Ultralong Versus Standard Long Peripheral Intravenous Catheters: A Randomized Controlled Trial of Ultrasonographically Guided Catheter Survival

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Study objective: Ultrasonographically guided intravenous peripheral catheters have dismal dwell time, with most intravenous lines failing before completion of therapy. Catheter length in the vein is directly related to catheter longevity. We investigate the survival of an ultralong ultrasonographically guided intravenous peripheral catheter compared with a standard long one.

Methods: We conducted a single-site, nonblinded, randomized trial of catheter survival. Adult patients presenting to the emergency department with difficult vascular access were recruited and randomized to receive either standard long, 4.78-cm, 20-gauge ultrasonographically guided intravenous peripheral catheters or ultralong, 6.35-cm, 20-gauge ultrasonographically guided intravenous peripheral catheters. The primary outcome was duration of catheter survival. The secondary outcome was the optimal length of the catheter in the vein to maximize survival. Additional intravenous-related endpoints included first-stick success, time to insertion, number of attempts, thrombosis, and infection.

Results: Between October 2018 and March 2019, 257 patients were randomized, with 126 in the standard long ultrasonographically guided intravenous peripheral catheter group and 131 in the ultralong group. Kaplan-Meier estimate of catheter median survival time in the ultralong group was 136 hours (95% confidence interval [CI] 116 to 311 hours) compared with 92 hours (95% CI 71 to 120 hours) in the standard long group, for a difference of 44 hours (95% CI 2 to 218 hours). The optimal catheter length in the vein was 2.75 cm, and intravenous lines with greater than 2.75 cm inserted had a median survival of 129 hours (95% CI 102 to 202 hours) compared with 75 hours (95% CI 52 to 116 hours) for intravenous lines with less than or equal to 2.75 cm, for a difference of 54 hours (95% CI 10 to 134 hours). Insertion characteristics were similar between the groups: 74.1% versus 79.4% first-stick success (95% CI for the difference −2% to 5%), 1.4 versus 1.3 for number of attempts (95% CI for the difference −0.1 to 0.3), and 6.9 versus 5.9 minutes to completion (95% CI for the difference −1.3 to 3.4) with ultralong versus standard long, respectively. There were no cases of infection or thrombosis.

Conclusion: This study demonstrated increased catheter survival when the ultralong compared with the standard long ultrasonographically guided intravenous peripheral catheter was used, whereas insertion characteristics and safety appeared similar. [Ann Emerg Med. 2019;■:1-9.]

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0196-0644/$-see front matter

https://doi.org/10.1016/j.annemergmed.2019.11.013

INTRODUCTION

Peripheral intravenous line insertion is the most commonly performed invasive procedure in the hospital setting, with 2 billion catheters used worldwide annually.[1] Nearly 90% of all hospitalized patients require intravenous access for treatment, with up to one third qualifying as having difficult vascular access, and in 75% of whom the traditional palpation method of intravenous line insertion fails and ultrasonographically guided intravenous peripheral catheter insertion offers improved success. Although ultrasonographically guided intravenous peripheral catheter placement is successful in 76% to 100% of patients with difficult vascular access,[2–6] the catheter dwell rate is concerning, with 46% to 56% of catheter failures occurring prematurely compared with intravenous line failure rates of 19% to 25%[2–4,7,8] with nondifficult vascular access. Causes of catheter failure include infiltration, dislodgment, phlebitis, and infection.[3,9]

The longest stocked catheter at most institutions is 4.78 cm or shorter, and increased catheter length in the

Editor's Capsule Summary

What is already known on this topic

Catheter survival depends on the length of the catheter in the vein.

What question this study addressed

This randomized trial compared a standard-length catheter with an ultralong catheter in patients with difficult venous access.

What this study adds to our knowledge

For 255 patients, the median survival was 96 hours for the standard catheter and 132 for the ultralong catheter, whereas complications were similarly low in both groups.

How this is relevant to clinical practice

In patients with difficult venous access, ultralong catheters have a longer survival.

vein improves longevity: if less than 30% of this catheter was situated in the vein, median time to failure was just 3.7 hours; if greater than 65% was situated in the vein, all intravenous lines survived to completion of therapy.[10] Midline catheters with lengths of 6 to 20 cm are a potential solution and have high success rates and longevity, but inserters require specialized training, the costs are significantly higher, and the rate of complications including thrombosis and infection appears far higher.[11–19]

The recent introduction of 6.35-cm ultralong peripheral intravenous lines may provide the benefits of midline catheters without the costs and complications. We hypothesized that ultralong catheters would have improved survival and a similar safety profile compared with the standard 4.78-cm intravenous catheter.

