Complication and Failures of Central Vascular Access Device in Adult Critical Care Settings

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Objectives: To examine the proportion and rate of central venous access device failure and complications across central venous access device types in adult intensive care.

Data Sources: A systematic search was undertaken in the electronic databases Cochrane Central Register of Controlled Trials (CENTRAL), Embase, U.S. National Library of Medicine National Institutes of Health (MEDLINE), and Cumulative Index to Nursing and Allied Health (CINAHL) in September 2017.

Study Selection: Included studies were of observational (prospective and retrospective) or interventional design and reported central venous access device failure and complications in adult ICU settings. Studies were excluded if they were published prior to November 2006 or not reported in English. Two reviewers independently screened articles, assessed eligibility, extracted data, and assessed risk of bias.

Data Extraction: Data were extracted on the primary outcome, central venous access device failure, and secondary outcomes: central venous access device complications (central line-associated bloodstream infection, catheter-related bloodstream infection, catheter-related thrombosis, occlusion, catheter removal due to suspected infection, dislodgement, breakage, and local infection). Patient and device data and study details to assess the study quality were also extracted.

Data Synthesis: A total of 63 studies involving 50,000 central venous access devices (396,951 catheter days) were included. Central venous access device failure was 5% (95% CI, 3–6%), with the highest rates and proportion of failure in hemodialysis catheters. Overall central line-associated bloodstream infection rate was 4.59 per 1,000 catheter days (95% CI, 2.31–6.86), with the highest rate in nontunneled central venous access devices. Removal of central venous access device due to suspected infection was high (17%; 20.4 per 1,000 catheter days; 95% CI, 15.7–25.2).

Conclusions: Central venous access device complications and device failure is a prevalent and significant problem in the adult ICU, leading to substantial patient harm and increased healthcare costs. The high proportion of central venous access devices removed due to suspicion of infection, despite low overall central line-associated bloodstream infection and catheter-related bloodstream infection rates, indicates a need for robust practice guidelines to inform decision-making surrounding removal of central venous access devices suspected of infection. (*Crit Care Med* 2018; XX:00–00)

Key Words: central venous access device; complications; failure; intensive care

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Central venous access devices (CVADs) are a vital medical device during critical care admission to facilitate the delivery of supportive and interventional medical therapies (1). In the United States alone, more than 5 million CVADs are inserted annually (2), with 43–80% of patients in the ICU requiring central access (3). The CVAD most commonly inserted in ICU are nontunneled CVADs (NTCVADs), peripherally inserted central catheters (PICCs), and hemodialysis (4). These devices are mainly indicated for short- to medium-term duration, whereas tunneled or implanted CVAD, primarily used outside of critical care, are indicated for chronic or complex health conditions necessitating access longevity. Despite CVAD commonality in the ICU, serious patient harm, relating to insertion and management, remains prevalent (5–10).

CVAD dysfunction is caused by both infective (local tissue infections or central line-associated bloodstream infections [CLABSIs]) or mechanical (thrombotic, occlusive, or dislodgement) complications (5, 11). Infective complications are viewed as a preventable source of patient harm and have a significant impact on patients and healthcare costs (12). CVAD-associated infections are caused by translocation of bacterium and fungi either intra- or extraluminally. Excess mortality due to CLABSI is estimated at 22% (13), with each diagnosis costing U.S. $32,000 (14), contributing to increased length of ICU admission (> 4 d) (15). Because of the severity of harm associated with CLABSI, CVADs are also frequently removed due to suspicion of infection. Early CVAD removal on sign of infection (e.g., unexplained pyrexia) is traditionally advocated, to remove the source of infection and prevent further harm (16).

Mechanical complications also cause significant CVAD dysfunction, and adverse sequelae, however, have not been the focus of global practice transformation, as seen with CLABSI. One of the most frequent and serious mechanical complications is catheter-associated venous thromboembolism (CAVTs). CAVTs are associated with significant morbidity and mortality (17) from dual sources: the increased risk of CLABSI due to microbial proliferation within the thrombus (18), and pulmonary embolism (17). Critical illness, supportive therapies, preexisting comorbidities, and catheter placement choices place patients at increased risk of CAVT development (19–21). Nonthrombotic causes of catheter occlusion, including mechanical obstruction and medication precipitate, and resultant catheter breakage, can cause treatment disruption. With the advent of light sedation and early mobilization, concern regarding the dislodgement of CVADs is rising in prominence as a serious, frequent, adverse event (22).

A systematic review of pediatric CVAD complications established 25% CVADs (95% CI, 21–29%) failed prior to completion of therapy (5). However, there is no such synthesis of CVAD data in ICU. The primary aim of this systematic review was to determine the proportion and rate of CVAD failure and complications across CVAD types in adult ICU. These data can be used by guide clinicians in benchmarking practice and informing patient safety and research priorities.

