Prevention of Peripheral Venous Catheter Complications With an Intravenous Therapy Team

A Randomized Controlled Trial

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Background: More than 25 million patients have peripheral intravenous (IV) catheters placed each year in US hospitals. Infusion therapy is believed to account for one third of all nosocomial bacteremias.

Methods: We performed a randomized, prospective, controlled study in a university-affiliated hospital to determine whether the use of an IV therapy team decreases peripheral venous catheter–related complications in adult medical patients. Patients were randomized to undergo peripheral catheter insertion and/or maintenance either by the IV team or by medical house staff. A dedicated observer reviewed catheter sites daily; findings were applied to a scoring system to define the severity of complications. Bacteremic complications were reviewed by a physician.

Results: Patients with catheters started by the house staff and maintained by ward nursing staff more often had signs or symptoms of inflammation (21.7%) than did patients with catheters maintained by the IV team (7.9%) (P < .001). Patients monitored by the IV team had a greater mean number of catheters placed per patient than did patients monitored by house staff (2.1 and 1.6, respectively) (P < .01). Three episodes of catheter-related sepsis occurred in house staff patients and none in IV team patients (P = .004).

Conclusions: An IV therapy team significantly reduced both local and bacteremic complications of peripheral IV catheters. Timely replacement of the catheter appeared to be the most important factor in reducing the occurrence of complications.

Arch Intern Med. 1998;158:473-477
PATIENTS, MATERIALS, AND METHODS

Michael Reese Hospital and Medical Center is a 650-bed university-affiliated hospital in Chicago, Ill. The 200-bed medical inpatient service occupies 2 buildings, to which patients were assigned based on bed availability. Patients were given a permanent 6-digit medical record number at their first hospital encounter; these medical record numbers were assigned in sequential order. The IV team (2 registered nurses) was available 5 days a week (Monday through Friday) from 9 AM to 5 PM to maintain and start peripheral IV catheters. Each IV nurse was assigned to one of the medical buildings for the entire study. The IV nurses were supervised and evaluated periodically by a nursing educator experienced in IV therapy.

PATIENT ASSIGNMENT

During 3 months, all inpatients receiving medical service were eligible for this trial. Patients with an even-numbered sixth digit in their medical record number were assigned to the IV team; those with an odd-numbered sixth digit had catheters started by the medical house staff. House staff also started IV team patient catheters when “after hours” insertion (between 5 PM and 9 AM on weekdays and all day on weekends) was required; catheters in these patients were maintained (including relocation of the catheter within 72 hours) by the IV team beginning the following weekday. Because the findings for the latter patients were comparable with those of the other IV team patients, as detailed in the “Results” section, they are included as IV team patients in the analyses.

IV CATHETER CARE

Before this trial, IV catheters were routinely started by medical house staff and maintained by floor nurses using Centers for Disease Control and Prevention recommendations.7 The following guidelines were followed throughout the study period. Peripheral 18- and 20-gauge Teflon catheters were inserted using an aseptic technique, and povidone-iodine ointment was placed over the insertion site prior to dressing with a sterile adhesive bandage. The catheter dressing was routinely changed every 48 hours; IV tubing was changed every 72 hours. Dressing change included cleaning the IV site with povidone-iodine and 70% isopropyl alcohol, then reapplying povidone-iodine ointment and an adhesive bandage. House staff were instructed to relocate IV catheters within 72 hours.

Each IV nurse was trained in peripheral IV catheter insertion and care according to the guidelines above. Catheters in the IV team group, including those inserted by the house staff when the IV nurses were not present, were re-dressed every 48 hours by the IV team; IV tubing was changed every 72 hours. The IV team protocol specified that no peripheral catheter was to remain in place for longer than 72 hours. The IV nurses evaluated catheter sites of all IV team patients daily; the IV nurse could change an IV catheter before 72 hours if a complication was believed to be present. Catheters inserted after hours by the house staff were also left in place by the IV nurses for 72 hours unless a complication was believed to be present.

Catheters started in the emergency department underwent similar care unless placed under emergent conditions. In this circumstance, the IV nurse changed the catheter within 24 hours. Catheters inserted before patient arrival at the hospital also were replaced by the IV nurses within 24 hours of insertion. House staff had been instructed similarly.

