Reaching One Peripheral Intravenous Catheter (PIVC) Per Patient Visit With Lean Multimodal Strategy: the PIV5Rights™ Bundle

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Highlights

- Lean leadership for process improvement.
- Prospective comparator multimodal design study.
- Vascular access specialty team (VAST group 2) versus generalist nursing model (group 1).
- First stick success of 96%.
- Statistically significant improvement in dwell time with VAST versus generalist nursing model (89% versus 15% lasting until end of therapy).
- Projected 2.9 million in savings annually.
- Peripheral intravenous catheter team centralized proposal to Chief Nursing Officer (CNO) with acceptance based on outcomes.
- Reduction in cost per bed per year using a vascular access specialty team of $3376.

Abstract

Background: Peripheral intravenous catheter (PIVC) sales per year exceed that of the number of people in the United States (US), 350 million. With only 37 million US hospital patient admissions per year, these data indicate an average usage of 10 PIVCs per patient admission, suggesting a very high failure, very low success rate, and excess cost associated with PIVC insertions. Patients often complain of multiple catheter insertion attempts, and published data reveal up to 53% of PIVCs fail before therapy ends.

Methods: Hartford Hospital (Hartford, CT) conducted a prospective comparator single-center clinical superiority design study to determine the impact of bundled practices including device insertions using vascular access specialty team (VAST) intravenous trained nurses versus current practice. The study used a 5 step multimodal best practice intervention strategy designated as the PIV5Rights Bundle with an aim to determine if the intervention outcomes and dwell time improved over current PIVC practices. The study group applied a Lean health care standard work process with a Six Sigma design, define, measure, analyze, improve, control approach that included VAST PIVC dwell time, complications, and economic impact compared with current state general nursing practice.

Results: Outcomes of the PIV5Rights Bundle in Group 2 (experimental) using a trained vascular access nursing team for insertion and management achieved a statistically significant result of 89% of catheters achieving end of therapy with a cost saving per bed of $3376 ($1405 versus $4781) per year as compared to standard practice (Group 1; control). Results of Group 1 reflected PIVC dwell time to end of treatment in only 15% of catheters. Prestudy catheter consumption analysis was 4.4 catheters per patient hospital admissions, reflecting waste within labor and supply costs for PIVC insertion and usage. Peripheral intravenous catheter retrospective audits for

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current practice demonstrated more than 50% catheters failed within the first 24 hours. This application of Lean methodology by Hartford Hospital with infusion therapy resulted in a projected $2.9 million annual savings of $3376 per bed per year for house-wide application.
Conclusions: Implementation of the PIV5Rights™ Bundle with a dedicated VAST proved to be a successful model, both from a patient and financial perspective. The journey to nursing excellence included identification of core measures and best practice evidence for PIVC placements as a procedure that affects nearly every patient entering a hospital. By centralizing ownership of vascular access with the team for insertion, management, and securement, the PIV Five Rights is the right approach to achieve the right results in transformation of hospital infusion therapy practices. Bundled approaches have often been used for central catheter infection reduction. This is the first study the authors have identified focusing on 1 PIVC per patient visit as a result of an evidence-based bundle and VAST.

Keywords: standardization, savings, Lean, intravenous, complications, cost control, IV staffing, IV team, IV therapy, peripheral catheter, selection, vascular access, peripheral IV, PIV, best practice, VAST, PIVC

Learning Outcome

By applying Lean leadership, infusion therapy practices were transformed with the PIV5Rights Bundle resulting in approval for increased vascular access specialty team (VAST) headcount, providing patients with fewer peripheral intravenous catheter (PIVC) attempts, longer safe PIVC dwell time, greater patient satisfaction, while lowering complications and hospital costs associated with intravenous (IV) therapy.

Introduction

In published clinical evidence, PIVC failure rates and complication incidence are as high as 53%, with approximately 1 out of every 2 catheters failing to make it to 5 days or to the end of treatment.[1,2] Peripheral catheter sales per year exceed the estimated number of people in the United States (US), 350 million.[3] With only 37 million US hospital patient admissions per year, these data indicate an average usage of 9.4 PIVCs per patient admission, suggesting a very high failure and very low success rate for PIVCs.[4] Up to 90% of PIVCs are prematurely removed prior to planned replacement or before therapy completion owing to failure of the catheter.[5,6] Clinicians may make several attempts to insert a PIVC successfully, with each attempt involving a needle puncture of the skin to cannulate the desired vessel, increasing the risk of complications to the patient. Improvement has been associated with the use of specialty teams, visualization technology such as ultrasound and safety associated with extending dwell time of PIVCs to removal only when clinically indicated.[7,8]

The use of a team approach for inserting PIVCs has increased first-time insertion success[9] and decreased device-related complications.[9,10] This VAST centralized model for PIVC insertion and maintenance compares to the generalist nursing decentralized model for insertion and care of PIVCs. Higher levels of inserter confidence built upon training, experience, and procedural competence suggest a team approach has positive insertion outcomes for patients.[11–13] While some VAST models focus on PIVC insertion only, others include follow-up care, which can include clinical tasks such as dressing assessment and evaluation for catheter removal or replacement. Even in the scope of "insertion only," teams have reported better outcomes for first-time insertion success.[14] Reducing the number of failed needle insertions is a useful infection prevention strategy,[15,16] and one that can reduce patient stress, length of hospital stay, and cost to the health care system.[17]

Background

Hartford Hospital (Hartford, CT), an 867 bed, Level 1 trauma center, documented approximately 105,000 patients who entered the emergency department (ED) in 2017. Inspired by the Chief Executive Officer's vision of 1 registration, 1 bill, 1 medical record, 1 standard of care, the VAST proposed the study of 1 patient, 1 IV catheter insertion with 1 attempt using the principles of Lean and Six Sigma methodology.