MATERIALS AND METHODS

Study Design

This was a single-site, prospective, 2-arm, nonblinded, randomized controlled trial of catheter survival. Two catheters were used in the comparison: a standard long, 20-gauge, 4.78-cm, Becton Dickinson Insyte Autoguard intravenous catheter and an ultralong, 20-gauge, 6.35-cm, B. Braun Introcan Safety intravenous catheter. The study was conducted in the United States at a large, academic, suburban tertiary care center with 1,100 hospital beds and 130,000 annual emergency department (ED) visits. The home institutional review board approved the study.

Selection of Participants

Using trained research associates, we recruited a convenience sample of ED patients aged at least 18 years with self-reported difficult vascular access and at least 1 of the following: history of requiring 2 or more intravenous attempts on a previous visit, previous requirement for a rescue catheter (ultrasonographically guided intravenous catheter, midline catheter, peripherally indwelling central catheter, or central venous access), end-stage renal disease and receiving dialysis, injection drug use, or sickle cell disease. Patients were excluded if they were previously enrolled, withdrew from the study, or presented when trained intravenous line inserters were unavailable. We obtained written informed consent from all enrolled patients or their legally authorized representative.

Using sealed opaque envelopes, research assistants randomized participants to either standard long or ultralong groups in a 1:1 ratio. The research assistant did not open the randomization envelope until eligibility was confirmed and consent obtained. The disparity in length was obvious and research staff and study subjects could not be blinded before insertion. The same research staff performed daily catheter follow-up to assess for functionality and complications.

A cohort of trained ED attending physicians, resident physicians, advance practice providers, nurses, and technicians who were proficient in ultrasonographically guided intravenous line placement using the single-user technique performed all insertions. Departmental certification in ultrasonographically guided vascular access involves attending a 2-hour vascular access didactic session followed by successful placement of ultrasonographically guided intravenous peripheral catheters in the ED. All inserters had at least 1 year of experience in this procedure. All inserters had previous experience with the standard long catheter and no inserters had experience with the ultralong catheter.

Inserters were directed to avoid the antecubital fossa and place the intravenous line at least 2 cm proximal to this crease. Under aseptic conditions, all inserters used a high-frequency linear transducer with the Mindray M9 unit (Mindray North America, San Jose, CA). Inserters saved both still images of the vein and cine loops of the catheter and stored them in Qpath (Telexy Healthcare, Maple Ridge, British Columbia, Canada). Research staff then postprocessed the image to measure the vein depth and diameter, as well as catheter length and angle of insertion. Postinsertion, inserters confirmed functionality blood sampling and saline solution flush without resistance, and catheters were secured with a 3.5×4-inch bordered dressing film (Tegaderm; 3M, Maplewood, MN).

At the procedure, research staff documented additional data points, including practitioner details, catheter type, the cannulated vein, time of placement, time to insertion (first needlestick to securement with dressing), number of attempts, and need for rescue inserter. The electronic medical record provided data including age, sex, body mass index, vital signs, relevant medical history, and admission bed type.

The research staff performed follow-up assessments in the hospital on the patients' catheters within 24 hours and then daily for the life of the catheter. Institutional policy requires catheter removal when clinically indicated, rather than a discrete dwell time. Furthermore, all lines are flushed with 3 mL normal saline solution every 8 hours to maintain patency and the site is assessed for infection, phlebitis, and mechanical complications. At each follow-up interval, the research assistant noted the time of evaluation and assessed catheter functionality. Research staff noted whether the study catheter survived to completion of therapy or failed prematurely, or required a rescue device, defined as any peripheral or central catheter placed after failure of the study device. A catheter was deemed functional if it could be flushed with 5 mL of saline solution without resistance. If the catheter failed before the follow-up assessment, the timing and reason for failure were obtained from the chart. If the patient was discharged before follow-up, then the time of discharge was documented and the intravenous line was presumed functional until discharge unless otherwise noted. The medication administration record was reviewed daily to evaluate commonly used vesicants and irritants. If clinical phlebitis or thrombosis was suspected, attending physicians ordered investigations, including ultrasonography, at their discretion.

