Journal of Multidisciplinary Healthcare

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ORIGINAL RESEARCH

A Retrospective Study of the Use of Antibiotic Lock Therapy and Cluster Nursing Management in Infections in Children with Short Bowel Syndrome or Solid Abdominal Tumours Treated with Totally Implantable Venous Access Ports

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Objective: To explore the effective response strategies for infections in infants with short bowel syndrome and solid abdominal tumours, treated with totally implantable venous access ports (TIVAPs).

Methods: A total of 210 children who were treated with a TIVAP in our department from 2020 to 2021 were selected for this retrospective study. Eight of these children diagnosed with a catheter-related bloodstream infection were studied in this study; antibiotic lock therapy (ALT) and cluster nursing management were used for treatment, and their effects on the infection outcome were observed.

Results: Among the eight children, seven access ports were successfully protected, and one catheter was removed from the right chest wall port due to repeated infection. In this one child, the left side was re-implanted.

Conclusion: The use of the ALT combined with cluster-based nursing can better treat infections of TIVAPs, improve the children's healing time, and has important clinical significance in the prevention of complications from the infection and improving the treatment and nursing of the patients diagnosed with these infections.

Keywords: totally implantable venous access port, short bowel syndrome and solid abdominal tumours, catheter-related bloodstream infection, cluster nursing management

Introduction

A totally implantable venous access port (TIVAP) is a closed intravenous infusion device placed subcutaneously in patients and can remain in the body for a long time. It mainly consists of an injection seat for punctures and a central venous catheter system, which relies on the local high flow rate of blood to rapidly dilute and disperse injected medication, prevent irritation and damage to the veins, and reduce the occurrence of extravasation and necrosis complications. It can be used for the infusion of various medications, blood and nutritional support therapy, and it provides safe, reliable, and it provides effective intravenous access for patients with long-term infusion therapy and chemotherapy needs. It has the advantages of having a long maintenance cycle, little effect on a patient's quality of life, and it can be used for an extended time compared with other intravenous accesses, reducing the risk of care.[1–3] However, TIVAPs, like other intravenous accesses, develop associated complications with their use, and according to the criteria recommended by the Infectious Diseases Society of America, TIVAP-associated infections are classified as local infections and bloodstream infections, with incidence rates ranging from 0.4%–29%.[4–6] Bloodstream infections are the

Received: 15 November 2022
Accepted: 11 January 2023
Published: 15 February 2023

most serious complication and an important factor leading to unplanned port removal. Some studies have shown that the occurrence of TIVAP complications is closely related to the aseptic operation of medical personnel, their health education, and their technical proficiency; it is also related to the lack of early observation, early detection, and early treatment as well as the quality of the technique used to flush and seal the tubes.[7] Antibiotic lock therapy (ALT) is an effective and valuable method utilised to inject and retain a high concentration of antibiotics into the catheter, allowing the antibiotics to penetrate the bacterial biofilm parenchyma, directly killing the bacteria and eradicating the biofilm. It is currently a valuable method in the treatment of catheter infections.[8,9] Another effective remedy for catheter infections is ALT combined with systemic antibiotics.[10]

Cluster nursing management is care that is practiced per evidence-based medicine theory, in which a series of nursing measures with a scientific basis are gathered to ensure the safety and effectiveness of care,[11,12] thus better reducing the incidence of infections. In our department, the use of ALT combined with cluster-based nursing for children with TIVAP infections has a more satisfactory effect; it is a targeted prevention and treatment method that can provide a basis for the expansion of future clinical nursing work, which is reported below.

Materials and Methods

General Information

In our department from 2020 to 2021, there were 300 children with short bowel syndrome and solid abdominal tumours, and 210 children with family members' consent received TIVAP implantation. Eight children with a catheter-related blood stream infection (CRBSI) were selected from 210 patients implanted with TIVAPs in our department from 2020 to 2021 by random sampling. Criteria for diagnosis of catheter-related infection were TIVAP catheter with the same pathogen detected in peripheral veins. Inclusion criteria: (1) Hospital stay ≥7days; (2) Catheter-related bloodstream infections occurred during hospitalization; (3) Family members and children were informed and consented to participate in this study; (4) Clear consciousness and normal perception. Exclusion criteria: (1) patients with hematologic disorders; (2) patients with systemic infections or that had other parts of the body that were damaged or infected; (3) patients with a TIVAP infection caused by surgical operation; (4) patients with abdominal solid tumours in the bone marrow suppression period; (5) patients who withdrew from the study. Among these eight children, there were two patients with short bowel syndrome due to necrotising enterocolitis and four patients with abdominal solid tumours. Patients aged between 3 and 36 months. The clinical data were shown in Table 1. This study was approved by the Medical Research Ethics Committee of Hebei Children's Hospital (Ethical number: Yi Yan Lun Shen 177 Hao).