METHODS

The review used standard methods for systematic reviews and is reported in accordance with Meta-analysis of Observational Studies in Epidemiology, where applicable (23). The review methods were prospectively registered on PROSPERO (CRD42016050292).

Eligibility Criteria

The review included observational (prospective and retrospective cohort) studies and control groups of randomized controlled trials (RCTs) which 1) enrolled study participants 18 years old or older, 2) with CVADs in ICU, and 3) reported outcomes of interest. Types of CVAD included in the study were NTCVADs, PICCs, hemodialysis catheters, tunneled, and totally implanted vascular access device (TIVD). We excluded studies in pediatric and neonates, CVAD insertions in non-ICU clinical settings, and that did not define CVAD type. We excluded studies published prior to November 2006 as we aimed to conduct a clinically relevant and contemporaneous review. We excluded studies not published in English, due to limited access to interpreters. Abstracts were included if data were sufficient to facilitate data extraction. Study authors were contacted to seek clarification concerning review inclusion eligibility and additional data.

Outcome Measures

The primary outcome was CVAD failure, defined as removal of CVADs before completion of therapy due to complications (5). The secondary outcomes were CVAD complications after successful CVAD insertion including CLABSI (24), catheter-related bloodstream infection (CRBSI) (12), CAVT (19), catheter removal due to suspected infection (25), occlusion, dislodgement (26), breakage (27), and local infection or phlebitis (26) (for detailed definitions, see **Supplemental Table 1**, Supplemental Digital Content 1, http://links.lww.com/CCM/D903).

Search Strategy and Study Selection

A systematic search for studies reporting CVAD failure or complications was undertaken in the following electronic databases on the September 30, 2017: Cochrane Central Register of Controlled Trials, Embase, U.S. National Library of Medicine National Institutes of Health, and Cumulative Index to Nursing and Allied Health. Medical search headings were developed by healthcare librarians including "vascular access devices," "central venous catheter," "central venous access device," "intensive care," and "critical care" (for full details, see **Supplemental Table 2**, Supplemental Digital Content 2, http://links.lww.com/CCM/D904). Additional studies were identified through hand-searching references.

Data Extraction and Quality Assessment

Two authors (M.T., J.S.) independently assessed titles and abstracts identified. Full texts of relevant studies were

reviewed and independently assessed for inclusion eligibility. A third author (A.U.) reviewed studies where consensus was not reached. Data extracted from included studies were number of patients, number of catheters, CVAD type, study method, frequency of CVAD failure/complications, catheter days, ICU type, and country of origin. Studies with multiple device types were split into substudies per device type. Data were extracted using a data extraction form, managed in Microsoft Excel (Microsoft, Redmond, WA).

Quality assessment tools were derived from three observational study assessment tools to comprehensively assess internal and external validity (28–30). The maximum score that each study could obtain was five (for full details, see **Supplemental Table 3**, Supplemental Digital Content 3, http://links.lww.com/CCM/D905).

Data Analysis

Score CIs with Freeman-Tukey double arcsine transformations were calculated for studies with dichotomous outcomes (failure/no failure), and Poisson CIs and standard errors were calculated for incidence rate (IR) outcomes. Pooled estimates were generated with random-effects meta-analysis and presented with 95% CIs. IR outcomes (continuous data) were pooled by using inverse variance with the DerSimonian and Laird method, per 1,000 catheter days and 95% CI; lower CI boundaries below zero were reported as zero. Heterogeneity between studies was assessed using the I^2 statistic, categorized as low (< 25%), moderate (25–75%), or high (> 75%). Subgroup and sensitivity analyses were performed by device type, risk of bias (ROB), and study method. Statistical analysis was performed using Stata 12 (Stata Corp, College Station, TX), with statistical significance at p value of less than 0.05.