Evidence demonstrates waste and inconsistency with the insertion and management of PIVC therapy.[18] Peripheral intravenous catheter failures cost the US health care system millions of dollars each year in waste, redundancy, and inefficiency, leading to repeated PIVC attempts, wasted time from nurses, wasted PIVC supplies, and overall system inefficiency.[18] Additionally, multiple replacements of PIVCs not only lead to patient distress and pain, but also results in delayed treatment, increased nursing and medical workload, raised hospital costs with multiple attempts, and increased risk for infection, vein injury, and other preventable PIVC complications.[19–21] Peripheral intravenous catheter failure due to complications of occlusion, phlebitis, infection, infiltration, and accidental dislodgment can be prevented with education, improved management, Anti-Reflux needleless connector (NC) technology, improved insertion techniques, and consistent disinfecting practices.

To demonstrate the goal of how 1 PIVC per patient could be achieved through a VAST, a study was initiated with a simple aim—to extend PIVC dwell time using a bundled approach that addressed common reasons for PIVC failure (infiltration, phlebitis, occlusion, infection, and accidental dislodgment). The standard model at Hartford Hospital had involved consulting a specialized IV team to handle patients with difficult IV access to place a peripherally inserted central catheter (PICC). Rather

than progress to a PICC and central catheter placement, the VAST added ultrasound PIVC training and placement as part of the team responsibilities. The VAST yielded such high success that the need for PICCs was reduced by more than 30%.[22]

Following hospital administrative support for the study and application of a Six Sigma process of define, measure, analyze, improve, control, 5 areas of opportunity emerged: PIVC proficiency, insertion, vein and catheter, technology, and assessment. Training for ultrasound-guided (USG) insertion, application of evidence for site selection, method of insertion, use of supplies with a PIVC insertion kit, longer catheter with optimized gauge, chlorhexidine (CHX) antimicrobial bordered securement dressing, along with implementation of a more efficient anti-reflux NC were all components selectively integrated into the methods that became the right approach for Lean PIV-5Rights Bundle.

Methods and Data Analysis

This single-center intent-to-treat, 2 group comparators of a multivariate intervention, current state (control arm = Group 1) versus VAST PIV5Rights™ (experimental arm = Group 2) study was conducted in a preselected 47 bed medical unit from November 2016 through February 2018. This prospective comparator multimodal design study had the aim to define the best approach for improving PIVC dwell time and outcomes while reducing failure rates (infiltration, occlusion, phlebitis, infection, and accidental dislodgment). The study was performed at Hartford Hospital in Hartford, CT. Hartford Healthcare Institutional Review Board approval was received (HHC-2017-0001) for the study and a statistician/senior scientist assigned to monitor and assist with the study. Inclusion criteria consisted of adult (≥18 years old) consented patients admitted to 1 medical surgical unit in the hospital, requiring a PIVC. Group 1 consisted of catheters placed by the generalist nurse; Group 2 consisted of catheters placed by VAST using the PIV5Rights (Table 1).

The Lean technique used in this study followed Six Sigma steps to define, measure, analyze, improve, and control work processes in the clinical setting. Lean is a method taken from Lean manufacturing that relies on a collaborative team effort to improve performance by systematically removing variation of practice while also pinpointing areas of waste, leading to greater efficiency and cost reduction.[23,24] The situational analysis program of this study worked through process, protocol, practice, products, and patient with literature review to collect data from current practice to compare with study results. Through this integrated approach, problems were identified and a bundle created for the study to address and eliminate inefficiencies.

This process followed the following steps:

1. The first step of the PIV5Rights clearly *defined* the goal of 1 PIVC per patient visit.
2. The second step *measured* and determined catheter consumption at the hospital each year. Due to a lack of consistent or measurable PIVC usage in the Epic Systems Corporation (Epic, Verona, WI) electronic medical record, PIVC inpatient consumption was collected from annualized supply chain purchasing records.
3. The third step *analyzed* and compared the total Hartford Hospital patient admissions.
   a) The number of inpatient PIVCs purchased annually was divided by the number of patient admissions which provided the total and average PIVC per patient admission. This number was further tied to the Hartford Hospital average length of stay.
   b) Analysis of the published evidence produced a PIVC insertion algorithm which included a 10 step PIVC insertion process creating *standard work* time interval.
   c) Nursing labor costs were calculated based on standard work and average registered nurse (RN) salary for bedside versus VAST RN per 20 minute PIVC insertion.
   d) The calculation of PIVC supplies used with each insertion established a cost basis for Group 1 of average usage supplies and Group 2 with standard work supplies of IV start kit, skin disinfection, catheter, NC, transparent dressing, change of tubing when applicable, and ultrasound as needed. Ultrasound cost was not included.
   e) The annual PIVC consumption data multiplied by the cost per PIVC placement established the per PIVC insertion economic impact to the hospital.
4. The *improve* step involved the VAST implementing the PIV5Rights™ approach (represented in Table 1, Figures 1 and 2).
   a) Right proficiency (competency of the inserter).
   b) Right insertion with the option of using ultrasound (VAST standardized method).
   c) Right vein and catheter (selection, vein, and catheter based on evidence).
   d) Right supplies and technologies: IV start kit, chlorhexidine gluconate/alcohol prep (Becton Dickinson, Chloraprep™), 22g 1.75″ catheter (BBraun, Introcan™ Safety), Anti-Reflux needleless connector (Nexus, TKO™), CHX antimicrobial bordered securement dressing (entrotech life sciences, PrevahexCHX™).
   e) Daily assessment, every 12–24 hours, of the insertion site with photo accountability.
5. The *control* process with standard work was established with a centralized VAST 1 PIVC per patient visit for all patients.