Treatment Method

Antibiotic Lock Therapy

All eight children were first treated with an empirical antibiotic infusion, and after the same pathogenic bacteria were found by blood culture (drawn from the TIVAP catheters and peripheral veins), the type of antibiotic was adjusted according to the results of drug susceptibility testing. Appropriate antibiotics were selected, and the antibiotic solutions were prepared according to the drug concentration requirements of the "antimicrobial lock" (according to the empirical treatment, 1000 times the Minimum Inhibitory Concentration, MIC). The volume of the TIVAP catheter and additional device volume is 2 mL. After the preparation, 2 mL of the antibiotic solution was extracted and slowly pushed into the TIVAP under positive pressure to fill the port body and the catheter. After the antibiotic solution was sealed, the TIVAP was no longer used for any drug infusion, and the planned drug administration was completed by the peripheral vein instead, the average treatment period was about 9.5 days. After an average of 7.0 days of ALT, if the child's body temperature was normal, blood was drawn through the TIVAP catheter and peripheral vein again for blood culture examination. If the blood culture was negative, all antibiotics were stopped and the use of the TIVAP was restarted. This anti-infection treatment cycle took an average of 8.3 days.

In this paper, case 6 was taken as an example. The drug sensitivity test results of this case showed that the MIC of vancomycin was 2 μg/mL, and the concentration of vancomycin was 1000 times of the MIC of the body, 2 mg/mL was selected as the concentration of tube sealing solution. The configuration method was as follows: dissolve 500 mg

Table 1 Basic Information of 8 Patients with TIVAP Catheter-Associated Bloodstream Infection

Cases	Gender	Age (Months)	Primary Disease	Placement Time	Infection Time	Curative Time	Clinical Symptoms	Blood Culture	Peripheral Blood Leukocytes ($X10/L^9$)	Peripheral Blood Neutrophils ($X10/L^9$)	Peripheral Blood CRP (mg/L)
1	Male	3	Short bowel syndrome	2020.9.26	2021.2.1	2020.12.28	High fever, drowsiness, increased enterostomy volume	Klebsiella pneumoniae	5.6	60.4	30.2
2	Male	24	Neuroblastoma	2021.3.10	2021.8.13	2021.8.14	Chills, high fever	Staphylococcus haemolyticus	8.8	54.6	26.5
3	Female	12	Hepatoblastoma	2020.12.29	2021.4.3	2021.4.5	Chills, high fever	Enterobacter cloacae	8.9	90.2	35.12
4	Male	4	Short bowel syndrome	2021.2.3	2021.6.30	2021.7.2	High fever, drowsiness, increased enterostomy volume	Staphylococcus epidermidis	1.6	90.47	40.37
5	Female	36	Right retroperitoneal teratoma	2020.12.3	2021.7.8	2021.7.10	Chills, high fever	Bacillus cereus	3.6	66.24	26.8
6	Female	30	Hepatoblastoma	2020.8.6	2021.6.5	2021.6.6	Chills, high fever	Staphylococcus aureus	5.4	86.3	50.26
7	Male	24	Left retroperitoneal neuroblastoma	2021.2.8	2021.5.21	2021.5.21	Chills, high fever	Burkholder complex ball bacteria of onion	24.2	67.5	72.47
8	Male	5	Short bowel syndrome	2020.10.30	2021.3.2	2021.3.3	High fever, increased enterostomy volume	Staphylococcus epidermidis	15.3	58.1	62.18

Abbreviations: TIVAPs, totally implantable venous access ports; CRP, C-reactive protein.

