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Original Article

Pain and Satisfaction Perceptions of Ultrasound-Guided Versus Conventional Peripheral Intravenous Catheterization: A Randomized Controlled Trial

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ABSTRACT

Background: While many emergency department (ED) patients need peripheral vascular catheterization, diagnosis and treatment are often delayed by difficult intravenous access (DIVA).
Aims: This study of ED patients with DIVA was designed to evaluate ultrasound (US)-guided peripheral intravenous (IV) catheterization, compare it with conventional catheterization, and analyse patient pain and satisfaction regarding catheterization.
Design: Randomized controlled clinical trial.
Methods: Adult patients treated in the ED who scored >3 on the Adult-Difficult Venous Catheterization scale were randomly assigned to either US-guided or conventional peripheral IV catheterization. Data were collected from April to December 2016. Study variables were catheter insertion success, number of catheterization attempts, time required to perform the procedure, catheter length and calibre, puncture site, complications, and catheter functioning. Pain and patient satisfaction were also analysed for each group and the full sample.
Results: 120 and 138 patients were recruited for the US-guided and conventional peripheral IV catheterization groups, respectively. For the US-guided compared to the conventional procedure, insertion success was greater (91.75% versus 89.9%; p=0.04), the mean (SD) number of attempts was lower (1.29 (0.59) versus 1.81 (1.28); p<0.001), mean (SD) satisfaction was greater (7.59 (2.04) versus 6.69 (2.28); p=0.03), and the mean (SD) required time in minutes was greater (7.89 (7.13) versus 5.1 (3.69); p=0.045). Mean (SD) pain was moderate in both groups (4.6 (2.75) versus 4.33 (2.91) (p=0.32). Logistic regression for the full sample indicated that more attempts and greater pain were both associated with reduced satisfaction, while use of higher-calibre catheters was associated with greater satisfaction.
Conclusion: US-guided compared to conventional peripheral IV catheterization in patients with DIVA was more successful, required fewer attempts, enabled use of longer and higher-calibre catheters, and led to greater patient satisfaction. Patients who underwent US-guided intravenous catheterization reported moderate pain, similar to that reported for the conventional procedure.
Clinical implications: US-guided peripheral intravenous catheterization improves ED patient care, as it requires fewer catheterization attempts. It is especially recommended for patients with DIVA.

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Some emergency department (ED) patients need peripheral vascular catheterization for blood sample extraction, for both diagnostic purposes and the administration of intravenous (IV) therapy. Diagnosis and treatment are sometimes delayed, however, by difficult IV access (DIVA), which additionally causes both discomfort and anxiety for the patient as well as some frustration for the health provider. IV catheterization can be guided by ultrasound (US), which helps detect veins not detected in a standard physical examination based on palpation and visualization. Keyes et al. (1999) published the first study of US-guided peripheral IV catheterization in the arms of patients with DIVA, reporting an overall insertion success rate of 91% (73% on the first attempt). US-guided peripheral IV catheterization has the advantages of avoiding repeated punctures and reducing use of central routes with their corresponding complications. Clinical practice guidelines for peripheral vascular access recommend using US in cases of DIVA (RNAO, 2021; Troianos et al., 2011)

A key aspect of overall quality of hospital care is satisfaction, a multifactorial concept that is influenced by patient expectations and experiences. Greater satisfaction has been reported by patients undergoing US-guided rather than conventional peripheral IV catheterization (Bauman et al., 2009; Romero-García, 2013). Costantino et al. (2005), in a clinical trial comparing peripheral IV catheterization procedures in 60 patients, reported not only insertion success rates of 87% and 33%, but also patient satisfaction scores of 8.7 and 5.7 (out of 10) for US-guided and conventional peripheral IV catheterization, respectively.

Insertion of an IV catheter causes discomfort, pain, and stress for the patient, and numerous failed attempts aggravate these effects (Beck et al., 2011). One ED study reported a mean numerical rating scale (NRS) pain score of 5.16 (standard deviation [SD]) 2.63) out of 10 for US-guided peripheral IV catheterization, and a mean (SD) pain score of 8.20 (1.79) for failed insertion compared with 4.98 (2.57) for successful insertion (Salleras-Duran et al., 2016). In systematic reviews of US-guided peripheral IV catheterization, Stolz et al. (2015) found that outcomes for this procedure were better than for the conventional procedure, with no difference in time requirements, whereas Parker et al. (2017) concluded that more evidence was required, despite the advantages reported for the US-guided procedure.

Overall, insertion success rates above 90% have been reported for US-guided peripheral IV catheterization, and although some catheters fail in the initial hours, this has not been specifically the case for the US-guided procedure (Fields et al., 2012; Keyes et al., 1999). However, the fact that US seeks deeper veins means that there is a risk of artery or nerve punctures, although this has been reported to be a relatively infrequent complication (Duran-Gehring et al., 2016).

