Computer Identification of Symptomatic Deep Venous Thrombosis Associated with Peripherally Inserted Central Catheters

R. Scott Evans, MS, PhD1,2, Lorraine H. Linford, RN, BS, CNSN3, Jamie H. Sharp, RN, CNSN3, Gayle White, APRN,CNSN3, James F. Lloyd, BS1, Lindell K. Weaver, MD4,5

1Medical Informatics, Intermountain Healthcare; 2Biomedical Informatics, University of Utah School of Medicine; 3Nutrition Support Service/PICC Team, LDS Hospital; 4Intensive Medicine, Intermountain Healthcare; 5Department of Medicine, University of Utah School of Medicine; Salt Lake City, UT

Abstract:

Peripherally inserted central catheters (PICCs) are considered a safe method to provide long-term antibiotic therapy, chemotherapy and nutrition support. Deep venous thrombosis (DVT) is a complication that requires early PICC removal, may extend hospitalization and can result in pulmonary embolism. PICC insertion teams strive to understand risk factors and develop methods to prevent DVTs. However, they can only manage what they can measure. At LDS Hospital, identification of PICC associated DVTs was dependent on verbal notification or manual surveillance of more than a thousand free-text vascular reports. Accurate DVT rates were not known which hindered prevention. We describe the development of a computer application (PICC-DVT monitor) to identify PICC associated DVTs each day. A one-year evaluation of the monitor by the PICC team and a review of 445 random vascular reports found a positive predictive value of 98%, sensitivity of 94%, specificity of 100% and a PICC team associated DVT rate of 2.8%.

Introduction

Peripherally inserted central catheters (PICCs) provide long-term intravenous access and facilitate the delivery of extended antibiotic therapy, chemotherapy and total parenteral nutrition. The PICC is inserted in a peripheral vein of the arm and advanced toward the heart until the catheter tip is in the superior vena cava. Nurses with special training or physicians use sterile technique and place the PICCs using a measured estimation from the insertion site to the heart or ultrasound and fluoroscopy. Chest radiographs are used to confirm the exact placement of the catheter tip. A sterile occlusive dressing is used to cover the insertion site and changed as needed to reduce the risk of infection.

Most PICC placements are without complications but some can be difficult due to small or irregular shaped veins and require alternate veins to be attempted. Severe placement complications can include arterial puncture and median nerve bisection12. If PICC placement is unsuccessful, a central venous catheter may have to be used.

PICCs can remain inserted for months, pose little risk of bleeding and are considered a safe alternative to other types of central venous catheters1. However, some studies have shown a high rate of PICC complications requiring early removal4,5. PICC associated problems include infection, phlebitis, line occlusion, catheter damage, catheter embolization and thrombosis. While efforts are implemented to prevent infection, some studies report that deep venous thrombosis (DVT) can be the most common adverse event associated with PICCs6,7. DVTs can be painful, require anticoagulation therapy and premature PICC removal followed by subsequent PICC replacement. Some DVTs result in long-term venous valve damage. Furthermore, the pulmonary embolism rate is reported to occur in 36% and 40% of DVT patients8,9. Of pulmonary embolism patients, mortality can be as high as 25%10. Studies on the overall incidence of DVTs associated with PICCs have included different patient populations and have shown DVT rates ranging from 2% to 38%11-15.

Except for central line and urinary catheter infection rates, an earlier study at LDS Hospital found that no consistent data was available on other central venous catheter complications and adverse medical device events in general16. Central venous catheter infection data was available due to a computerized infectious disease monitor that identified hospital-wide infection rates17. The PICC team at LDS Hospital used a paper document to record PICC-associated DVTs. This information was used to perform baseline and root cause analyses of identified DVTs for the purpose of future DVT prevention. Documentation of DVTs was only found in dictated (free-text) reports from ultrasound vascular studies. The PICC team was dependant on verbal notification.
or intensive manual surveillance of all vascular studies to document DVTs associated with PICCs. Thus, most information needed for DVT analysis was not collected and prevented appropriate changes and improvement in practice by the PICC team and nursing. Moreover, the actual symptomatic DVT rate associated with PICCs was not known at LDS Hospital or any other hospital at Intermountain Healthcare. It was determined that the PICC team needed a computerized method similar to the infectious disease monitor to provide daily identification of all symptomatic DVTs associated with PICCs. This paper describes the development of this computer tool and a one-year evaluation.