Outcome Measures

The primary endpoint was median duration of catheter survival in both the standard long and ultralong groups. Because catheter length in the vein is a critical determinant of survival, the secondary outcome was a cutoff value for length of the catheter in the vein that yielded optimal catheter survival. This length was independent of the type of catheter. The intravenous-related endpoints were overall intravenous placement success, first-stick success, time to completion of insertion, and number of attempts. Safety endpoints, which were assessed through clinical laboratory results, imaging results, and review, were the incidence of infections, thrombosis, and need for rescue catheters.

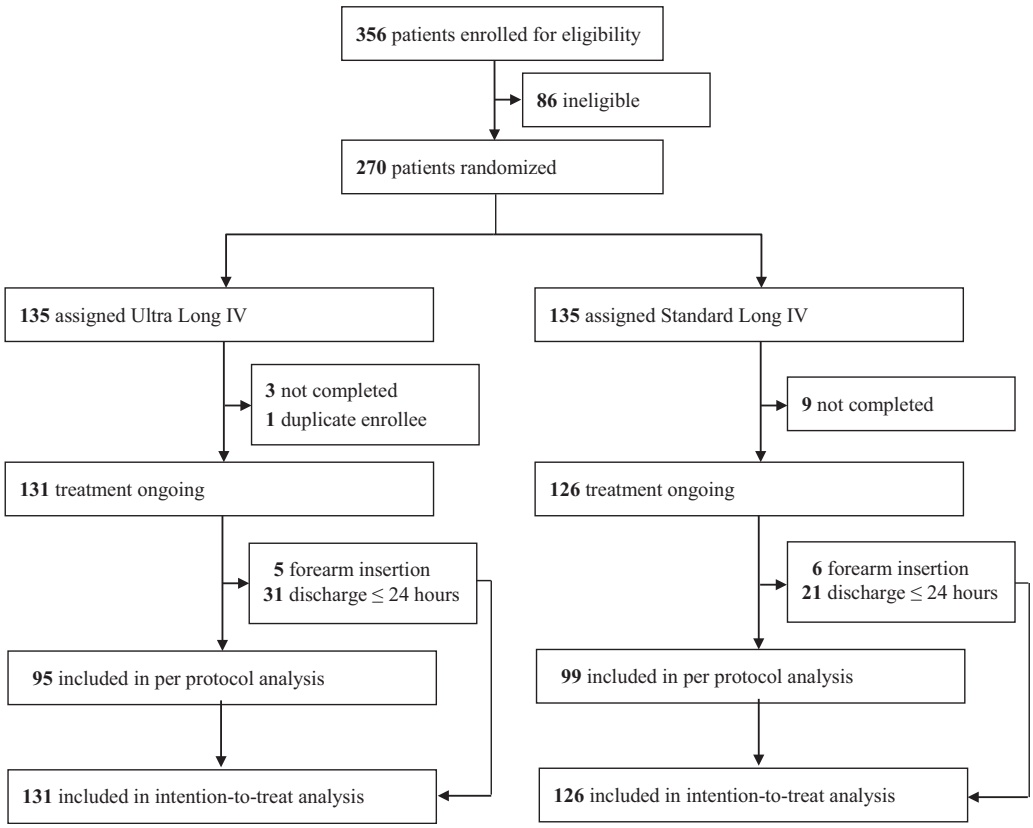


Figure 1. Trial profile of ultrasonographically guided long peripheral intravenous catheters.

Table 1. Patient and intravenous characteristics at the initial assessment.

