*Original Article*

# First-Attempt Success Rate of Ultrasound-Guided Peripheral IV Access using a Handheld Ultrasound Machine in a Simulation Model

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***Background:*** Although peripheral Intravenous (IV) cannulation is a routine procedure performed by nurses, IV access can be difficult to achieve, particularly in emergency patients who have critical illnesses. Ultrasound is used in this procedure to increase the success rate in novice practitioners.

***Objective:*** We aimed to determine the first-attempt success rate of ultrasound-guided peripheral IV (USGPIV) performed by emergency nurses in simulation model after having undergone training in the procedure.

***Materials and Methods:*** This was prospective descriptive study. The participants consisted of 61 emergency nurses at Srinagarind Hospital Emergency Department from January to April 2020. USGPIV cannulation training was provided by an emergency physician who is also a specialist in emergency ultrasound. After training, we calculated the number of attempts and time required to successfully complete USGPIV in a simulation model. Following this, participants responded to a questionnaire to evaluate their confidence in performing the procedure, as well as its feasibility and practical application. Data were analyzed using a Kolmogorov-Smirnov test, and $p<0.05$ was considered to be significant.

***Results:*** Sixty-one emergency nurses were included. The first-attempt success rate of USGPIV was 85.25% (95% CI 0.761, 0.944), and the mean time required was 47.33±4.89 sec. (95% CI 37.547, 57.103). Fifty-nine participants (96.72%) completed the questionnaire. All items had a mean score of greater than 3 points, with confidence score being the highest.

***Conclusion:*** Emergency nurses with no previous experience with USGPIV were able to perform a simulated version of the procedure with a high first-attempt success rate after a short training session. Further studies should be conducted to evaluate nurses' USGPIV competency in real patients.

***Keywords:*** Ultrasound, Peripheral IV cannulation, Emergency medicine, Emergency nurse

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Peripheral intravenous (PIV) cannulation is an essential procedure in the emergency department, which in Thailand, is mostly performed by nurses. Peripheral vein cannulation is more difficult in some patients[1] such as those with skin and soft tissue edema, hypotension or shock, obesity, history of intravenous drug use, history of chemotherapy, or history of frequent admission[2].

Traditionally, peripheral vein cannulation is conducted using visual inspection and palpation of the extremity to locate the vein. However, in the last decade, Ultrasound-Guided Peripheral Intravenous (USGPIV) cannulation has come to be used by emergency physicians, anesthesiologists, and/or nurses in order to reduce procedure of central venous catheter, time necessary to complete the procedure, costs, complications (such as hematoma), and patient discomfort[3-5]. The USGPIV has been fallen into the traditional practice in emergency nurses in some country which performed follow the clinical practice guideline[6]. For example, in 2019, the American Institute of Ultrasound in Medicine (AIUM) published guidelines for the use of ultrasound to guide vascular access procedures for practitioners in the United States.

In terms of ultrasound equipment, handheld ultrasound machines are currently more commonly used in the emergency department than stationary devices[7] due to their has battery itself, portability, and suitability in bedside procedures such as pleurocentesis, abdominal paracentesis, and peripheral venous access[8,9].

Although emergency medicine residents are trained in obtaining USGPIV access, there have been no studies examining the use of USGPIV placement by nurses in Thailand. In this study, introduced USGPIV cannulation as a technique to be used by emergency nurses.

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## Materials and Methods

### *Study design*

This was a prospective, single-center, descriptive study in tertiary university hospital in Thailand. Ethics approval was provided by the Khon Kaen University Ethics Committee for Human Research, and the study was registered with the Thai Clinical Trials Registry (HE631185).

### *Participants*

In April 2020, nurses at the Khon Kaen University Faculty of Medicine Emergency Department were enrolled to this study using convenience sampling. None of the participants had any previous knowledge of or experience with USGPIV access. No monetary incentive was provided. Written informed consent was obtained from each participant prior to enrollment.

### *Sample size calculation*

The sample size for analysis of estimating a population proportion with specified absolute precision was determined based on a study by Van Loon[10]. We hypothesized a prevalence of 0.81, an absolute precision of 0.1, and a standard normal value of 1.96. The power analysis was determined using an alpha of 0.05. Hence, we determined that a total of at least 60 subjects would be required.

