



## Original Contribution

## Standard long IV catheters versus extended dwell catheters: A randomized comparison of ultrasound-guided catheter survival



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## ABSTRACT

**Introduction:** Establishing peripheral intravenous (IV) access is a vital step in providing emergency care. Ten to 30% of Emergency Department (ED) patients have difficult vascular access (DVA). Even after cannulation, early failure of US-guided IV catheters is a common complication. The primary goal of this study was to compare survival of a standard long IV catheter to a longer extended dwell catheter.

**Methods:** This study was a prospective, randomized comparative evaluation of catheter longevity. Two catheters were used in the comparison: [1] a standard long IV catheter, the 4.78 cm 20 gauge Becton Dickinson (BD); and [2] a 6 cm 3 French (19.5 gauge) Access Scientific POWERWAND™ extended dwell catheter (EDC). Adult DVA patients in the ED with vein depths of 1.20 cm–1.60 cm and expected hospital admissions of at least 24 h were recruited.

**Results:** 120 patients were enrolled. Ultimately, 70 patients were included in the survival analysis, with 33 patients in the EDC group and 37 patients in the standard long IV group. EDC catheters had lower rates of failure ( $p = 0.0016$ ). Time to median catheter survival was 4.04 days for EDC catheters versus 1.25 days for the standard long IV catheter. Multivariate survival analysis also showed a significant survival benefit for the EDC catheter ( $p = 0.0360$ ).

**Conclusion:** A longer extended dwell catheter represents a viable and favorable alternative to the standard longer IVs used for US-guided cannulation of veins >1.20 cm in depth. These catheters have significantly improved survival rates with similar insertion success characteristics.

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## 1. Introduction

Establishment of functioning peripheral intravenous (IV) access is a vital step to provide care in the emergency and inpatient settings. While the traditional method of vein palpation for cannulation is effective in the majority of patients, those with difficult vascular access (DVA) present a daily challenge to hospital staff. There are approximately 150 million IVs placed annually in the US [1], with 10–30% of Emergency Department (ED) patients classified as DVA [2]. In these patients, placement of an ultrasound (US) guided IV catheter is a viable and safe option, and has been shown to increase patient satisfaction [3]. With the traditional method of IV placement, cannulation occurs in only 25–35% of DVA patients, as compared 76–100% with the use of US-guidance [4–7]. Patients with a medical history of obesity, IV drug abuse (IVDA), end-stage renal disease (ESRD), and/or sickle cell disease have been shown to have DVA using the traditional technique [8–12].

Although these patient characteristics help identify DVA patients through the traditional approach, when using US-guidance for cannulation, it has been shown that only the vessel characteristics, including depth, diameter, and location determine success of cannulation, rather than patient-specific medical history [13–15]. A recent systematic review and meta-analysis of the literature showed that the use of US guidance improves the success of IV insertion in DVA patients, without a difference in time to cannulation or number of attempts [16]. Other studies have shown decreased time to cannulation and decreased number of attempts in DVA patients with the use of US-guidance.

Once cannulated, the survival time of IV catheters is problematic, with early failure a common complication. Overall failure rates after successful IV cannulation for US-guided IVs is 45–56% when compared to traditional IV placement failure rates of 19–25% [3–6,17]. The most common cause of US-guided IV failure is infiltration, while other causes include catheter dislodgement and phlebitis [5,18].

There are a few related characteristics of the cannulated vessel and vascular access device that impact catheter survival: depth of vein, amount of catheter residing in vein, and length of the vascular access

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device. Keyes et al. demonstrated that for vessels >1.2 cm in depth, the survival probability at 48 h was 0.29 using a 4.78 cm 20 gauge catheter, compared to 1.0 and 0.62 using vessels of <0.4 cm and 0.4–1.19 cm, respectively [13]. In a prior publication, the lead investigator (AB) found that catheter failure was high when <30% of the catheter resided in the vein. As the catheter length of 4.78 cm remained a standard variable, increased vein depth correlated with decreased amount of catheter in vein and poor survival. Vein depth was measured at a median 0.93 cm for IVs that survived and a median of 1.15 cm for those that failed [19]. While survival prognosis is poor for veins deeper than 1.20 cm, this is a commonly encountered vein depth. Recent literature has also evaluated placement of long vascular access devices, 8–15 cm in length using direct seldinger technique in the basilic and brachial veins for deeper veins. The intrinsic length of these catheters allows for greater amount of the catheter to reside in the vein. These catheters have properties intermediate to PICC/midlines and standard peripheral IVs. Although very high success rates and improved longevity have been demonstrated with these devices, they require more steps akin to central line insertion compared to traditional US-guided IV placement and greater product costs [6,16,20].

In recent years, other vascular access devices (VADs) have entered the market that includes longer catheter lengths with built-in guidewires to simplify the seldinger technique. These devices offer the proposed benefits of easier vein cannulation using a guidewire, as opposed to the catheter over needle technique. Many of these extended dwell/midline catheters have also been FDA approved for use up to 29 days after insertion, implying a longer survival profile. The primary goal of this study was to compare survival of the standard 4.78 cm IV catheter to a longer 6 cm extended dwell catheter with a built-in guidewire at vessel depths >1.20 cm.

