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Symptomatic Deep Vein Thrombosis Associated With Peripherally Inserted Central Catheters of Different Diameters: A Systematic Review and Meta-Analysis

Amit Bahl, MD[1], Kimberly Alsbrooks, BSN, RN, RT(R), VA-BC[2], Smeet Gala, MS, BTech[2], and Klaus Hoerauf, MD, PhD, DBA[2,3]

Abstract

We assessed the relationship between peripherally inserted central catheter (PICC) diameters and symptomatic deep vein thrombosis (DVT) rates. We conducted a systematic search for articles published between 2010 and 2021 reporting DVT incidence by catheter diameter in patients who had a PICC, followed by meta-analyses for DVT risk in each diameter group. Pooled DVT rates were incorporated into an economic model. Of 1627 abstracts screened, 47 studies were included. The primary meta-analysis of 40 studies demonstrated the incidence of DVT was 0.89%, 3.26%, 5.46%, and 10.66% for 3, 4, 5, and 6 French (Fr) PICCs ($P = .01$ between 4 and 5 Fr). Rates of DVT were not significantly different between oncology and nononcology patients ($P = .065$ for 4 Fr and $P = .99$ for 5 Fr). The DVT rate was 5.08% for ICU patients and 4.58% for non-ICU patients ($P = .65$). The economic model demonstrated an annual, incremental cost savings of US$114 053 for every 5% absolute reduction in 6 Fr PICCs use. Using the smallest PICC that meets the patients' clinical needs may help to mitigate risks and confer savings.

Keywords

systematic review, meta-analysis, peripherally inserted central catheters, venous thromboembolism, upper extremity deep vein thrombosis, catheter-related thrombosis, catheter diameter, French size

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Introduction

Peripherally inserted central catheters (PICCs) are increasingly being used in vascular access for the delivery of medication, anesthesia, chemotherapy, and/or parenteral nutrition.[1–3] Nonetheless, PICC-associated complications do exist, such as thrombosis, and may result in adverse patient outcomes and treatment delays. Despite these complications, PICCs are ideal for gaining central access when compared to other catheters, as they may be more cost-effective and can be conveniently placed by a dedicated vascular access specialty team.[4]

Deep vein thrombosis (DVT) is a complication associated with central catheters such as PICCs that has gained considerable attention for its potential to cause serious conditions, such as pulmonary embolism and postthrombotic syndrome.[1] Reports of PICC-associated DVT have prompted healthcare teams to limit its use due to concerns about complications, particularly in patient populations with multiple comorbidities, such as oncology and critically ill patients. Although care surrounding the use of PICCs is warranted, the incidence of PICC-associated DVT is highly variable, with current estimates ranging from 0% to 71.9%.[1] Heterogeneity in study designs, patient populations, and DVT definitions (eg, symptomatic or asymptomatic) within existing literature have

[1] Department of Emergency Medicine, Beaumont Hospital, Royal Oak, MI, USA
[2] Medical Affairs, Becton Dickinson and Company, Franklin Lakes, NJ, USA
[3] Department of Anesthesiology and Intensive Care, Medical University of Vienna, Wien, Austria

Corresponding Author:
Kimberly Alsbrooks, Medical Affairs, Becton Dickinson and Company, 18-03 NJ-208, Franklin Lakes, NJ 07417, USA.
Email: kim.alsbrooks@bd.com

contributed to this observed variability. In addition, some evidence has suggested that different PICC sizes may be associated with varying incidence rates of DVT.[2] PICCs with larger diameters have been reported to be associated with higher DVT rates, as they are more likely to obstruct venous blood flow and so predispose patients to thrombotic events.[5] For this reason, reported PICC-associated DVT rates to vary appreciably across different studies, depending on whether larger (between 5 and 6 French [Fr]) or smaller (between 3 and 4 Fr) PICCs were used.[5]

In addition to these complication risks, a significant economic burden has been associated with managing thrombotic events such as DVT. For an average inpatient stay of 5 days, each initial episode of DVT can cost about US$30 591 to manage, with the potential for downstream reoccurrences.[6] Other studies have reported DVT costs ranging from US $15 973 to US$33 200 depending on resource types and hospitalization duration.[7,8] In 2012, managing DVT events was estimated to cost between US$4.9B and US$7.5B, primarily driven by inpatient hospitalization.[9]

Since the clinical and economic burden of PICC-associated DVT has been quantified, substantial efforts have been made to better understand the risk factors associated with this adverse event. Some data have suggested that decreasing PICC sizes can mitigate the risk of developing DVT, as smaller catheters are less likely to impede blood flow through the targeted vein; however, other factors may also be important.[2] The current Infusion Nurses Society guidelines recommend the use of PICCs with a catheter-to-vein ratio of no more than 45% prior to insertion of a vascular access device in the upper extremity.[10] Thus, choosing a PICC with the smallest possible size appropriate for therapy may be an important preventative measure against developing DVT with the potential to optimize clinical care and reduce economic burden.

The objectives of this study were to (1) conduct a systematic literature review (SLR) and meta-analysis to quantify the relationship between PICC size and symptomatic DVT risks, and (2) develop an economic model to estimate the healthcare resource costs of managing PICC-associated DVT across different PICC diameter utilization scenarios.