PATIENT DATA

A trained IV observer inspected catheter sites on weekday evenings (Tuesday through Friday) and during the day on Saturday, which resulted in minimal contact with the IV team nurses. Observations were made and recorded for all IV team patients. Observations of house staff patients were limited to a subset (those with an even-numbered sixth digit of the medical record number) due to time limitations. The observer did not interact with house staff, floor nurses, or the IV nurses.

For each catheter site observed, the presence of the following was recorded: tenderness greater than 4 cm from insertion site; warmth; erythema 3 to 6 cm from site or greater than 6 cm from site; induration or swelling more than 3 cm from site; palpable cord 3 to 6 cm from site or more than 6 cm from site; and purulent drainage at the insertion site. Also noted were the date and time of dressing and/or tubing changes, catheter gauge, and catheter location. Catheter sites were observed for 48 hours after catheter removal. A definition of phlebitis was established on a point system using these local complications: tenderness, 1 point; warmth, 1 point; erythema 3 to 6 cm from site, 1 point; erythema more than 6 cm from site, 2 points; and induration or swelling, 2 points. Infiltration was accorded 3 points due to induration and tenderness alone. Phlebitis was defined as 3 or more points in any other combination.

To ensure the accuracy of the observer's work, supervising physicians made 3 unannounced audits of the observer during the study by performing independent site assessments, which confirmed the observer's findings.

Hospital records of any patient with blood cultures positive for microorganisms during the study period were investigated by experienced infection control nurses, who were unaware of the specific team assignments. All bacteremias potentially attributable to peripheral IV catheters were reviewed by a physician. The diagnosis of catheter-related bacteremia required an appropriate clinical picture, the presence of phlebitis (as defined earlier), or positive culture of the catheter site or tip, and no alternate explanation for the bacteremia.

Demographic data (age, sex, race, and discharge diagnoses) and exposure to IV medications were obtained for all patients from computerized hospital databases.

STATISTICAL ANALYSIS

The independence of the demographic characteristics and diagnoses between groups was tested using Pearson χ2 procedures. The significance of the difference in total complication rates between groups was evaluated using a t test. Standard errors of the total rates were computed using catheters as the sampling unit. For comparison purposes, SEs were also computed using patients and ratio estimate procedures to account for the varying number of catheters per patient. To evaluate the effects of possible confounding of demographic variables and diagnoses on complication rates, multiple regression analyses were performed.
The study groups were well matched (Table 1). Patient diagnoses were categorized according to potential risk factors for catheter-related complications and were similar between the study groups (Table 1). Exposure to IV medications during the study period was also similar for the study patients, including exposure to specific antibiotics, potassium, parenteral nutrition, chemotherapeutic agents, and blood products (data not shown). Demographic and exposure factors for the IV team patients who had catheters started after hours by the house staff were similar to those of the other IV team patients.

Patients in the IV team group had a greater mean number of catheters placed per patient than did house staff patients (2.1 and 1.6, respectively) (P<.01). More than 1 IV catheter was placed in 50% of IV team patients but in only 36% of house staff patients, which may reflect better adherence in the former group to the requirement of changing the catheter site every 72 hours. The length of time the catheter remained in place was similar in patients whose catheter was started by the IV team and in those IV team patients whose catheter was started after hours by the house staff. The IV nurses were successful in their first IV insertion attempt 81% of the time. This information was not available for catheters started by house staff.

The complications for the study patients are summarized in Table 2. Tenderness, induration, and erythema accounted for more than 90% of all complications. A total of 30 (21.7%) local complications were noted in the 138 house staff catheters, compared with 58 (7.9%) in the 737 IV team catheters; those IV team catheters started by the IV team and those started after hours by house staff had similar complication rates (9.3% and 6%, respectively). House staff catheters more often had multiple complications (6.5%) than did IV team catheters (1.0%); those IV team catheters started by the IV team and those started after hours by house staff had similar rates of multiple complications (0.7% and 1.3%, respectively). The incidence (Table 2) of phlebitis and infiltration (as defined by our point system) was greater in the house staff patient group (P<.001).

