

Analysis of the Current Application of Peripheral Intravenous Catheter and Indwelling Failure in the Department of Hepatobiliary Surgery

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Abstract: Background: PIVC therapy is the most common hospital procedure. Its insertion and maintenance are easy to fail. Objective: To investigate the current application of peripheral venous catheter (PIVC) in the department of hepatobiliary surgery and the risk factors that lead to indwelling failure. Peripheral intravenous catheter therapy is one of the most common treatment procedures but has a relatively high failure rate during insertion and indwelling. Methods: A cross-sectional correlation study was adopted. Clinical data of patients receiving PIVC from March to June in 2019 in our hospital were collected. All patients were inserted with closed 24G IV catheters manufactured by BD Company, sealed with 50U/mL heparin saline and secured by 3M Tegaderm Film-Transparent film dressing. Estuation caused by any reasons within 72 hours that failed to complete the treatment was considered to be indwelling failure. Univariate analysis was performed to analyze the effect of gender and age on the indwelling time, and logistic regression was used to analyze the related factors of indwelling needle-induced complications. The methods were consistent with the STROBE criteria (Supplementary File 1). Results: 445 patients were enrolled and clinical data from 395 patients were analyzed eventually, with a total of 773 PIVC cases. The indwelling time varied from 0.5h to 329h (median time 49.00±0.86h). Indwelling site: back of the hand (61%), forearm (28%), joint (6%), upper arm (4%) and finger (1%). The success rate of one-time puncture was 92%. PIVC indwelling failure rate was 46% which appeared to be higher in females and older people. Complications included exudation (72%), phlebitis (8%), blockage (5%) and errhysis (4%). There were no statistically significant differences in the incidence of complications in each indwelling period ($P>0.05$). Logistic regression analysis showed that complications were independent risk factors for catheter indwelling failure (OR: 26.98, $P<0.01$). Conclusions: PIVC mostly performed on the back of the hand and its indwelling time was associated with patients' gender and age in the department of hepatobiliary surgery. The occurrence of complications was an independent factor for PIVC failure.

Keywords: Peripheral Venous Catheter, Indwelling Failure, Department of Hepatobiliary Surgery

1. Introduction

Peripheral Intravenous Catheter (PIVC) was widely applied in Europe and the United States in the 1960s. Nearly 2 billion PIVC were consumed around the world each year with 200 million in the United States. It was reported that 79.1%-89.1% inpatients in China received IV infusion, and 99.3% patients had IV indwelling needles in first-class hospitals [1]. In Spain, approximately half of hospitalized patients received intravenous catheters among which 95% were PIVC [2-3].

Generally speaking, PIVC therapy is one of the most common hospital procedures. However, it has a relatively high failure rate during insertion and indwelling for many reasons.

According to the cross-sectional study on venous treatment conducted in our hospital in Mar 27, 67.96% hospitalized patients had infusion among which 66% were PIVC. As a large number of patients required operations in the department of hepatobiliary surgery, the infusion rate reached up to 80.6% with about 2/3 PIVC patients. However, situations like displacement, phlebitis, blockage, leakage, errhysis and

infection during the procedure often resulted in early extubation which interrupted the treatment, increased catheter consumption and the risk of infection and damaging peripheral veins so that patients might suffer additional discomfort and pain, or even affected the intravenous medication time in severe cases. In this study, intravenous indwelling time less than 72h or extubation within 72h before finishing the treatment were considered to be indwelling failure [4]. Many studies had done to study indwelling failure. Some studies showed that more than 69% cases failed to indwell needles before completing the treatment [5-7]; Xu Chunmei *et al* [8] found that failure rate could reach 33.3%; Rickard CM [9] suggested that the overall PIVC indwelling failure rate was between 35% and 50%. The *2016 Infusion Therapy Standards of Practice* published by the Infusion Nurses Society (INS) in the United States mentioned that the appropriate indwelling time for PIVC was around 72-96h but routine catheter replacement was not recommended [4, 9]. However, it was recommended to remove the catheters as soon as possible once there were symptoms (e.g phlebitis or other complications) occurred on the indwelling site or the treatment was finished [10, 11]. To strengthen the investigation of the current PIVC application in the department of hepatobiliary surgery, this research was conducted to find out the risk factors of indwelling failure and the problems in clinical practice so as to eventually provide more theoretical support on clinical trial for hepatobiliary surgery nursing team and improve the quality of clinical nursing.