Variables*	UL Ultrasonographically Guided IV Peripheral Catheters (n=131)	SL Ultrasonographically Guided IV Peripheral Catheters (n=126)
Patient characteristics		
Age, y	60.2 (18.2)	58.2 (18.6)
Sex, No. (%)		
Men	39 (29.8)	34 (27.0)
Women	92 (70.2)	92 (73.0)
IV drug use, No. (%)		
No	124 (94.7)	125 (99.2)
Yes	7 (5.4)	1 (0.8)
Previous multiple IV attempts, No. (%)		
No	0	0
Yes	131 (100.0)	126 (100.0)
Previous rescue catheter, No. (%)		
No	38 (29.0)	37 (29.4)
Yes	93 (71.0)	89 (70.6)
ESRD, No. (%)		
No	109 (83.2)	105 (83.3)
Yes	22 (16.8)	21 (16.7)
History of sickle cell disease, No. (%)		
No	128 (97.7)	125 (99.2)
Yes	3 (2.3)	1 (0.8)
BMI, kg/m^2	31.9 (9.2)	31.5 (10.8)
Systolic blood pressure, mm Hg	140.0 (28.2)	142.2 (27.7)
Diastolic blood pressure, mm Hg	74.5 (14.2)	76.0 (15.6)
Pulse rate, beats/min	88.8 (19.9)	89.1 (18.8)
IV line characteristics, No. (%)		
Disposition		
Observation stay	46 (35.1)	38 (30.2)
Regular	44 (33.6)	53 (42.1)
ICU/ICU step-down	18 (13.7)	13 (10.3)
Discharge	23 (17.6)	22 (17.5)
Location		
Basilic	51 (38.9)	52 (41.3)
Brachial	54 (41.2)	39 (30.9)
Cephalic	25 (19.1)	30 (23.8)
Unknown	1 (0.8)	5 (4.0)
IV line inserters		
Physician	87 (66.4)	83 (65.9)
Nonphysician	44 (33.6)	43 (34.1)
Diameter of vein, cm	0.3 (0.1)	0.3 (0.1)
Depth of vein, cm	1.0 (0.3)	1.0 (0.3)
Length of catheter in vein, cm (%)		
≤2.5	8 (6.1)	39 (30.9)
2.5–2.75	8 (6.1)	10 (7.9)
2.75–3.0	9 (6.9)	14 (11.1)
>3.0	73 (55.7)	39 (30.9)
Unmeasured	33 (25.2)	24 (19.1)

Table 1. Continued.

Variables*	UL Ultrasonographically Guided IV Peripheral Catheters (n=131)	SL Ultrasonographically Guided IV Peripheral Catheters (n=126)
Distance from antecubital fossa, cm (%)		
<2.5	27 (20.6)	29 (23.0)
≥2.5	104 (79.4)	95 (75.4)
Unmeasured	0	2 (1.6)
Angle of insertion, degrees (%)		
0–30	73 (55.7)	71 (56.3)
≥31	38 (29.0)	40 (31.8)
Unmeasured	20 (15.3)	15 (11.9)

UL, Ultralong; *IV*, intravenous; *SL*, standard long; *ESRD*, end-stage renal disease; *BMI*, body mass index.
Data are presented as mean (SD) or No. (%) in the intention-to-treat population, n=257.
*Only the length of the catheter in the vein showed a statistical difference on UL and SL ultrasonographically guided IV peripheral catheters.

Primary Data Analysis

We performed a sample size calculation to compare the duration of survival of ultralong and standard long catheters assuming a type I error (α) of 5%. At study design, we estimated that a median survival time for the standard long catheter of 30 hours (1.3 days) could be clinically relevant.[2–5] A sample size of 182 subjects (91 per group) achieved a power of 80% to detect a hazard ratio of 0.63 or less for line failure of ultralong catheters, based on a log-rank test with a loss-of-completion rate of 10% in both groups.

The intention-to-treat analysis included all patients who were randomly assigned to receive a type of catheter insertion without loss of completion. All patients with a functional intravenous catheter that was removed with less than 24 hours' dwell time were excluded from the per-protocol survival analysis. A bivariate analysis stratified by ultralong versus standard long was performed with a *t* test (or equivalent nonparametric) or χ^2 test (or equivalent Fisher's exact test), depending on continuous or categoric variables, respectively. For the primary endpoint, we estimated median survival time in both ultralong and standard long groups for the intention-to-treat and per-protocol populations, using Kaplan-Meier estimates (ie, total probability of survival at the end of a particular time was 0.5) with the corresponding 95% confidence interval (CI) and using the log-rank test on the comparison of catheter survival times. A Cox proportional hazards regression model was used to evaluate the effect of an ultralong catheter on the line survival as well. We report the hazard ratio between survival in ultralong and standard long catheters with 95% CI. In addition, we adjusted for a number of clinical characteristics of patients, including age and sex, history of end-stage renal disease, body mass index, systolic blood pressure and pulse rate, and vein depth, by using a covariate-adjusted Cox regression model of the primary endpoint. We tested a proportional hazards

Table 2. Intravenous line-related endpoints.

