZGG), British Medical Journals (BMJ), UpToDate, and Medlive guide; ② professional association websites: Infusion Nursing Society (INS), International Union of Angiology (IUA), International Society on Thrombosis and Haemostasis (ISTH), American Society of Hematology (ASH), American Society of Pediatric Hematology/Oncology (ASPHO) and Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN). The search of the guidelines and professional association websites was completed from July 18, 2021 to July 22, 2021.

We searched the Cochrane Library, PubMed, EMBASE and Web of Science English databases, as well as VIP, Wanfang and CNKI Chinese databases. The specific retrieval strategy was formulated according to the characteristics of each database. The time limit for database retrieval was from the establishment of each database to July 17, 2021, and the retrieval strategy was attached in Supplemental Material S1.

Literature inclusion and exclusion criteria

The inclusion criteria of the literature were as follows: (1) Published guidelines, systematic reviews and expert consensus; (2) Children (≤18 years old) with CVAD catheterization included in these studies; (3) Recommendations on risk factor assessment, prevention and management of CRT in children; (4) Clear recommendation; (5) Expressed in Chinese or English; (6) The revised guidelines should be incorporated into the latest version.

The exclusion criteria of the literature were as follows: (1) Guideline interpretation, translated versions of foreign guidelines and repeated guidelines; (2) Meeting summaries, draft guidelines, discussion drafts, and other relevant documents of guidelines; (3) Clinical practice implementation and application research of the guidelines; (4) Evidence list without methodological description; (5) Conference report, normative document and government draft; (6) Systematic reviews at the stage of the research plan or included in the guidelines; (7) No access to the full text.

Literature screening and data extraction

According to the inclusion and exclusion criteria of the literature, two members of the research group who have received evidence-based nursing training independently screened the literature by reading the title, abstract and full text. If there was any disagreement, the two researchers should negotiate to resolve it. If they still cannot reach an agreement, the third researcher should be asked to step in and give his/her opinions. The data extraction table was made by the following items: articles (type), author/institution/organization, year (published/last updated), country, source (published institution/organization) and tools for evidence grading and recommendation strength.

Literature quality evaluation

The quality of the included articles was evaluated independently by three members of the research group trained in evidence-based nursing through the evaluation tools. If there was a conflict of opinion, the fourth member would be asked to make the judgment.

The evaluation of the Guidelines was conducted by the Appraisal of Guidelines for Research and Evaluation II (AGREE II) [16]. The AGREE II covers six aspects: scope and object, participant, rigor, clarity, application, and independence. Based on the standardized scores in each field, the overall quality of the guidelines was evaluated, and whether to recommend the guidelines was formulated by the 3-level standards. The criteria are as follows [17, 18]: if the number of fields with a standardized score < 30% was greater than or equal to three, the guideline is considered to have poor evidence quality and is not recommended temporarily (Grade C); if there were fields with standardized scores < 60%, and the number of fields with scores ≥ 30% was greater than or equal to three, the guideline needs to be modified and then it is recommended (Grade B); if standardized scores in the six fields were all ≥ 60%, the guideline does not need to be modified and can be directly recommended (Grade A).

The systematic review was assessed by a critical appraisal tool for systematic reviews (AMSTAR 2) scale [19]. In the AMSTAR 2 scale, there are 16 items (items 2, 4, 7, 9, 11, 13 and 15 are critical items and the remaining are noncritical items) and 3 evaluation indexes ("Yes", "Partly yes", and "No"). Based on the criticality and evaluation results, the systematic review study was graded

with "confidence", and there were four "confidence" quality levels, namely critically low-quality, low-quality, intermediate-quality and high-quality. The detailed classification of four "confidence" quality levels is as follows [19, 20]: if there is more than one key item with or without non-key items and does not meet the standard, the systematic review is rated as critically low; if only there is one key item accompanied by or not accompanied by non-key items and does not meet the standard, this systematic review is rated as low grade; if there are more than one non-key items and does not meet the standard, this systematic review is rated as intermediate; if there is less than one or equal to one noncritical item and does not meet the standard, this systematic review is rated as high.

The Expert Evaluation Standard (2016) of the JBI Evidence-based Health Care Center in Australia was used to evaluate studies based on expert opinions and professional consensus. The evaluation standard included 6 items, and the evaluation grade of each item was "yes", "no", "unclear" and "not applicable" [21]. The inclusion criteria of the literature were as follows [22]: at least four of the six items were rated "yes". The exclusion criteria of the literature were as follows: at least two of the six items had an evaluation grade of "unclear" or included an evaluation grade of "not applicable".

Evidence quality evaluation process

Content analysis was used to analyze the included articles. Taking the included articles as analysis samples, the main evidence of CRT preventive care in children was summarized, and the topic/sub-topic of the evidence was determined. In the process of extracting recommendations, when there were conflicting evidence conclusions from different sources, this study complied with the following principles [23]: evidence-based outcome, high-quality evidence, the latest published authoritative literature and guidelines authorized by Chinese institutions were preferred. Two trained members of the research group independently evaluated the included studies. In case of conflicting opinions, the third researcher made the final decision on inclusion or exclusion.

Criteria for determining evidence level and recommendation level

The recommendation level of the evidence follows the original rating level in the studies. If there are repeated recommendations in multiple guidelines, the guideline with the highest score will be selected based on the quality evaluation result of AGREE II scale, and the recommendation of evidence level in the guideline shall prevail. If the level and recommendation level of evidence in the original literature is not determined, the evidence will be evaluated by the JBI grading of evidence and recommendation system (2014 edition) [24]. According to the source of evidence and the type of literature, the evidence level of the included studies was pre-graded into five levels from Level 1 to Level 5. According to JBI feasibility, appropriateness, mean-fullness, and effectiveness (FAME) structure, the recommendation strength of evidence was determined to be strong recommendation or weak recommendation.