2. Methods

2.1. Design

Patients receiving PIVC infusion from March to June in 2019 in the the department of hepatobiliary surgery of the First Affiliated Hospital of Jinan University were enrolled in the study. Inclusion criteria incorporated patients aged ≥ 18 years with oral consent from themselves or family members. Exclusion criteria were patients who inserted open indwelling needle during operation, or had short-term peripheral venous hyper-nutrition or unstable vital signs that might require first aid measures at any time, and patients with missing data or who dropped out were excluded as well. All patients were applied with closed 24G IV catheters manufactured by BD Company, sealed with 50U/mL heparin saline and secured by 3M Tegaderm Film-Transparent film dressing (1264W). The indications of extubation were the occurrence of complications or completed treatment with no routine catheter replacement required. The criteria for complications were evaluated by visual phlebitis rating scale [9]. Exudation

referred to the situations that the infusion fluid leaked from the vascular access into the surrounding tissue and the tissue became swollen, painful, and the infusion speed slowed down or venous access blocked. Catheter blockage referred to the inability to deliver medication or to pump blood from the catheter or both happened without fluid leakage. Accidental catheter detachment referred to be partial or complete catheter detachment from the vein, resulting in catheter function loss before reaching the indications of extubation. Catheter-related bloodstream infection referred to the occurrence of bacteremia or mycelial infection in patients along with clinical symptoms like chills and fever ($> 38^{\circ}\text{C}$) during catheterization or within 48h after extubation with the infections caused by external sources excluded. Errhysis usually occurred at the puncture site under dressing and impeded the observation of the puncture site [12].

2.2. Data Collection and Tools

According to the self-designed sheets based on literature and PIVC shift sheets [13], information like insertion time, extubation time, complications, puncture times, performers, extubation causes and intubation conditions on each shift were collected to find out the problems and deal with them in time. The STROBE checklist was used (Supplementary File 1).

2.3. Data Analysis

Data were analyzed by SPSS22.0, and the missing data were excluded. The continuous variables with normal distribution were expressed as mean, standard deviation and median, while the classified variables were expressed as frequency and percentage. Univariate analysis was applied to analyze the effect of gender and age on the indwelling time, and multivariate logistic regression was applied to analyze the potential risk factors of indwelling failure.

3. Results

445 patients' clinical data were collected initially but according to the research criteria, 50 patients with 120 PIVC cases were ruled out due to missing information about insertion or removal time, names or diagnosis results. 395 patients (220 (59%) males and 175 (41%) females, average age 57.5 ± 16.1) with total 773 PIVC cases were included in the study eventually among which 353 (46%) PIVC cases suffered from indwelling failure. The failure was mainly caused by complications like leakage, phlebitis, blockage, errhysis and detachment, as shown in table 1. In this study, the success rate of PIVC one-time puncture was 92% and 2.1 catheters were consumed by each patient on average.

Table 1. Summary of baseline characteristics of peripheral venous catheters.

Variable	PIVC indwelling failure			RR (95%CI)/t	P
	Yes (N=353; 46%), No.(%)	No (N=420; 54%), No. (%)	Total (N=773), No.(%)		
Gender (N=395)					
Man (N=220)	189 (42)	263 (58)	452 (58)	1	
Woman (N=175)	164 (51)	157 (49)	321 (42)	1.454 (1.090-1.938)	0.011*

Variable	PIVC indwelling failure			RR (95%CI)/t	P
	Yes (N=353; 46%), No.(%)	No (N=420; 54%), No. (%)	Total (N=773), No.(%)		
Age					
Mean (SD)	59.4 (16.0)	56.0 (16.0)	57.5 (16.1)	2.968	0.003*
Puncture area					
Finger	5 (56)	4 (44)	9 (1)	1.346 (0.352-5.149)	0.924
The back of hand	203 (43)	272 (57)	475 (61)	0.804 (0.582-1.110)	0.184
Wrist/elbow joint	26 (58)	19 (42)	45 (6)	1.474 (0.770-2.820)	0.240
Forearm	104 (48)	112 (52)	216 (28)	1	-
Upper arm	15 (54)	13 (46)	28 (4)	1.243 (0.564-2.736)	0.589
Number of puncture attempts					
1	320 (45)	384 (55)	704 (91)	1	
≥2	33 (48)	36 (52)	69 (9)	0.909 (0.554-1.492)	0.706
Complication					
Seepage	251 (73)	94 (27)	345 (45)	-	-
Phlebitis	29 (76)	9 (24)	38 (5)		
Tube plugging	22 (59)	15 (41)	37 (5)		
Errhysis	16 (84)	3 (16)	19 (2)		
Detached	6 (75)	2 (25)	8 (1)		
Indwelling time (h)					
Mean (SD)	36.7 (17.5)	75.7 (44.8)	57.9 (40.0)	-	-

*refers to $P < 0.05$.