https://doi.org/10.2147/JMDH.S397737

vancomycin in 10 mL 0.9% NaCl injection, add 0.1 mL liquid (containing 5 mg vancomycin) into 2.4 mL 0.9% NaCl injection to obtain 2 mg/mL vancomycin tube sealing solution. Vancomycin used for systemic treatment was 20 mg/kg input through TIVAP, once/12 h, 20 mL/h intravenous infusion, 2 mL tube sealing solution was withdrawn before each infusion of vancomycin for systemic treatment and discarded, ALT tube sealing was performed after the infusion, and the drug in the catheter remained at the therapeutic level. ALT combined with systemic antibiotics was administered until the body temperature of the child was normal, ie, 10 days, treatment was stopped. Catheter blood culture and peripheral venous blood culture were re-examined before treatment was stopped, and all antibiotics were stopped after negative treatment, and TIVAP was restarted. The same goes for other ALT treatments. The treatment was shown in Table 2.

Cluster-Based Nurse Management Methods

(1) The cluster nursing team's methods are as follows: (1) the establishment of an intravenous therapy team; (2) the improvement of operational methods; (3) attention is given to the objective environment; and (4) strengthening of psychological guidance. The methods are shown in Table 3.

(2) The Self-rating Anxiety Scale is utilised: this scale was developed by Zung in 1971 as a measure to assess the subjective symptoms of anxiety in patients. It consists of 20 items and is used to measure the presence and severity of anxiety symptoms.[13] The Self-rating Anxiety Scale is used to evaluate the anxiety of patients, and psychological counseling for patients according to this evaluation result can help patients better recover.

Results

Seven of the eight children were successfully port-protected, and one case of infection was not effectively controlled (Table 4). The success rate of port-protected was 87.5% (7/8×100%). The infection was uncontrolled in case 4 and the port was removed. Among them, 5 cases were infected with Gram-positive bacteria (case 2, 4, 5, 6, 8), and the qualified rate of ALT use was 80.0% (4/5×100%), and 3 case was infected with Gram-negative bacteria (case 1, 3, 7), and the qualified rate of ALT use was 100% (3/3×100%). The types of antibiotics used were adjusted according to the MIC results of drug sensitivity test, and appropriate antibiotics were selected. The specific MIC values were supplemented in Table 2. Therefore, the effect of ALT combined with cluster nursing management method to control CRBSI was ideal. See Table 4.

Table 2 Antibiotic Locks Therapy

Cases	Primary Disease	Systemic Antibiotics	Frequency (h/1 Time)	Application Length	Dose (mg/kg)	ALT Antibiotic Therapy	Application Length	MIC (ug/mL)
1	Short bowel syndrome	Teicoplanin	8	10	20	Teicoplanin	7	≤0.12
		Cefoperazone Sodium and Sulbactam Sodium	12	8	40	Cefoperazone Sodium and Sulbactam Sodium	5	≤0.5/8
2	Neuroblastoma	Piperacillin sodium tazobactam sodium	8	8	8	Piperacillin sodium tazobactam sodium	5	2
3	Hepatoblastoma	Piperacillin sodium tazobactam sodium	8	7	50	Piperacillin sodium tazobactam sodium	5	≤4/4
4	Short bowel syndrome	Meropenem	8	10	20	Vancomycin	7	2
5	Right retroperitoneal teratoma	Piperacillin sodium tazobactam sodium	12	9	15	Ertapenem	6	≤0.25
6	Hepatoblastoma	Teicoplanin	8	10	20	Teicoplanin	7	2
7	Left retroperitoneal neuroblastoma	Meropenem	8	10	20	Meropenem	8	2
8	Short bowel syndrome	Vancomycin	12	12	20	Vancomycin	12	4

Notes: The patient in case 1 failed to be treated with empirical antibiotics first, and then continued to be treated with another antibiotic selected according to clinical experience combined with the results of drug sensitivity test.
Abbreviations: ALT, antibiotic lock therapy; MIC, Minimum Inhibitory Concentration.