## 2. Methods

### 2.1. Study design

This study was a prospective, randomized comparative evaluation of catheter longevity, conducted at a single, tertiary care, level 1 trauma center with an annual ED census >130,000 visits and 1100 hospital beds. Two catheters were used in the comparison: [1] a standard long IV catheter, the 4.78 cm 20 gauge Becton Dickinson (BD); and [2] a 6 cm 3 French (19.5 gauge) Access Scientific POWERWAND™ extended dwell catheter (EDC). Both catheters are composed of a proprietary polyurethane blend aimed towards optimal biocompatibility. POWERWAND™ is a power injectable device with a built-in guidewire inserted using accelerated seldinger technique. Using this technique, the entire unit (catheter over needle and built-in guidewire) was advanced into the vessel. The built-in guidewire was then advanced through the unit without moving the needle, followed by advancement of the catheter. Leaving the catheter in place, the remainder of the unit was then withdrawn. This study was approved by the institutional review board (IRB). Written, informed consent was obtained for all study participants.

VADs were placed by four attending physicians, one US fellow, and a select group of trained ancillary staff (5 ED nurses and 2 ED technicians) who were proficient in US-guided IV placement using single-user technique.

### 2.2. Selection of participants

The subject population consisted of a convenience sample of patients presenting to the ED. Initial screening took place by the ED staff who notified a member of the research team when treating a potentially DVA patient, as defined in the inclusion criteria. Patients were consented by trained research staff. They were then randomized using an envelope system of randomization to either the EDC or standard long IV catheter arm. This was a simple randomization done by the

biostatistics department using a computerized system with a 1:1 ration for each group. The research assistant did not open the randomization envelope until all inclusion criteria was met and the inserter had chosen an appropriate vessel. Patient enrollment took place between November 2017 and February 2018.

Inclusion criteria consisted of age of at least 18 years, an expected length of hospital stay >24 h, and have DVA. A DVA patient was defined as a patient with self-reported difficult access and one of the following: 1. History of 2 or more IV attempts on a previous hospital visit; 2. Self-reported history of need for a rescue catheter such as an US-guided IV, midline catheter, PICC or CVC; 3. History of IVDA; or 4. History of ESRD on dialysis.

Patients were excluded post enrollment from the survival analysis if: 1. Vein depth was <1.20 cm or >1.60 cm; 2. Practitioner was unable to establish access; 3. Patient was discharged within first 24 h with a functional IV; 4. Patient withdrew from the study; 5. No available inserters. These patients were classified as screen fails.

### 2.3. Practitioner recruitment/training

The lead investigator recruited ED attending physicians and ED ancillary staff departmentally certified in US-guided IV placement to voluntarily participate in the study as an inserter. Departmental certification involves attending a two-hour vascular access didactic session follow by successful placement of ten supervised ultrasound-guided peripheral lines in the emergency department. The didactic session includes a discussion of relevant anatomy, insertion techniques, pitfalls and training with the Blue Phantom 2™ Vessel Ultrasound training Block (CAE Healthcare, 6300 Edgelake Drive, Sarasota, FL 34240). During this session staff are trained to use an angle of insertion of approximately 45 degrees and to “walk” the needle tip by visualizing it throughout the course of the soft tissue from the point of puncturing the skin to cannulation the vessel. Twelve staff (5 physicians, 5 nurses, and 2 technicians) expressed interest in the study and participated in the initial training process. All inserters had at least 1 year of experience in this procedure. A cohort of 8 staff (5 physicians and 3 nurses/techs) ultimately placed catheters in this study. While all practitioners were proficient with placement of US-guided 4.78 cm IV catheters, all providers were trained on placement of the extended dwell 6 cm catheter. Training consisted of an educational curriculum led by the clinical support team at Access Scientific. Training included short didactics followed by hands-on training with the device using the Blue Phantom 2™ Vessel Ultrasound training Block (CAE Healthcare, 6300 Edgelake Drive, Sarasota, FL 34240). Providers then placed between 4 and 7 successful EDCs on ED patients requiring IV access prior to study subject enrollment to ensure proficiency with placing the EDC.

### 2.4. Initial assessment

Patients were initially identified for the study based on meeting DVA criteria as above and having an expected hospital length of stay >24 h. Based on these criteria patients were consented, enrolled, and randomized. The research team and all investigators were trained to perform uniform bedside assessment, specifically to obtain vessel depth measurements, vein diameter measurements, and capture images of the catheter within the cannulated vein. After initial enrollment, an inserter was called to assess the patient's vasculature for further eligibility. They assessed the cephalic, brachial, and basilic veins in both proximal upper extremities. If the patients did not meet the vein depth criteria, they were excluded from the study. The inserters were blinded to which device patients were randomized to until after the vessel for cannulation was selected. Ultrasound was performed using a high-frequency linear transducer using the Mindray M9 unit (Mindray North America, San Jose, CA). Still images were saved on the machine and saved to Qpath™ (Telexy Helthcare, Maple Ridge, BC, Canada), a HIPAA compliant online point-of-care image archiving software. Vein depth and

diameter measurements were recorded in short axis. Inserters evaluated the vessel for valves, thrombosis, trajectory, and collapsibility. If the vein was appropriate for cannulation, the practitioner continued with the procedure. Post-cannulation, the practitioner measured the catheter length in vein in long axis. The catheter was secured with clear tape at the discretion of the inserter and a film dressing, a 4" by 4 ¾ "Tegaderm™ (3 M Company, Maplewood, Minnesota). Functionality was confirmed with blood sampling and saline flush without resistance.

A dedicated research assistant also documented practitioner details, the VAD used, time of VAD placement, length of time required to place the VAD using the tourniquet-to-tegaderm interval, number of attempts (each new skin puncture was considered a separate attempt), need for a rescue inserter, the vein that was cannulated, and the reason for the US-guided placement. Additional data collected from the electronic medical record included: age, gender, body mass index (BMI), vital signs, relevant past medical history, and admission data. Admission data included: bed type (observation, regular floor, intensive care unit) and medical or surgical service.