Since nurses are the first to attempt catheter insertion using the US-guided approach, they should also resolve any DIVA problems. Nurse training is therefore key, as time is lost if there has to be a switch in the health provider performing the procedure (Davis et al., 2021; Morata and Bowers, 2020). From this perspective, a lack of suitable training can be considered to undermine the potential success of the technique, as evidenced by a study of 219 patients by Schoenfeld et al. (2011), who reported not only a 78.5% success rate for US-guided peripheral IV catheterization, but also greater success rates for US-trained health providers.

While US-guided peripheral IV catheterization has been reported to decrease the umbers of attempts and increase satisfaction in patients with DIVA, it is not yet widely implemented in EDs. We therefore compared ED use of US-guided and conventional peripheral IV catheterization with the aim of determining benefits and analyzing patient perceptions of both pain and satisfaction.

Our aim was, in relation to ED patients with DIVA, to compare US-guided and conventional peripheral IV catheterization (US-guided group and control group, respectively) in terms of the following criteria: catheter insertion success, number of attempts, time required to perform the procedure, catheter length and caliber, puncture site, complications, anesthesia use, catheter functioning, and patient perceptions of pain and satisfaction.

Methods

Study Design

Randomized controlled clinical trial.

Setting and population.

The study was carried out in a suburban first-level community hospital ED. The study population included adult patients (aged ≥18 years) admitted to the medical care area of the ED. Included were patients requiring an IV catheter who scored ≥3 on the Adult-Difficult Venous Catheterization (A-DICAVE) scale (Salleras-Duran et al., 2020). Excluded were patients with impaired cognitive faculties or altered levels of consciousness.

Power calculation.

On the basis of results for a pilot study of the two key variables of pain and satisfaction, carried out in the same ED (Salleras-Duran et al., 2016), sample size was calculated for an alpha risk of 0.05 and a beta risk of <0.2 in a two-tailed comparison. Hence, to detect a difference of ≥1 point in the NRS pain score and a difference of ≥2 in a 10-point Likert satisfaction assessment scale, 121 patients each were required for the US-guided group and the control group. SD was assumed to be 2.7 and loss to follow-up was estimated at 5%.

Intervention.

The study, carried out between April and December 2016, included ED adult patients who met our study inclusion criteria. The nurse in charge assessed all patients attended to in the ED medical care area using the A-DICAVE scale (Salleras-Duran et al., 2020), a validated, simple, and rapidly administered instrument that measures DIVA in terms of three items, each scored from 0 (no difficulty) to 5 (maximum difficulty): visual appearance of veins, palpable appearance of veins, and a history of DIVA. Patients were informed of the purpose of the study and were asked for their informed consent before participating.

Randomization.

Patients requiring a peripheral catheter, with an A-DICAVE score ≥3, with DIVA, and who consented to participate were randomized to either the US-guided group or the control group. If catheterization was not achieved, to avoid an excessive number of attempts and the corresponding discomfort, the health provider could assign the patient to the alternative group (the corresponding data were analyzed in both groups).

Data Collection

Data collected in a questionnaire of our own design were as follows: sociodemographic data (age and sex), procedure (US-guided or conventional peripheral IV catheterization), catheter insertion success, number of attempts, and time taken (measured in minutes from tourniquet placement to catheter insertion).

Data were also collected as follows: puncture site, i.e., upper arm, forearm, cubital fossa (shoulder to elbow, wrist to elbow, and inside elbow, respectively) and hand; puncture-related complications (artery or nerve puncture); anesthesia use; catheter functioning (60 minutes and 24 hours after insertion); and length, caliber, and type of catheter used, whether short catheters (3.2-4.5 cm) or midline catheters. Midline catheters measure 10-cm or 20-cm long and require insertion using the Seldinger technique (the site is punctured with a sharp needle, and a guidewire and introducer cannula are used to insert the catheter).

Pain was measured using the NRS (0 = no pain to 10 = worst pain imaginable). Satisfaction was evaluated on a 10-point Likert scale (0 = minimum satisfaction to 10 = maximum satisfaction). Both pain and satisfaction were evaluated immediately after the procedure.

US-guided peripheral IV catheterization was performed by suitably trained nurses who had received 20 hours of training in US theory, US-related anatomy, and in simulated practice (at the time of the study, 35% [n = 18] of nurses had been trained). The research team consisted of three nurses who oversaw data collection. Pain and satisfaction data were collected by a person other than the health provider who had performed the catheterization.