	UL Ultrasonographically Guided IV Peripheral Catheters (n=131)	SL Ultrasonographically Guided IV Peripheral Catheters (n=126)	Difference (95% CI)
Causes of IV line removal, No. (%)			
Infiltration	6 (4.6)	16 (12.7)	−8.1 (−14.9 to −1.3)
Dislodgment	8 (6.1)	3 (2.4)	3.7 (−1.2 to 8.6)
Occlusion	8 (6.1)	5 (4.0)	2.1 (−3.2 to 7.5)
Phlebitis	3 (2.3)	11 (8.7)	−6.4 (−12.0 to −0.9)
Other	16 (12.2)	18 (14.3)	−2.1 (−10.4 to 6.2)
First-stick success, No. (%)	97 (74.1)	100 (79.4)	−5.3 (−1.6 to 5.0)
No. of attempts	1.4 (0.9)	1.3 (0.7)	0.1 (−0.1 to 0.3)
Time to completion, min	6.9 (10.1)	5.9 (9.1)	1.0 (−1.3 to 3.4)

Data are presented as mean (SD) or No. (%) in the intention-to-treat population, n=257.

assumption for models by a term of the predictor with the logarithm of survival time and there was no violation of this assumption.

The secondary outcome was ascertainment of a dichotomous value for optimal length of the catheter in the vein. In accordance with a previous investigation, we hypothesized that optimal survival would be achieved with greater than 3.1 cm of catheter in the vein.[10] We used Contal and O'Quigley's method with a log-rank test to determine a potential cutoff point.

The intravenous-related and safety endpoints were presented with descriptive statistics.

All tests of statistical significance were indicated with 2-sided 95% CIs. All analyses were performed with R (version 3.5.3; R Foundation for Statistical Computing, Vienna, Austria) and SAS (version 9.4; SAS Institute, Inc., Cary, NC).

RESULTS

Between October 2018 and March 2019, 356 patients were screened and 270 eligible patients were randomized to ultralong (n=135) or standard long (n=135) catheter. Overall, 13 patients (5%) were excluded from the primary analysis, including 12 whose placement was not completed and 1 who was a duplicate enrollee, leaving 257 patients for the intention-to-treat analysis: 126 in the standard long group and 131 in the ultralong group. Because catheter survival was the primary endpoint, patients discharged before 24 hours' hospital length of stay with a functional catheter (52; 19%) and those with forearm insertions (11; 4%) were also excluded, leaving 194 patients for per-protocol analysis (Figure 1).

Patient characteristics were similar between both groups for patients and insertion-related variables (Tables 1 and 2). There was no difference between groups in average number of attempts; time to placement; first-stick success; and depth, diameter, and site of the vein. The only difference was catheter length in the vein.

In the intention-to-treat analysis, there was a significant survival benefit in the ultralong group compared with the standard long group (unadjusted hazard ratio 0.54; 95% CI 0.35 to 0.82). The median ultralong survival duration was 136 hours (5.7 days) (95% CI 116 to 311 hours) and median standard long duration was 92 hours (3.9 days) (95% CI 71 to 120 hours), for a difference of 44 hours (1.8 days) (95% bootstrapped CI 9 to 218 hours) (Figures 2*A* and 3*A*). In multivariable Cox regression analysis, results showed that the risk of failure in the ultralong group was approximately 50% lower than in the standard long group (adjusted hazard ratio 0.44; 95% CI 0.28 to 0.70). We found similar results in the per-protocol analysis (Figures 2*B* and 3*B*).

The optimal length in the vein to maximize catheter survival was calculated at greater than or equal to 2.75 cm (unadjusted hazard ratio 0.52; 95% CI 0.32 to 0.83). In the intention-to-treat analysis, catheters with greater than