Expert consultation

In this study, relevant experts were invited to participate in online and offline meetings to collectively discuss the best evidence extracted. Ten experts from the Xiangya Nursing School and Xiangya Hospital of Central South University from different fields participated in this study, covering CVAD placement care, pediatric nursing, cardiovascular surgery nursing, nursing management, evidence-based nursing, nursing education, cardiovascular surgery and pharmacy. Xiangya Hospital is one of the China's top tertiary class A general hospitals, integrating medical, educational and scientific research. JBI Xiangya Center for Evidence-Based Practice and Healthcare Innovation was established in 2019, serving as an excellent platform for evidence-based nursing research in this study. The purpose of expert consultation is to analyze the pros and cons and obstacles of nurses' application of evidence based on medical situation in China and the wishes of the children's families, improve relevant evidence or remove inapplicable evidence according to clinical applicability, and finally localize the best evidence.

Data analysis

The SPSS 20.0 was used for statistical analysis. The basic characteristics of the included articles were analyzed descriptively. In the quality evaluation process of the guidelines, the intraclass correlation coefficient (ICC) ranging from 0 to 1.0 was used to evaluate the consistency of evaluation results among the three members of the research group [25]. When the ICC value is less than 0.40, it indicates that there is poor consistency among study members regarding the quality evaluation results of the guideline. If the ICC value ranges from 0.40 to 0.75, the consistency among the three members is fair. If the ICC value is greater than 0.75, the consistency among the three members is high [26]. The standardized score for each area of the guideline can be calculated by the following equation: (actual score—minimum possible score)/(maximum possible score—minimum possible score) × 100%. Then, the mean, minimum and maximum values were used to describe the standardized scores in each field. The general information of experts

was analyzed by mean ± standard deviation or frequency (%), and the expert consultation results were evaluated by the authority degree of expert opinions. The individual authority coefficient of the expert was calculated as: (academic level + judgment basis + familiarity) /3. The overall authority coefficient of experts was calculated by the ratio of the sum of experts' individual authority coefficients to the number of experts [27].

Results

Selection process and general characteristics of the included articles

A total of 642 articles were initially retrieved. Based on the inclusion and exclusion criteria, 7 evidence-based guidelines, 7 systematic reviews and 9 expert consensuses were eventually included. Figure 1 shows the process of literature selection. Table 1 presents the basic features of the literature.

Quality evaluation results of the included articles

Quality evaluation results of the guidelines

Consistency tests for the intra-group correlation coefficients included in the guidelines were conducted. The results show that the ICC value of the guideline quality evaluation results of the three evaluators was all greater than 0.75 ($P < 0.05$), indicating good consistency among the evaluators in the evaluation process, as shown in Table 2. Table 3 shows the standardized scores for the six areas of the guidelines. Among the six fields, the overall average score of five fields is more than 50%, among which the average score of the "clarity" field is the highest (90.48%), followed by the "independence" field (85.71%), and the average score of "application" field is the lowest (42.66%). The overall evaluation results are as follows: 1 guideline is grade A and highly recommended, and the remaining 6 guidelines are grade B and recommended to be used in clinical practice after modification.

Quality evaluation results of systematic reviews

Among the 7 systematic reviews included in this study, the overall confidence of the study conducted by Barco et al. [34] is evaluated as "low", studies conducted by Sharathkumar et al. [38] and Wang et al. [39] as "critically low", and the rest as "high" [35–37, 40]. In terms of critical entries, 2 studies [34, 39] are not registered in advance, and 4 [34–37] studies contain the comprehensive retrieval. Schoot et al. [36] only provided a list of excluded articles without elaborating on the exclusion reasons. Barco et al. [34] did not merge the data due to an insufficient number of included studies, and Sharathkumar et al. [38] did not consider the risk bias. In the other 3 studies [35–37], the publication bias was fully analyzed. Supplemental Table S1 shows the quality evaluation results of systematic reviews by AMSTAR II. The articles were all included.

Quality evaluation results of expert consensuses

There are 9 expert consensuses included in this study. Consensus 2 [13] pointed out that CVC should be inserted into the superior vena cava system in the right limb (if possible) to prevent CRT. Consensus 3 [42] proposed that CVC should be inserted into the right internal jugular vein, which is inconsistent with the major opinions that CVC inserted from the left and right side of the