Validity, Reliability, and Rigor

The A-DICAVE scale has been validated for DIVA analysis in a study conducted in the same ED. In terms of concurrent validity, it correlated positively with numeric rating scales ($r^2 = 0.82$; $p < .001$). Regarding predictive validity, a univariate logistic regression analysis dichotomized A-DICAVE scoring into 1-2 attempts and >2 attempts (odds ratio [OR] 2.76; 95% confidence interval [CI]: 1.857-4.08; $p < .001$). Diagnostic discrimination was reflected in sensitivity and specificity values of 93.75% and 78.99%, respectively, while negative and positive predictive values were 99.6% and 15.96%, respectively. A Cronbach's alpha of 0.81 indicated good internal consistency for the scale items.

The NRS used to evaluate pain is frequently used for patients in a critical condition and is well correlated with other such scales (Dijk et al., 2012). The 10-point Likert scale used to evaluate satisfaction has previously been used in a study in the same ED (Salleras-Duran et al., 2016), and also in other studies of US-guided catheterization (Costantino et al., 2005; Mahler et al., 2010).

Ethical Considerations

The research was approved by the Institutional Review Board/Ethics Committee of the reference hospital (Protocol No. 2015.098). Written informed consent was obtained from the participants, who were assured that they were free to leave the study at any time, that participation or non-participation would in no way affect their receipt of the best possible treatment, and that they could decide how information collected on them at any time could be used. Spanish Organic Law 15/1999 on the protection of personal data was respected, and patient confidentiality and anonymity were guaranteed. The researchers applied the Code of Good Research Practice, and declare an absence of any conflict of interest that could alter research outcomes.

Data Analysis

The US-guided group and control group were analyzed for comparability and for possible relationships between the different variables. Numerical variables were descriptively analyzed by calculating central tendency (mean) and dispersion values, i.e., SD, median, and interquartile range (IQR). Categorical variables were expressed as frequencies (n) and percentages (%). The Mann-Whitney *U* or Kruskal-Wallis test was used to analyze the numerical variables, Pearson's χ^2 test was used for bivariate analysis of the categorical variables, and Spearman's correlation coefficient was calculated for the continuous variables. Multivariate logistic regression was used to analyze features potentially influencing DIVA.

Results were considered significant for $p < .05$. Data were analyzed using SPSS version 18 for Windows (SPSS, Chicago, IL).

Results

Participants

A total of 256 patients participated; 68.8% (n = 176) were women and 31.2% (n = 80) were men. Mean (SD) age was 68.57 (17.79) years (range, 20-98), and the median (IQR) age was 71 (23) years. The 256 patients, representing 258 cases, were randomized 120 cases and 138 cases to the US-guided and control groups, respectively. Figure 1 shows the CONSORT clinical trial flowchart.

Women accounted for 65.5% (n = 78) and 71.5% (n = 98) of the US-guided group and the control group, respectively ($p = .3$). Mean (SD) age was 68.5 (17.91) years and median (IQR) age was 72 (23) years for the US-guided group, and 68.64 (17.57) years and 71 (24) years for the control group ($p = .95$).

Significant differences were identified between the groups in relation to DIVA as reflected in the A-DICAVE scale; scores were higher in the US-guided group than in the control group (mean [SD] 4.1 [8.87] and median [IQR] 4 [2] versus 3.64 [0.89] and 3 [2]; $p < .001$). DIVA was also analyzed (excluding patients who had switched groups), resulting in a mean (SD) of 4.1 (0.87) for the US-guided group versus a mean (SD) of 3.58 (0.86) for the control group ($p < .001$). The groups were considered valid for analysis.

Catheter Insertion Success, Number of Attempts, and Time Required

There was no statistically significant difference between the US-guided and control groups regarding catheterization success, which was high for both, at 91.7% (n = 110) and 89.9% (n = 124), respectively ($p = .62$). In patients with A-DICAVE >3, for the US-guided group versus the control group, the success rate was greater (92.5% [n = 74] versus 80.4% [n = 41]; $p = .04$), fewer attempts were necessary (mean [SD] 1.29 [0.59] and median [IQR] 1 [0] versus mean [SD] 1.81 [1.28] and median [IQR] 1 [1]; $p < .001$), and more time was required (mean [SD] 7.89 [7.13] and median [IQR] 5 [8] minutes versus mean [SD] 5.1 [8] and median [IQR] 5 [5] minutes; $p = .045$).

Catheter Type, Puncture Site, Complications, and Catheter Functioning

The catheters used for the US-guided group were thicker (16G, 18G, and 20G calibers) and longer (midlines, i.e., 10 to 20 cm) than those used for the control group patients (22G and 24G calibers; 3.2 to 4.5 cm). While no differences were observed regarding the arm used, the puncture site was mainly the upper arm for the US-guided group patients, and the cubital fossa or hand for the control group patients. There was a single complication in the US-guided group (without side effects), due to accidental nerve puncture that was detected from the pain reaction of the patient. No differences were evident regarding catheter functioning (Table 1).

