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Reducing the Prevalence of Catheter-Related Infections by Quality Improvement: Six-Year Follow-Up Study

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Abstract

Background: Peripheral venous catheter (PVC) insertion is a crucial nursing action during life support. Several factors that increase the risk of thrombophlebitis associated with PVCs have been reported. **Objective:** We wish to evaluate the impact of a quality improvement regarding PVC treatment for patients with coronary heart diseases. **Method:** A longitudinal, quantitative observational study was carried out in 2008 and 2013 in a hospital in southern Sweden with 360 consecutive patients suffering from acute chest pain. New routines for PVC treatment were included in the hospital with daily inspection according to a checklist. A structured observation protocol was used to survey the prevalence of thrombophlebitis between 2008 and 2013. Also, we examined the relationship between the location and luminal diameters of PVCs. **Results:** The student's *t*-test showed significant differences between 2008 and 2013 with respect to luminal diameter of PVCs ($p = 0.002$), prevalence of thrombophlebitis ($p = 0.003$) and number of days with PVC left *in situ* ($p < 0.001$). **Conclusion:** These findings emphasize the value of using systematic daily inspections and checklists to achieve quality and safety in patients with acute chest pain having PVC-based treatment.

Keywords

Bloodstream Infection, Peripheral Venous Catheter, Quality Improvement, Thrombophlebitis

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1. Introduction

Insertion of a peripheral venous catheter (PVC) is a crucial nursing action during life support in emergency (prehospital or hospital) settings for patients with symptoms of acute myocardial infarction. In hospitalized patients, administration of pharmaceutical substances *via* the intravenous route is the most common invasive procedure [1] [2].

Risks associated with intravenous therapy include thrombophlebitis (prevalence of 2.3% - 35%) and intravenous catheter-related bacterial infection ($\approx 0.8\%$) [3]. Major differences in studies reporting the prevalence of thrombophlebitis may be due (at least in part) to differences in: survey selection; follow-up times; definitions of thrombophlebitis. An acceptable prevalence of thrombophlebitis is $\leq 5\%$ but higher levels are acceptable if a PVC is inserted by paramedics [4] [5]. Anderson *et al.* show that, for patients receiving medication that excite peripheral vessels, elective changing of intravenous PVCs results in marked reduction in the prevalence of peripheral venous thrombophlebitis [6]. Recent studies have shown that re-siting PVCs (if indicated clinically) does not lead to more complications or reduced healthcare costs compared with changing such PVCs routinely every 72 h [7]-[9]. However, guidelines recommend that PVCs should be re-sited every 48 - 96 h in adults. This strategy has been shown to restrict the risk of infection, and most hospitals follow this recommendation [10] [11]. In a review conducted by the Cochrane Collaboration in 2015, there was no evidence to support re-siting of PVCs every 72 - 96 h to minimize the risk of bacterial infections and phlebitis [12] [13]. In addition, guidelines state that ongoing, close monitoring of the cannula site, along with timely treatment, will help to identify complications. However, those guidelines cite only one study [14] to support this recommendation. Hence, consensus regarding current use of PVC is lacking.

1.1. Problems at a County Hospital in Southern Sweden

Evidence-based PVC treatment results in reduced risks for patients and excessive healthcare costs [9] [12] [15]. However, guidelines are based on incongruous literature and emphasize the duration of PVC-based treatment. Daily observation as well as documentation of puncture sites and luminal diameter may provide more relevant information [10].

In the Swedish healthcare system, nurses are responsible for informing patients why PVCs need to be inserted, as well as their maintenance, removal and documentation. Each year in Sweden, nurses insert ≈ 5 million PVCs [16]. Such everyday tasks necessitate considerable demands on knowledge and skills. All nursing students in Sweden undergo education and training on PVC insertion.

The present study took place in County Hospital in southern Sweden. Ward review revealed that $\approx 6\%$ - 10% of patients at County Hospital had suffered from infections that could lead to thrombophlebitis upon PVC-based treatment. Therefore, it was decided at the departmental level to work with quality improvements (QIs) for nurses regarding PVC management.