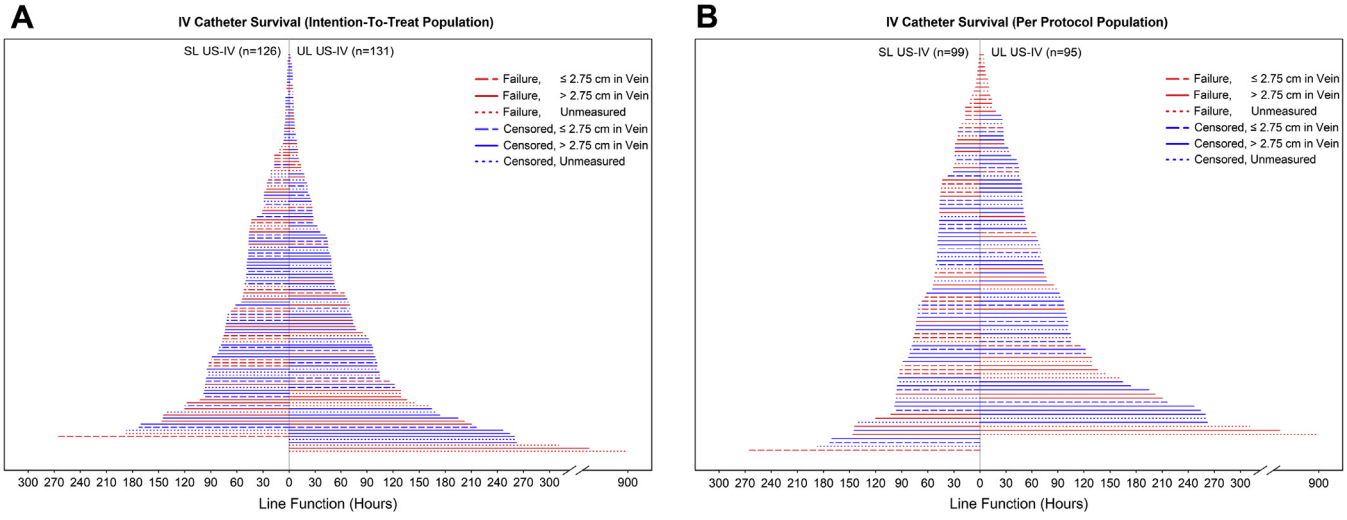


Figure 2. Probing individual patient-level's catheter survival. *A* and *B*, Mirror-type plots showing the dwell time of IV line function on each patient, stratified by UL and SL ultrasonographically guided intravenous peripheral catheters in the intention-to-treat population and per-protocol population. Red horizontal lines (failure) and blue horizontal lines (censored) incorporated with line type dashed (≤2.75-cm length of catheter in the vein), line type solid (>2.75-cm length of catheter in the vein), and line type dotted (unmeasured length of catheter in the vein) indicate dwell time until IV line removal resulted from the line failure and that until the completion of IV line use or hospital discharge, respectively.

2.75 cm in the vein had a median survival of 129 hours (5.4 days) (95% CI 102 to 202 hours) compared with 75 hours (3.1 days) (95% CI 52 to 116 hours), for a median difference of 54 hours (2.3 days) (95% bootstrapped CI 10 to 134 hours). Similar results were found in the per-protocol analysis (Figure 3*C* and *D*).

Ninety patients (68.7%) in the ultralong group reached completion of therapy compared with 73 (57.9%) in the standard long group in the intention-to-treat population (95% CI for the difference –0.9% to 22.5%). On average, the ultralong group required a mean 0.48 rescue catheters to reach completion of therapy compared with 0.91 in the standard long group (95% CI for the mean difference –0.83 to –0.03).

The most common causes for intravenous removal were phlebitis and infiltration. Although vesicant and irritant medications appeared similar, patients in the standard long group had 11 cases of phlebitis and 16 infiltrations, whereas the ultralong group had 3 cases and 6 infiltrations. Cases of dislodgement and occlusion were low (Table 2). No patients developed a catheter-related bloodstream infection, whereas 3 patients in the standard long group