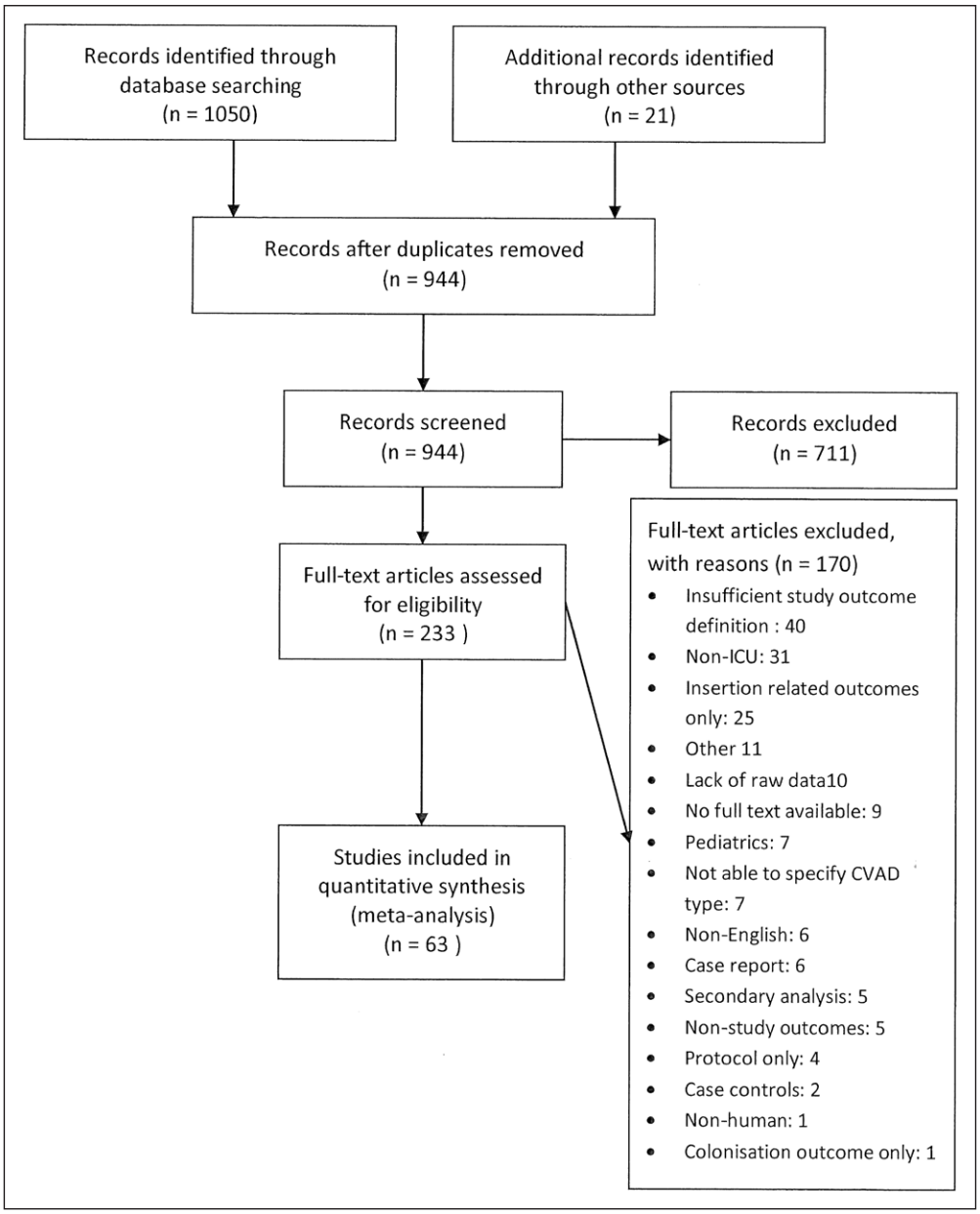

Figure 1. Preferred Reporting Items for Systematic reviews and Meta Analysis flowchart of articles screened for inclusion in the systematic review. CVAD = central vascular access device.

RESULTS

Figure 1 displays the inclusion and exclusion processes. Electronic databases search yielded 1,048 articles, and an additional 21 studies were identified from references. Following duplicate removal, 944 titles and abstracts were screened, and 233 full texts were assessed. After exclusion of 170 articles, 63 individual studies (10 studies were split into 21 substudies, totaling 74 entries due to multiple device types) were included in the meta-analysis, containing 50,000 CVADs and 396,951 catheter days.

Characteristics of Included Studies

Studies originated in Europe (31; 49%) (31–61), North America (12; 19%) (8, 62–72), South America (5; 8%) (22, 73–76), Oceania (6; 10%) (77–82), Asia (4; 6%) (83–86), and Middle East (5; 8%) (87–91). There were 24 RCTs (38%), 28 prospective (44%), and 11 retrospective studies (17%). As described in **Supplemental Table 4** (Supplemental Digital Content 4, http://links.lww.com/CCM/D906), a mix of ICU specialties were represented, with 25 studies (34%) not specifying ICU specialty.