Methods

Search Strategy

We conducted the SLR and meta-analysis in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Figure 1). A protocol was not prepared, and the review was not registered. The search strategy was designed by a medical information specialist using key terms and controlled vocabulary that were relevant to the research question and scope of this review (eg, catheter-related thrombosis). The search strategy targeted single-armed studies, comparative observational studies, and randomized controlled trials published between January 2010 and June 2021. We searched Ovid MEDLINE, Embase, and EBM reviews (including Cochrane and CENTRAL databases). There were no language limits integrated into the search; however, non-English articles were manually excluded during screening. Duplicate records were removed. The search strategy and PRISMA checklist are provided in Appendix 1 of the Supplemental Material.

Study Selection

All relevant articles identified from the search were transferred to the systematic review software DistillerSR (version 2.35, Evidence Partners Inc., Ottawa, ON, Canada) for screening. The screening process consisted of 2 phases. In the first phase, the title and abstract of each article were reviewed based on inclusion/exclusion criteria. In the second phase, articles were reviewed in their entirety to assess their eligibility for the meta-analysis. The screening was completed by 2 reviewers. Any discrepancies were resolved by consensus and where necessary, a third adjudicator.

The inclusion/exclusion criteria used for the screening process followed the Population, Intervention, Comparators, Outcomes, and Study design (PICOS) framework. Because PICCs are traditionally placed in the upper limbs, we included studies with PICC insertion in the upper arm but excluded studies with PICC placement in the lower limbs. Studies that did not mention thrombosis were excluded. The outcome of interest was symptomatic DVT. Narrative reviews, pre-clinical studies, pilot and/or feasibility studies, editorials, and commentaries were excluded. To ensure the extracted data could be used for the meta-analysis, articles that reported DVT rates in aggregate (eg, one DVT rate for 4 and 5 Fr PICCs) were excluded. Within studies, subgroups based on PICC size were excluded if data were available for <20 catheter placements.

We found that many studies were missing necessary information to determine their eligibility for the meta-analysis, such as whether venous thrombosis developed in a deep or superficial vein. Excluding these studies could limit the robustness and generalizability of our findings, so a scenario analysis was conducted using all studies that could be potentially relevant (Appendix 2 of the Supplemental Material). For this 'DVT expanded definition' scenario analysis, we included studies that did not specify whether the DVT episode was symptomatic or did not clearly indicate the type of thrombosis (eg, venous thrombosis not classified as being deep vein or superficial). However, studies (or study data) in which DVTs were explicitly described as being asymptomatic (eg, identified only by imaging) were excluded.

Data Analysis

Basic study and patient characteristics and outcome-specific data were extracted into a Microsoft Excel (version 2102, Microsoft Corporation, Redmond, WA, USA) spreadsheet. The extracted information included the first author's surname, year of publication, total sample size across all catheter diameters, population type (ie, oncology vs non-oncology, intensive care [ICU] vs non-ICU), setting (eg, critical care), region, key