The IV catheter local complication rates for patients in the 2 medical buildings were similar (9.5% vs 10.6%). Most (89.8%) catheters were started in the forearm and hand. Although a higher complication rate was noted in catheters started proximal to the antebrachial fossae, the difference was not statistically significant (P=.60) and did not contribute to group differences.

Three episodes of catheter-related bacteremia occurred in patients assigned to the house staff group, compared with no incidences in the IV team group. Two of these episodes might have been prevented had the patient been cared for by the IV team. In these instances, the catheters had been in place for 72 and 96 hours, and both patients had Staphylococcus aureus in cultures of insertion site and blood. The 72-hour catheter had been inserted by paramedics prior to transfer to the emergency department, and would have been changed by the IV team within 24 hours. Local complications noted in these 3 catheters included erythema, swelling, tenderness, warmth, and/or induration. As a result of these infections, hospital stay for each of the 3 patients was prolonged at least 4 days.

The IV complication rates were related to the number of days the catheters remained in place (Figure 2). House staff catheters had the highest complication rate for each day observed, which was significantly different (P<.001) from those catheters started and/or maintained by the IV team. This difference, as assessed by multiple regression analysis, was independent of demographic factors, medical diagnoses, and IV medications. These data suggest that maintenance, including timely removal of the catheter, is most important in decreasing catheter-related complications. The lower complication rates after day 4 in the house staff group may be due to the recognition of local site complications and subsequent removal of the IV catheters. Results analyzed for the complication rate per catheter or per patient were similar.

### Table 1. Demographic Characteristics and Diagnoses of Study Patients

<table>
<thead>
<tr>
<th>Criteria</th>
<th>House Staff Group</th>
<th>IV Team Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average age, y</td>
<td>58</td>
<td>60</td>
</tr>
<tr>
<td>Female</td>
<td>43 (49)</td>
<td>196 (55)</td>
</tr>
<tr>
<td>Black†</td>
<td>68 (80)</td>
<td>288 (84)</td>
</tr>
<tr>
<td>Diagnoses‡</td>
<td>81 (100)</td>
<td>331 (100)</td>
</tr>
<tr>
<td>Active infection</td>
<td>42 (52)</td>
<td>169 (51)</td>
</tr>
<tr>
<td>Skin disease</td>
<td>17 (21)</td>
<td>64 (19)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>13 (16)</td>
<td>73 (22)</td>
</tr>
<tr>
<td>Active malignancy</td>
<td>14 (17)</td>
<td>65 (20)</td>
</tr>
<tr>
<td>Collagen vascular disease</td>
<td>11 (14)</td>
<td>40 (12)</td>
</tr>
<tr>
<td>AIDS</td>
<td>5 (6)</td>
<td>9 (3)</td>
</tr>
</tbody>
</table>

*Distribution of demographic characteristics and diagnoses is not significantly different between groups at P>.10 using Pearson χ² test. Average age was not significantly different (P=.49, t test). IV indicates intravenous; AIDS, acquired immunodeficiency syndrome.

†Race information was not available for 3 house staff and 10 IV team patients. Missing cases omitted from total when computing race percentages.

‡Diagnosis information was not available for 6 house staff and 23 IV team patients. Diagnoses percentages sum to more than 100 because of multiple diagnoses.
This study demonstrates that the work of an IV therapy team can significantly reduce local and infectious complications of peripheral IV catheters. The overall local complication rate was 21.7% in house staff catheters and 7.9% in IV team catheters (Table 2). For each day observed, the local complication rate was higher in the house staff catheters (Figure 2), which also had a significantly higher rate of multiple complications.

Other studies have suggested that IV teams may consistently lower phlebitis rates.6,4 Tomford et al7 using sequential controls, found that institution of an IV team decreased the incidence of phlebitis from 32% to 15% and decreased major complications (cellulitis and suppurative phlebitis) from 2.1% to 0.2%, with no episodes of catheter-related bacteremia. Hamory et al8 found that institution of an IV team decreased the phlebitis rate by 50%, although the incidence of phlebitis was low (5% in non–IV team and 2.5% in IV team patients). No severe complications or bacteremias were observed in that study, but insertion sites were not followed up after catheter removal. Other studies also have reported a lesser phlebitis rate in IV team patients.6,9 However, in many of these studies, both steel and plastic catheters were inserted in control patients by a wide variety of hospital personnel in emergency departments, operating rooms, intensive care units, and medical and surgical wards, making it difficult to compare groups.