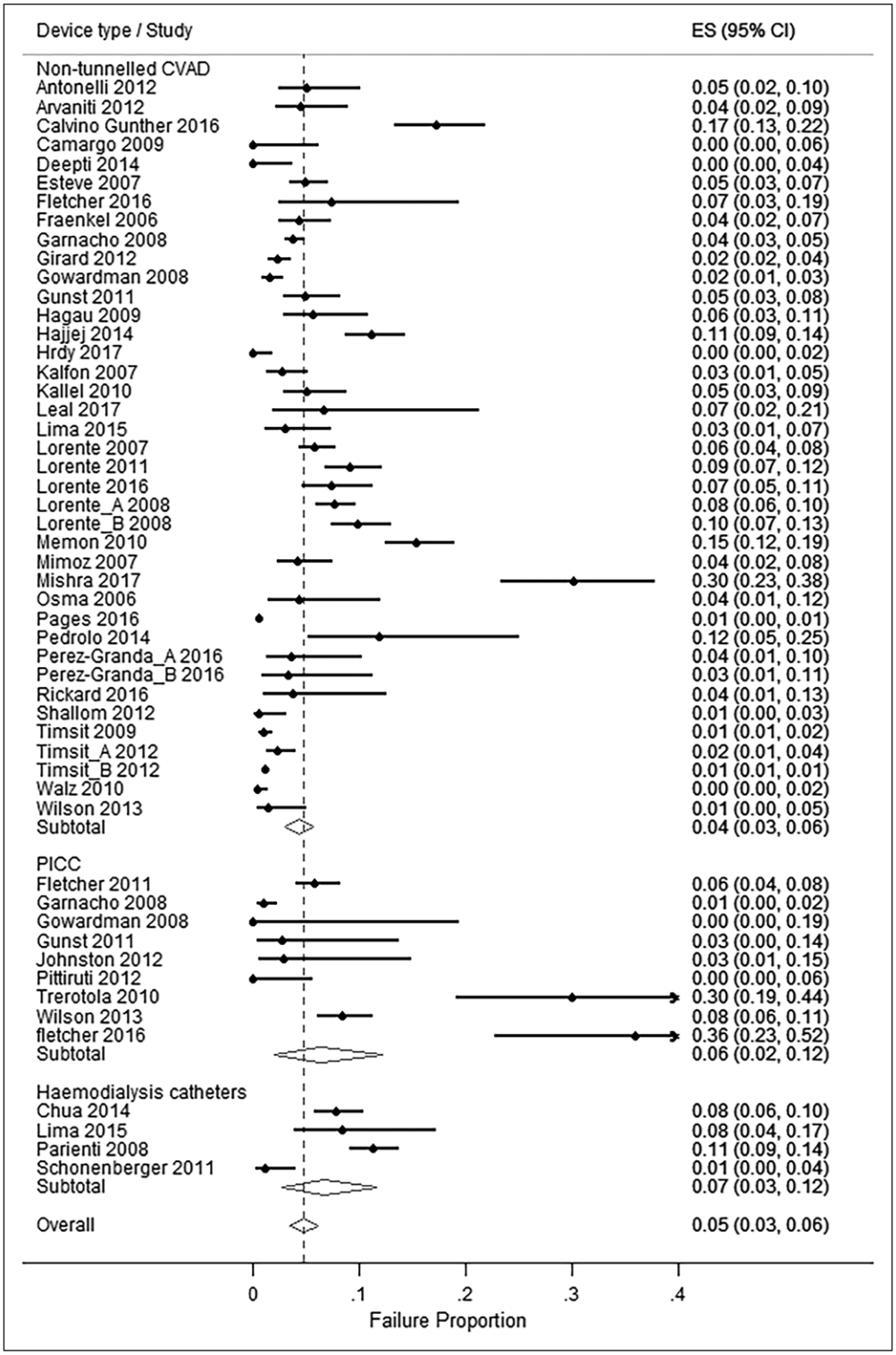

Figure 2. Proportion of central vascular access device (CVAD) failure ($n = 54$ studies). ES = effect size, PICC = peripherally inserted central catheter.

There were no studies that assessed tunneled and implanted CVADs or CVAD breakage.

Study Quality

The majority of studies were high quality, with 31 studies (49%) scoring five points, 25 studies (40%) with four points, and seven studies (11%) with two to three points. Catheter days were not reported in 13 studies and were excluded from the meta-analysis reporting complications per 1,000 catheter days (22, 34, 36, 49, 55, 56, 63, 64, 67, 72, 76, 82, 85). Due to lack of consistency in outcome definitions, some study outcomes were not eligible including catheter dysfunction (34), CRBSI (73), kinking (76), fixation failure (74, 76), displacement (76), infection (22, 56), exudate (74), catheter-related infection (57–59), catheter infection (56), and local reaction (74).

CVAD Failure

Figures 2 and 3 outline forest plots of proportion and IR of CVAD failure by CVAD type. Overall, 5% (95% CI, 3–6%) of CVADs failed before the completion of therapy (54 studies; 25,770 CVADs) at a rate of 5.43 (95% CI, 4.43–6.43) per 1,000 catheter days (44 studies; 232,001 catheter days) (**Tables 1** and **2**). Hemodialysis catheters had highest pooled failure proportion at 7% (95% CI, 3–12%; four studies; 1,481 CVADs) and highest pooled IR 11.2 (0–22.9) per 1,000 catheter days (three studies; 8,809 catheter days). PICCs had second highest pooled failure proportion at 6% (95% CI, 2–12%; nine studies; 1,654 CVADs) but had the lowest pooled IR 3.98 (95% CI, 0.57–7.40) per 1,000 catheter days (six studies; 13,078 catheter days). Overall, study heterogeneity reporting failure proportion was high ($I^2 = 95\%$) and for device type ($I^2 = 89$–95%). Test for heterogeneity between subgroups (device types) was nonsignificant ($p = 0.40$) for the proportion analysis and significant for the IR analysis ($p < 0.01$).