1.2. Intended Improvement

The intended improvement was to reduce the prevalence of bacterial infections and phlebitis. To achieve improvements in PVC-based treatment, efforts from healthcare professionals are needed [17]. Systems analyses of adverse events [18] have emphasized that the intended outcome can be achieved if healthcare professionals and patients collaborate to obtain quality and safety in healthcare (Table 1). Patients should also follow guidelines for identification of the symptoms of thrombophlebitis (redness or swelling) and report them to nurses. An additional intended outcome was to investigate the prevalence of thrombophlebitis in patients with chest pain who received paramedic care. In addition, to improve outcome, systematic data-guided activities were carried out [19].

1.3. Quality Improvement

Quality Improvement (QI) is being adopted increasingly in healthcare in Sweden and overseas. In the present study, a QI method, root cause analysis (RCA) [20] [21], was used to identify and understand in a systematic way the underlying reasons why a problem or error occurs. RCA is important for the prevention of injuries and errors in healthcare [22]. Evidence regarding the improvement and successful outcomes desired from healthcare professionals is lacking [23] [24]. Consequently, evaluation of improvement interventions regarding the safety

of PVC-based treatment will be useful for healthcare professionals [18] [23] [25]. Therefore the aim of this study was to evaluate the impact of QI regarding PVC-based treatment for patients with coronary heart diseases.

2. Materials and Methodology

2.1. Study Design and Selection Criteria

This was a longitudinal, quantitative, observational study carried out in 2008 and 2013 at a surgical and medical clinic in County Hospital in South of Sweden. A total of 360 (2008: $n = 145$; 2013: $n = 215$) consecutive patients with symptoms of chest pain admitted to the Emergency Ward and then transported immediately to the Department of Cardiac Diseases where enrolled in the study.

2.2. Improvement Intervention

QI was initiated by a development leader after review of the prevalence of thrombophlebitis on the ward. Using local data and discussion of the prevalence with those involved can lead to deeper understanding of local problems [20]. To analyze the cause of thrombophlebitis, the development leader interviewed nurses and asked three main questions: “What happened?”, “How did it happen?” and “Why did it happen?” Information obtained during the interview regarding contributory factors (as perceived by the nurses) was used to improve the routines of safe PVC-based treatment. New routines included daily inspection according to a checklist (Table 2) and re-siting the PVC every third day (or more often if necessary) (Table 1). If drugs that irritated blood vessels were administered, then the PVC was re-sited each day. In conjunction with PVC insertion, nurses rinsed the PVC with 10 mL of physiologic (0.9%) sodium chloride (NaCl). After each injection, the PVC was flushed with 10 mL of NaCl. The PVC was flushed every day with 10 mL of NaCl. Step-by-step improvement interventions (Table 3) involved all nurses on the ward.

2.3. Data Collection

A structured observational protocol was used for data collection (Table 2). All PVCs were inserted by prehospital paramedics from ambulances (the first PVC or (“PVC1”) and by healthcare professionals from the Department of Cardiac Diseases (second, third and fourth PVC (“PVC2”, “PVC3” and “PVC4”, respectively). All patients were followed up from the insertion to removal of PVCs. Sex and age of patients were taken from individual patient records. Also, how long the catheter was *in situ*, as well as its diameter and location, were recorded. In accordance with Swedish guidelines for regular changing of PVCs to prevent thrombophlebitis [26], we observed PVC sites for 12 - 72 h [2] [26]. Only specialist nurses made the observations (Table 1), and made assessments according to criteria for thrombophlebitis classification. Each PVC location was observed every day after 12, 24, 48 and 72 h (Table 2). If redness (grade > 1) or further signs of thrombophlebitis were observed, the PVC was removed. In patients without signs of thrombophlebitis, the PVC were removed or replaced after 72 h.