Pain Perceptions

No statistically significant differences were found between the pain reported by the four anaesthetized patients (mepivacaine

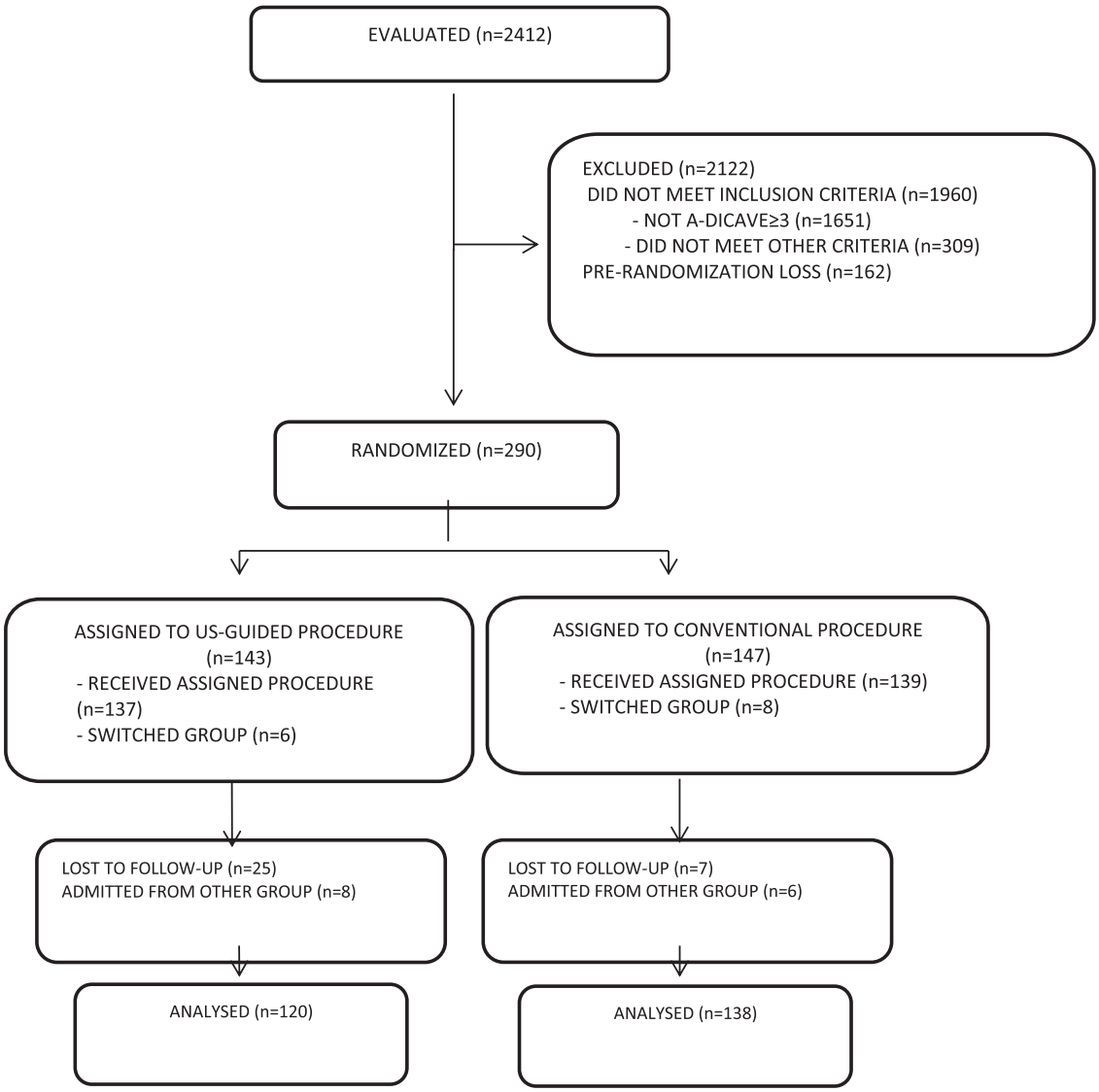

Figure 1. Ultrasound-guided and conventional peripheral intravenous catheterization clinical trial flowchart (CONSORT).