Table 3 Cluster-Based Caring Management Methods and Summary of TIVAPs Complications Reported in Literature

Cluster-based caring management methods	Establishment of an intravenous therapy team	More than 8 years of work, Supervisor nurse title or above
		Obtain municipal or above qualification certificate
		Regular training, assessment
	Improvement of operational methods	Strict hand hygiene, using aseptic non-contact technology operation
		Developing uniform standards and operating procedures, and enforcing strictly
		Laying of perforated towel during puncture and proper disinfection of skin
		Daily risk alert assessment
		Correctly flush and seal the tube
		Accurate timing of fluid replacement
	Attention to the objective environment	1 hour daily UV disinfection in the intravenous therapy room
	Strengthening of psychological guidance	Targeted psychological intervention using Zung Self-Rating Anxiety Scale
TIVAP complication	Our patients	High fever, drowsiness, increased enterostomy volume, chills
	Patients in literature[17]	Abrupt onset of fever and/or chills, hypotension, high fever
	Patients in literature[18]	Hemopneumothorax, local infection, bacteremia or fungemia Bacteremia, fever (>38°C), chills or hypotension
	Patients in literature[19]	Metastatic spread of tumor at the insertion site

Notes: 1. Aseptic non-contact technique is a more specific and standardized aseptic technique. The principle is to combine standard prophylaxis with aseptic technique and non-contact technique, which originates from injection practice.
Abbreviations: TIVAPs, totally implantable venous access ports; UV, ultra violet.

Table 4 Outcome of Using Antibiotic Locks Combined with Cluster-Based Caring Management

Cases	Primary Disease	Bacterial Infection	Whether to Use Cluster-Based Care	Outcome
1	Short bowel syndrome	Gram-negative bacterium	Yes	Port Protection Success
2	Neuroblastoma	Gram-positive bacterium	Yes	Port Protection Success
3	Hepatoblastoma	Gram-negative bacterium	Yes	Port Protection Success
4	Short bowel syndrome	Gram-positive bacterium	Yes	Infection uncontrolled, take port
5	Right retroperitoneal teratoma	Gram-positive bacterium	Yes	Port Protection Success
6	Hepatoblastoma	Gram-positive bacterium	Yes	Port Protection Success
7	Left retroperitoneal neuroblastoma	Gram-negative bacterium	Yes	Port Protection Success
8	Short bowel syndrome	Gram-positive bacterium	Yes	Port Protection Success

Discussion

Children with short bowel syndrome and children with solid abdominal tumours are immunocompromised and require long-term infusion of intravenous nutrition or intermittent chemotherapy. For the long-term infusion of chemotherapy drugs, intravenous nutrition, antibiotics, and blood products, and for repeated intravenous blood collection, TIVAPs are globally and widely used as infusion devices that can be utilised for extended time periods. The application of TIVAPs is also becoming popular in China.[14,15] With the expansion of clinical demand and the improvement of TIVAP technology, it is being chosen for an increasing number of children when they are faced with long-term infusion therapy needs such as intravenous nutrition or multiple chemotherapy treatments.[16] The use of TIVAPs reduces the workload of nurses,

reduces children's pain, improves children's quality of life, and increases nurse–patient satisfaction. However, complications are inevitable with the use of TIVAPs, such as hemopneumothorax, air embolism, drug extravasation, local infection, and catheter dissection and displacement. Among these complications, CRBSI is quite serious. Catheter-related bloodstream infection is a primary infection, unrelated to other site infections, and occurs during indwelling vascular catheterisation and within 48 hours after the removal of the vascular catheter. With CRBSI, the patient develops bacteraemia or fungemia bacteraemia with symptoms of infection such as fever (>38°C), chills, or hypotension. Subsequently, CRBSI is diagnosed if the same species and pathogenic bacteria with the same drug-sensitive results are cultured from the catheter and the peripheral blood.[17,18] Other studies have reported that TIVAP is associated with a metastatic tumour at the insertion site of the port. Mangla et al reported on the first patient with squamous cell carcinoma of the hypopharynx who developed tumour seeding not only at the insertion site of the TIVAP but also along the tunnel tract of the catheter itself.[19] Of the 200 children selected for this study that were implanted with TIVAPs in our department, eight were diagnosed with CRBSIs, and the infection rate was 3%, which is consistent with the findings from the Infectious Diseases Society of America mentioned above (Table 3).