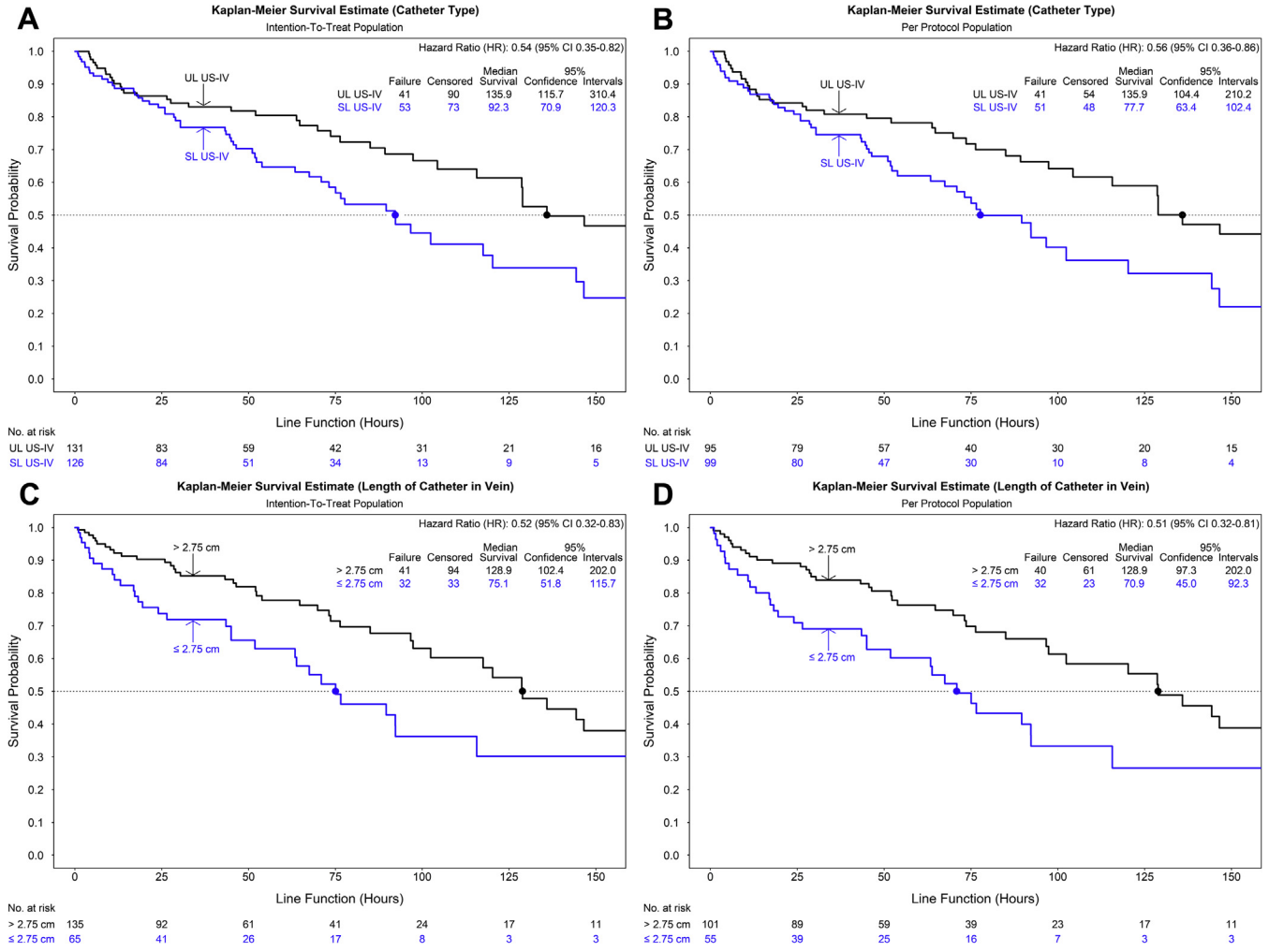


Figure 3. Intravenous catheter survival curves by the Kaplan-Meier estimates. The ends of the survival curves represent most of the data. Plots indicate the median survival hours of line function at the survival probability most near 0.5 and the corresponding 95% CIs. *A*, The median survival duration was 136 hours (95% CI 116 to 311 hours) in the UL ultrasonographically guided IV peripheral catheters and 92 hours (95% CI 71 to 120 hours) in the SL ultrasonographically guided IV peripheral catheters in the intention-to-treat population. *B*, Median UL survival duration was 136 hours (95% CI 105 to 210 hours) and median SL duration was 78 hours (95% CI 64 to 103 hours) in the per-protocol population. *C*, IV catheters with greater than 2.75 cm in the vein had a median survival of 129 hours (95% CI 102 to 202 hours) compared with 75 hours (95% CI 52 to 116 hours) for catheters with less than or equal to 2.75 cm in the intention-to-treat population. *D*, IV catheters with greater than 2.75 cm in the vein had a median survival of 129 hours (95% CI 97 to 202 hours) compared with 71 hours (95% CI 45 to 92 hours) for catheters with less than or equal to 2.75 cm in per-protocol population.

had ultrasonographic diagnosis of superficial thrombophlebitis.