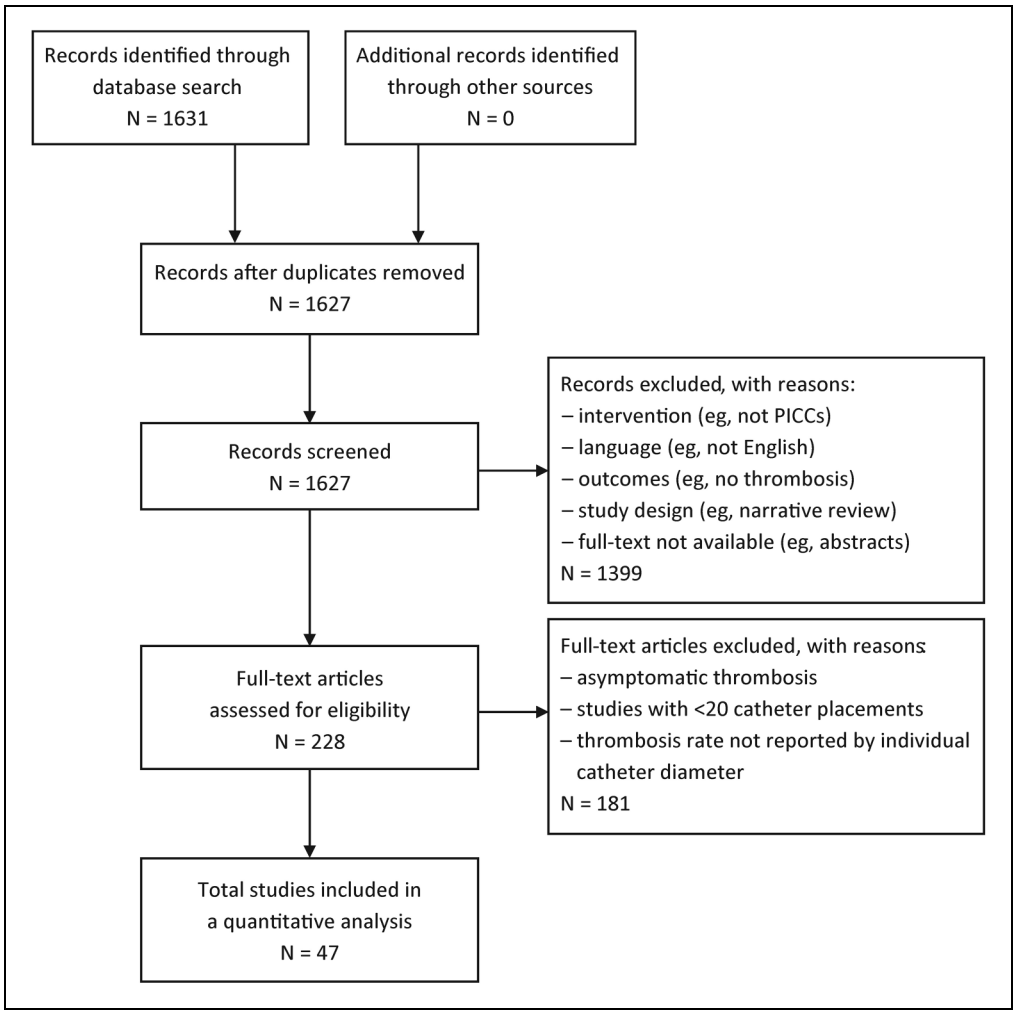

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

baseline characteristics (eg, age), number of PICCs inserted by catheter diameters, number of DVT episodes by catheter diameters, and incidence rate of DVT by catheter diameters. Extractions were completed by a single reviewer and were reviewed for accuracy by a second reviewer. Reviewers worked independently to extract data.

Statistical Analysis

Random effects and single-arm meta-analyses were performed for DVT risk in each catheter diameter group. All statistical analyses were performed using R (version 3.6.1, https://www.r-project.org/), and statistical significance was assessed using an alpha value of 0.05. Analysis of variance (ANOVA) tests were conducted to examine the effect of each Fr size within each subgroup and determine if there was at least one significant difference between the means. A Tukey-Kramer procedure was done to perform multiple pairwise comparisons to assess the potential differences between each pair of means. This allowed a more detailed examination of the differences between the groups. Lastly, two-sample *t*-tests were run to compare the results of the oncology and nononcology subgroups. All statistical tests were two-sided, and variances were assumed to be unequal.

I^2 values were calculated to describe the percentage of variance attributable to heterogeneity between studies. The following ranges were used to interpret I^2 values regarding the degree of heterogeneity present between the synthesized studies for each comparison: 0% to 40% represented minimal heterogeneity, 30% to 60% represented moderate heterogeneity, 50% to 90% represented substantial heterogeneity, and 75% to 90% represented considerable heterogeneity. If the I^2 value was between 75% and 90% but the confidence intervals (CIs) for the effect measures overlapped between studies, then the heterogeneity was classified as substantial. If the I^2 value was between 75% and 90% and the CIs for the effect measures did not overlap between studies, then the heterogeneity was classified as considerable.

Economic Model

The healthcare resource costs of managing PICC-associated DVT episodes were estimated by developing an economic model using Microsoft Excel (version 2102, Microsoft

Corporation, Redmond, WA, USA). The model design was consistent with the guidelines from the International Society for Pharmacoeconomics and Outcomes Research. Based on a set of inputs (Appendix 4 of the Supplemental Material) the model estimated the cost increase or savings over a one-year timeframe for different PICC size utilization scenarios.

The model compared 2 scenarios: current practice, in which PICC sizes were evenly distributed across all sizes, and future practice, in which the proportion of either 6 Fr or both 6 Fr and 5 Fr PICCs was progressively reduced and redistributed across smaller Fr sizes. An even distribution of different PICC sizes was assumed in the current scenario as practice patterns can vary greatly across clinical settings and within different patient populations.[2] We made the simplifying assumption that patients had similar characteristics (eg, frequency of catheter changes) across catheter size.

The cost to manage each DVT episode was taken from Magnuson et al,[6] which reported costs for a mean hospitalization length of stay of 6.4 days, outpatient care (eg, physician visits), compression stockings or devices, and other ancillary costs. The management cost per DVT episode was published in 2017 US dollars. As a conservative approach, we chose not to inflate this cost due to the balance between rising costs of labor (eg, nursing costs) and diminishing costs of technology (eg, laboratory tests). A sensitivity analysis was conducted with $\pm 25\%$ of this published cost. A difference in acquisition cost was not modeled for different PICC diameters, as it was determined this cost would be negligible within the analysis, and these costs can vary across settings. The incidence rates of PICC-associated DVT were taken from the results of our primary meta-analysis (Figure 2), which are described below.

Results

Search Results

Figure 1 shows the results of the systematic search and screening process. In total, 1627 records were identified through database searches after removing duplicates, of which 1399 were excluded at the abstract screening phase. Of the remaining 228 records, 181 were excluded at the full-text screening phase, primarily due to inadequate reporting of outcomes. In total, 47 clinical studies were included in the meta-analysis.

Meta-Analysis

Of the 47 clinical studies identified via the SLR, the 40 studies that clearly reported symptomatic DVT rates were included in the primary meta-analysis. Table 1 provides a summary of the key study characteristics of these 40 studies.

The primary random effects meta-analysis of 40 studies reporting on symptomatic DVT patients demonstrated that the rate of DVT increased with increasing catheter diameter (3 Fr: 0.89%; 4 Fr: 3.26%; 5 Fr: 5.46%; 6 Fr: 10.66%) with a statistically significant difference observed between 4 and 5 Fr PICC sizes (Tukey-Kramer, $P = .01$) (Figure 2). Minimal differences were observed between fixed and random effects models. Similarly, these results were closely comparable to the "expanded DVT definition" scenario that included 47 studies in total, with pooled DVT rates found to be 0.89%, 3.43%, 5.12%, and 10.66% for 3, 4, 5, and 6 Fr PICC data, respectively (Appendix 2 of the Supplemental Material).