Antibiotic lock therapy is a new method for the prevention and treatment of catheter infections that regularly loads the dead space of the device with a high concentration of antibiotic solution (100–1000 times the minimum inhibitory concentration) and retains it for a period for the purpose of destroying the bacterial biofilm structure and sterilisation of the catheter. The traditional way to deal with infection is the systemic application of antimicrobial drugs, but this treatment often increases the drug resistance of the bacteria, and the treatment cycle is long and ineffective. However, ALT can directly penetrate the bacterial biofilm parenchyma with the antimicrobial medication, effectively killing the bacteria. Additionally, the application of a small amount of the antimicrobial drug (as is required in ALT) minimises the chance of drug resistance. In this study, we chose eight children with short bowel syndrome and solid abdominal tumours and implanted with TIVAPs. The criteria for diagnosis of catheter-related infection were TIVAP catheter with the same pathogen detected in peripheral veins. Among them, case 2, 4, 5, 6, 8 were infected with Gram-positive bacteria, and the qualified rate of ALT use was 80.0%. Case 1, 3, 7 was infected with Gram-negative bacteria, and the qualified rate of ALT use was 100%. Case 1, 2, 3, 5, 6, 7, 8 were successfully port-protected, and case 4 infection was not effectively controlled. The success rate of port-protected was 87.5%. The infection in case 4 was uncontrolled and the port was removed. In this study, out of the eight infected children, seven were successfully protected, proving that ALT can significantly alleviate the CRBSI and inhibit the settlement of bacteria in the catheter. These findings are the same as the study by Zhang et al[20] and Ao et al.[21]

Totally implantable venous access ports provide a safer intravenous access for children with short bowel syndrome and solid abdominal tumours that are treated with long-term and repeated infusions. They also reduce the pain and risk of repeated venepunctures in children and are now being increasingly utilised in clinical practice. However, there are complications in the process of TIVAP application, and the outcomes of these complications are highly dependent on daily nursing care practices. In addition to the simple application of ALT, our department adopted a cluster-based nurse management method for the eight infected children and set up an intravenous therapy team. The nurses of this specialised team were required to have more professional theoretical knowledge and a higher skill level than the nurses in the general wards. They also required stronger observation and analysis abilities, so that any problems could be detected early and solved in a timely and effective manner in the process of using TIVAPs.[22] This was done in coordination with improving the operation methods, paying attention to the objective environment, and strengthening the psychological guidance of the children and their families to achieve better results in the treatment of CRBSI in paediatric infusion ports. These nursing criteria are the same as were outlined by Tan et al[23] The administration of cluster-based nursing care to oncology patients reduces the probability of complications and optimises the quality of life of the patients.

In practice, ALT faces the same resistance problems as the standard intravenous administration of antibiotics because this technique often requires a continuous, high-concentration, and prolonged use of antibiotic solutions to seal the tube. If too much of the sealing solution enters the bloodstream, the endothelial cells can be damaged; in addition, these solutions may accelerate the induction of bacterial resistance to this type of antibiotic.[24] At the same time, cluster-based nursing management methods require stringent care (eg, the prohibition of the sealing solution entering the patient's bloodstream to prevent antibiotic resistance and other adverse events). Improper care can easily lead to increased

infections and the increased need for treatment (eg, the need to aspirate all the bactericidal sealing solution from the lumen of the central cardiovascular access device at the end of the sealing phase).[25] While there are still some drawbacks to the use of ALT or the cluster-based caring management approach when used alone, the combination of both can achieve satisfactory results in the treatment of TIVAP infections in children with short bowel syndrome and children with solid abdominal tumours. The results of this study demonstrate that the use of both ALT and cluster-based nursing accelerate the recovery of these children and that it is worthy of clinical promotion.

However, because the efficacy of infection control is related to the types of infected bacteria, aseptic operation of medical staff and technical management methods, in this study, all the children infected with Gram-negative bacteria were successfully protected by ALT combined with bunch-based nursing management, while one of the children infected with Gram-positive bacteria was not successfully protected. Therefore, appropriate antibiotics should be selected according to clinical experience combined with drug sensitivity test results. Combined with the limited sample size in this paper, further clinical studies are needed to achieve the best results.

Conclusion

The ALT combined with cluster-based nursing is more effective for the treatment of TIVAPs infections in children and can prevent the complications caused by TIVAPs infections and improve the children's healing time. It has important clinical significance for improving the treatment and care of patients with confirmed TIVAPs infections.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of our hospital (approve number: 177), and informed consent was obtained from legal guardians.

Funding

The project of Hebei Provincial Health and Health Commission: 20211427.

Disclosure

All of the authors had no any personal, financial, commercial, or academic conflicts of interest separately for this work.

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