### 2.5. Follow-up assessment

The research assistant performed follow-up assessments on the patients' catheters within 24 h and then daily for the life of the VAD. At each follow-up interval, the research assistant noted the time of evaluation and assessed for catheter functionality. A catheter was noted as functional if the VAD drew back 5 ml of blood, if it flushed with 5 ml of normal saline, or if there was IV fluids or medications actively dripping through the VAD. If the catheter was identified to have failed during the follow-up assessment the date and time of failure and the reason for failure was obtained from chart review or through discussions with the patient, family member or ancillary staff who had direct patient contact. If the patient was discharged prior to the time of follow-up assessment then the time of discharge was documented and the IV was presumed functional until time of discharge unless otherwise noted in the chart. The research assistant was not blinded to the catheter type during follow-up assessment as the appearance of the catheters is clearly different. Our institution does not require periodic removal or replacement peripheral catheters. The IV site is evaluated daily by ancillary staff for infection or other complications. Further, per institutional policy, IV lines are flushed with 3 ml of normal saline every 8 h to maintain patency.

### 2.6. Outcomes

The primary outcome was to compare a standard long (4.78 cm) IV catheter and an extended dwell (6 cm) catheter in terms of survival at depths >1.20 cm and <1.6 cm. A depth of 1.20 cm was chosen as this depth is associated with a poor survival. The cutoff of 1.6 cm at the other extreme represents our institutional cut-off guideline for US-guided IV insertions.

Secondary outcome measures included comparison of devices to determine overall success, 'first stick' success, time to insertion, number of attempts, and length of catheter in vessel. Vessel identification, diameter and depth were also reviewed to assess effects on catheter longevity.

### 2.7. Statistical analysis

Based on a review of previous literature and prior clinical experience, the investigators assumed that the for the Standard Long IV catheter, the median survival time was 1 day. In addition, the median survival time was assumed to be 3 days for patients receiving the EDC catheter [13,17,19–21]. Given these assumptions for median survival time between the two catheters, a minimum of 17 patients randomized to each catheter was required in order to provide 80% power to detect a significant effect.

SAS 9.4 (SAS Institute Inc., Cary, NC, USA) software was used for all statistical analysis. Two Sample Independent T-Tests and Chi-Square Tests were used to analyze patient demographics, vessel characteristics (mean vessel depth, diameter), difficult IV access characteristics (IVDU, ESRD, prior multiple IV attempts, prior rescue catheters), insertion characteristics (mean time to insertion, mean number of attempts, first attempt success, time to completion), and length of catheter in vessel. T-Tests compared continuously measured characteristics while Chi-Square Tests compared categorical variables.

Kaplan-Meier survival curves were used to compute estimates of catheter survival. Hazard ratios, median survival time, and a Log-Rank test quantify differences in catheter survival. In addition, a multivariate Cox regression model with robust standard errors evaluated the difference in survival between the two catheters; adjusting for the effect of age, hypertension, and vein location. A stepwise variable selection was used to include only variables that had any association with the outcome. An entry *p*-value of 0.30 and a staying *p*-value of 0.35 was used. These *p*-values were conservative to ensure that any variables that had any degree of association were included in the model. Effects included in the Cox model were chosen via stepwise variable selection. From this model, adjusted Kaplan-Meier curves also were computed. Proportional hazards assumptions were adequately met and there was no evidence of collinearity or significant interaction effects in the model.

### 2.8. External funding

The study was funded through an unrestricted educational grant from Access Scientific. This company is the manufacturer of the POWERWAND™, an extended dwell catheter. The principal investigator designed and implemented the study protocols without any input or oversight from Access Scientific. Access Scientific had no access to the data prior to, during, or after data analysis, which was done independently by the institution of the principal investigator.

## 3. Results

Of the 120 patients consented and enrolled into the study, 59 patients were randomized to the standard long IV arm and 61 patients into the EDC arm. There were 50 patients excluded and denoted as screen fails, leaving 70 patients in the final data set for the survival analysis with 33 in the EDC group and 37 in the standard long IV catheter group. Catheter placement in the vessel of interest (depth > 1.2 cm) was successful in 70/78 (89.7%) of patients. Fig. 1 illustrates the enrollment scheme with further details. Fig. 2 outlines the details of the 8 patients with unsuccessful IV placement.

There was a significant survival benefit of the EDC catheter compared to the Standard Long IV catheter (Log-Rank *P* = 0.0016) (Fig. 3). For EDC catheters, there was a 66% lower hazard of failure (HR: 0.44, 95% CI: (0.24, 0.80)). Median catheter survival was approximately 4.04 days for EDC catheter versus 1.25 days for the Standard Long IV catheter.

Under multivariate survival analysis, there is evidence of a significant survival benefit for the EDC catheter as compared to the Standard Long IV catheter (HR: 0.50, 95% CI: (0.26, 0.96); *P* = 0.0360). In the adjusted analysis, the approximate time of EDC median catheter survival is 4.60 days while it is 1.30 days for the Standard Long IV catheter (Fig. 3). The C-Statistic of the Cox model is 0.75.

In the EDC group, 16 patients completed therapy and 17 catheters failed prior to patient discharge. In the standard long IV arm, 10 patients completed therapy and 27 catheters failed prior to patient discharge. For those patients that experienced catheter failure, reasons for failure included the catheter being dislodged early, pain, infiltration, failure (no reason specified), leaking, or kinked.