### *Study protocol*

We conducted this study at the emergency department. At the beginning of the study, all volunteer nurses participated in a USGPIV placement workshop, which included a 30-minute didactic session and 30-minute hands-on session. This workshop was taught by an emergency physician who was a specialist in emergency ultrasound. Participants were taught about probe orientation, image optimization using depth and gain, upper extremity venous anatomy, using vascular ultrasound to identify the appropriate vein, the transverse approach, and dynamic technique (in which the operator holds the US probe with their nondominant hand and the needle in their dominant hand while visualizing the needle tip entering the vein) using a simulation model (Figure 1).

The simulation model was created based on a study by Chao[11] and the phantom was created using gelatin powder, fiber powder, and a latex tube (Figure 2). The quality of the phantom was examined prior to the study and was determined to provide an adequate sonographic view (Figure 3) and able to sustain multiple punctures.

After the training period, participants' skills were evaluated by the emergency physician who taught the workshop and an examiner who had no previous association with participants. Data were recorded as number of attempts to successfully obtain USGPIV access and the time required to complete the procedure. Following the study, participants completed a questionnaire regarding their confidence in performing the procedure, as well as its feasibility and practical application based on a 5-point Likert scale.

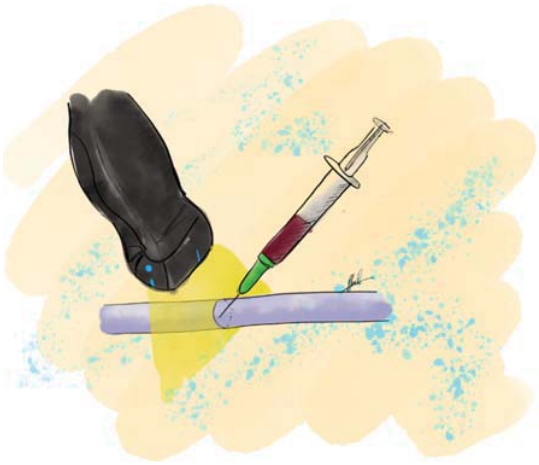

**Figure 1.** USGPIV access using the transverse approach.

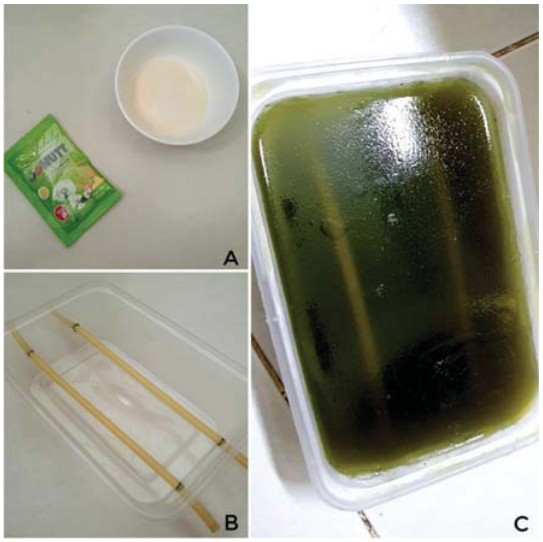


**Figure 2.** A) fiber powder (Left) and gelatin powder (right), B) latex tube and box, C) finished model.

The primary outcome of this study was participants' first-attempt success rate for USGPIV access.

### *Ultrasound equipment*

This study was conducted using the Butterfly IQ handheld ultrasound machine (2D array, 9,000 micro-machined sensors, USA). All images were obtained in B mode, and no color Doppler was used. The transducer was set to the vascular image preset.

### *Statistical analysis*

Quantitative data are presented as means ± standard deviations and qualitative data as proportions and percentages. We used the Kolmogorov-Smirnov test to analyze the time and number of attempts required to obtain successful USGPIV access. A two-tailed $p<0.05$ was considered statistically significant. All data analysis was performed using Stata version 10.1 (StataCorp, College Station, TX).

## Results

A total of 61 emergency nurses participated in this study. The average age of the participants was 29.92±6.14 years, and 88.52% (n = 54) were female. The first-attempt success rate was 85.25% (95% CI 0.761, 0.944; Table 1). The mean time required to complete the procedure was 47.33±4.89 sec. (95% CI 37.547, 57.103), with a minimum and maximum of 18.09 sec and 228.66 sec, respectively.