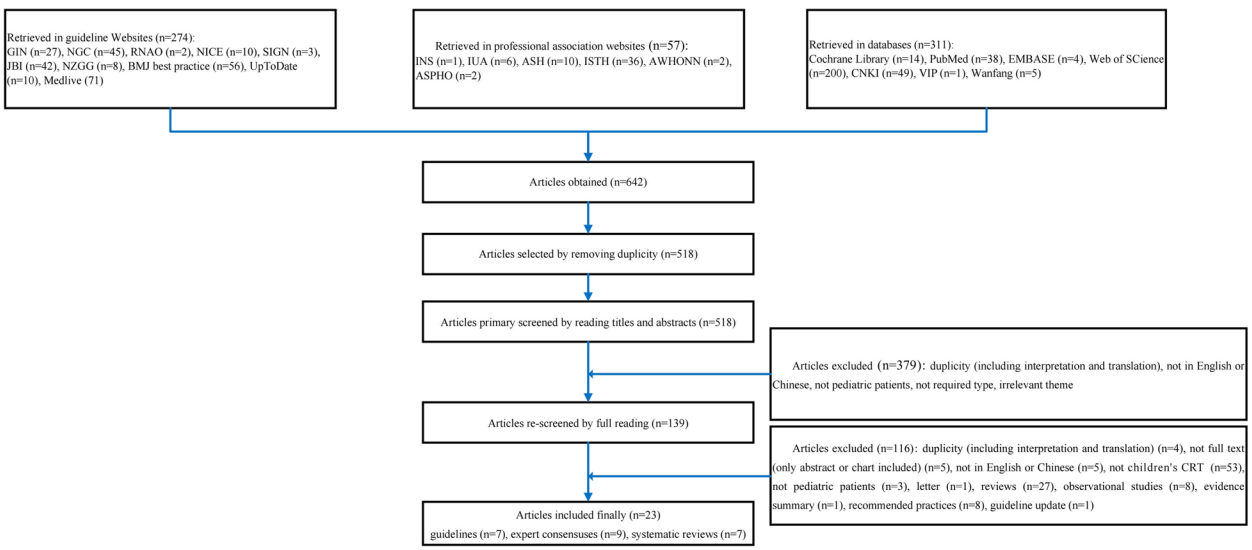

Fig. 1 Flowchart of literature screening

Table 1 General information of included articles

Articles	Author/Institution/Organization	Year	Country	Source	Tools for evidence grading and recommendation strength
Guideline 1 [28]	Hartman et al	2018	Israel, United Kingdom, Hungary, China, etc	Web of Science	GRADE
Guideline 2 [2]	Monagle et al	2018	Australia, Canada, Mexico, United States, etc	PubMed	GRADE
Guideline 3 [29]	Sibson et al	2018	United Kingdom	Web of Science	GRADE
Guideline 4 [30]	ASCO	2013	United States	GIN	Jadad
Guideline 5 [31]	Expert Committee of Guidelines for Prevention and Treatment of Thrombotic Diseases in China	2018	China	CNKI	GRADE
Guideline 6 [32]	American College of Chest Physicians	2012	United States	BMJ best practice	GRADE
Guideline 7 [33]	Working group on evidence-based guidelines for clinical practice of intravenous infusion therapy in children	2021	China	CNKI	GRADE
Systematic review 1 [34]	Barco et al	2017	Netherlands, Germany	Web of Science	—
Systematic review 2 [35]	Brandão LR, Shah N, Shah PS	2014	Canada	The Cochrane Library	—
Systematic review 3 [36]	Schoot et al	2013	Netherlands	The Cochrane Library	—
Systematic review 4 [37]	Shah PS, Shah N	2014	Canada	The Cochrane Library	—
Systematic review 5 [38]	Sharathkumar et al	2020	United States, United Kingdom, Canada, Austria, Israel	Web of Science	—
Systematic review 6 [39]	Wang et al	2020	China	CNKI	GRADE
Systematic review 7 [40]	Tian et al	2020	China	Web of Science	—
Expert consensus 1 [41]	Ewenstein et al	2004	United States	Web of Science	The rating system adopted has been modelled on that of the US Centers for Disease Control and Prevention (CDC)
Expert consensus 2 [13]	Giordano et al	2015	Italy	Web of Science	Infectious Diseases Society of America (IDSA) -United States Public Health Service grading system for ranking recommendations
Expert consensus 3 [42]	ITAC-CME	2013	International	Medlive	GRADE
Expert consensus 4 [43]	Expert Committee of Thrombosis and Vascular Special Fund of China Health Promotion Foundation	2020	China	Medlive	—
Expert consensus 5 [44]	Shanghai Cooperation Group on Central Venous Access; Expert Committee on Vascular Access, Committee of Experts on Focused Diagnosis and Treatment of Solid Tumors, Shanghai Anti-Cancer Association	2019	China	Medlive	—
Expert consensus 6 [3]	Chinese Chapter of the International of Angiology; Peripheral Vascular Disease Chapter, Chinese Geriatrics Society	2020	China	Medlive	—
Expert consensus 7 [45]	Chinese College of Interventionalists	2019	China	Medlive	—

Table 1 (continued)

Articles	Author/Institution/Organization	Year	Country	Source	Tools for evidence grading and recommendation strength
Expert consensus 8 [46]	Zhejiang Implantable Venous Access Port Collaboration Group(ZIVAPCG)	2018	China	CNKI	—
Expert consensus 9 [47]	The Expert Group on Safety Management o f Central Venous Access Device	2020	China	Medlive	GRADE

—: None

Table 2 Results of internal consistency (ICC) test of evaluators

Guideline	ICC	95%CI	*F*	*P*
Guideline 1 [28]	0.914	(0.838,0.959)	32.611	0.000
Guideline 2 [2]	0.858	(0.738,0.932)	20.612	0.000
Guideline 3 [29]	0.898	(0.807,0.952)	29.449	0.000
Guideline 4 [30]	0.786	(0.602,0.897)	14.572	0.000
Guideline 5 [31]	0.840	(0.712,0.922)	16.400	0.000
Guideline 6 [32]	0.923	(0.845,0.965)	42.887	0.000
Guideline 7 [33]	0.804	(0.640,0.906)	15.480	0.000

body exists no difference in reducing CRT from other consensuses. Among all the items included in the study, at least 4 items were evaluated as "Yes", and the overall evaluation was high. Therefore, these studies were all included (Supplemental Table S2).

Summary and localization of the best evidence for CRT preventive care in hospitalized children

A total of 91 evidence were extracted and summarized in the first draft by using the method of content analysis. Evidence grading and recommendation strength were carried out in accordance with the principle of setting the evidence and recommendation levels in advance. Expert consultation was further carried out to localize the summarized evidence. The average age of experts was (41.40 ± 7.34) years old, and the average working years were (19.30 ± 12.00) years (Supplemental Table S3). The individual authority coefficient of 10 experts in this study was > 0.70, and the overall authority coefficient of the experts was 0.815, indicating that they have highly authoritative and the research results were acceptable (Supplemental Table S4). We revised and localized the items according to suggestions from experts. Finally, 68 best evidence were obtained from 14 topics, including personnel qualifications and quality management, pediatric patient selection, risk assessment, CVAD selection and use, tip position, catheter maintenance, basic prevention, drug prevention, imaging examination, health education, nursing records, follow-up, CVAD removal and others, as shown in Table 4.

Summary and description of best evidence

In this study, the best evidence conforming to the Chinese clinical situation for CRT preventive care in hospitalized children was summarized through comprehensive retrieval, systematic evaluation and expert analysis of relevant evidence-based resources. This provides a theoretical basis for Chinese pediatric nurses to strengthen the management of CRT in hospitalized children.