Table 1
Ultrasound-Guided Versus Conventional Peripheral Intravenous Catheterization: Catheter Type, Puncture Site, Complications, and Catheter Functioning

	Ultrasound-Guided Procedure n (%)	Conventional Procedure N (%)	p^a
Catheter length (n = 234)			
Long (10-20 cm)	33 (97.1)	1 (2.9)	**<.001**
Short (3.2-4.5 cm)	76 (38)	124 (62)	
Catheter caliber (n = 175)			
Thin (22G, 24G)	3 (6.5)	43 (93.5)	**<.001**
Thick (20G, 18G, 16G)	59 (45.7)	70 (54.3)	
Arm (n = 221)			
Right	54 (45.4)	65 (54.6)	.5
Left	51 (50)	51 (50)	
Puncture site (n = 222)			
Hand	1 (2.3)	42 (97.7)	**<.001**
Forearm	11 (32.4)	23 (67.6)	
Cubital fossa	35 (43.8)	45 (56.2)	
Upper arm	59 (90.8)	6 (9.2)	
Complications			
Nerve puncture	1 (0.83)	0	.95
Catheter functioning			
At 60 minutes	Yes 107 (99.1)	Yes 116 (99.1)	.95
(n = 225)	No 1 (0.9)	No 1 (0.9)	
At 24 hours	Yes 31 (88.6)	Yes 11 (78.6)	.65
(n = 49)	No 4 (11.4)	No 3 (21.4)	

[a] χ^2 test.

Table 2
Patient-Reported Pain Related to Specific Variables (Full Sample)

Pain Pain by category (n = 250)	Mild (NRS <4)	Moderate (NRS 4-6)	Severe (NRS >6)		
	100 (40%)	86 (34.4%)	64 (25.6%)		
Sex (n = 248)	Men	Women			
	4.18 (2.8)	4.64 (2.85)	$p = .23$[a]		
Success (n = 250)	Yes	No			
	4.33 (2.79)	6.37 (2.57)	**$p = .003$**[a]		
Attempts (n = 247)	≤2 attempts	>2 attempts			
	4.21 (2.79)	6 (2.46)	**$p = .001$**[a]		
Catheter length (n = 231)	Short (3.2-4.5 cm)	Long (10-20 cm)			
	4.14 (2.84)	5.38 (2.15)	**$p = .009$**[a]		
Catheter caliber (n = 174)	Thin	Thick			
	3.87 (2.83)	4.11 (2.79)	$p = .58$[a]		
Arm (n = 218)	Right	Left			
	4.35 (2.83)	4.16 (2.67)	$p = .73$[a]		
Puncture site (n = 219)	Hand	Forearm	Cubital fossa	Upper arm	$p < .001$[b]
	4.7 (2.81)	4.18 (2.75)	3.33 (2.69)	5.27 (2.43)	

[a] Mann-Whitney *U*.
[b] Kruskal Wallis. All values are reported as mean (SD) except where otherwise indicated. NRS = numerical rating scale.

2%, 0.2 cc administered subcutaneously) compared with the non-anaesthetized patients (mean [SD] of 2 [2.45] versus 4.48 [2.82] NRS points; $p = .08$). These four cases were excluded from the subsequent pain analysis.

No significant differences in pain scores were observed between the groups, with mean (SD) 4.66 (2.75) points for the US-guided group versus 4.33 (2.91) points for the control group ($p = .32$); nor were differences observed in patients scoring A-DICAVE>3, with mean (SD) 4.76 (2.88) points versus 5.08 (2.6) points ($p = .54$).

The overall pain score, irrespective of the procedure used, was mean (SD) 4.45 (2.83) and median (IQR) 5 (5). Results for pain, rated as mild (NRS<4), moderate (NRS 4 to 6), or severe (NRS >6) according to different clinical variables, are summarized in Table 2. Note that the four patients who received anesthesia before puncture were not included in this analysis. The Spearman's correlation coefficient between age and pain was r = 0.04 ($p = .55$).

Variables showing a statistically significant relationship with pain perceptions were A-DICAVE score, insertion success, number of attempts, time taken, catheter length and caliber, and puncture site. Pain was greater for higher A-DICAVE scores (a slightly positive correlation of r = 0.19; $p = .003$), unsuccessful insertion ($p = .003$), and >2 attempts ($p = .001$). Pain was likewise greater when more time was required (a slightly positive correlation of r = 0.29; $p = .001$) and when midlines were used ($p = .009$). Finally, upper arm punctures were more painful than punctures in either the forearm ($p = .04$) or the cubital fossa ($p < .001$), and hand punctures were more painful than punctures in the cubital fossa ($p = .01$).

The logistic regression analysis included the full sample to identify predictors of pain, categorized from the 50th percentile as mild (NRS = 0 to 4 points) or moderate/severe (NRS >4 points). The following variables were included in the model, adjusted by age and sex: A-DICAVE score, number of attempts, catheter caliber, and puncture site. The model explained 21.1% of the variance (Nagelkerke index), and the number of attempts and puncture site (cubital fossa) were significant variables. Table 3 reports the OR for each variable along with the 95% CI.

Table 3
Multivariate logistic regression analysis of pain.