In a subgroup analysis of oncology patients, the rate of symptomatic DVT was quantified to be 4.13% for 4 Fr (11 studies), 8.06% for 5 Fr (6 studies), and 11.11% for 6 Fr (1 study) PICCs (Figure 3). There was insufficient evidence to conclude for any differences between the PICC sizes within the oncology subgroup ($P > .05$). In the nononcology study subgroup, pooled DVT rates were calculated to be 1.17% for 4 Fr, 4.52% for 5 Fr, and 10.72% for 6 Fr (Figure 4). Significant differences were found between the 3, 4, and 5 Fr DVT rates ($P < .05$) within the nononcology subgroup. When comparing results between the oncology and nononcology subgroups, the DVT rates were not deemed to be significantly different for either the 4 or 5 Fr size groups ($P = .065$ for 4 Fr and $P = .99$ for 5 Fr).

In terms of setting of care, a subgroup analysis was completed based on the presence of ICU patients across a total of 24 unique studies (Appendix 3 of the Supplemental Material). The rate of symptomatic DVT was reported to be 5.08% for ICU patients and 4.58% for non-ICU patients; this difference was not statistically significant ($P = .65$). Given limitations in data reporting, results could not be synthesized by both ICU status and PICC diameter.

Overall, heterogeneity varied widely across meta-analyses ranging from an I^2 of 0% (eg, single studies) to 97% for the overall symptomatic DVT population analysis; heterogeneity was reduced in certain subgroup analyses.

Economic Model

The economic model suggested that reducing the use of higher catheter diameters would result in cost savings for an institution with an annual PICC population size of 1000 patients. Across populations, an incremental annual cost savings of US$114 053 was predicted for every 5% absolute reduction in 6 Fr PICCs (ie, redistribution to smaller catheter diameters [ie, 3, 4, or 5 Fr]) (Appendix 4 of the Supplemental Material). Similarly, an incremental annual cost savings of US$183 087 was predicted when both 5 and 6 Fr catheters were reduced by 5% each to increase the use of 3 and 4 Fr PICCs (Appendix 4 of the Supplemental Material). In a scenario analysis, when the management cost of DVT varied by $\pm 25\%$ to consider the range of economic impact, annual cost savings ranged from US$85 540 to US$142 567 for every 5% reduction in 6 Fr PICCs use. The annual cost savings were predicted to range from US$137 315 to US$228 859 for every 5% reduction in each of 5 and 6 Fr sized PICCs.

Discussion

The objective of this study was to quantify symptomatic DVT rates by commonly used PICC sizes (ie, between 3 and 6 Fr). Notably, the literature broadly evaluated DVT rates that are