Personnel qualification and quality management

Articles 1–5 of the evidence summarize how to guarantee the personnel qualifications responsible for the management of CVAD, three of which are strong recommendations. It is necessary to construct a professional team for intravenous therapy to promote the establishment and implementation of standardized evidence-based practice protocols and policies [33]. The characteristics of different hospitals should be considered, such as the differences in hospital level, type (general hospital or specialized hospital), and the abilities of members of the intravenous therapy team, and then the training program should be developed in accordance with the characteristics of the hospital and the stage of the intravenous therapy team members. It is suggested to improve the quality control responsibility by establishing an evaluation index system, supervision system and improvement system for intravenous therapy [33].

Pediatric patient selection

Articles 6–7 provide a summary of the topic. CVAD is appropriate for individuals who require reliable long-term

Table 3 Quality evaluation results of the guidelines

Guidelines	Percentage of field standardization (%)						≥ 60% field number (n)	≤ 30% field number (n)	Recommendation level
	Scope and object	Participant	Rigor	Clarity	Application	Independence			
Guideline 1 [28]	62.96	62.96	84.03	92.59	25.00	72.22	5	1	B
Guideline 2 [2]	87.04	96.30	69.44	88.89	87.50	77.78	6	0	A
Guideline 3 [29]	64.81	24.07	68.75	87.03	25.00	97.22	4	2	B
Guideline 4 [30]	92.59	87.03	92.36	88.89	47.22	100	5	0	B
Guideline 5 [31]	88.89	87.04	68.75	88.89	27.78	72.22	5	1	B
Guideline 6 [32]	75.93	33.33	46.52	90.74	29.17	83.33	3	1	B
Guideline 7 [33]	81.48	88.89	85.42	96.30	56.94	97.22	5	0	B
Mean	79.10	68.52	73.61	90.48	42.66	85.71	—	—	—

—: None

Table 4 The final version of evidence-based nursing program for CRT preventive care in hospitalized children

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
Personnel qualification and quality management	Responsible Team	1. For pediatric specialty hospitals, it is recommended to construct a pediatric intravenous access management team. For comprehensive hospitals with pediatric specialties, there must be pediatric nurses playing a role in the intravenous access management team at least. If the comprehensive hospital has large pediatric departments (100 beds), a separate pediatric intravenous access management team can also be considered [33]	GRADE	D	Strong
		2. The placement, use and maintenance of CVAD should be conducted by qualified and trained professionals [47]	GRADE	D	Strong
	Personnel Training	3. It is recommended to establish a nurse training system to prevent CRT blockage [47]	GRADE	B	Weak
		4. It is recommended to develop evaluation indicators for the core competency of the use and maintenance of CVAD, conduct systematic theoretical courses, formulate standard operating procedures, and implement rigorous assessment and evaluation, to improve the quality of training [47]	GRADE	B	Strong
	Quality control	5. It is recommended to set up an intravenous infusion safety management committee, develop a perfect infusion management system, and establish quality control systems such as an intravenous infusion transmission network system, to reduce the occurrence of catheter-related complications [47]	GRADE	A	Strong
Pediatric patient selection		6. CVADs should be reserved only for the medical needs of individual pediatric patients [41]	CDC	D	Weak
		7. CVAD placement should remain for individuals whose families express a willingness and commitment to master the required skills and are expected to exercise diligence in the care of the CVAD [41]	CDC	C	Strong

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
Risk assessment		8. Caregivers and healthcare professionals should maintain a great suspicion index for the presence of CRT [41]	CDC	A	Strong
		9. Pediatric CRT diagnosed on the basis of ultrasound is usually asymptomatic [33]	GRADE	B	Strong
		10. Thrombotic and bleeding risk assessments are recommended for children who need CVAD [43]	JBI	5b	Strong
		11. In the development of pediatric CRT, non-tunneled catheters, and antibiotic therapy are protective. History of thrombosis, gastrointestinal/liver disease, hematologic disease (e.g., ALL), tumors, sepsis, hemodialysis, ECMO, cardiac catheterization, PN/TPN, PICC placement (compared to tunneled catheters and PORT), femoral vein placement (compared to subclavian vein placement), multiple catheters, multiple catheter lumens, CLABSI, catheter dysfunction, and long-term indwelling catheter are risk factors [39, 40, 43]	GRADE	D	Strong
		12. Routine screening for thrombotic disease is currently not warranted until the first CVAD is placed, unless the individual has experienced a catheter-independent thromboembolic event [41]	CDC	A	Strong
CVAD selection and use	Size	13. The infusion device with the least number of lumens and the minimum diameter should be selected under meeting the therapeutic needs [3]	JBI	5b	Strong
		14. Catheters should be selected according to the conditions of the vessel to be placed, and the recommended ratio of the outer diameter of catheter to the inner diameter of the placed vein is ≤ 0.45% [3]	JBI	3c	Strong
	Type	15. PICC could be selected for neonates, very low and ultra-low birth weight infants [47]	GRADE	A	Strong

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
		16. For children requiring a CVAD and at a high risk of CRT, an internal device (PORT) should be prioritized over an external tunneling device (Hickman or Broviac catheter) [29]	GRADE	B	Weak
		17. Until further pediatric data are available, we recommend that tunneled lines can be preferred to PICC in children with cancer where feasible [29]	GRADE	B	Weak
		18. It is suggested that children with chronic kidney disease (whether or not they are in the end-stage) should consult with the physician about the plan of hemodialysis vascular access before indwelling the catheter, and determine the location and type of catheter after a thorough weighing of the pros and cons [3]	JBI	5b	Strong
	Site	19. It is suggested that CVAD be placed from either left or right, and the jugular vein, subclavian vein, cephalic arm vein and femoral vein should be considered in turn to reduce the risk of CRT [29, 30, 33]	GRADE	B	Strong
	Puncture	20. Ultrasound-guided puncture is recommended for central venous catheterization [33]	GRADE	C	Strong
		21. Ultrasound-assisted internal jugular vein puncture is preferred for PORT. Localization with the help of an X-ray is recommended. For neonates, echocardiography and electrocardiography can also be used [44]	JBI	3d	Strong
		22. The recommended location of PORT placed into the child is below the clavicle and above the 5th intercostal space [33]	GRADE	D	Weak
	Fixation	23. It is suggested CVAD be secured with complete dressings, StatLock, polyurethane clear dressings, or tissue adhesives [33]	GRADE	D	Strong