For Group 2, the trained IV nurse assessed the veins, placed the PIVC using an USG vein visualization technology when needed based on vein depth and judgment of the nurse. The skills of these IV nurses were compared to Group 1 ED nurses who place PIVCs but were not trained as IV nurses and did not use vein visualization technology. Vein and catheter selection for Group 2 followed the Infusion Nurses Society Standards for avoidance of areas of flexion, preference of forearm, and assessment of vein size to catheter size. Site location preference was the forearm cephalic with corresponding catheter using a 22 gauge (0.711 mm outer diameter) and 1.75″ (3.8 cm) length. For Group 2, supplies of PIVC sterile start kits were used to standardize the procedure with consistent skin disinfection of

Table 1. **LEAN PIV5Rights**

The Right Approach Bundle	Group 1	Group 2	Factors to Avoid	Key Research
P = Proficiency	Staff Nurses and emergency medical technologists (unable to calculate)	Proficient Infusion Team Nurse (96% proficiency with insertion)	Increases in time and supply costs. Goal 1 PIVC per patient	**[1, 18, 24-33]**
I = Insertion	No ultrasound (100%)	Insertion using ultrasound (82%) when necessary	Multiple attempts at PIVC placement	**[34-39]**
V = Vein and Catheter	Placement variability Insertions to hand/wrist/antecubital vein or other point of flexion (66%)	Placement in the hand/wrist/antecubital vein or other point of flexion (2%). Vein selectedin the Forearm (basilic or cephalic) (91%)	Avoid PIVC failure, dislodgment or other complications	**[7, 22, 24, 40, 41]**
5 = Supplies & Technology	1. Variable 2. Prepping 3. Variable sized catheters 4. Neutral needleless connector 5. Variable dressings and securement with tape	1. IV Kit (100%) 2. CHG/alcohol prep 3. 22g 1.75" catheter 4. Anti-reflux needleless connector 5. CHX Antimicrobial bordered securement dressing and tape chevron changed q7 days	Avoid variability and inconsistency in practice. Achieve longer dwell time with appropriate supplies.	**[7, 25, 42-48]**
R = Review & Assessment	Insertion documentation without number of attempts (100%), assessment documentation (0%)	Completed insertion and assessment documentation (100%). Photo documentation performed 1-2 times daily with functional review including flushing (<5 minutes)	Complications associated with dressing and securement. Inconsistencies that contribute to complications.	**[24, 49-60]**

alcohol chlorhexidine gluconate (CHG) and CHX antimicrobial bordered securement dressing. An Anti-Reflux NC was used in Group 2 as opposed to the neutral NC in Group 1. Vein selection and supplies used in Group 1 were variable, as was consistent with their current standard practice.

Postplacement PIVCs were managed in Group 2 with routine disinfection of the hub prior to IV access, consistent administration of saline flush, dressing changes every 7 days or as clinically indicated, and site assessment once or twice daily. A 3 mL push, pause saline flush was performed by the study nurse daily for Group 2 to check for patency and PIVC functionality. To ensure compliance, the bar code of the saline flush was scanned into the iPad app data field. Prior to all IV access and including flushing, the hub was disinfected with an alcohol wipe and capped with a passive alcohol impregnated port protector to monitor for compliance.

Assessment data collection by the study team nurses was performed using a validated collection tool integrated into a visual Cloud-based iPad (Apple, Inc. Cupertino, CA) Command app (Commandapp.com; Overland Park, KS) with photo documentation included in every assessment, consistent with the study requirements and parameters for assessment. The nurses evaluated and photographed the PIVC site with each assessment and followed a checklist assessing for complications, device discontinuation, or catheter failure. Documentation of 21 assessment inputs related to the patient's PIVC condition (i.e., phlebitis scale, redness scale, pain) were collected by a study team nurse over a brief (<5 minute) daily engagement. Data collected by study team nurses on dwell time, complications, and satisfaction were documented at least once per day using an iPad app that automatically uploaded the data to a HIPAA-compliant Cloud server.

Figure 1.

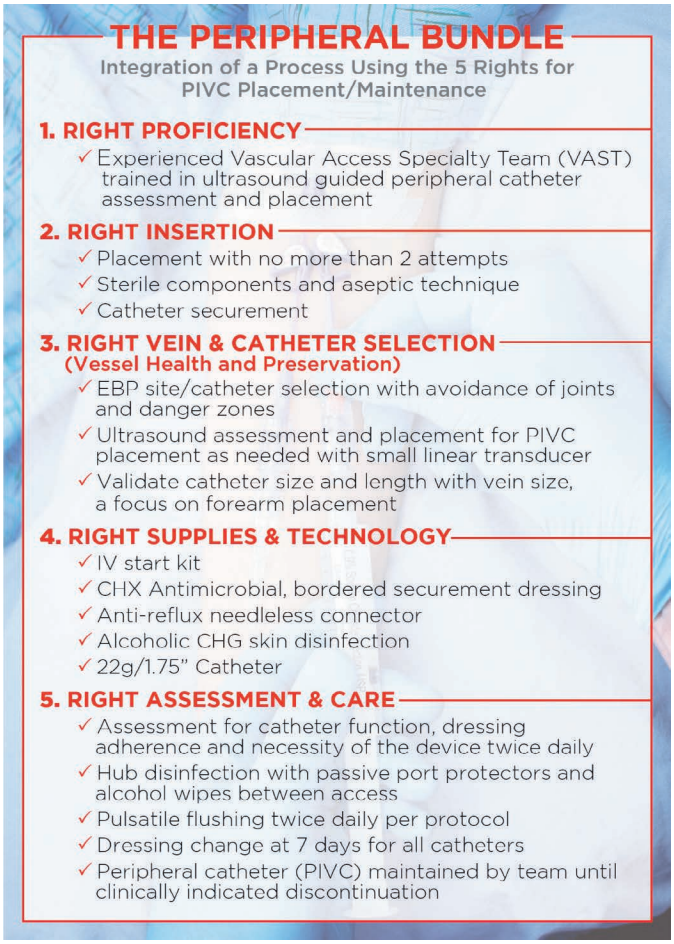


Figure 2. **The peripheral bundle.**

The study was powered at 85% to detect a difference in mean dwell time of 1.5 days (6 versus 4.5). To achieve this power, the study sought to enroll 211 catheters, including a 5% anticipated attrition rate for postenrollment exclusions. All statistical analyses were conducted with SPSS version 21 (IBM, Armonk, NY) with an a priori α level of 0.05. Student's *t* test or Mann-Whitney U test was used to evaluate differences in continuous variables between groups. Spearman's ρ was used to evaluate the correlation with success rates.