If a complication was noted, observation of symptoms continued after PVC removal until the patient was asymptomatic. If complications remained after discharge from hospital, or symptoms recurred, patients were requested to visit their general practitioner.

2.4. Ethical Considerations

The study followed the principles outlined in the Declaration of Helsinki, and was approved by the Ethics Committee [27]. Eligible patients were given information about the study, and informed consent was obtained from all patients.

2.5. Statistical Analyses

Background variables are presented as the mean, 95% confidence interval (95% CI), frequency, and percentage. Comparisons between categorical variables in 2008 and 2013 were made with the chi-squared test. But when more than 20 percent of the cells had an expected value less than five have instead Fisher’s exact test been used. Bootstrapping was used to calculate 95% CIs. Analysis of crosstabs with more than four cells have also Correspondence analysis have been used [28]. For variables on scale levels (e.g., PVC 1-4, age) the independent sam-

Table 1. Guideline for symptoms of thrombophlebitis and interventions for PVCs.

Degree	Symptom of thrombophlebitis		Intervention for PVC
0	No complication	No discomfort or slight discomfort; tenderness upon insertion.	No action.
1	Slight thrombophlebitis	Redness and tenderness < 15 × 15 mm.	Stop treatment and remove the PVC. Hirudoid® ointment applied one to several times daily.
2	Medium thrombophlebitis	Redness, tenderness pain, swelling > 15 × 25 mm; increased temperature in the area.	Stop treatment and remove the PVC. Hirudoid® ointment applied one to several times daily. Inform the attending physician.
3	Severe thrombophlebitis	Redness, tenderness pain, swelling > 25 × 50 mm; increased temperature in the area and palpable cord in the vein.	Stop treatment and remove the PVC. Inform the attending physician.
4	Very severe thrombophlebitis	Redness, pain, swelling more than 50 × 50 mm; increased temperature in the area and palpable cord in the vein; pain spreading up to the arm; possible fever	Stop treatment and remove the PVC. Inform the attending physician.

Modified checklist from Lundgren *et al.*, 1993 [30].

Table 2. Checklist for PVC insertion.

PVC in	PVC	Flush	Flush	PVC out	Thrombophlebitis	Complications	Intervention
Date Clock: /Sign	Size Place /Sign	Date /Sign	Date /Sign	Date Clock: /Sign	Degree 0-4 /Sign		

Table 3. Improvement intervention.

Intervention	Process
To improve the way to PVC-based treatment is carried out	*A comprehensive review of international and national literature on PVC treatment was done *A checklist was composed based on the review *Secure assessment of thrombophlebitis by defining the extent of thrombophlebitis *Information for all staff on the ward for people with heart disease using the new guideline
To test and evaluate compliance to the checklist	*Follow-up of 60 patients was conducted *Nurses' documentation and comments regarding the new working process was reviewed
To improve the checklist further and working practices	*Meetings with nurses where follow-up was discussed *Create conditions to facilitate compliance with the new guideline. The checklist included equipment for appropriate PVC-based treatment.
To establish the new guideline as a routine	*Follow-up of working practices as a regular discussion at monthly meetings
To secure the quality of the new routine	*Continuous follow-up of the checklist

ple *t*-test was used. However, none of these variables had a normal distribution according to Kolmogorov-Smirnov and Shapiro-Wilk tests ($p < 0.05$). Therefore, a non-parametric test and Mann-Whitney U-test were also used. Both tests reported significant and non-significant variables, so only *p* values for the independent sample *t*-test are reported. Significance was set at $\alpha = 0.05$. Statistical analyses were made using SPSS v22 (IBM, Armonk, NY, USA).