3.1. Indwelling Time

Results showed that the indwelling time of all PIVC cases varied from 0.5h to 329h with an average indwelling time of 57.89 ± 1.44 h and a median indwelling time of 49.00 ± 0.86 h. There were 112 cases (14%) within 24h, 234 cases (30%) between 24 to 48h, 204 cases (26%) between 48 to 72h, 106 cases (14%) between 72 to 96h and 117 cases (15%) above 96 h, as shown in table 2.

3.2. Selection of Puncture Site

PIVC indwelling was mostly performed on the back of the hand (475 cases, 61%) along with 216 cases (28%) on the forearm, 45 cases (6%) on the joint, 28 cases (4%) on the upper arm, and 9 cases (1%) on the fingers, as shown in table 2.

Table 2. Summary of PIVC characteristics in different indwelling periods.

Variable	Indwelling time (h)					χ^2	P
	h<24 (N=112, 14%), No. %	24≤h<48 (N=234, 30%), No. %	48≤h<72 (N=204, 26%), No. %	72≤h<96 (N=106, 14%), No.%	h≥96 (N=117, 15%), No.%		
Puncture site							
Finger	0 (0)	6 (67)	0 (0)	3 (33)	0 (0)		
The back of hand	72 (15)	142 (30)	131 (28)	61 (13)	69 (14)		
Wrist/elbow joint	7 (16)	13 (29)	12 (27)	7 (16)	6 (12)		
Forearm	27 (13)	65 (30)	54 (25)	32 (15)	38 (17)		
Upper arm	6 (21)	8 (29)	5 (18)	5 (18)	4 (14)		
Complication							
Seepage	47 (14)	111 (32)	93 (26)	47 (14)	47 (14)	2.088	0.720
Phlebitis	10 (26)	12 (32)	7 (18)	6 (16)	3 (8)	6.353	0.174
Tube plugging	5 (13)	9 (24)	8 (22)	4 (11)	11 (30)	6.521	0.163
Errhysis	2 (11)	10 (52)	4 (21)	1 (5)	2 (11)	4.926	0.295
Detached	4 (50)	2 (25)	0 (0)	2 (25)	0 (0)	11.218	0.024*
Not need	31 (11)	78 (27)	86 (29)	46 (16)	(17)		

*refers to $P < 0.05$.

3.3. Complication Analysis

In all PIVC removal causes, leakage occurred in 345 patients (72%); 38 cases (8%) phlebitis, mainly type I, II; 37 cases (5%) blockage; 19 cases (4%) errhysis; 8 cases (2%) detachment. No catheter-related bloodstream infections occurred; 26 cases (8%) asked for early extubation due to discomfort or leaving; 2 cases (1%) removed the catheters by themselves; 2 cases (1%) had loose dressing; 1 case transferred to another department and 2 cases (1%) removed with unknown reasons, as shown in table 2.

The results from the rank sum test of Kruskal Wallis H showed that leakage ($\chi^2=2.088$, $P=0.720$), phlebitis ($\chi^2=6.353$, $P=0.174$), blockage ($\chi^2=6.521$, $P=0.163$), errhysis ($\chi^2=4.92$, $P=0.295$) in different periods (within 24 hours, 24 to 48h, 48 to 72h, 72 to 96h, above 96h) had no statistically significant difference, while the incidence of catheter detachment in different periods ($\chi^2=11.218$, $P=0.024$) was statistically significant and had the highest incidence (50%) within 24 hours.