CVAD Complication

NTCVAD Complications. NTCVAD had highest proportion and IR of CRBSI (4% [95% CI, 3–5%; 32 studies; 22,784 CVADs];

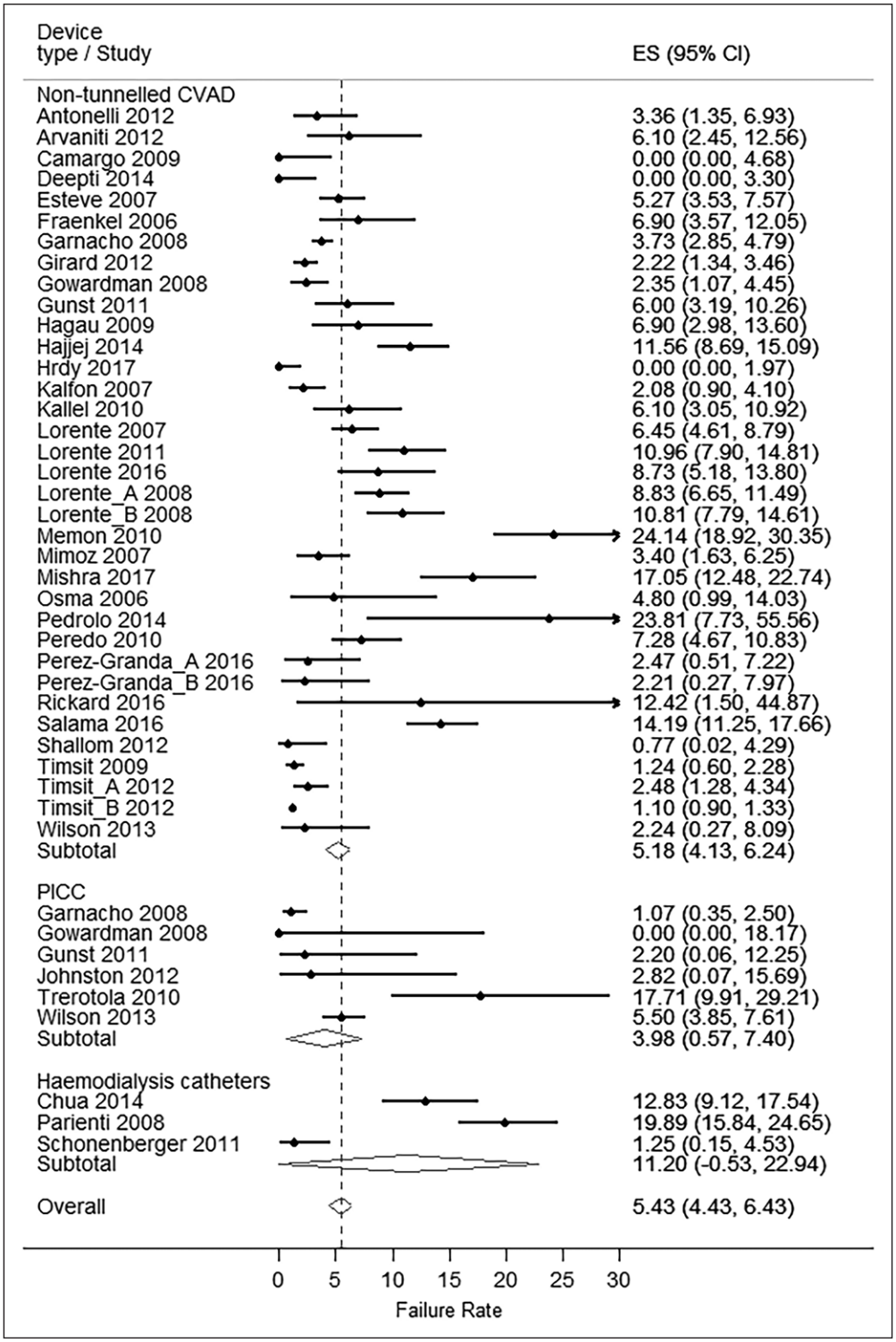

Figure 3. Incidence rate of central vascular access device (CVAD) failure (per 1,000 catheter days) ($n = 44$ studies). ES = effect size, PICC = peripherally inserted central catheter.