3. Results

QI on the ward resulted in significant reductions in the prevalence of complications associated with PVC-based treatment by healthcare professionals (PVC 2-4) in 2013 compared with those in 2008 ($p = 0.04$). Upon treatment by paramedics (PVC1), the prevalence of complications increased significantly ($p = 0.03$) (Table 4). In both groups, the number of days that the PVC was *in situ* (Table 5) increased significantly ($p = 0.001$) from a mean of 2.1 days in 2008 to 2.5 days in 2013. There is a significant difference ($p = 0.002$) between 2008 and 2013 with regard to luminal diameter, complications, and days the PVC was left *in situ* (Table 4, Table 5). Correspondence analyses showed that at PVC1, a blue PVC (lumen diameter, 0.9 mm) gave the strongest con-

Table 4. Distribution of PVCs with location, luminal diameter and complications for 2008 and 2013.

		2008			2013			p
		n	%	95% CI	n	%	95% CI	
Location of PVC1 (paramedics)	Upper hand	57	41.9	33.8 - 50.0	86	41.5	35.3 - 48.3	0.96
	Forearm	57	41.9	33.8 - 50.0	85	41.1	34.8 - 47.8	
	Antecubital	22	16.2	10.3 - 22.8	36	17.4	12.6 - 22.7	
	Neck	-	-	-	-	-	-	
	Legs	-	-	-	-	-	-	
Location of PVC2-4 (healthcare professionals)	Upper hand	16	20.3	11.4 - 29.1	28	20.3	13.8 - 26.8	0.08
	Forearm	30	38.0	27.8 - 42.4	69	50.0	42.0 - 58.0	
	Antecubital	30	38.0	26.6 - 48.1	41	29.7	22.5 - 37.7	
	Neck	1	1.3	0 - 3.8	-	-	-	
	Legs	2	2.5	0 - 6.3	-	-	-	
Luminal diameter (mm) PVC1 (paramedics)	Yellow (0.7)	1	0.7	0 - 2.1	-	-	-	0.002
	Blue (0.9)	44	31.2	23.4 - 39.0	35	16.9	11.6 - 22.0	
	Pink (1.1)	89	63.1	54.6 - 70.9	147	71.0	64.7 - 77.3	
	Green (1.3)	7	5.0	2.1 - 9.2	25	12.1	7.7 - 16.4	
Luminal diameter (mm) PVC 2-4 (healthcare professionals)	Yellow (0.7)	1	1.3	0 - 5.1	-	-	-	0.07
	Blue (0.9)	18	22.8	13.9 - 32.9	16	11.7	6.6 - 16.8	
	Pink (1.1)	54	68.4	58.2 - 78.5	96	70.1	62.8 - 77.4	
	Green (1.3)	6	7.6	2.5 - 12.7	25	18.2	12.4 - 24.8	
Complications PVC1 (paramedics)	No thrombophlebitis	143	97.9	95.2 - 100	176	92.6	88.9 - 96.3	0.03
	Thrombophlebitis	3	2.1	0 - 4.8	12	7.4	3.7 - 11.1	
Complications PVC 2-4 (healthcare)	No thrombophlebitis	50	87.7	78.9 - 94.7	83	96.5	91.9 - 100	0.04
	Thrombophlebitis	7	12.3	5.3 - 21.1	3	3.5	0 - 8.1	

First PVC (PVC1), second PVC (PVC2), third PVC (PVC3), fourth PVC (PVC4) and age in years for 2008 and 2013 in terms of number (n), percentage (%), 95% confidence interval (95% CI) and probability (p).

Table 5. Sex, age, and number of days PVC left *in situ* for 2008 and 2013.

		2008			2013			p
		n	%	95% CI	n	%	95% CI	
	Female	65	44.5	36.3 - 52.7	80	38.1	31.9 - 45.2	0.23
	Male	81	55.5	43.7 - 67.3	130	61.9	54.8 - 68.1	
	Age in years	146	69.9	68.0 - 71.1	210	70.6	68.5 - 72.7	0.62
	Days PVC1	127	2.1	1.9 - 2.2	184	2.5	2.3 - 2.7	<0.001
	Days PVC2							
	Days PVC3							
	Days PVC4							

m: mean

tribution, followed by a green PVC (1.3 mm) and then a yellow PVC (0.7 mm), and the difference was significant. PVCs with a smaller luminal diameter (e.g., blue, 0.9 mm) were used less often and those with a larger luminal diameter (e.g., green, 1.3 mm) were used more often in 2013 compared with 2008. Yellow PVCs (0.7 mm) were not used at all in 2013 compared with 2008. PVCs with larger luminal diameters were used more often in 2013 compared with 2008.