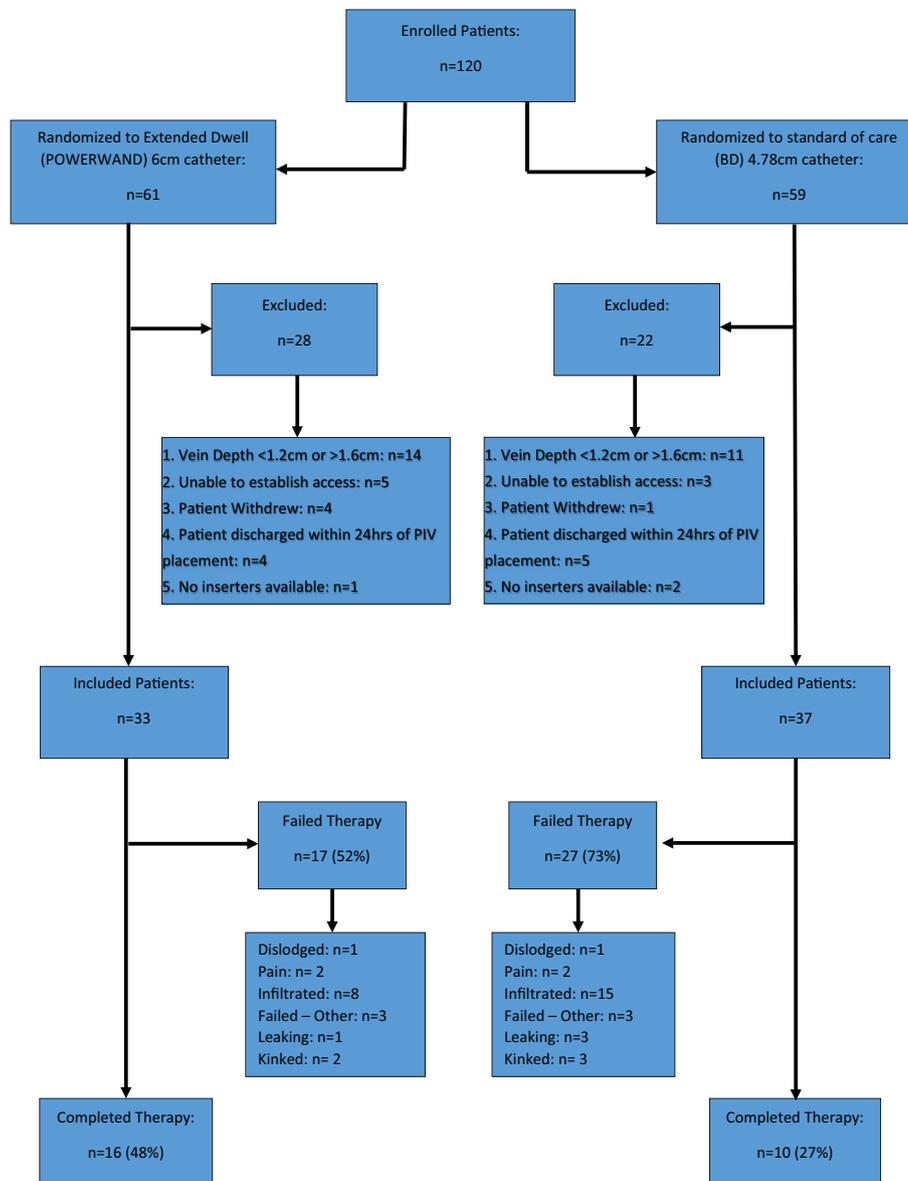


Fig. 1. Enrollment and completion of therapy scheme.

Table 1 illustrates patient demographics and shows no statistical difference in patient population in regards to age, gender, BMI, heart rate at the time of IV insertion, admission type, and service type. Furthermore, Table 1 illustrates no difference in groups in reference to difficult IV access characteristics (history of IVDU, ESRD on HD, Prior multiple IV attempts, prior need for rescue catheter).

There was no significant difference between the average vein depth for EDC catheters (1.39 cm) and the standard long IV catheters (1.35 cm) ( $P = 0.1873$ ). Vein characteristics including vein diameter and location were similar in both groups (all  $P \geq 0.05$ ). Physicians placed 82% of catheters and there were no differences in the rate of physician placement between catheters ( $P = 0.8276$ ). Table 2 illustrates this data.

No difference was observed in first stick success rate between catheter type, with 72.7% of patients in the EDC group versus 78.4% in the standard long IV group successfully cannulated with one insertion attempt ( $p = 0.5820$ ). Time to IV insertion for the standard long IV group was shorter at 5.37 min compared to 8.66 min for EDC catheters. ( $p = 0.029$ ). For the 43 out of 70 patients with available catheter length data, the EDC group had a mean catheter length in vein of 2.90 cm as compared to 2.39 cm for the standard long IV group ( $p = 0.0057$ ).

#### 4. Discussion

Despite the significant advancements which have been made in vascular access, including utilization of ultrasound as an adjunct, peripheral IV access continues to cause challenges in both the ED and inpatient settings, especially in terms of catheter survival. Numerous studies have shown that both US-guided and conventional peripheral IVs fail prematurely in patients with DVA, resulting in increased patient morbidity. Our results are consistent with other studies that demonstrate premature failure of US-guided standard IVs. Dargin et al. demonstrated that US-guided IVs fail often and quickly with a failure rate of 56% and median time to failure of 26 h. Further, 47% of these failures occurred within the first 24 h [3]. Similarly, in our investigation 73% of patients in the standard long IV arm experienced failure prior to completion of therapy. Out of 37 patients in the standard long IV group, 16 patients experienced IV failure within the first 24 h. Our results illustrate the relevance of this issue in the acute setting. Nearly half of all patients admitted with an US-guided IV experience failure suggesting this intervention is only a temporizing measure. With a large population of difficult access patients requiring US-guidance, prolonged ED stays in many