3.92 per 1,000 catheter days [95% CI, 3.11–4.74; 29 studies; 214,012 catheter days]) and CLABSI (3% [95% CI, 1–5%; 10 studies; 19,115 CVADs]; 5.28 per 1,000 catheter days [95% CI, 2.34–8.23; per 1,000 catheter days; eight studies; 139,082 catheter days]) with high heterogeneity within studies. NTCVAD also had highest proportion and IR of catheter removal due to suspected catheter infection (20% [95% CI, 15–25%; 15 studies; 8,003 CVADs]; 23.6 per 1,000 catheter days [95% CI, 17.9–29.3; per 1,000 catheter days; 14 studies; 48,010 catheter days]) with high heterogeneity within studies. NTCVAD had highest local infection proportion (2%; 95% CI, 1–3%; six studies; 1,994 CVADs) and IR (3.01; 95% CI, 1.97–4.06; per 1,000 catheter days; three studies; 12,216 catheter days) with low to moderate heterogeneity of studies with significant effect size (**Supplemental Fig. 1**, Supplemental Digital Content 5, http://links.lww.com/CCM/D907–**legend**, Supplemental Digital Content 9, http://links.lww.com/CCM/D911; and **Supplemental Fig. 2**, Supplemental Digital Content 6, http://links.lww.com/CCM/D908–legend, Supplemental Digital Content 9, http://links.lww.com/CCM/D911).

PICC Complications. PICC had highest CAVT proportion (11%; 95% CI, 7–16%; nine studies; 1,638 CVADs), but the lowest CAVT IR of 9.31 per 1,000 catheter days (95% CI, 5.39–13.2; five studies, 12,831 catheter days) with moderate heterogeneity within studies. One study investigated PICC occlusion and reported proportion of 38% (95% CI, 24–55%; one study; 34 CVADs) and IR of 36.6 (95% CI, 15.1–58.2) per 1,000 catheter days.

Hemodialysis Catheters Complications. Hemodialysis catheters had the highest IR for CAVT 26.6 per 1,000 catheter days (95% CI, 0.00–80.9; two studies; 4,439 catheter days).

Subgroup Analysis

Medical ICU had the highest proportion of NTCVAD failure (7%; 95% CI, 2–16%; six studies; 2,014 CVADs] and ICUs that did not report their ICU type had the highest IR of NTCVAD failure (7.03; 95% CI, 4.64–9.41; 10 studies; 137,235 catheter days) (**Supplemental Table 5**, Supplemental Digital Content 7,

TABLE 1. Proportions of Central Vascular Access Device Complications Across Device Type (Subgroups) in Included Studies

Event and CVAD Type	Studies	CVADs	Outcomes	Pooled %	95% CI
Failure					
Overall	54	25,770	1,115	5[d,e,h]	3–6
NTCVAD	41	22,635	885	4[d,e]	3–6
PICC	9	1,654	100	6[d,e]	2–12
Hemodialysis	4	1,481	130	7[d,e]	3–12
Catheter-related bloodstream infection					
Overall	40	24,865	658	3[d,e,g]	2–4
NTCVAD	32	22,784	637	4[d,e]	3–5
PICC	5	671	6	0[b,f]	0–1
Hemodialysis	3	1,410	15	1[a,e]	1–2
Central line-associated bloodstream infection					
Overall	14	20,297	405	2[d,e,h]	1–4
NTCVAD	10	19,115	349	3[d,e]	1–5
PICC	4	1,182	56	1[a,e]	0–3
Removal of catheter due to suspected catheter infection					
Overall	19	9,306	1,527	17[d,e,g]	13–22
NTCVAD	15	8,003	1,407	20[d,e]	15–25
PICC	2	66	8	10[a,e]	3–19
Hemodialysis	2	1,237	112	9[a,e]	7–11
Catheter-associated venous thrombosis					
Overall	22	7,224	729	10[d,e,g]	4–17
NTCVAD	11	4,790	547	9[d,e]	1–22
PICC	9	1,638	163	11[d,e]	7–16
Hemodialysis	2	796	19	1[a,e]	0–2
Occlusion/blockage					
Overall	5	807	96	11[d,e,g]	4–22
NTCVAD	3	702	78	8[a,e]	1–20
PICC	1	34	13	38[a,e]	24–55
Hemodialysis	1	71	5	7[a,e]	3–15
Dislodgment/migration					
Overall	16	4,934	114	2[d,e,h]	1–3
NTCVAD	13	4,759	108	2[d,e]	1–3
PICC	2	104	5	2[a,e]	0–7
Hemodialysis	1	71	1	1[a,f]	0–8
Local infection/phlebitis					
Overall	7	2,044	44	1[c,e,h]	1–3
NTCVAD	6	1,994	44	2[c,e]	1–3
PICC	1	50	0	0[a,f]	0–7

CVAD = central vascular access device, NTCVAD = nontunnelled CVAD, PICC = peripherally inserted central catheter.
Heterogeneity of studies: [a]cannot be calculated, [b]low (< 25%), [c]moderate (25–75%), or [d]high (> 75%).
Effect-size test: [e]significant or [f]nonsignificant.
Test for heterogeneity between subgroups: [g]significant or [h]nonsignificant.
No hemodialysis studies for central line-associated bloodstream infection and local infection/phlebitis outcomes.