Methods

Background: LDS Hospital is a 500-bed, Level One trauma facility and a major teaching center for the University of Utah School of Medicine. The hospital information system consists of the HELP (Health Evaluation through Logical Processing) and HELP2 platforms that have been used for over 30 years. A key feature of the information system is the integrated electronic medical record (EMR) that contains most clinical information. The majority of the data in the EMR is coded which allows direct access by medical logic modules or other applications to analyze the data. Patient information in the form of dictated reports are not coded and are stored as free-text documents that can be accessed and reviewed through the information system.

Most patients with PICCs at LDS Hospital have them inserted by the PICC team that reports through the Nutrition Support Service. About 9% of PICCs are inserted by interventional radiology and a few are inserted before admission. The PICC team at LDS Hospital is comprised of 10 nurses with special training and internal certification to insert PICCs. The team places around 1,700 PICCs per year with an insertion success rate of 94%. Most patients do not require transport to interventional radiology in order to obtain proper PICC placement.

Development: All pertinent PICC insertion information is charted by the PICC team through the information system and stored as coded data (Figure 1). The data includes the date/time of insertion, person inserting the PICC, line status (active or removed), date/time of removal, person removing the catheter, reason for removal, catheter-type and insertion arm and vein.

A computer program, PICC-DVT monitor, was developed to make a sequential search of each hospitalized patient every day and look for the codes for an active PICC or one removed during the previous 5 days. When found, the program looked for the presence of any vascular study reports after the PICC insertion date/time. If found, the dictated report(s) were analyzed using a “keyword” driven procedure we developed to do natural language processing of the free-text. Since vascular study reports are just coded as “Vascular Study”, all vascular reports for PICC patients had to be analyzed.

Like wise, information to differentiate lower or upper extremity reports and other vascular studies was only contained in the free-text dictation. The natural language procedure made an initial scan of the report to separate header information from the findings. Header information contained the indication or reason for the vascular study and could contain DVT text that could produce a false alert. All text in the “Findings” and “Conclusion” sections of the report were then parsed a sentence at a time and scanned for keywords and key-phrases indicating the presence of a DVT, negative words and phrases that would “cancel-out” the key terms and the relational order of the key and negative terms (Figure 2). Upper- and lower-case representations, possible abbreviations and possible misspellings of each key and negative term were included in the scanning of each sentence. Phrases needed to be further checked for the presence of a “carriage return/line feed” between the words since they are different than a “space”. The vein information from the PICC charting was used to determine if the DVT was in the same arm and vein or ascending vein as the PICC. Numerous vascular studies were examined to identify how the presence of DVTs could be reported.

When the computer program identified a DVT associated with a PICC, an alert was formatted and sent to the printer in the PICC team office. The report was designed by the PICC team to contain the pertinent information they needed for patient follow-

```
<table>
<thead>
<tr>
<th>Code</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>(203 1 60 3 190 15 185 0)</td>
<td>House staff</td>
</tr>
<tr>
<td>(203 1 60 4 190 15 185 185)</td>
<td>Inserted by</td>
</tr>
<tr>
<td>(203 1 60 3 191 90 10 0)</td>
<td>Removed</td>
</tr>
<tr>
<td>(203 1 60 3 191 20 205 0)</td>
<td>Time inserted</td>
</tr>
<tr>
<td>(203 1 60 3 191 80 205 0)</td>
<td>Time of removal</td>
</tr>
<tr>
<td>(203 1 60 4 190 15 185 186)</td>
<td>Removed by</td>
</tr>
<tr>
<td>(203 1 60 3 191 80 41 0)</td>
<td>Remove Reason</td>
</tr>
<tr>
<td>(203 1 60 3 191 10 100 0)</td>
<td>Patient Location</td>
</tr>
<tr>
<td>(203 1 60 3 190 2 55 0)</td>
<td>Peripheral central catheter</td>
</tr>
<tr>
<td>(203 1 60 3 190 7 75 0)</td>
<td>Right arm</td>
</tr>
<tr>
<td>(203 1 60 3 190 7 95 0)</td>
<td>Upper extremity</td>
</tr>
<tr>
<td>(203 1 60 3 190 7 12 0)</td>
<td>Basilic vein</td>
</tr>
</tbody>
</table>
```

Figure 1. Example of coded data charted by PICC team.
up and analysis (Figure 3). Each alert identified the date of the vascular study along with needed patient demographic and current location information to facilitate patient intervention. Any PICC insertion information charted by the PICC nurse was also included. Patient pharmacy information was then examined for the presence of any anticoagulation therapy and appended to each alert. A file containing information from each DVT alert was stored on the information system and interfaced to an Oracle table to facilitate analysis and reporting.