3.4. Analysis of Related Factors of Complications

In the univariate analysis, PIVC indwelling failure rate in

females were 1.5 time greater than that in males ($RR: 1.454, 95\% CI: 1.090-1.938, P=0.011$); Older patients had higher PIVC indwelling failure rate ($t=2.968, P=0.003$). Logistic regression analysis showed that the occurrence of complications ($OR: 26.98, 95\%CI: 17.48-41.64, P<0.01$) was an independent factor of

catheter indwelling failure, and the impacts of the five complications on indwelling failure was: errhysis (84%)>phlebitis (76%)>detachment (75%)>exudation (73%)>blockage (59%), as shown in table 3.

Table 3. Multivariate logistic regression analysis of PIVC indwelling failure.

Variable	PIVC retention failure		OR (95% CI)	P
	Yes (N=353; 46%), No. (%)	No (N=420; 54%), No. (%)		
Gender (N=395)			-	0.09
Man	189 (42)	263 (58)		
Woman	164 (51)	157 (49)		
Age			-	0.26
Mean (SD)	59.4 (16.0)	56.0 (16.0)		
Puncture area			-	0.43
Finger	5 (56)	4 (44)		
The back of hand	203 (43)	272 (57)		
Wrist/elbow joint	26 (58)	19 (42)		
Forearm	104 (48)	112 (52)		
Upper arm	15 (54)	13 (46)		
Number of puncture attempts			-	0.45
1	320 (45)	384 (55)		
≥2	33 (48)	36 (52)		
Complication			26.98 (17.48-41.64)	<0.01**
Yes	324 (72)	123 (28)		
No	29 (9)	297 (91)		

**refers to $P<0.01$.

4. Discussion

This research was a single-center study of intravenous catheterization in the department of hepatobiliary surgery. The application of PIVC seemed to have less risk than that of CVC in adults with higher utilization rate and larger consumption. Therefore, it was necessary to investigate the failure rate of PIVC indwelling and the complications related to PIVC (e.g. exudation, phlebitis, blockage, detachment, errhysis, infection) to ease the pain and anxiety of patients' re-catheterization and reduce the unnecessary consumption of indwelling needles. The success rate of PIVC one-time puncture in this research was 92% which was higher than that in the study of Sercan et al [14], 71% success rate in old people. Other results [15] suggested that the success rate of the first puncture in 1201 cases was 73%. This study was conducted mainly by nurses who were licensed and had received hospital training and scored more than 80 points in the assessment of intravenous indwelling needle puncture. In the United States, the United Kingdom, Australia and some other countries, venipuncture can only be operated by professionally certified nurses or doctors. However, although there are professionally certified nurses for venous treatment, venipuncture is allowed to be performed by any registered nurses in China. Despite the high success rate of one-time puncture, the failure rate of indwelling was 67.6% which was higher than that (45%-50%) found by Robert et al [16-20]. At present, there are still no relevant studies on indwelling failure rate in China.

4.1. Selection of Puncture Site

Most nurses and patients tend to choose the back of the

hand as the puncture site, which maybe related to the fact that teachers began to train medical students from the distal intravenous injection and the students accustomed to practice on the back of the hand. The *2016 Infusion Therapy Standards of Practice* pointed out that the forearm was the optimal position for indwelling needles, and the infusion practice standards in China suggested the same [21]. Studies showed that catheterization in forearm vein lasted longer and had a low incidence of adverse reactions with high satisfaction rate among patients and little impact on the limb activities so forearm vein was an ideal vessel for puncture [22-23]. Forearms provided a relatively large surface area to secure PIVC to help reduce pain, prolong indwelling time and reduce the incidence of accidental catheter displacement or blockage. Some studies also suggested that there was no significant correlation between the puncture site and the indwelling time of PIVC [24]. In this study, forearm venipuncture was performed in 216 cases (28%), lower than the percentage (35.38%) reported by Wei Tao et al [25], along with 475 cases (61.4%) on the back of the hand, 45 cases (5.8%) on joint, 28 cases (3.6%) on upper arm, and 9 cases (1.2%) on fingers, which was consistent with the results put forward by Evan Alexandrou et al that 1/3 of PIVC was performed on the forearm, and mostly on the back of the hand, forearm vein or wrist [26]. However, these results were not consistent with the optimal operation sites recommended by the *2016 Infusion Therapy Standards of Practice*. Therefore, training in site selection should be enhanced and should begin in school so that nursing students can recognize the importance of it as early as possible. Before intravenous therapy, nurses should complete the health education for patients and value the importance of site selection. Also, further investigation and

corresponding measures should be put forward in view of the deficiencies in patients' health education.