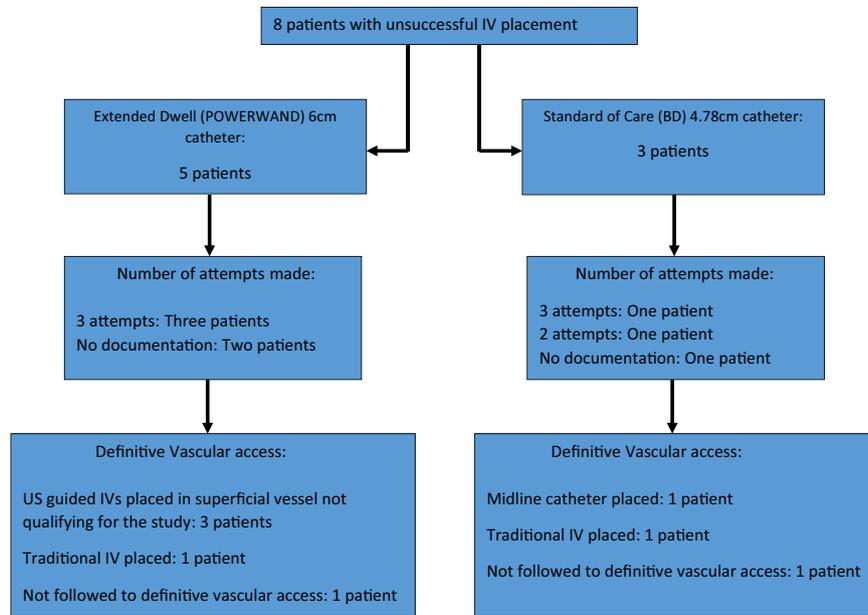


Fig. 2. Distribution of patients with unsuccessful IV placement.

institutions, and frequent ED inpatient boarding [22,23], ED providers may find themselves regularly dealing with vascular access problems once the initial catheter has failed. Furthermore, patient safety may be

jeopardized when an IV fails, especially in facilities that lack resources and staff experienced in US-guided vascular access. This may lead to a delay in the transition to inpatient teams, interrupted medical therapy, painful phlebitis, frequent reinsertions, increased hospital length of stay, increased morbidity/mortality from infections and/or skin necrosis from caustic medication infiltration, increase utilization of invasive procedures such as PICC lines or central venous catheters, and wasted medical/nursing time [24]. Extended dwell catheters offer a viable solution for some patients with veins deeper than 1.20 cm. In our study only 5 of 33 EDCs failed within the first 24 h. Our data suggests that these catheters should be considered as a viable alternative to the standard care IV catheters that most institutions stock.

The enhanced survival profile of the EDC is at least in part related to the length of the catheter in vein. The EDC used in our study was 1.22 cm longer than the standard long IV catheter and our results indicate a statistically significant greater amount of catheter in vein in the EDC group. There was some difficulty in adequate visualization of the catheter in vein post cannulation, leading to adequate measurements

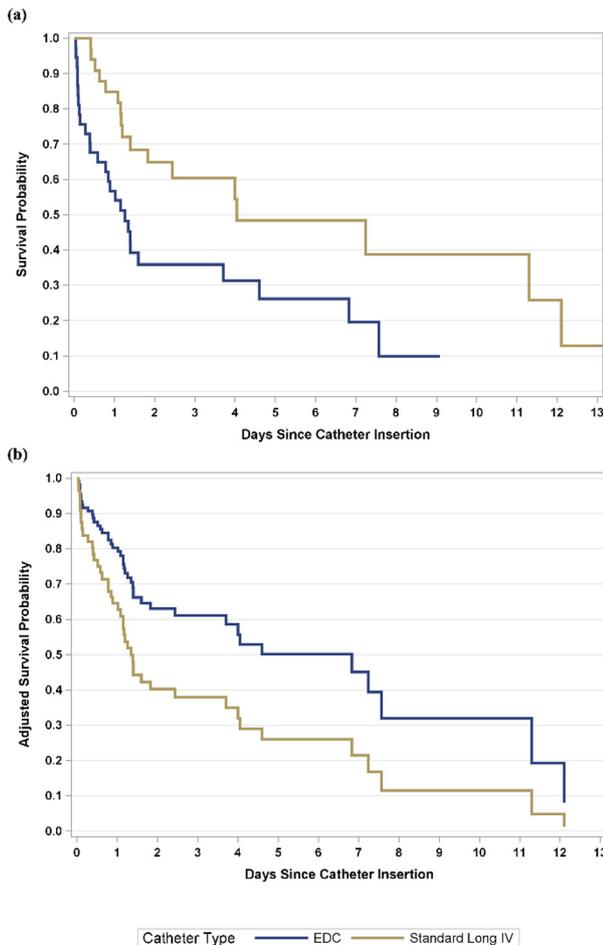


Fig. 3. Panel (a) shows the Kaplan-Meier (unadjusted) survival curves. Panel (b) are the direct adjusted survival curves, adjusting for age, hypertension, and vein location.