4. Discussion

Six-year follow-up of an improvement intervention in patients who received treatment for acute chest pain in a coronary care unit highlighted the benefits of avoiding unnecessary changes of PVCs. PVCs were replaced for clinical indications or every 72 h. This result supports the work of Rickard *et al.*, who use clinical indicators to

decide if PVCs should be replaced or removed, as opposed to the usual prescribed length of time (≤ 72 h), the PVC has been *in situ* [15]. The present study as well as that of Webster *et al.* show the benefits of avoiding unnecessary changes of PVCs, such as a reduction in: patient discomfort; equipment costs; staff workload [9] [15]. This knowledge should be taken into account given that PVC insertion often results in swelling and redness as early as 6 h after insertion [29]. However, inter-patient differences in reactions to PVCs mean that they should be inserted or changed only if it is indicated clinically and not according to a fixed schedule (72 h).

From a QI perspective, patients' knowledge of the symptoms and signs of thrombophlebitis is important. Lundgren *et al.* showed that residual symptoms of thrombophlebitis after PVC removal could be apparent ≤ 5 months after hospital discharge [30]. Therefore, patients should be aware of the signs and symptoms associated with discharge from care: redness, swelling, increased temperature at site, palpable induration, fluid discharges, pain, and pain upon palpation. If two of these symptoms emerge based on the site where the PVC is removed, patients should contact the hospital for extra checks and treatment [3] [30].

During the period of the survey (2008-2013), a significant reduction in the prevalence of thrombophlebitis was noted in patients who had their PVC replaced as a result of clinical indications or every 72 h. This treatment was a part of the improvement work implemented by all nurses on the ward (Table 3). This result is supported by prospective longitudinal studies showing that infections and the risk of superficial thrombophlebitis are highest in the first day after PVC insertion [4] [31]. Swedish guidelines have shown that PVCs should be inserted within the shortest possible time and be replaced every 24 - 72 h [26]. Data on the prevalence of thrombophlebitis if PVCs are re-sited 72 - 96 h after insertion or on clinical indications are lacking and there is no evidence of benefit to support current practice of changing PVC routinely every three to four days [12].

An improvement intervention must be evaluated through systematic collection of data to measure the effects of that intervention [32]. The number of days a PVC was left *in situ* to show a significant increase from 2008 to 2013 (Table 5) within prehospital care (PVC1) and on the ward (PVC 2-4). However, the prevalence of thrombophlebitis increased significantly within prehospital care but decreased significantly on the ward. These results may be related to a lack of planning of the improvement intervention from healthcare professionals [33]. A patient-centered perspective to improve clinical performance facilitates improvement interventions [34]. There is evidence on the consequences of involving only a single care process in improvement interventions [33]. Patient-centered thinking emphasizes a holistic view in the efforts of healthcare professionals for QI, and includes all the people involved in patient care [35]. Care of patients with acute chest pain involves at least two processes: prehospital and inpatient. Nurses on the ward are involved in the improvement intervention but the paramedics in the prehospital setting are not. These results may emphasize the need of involving healthcare professionals in each step of patient care. Therefore the method used in this QI captures the nurses perception of lack of experience as one of the root cause to thrombophlebitis [20].

Zingg *et al.* also found that if untrained or inexperienced healthcare workers insert PVCs, the risk of thrombophlebitis increases [36]. This phenomenon can probably not explain the increase in the prevalence of thrombophlebitis in our study because all paramedics were registered nurses in 2013 (though their level of experience was not known). The improvement intervention regarding evidence-based PVC treatment involved all nurses on the ward, and the improvement intervention was undertaken in several steps.