	Odds Ratio	Confidence Interval (95%)	*p*
A-DICAVE score			
3	-	-	-
4-5	0.758	(0.367-1.567)	
Attempts			
1-2	-	-	**-**
3-5	3.673	(1.287-10.485)	**.015**
Catheter caliber			
Thick (20G,18G,16G)	-	-	-
Thin (22G, 24G)	0.696	(0.292-1.655)	.705
Puncture site			
Upper arm	-	-	**-**
Forearm	0.355	(0.110-1.142)	.82
Cubital fossa	0.138	(0.048-0.392)	**<.001**
Hand	0.414	(0.128-1.338)	.141

A-DICAVE score = Adult-Difficult Venous Catheterization score.

Satisfaction Perceptions

There were no significant satisfaction score differences between the two groups (US-guided group mean [SD] 7.8 [2.04] versus control group mean [SD] 7.61 [2.28]; $p = .73$). However, for patients with A-DICAVE >3, the satisfaction of US-guided group patients was greater than that of control group patients (mean [SD] 7.59 [2.04] versus mean 6.69 [2.28]; $p = .03$).

The satisfaction expressed by the sample overall was mean (SD) 7.7 (2.17) and median (IQR) 8 (3). Spearman's correlation between age and satisfaction was r = -0.52 ($p = .42$). A slightly negative correlation was observed between satisfaction and DIVA, i.e., greater difficulty led to less satisfaction (r = −0.18; $p = .004$), and also between satisfaction and more time required (r = -0.25; $p = .002$). The number of attempts was negatively correlated with both satisfaction and pain, i.e., more attempts led to less satisfaction (r = -0.41; $p < .001$), and more pain meant less satisfaction (r = -0.49; $p < .001$). A statistically significant relationship was established with catheter length and caliber, as shorter thicker catheters led to greater satisfaction. Satisfaction was also greater for the cubital fossa as the puncture site compared to the hand ($p = .008$), upper arm ($p < .001$), or forearm ($p = 0.45$) (Table 4).

The logistic regression analysis included the full sample to identify predictors of satisfaction, divided into two categories from the 50th percentile (<8 points and ≥8points). The following variables were included: procedure type, number of attempts, catheter caliber, puncture site, and pain. The model accounted for 27.3% of the variance (Nagelkerke index), and the number of attempts, catheter

Table 4
Patient-Reported Satisfaction Related to Specific Variables (Full Sample).

Satisfaction					
Sex (n = 201)	Men	Women	*p*		
	7.79 (0.59)	7.64 (1.28)	.87[a]		
Attempts (n = 250)	≤2 attempts	>2 attempt			
	7.93 (2.09)	6.44 (2.21)	**<.001**[a]		
Pain by category	Mild	Moderate	Severe		
	8.76 (1.29)	7.59 (1.81)	6.16 (2.72)	**<.001**[b]	
Success (n = 253)	Yes	No			
	7.9 (2.1)	5.45 (2.1)	**<.001**[a]		
Catheter length (n = 233)	Short (3.2-4.5 cm)	Long (10-20 cm)			
	8 (2.14)	7.21 (1.45)	**.01**[a]		
Catheter caliber (n = 175)	Thin	Thick			
	7.37 (2.25)	8.26 (2.02)	**.01**[a]		
Arm (n = 220)	Right	Left			
	8.08 (1.94)	7.8 (1.99)	.3[a]		
Puncture site (n= 221)	Hand	Forearm	Cubital fossa	Upper arm	
	7.51 (2.35)	7.82 (1.99)	8.54 (1.72)	7.45 (1.91)	**.01**[b]

[a] Mann-Whitney *U*.
[b] χ^2 test.All values are reported as mean (standard deviation [SD]).

Table 5
Multivariate Logistic Regression Analysis Of Satisfaction

	Odds Ratio	Confidence Interval (95%)	*p*
Procedure			
Ultrasound-guided	-	-	-
Conventional	0.555	(0.184-1.679)	.297
Attempts			
1-2 attempts	-	-	-
3-5 attempts	0.335	(0.112-0.997)	**.049**
Catheter caliber			
Thick (20G,18G,16G)	-	-	-
Thin (22G,24G)	0.247	(0.097-0.631)	**.003**
Puncture site			
Upper arm	-	-	-
Forearm	1.303	(0.326-5.209)	.708
Cubital fossa	2.268	(0.643-7.999)	.203
Hand	3.470	(0.782-15.400)	.102
Pain			
NRS = 0-4 points	-	-	-
NRS >4 points	0.265	(0.113-0.618)	**.002**

NRS = numerical rating scale.

caliber, and pain were significant variables. Table 5 reports the OR for each variable along with the 95% CI.