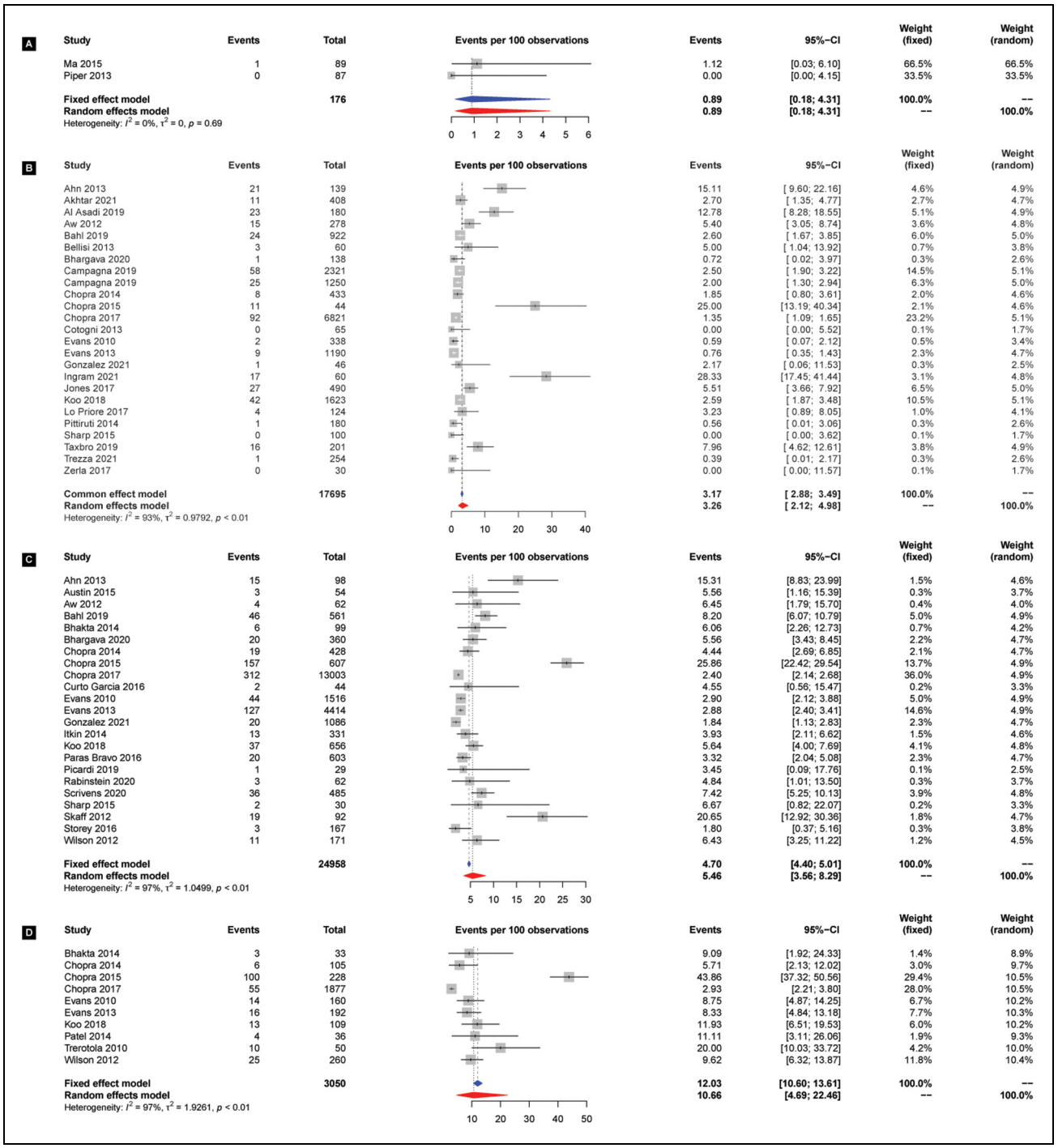

Figure 2. Forest plots of symptomatic deep vein thrombosis (DVT) risk for (A) 3 Fr, (B) 4 Fr, (C) 5 Fr, and (D) 6 Fr catheter diameters.

asymptomatic, symptomatic or a combination of both. We chose to focus on symptomatic DVT rates as these are most clinically applicable and most relevant from a health economics perspective. Our analysis demonstrated that symptomatic DVT rates tended to increase by catheter diameter across populations. Furthermore, applying these results to economic modeling illustrated the potential cost savings associated with reducing the use of larger catheter diameters through the avoidance of DVT management-related costs.

Although several publications have reported on DVT rates with catheter use, to our knowledge, a meta-analysis of rates by catheter diameter has not yet been published. Consequently, it was important to conduct a study to gather and assess all reported information to better understand the relationship between DVT rates and catheter diameter.[5,7] A meta-analysis by Schears et al (2020) concluded that PICC diameters influence DVT rates, where catheter diameter sizes were segregated by small (ie, 4 Fr) and larger (ie, 5 and/or 6 Fr) sizes; however,

Table 1. Summary Characteristics of Studies Included in the Primary Meta-Analysis (Symptomatic DVT).

Author and Year	Region	Study Design	Population	Total PICCs	PICC Sizes Evaluated (Fr)
Ahn et al 2013[12]	US	Retrospective	Oncology	237	4, 5
Akhtar and Lee 2021[11]	Canada	Retrospective	Oncology	408	4
Al-Asadi et al 2019[13]	UK	Retrospective	Oncology	180	4
Austin et al 2015[14]	Canada	Retrospective cohort	Nononcology	73	5
Aw et al 2012[15]	Canada	Retrospective cohort	Oncology	340	4, 5
Bahl et al 2019[16]	US	Retrospective chart review	Nononcology	1483	4, 5
Bellesi et al 2013[17]	Italy	Retrospective database	Oncology	60	4
Bhakta et al 2014[18]	US	Retrospective chart review	Nononcology	7179	5, 6
Bhargava et al 2013[2]	US	Case-control	Mixed	497	4, 5
Campagna et al 2019[19]	Italy	Retrospective database	Oncology	2321	4
Campagna et al 2019[20]	Italy	Retrospective database	Mixed	1250	4
Chopra et al 2014[21]	US	Retrospective cohort	Mixed	966	4, 5, 6
Chopra et al 2015[4]	US	Prospective	Mixed	909	4, 5, 6
Chopra et al 2017[22]	US	Retrospective cohort	Mixed	23 010	4, 5, 6
Cotogni et al 2013[23]	Italy	Prospective	Oncology	65	4
Curto Garcia et al 2016[24]	Spain	Prospective observational	Oncology	44	5
Evans et al 2010[25]	US	Prospective observational	Nononcology	2014	4, 5, 6
Evans et al 2013[7]	US	Prospective observational	Nononcology	5796	4, 5, 6
Gonzalez et al 2021[26]	Spain	Prospective cohort	Mixed	1142	4, 5
Ingram et al 2021[27]	Australia	Retrospective case control	Mixed	76	4
Itkin et al 2014[28]	US	Prospective randomized	Mixed	332	5
Jones et al 2017[29]	UK	Retrospective	Oncology	490	4
Koo et al 2018[30]	Australia	Retrospective cohort	Mixed	3020	4, 5, 6
Lo Priore et al 2017[31]	Switzerland	Prospective observational	Mixed	135	4
Ma et al 2015[32]	US	Retrospective	Nononcology	89	3
Paras-Bravo et al 2016[33]	Spain	Retrospective cohort	Oncology	603	5
Patel et al 2014[34]	Australia	Prospective randomized	Oncology	36	6
Picardi et al 2019[35]	Italy	Prospective randomized	Oncology	46	5
Piper et al 2013[36]	Canada	Retrospective chart review	Nononcology	95	3
Pittiruti et al 2014[37]	Italy	Prospective	Oncology	180	4
Rabinstein et al 2020[38]	US	Retrospective	Mixed	62	5
Scrivens et al 2020[39]	Canada	Retrospective cohort	Oncology	485	5
Sharp et al 2015[40]	Australia	Prospective	Mixed	136	4, 5
Skaff et al 2012[41]	Canada	Retrospective chart review	Oncology	92	5
Storey et al 2016[42]	US	Prospective randomized	Mixed	167	5
Taxbro et al 2019[43]	Sweden	Retrospective	Oncology	201	4
Trerotola et al 2010[44]	US	Prospective	Nononcology	50	6
Trezza et al 2021[45]	Italy	Prospective randomized	Oncology	254	4
Wilson et al 2012[46]	US	Retrospective cohort	Mixed	431	5, 6
Zerla et al 2017[47]	Italy	Prospective observational	Oncology	30	4