Table 1  
Patient characteristics.

| Patient characteristics                   | EDC (n = 33)  | Standard long IV (n = 37) | P-value |
|-------------------------------------------|---------------|---------------------------|---------|
| Mean age                                  | 62.73 (15.20) | 58.68 (18.98)             | 0.2270  |
| Gender                                    |               |                           | 0.7781  |
| Male (%)                                  | 9 (27.27%)    | 9 (24.32%)                |         |
| Female (%)                                | 24 (72.73%)   | 28 (75.68%)               |         |
| BMI                                       | 34.00 (9.42)  | 33.72 (16.76)             | 0.9317  |
| Heart rate <sup>a</sup>                   | 85.52 (19.31) | 87.53 (18.00)             | 0.6555  |
| Admission location                        |               |                           | 0.7298  |
| Observation                               | 10 (30.30%)   | 11 (29.73%)               |         |
| Regular                                   | 16 (48.48%)   | 20 (54.05%)               |         |
| Progressive/ICU                           | 7 (21.21%)    | 6 (16.22%)                |         |
| Medicine <sup>b</sup>                     | 31 (93.94%)   | 33 (91.67%)               | 0.7160  |
| Surgery <sup>b</sup>                      | 2 (6.06%)     | 3 (60.00%)                |         |
| Blood vessel and inserter characteristics |               |                           |         |
| History of intravenous drug use           | 2 (6.06%)     | 3 (8.11%)                 | 0.7399  |
| ESRD on HD                                | 4 (12.12%)    | 9 (24.32%)                | 0.1900  |
| Prior Multiple IV Attempts                | 33 (100%)     | 37 (100%)                 | –       |
| Prior Rescue Catheter                     | 23 (69.70%)   | 27 (72.97%)               | 0.7620  |

<sup>a</sup> Total number of patients with available data: EDC group n = 33; SOC group n = 36.

<sup>b</sup> Total number of patients with available data: EDC group n = 33; SOC group n = 36.

**Table 2**  
Blood vessel and insertion characteristics.

| Blood vessel and insertion characteristics          | EDC<br>(n = 33) | Standard long IV<br>(n = 37) | P-value |
|-----------------------------------------------------|-----------------|------------------------------|---------|
| Mean vein depth (cm) <sup>a</sup>                   | 1.39 (0.13)     | 1.35 (0.12)                  | 0.1873  |
| Mean vein diameter (cm) <sup>b</sup>                | 0.41 (0.14)     | 0.40 (0.11)                  | 0.6960  |
| Location <sup>c</sup>                               |                 |                              | 0.1118  |
| Basilic                                             | 20 (62.50%)     | 16 (43.24%)                  |         |
| Brachial                                            | 7 (21.88%)      | 17 (45.95%)                  |         |
| Cephalic                                            | 5 (15.63%)      | 4 (10.81%)                   |         |
| Physician inserter                                  | 27 (81.82%)     | 31 (83.78%)                  | 0.8276  |
| Mean # of attempts                                  | 1.42 ± 0.79     | 1.35 ± 0.82                  | 0.7078  |
| First stick success                                 | 24 (72.73%)     | 29 (78.38%)                  | 0.5820  |
| Mean time to completion (minutes) <sup>d</sup>      | 8.66 ± 7.36     | 5.37 ± 3.56                  | 0.0217  |
| Mean length of catheter in vessel (cm) <sup>e</sup> | 2.9 ± 0.52      | 2.39 ± 0.62                  | 0.0051  |
| Median days to failure                              | 4.04            | 1.25                         | 0.0016  |

<sup>a</sup> Total number of patients with available data: EDC group n = 47; SOC group n = 50.

<sup>b</sup> Total number of patients with available data: EDC group n = 45; SOC group n = 50.

<sup>c</sup> Total number of patients with available data: EDC group n = 32; SOC group n = 37.

<sup>d</sup> Total number of patients with available data: EDC group n = 31; SOC group n = 35.

<sup>e</sup> Total number of patients with available data: EDC group n = 25; SOC group n = 18.

of this variable in only 43 of 70 cases. The likely explanation for impaired catheter visualization is increased depth of vein compared to our previous study. In that investigation, we determined that >3.10 cm of the IV catheter should reside in the vein for optimal survival [19]. Ultimately, only 11 patients had greater than or equal to 3.10 cm of the catheter residing in the vein. In these patients there was a 33% lower hazard of catheter failure. While this finding did not reach statistical significance, it is likely reflective of this outcome being underpowered rather than a reflection of the results. Another study using significantly longer 8–15 cm catheters in a critical care study population also found improved longevity. Although catheter length in vessel was not specifically evaluated, we assume that a significant amount of the catheter likely resided in the vein based on the length of the catheters [17]. The survival profile may also be related to intrinsic properties of the catheter itself such as the composition and/or the guidewire component. This potential difference was not specifically assessed.

Upon design of this study, we speculated that nearly all extended dwell catheters would have >3.10 cm residing in the vein and many closer to 4 cm based on application of the Pythagorean theorem and assumption of a 45-degree angle of insertion. However, the catheter in vein length exceeded >3.10 cm for the extended dwell catheter in only 9 of 33 cases. While our assumption was that most providers insert the needle at a 45-degree angle based on our recommendations and teaching protocols, this was not always the case. Although measurement of vein depth is a standard and easily reproducible measurement, entry with an angle of insertion of 45 degrees is difficult to verify without use of a needle guide. In fact, the method of insertion of the EDC required thumb and index finger placement on the top and bottom