From 2008 to 2013, when paramedics inserted PVCs, a significant increase in the prevalence of thrombophlebitis ($p = 0.04$) was noted (Table 4), a result that is in accordance with other studies [5] [37]. Swedish guidelines for paramedics state that all patients with acute chest pain should have the PVC inserted in the forearm to enable injection of vital agents. However, the expectation of "load and go" treatment of patients with chest pain in hospital could affect PVC handling. Preparing the patient for rapid transport could result in poor hygiene with respect to PVC insertion.

National and local guidelines recommend that paramedics should insert PVCs with luminal diameters of ≥ 1.1 mm in patients with acute chest pain. Our results showed a significant reduction in use of PVCs of luminal diameter 0.7 mm and 0.9 mm to favor of 1.1 mm. In 2008, PVCs with a luminal diameter of 1.1 mm were inserted in 63% of patients, whereas in 2013 it was 71%, which should have reduced the risk of thrombophlebitis. Studies have shown that a smaller luminal diameter increases the risk of thrombophlebitis because small catheters allow more blood flow into adjacent tissues [3] [38]. Also, the material and lumen of catheters can increase the risk of thrombophlebitis [39]-[41].

Paramedics who instigated PVC-based treatment did so in significantly more upper-arm locations in 2008 and 2013 (Table 4). These results are not in accordance with recommendations that a PVC should be inserted in a

Table 6. Medicines (i.v.) given by paramedics to treat chest pain.

2008	2013
1 Ketogan Novum [®] , 5 mg/mL *Ketobemidone	1 Morphine [®] diluted to 1 mg/mL and not diluted to 10 mg/mL *Morphine
2 Ringer-Acetat [®] *Isotonic crystalloid solution	2 Ringer-Acetat [®] *Isotonic crystalloid solution
3 Stesolid novum [®] 5 mg/mL *Diazepam	3 Perfalgan [®] 10 mg/mL *Paracetamol
4 Adrenalin [®] 0.1 mg/mL *Adrenalin	4 Stesolid novum [®] 5 mg/mL *Diazepam
5 Furix [®] 10 mg/mL *Furosemide	5 Zofran [®] 2 mg/mL *Ondansetron

*Genericname

larger vein (e.g. in the forearm) in patients suffering from chest pain [42]. This treatment could be one of the reasons why patients had a significantly higher prevalence of thrombophlebitis. In addition, the current most common treatment for acute chest pain increases the risk of thrombophlebitis. This treatment (**Table 6**) changed from 2008 to 2013 to increased use of morphine (i.v.) as first-line treatment for acute chest pain instead of ketobemidone; morphine may increase the risk of thrombophlebitis [29] [43].

Significant increases in the prevalence of thrombophlebitis could be explained by inappropriate disinfection of skin in conjunction with PVC-based treatment [42]. One reason could be the difficulties of working in an aseptic manner in the environment where the patient with acute chest pain is collected. This hypothesis is supported by the significantly lower prevalence of thrombophlebitis on the ward, where aseptic conditions can be controlled and improved. Studies have shown that appropriate aseptic conditions prevent thrombophlebitis [31] [40] [44].

4.1. Methodological Considerations

One of the strengths of our follow-up study was that we could record changes over time that may have been affected by new work practices [45]. However, these comparisons were made over time at the group level, so the same patients and staff were not compared. Also, we did not have information on the time of day patients received PVC-based treatment, or distribution of night-time and daytime patients in 2008 and 2013. Furthermore, frequencies in the tables for some options were low, which reduced the statistical power of our study [28].

4.2. Clinical Implications

QI on the ward showed a significant reduction in the prevalence of thrombophlebitis. These findings emphasize the value of using systematic daily inspections and checklists to achieve quality and safety in healthcare. In improvement interventions regarding PVC-based treatment, the impact that healthcare professionals in other units has on patient care must be considered. In addition, patients must be encouraged to take part in the follow-up of improvement interventions.

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Disclosure

There are no conflicts of interest to disclose.

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