Only PICC sizes for which symptomatic DVT rates were available based on ≥20 catheter placements were reported in the table.
Abbreviations: DVT, deep vein thrombosis; ICU, intensive care unit; IP, inpatient/hospital ward; OP, outpatient; UK, United Kingdom; US, United States.

this meta-analysis was not as comprehensive as the current study (eg, did not include single-arm data) and was not able to delineate between each type of catheter diameter due to reporting issues.[5] Additionally, Balsorano et al (2019) published a meta-analysis focusing on symptomatic DVT.[1] Their results demonstrated that the weighted rate of DVT was 2.4%, with a higher rate in onco-hematologic patients of 5.9%. Rates by catheter diameter were not examined in this study.[1] In a three-year, prospective, observational study of PICC-associated DVT rates by catheter diameter at a tertiary hospital with trained and experienced PICC placers, results suggested that symptomatic DVT rates were significantly reduced when smaller catheter diameters were adopted ($P < .04$).[7] This study evaluated DVT rates by the number of lumens and catheter diameters, where the triple lumen group included a mix of 5 and 6 Fr PICCs. These readouts are consistent with the general results from our study, especially with the nononcology patient population (Figure 4). Our results also align with the current infusion therapy standards of practice from the Infusion Nurses Society, which describe several lines of evidence indicating that DVT risk is higher with larger diameter PICCs.[10] Additional well-designed studies of symptomatic DVT rates between PICC sizes can help confirm our findings.

Several factors may contribute to the occurrence of PICC-associated DVT, with increased PICC sizes being one important contributor.[5] Advances in clinical practice have addressed some well-known thrombotic risk factors (eg, use