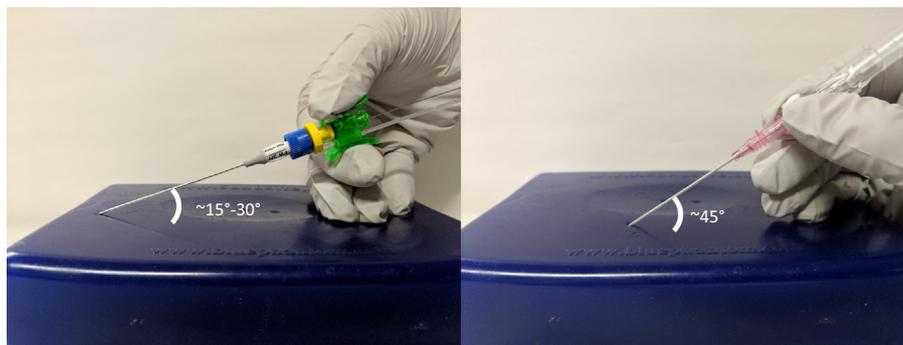
surface, respectively (Fig. 4), making the 45-degree angle difficult to achieve. While not directly measured, it was evident from the results that the angle of insertion was likely significantly <45 degrees for a more natural insertion. This is consistent with the results of another study, in which it was noted that inserters enter the skin at angle measurements of 15–30 degrees [25]. As the angle of insertion impacts quantity of catheter residing in vein and ultimately survival, this variable should be considered by inserters when evaluating vein depth and determining the best VAD option for a patient.

The EDC offers a more secure solution for patients with difficult access and deeper veins with a better survival profile compared to the standard of care IV catheter (time to median failure 4.04 days versus 1.25 days). Further, the time to insertion for these catheters is not substantially different than for placement of an US-guided IV. While on average the EDC took an additional 3 min for placement, this difference likely has no clinical significance with limited disruption in workflow and is offset by the improved performance of the IV catheter. Neither device was placed in sterile fashion, and there was no difference in pre-procedure preparation for either device. Although there were a few additional steps to insertion of the EDC, these steps compromised a marginal time difference based on our experience. The difference may in part be due to the learning curve with using a new device, as our inserters were highly competent with the standard long IV prior to the study.

In our study, the ‘first stick’ success rates (73% for EDC, 78% for standard long IV) were comparable to the rates reported in published literature [2,4,5,14,15,17,25]. Prior data looking at cannulation of the deep brachial and basilic veins demonstrated a 91% success rate, with a 73% first stick success rate in patients with difficult access [2]. Similarly to the technique described by Ueda and Hussey [25], as opposed to the “triangulation technique” our institution teaches inserters to visualize the needle tip with the US throughout the course of the soft tissue prior to cannulating the vein, then continue to “walk” the needle further into the vein prior to threading the catheter. Although our overall success rates with cannulation were only 89.7%, this was due to selection of only deep vessels. If a deep vessel was not able to be cannulated, it was counted as a failure. In three of these patients the inserter then went on to insert an US-guided IV into a more superficial vessel not qualifying for the study based on depth.

## 5. Limitations

The small sample size is a limitation of the study. The sample size may not have been large enough to control for inserter, vessel, and patient related variables that impact survival. Based on feasibility of enrollment, a convenience sample rather than consecutive difficult access patients was used. Further, the investigators were not blinded to the type of device as the external appearance of the EDC hub is clearly different than the IV hub. However, follow-ups were done consistently



**Fig. 4.** POWERWAND versus Standard long IV insertion angle.

by dedicated research staff and not the investigators to minimize the impact of the lack of blinding.

Another limitation in the use of extended dwell catheters is the dedicated training required for proficient line placement. In our study, while physicians, nurses, and techs were recruited to enroll for the study, 58/70 (82.9%) insertions were performed by the physicians. Although there are similarities to placement of an EDC and a standard US-guided IV, there are additional steps that are not necessarily intuitive and may take time and experience to master. These steps including holding the catheter securely with the primary hand, while advancing the guidewire with the other hand, followed by releasing a clamp on the device with the primary hand to advance the catheter. However, other literature has noted that with brief but comprehensive training, ED technicians are competent at placing US-guided VADs, and that there is no difference between nurses, technicians, and physicians [2,26].

Although we had high ‘first stick’ success rates even in difficult to access patients and deep vessels, all of our insertions were done by highly experienced nurses, technicians, and physicians in a single tertiary care academic center, and the results may not be easily generalizable to other settings.

This study did not assess specific complications other than failure of using longer catheters. Phlebitis and infection are common complications associated with some VADs. Use of a guidewire in theory may cause endovascular trauma and increase the risk of phlebitis. In one study with longer (8–15 cm) catheters, there was no increase in phlebitis rates when using the longer catheters [17]. Peripheral IVs have the lowest infection risk profile. There is limited published data on midline or extended dwell catheters regarding infection risk [27,28]. Thus, while survival is clearly enhanced using the extended dwell device, the complication profile was not specifically compared with the US-guided peripheral IV.

## 6. Conclusion

A longer extended dwell catheter represents a viable and favorable alternative to the standard longer IVs used for US-guided cannulation of veins >1.20 cm in depth. These catheters had significantly improved survival rates with similar insertion success characteristics in our study population. Further multicenter, larger investigations are recommended to verify our findings.

## Declaration of interest/funding information

The study was funded through an unrestricted educational grant from Access Scientific. This company is the manufacturer of the POWERWAND, an extended dwell catheter. The principal investigator designed and implemented the study protocols without any input or oversight from Access Scientific. Access Scientific had no access to the data prior to, during, or after data analysis, which was done independently by the institution of the principal investigator.