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
	Time	24. For children with ALL, it is not necessary to delay CVAD placement until the termination of ALL induction therapy. The decision regarding placement timing should also consider the physical and psychological consequences of delayed placement in individuals with poor venous access [29]	GRADE	B	Weak
Tip position		25. The safest location of the tips is the junction of the superior vena cava and the superior wall of the right atrium. For CVADs placed in the lower extremities, the tips should be located above the diaphragm in the inferior vena cava. For newborns and infants under 1-year-old, the tips should be avoided into the heart [3, 13, 41, 42]	GRADE	A	Strong
		26. Non-infectious complications of PICC would occur if the tip is not in a central position [33]	GRADE	D	Strong
		27. Catheters with ectopic tips should be adjusted to a central position before continued use [3]	JBI	5b	Strong
		28. The end of the PORT catheter in children should be located in the inferior segment of the superior vena cava, not exceeding the junction of the superior vena cava and the right atrium, and roughly 1.5 vertebrae below the augmentation on the chest radiograph [45]	JBI	3d	Strong
		29. Bedside ultrasound is recommended to determine the position of catheter tips and CVAD ectopia [33, 41]	GRADE	D	Strong
Catheter maintenance	Flushing/sealing	30. Flushing with saline or heparin is recommended to maintain CVAD patency rather than leave it untreated [30, 32, 41, 47]	GRADE	C	Weak

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
		31. Applying the flushing/sealing technique correctly. The catheter should be clamped and the syringe should be separated in sequence to reduce blood reflux. Drug compatibility shall be checked when infusing ≥2 drugs simultaneously, and flushing the line adequately with 0.9% sodium chloride solution or changing the infusion set before each infusion [3]	JBI	5b	Strong
	PORT maintenance	32. Maintaining catheters regularly as required, flushing properly and timely, and sealing with urokinase when a thrombosis occurred [46]	JBI	2d	Strong
		33. Flushing catheters in the sequence of "isotonic saline - drug injection - isotonic saline - heparin solution" and keeping the bevel of the non-invasive needle-point flushed in the opposite direction of the exit to maintain the PORT patency [47]	GRADE	D	Weak
		34. Generally choose a 24 G non-invasive needle. Using a syringe >10 ml when flushing/sealing. Confirming the patency when drawing back the blood, and determining causes if no blood is returned. Using Saline in pulse style to flush catheters and diluted heparin solution to seal the lines under positive pressure. Routine maintenance should be carried out if the PORT is not used for 1 month in the treatment intervals [45]	JBI	5b	Strong
basic prevention		35. It is encouraged to carry out daily activities, adequate hydration, early limb movement on the side of catheter placement, and appropriate exercise to prevent thrombosis if possible [3]	JBI	5b	Strong
Drug prevention		36. Using anticoagulants or thrombolytic drugs for the sole purpose of preventing CRT is not recommended [3, 13, 30, 34–36, 38, 42, 47]	GRADE	B	Weak

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
		37. For children with short- or medium-term CVADs, we recommend against the use of routine thrombo-prophylaxis [31, 32]	GRADE	B	Strong
		38. For specific children at increased risk of thrombosis, thromboprophy-laxis with Low Molecular Weight Heparin (LMWH) for CRT prevention should be considered, such as children with ALL or lymphoma can be treated with prednisone/E. coli-asparaginase or a history of thrombotic events [13]	Diseases Society of America (IDSA) - United States	II	Strong
		39. Both selecting heparin-bonded or non-heparin-bonded catheters are recommended [33, 37]	GRADE	B	Strong
		40. For blocked CVADs, tPA should be used to restore patency. A second dose is recommended if the CVAD does not recover at least 30 minutes after local thrombolysis. If the CVAD remains blocked after two local thrombolytic agents, radiologic imaging is recom-mended to exclude CRT [32]	GRADE	C	Weak
Imaging examination		41. In the case of suspected CRT, ultra-sound Doppler is the first-line diagnostic investigation, but is not recommended to screen for CRT indiscriminately in all children before further evidence [3, 13, 38]	JBI	3a	Strong
		42. For the CRT diagnosis, CT or MRI should be performed as a second-line imaging test if ultrasound Doppler is not available or the results are unreli-able or suspected to be falsely negative [13]	Diseases Society of America (IDSA) - United States	II	Weak
Health education		43. Clinical staff should provide educa-tion to children and their caregivers with CVAD [46, 47]	GRADE	D	Strong
		44. It is recommended to educate children and their caregivers in the form of checklists on intravenous therapy in hospital or at home [33]	GRADE	D	Weak

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
		45. It is recommended to conduct targeted informed consent interviews and signatures for caregivers according to the different CVADs [33]	GRADE	D	Weak
		46. Caregivers should be trained. After training, caregivers should master how to care for the site, maintain patency, check for signs of infection and other complications, and seek help to solve problems [41]	CDC	C	Weak
		47. Preschool children should not be allowed to access to CVADs and any adults who will assist in the care of CVADs should attend a training course [41]	CDC	C	Weak
		48. The caregivers should be required to use a CVAD model and children to reveal complete care of the CVAD at least twice [41]	CDC	C	Weak
Nursing records		49. The type and name of CVAD, barcode, date of insertion, inserter, anatomical position, management, type and treatment of complications, and reason for and date of CVAD removal should be kept in the medical record [41]	CDC	B	Strong
		50. It is recommended to keep a comprehensive record regarding all CVAD-related problems like infection, thrombosis and mechanical complications [41]	CDC	C	Weak
Follow-up		51. Guidelines should be developed and established at the treatment center for the ongoing management, tracking and follow-up of patients/families with CVADs [41]	CDC	B	Strong
		52. Adherence to and knowledge of guidelines should be periodically evaluated in all patients with CVADs [41]	CDC	B	Strong