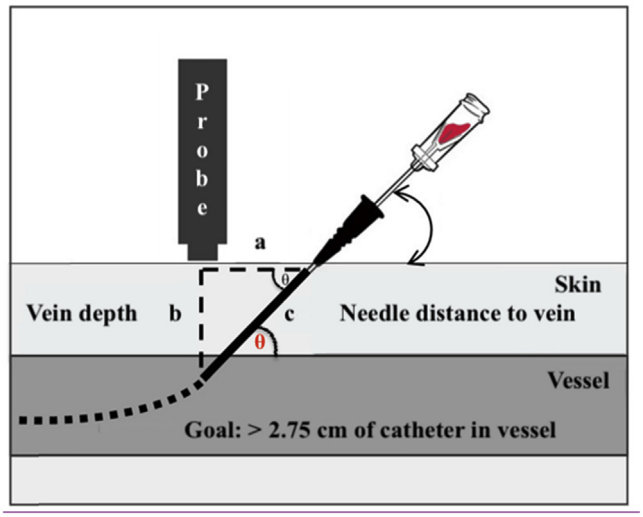
LIMITATIONS

This was a single-center study of patients with difficult vascular access and demographics may vary at other sites. Although patients were randomized, the sample was not consecutive and excluded patients may have been systematically different from those enrolled. Before catheter insertion, study personnel could not be blinded to treatment arm, although research staff evaluating outcomes were not aware of assignments, which may have diminished potential bias. Catheters were placed only proximal to the antecubital fossa and our results may be challenging to extrapolate to other veins. The cause and time of failure were abstracted from nursing documentation in the electronic medical record, and timing and true reason for catheter failure may be misrepresented, although the direction and magnitude of bias are uncertain.

DISCUSSION

Ultrasonographically guided intravenous catheter survival is dismal, with premature failure in 43% to 47% of cases occurring within the first 24 hours of intravenous placement.[5,20] In our study of patients with difficult vascular access who were randomized to either an ultralong or standard intravenous catheter in upper arm veins, ultralong catheters had a significantly longer median survival time of 5.6 days compared with 3.8 days for standard long catheters. These results were consistent across both the intention-to-treat and per-protocol analyses. Secondary outcomes such as time to insertion were similar, and rates of infection and thrombosis were low in both groups. Although our results support the improved survival of ultralong catheters, both catheter types had improved survival profile compared with that in the existing literature for ultrasonographically guided intravenous line insertions, which may be due to avoiding the placement proximal to the antecubital fossa and use of bordered dressings.[21]

Increased length of the catheter in the vein is strongly associated with enhanced survival.[5,12,22] Our cutoff of greater than 2.75 cm of catheter in the vein leads to optimal catheter survival regardless of the catheter type, and we provide recommendations for inserters to choose the ideal catheter length based on preprocedure assessment of vein depth and inserter preference for angle of insertion (Figure 4). Unfortunately, the longest commonly stocked intravenous catheter available at many institutions is 4.78 cm, in many cases an insufficient length to place at least



Angle of Insertion		15°	30°	45°
Maximum Depth of Vessel	SL US-IV	0.53 cm	1.01 cm	1.44 cm
	UL US-IV	0.93 cm	1.80 cm	2.55 cm

US-IV=ultrasound-guided intravenous. UL=ultra long. SL=standard long.

Figure 4. 2.75-cm Rule. Recommendation on catheter length was based on depth of the vessel and inserter preference for the angle of insertion.

2.75 cm in deeper veins. In these scenarios, the 6.35-cm ultralong catheter may be a favorable alternative.

Ultralong catheters can likely be adopted at most acute care environments. A large cohort of proficient inserters with a variety of credentials performed the insertions in this trial without requiring additional training. Although midline and extended-dwell catheters have increased survival compared with standard long catheters,[22] placement of the former catheters is more akin to central venous cannulation and therefore requires specific training and costs up to 18 times that of standard long or ultralong insertions.[23,24]

In conclusion, our study supports the use of ultralong catheters over the standard long options for upper arm insertions because these catheters have a favorable survival profile for difficult-access patients. Furthermore, because these catheters have similar insertion characteristics and do not require additional training for insertion competency, their adoption can occur without difficulty by inserters who are proficient in ultrasonographically guided intravenous placements.

Supervising editor: Frank Scheuermeyer, MD, MHSc. Specific detailed information about possible conflict of interest for

individual editors is available at https://www.annemergmed.com/editors.

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Author contributions: AB and JP were responsible for the study concept and revision of intellectual content. AB, N-WC, and JP were responsible for study design. AB, MH, LL-C, and JP were responsible for recruitment and enrollment. AB, MH, N-WC, and JP were responsible for analysis and interpretation of data. All authors were responsible for critical writing. AB was responsible for final approval of the version of the article to be published. AB takes responsibility for the paper as a whole.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). Dr. Bahl reports receiving a grant from B. Braun Medical, Inc. to conduct the study. He also reports receiving a grant for ultrasound equipment from Mindray North America for the study.

Publication dates: Received for publication July 2, 2019. Revisions received August 11, 2019; September 27, 2019, and October 9, 2019. Accepted for publication November 14, 2019.

Trial registration number: NCT03655106

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication. B. Braun Medical had access only to the final published work.

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