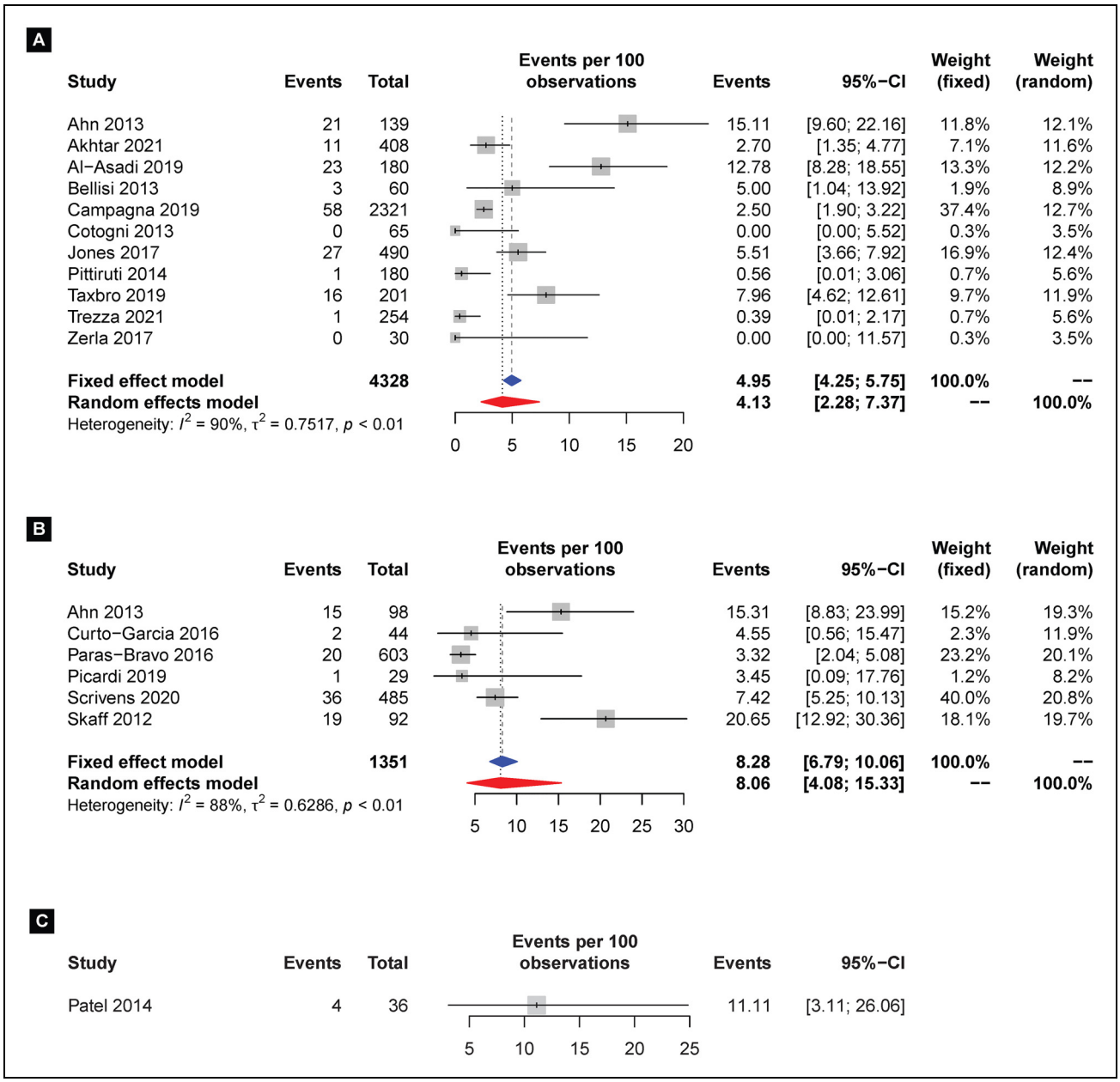

Figure 3. Forest plots of symptomatic deep vein thrombosis (DVT) risk for oncology subgroup for (A) 4 Fr, (B) 5 Fr, and (C) 6 Fr catheter diameters.

of single- vs multi-lumen PICCs and patient-related factors).[5] Over the past decade, practice patterns have changed to evaluate the catheter-to-vein ratio.[10,40] A ratio of 3 is suggested to decrease thrombotic complications.[1] Since blood flow is laminar and has higher velocity in the center compared to the peripheral walls of the vessel, a PICC that is placed at the center of the vein has a considerable impact on blood flow rate.[40] As a result, a smaller PICC to vein ratio may minimize the risk of developing DVT, as smaller PICCs may have a reduced impact on flow rates. In a prospective study that used both electrocardiography and radiographic imaging to confirm the tip location of PICC placements (n = 42 687 catheters) across 52 sites, the combined rate of DVT was 1.4% across all Fr sizes, which suggested evolving technology and optimal risk management strategies can further reduce the likelihood of developing DVT.[48]

The economic model suggested potential cost savings by reducing and redistributing the use of 6 Fr PICCs evenly across 3, 4, and 5 Fr PICCs, which can be explained by the lower symptomatic DVT risk associated with smaller PICC sizes. Cost savings increased further with the reduction of both 5 and 6 Fr catheter used. Our results were robust to sensitivity analyses on the cost of DVT, which has been shown to vary in the literature and may depend on local settings and treatment practices. Extending our model calculation to 2.7 million PICCs placed in all of the USD in 2020, the use of smaller size