Our study differs from most prior studies by being randomized and prospective. We used only Teflon catheters and studied only medical patients. Also, this study included a group of catheters started by house staff but maintained and restarted as needed by the IV team to reflect typical hospital conditions. The fact that this group had complication and phlebitis rates similar to those of the group with catheters started and maintained by the IV team has 2 important implications. First, under a realistic 9 AM to 5 PM, Monday through Friday work schedule, a dedicated IV team can be associated with significantly lower complication rates. Second, the lower rates mostly reflect the impact of the IV team on maintaining and relocating IV catheters within 72 hours (or within 24 hours for catheters started in emergent conditions).

The phlebitis rates in the present study (Table 2) are lower than some reported rates of 25% to 35%.1 This probably reflects differences in definition and study design. First, the presence of a local site complication in this study, unlike previous studies, most often required an objectively observed abnormality at least 3 cm from the catheter insertion site. This was a deliberately strict definition designed to distinguish between actual catheter complications and symptoms caused by the presence of the catheter itself. Second, the point system used in this study to define the presence of phlebitis differs from criteria used in other studies, in which either a qualitative scale of patient symptoms or the presence of from 1 to 3 local abnormalities was accepted as sufficient to define phlebitis.6,7,9,11 Applying criteria from these previous studies to our study results in a phlebitis rate of 13% for house staff catheters and 6.6% for IV team catheters. Thus, patients cared for by the IV team fared better by any of the criteria that we or others have used. In fact, the objective criteria used to define phlebitis in our study likely give a conservative estimate of phlebitis incidence and may underestimate the effect of an IV team on reducing complication rates.

### Table 2. Complication Rates of Catheters by Group

<table>
<thead>
<tr>
<th>Criteria</th>
<th>House Staff Group</th>
<th>IV Team Group*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. of catheters</td>
<td>138 (100.0)</td>
<td>737 (100.0)</td>
</tr>
<tr>
<td>Local complications‡</td>
<td>30 (21.7)</td>
<td>58 (7.9)</td>
</tr>
<tr>
<td>None</td>
<td>120 (87.0)</td>
<td>688 (93.4)</td>
</tr>
<tr>
<td>Tenderness &gt;4 cm from site</td>
<td>10 (7.2)</td>
<td>12 (1.6)</td>
</tr>
<tr>
<td>Warmth</td>
<td>0 (0)</td>
<td>7 (0.9)</td>
</tr>
<tr>
<td>Erythema</td>
<td>7 (5.1)</td>
<td>20 (2.7)</td>
</tr>
<tr>
<td>Induration and/or swelling &gt;3 cm from site</td>
<td>13 (9.4)</td>
<td>18 (2.4)</td>
</tr>
<tr>
<td>Cord 3-6 cm from site</td>
<td>0 (0)</td>
<td>1 (0.1)</td>
</tr>
<tr>
<td>No. of local complications per catheter‡</td>
<td>1</td>
<td>9 (6.5)</td>
</tr>
<tr>
<td>2</td>
<td>6 (4.3)</td>
<td>5 (0.7)</td>
</tr>
<tr>
<td>3</td>
<td>3 (2.2)</td>
<td>2 (0.3)</td>
</tr>
<tr>
<td>Frequency of defined complications§</td>
<td>Phlebitis</td>
<td>2 (1.4)</td>
</tr>
<tr>
<td>Infiltration</td>
<td>7 (5.1)</td>
<td>4 (0.5)</td>
</tr>
<tr>
<td>IV-related bacteremia</td>
<td>3 (2.2)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

*IV indicates intravenous.

‡At test of difference of total complication rates between groups: P < .001; 95% confidence interval of difference in total complication rates (13.8%), 3.2-24.5. Standard errors using catheters as sampling unit are house staff, 5.3; and IV team, 1.2. Comparable SEs using patients as sampling unit and ratio estimates to account for the varying number of catheters per patient are house staff, 6.2; and IV team, 1.3.