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
		53. The use of CVAD techniques by caregivers should be reassessed during a comprehensive visit. Appropriate care of the CVAD should be monitored more frequently and enhanced if catheter problems occur [41]	CDC	C	Weak
		54. Children requiring long-term CVADs should be followed-up regularly to reconsider the necessity of CVAD retention [38]	JBI	3a	Strong
		55. In rapidly growing children, X-ray examination of catheter tip location may be warranted to monitor for poor positioning [41]	CDC	C	Weak
CVAD removal	Removal indications	56. Routine catheter removal is not recommended. Catheter removal should be considered when it is no longer needed for treatment, dysfunctional, positioning abnormal, combined with catheters related bloodstream infection, and with progressive CRT symptoms despite a standard anticoagulation treatment or in a condition of anticoagulation contraindication [3, 13, 30–32]	GRADE	B	Strong
		57. If a patient still needs a CVAD, rescuing the dysfunctional catheter, rather than removing and inserting a replacement, is the preferred approach [41, 32]	GRADE	C	Weak
	Removal time	58. To prevent thrombus from falling off, bleeding, and difficulty in removing, it is recommended to receive a period of anticoagulation, and then confirm there is no floating thrombus, thrombus, and the catheter does not adhere to the vascular wall by ultrasound before removal [3]	JBI	5b	Strong

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
		59. For children with CVAD in place who have a CRT and still requires the CVAD, we recommend that prophylactic doses of VKAs or LMWH after the initial 3 months of therapy can be given until the CVAD is removed. If recurrent thrombosis occurs while the child is receiving prophylactic therapy, we recommend continuing the therapeutic doses until the CVAD is removed and for a minimum of 3 months after the thrombosis [32]	GRADE	C	Weak
	Removal operation	60. When the platelet count is above 50× 10^9/L, and the international normalized ratio (INR) is less than 1.5, the following procedure is recommended: firstly the child should take the supine position, and is guided to perform Valsalva during removal. After that, we suggest covering the puncture point with a closed dressing, then checking the integrity of the catheter removed. If a bloodstream infection related to the catheter is suspected, culturing the catheter tip should be performed. In case of difficulty in removal, experts in vascular surgery and intervention should be contacted for advice [33]	GRADE	D	Weak
		61. Professionals who remove the catheter are required to be familiar with the fixation, length, allowable elastic deformation range, etc. of the catheter to prevent the catheter from breaking due to improper operation [3]	JBI	5b	Strong
	Precautions in other special cases	62. Removing a functional CVAD is not recommended in pediatric patients with symptomatic CRT who continue to require venous access [2]	GRADE	D	Weak
		63. Removing the non-functional or unwanted CVADs is recommended for pediatric patients with symptomatic CRT [2]	GRADE	D	Strong

Table 4 (continued)

Topics	Subtopics	Recommendations	Tools	evidence level	recommendation level
		64. It is recommended to delay removal of a CVAD until after initiation of anticoagulation for days, rather than immediate removal in pediatric patients with symptomatic CRT who no longer require venous access or in whom the CVAD is nonfunctional [2]	GRADE	D	Weak
		65. For children with large (> 2 cm) movable right atrial thrombosis, anticoagulation, with appropriately timed CVAD removal, and consideration of surgical intervention or thrombolysis are suggested based on individualized risk-benefit assessment [32]	GRADE	C	Weak
	Treatment of difficulty in removal after CRT	66. First of all, giving up the plan of immediate catheter removal, actively finding out the reasons, and providing sufficient psychological support for children and (or) long-term caregivers. Trying to use rest, posture change, hot compress, and vasospasmolytic drugs to remove the catheter. During the removal process, additional strength is allowed, but violence is not allowed. If the catheter cannot be removed after many attempts, the vascular surgeon or interventional physician shall be invited to consult and decide whether to cut or remove the catheter under the guidance of digital subtraction angiography in combination with imaging examination [3]	JBI	3a	Strong
Others		67. If a new catheter needs to be inserted, the status of the superior venous system must be assessed by ultrasound Doppler or ultrasound scan [13]	Infectious Diseases Society of America (IDSA) -United States	III	Weak
		68. CRT prevention in children should not be separated from overall VTE prevention. For children at a high risk of CRT, it is still necessary to take corresponding preventive measures against the risk factors of VTE [3]	JBI	5b	Strong recommendation

vascular access and are unable to utilize the peripheral venous route because of small, immature veins, poor tolerance of repeated venipuncture in children, frequent need for access and/or a caregiver's inability to master peripheral vein access [41]. Therefore, CVADs can only be placed in a lien if the child has a therapeutic need. CVAD requires meticulous adherence to sterile technique, and the family's capability and commitment to meet this requirement must be carefully evaluated. It is essential that caregivers must be able to monitor for and recognize complications, such as infection, thrombosis and mechanical problems [41].

Risk assessment

Five strong recommendations are included on this topic. The majority of pediatric patients with CRT are asymptomatic [48]. The systematic review conducted by Neshat-Vahid et al. has shown that among the included 16 studies of 1279 pediatric patients with CVCs, the incidence of symptomatic CRT is only 5% [49]. Therefore, a high index of suspicion regarding the presence of CRT should be maintained for it is usually asymptomatic [33, 41]. It is recommended to assess the risk of CRT in children [43]. Multiple risk factors have been associated with a higher risk of CRT [33, 39, 40]. Routine thrombotic screening prior to initial CVAD placement is not recommended unless the patient has ever experienced a thromboembolic event unrelated to the catheter [41]. The screening for thrombophilia depends on the following clinical circumstances [50]: ①If the child's first VTE episode is associated with CVAD, screening for thrombophilia is not recommended. ②If the child has recurrent VTE (including recurrent CRT), a thrombophilia screening is recommended. ③For individuals with a clear family history of VTE or thrombophilia, e.g., a first-degree relative under 40 years old with VTE, thrombophilia screening is recommended if there are other risk factors or underlying diseases contributing to the risk of thromboses, such as cancer, CVAD, trauma, or major surgery.