TABLE 2. Incidence Rates of Central Vascular Access Device Complications Per 1,000 Catheter Days Across Device Type (Subgroups) in Included Studies

Event and CVAD Type	Studies	Catheter Days	Outcomes	Pooled Incidence Rate	95% CI
Failure					
Overall	44	232,001	995	5.43[d,e,g]	4.43–6.43
NTCVAD	35	210,114	813	5.18[d,e]	4.13–6.24
PICC	6	13,078	58	3.98[d,e]	0.57–7.40
Hemodialysis	3	8,809	124	11.2[d,f]	0.00–22.9
Catheter-related bloodstream infection					
Overall	36	228,999	621	3.35[d,e,h]	2.67–4.03
NTCVAD	29	214,012	600	3.92[d,e]	3.11–4.74
PICC	4	6,178	6	0.88[b,f]	0.00–1.83
Hemodialysis	3	8,809	15	1.69[b,e]	0.70–2.67
Central line-associated bloodstream infection					
Overall	10	149,018	343	4.59[d,e,g]	2.31–6.86
NTCVAD	8	139,082	299	5.28[d,e]	2.34–8.23
PICC	2	9,936	44	2.50[d,f]	0.00–7.19
Removal of catheter due to suspected catheter infection					
Overall	18	56,274	1,270	20.4[d,e,g]	15.7–25.2
NTCVAD	14	48,010	1,150	23.6[d,e]	17.9–29.3
PICC	2	1,050	8	5.13[c,f]	0.00–14.4
Hemodialysis	2	7,214	112	14.8[d,e]	6.93–22.7
Catheter-associated venous thrombosis					
Overall	14	40,387	268	8.34[d,e,g]	5.59–11.1
NTCVAD	7	23,117	146	10.2[d,e]	4.36–16.0
PICC	5	12,831	103	9.31[c,e]	5.39–13.2
Hemodialysis	2	4,439	19	26.6[d,f]	0.00–80.9
Occlusion/blockage					
Overall	4	5,468	91	17.0[d,e,g]	3.79–30.3
NTCVAD	3	5,113	78	13.1[d,f]	0.00–27.0
PICC	1	355	13	36.6[a,e]	15.1–58.2
Dislodgment/migration					
Overall	9	34,279	98	2.75[d,e]	1.51–3.98
NTCVAD	9	34,279	98	2.75[d,e]	1.51–3.98
Local infection/phlebitis					
Overall	4	13,063	39	2.45[c,e,g]	0.54–4.35
NTCVAD	3	12,216	39	3.01[b,e]	1.97–4.06
PICC	1	847	0	0.00[a,f]	0.00–2.18

CVAD = central vascular access device, NTCVAD = nontunnelled CVAD, PICC = peripherally inserted central catheter.

Heterogeneity of studies: [a]cannot be calculated, [b]low (< 25%), [c]moderate (25–75%), or [d]high (> 75%).

Effect-size test: [e]significant or [f]nonsignificant.

Test for heterogeneity between subgroups: [g]significant or [h]nonsignificant.

No hemodialysis studies for central line-associated bloodstream infection, occlusion/blockage, dislodgement/migration, and local infection/phlebitis outcomes. No PICC studies for dislodgement/migration outcome.

http://links.lww.com/CCM/D909). The heterogeneity between subgroups was nonsignificant for NTCVAD failure proportion.

Sensitivity Analysis

The results of sensitivity analysis comparing pooled proportions and IRs of CVAD failure across device types are described in **Supplemental Table 6** (Supplemental Digital Content 8, http://links.lww.com/CCM/D910). The proportion and IR of failure in NTCVAD was higher in the high ROB group (5% [95% CI, 3–7%; 25 studies; 17,151 CVADs]; 5.96 per 1,000 catheter days [95% CI, 4.61–7.30; 24 studies; 183,184 catheter days]) compared with the low ROB group (3% [95% CI, 1–6%; 16 studies; 5,484 CVADs]; 3.71 per 1,000 catheter days [95% CI, 1.68–5.75; 11 studies; 26,930 catheter days]).

For PICCs, the lower ROB group had higher failure proportion (8%; 95% CI, 2–16%; four studies; 1,014 CVADs vs 5%; 95% CI, 0–17%; five studies; 640 CVADs) and IR (5.50; 95% CI, 3.62–7.38 vs 3.70; 95% CI, 0.00–8.24).