Economic evaluation was performed by extracting consumption data for only the catheters used in inpatient units. Savings were then projected evaluating the subset of inpatient supplies. Therefore, this analysis excluded catheter consumption of all outpatient and EDs. The 10 step process was defined for insertion of a peripheral IV device, and supplies used in conjunction with the insertion were evaluated for cost. Time calculations were extracted from combined validation of time studies used at Hartford Hospital and published evidence of average insertion time for nursing time.[25] Labor costs were obtained from an employment human resource national database (Glassdoor).

Results

The study enrolled 125 patients with total catheter placements meeting inclusion criteria of 114. Within the 114 patients, 207 catheters were allocated to each group, 94 (45.4%) to Group 1 and 113 (54.6%) to Group 2 (Tables 2–4). Baseline demographics are represented in Table 2, demonstrating 54% male and 46% female with concentrated age grouping between 41 and 90. Each PIVC was evaluated as a separate event with 89% of Group 2 and 15% of Group 1 catheters reaching end of treatment. Patients transferred to another unit or who required a central catheter were ultimately excluded from the study (n = 11).

Table 2. **Demographics With Vancomycin**

	Group 1 n=94	Group 2 n=113	Total Sample n=207
Gender			
Male	51 (54%)	56 (50%)	107 (52%)
Female	43 (46%)	57 (50%)	100 (48%)
Age			
18-40	8 (9%)	11 (10%)	19 (9%)
41-60	26 (28%)	32 (28%)	58 (28%)
61-75	26 (28%)	38 (34%)	64 (31%)
76-90+	34 (36%)	32 (28%)	66 (32%)
Medication			
Vancomycin	30 (32%)	29 (26%)	59 (29%)

Table 3. **PIV Insertion Location**

	Group 1 n=94	Group 2 n=113	Total Sample n=207
Vein			
Cephalic	35 (37%)	100 (89%)	135 (65%)
Basilic	7 (8%)	5 (4%)	12 (6%)
Median	37 (39%)	6 (5%)	43 (21%)
Radial	15 (16%)	2 (2%)	17 (8%)
PIVC Placement			
Forearm	32 (34%)	103 (91%)	135 (65%)
Upper Arm	0	8 (7%)	8 (4%)
Antecubital Fossa	40 (43%)	0	40 (19%)
Wrist/Hand	21 (22%)	0	21 (10%)
Other/Radial	1 (1%)	2 (2%)	3 (2%)

Table 4. **Complication Results**

	Group 1 n=94	Group 2 n=113	Total Sample N=207	p Value
Success Rate				
Catheters with Completion of Treatment	14 (15%)	101 (89%)	115 (56%)	<0.001
Catheter Failure/Causes of Removal				
Location/Patient Complaint	27 (29%)	0	27 (13%)	<0.001
Site Symptomatic	15 (16%)	0	15 (7%)	<0.001
Other	38 (40%)	12 (11%)	50 (24%)	<0.001
Total Catheter Failure	80 (85%)	12 (11%)	92 (44%)	<0.001
Complications Resulting in Catheter Removal				
Accidental Dislodgment	1 (1%)	1 (1%)	2 (1%)	N/A
Catheter Occlusion	8 (9%)	0	8 (4%)	0.002
Infiltration	7 (8%)	4 (4%)	11 (5%)	0.212
Phlebitis	13 (14%)	5 (5%)	18 (9%)	0.017
Pain	9 (10%)	2 (2%)	11 (5%)	0.013

Table 5. **Summary of Results for Dwell Time, Complications, and Cost**

THE RESULTS		
Variable	**Group 1 (n=94)**	**Group 2 (n=113)**
Success Rate (therapy completed)	15%	89%
Dwell Time, Hours (mean ± SD, P<0.001)	29.6 ± 18.0	71.4 ± 58.8
Complication Rate (%, P<0.001)	40%	11%
Cost/Bed/Year (2018 USD)	$4,781	$1,405

Location of insertion is represented in Table 3 with forearm used in 91% of Group 2 patients as part of the focus of the designated PIV5Rights; in Group 1, the forearm was used in only 34% of patients. Group 1 positioned 66% of PIVCs in areas of flexion/joints (Table 6), none in the upper arm, whereas the clinicians in Group 2 inserted 9% in areas other than the forearm (Table 7), with only 2% positioned in radial or other potential flexion areas.

Mean dwell time (±SD) for Group 2 (n = 113) was 71.4 ± 58.8 hours, with an upper level of 333.2 hours (13.88 days) versus Group 1 (n = 94) at 29.6 ± 18.0 hours with an upper level of 111.0 hours (4.6 days). The difference between Group 2 and Group 1 was statistically significant for dwell time ($P < 0.001$), noted in Table 5 with an overall average daily increase in Group 2 of 66.7% longer dwell of the catheters than Group 1, more than twice as long.