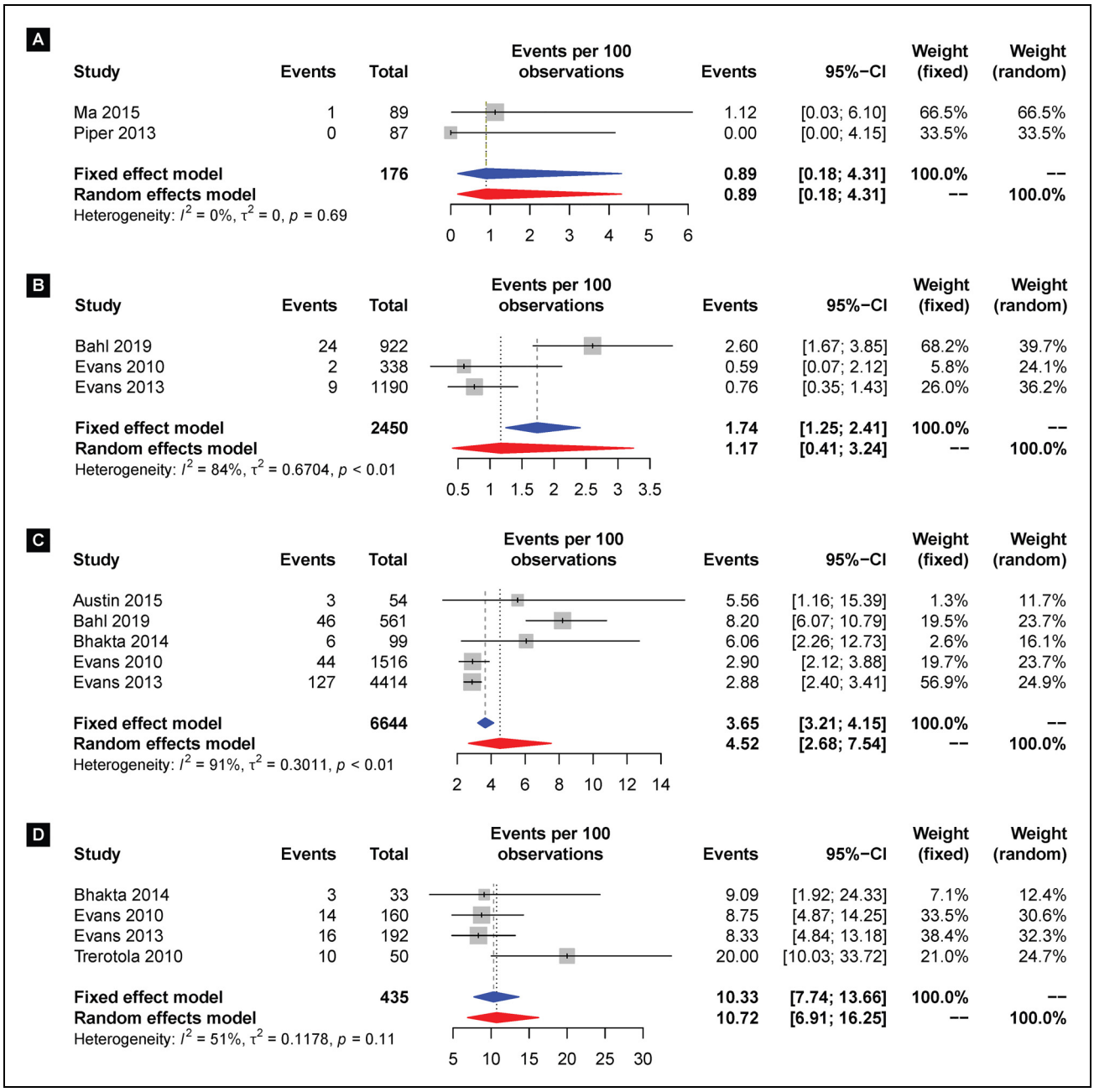

Figure 4. Forest plot of symptomatic deep vein thrombosis (DVT) risk for nononcology subgroup for (A) 3 Fr, (B) 4 Fr, (C) 5 Fr, and (D) 6 Fr catheter diameters.

catheters could be associated with an annual cost savings of US $307 944 302.[49]

In modern practice, it may be practical for clinicians to choose smaller-size catheters without sacrificing catheter capabilities and performance. Larger catheter diameters may be used in clinical practice due to necessity (eg, indications for a specific Fr size and lumen number), convenience, or uncertainty in guideline recommendations by population type. As multiple lumens may be needed depending on the clinical situation, it is possible for clinicians to maintain the required number of lumens while also reducing the size of the catheter. For instance, the use of 6 Fr catheters may be greatly reduced by using 5 Fr triple lumens and some 5 Fr use may be eliminated with the availability of 4 Fr double lumens. However, it may not be possible to avoid all use of 5 Fr since it is the smallest catheter diameter with a triple lumen option for simultaneous treatment delivery. Given the risk of catheter-associated DVT as it relates to diameter sizes, clinicians should deliberately assess this variable prior to insertion with the goal of balancing the risks of thrombosis yet delivering adequate therapy. To achieve this, clinicians should choose the smallest diameter or fewest lumens needed for the anticipated therapy.

This study has some important limitations. Although our meta-analysis was comprehensive with the inclusion of randomized, nonrandomized, and single-arm data, observational evidence is inherently more limited than Level 1 evidence. However, to focus on symptomatic DVT rates, assess data by catheter diameter, and explore various subgroup analyses, we chose to include all types of observational evidence (but limiting our analysis to study subgroups with a sample size of ≥ 20 per catheter diameter) as well as single-arm data. This allowed our analysis to be the most comprehensive evidence published in this space. Most of the studies included in our meta-analysis were in an oncology population or a mixed population of oncology and nononcology patients, which may have resulted in higher DVT rates than would be expected in the general population. Second, heterogeneity was high in our pooled estimates, as exhibited by high I^2 values across several of the random effects meta-analysis pooled results. This can be explained by the fact that many types of populations were considered in these studies, including those in ICU, non-ICU, inpatient, outpatient, and home-based delivery settings. The high heterogeneity is a limitation in the interpretation of the meta-analysis results, especially when a lower volume of studies exists within any one meta-analysis. To some extent, this heterogeneity was associated with a couple of studies that contributed outlier results. Additional well-described DVT studies are needed to reduce the level of uncertainty associated with meta-analyses in this space. Provided these studies become available, we would expect future analyses to have lower heterogeneity. Nevertheless, a linear trend could still be observed in rates of DVT with increasing catheter diameter, a finding that aligns with earlier published literature. Subgroup analyses (eg, oncology vs nononcology) helped to control for some of this heterogeneity; however, the data by catheter diameter was not readily available for ICU and non-ICU patients and an insufficient number of studies were available to compare pediatric and adult populations. Third, we chose a simplified modeling approach and structure given the assumption that DVT costs and rates would be the most impactful drivers of an economic evaluation. Although we explored increasing or decreasing the costs of DVT in a sensitivity analysis, cost savings results were still maintained with the different PICC utilization scenarios that were explored. Future economic analyses are required to consider other local resource parameters that may impact the results, as well as to localize economic findings to region-specific settings and institutions. Finally, we chose to not include PICC costs in our economic analysis, as it was not anticipated to be a driver of economic results. It is important to note that the magnitude of upfront expenses associated with acquiring PICCs of different diameters was assumed to be similar; however, these costs may become important in assessing scenarios with very minor changes in the distribution of different PICC diameters.

Conclusion

To our knowledge, this is the first meta-analysis that assessed pooled symptomatic DVT rates by common PICC sizes. An economic evaluation suggested important cost savings are associated with minimizing the use of 5 and 6 Fr PICCs, where possible. Larger PICC diameters are associated with a greater risk of symptomatic DVT. Additional well-designed studies of symptomatic DVT in smaller PICC sizes can help confirm this finding. Using the smallest PICC that meets the patients' clinical needs would help to mitigate this risk and may confer economic savings.

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Data Availability Statement

This study was based on data extracted from previously published research, and most of the data and study materials are available in the public domain.

Declaration of Conflicting Interests

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Ethics Statement

No ethics approval was required.

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ORCID iDs

Amit Bahl https://orcid.org/0000-0001-9495-1293
Kimberly Alsbrooks https://orcid.org/0000-0002-8684-7100

Supplemental Material

Supplemental material for this article is available online.

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