DISCUSSION

This is the first study to systematically identify and meta-analyze CVAD failure and complications across all types of CVADs in the ICU population. This study has established 5% (95% CI, 3–6%) of CVADs fail before the completion of treatment, in the adult ICU. In comparison to the review in general pediatrics (25%; 95% CI, 21–29%), our review revealed considerably lower failure (5). However, the pediatric review included predominantly long-term CVADs (58% tunneled and TIVD) (92), increasing opportunity for failure to occur. CVAD failure of 5% for adult critical care is alarming considering the type of time-sensitive treatments being disrupted (e.g., inotropic support) and the dominance of short-term CVADs.

The pooled estimates for CLABSI was 4.59 per 1,000 catheter days, which was higher than the most recent reports by ICU surveillance databases, in the United States (93) and Australian/New Zealand (94). However, in Europe, the CLABSI rate was 3.6 per 1,000 catheter days (95), and International Nosocomial Infection Control Consortium surveillance data reported 4.1 per 1,000 catheter days (96), which were similar to our result. The variance can be explained in part, as some surveillance studies did not report individual CVAD types and were not eligible for inclusion. The review also included multiple sites from lower socioeconomic levels (e.g., India and Brazil), than the Australian and U.S. databases, which is associated with higher risk of infection (97) Overall, the rate of CLABSI described in this review is much higher than the far-reaching goal of zero CLABSI proposed by Institute for Healthcare Improvement, and World Health Organization (98).

A key finding was the large number of catheters removed in ICU on suspicion of catheter infection. There is a significant practice issue with 1,527 catheter removed due to suspected infection, but only 169 emerged as confirmed CRBSI/CLABSI. A number of studies (25, 99, 100) have investigated the effects of immediate, deferred, or no removal of CVADs suspected of infection and found that there was no difference in morbidity or mortality between groups. Practice guidelines consistently recommend using clinical judgment regarding the appropriateness of removing the catheter, if infection is evidenced elsewhere or if a noninfectious cause of fever is suspected (12). Additionally, the Infectious Diseases Society of America recommends short-term catheters should be removed if the CLABSI is due to gram-negative bacilli, *Staphylococcus aureus*, enterococci, fungi, and mycobacteria (101). However, a practice guideline specific to the management of CVADs suspected of infection in ICU has not been developed, resulting in clinicians erring toward caution, and removing CVADs early, without microbiological confirmation of CLABSI. Even with caution, many CVADs appear to be unnecessarily removed, leaving patients to experience treatment delays, and undergo additional risky insertion procedures (25, 99). The development of robust evidence and guidelines which inform clinical practice concerning the diagnosis and management of devices with suspected infection should be a priority for researchers and policy makers.

From our data, it is clear that CVAD complication risk can be device specific. PICC complications were high, particularly for CAVT, which in turn resulted in a high proportion of failure for blockage/occlusion. Consequently, PICC placement in adult ICU patients should not be viewed as less risky than NTCVAD placement and, indeed, requires vigilant monitoring and surveillance (5, 19). However, it is necessary to be cautious interpreting the CAVT results, many may have been asymptomatic only, with uncertain clinical importance.

CAVT in hemodialysis catheters is concerning, as shown by a pooled IR of 26.6 per 1,000 catheter days. Although the effect size was nonsignificant due to the inclusion of only two studies, early data indicates the possibility of harm in this population (102). Additionally, no hemodialysis catheters studies reporting CLABSI and local infection or phlebitis were identified, and only one study reported dislodgement and occlusion. There is a dearth of evidence to support hemodialysis catheter CAVT prevention practices during ICU admission (103). Research in this area is urgently required, to both provide more certain estimates of complication incidence, and inform practice development.

This review gives insights into a number of problems associated with CVAD use and provides opportunities for practice improvement. However, the review has some limitations. Due to the lack of studies reporting CVAD numbers and days, some data were not suitable for meta-analysis, which may have resulted in estimate imprecision. Consistency in reporting of such metrics needs to be prioritized by the research community, so that accurate pooled estimates can be produced. Studies that failed to specify the CVAD type were not included, and, because of this, 13 surveillance studies (91, 104–115) were ineligible. Lastly, although the pooled proportion of failure of all CVADs was homogenous, overall the meta-analysis had high heterogeneity across studies and within subgroups, especially for NTCVAD studies. This is expected due to the heterogeneous nature of critically ill patients (116). A subgroup analysis by type of ICU was attempted but could not be interpreted meaningfully due to insufficient studies. Despite these

limitations, this study provides opportunities for benchmarking in CVAD health and highlights areas requiring further investigation.

CONCLUSIONS

This systematic review identified CVAD complications and failure are significant problems in adult ICU, and advances are necessary. Hemodialysis catheters require focused research and practice innovation, due to the paucity of evidence and potentially high complication rates. There is an urgent need for robust practice guidelines regarding the management of suspected CVAD infection to prevent unnecessary catheter removal and subsequent harm to patients.

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