CVAD selection and use

Articles 13–24 summarize the selection and use of CVAD from size, type, site, puncture, fixation, and time, 8 of which are strong recommendations. The appropriate intravenous therapeutic device should be selected according to the physicochemical properties of the drug, and the age, venous conditions, treatment duration, and disease status of the child [33]. On the premise of meeting medical needs, CVAD with the least number of lumens and the minimum diameter should be selected [3]. Placement of CVAD from the left or right side of the body did not significantly reduce the incidence of CRT [29, 30]. There are insufficient data to support a preference for the jugular or subclavian vein for CVAD. Femoral vein access is associated with a high risk of thrombosis in children and should be avoided if possible [29, 30]. The maximum duration that CVAD can be left in place has not been determined [41], but in children with ALL, there is no definitive evidence that delaying CVAD placement until the end of ALL induction therapy reduces the risk of CRT, and the delayed placement in children with poor venous access may also result in physiological and psychological consequences to some extent [29]. Ultrasound-guided CVAD placement significantly improves the rate of success, reduces the times of punctures, and decreases the incidence of complications [47]. Studies from the United States and Australia have demonstrated no difference in catheter failure and complications when CVADs are secured by different methods [51–53].

Tip position

Articles 25–29 are summarized on this topic, all of which are strong recommendations. When the catheter tip is closer to the right atrium, the blood flow at the location of the catheter increases, thereby rapidly diluting the drug and reducing the damage to the intima. At the same time, it also lowers the ratio of the drug liquid volume to the blood flow, and has less impact on local hemodynamics [3]. Studies have shown that a reduced risk of CRT is reduced when the catheter tip is located in the lower 1/3 of the superior vena cava or the junction of the right atrium and the superior vena cava [54, 55]. CVAD should not be used until the catheter tip position is confirmed or adjusted by ultrasound, X-ray or other imaging modality [3, 33, 41].

Catheters maintenance

Articles 30–34 summarize the methods to reduce catheter dysfunction, 3 of which are strong recommendations. Catheter dysfunction plays an important role in unplanned catheter removal, including thrombotic dysfunction caused by thrombus, fibrin sheaths, and fibrin tails in the lumen (about 60%), and non-thrombotic dysfunction due to drug precipitation or mechanical problems [56]. A randomized controlled trial (RCT) [57] and a systematic review [58] showed no difference between saline irrigation and heparin irrigation in preventing CRT, reducing deposition to ensure long-term catheter use, and both were safe and effective. When a non-invasive needle is used to maintain the PORT patency, flushing with saline is followed by drug or blood administration and then saline is recommended [47]. Moreover, studies have shown a significant difference in the flushing effectiveness between the needle tip inclined plane parallel and opposite to the outlet channel when inserted into the puncture septum, the latter method is better [47].

Basic prevention

Article 35 summarizes the basic prevention of CRT and is a strong recommendation. Non-drug strategies are encouraged to use to prevent CRT if possible. One study noted that children with malignant tumors and their families had poor compliance with PICC implants during daily fist exercises [59]. The following medical counseling games are proven to be effective in improving the basic prevention of CRT in children with ALL and their families. Due to the unhealed puncture wound in the early stage and the pain, the child is afraid of exercise. In the case of little blood leakage, the child is encouraged to moderately move the arm. Before the first maintenance of PICC, the child is encouraged to perform the "Little Tail Love Exercise" supervised by the guardians: Firstly, the child can watch the pre-recorded arm exercise video at the bedside. Secondly, the nurse demonstrates it face to face and teaches the child to do the loose-fist clenching, arm straightening-bending and ear-touching exercises, with 3 times a day and 20 actions each time. Finally, a "thumbs up" will be given to the child after completing tasks [60].

Drug prevention

Articles 36–40 are summarized on this topic, 3 of which are strong recommendations. Currently, the preventive use of anticoagulants or thrombolytic drugs for the sole purpose to prevent CRT is not recommended [3, 13, 30, 34–36, 38, 42, 47], but LWMH should be considered for children at high risk of thrombosis [13]. Low molecular weight heparin is associated with a lower risk of thrombocytopenia and osteoporosis than unfractionated heparin, and less interference with medication and diet than vitamin K antagonists [13]. Studies [36, 61] have shown that LMWH is not found to increase the bleeding risk, but further data are needed to demonstrate the value of CRT prevention in children with various specific diseases [3]. A meta-analysis [37] revealed that heparin-bonded catheters do not reduce the CRT and thrombocytopenia, indicating whether the CVAD is bonded with heparin or not is not significant. It is recommended to use t-PA to restore the patency of blocked CVAD, and an ultrasound should be performed if two doses of local thrombolysis make no difference in the patency [32].

Imaging examination

Articles 41–42 are summarized on this topic, one of which is rated as strong recommendation. When a CRT is suspected, Ultrasound Doppler is preferred, which can indicate the location and extent of CRT and infer the thrombus freshness based on echo intensity [62]. However, the use of ultrasound to screen for CRT indiscriminately is not recommended [63]. CT or MRI may be an option if Doppler is not available or the results are unreliable or suspected to be false negatives [13]. Thrombosis in the vena cava, common iliac vein, subclavian vein, and nameless vein, as well as coexisting extravascular compression factors like tumors and thoracic outlet compression, can be clearly diagnosed by CT or MRI [64].