Peripheral intravenous catheters lasting until therapy completion in Group 1 was 15% (n = 14 of 94) and in Group 2 was 89% (n = 101 of 113) 1 PIVC per patient visit, representing a statistically significant difference ($P < 0.001$; Table 4). Within Group 2, 89% (n = 101) of the 1 PIVC per patient admission demonstrated reduction of complications with 0% occlusions, 43% decrease in PIVC infiltrations, 61% decrease in PIVC phlebitis, 77% decrease in pain reported by patients. Reasons for catheter discontinuation included patient pain or complaints in Group 1 of 29% (n = 27) and 0% (n = 0) in Group 2; complications identified of a symptomatic site with Group 1 of 16% (n = 15) and Group 2 0% (n = 0); all other reasons for catheter removal with total catheter failure were statistically significant. Total catheter failure/removal in Group 1 of 85% (n = 80) and 11% (n = 12) in Group 2.

Specific catheter removals with individual complications of accidental dislodgment, catheter occlusion, infiltration, phlebitis, pain, and infection from Group 1 to Group 2 did not represent statistically significant differences; however, overall complication rate differences of 40% for Group 1 and 11% for Group 2 were statistically significant as noted in Table 5. The calculation of extended dwell time and reduced complication rate represented an economic difference of Group 1 generalist nurse cost per bed of $4781 versus $1405 cost per bed in Group 2 VAST.

Economic results for the total retrospective catheter consumption at Hartford Hospital, obtained from materials management review of purchasing records, was 247,000 PIVCs for all departments per year and 148,200 PIVCs used specifically with hospital patient admissions. The resultant average of 4.4 PIVCs per patient admission was calculated retrospective to the study, based on hospital PIVC insertion practices. The analysis of published evidence produced a PIVC insertion al-

Table 6.

GROUP 1: Waste, Variability, Defects

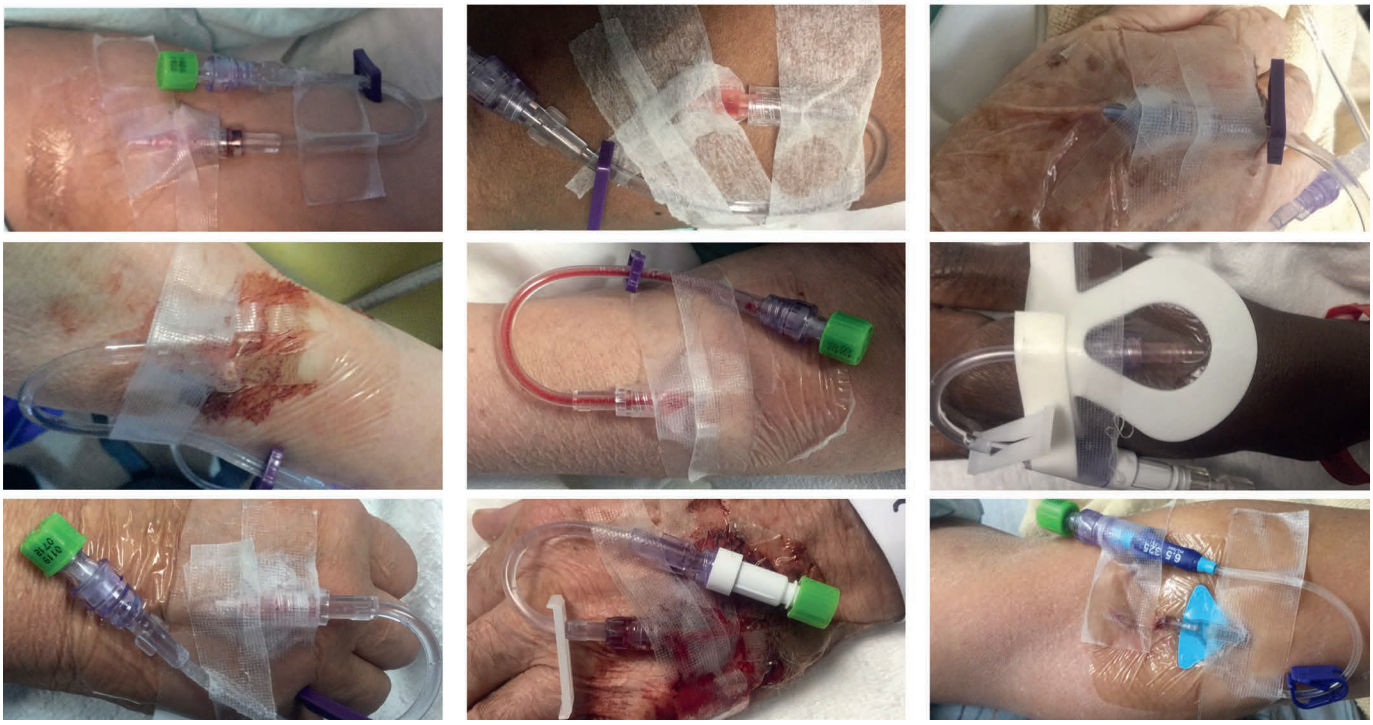
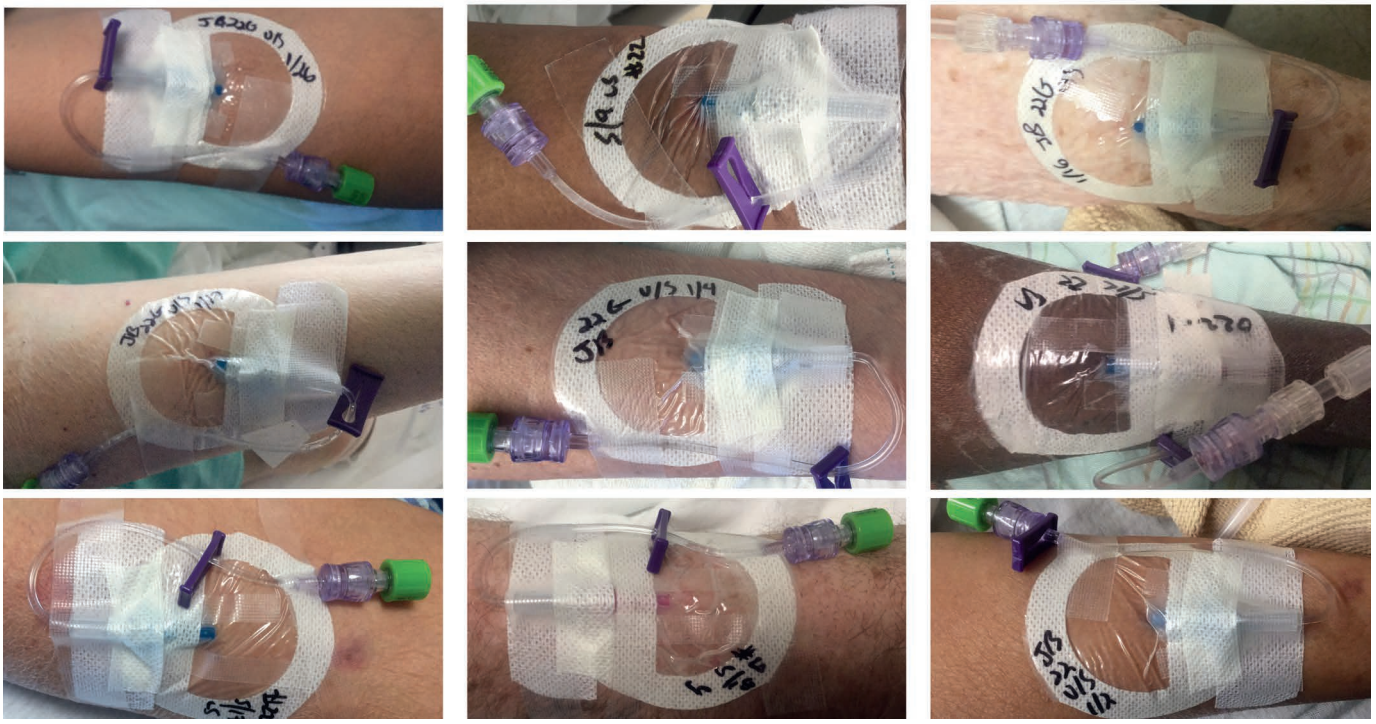