4.2. Selection of Catheter Type

In order to meet the treatment needs, all patients in this study received treatment with 24G intravenous catheters, and those patients who needed larger size of catheters for treatment and rescue were excluded. Wallis et al [3] indicated that although the 22G or smaller indwelling needles can reduce the incidence of phlebitis, it increased the risk of accidental catheter displacement. The *2016 Infusion Therapy Standards of Practice* published by Infusion Nurses Society (INS) recommended that the smallest type of indwelling catheter should be selected as long as it can meet the treatment needs. However, some clinical studies also questioned that 20G peripheral catheter was the optimal choice for adults [27]. Therefore, more studies are required to determine whether the catheter size should be as small as possible.

4.3. Connection Between Age, Gender and Indwelling Time

In univariate analysis, females had a higher risk of PIVC indwelling failure than males, and the failure rate appeared to be higher in older patients, which was consistent with the results put forward by Wallis et al [28-32] that females were more likely to suffer from PIVC indwelling complications than males, and the older the patients were, the shorter the indwelling time became. However, logistic regression analysis showed that the occurrence of complications was an independent risk factor only if the PIVC indwelling time was less than 72h.

4.4. Connection Between Indwelling Time and Complications

The results showed that the indwelling time varied from 0.5h to 329h with an average indwelling time of 57.89 ± 1.44 h and a median indwelling time of 49.00 ± 0.86 h. There were 112 cases (14%) within 24h, 234 cases (30%) between 24 to 48h, and 204 cases (26%) between 48 to 72h. Approximately 1/2 PIVC could not last longer than 48h, which was consistent with the results that 50% of PIVC failed on the second day, reported by Kathy Kokotis et al [33]. Zhang L believed that the longer the indwelling time was, the higher the failure rate was [34]. Studies also showed that the incidence of complications (e.g. blockage, displacement, infiltration, exudation and phlebitis) related to PIVC reached up to 69% [35-37]. Logistic regression analysis showed that the occurrence of complications, such as exudation, phlebitis, blockage and errhysis was an independent risk factor for PIVC catheterization less than 72h. Among all the complications, incidence of leakage was as high as 44.63%, which may be associated with the characteristics of the surgical patients. After general anesthesia, dullness, limb activity limitations and other side effects of patients may affect the infusion that the motionless limbs can prevent the leakage caused by the slip of catheters but it could also lead to poor blood circulation and venous reflux, resulting in local swelling and early PIVC

extubation. In addition, general-anesthetized patients cannot drink water for a period of time before and after the operation so a large amount of fluid needed to be injected after the operation but the rehydration might aggravate the burden of infusion limbs, which could lead to local swelling on the puncture site. Among the five kinds of complications, exudation, phlebitis, blockage and errhysis in each period of the indwelling time had no statistical difference, indicating that they might occur in any period. Studies showed that phlebitis usually occurred relatively early (within 24h) [38]. No phlebitis above type II and catheter-related bloodstream infections were found in this study. Although the incidence of phlebitis in each time period was not statistically significant, statistics showed that 58% of phlebitis had occurred within 48 hours. Therefore, more attention should be paid to the early prevention of phlebitis during nursing work. Additionally, the incidence of catheter detachment was statistically significant in different indwelling periods with 75% occurred within 48h, which may be related to the large degree of limb movement on the indwelling side. Health education after indwelling was extremely important as well because 25% of catheter detachment occurred between 72h and 96h, which may be caused by loose dressing.

The study was limited to patients in the department of hepatobiliary surgery and excluded the intraoperative intravenous catheterized patients, and therefore did not cover all catheterized inpatients. In addition, this study did not investigate the frequency of dressing changes and the criteria for dressing replacement during indwelling and also ignored the delayed extubation time and the patients' hand movements with intravenous indwelling.

5. Conclusion

This research on PIVC patients in the department of hepatobiliary surgery showed that the nurses had good venipuncture skills but still required more training and practice in the optimal indwelling position selection and the observation and prevention of complications. Administrators should choose appropriate evaluation tools, strengthen the assessment on nurses' PIVC practice, analyze the causes of complications, and carry out active prevention measures to have a timely detection and early treatment.

Author Contributions

Xiaolan Wang and Mengying Qi contributed equally to this work.

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