Discussion

Discussion of Results

Our finding of a high catheter insertion success rate (91.7%) for US-guided peripheral IV catheterization coincides with several previous studies reporting rates of between 78% and 98.9% (Adhikari et al., 2010; Bauman et al., 2009; Schoenfeld et al., 2011). As for conventional peripheral IV catheterization, we report a greater success rate (89.9%) than other studies that compared both procedures, e.g., Costantino et al. (2005), who reported a 50% insertion success rate for the conventional procedure versus 80% for the US-guided procedure. Coinciding with Bauman et al. (2009), we found no significant differences for A-DICAVE ≥3 between the two procedures. Nevertheless, we found that US-guided peripheral IV catheterization was more successful for patients with A-DICAVE >3, suggesting that this approach is a good option for catheterization of patients with DIVA.

More attempts were needed for the conventional procedure (1.8 attempts) than for the US-guided procedure (1.3 attempts). Of patients who needed >2 attempts, 82% were catheterized with the conventional procedure, confirming findings reported elsewhere (Bauman et al., 2009).

More time was needed for the US-guided procedure (7.9 minutes) than for the conventional procedure (5.1 minutes). Other studies have reported no significant time difference (Stein et al., 2009), while yet other studies have reported less time needed for the US-guided procedure (Bauman et al., 2009; Costantino et al., 2005).

Midline peripheral IV catheters were used more for the US-guided procedure than for the conventional procedure. These allow for treatments of longer duration, as the catheter can remain functional for several weeks; they also result in a lower rate of phlebitis, which obviates the need for catheter replacement during hospitalization and helps preserve vein integrity (RNAO, 2021). As for thickness, catheter calibers ranged between 16G and 24G, with mostly thicker catheters (16G, 18G, and 20G) used for the US-guided procedure. Large- caliber catheters ensure the greater infusion of fluids necessary for ED care of patients (RNAO, 2021), with Bridey et al. (2018) reporting use of thicker peripheral catheters for the US-guided procedure.

Regarding the target arm for puncture, no differences were observed between the US-guided and the conventional procedures. Despite RNAO (2021) recommendations to consider patient preferences and to preferably use the non-dominant arm, in our study, the right arm (dominant for the majority of our patients) was mostly catheterized, in line with the report by Loon et al. (2016) that most catheters are inserted in the dominant arm.

We identified differences in puncture sites in our study. Thus, the hand or cubital fossa (where veins are most visible) was used for the conventional procedure, corroborating other studies (Loon, et al., 2016), while the upper arm was primarily used for the US-guided procedure, in accordance with guidelines (RNAO, 2021) and coinciding with other studies (Bauman et al., 2009).

The single complication that occurred in our study was a nerve puncture during US-guided peripheral IV catheterization, detected from the intense pain reported by the patient; the pain subsided once the needle was removed and there were no side effects. This low complication rate coincides with findings by other authors (Bauman et al., 2009; Duran-Gehring et al., 2016); furthermore, our zero rate of accidental arterial puncture was lower than reported elsewhere (Schoenfeld et al., 2011). Our results corroborate those of Bauman et al. (2009), who reported accidental arterial and nerve puncture rates of 9.8% and 2.4%, respectively, for the US-guided

procedure, and no case of accidental nerve or arterial puncture for the conventional procedure.

There were no significant differences in catheter functioning between the procedures, with virtually all catheters (99.1%) functioning in the first 60 minutes in both groups; this result compares favorably with the 8% and 10% 60-minute failure rates reported by Keyes et al. (1999) and Fields et al. (2012). At 24 hours, 88.6% of the US-guided catheters and 78.6% of the conventional catheters were still functioning; this result compares favorably with the 33% and 37% 24-hour failure rates reported by Adhikari et al. (2010) for the US-guided and conventional procedures, respectively.

NRS-scored pain as reported by the full sample of patients was a mean of 5 points, reflecting moderate pain and confirming that IV catheterization is painful, as already reported by other studies (Beck et al., 2011). A significant proportion of patients (25%) reported severe pain. Pain, even though considered a multifactorial experience (Shug et al., 2015), was not found to be related to age or sex.

Although there was no difference between the groups in terms of reported pain, pain reported for successful catheterization was less than for failed catheterization, corroborating existing evidence (Salleras-Duran et al., 2016). Broadly speaking, and logically, as the procedure became more complicated (requiring more attempts and more time), catheterization became more difficult and infusion pain increased, confirming evidence documented elsewhere (Loon et al., 2016).