LDS Hospital Vascular Study Report
Study Date: 02/14/2007
Transcribed: 02/15/07 at 10:14
INDICATIONS: swelling
FINDINGS - RIGHT UPPER EXTREMITY:
Limited visualization of the elbow and wrist due to bandages. Duplex scan of the veins was remarkable for an indwelling trans-basilic PICC catheter. There is evidence of deep venous thrombosis seen in the subclavian and axillary vein(s) associated with an indwelling PICC catheter. All other vein segments were clear, compressible and normal in appearance throughout the right upper extremity.
CONCLUSIONS
1. Deep venous thrombosis, right upper extremity, involving the subclavian and axillary vein(s) associated with indwelling catheter.
2. Indwelling trans-basilic PICC catheter, right upper extremity.

Figure 2. Example of a partial free-text vascular study report used to identify the presence of a DVT.

LDS Hospital Vascular Study Report
Study Date: 02/14/2007
Transcribed: 02/15/07 at 10:14
INDICATIONS: swelling
FINDINGS - RIGHT UPPER EXTREMITY:
Limited visualization of the elbow and wrist due to bandages. Duplex scan of the veins was remarkable for an indwelling trans-basilic PICC catheter. There is evidence of deep venous thrombosis seen in the subclavian and axillary vein(s) associated with an indwelling PICC catheter. All other vein segments were clear, compressible and normal in appearance throughout the right upper extremity.
CONCLUSIONS
1. Deep venous thrombosis, right upper extremity, involving the subclavian and axillary vein(s) associated with indwelling catheter.
2. Indwelling trans-basilic PICC catheter, right upper extremity.

Figure 2. Example of a partial free-text vascular study report used to identify the presence of a DVT.

The computer program was tested for two months by the PICC team to validate an acceptable positive predictive value of each DVT alert and resolve any format issues. Some modifications to the natural language process and report format were made during that time. The “time driver” on the information system was used to activate the program each day at 9:00AM. The report was released for production on 01/01/2006.

During the study year, a nurse from the PICC team was designated to check the alert printouts each day for patient follow-up and documentation. Each DVT alert was verified by the nurse and categorized by how and where the PICC was inserted. To determine the over all sensitivity and specificity of the PICC-DVT monitor, a random sample of 445 vascular reports was selected from a list of all patients with vascular study reports after PICC insertions during 2006. As an initial test of the new DVT information, DVTs rates were compared between PICC patients with any ICD9 code for cancer and those without using the chi-square test. This study was approved by the Institutional Review Board.

Results
From 01/01/2006 through 12/31/2006, 25,587 patients were admitted for a total of 127,132 patient days at LDS Hospital. During the study year, the PICC team inserted 1,688 PICCS and 1,141 vascular studies were reported for PICC patients of which 788 vascular studies from 497 distinct patients were ordered after PICCs were inserted.

During 2006, the PICC-DVT monitor identified 56 PICC associated DVTs (Table). All 56 DVT alerts were followed up by the PICC team and 55 (98%) were determined to be PICC associated DVTs and 44 (80%) were from PICCS inserted by the PICC team. The one false positive alert was due to incorrect charting of a central line as a PICC until the DVT was reported. One DVT associated with a PICC was identified by the PICC team through verbal communication and not identified by the PICC-DVT monitor. Eleven DVTs were from PICCs inserted outside the hospital or by radiology.

From the 445 random vascular studies reported after PICC insertions, 47 DVTs were identified of which 44 (sensitivity = 94%) were identified by the PICC-DVT monitor. No false positive alerts were identified (specificity = 100). Since the incorrect charted PICC line was no longer identified as a PICC at the time of the retrospective vascular study review, it did not get included. Cancer patients with PICCs were found to have a higher DVT rate compared to non-cancer patients (4.5% vs 3.4%), but the difference was not significant. PICCs inserted by the PICC team had a DVT rate of 2.8% compared to 3.7% for all PICC patients.

Many patients had DVTs in a leg or a different arm or vein from the PICC. The most complex part of the natural language logic was to make sure the DVT was in the same arm and same or ascending vein as...
the PICC. This situation was identified during the testing before the study period and represented most of the changes to the logic. It also accounted for the one missed DVT identified by the PICC team the first month of the study. The PICC was inserted in the basilic vein which feeds into the axillary and subclavian veins where the DVT was identified. The three DVTs missed by the PICC-DVT monitor identified during the random vascular study review were due to use of terms not identified during development or testing. On occasion, the vascular report contained the phrase, “associated with an indwelling catheter”. The identification of DVTs by the natural language logic did not look for that phrase in the report since it was not always included in the vascular report.