Table 7.

GROUP 2: Standard Work, EVB-Best Practice



gorithm which included a 10 step PIVC insertion process created a work time interval of 20 minutes.[26–29] A calculated hourly nursing labor cost (group 1) of $16.17 (RN $48.50/hour) per 20 minute PIVC insertion was applied to Hartford Hospital nursing activities from projected nursing minutes for admitted patients during insertion of 2,964,000 or 49,400 hours (national average salary for this job title is $69,270).[30] Peripheral intravenous catheter supply costs of $11.80 for each PIVC insertion was formulated from the supply items generally used with each insertion in Group 1. Labor and supply costs for Group 1 for peripheral catheter placement were calculated by adding labor cost of $16.17 plus supply cost of $11.80 for a total PIVC insertion cost of $27.97. By multiplying the number of PIVCs consumed (148,200 catheters purchased) each year by the insertion cost of $27.97 equals the total baseline PIVC cost of $4.1 million for Hartford Hospital per year or $4781 per bed per year (divided by 867 beds; Table 8).

This application of the multimodal best practice intervention bundle strategy named the PIV5Rights within Group 2 resulted in an 80% decrease in PIVC consumption (36,835 versus 148,200) from the baseline annual consumption. For Group 2, the first-time success of 96% and 1.1 PIVC per patient had a reduction of nursing time for hospitalized patients of 736,700, saving 37,122 hours in comparison to Group 1. The calculated hourly nursing labor cost was higher in Group 2 at $18.68 (VAST RN $56.01/hour) representing a 14% increase. Group 2 also had higher supply costs of $14.40 representing a 19% increase associated with the addition of standard work supplies using IV start kit, NC, IV tubing, and CHX antimicrobial bordered securement dressing (Figure 2). Labor and supply costs for Group 2 for PIVC placement cost was calculated by adding labor cost $18.68 plus supply cost $14.40 for a total PIVC insertion cost of $33.08. Calculation for admissions of 33,486, multiplied by 1.1 success rate to equal 36,835 catheters used, will demonstrate a cost basis for the 36,835 usage, multiplied by the insertion $33.08, for a total of $1.2 million. The decentralized Group 1 method of placement and management of PIVCs cost was $4781 per bed per year versus the VAST Group 2 at $1405, a 71% reduction in cost (Tables 8 and 9). The cost reduction per bed for house-wide implementation reflected a reduction of $3376 per bed per year and projected $2.9 million in annual savings.

Discussion

The number one concern of patients is pain associated with how many times they will be stuck with a needle. Reducing the number of IV attempts and extending the functionality of a PIVC without complications are keys to reducing waste, improving efficiency, and increasing patient satisfaction of services. Recognizing that IV access is pivotal to the administration and delivery of treatment in acute care, efforts to evaluate, optimize, and successfully extend the dwell time of peripheral catheters should be considered by leadership as a strategy for hospital cost reduction options. The Lean and Six Sigma approach applied in this study was successful in addressing these issues with significant gains in reducing catheter failure and waste through the application of a bundle of evidence-based practices designed to improve efficiency, test the specialist model, and achieve safety with reduction of complications. The PIV5Rights approach resulted in a cost savings much higher than ever anticipated.

Table 8.