Catheter caliber did not affect the pain experienced, but pain did vary depending on catheter length and puncture site. Use of longer catheters (i.e., midlines) increased pain, and the fact that 94% of long catheters were inserted in the upper arm may explain the difference in reported pain. Ballesteros-Peña et al. (2018) report that catheterization pain is modulated by different variables, one of which is the puncture site. Greater pain may also be related to the manipulation required to insert midlines (Seldinger technique). Anaesthesia use is infrequent for catheterization, despite the acknowledged pain; in our study, although reported pain was less in the patients injected with anaesthesia, the finding was not statistically significant, probably because only four patients were anaesthetized. Balanyuk et al. (2018) reported less pain (as assessed using an NRS) for distraction techniques than for anaesthesia. Our predictive model indicates greater pain with more attempts, and less pain when the cubital fossa is the puncture site.

Satisfaction with the US-guided procedure was high in our study, at 7.8 points out of 10, a finding very similar to the 7.6 reported previously for the same ED (Salleras-Duran et al., 2016). Satisfaction was similar in both groups, contradicting other studies comparing both procedures that reported greater satisfaction with the US-guided approach (Bauman et al., 2009; Costantino et al., 2005). Our high score for the US-guided procedure (7.8 points) was similar to scores reported by those same studies, whereas our satisfaction score for the conventional procedure (mean 7.6 points) was higher (Bauman et al., 2009; Costantino et al., 2005). Analyzing only patients with A-DICAVE >3, the US-guided group patients experienced greater DIVA, corroborating both Bauman et al. (2009) and Costantino et al. (2005).

Satisfaction in the full sample was not related to age or sex, but was greater when less time was needed for the procedure, and was less when more attempts were needed and when the procedure did not conclude successfully. These items are interrelated as they would indicate that greater procedure complexity leads to less satisfaction (Shug et al., 2015). The variables that predicted satisfaction were the number of attempts, catheter caliber, and pain; less satisfaction was reported for more attempts and more pain, while greater satisfaction was associated with thicker (lower caliber) catheters.

Patients catheterized with shorter catheters expressed more satisfaction, and, as mentioned, satisfaction was even greater for thicker catheters. This finding may be influenced by the fact that thicker catheters are typically used for the cubital fossa and may require fewer attempts.

There were no differences in relation to the catheterized arm—mainly the right (dominant) arm in our patients. As for puncture site, catheters inserted in the cubital fossa were associated with greater satisfaction than catheters placed in other sites. Satisfaction in our study was measured immediately after performing the procedure, but a patient's perceived satisfaction might vary after several days of performing daily activities if the dominant arm or the cubital fossa is catheterized (Larsen et al., 2017).

Satisfaction varied depending on the reported pain, with less pain reflecting greater satisfaction. Specifically, patients who reported severe pain (>6) reported a mean satisfaction score of 6.2, whereas the score for patients who reported mild pain (<4) was 8.8. Those results suggesting that pain affects perceptions of satisfaction point to the importance of ED pain management, and specifically the pain caused by a nursing procedure.

Study limitations

Our research was conducted at a single center, so findings may be extrapolated to similar populations, but not to all areas of ED care. The existence of possible sources of bias also needs to be considered, specifically in patient-reported perceptions of pain and satisfaction if the health provider's explanation was misunderstood, and as a consequence of the data being collected by health providers employed in the same ED. Finally, bearing in mind that the US-guided technique facilitates the insertion of greater caliberand longer catheters, we considered it important not to restrict the study to just one type of catheter, even though this could bias results regarding pain and satisfaction. This issue will be considered in future studies.

Conclusions

US-guided compared to conventional peripheral IV catheterization required fewer attempts and had a higher insertion success rate in patients with DIVA. Although the US-guided procedure required more time, it was associated with a very low rate of complications, and also allowed longer and thicker catheters to be used. Pain was related to whether or not the procedure was successful, the number of attempts, catheter length and caliber, and puncture site. As for satisfaction, patients with DIVA reported greater satisfaction with the US-guided procedure. Satisfaction perceptions overall were related to DIVA, time required for insertion, the number of attempts, the pain experienced, insertion success, catheter type, and the puncture site.

Implications for Nursing Practice

US-guided peripheral IV catheterization improves ED patient care by requiring fewer attempts, and so is especially recommended for patients with DIVA. The fact that those patients report greater satisfaction would suggest a need for more nurses to receive training in US-guided peripheral IV catheterization.

The non-negligible pain experienced by our participants (moderate overall, but severe in 25% of cases) should alert health providers to the importance of evaluating catheterization pain.

The fact that fewer attempts are required for US-guided catheterization may reduce the material and time costs associated with catheterization, so further research is needed to analyse this procedure in both general and cost terms.

While the US-guided procedure facilitates the use of longer and thicker catheters, nurses need to ensure that caliberand length are selected according to the needs of the patient.

Declaration of Competing Interest

The researchers applied the Code of Good Research Practice and declare an absence of any conflict of interest that could alter research outcomes.

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