Table. Verification of PICC-DVT monitor.
1/1/06 through 12/31/06

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PICC-DVT monitor alerts</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>DVT alerts verified by PICC team</td>
<td>55</td>
<td>(98)*</td>
</tr>
<tr>
<td>DVTs from PICCs identified by PICC team and not by PICC-DVT monitor</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Random vascular reports with DVTs</td>
<td>47 (100)</td>
<td></td>
</tr>
<tr>
<td>DVTs identified by PICC-DVT monitor</td>
<td>44 (94)*</td>
<td></td>
</tr>
<tr>
<td>Random vascular reports without DVTs</td>
<td>398 (100)</td>
<td></td>
</tr>
<tr>
<td>Vascular reports identified without DVTs</td>
<td>398 (100)*</td>
<td></td>
</tr>
<tr>
<td>DVTs by PICC-DVT monitor</td>
<td>229</td>
<td></td>
</tr>
</tbody>
</table>

Discussion

The true incidence of PICC associated DVTs is probably under reported. Routine vascular studies are only performed on symptomatic patients. Thus, if the thrombi are not symptomatic, they will only be identified through prospective studies of all PICC patients. Since we can only manage what we can measure, the PICC team at LDS Hospital was hindered in their ability to reduce the number of symptomatic DVTs associated with their inserted PICCs. Without that information, they could not measure the impact of their improvement processes, could not compare themselves with other hospitals or perform consistent root-cause analysis. Since all vascular study dictations were just listed as “Vascular Study” in the information system, the PICC team resorted to a manual review of reports after PICC insertion times to identify PICC associated DVTs. During the random vascular study review, some patients had as many as nine vascular reports after a PICC was inserted. The natural language process used for the PICC-DVT monitor was adapted from the one used by other applications like the Antibiotic Assistant at Intermountain Healthcare to analyze free-text reports from chest X-rays, echocardiograms and pathology reports for evidence of infection. This process has worked well for years, but each of the key words and negative terms have to be specific for the type of narrative report analyzed.

The PICC-DVT monitor now provides the PICC team with the reliable information they need to identify DVTs and improve their methods to do root-cause analysis. The comparison of DVT rates between cancer and non-cancer patients was a start. Moreover, the PICC team can now spend more time doing patient follow-up and finding ways to prevent DVTs rather than using their time to identify which of their patients experienced DVTs. In addition, the PICC team now has accurate information to share with physicians concerning risk factors and expected DVT rates associated with PICC team insertions; which validates their input regarding optimal venous access device selection for specific patients. Information concerning risk factors and expected DVT rates can now be shared with patients when obtaining informed consent for PICC insertion.

The PICC team is now developing a more detailed charting program that will allow them to enter more information concerning potential patient risk factors, insertion techniques and the type and size of the catheters. From this added information, they will be able to identify suboptimal techniques, catheter specific problems, preferential vein selection, and patient-specific risk factors.

A few studies to identify PICC associated risk factors for DVTs have been published and include younger age, history of DVT, discharge to a skilled-nursing facility, amphotericin B therapy, cancer treatment and larger diameter catheters. Another small study of 26 patients did not find any statistical correlation between DVTs and site of insertion, catheter size, patient history of hypertension, hypercholesterolaemia, coronary artery disease, diabetes mellitus, cardiac insufficiency, smoking or cancer. A study comparing unfractionated and low molecular weight heparin as antithrombotic prophylaxis showed a decreased DVT rate in patients receiving the low molecular weight heparin. However, the use of prophylactic anticoagulation did not reduce the risk of DVT in another study. The difference in these findings indicates that more studies need to be conducted to identify effective and safe prevention strategies.

Studies have shown that PICC complication rates can be reduced through increased staff and patient education, improved insertion technique and the use
of trained PICC nurses\textsuperscript{20,21}. Reductions in PICC complication rates over a two-year period resulted in cost savings by reducing PICC reinsertions and a decrease in the use of thrombolytic agents\textsuperscript{22}.

**Conclusion**

The PICC-DVT monitor was found to provide a dependable and consistent method to identify symptomatic DVTs associated with PICCs within 24 hours of identification by vascular report. This information will provide the foundation for the PICC team to improve their patient follow up and long-term root-cause analysis for DVT prevention.

**References**