	GROUP 1 CATHETERS		GROUP 2 CATHETERS	
33,486 ADMITS 75% of 44,648 admits have an IV catheter placed	CATHETER USAGE (Admits Only)	CATHETERS PER PT VISIT	CATHETER USAGE (Admits Only)	CATHETERS PER PT VISIT
CATHETER USAGE	**148,200 Catheters**	**4.4** 148,200 ÷ 33,436	**36,835 Catheters** 89% Success Rate - 1 Catheter 33,486 * 1.1	**1.1**
	Nurse Hours	FTE Equivalent	Nurse Hours	FTE Equivalent
TIME TO PLACE IV	49,400 148,200 * 20 minutes ÷ 60	**23.75** 2,080h/yr. per FTE	12,278 36,835 * 20 minutes ÷ 60	**5.9** 2,080h/yr. per FTE

	Labor	Supplies	Cost per IV	Total	Labor	Supplies	Cost per IV	Total
IV Costs	$16.17 RN @ $48.50/hr	$11.80 Catheter, Tubing, Connectors/Caps, Kit	$27.97 $16.17 + $11.80	**$4,145,154** 148,200 * 27.97	$18.68 IV-trained RN @ $56.01/hr"	$14.40 Adds better technology	$33.08 $18.68 + $14.40	**$1,218,502** 36,835 catheters * 33.08
PER BED				**$4,781** $4.1M/867 beds				**$1,405** $1.2M/867 beds

Ideally, hospitals would construct strategies to replicate this approach to achieve 1 PIVC per patient visit. Bundles of practices have been popular in the literature since the success of the Pronovost work in 2006 within Michigan intensive care units in application of the central line bundle.[31] Application of the PIV5Rights Bundle results were not only tracked according to patient data collection, but also through materials and supply acquisition. The extended dwell of 89% versus 15% for Group 2 versus Group 1 represented a sevenfold improvement in IV management and an 80% reduction in catheters purchased/used. This level of improvement was attributed to the intentional applications of a specific bundle of practices. Combining previously studied practices into a bundle of best practices, clinicians are educated in standard work and trained to perform procedures consistently with measurable compliance. While this study was focused on peripheral catheter applications, the sheer volume of PIVC insertions makes these devices a pertinent area of study.

The goal of the PIV5Rights was to evaluate available evidence to establish a method and bundle to achieve the ideal of 1 PIVC per patient visit. As part of the Lean approach to continuous improvement, an evidence-based product bun-

Table 9.

GROUP 2 vs. GROUP 1	
37,122 49,400-12,278	**HOURS**
$2,926,652 4,145,154-1,218,502	**PER YEAR**
$3,376 $4,781-$1,405	**PER BED**

dle was selected. Each component of the PIV5Rights Bundle approach incorporated individual recommendations into a set of best practices, supported by research, systematic reviews, and recommendations that resulted in higher PIVC insertion success, longer dwell time without complications, reduced use of supplies and greater patient safety from improved outcomes (Fig. 2).

Right Training and Right Insertion

Through implementation of a trained VAST for PIVC insertion, Lean standard work was established providing consistent, measurable, and controlled application of all 5 areas of the PIV5Rights Bundle. Vascular access specialty team trained clinicians were skilled with assessment using ultrasound, selecting the most appropriate vein, and PIVC, performed with a high level of insertion first-stick success, consistently used the same method and supplies for insertion and securement, performed daily assessment checking for PIVC function, dressing adherence, and complications. While this was a multimodal study, making it difficult to provide conclusions for individual aspects of the bundle for cause and effect, the right inserter Group 2 represented the knowledge and ability to select the best location and insert with superior skill than in Group 1 as reflected in the results. Results of the study with the VAST reflected insertion first-stick proficiency at 96% success. This is consistent with the Costantino study where USG insertion of PIVCs reached 97% compared to traditional at 33%.[32]

The study failed to capture the number of attempts or percentage of success associated with Group 1 due to inconsistencies and variations in software and electronic medical record documentation in the ED and designated unit. Multiple attempts or restarts of the PIVC may be associated with higher infection rate.[16] In 2011, Centers for Disease Control and Prevention listed updated guidelines to prevent catheter-related bloodstream infections and recommended to (1) continuously train and develop the health care team and conduct daily routine surveillance of the insertion site during dressing changes; (2) consider use of specialized "IV teams," as they have shown unequivocal effectiveness in reducing the incidence of catheter-related bloodstream infections, associated complications, and costs.[33]

Proficiency of the VAST group was further validated in the PIV5Rights study with 89% of catheters reaching completion of treatment. The current PIVC site rotation policy involving mandatory PIVC replacement at 72–96 hours after initial placement required evidence to prove safety with the change to extended dwell time. Group 2 achieved 1 PIVC per patient visit with 11% complications compared to 40% complications in Group 1 adhering to scheduled rotation of PIVCs. The use of specialists in Group 2 was a key factor in achieving greater first-time insertion success and longer dwell time without catheter rotation that led to statistical significance. Based on these results, Hartford Hospital started the implementation process of PIVC clinically indicated removal for all devices inserted by the VAST (group 2).[8,34]

Incorporation of guidelines and recommendations from evidence was necessary in the development of the PIV5Rights Bundle. Insertion of PIVC by a proficient inserter used policy controls that limited attempts to 2, employed ultrasound guidance when needed and followed recommendations consistent with the Infusion Nurses Society Infusion Standards.[35] Lean standard work for the insertion procedure within Group 2 applied foundational principles of aseptic technique, use of sterile supplies in a kit, and training to produce consistent results with securement of each PIVC.[36,37] Inconsistency and much variation in supply usage, securement, and dressing application was evident in the documentation of the daily assessment photos of Group 1. These variations in insertion practices may have contributed to increased catheter movement, more frequent dressing changes, and catheter failure.