## References

- Zingg Walter, Pittet Didier. Peripheral Venous Catheters: an under-Evaluated Problem. *Int J Antimicrob Agents* 2009;34(Suppl 4):S38–42 Elsevier [www.sciencedirect.com/science/article/pii/S0924857909705655?via%3Dihub](http://www.sciencedirect.com/science/article/pii/S0924857909705655?via%3Dihub).
- Duran-Gehring P, Bryant L, Reynolds JA, Aldridge P, Kalynych CJ, Guirgis FW. Ultrasound-guided peripheral intravenous catheter training results in physician-level success for emergency department technicians. *J Ultrasound Med* 2016;35(11):2343–52.
- Schoenfeld E, Shokoohi H, Boniface K. Ultrasound-guided peripheral intravenous access in the emergency department: patient-centered survey. *West J Emerg Med* 2011;12(4):475–7.
- Costantino TG, Parikh AK, Satz WA, et al. Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. *Ann Emerg Med* 2005;46(5):456–61.
- Keyes LE, Frazee BW, Snoey ER, et al. Ultrasound-guided brachial and basilic vein cannulation in emergency department patients with difficult intravenous access. *Ann Emerg Med* 1999;34(6):711–4.
- McCarthy ML, Shokoohi H, Boniface KS, et al. Ultrasonography versus landmark for peripheral intravenous cannulation: a randomized controlled trial. *Ann Emerg Med* 2016;68(1):10–8.
- Bahl A, Pandurangadu AV, Tucker J, Bagan M. A randomized controlled trial assessing the use of ultrasound for nurse-performed IV placement in difficult access ED patients. *Am J Emerg Med* 2016;34(10):1950–4.
- Dargin JM, Rebholz CM, Lowenstein RA, et al. Ultrasonography-guided peripheral intravenous catheter survival in ED patients with difficult access. *Am J Emerg Med* 2010;28(1):1–7.
- Elia F, Ferrari G, Molino P, et al. Standard-length catheters vs long catheters in ultrasound-guided peripheral vein cannulation. *Am J Emerg Med* 2012;30(5):712–6.
- Soifer NE, Borzak S, Edlin BR, et al. Prevention of peripheral venous catheter complications with an intravenous therapy team: a randomized controlled trial. *Arch Intern Med* 1998;158(5):473–7.
- Dychter SS, Gold DA, Carson D, et al. Intravenous therapy: a review of complications and economic considerations of peripheral access. *J Infus Nurs* 2012;35(2):84–91.
- Jacobson AF, Winslow EH. Variables influencing intravenous catheter insertion difficulty and failure: an analysis of 339 intravenous catheter insertions. *Heart Lung* 2005;34(5):345e359.
- Fields JM, Dean AJ, Todman RW, et al. The effect of vessel depth, diameter, and location on ultrasound-guided peripheral intravenous catheter longevity. *Am J Emerg Med* 2012;30(7):1134–40.
- Witting MD, Schenkel SM, Lawner BJ, Euerle BD. Effects of vein width and depth on ultrasound-guided peripheral intravenous success rates. *J Emerg Med* 2010;39(1):70–5.
- Panebianco NL, Fredette JM, Szyld D, Sagalyn EB, Pines JM, Dean AJ. What you see (sonographically) is what you get: vein and patient characteristics associated with successful ultrasound-guided peripheral intravenous placement in patients with difficult access. *Acad Emerg Med* 2009;16(12):1298–303.
- Egan G, Healy D, O'Neill H, Clarke-Moloney M, Grace PA, Walsh SR. Ultrasound guidance for difficult peripheral venous access: systematic review and meta-analysis. *Emerg Med J* 2013;30(7):521–6.
- Fabiani A, Dreas L, Sanson G. Ultrasound-guided deep-arm veins insertion of long peripheral catheters in patients with difficult venous access after cardiac surgery. *Heart Lung* 2017;46(1):46–53.
- Stone P, Meyer B, Aucoin J, et al. Ultrasound-guided peripheral IV access: Guidelines for practice. *American Nurse Today* 2013;8(8).
- Pandurangadu A, Tucker J, Brackney A, Bahl A. Ultrasound-guided intravenous catheter survival impacted by amount of catheter residing in vein. *Emerg Med J* 2018. <https://doi.org/10.1136/emmermed-2017-206803> [Epub ahead of print].
- Scoppettuolo G, Pittiruti M, Pitoni S, et al. Ultrasound-guided “short” midline catheters for difficult venous access in the emergency department: a retrospective analysis. *Int J Emerg Med* 2016;9(1):3–016-0100-0. [Epub 2016 Feb 4].
- Matthew J, et al. The effect of vessel depth, diameter, and location on ultrasound-guided peripheral intravenous catheter longevity fields. *Am J Emerg Med* 2012;30(7):1134–40.
- Olshaker JS, Rathlev NK. Emergency department overcrowding and ambulance diversion: the impact and potential solutions of extended boarding of admitted patients in the emergency department. *J Emerg Med* 2006;30:351–6.
- American College of Emergency Physicians. *Emergency Department Crowding: High-impact Solutions*; July 2008.
- Gorski L, Hadaway L, Hagle ME, et al. *Infusion therapy standards of practice*. Vol 39 (15). Infusion Nurses Society: Norwood, MA; 2016.
- Ueda K, Hussey P. Dynamic ultrasound-guided short-axis needle tip navigation technique for facilitating cannulation of peripheral veins in obese patients. *Anesth Analg* 2017;124(3):831–3.
- Oliveira L, Lawrence M. Ultrasound-guided peripheral intravenous access program for emergency physicians, nurses, and corpsmen (technicians) at a military hospital. *Mil Med* 2016;181(3):272–6.
- Chopra Vineet, et al. Bloodstream infection, venous thrombosis, and peripherally inserted central catheters: reappraising the evidence. *Am J Emerg Med* 1 Aug. 2012;125(8):733–41. <https://doi.org/10.1016/j.amjmed.2012.04.010>.
- Hadaway Lynn. Short peripheral intravenous catheters and infections. *J Infus Nurs* 2012;35(4):230–40. <https://doi.org/10.1097/nan.0b013e31825af099>.