§Phlebitis and infiltration frequencies differ significantly between groups, Pearson χ² P < .001. Odds ratio of no complications vs 1 or more complications, (688/49)/(129/9)=10.2; 95% confidence interval, 3.2-24.5.

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Finally, the observer’s schedule (on 5 days, off 2 days) may have resulted in an underestimation of complications.

In addition to the decrease in local complications, no catheter-related bacteremias occurred in IV team patients, compared with 3 episodes in house staff patients. Review of the medical records suggested that 2 of the 3 bacteremias in the house staff group might have been prevented had the patients been in the IV team group because of its adherence to the established site change protocol. The bacteremia rate of 2% in the house staff patients is higher than the currently accepted rate of 0.2% to 0.5% for peripheral catheters.\(^1\) It is possible that the presence of the IV team heightened attention to catheter-related complications among both infection control nurses and house staff, resulting in better documentation of catheter-related complications. Nonetheless, the overall bacteremia rate for all catheters placed during the present study period was 0.3%.

In our study, maintenance and timely removal of the IV catheter appeared to be more important than the specific personnel inserting the catheter in determining the occurrence of complications. Although this study did not investigate reasons for house staff noncompliance with the requirement to change IV sites within 72 hours, the many demands placed on busy house staff and ward nurses may be at least a partial explanation. No study to date has compared an IV team with measures, such as continuing education or certification requirements, that might increase compliance of those responsible for IV care.

Two potential sources of bias in our study require comment. First, the observer who gathered data on catheter complications was not blinded to treatment assignment. The observer’s findings, however, were validated by unannounced audits, which suggests that bias in data collection is unlikely to have affected the findings significantly. In addition, documentation of bacteremia was performed by independent surveillance of all hospital blood culture results. Second, although observations of house staff catheters were limited to a subset of those patients, the number of catheters observed in the house staff group was about 50% less, and the number of patients one third less, than expected based on the number of patients admitted during the 3 months of the study. This probably reflects time constraints and the fact that house staff catheters remained in place for a longer period, with the consequence that house staff patients had fewer catheters placed. Nevertheless, the demographic and clinical characteristics (Table 1) and the parental exposures of the patient groups were comparable.

Although we clearly documented a lower incidence of IV complications among the IV team patients (Table 2 and Figure 2), we did not rigorously assess the cost-effectiveness of the team. Haley et al\(^12\) estimated that a primary bacteremia adds 7.4 days to the average hospital stay; preventing the cost of these complications and of potential medicolegal expenses could offset part of the cost of a team. Members of IV teams are also superior to other hospital staff in documenting use and reducing waste.\(^6,13\) For all of these reasons, an IV team may save more than its costs,\(^13\) but this is difficult to prove. In addition, an IV team may have less tangible but very important effects, such as improving house staff morale. In a satisfaction survey during this study (data not shown), medical house staff reported that the IV nurses were more successful with difficult catheter insertions, that patient–house staff and nurse–house staff relations improved, and that house staff levels of frustration decreased. This is in keeping with a survey that showed that approximately 90% of medical residents and faculty believe that insertion of the initial IV catheter on admission should be performed by hospital personnel other than medical house staff.\(^14\)

Finally, at a time when the structure and emphasis of medical house staff training programs is under critical evaluation, with particular concern directed toward time spent on educational activities and relieving stress attributed to excessive workload, an IV team may increase educational time for house staff. An IV team also may provide important teaching and quality assurance functions by instructing and evaluating other hospital personnel and students on aseptic techniques and proper IV insertion and maintenance.

Accepted for publication July 9, 1997.

There was no external financial support for this study. Partial funding was provided by the Research and Education Foundation of the Michael Reese Medical Staff.

We would like to acknowledge the significant contributions of the Michael Reese Hospital IV Team Task Force members: James Kennedy, MS; Sidney Cohen, MD (deceased); Audrey Klop, RN, PhD; Maureen Weber, RN; Mac Watkins, RN; and Sheila Winfield, RN. We would also like to thank Serena Garella, MD, and Jordan J. Cohen, MD, and the Michael Reese Hospital medical house staff for their support of the project, and to recognize Diane Patton for administrative research support.

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