Right Vein and Catheter Selection

Evidence supporting better outcomes and longer dwell with PIVCs inserted in the forearm and avoiding areas of flexion contributed to the second right vein and catheter selection aspect of the PIV5Rights Bundle.[8] Results and photo evidence taken during assessment supported the view that dwell time of PIVCs was positively affected by selection of the optimal location and catheter (Table 3). Only 15% (n = 14) of PIVCs in Group 1 reached completion of therapy while 89% (n = 101) remained in place for the full length of treatment in Group 2 with the PIV5Rights and team approach representing a statistically significant difference (Table 4).

Right Supplies and Technology

In a prior process improvement, Hartford Hospital added the use of evidence-based technology of Anti-Reflux needleless connectors to the central venous access devices with significant success in reducing occlusion and prolonging device function.[38–40] Failure rates associated with IVs are greater than 50% for indwelling peripheral catheters.[1,2] Causes of PIVC failure include inconsistencies in securement and dressings, inconsistent flushing practices, and reflux blood within catheter. Based upon 2016 Helm meta-analysis, catheter occlusions represented the highest PIVC failure mode of 22.8%.[1] To overcome the number one complication failure mode of PIVC occlusions, Hartford chose to incorporate the antireflux NC with proven documented results of 69% reduction in occlusions into the PIV5Rights Bundle.[22] This Anti-Reflux needleless connector contains a silicone diaphragm in its fluid pathway, preventing unintentional blood reflux into the lumen of catheters. Published data on this Anti-Reflux needleless connector demonstrated reduction of complications, lower annual NC consumption, cost decrease of 36%, greater than 50% improvement in catheter dwell times due to PIVC patency (longer dwell yields fewer PIVC and supplies purchased), and a $100,000 to $500,000 in annualized value per 500 bed facility.[22,39,41,42]

As concerns over infection continue to rise for peripheral catheters and in consideration of the potential for dwell times well beyond 72 hours, Hartford Hospital chose to incorporate a CHX antimicrobial bordered securement dressing into the bundle for added PIVC protection.[43] Using the combination of skin disinfection of CHG/alcohol antiseptic agent, 1.75″, 22 gauge PIVC, CHX antimicrobial bordered securement dressing, and

anti-reflux needleless connector with a daily care and maintenance plan led to superior performance and reduced cost related to improvements in efficiency from the 5 step PIV5Rights Bundle.

Right Assessment and Care

In the assessment and care portion of the bundle, Group 2 performed daily or twice daily full assessments of the insertion site, dressing adherence, and catheter function. Most notable in this section was the level of accountability built into the bundle requiring photo verification of the status of the dressing adherence and catheter position. Photos were also taken of Group 1 PIVCs that required replacement, were not compliant with dressing policies (e.g., nonadherent, Band-Aid, or tape only cover), or were falling out (Table 6).

Significant differences were present in the 2 groups with many inconsistencies in securement and dressing practices in Group 1. Group 2 applied standard work from Lean to ensure consistency in securement and dressing practices. Group 2 applied evidence for clinically indicated removal and, with consistent monitoring, proved safety in longer PIVC dwell time.[8] By using the Lean standard work of consistent supplies and practices with IV start kits, taping practices, sterile tape, and dressing application, Group 2 reduced all complications that could have contributed to PIVC failure (Table 7).

Economic Impact

In evaluating any best practice initiative, the impact of cost, positive or negative, must be considered. In this study, the positive cost impact exceeded the expectations of the study team for comparison of Group 1 and Group 2 results (Tables 8 and 9). Group 2, with longer dwell time and 89% reaching end of treatment, resulted in a 90% reduction in catheters purchased/used and projected whole hospital savings of greater than $2 million (Table 8). Despite increases in labor cost, supplies, and cost per placement, the total number of insertions and catheters were so dramatically reduced with 1 PIVC per patient admission that final figures were only a fraction of the cost of the prior practice (i.e., 4.4 catheters per patient admission). Based upon the original Group 1 Hartford Hospital annual PIVC cost of $4,145,154 or $4781 annual cost per bed, the results of the clinical study with a PIVC team specialist model using the best practice bundle created a significant savings with 1.1 PIVC per patient. Using the annual patient admissions of 33,486 times the 1.1 PIVC per patient, the annual PIVC consumption would fall from 148,200 to 36,385. This intervention resulted in a waste reduction of nursing time and supply cost of $2,926,652 or an overall savings of $3376 annual per bed. The combined PIV5Rights Bundle improved nursing efficiency, validated the PIVC specialist model, and achieved superior patient safety with a reduction of PIVC complications and finally delivered a proven economic impact, much higher than ever anticipated, with an overall hospital cost savings in the millions.

Limitations

Data analysis and direct comparison of number of attempts between the 2 groups was impaired due to the differing electronic medical record software and incomplete insertion documentation in the ED versus the medical/surgical areas. Cost analyses were based on material management supply costs, collected retrospectively and prospectively, based on annual consumption and other economic data calculations represented in the references noted within the figures.

Conclusions

By applying Lean leadership, infusion therapy practices were transformed with a PIV5Rights Bundle, resulting in fewer PIVC attempts, improved PIVC dwell time, greater patient satisfaction, while lowering complications and hospital costs associated with IV therapy. Hartford Hospital applied a PIV5Rights methodology to infusion therapy and projected a $2.9 million annual savings or $3376 per bed per year. The savings were reported to administration as a justification for growing the VAST services. Dollars were attributed to an improvement in efficiency to the level of 89% success in achieving 1 PIVC per patient visit. Failure of IV access is all too common, resulting in multiple attempts, patient pain, and excessive use of supplies. Evidence demonstrates that it takes the right approach to achieve the right result when you set a goal to transform infusion therapy practices to 1 PIVC per patient visit, while also reducing cost.

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