Health education

Articles 43–48 are summarized on this topic, and only article 43 is rated as strong recommendation. Healthcare providers should teach children and caregivers about the purpose of administration, the use of infusion devices, and the risk of potential complications, and avoid excessive use of medical terminology in health education [65]. It is important to note that preschool children should not be allowed access to CVADs and that any caregiver who will assist in the maintenance of the CVAD should attend a course of training [41]. Caregiver competency should also be assessed, such that caregivers demonstrate the care of CVAD on the model and the child at least twice [41]. In order to promote health education for children and their families, an educational checklist related to intravenous therapy in hospital or at home is available, consisting of four parts [33]: (1) General information about the child (name, age, weight); (2) The main caregivers (education level, willingness to learn, religious beliefs, language communication fluency); (3) Teaching methods (oral, written, multimedia, demonstration, others); (4) Teaching contents. The medical staff should inform the children and their caregivers that if the skin at the puncture site of CVAD is swollen, the local dressing oozes blood and liquid, and the film is wet, loose or curled, they should immediately contact the medical staff and return to the hospital for treatment if necessary.

Nursing records

Articles 49–50 are summarized on this topic, one of which is rated as strong recommendation. A complete record regarding CVAD nursing and problems is of great significance for tracking the whole process of catheters placement and providing a clinical basis for further management and improvement of CVAD, and facilitating the data collection for nursing teaching and research [41]. Considering that electronic health records (EHRs) are commonly applied in clinical practice nowadays, and nurses have limited ability to assess the safety of venous access and intravascular catheters, the role of EHRs in strengthening symptom monitoring, risk warning and clinical decision support deserves further exploration to promote the implementation of standardized intravascular catheter surveillance [66].

Follow-up

Articles 51–55 are summarized on this topic, 3 of which is rated as strong recommendation. Children with CVAD catheterization often travel back and forth between their families and hospitals. Based on this particularity, pediatric nurses need to follow up with the children and their caregivers to meet their nursing needs after discharge and ensure the continuity of nursing services. For pediatric nurses, guidelines should be developed and instituted for ongoing management, tracking and follow-up in CVAD treatment centers, and the knowledge of and adherence to guidelines should be periodically assessed in all CVAD users [41]. For children, regular follow-up is recommended for children requiring long-term CVAD placement to reconsider the need for CVAD [38], and for rapidly growing children, X-rays of the catheter tip position are recommended to monitor for abnormal positioning of the tip [41]. For caregivers, their skills in using the CVAD should be reassessed at each comprehensive follow-up visit, and if the catheter becomes problematic, more frequent monitoring and enhanced care of the CVAD should be executed [41].

CVAD removal

Articles 56–66 summarize the indications, time, and operations, of removal, and precautions in special cases, and treatment of difficulty in removal after CRT, 5 of which are rated as strong recommendations. Current guidelines do not recommend routine catheter removal [65, 67, 68]. If the catheter is still required for treatment, it should be retained and used under anticoagulation therapy [65, 67, 69]. When there is a combination of contraindications to anticoagulation, or continued progression of symptoms despite anticoagulation therapy, catheter removal should be considered. In clinical practice, however, the dependence on catheters for treatment and the feasibility of re-establishing venous access need to be assessed [3]. For patients who are highly catheter-dependent and have difficulty establishing new venous access, the value of retaining the catheter needs to be weighed against the other potential risks associated with thrombosis, and the catheter can be retained under close observation and follow-up [3]. In terms of timing of catheter removal, for catheter-associated DVT, it is recommended to be removed after a period of anticoagulation to facilitate thrombus stabilization [70]. However, for other types of CRT, the removal timing is not restricted considering the small volume of the thrombus [3].

Others

Articles 67–68 are summarized on this topic and article 68 is rated as strong recommendation. It should be noted that CRT prevention in children cannot be separated from overall VTE prevention, especially the DVT of the lower extremities caused by CRT is greatly harmful to children. Therefore, it is still necessary to take appropriate preventive measures against the risk factors of VTE for children at a high risk of CRT [3].

Study strengths and limitations

In this study, the best evidence on the preventive care of CRT in hospitalized children was summarized and localized to provide pediatric nurses with an evidence-based reference in clinical practice. This study provides a theoretical basis and technical standards for pediatric nurses to strengthen the risk prevention and management of CRT in hospitalized children, and guarantees the safety of children with tubes.

Nevertheless, this study only summarizes the evidence and has not yet completed the transition from scientific evidence to clinical practice, and the evidence-based decision-making and practice are required to validate the effectiveness of the best evidence of CRT preventive care for children.

Conclusions

In this study, an evidence-based nursing prevention program for CRT in hospitalized children was constructed through a rigorous and scientific process of literature search and screening, literature quality evaluation, best evidence aggregation, and expert consultation. In the adaptive application process, the latest evidence and the professional judgment of nurses are complementary in implementation, that is, the evidence points to gaps in nursing practice, and the professional judgment of nursing helps the evidence to truly take root in the clinical situation. Therefore, it is recommended for nurses to use the best evidence combined with their own clinical experience, patient needs, and actual clinical scenarios, to develop individualized preventive care and management plan and ultimately realize the transformation of the best evidence.

Abbreviations

CVAD	Central venous access device
VTE	Venous thromboembolism
CRT	Central venous access device-related thrombosis
DVT	Deep venous thrombosis
PE	Pulmonary embolism
PTS	Post-thrombotic syndrome
CVC	Central venous catheter

Supplementary Information

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Supplementary Material 1.

Conflicts of interest
All authors have completed the ICMJE uniform disclosure form. The authors have no conflicts of interest to declare.

Authors' contributions
LT and YL: conception and design. YL: administrative support. LT, XF, ML and JJ: collection and assembly of data. LT, XF, HL and WL: data analysis and interpretation. LT and XF: drafting of the manuscript. All authors were responsible for the critical revision of the manuscript and reviewing.

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Availability of data and materials
All data generated or analysed during this study are included in this published article and its supplementary appendix.

Declarations

Ethics approval and consent to participate
Ethical approval for this study was obtained by a medical ethics committee in Northwest China [No. 20200326-02]. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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