Fifty-nine of the participants completed questionnaire, which evaluated their confidence in performing the procedure, as well as its feasibility and practical application, with participant confidence receiving the highest mean score (Table 2). Almost all participants rated all items as 3 or higher. However, one participant gave the practical application of the procedure a score of 2, indicating dissatisfaction (Table 3).

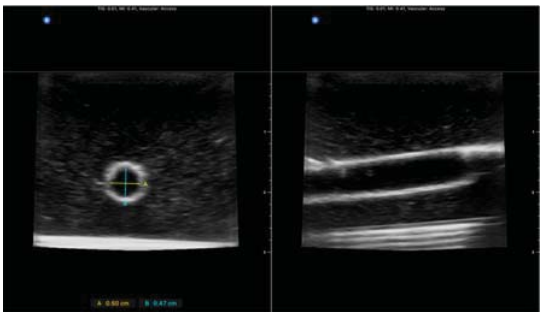

**Figure 3.** Sonographic view from the simulation model.

**Table 1.** Number of attempts required to complete the procedure (frequency)

| Number of attempts | Frequency (%) | 95% CI |
|---|---|---|
| 1 | 52 (85.25) | 0.761, 0.944 |
| 2 | 6 (9.84) | 0.021, 0.175 |
| 3 | 3 (4.92) | -0.007, 0.105 |

## Discussion

Peripheral IV cannulation is a common procedure performed by nurses in the emergency department. In this study, we introduced PIV cannulation using ultrasound to our emergency nurses. Our primary outcome was the first-attempt success rate of USGPIV cannulation, as it has been shown to increase hospital efficacy[12,13]. Failure to obtain peripheral IV cannulation on the first attempt may result in delays in diagnosis and treatment[14,15]. Furthermore, healthcare costs and the rate of complications (such as hematoma formation, arterial puncture, extravasation of fluid, phlebitis, and paresthesia)[3,16] have been shown to increase exponentially in such cases[17]. Previous studies shown the success rate of USGPIV cannulation to range from 20 to 86%[18-22]. The first-attempt success rate of USGPIV access in this study was 85.25%, which was consistent with those found in several previous studies (although those studies were conducted in real patients)[18,19]. We found one study in which the first-attempt success rate was only 20%, but the finding was not statistically significant ($p$-value = 0.278)[22]. In this study, the maximum number of attempts was 3, which 4.92% of participants reached.

Previous studies have shown image quality from the ultrasound equipment to be a factor that affects the primary outcome[23] for example, noticed that the first-attempt success rate was higher in more recently published

**Table 2.** Mean questionnaire scores for each item

| Item | Scores; mean ± SD | Scores; min | Scores; max |
|---|---|---|---|
| Feasibility | 3.95±0.78 | 3 | 5 |
| Confidence | 4.19±0.57 | 3 | 5 |
| Practical application | 4.14±0.68 | 1 | 5 |

**Table 3.** Score frequency for each item

| Item | Frequency (%) | | | | |
|---|---|---|---|---|---|
| | 1<br>Not all satisfied | 2<br>Slightly satisfied | 3<br>Neutral | 4<br>Very satisfied | 5<br>Completely satisfied |
| Feasibility | 0 | 0 | 19 (32.20) | 24 (40.70) | 16 (27.1) |
| Confidence | 0 | 0 | 5 (8.5) | 38 (64.4) | 16 (27.1) |
| Practical application | 0 | 1 (1.7) | 7 (11.9) | 34 (57.6) | 17 (28.8) |

studies because of the development of higher definition ultrasound machines. Some studies have also found the technique used to be a factor. In this study, we used the transverse approach because studies by Maddal[24] and Yunyang[25] found that this method increased the chance of successful cannulation on the first attempt. However, several other studies[26-29] found that the success rate did not depend on the approach used.

The mean time required to achieve access in this study was 47.33±4.89 sec, which was shorter than those found in studies by Aponte[21] and Kerforne[30] but not to a statistically significant extent (303.7±294.6 sec [*p*-value = 0.15] versus 435±304 sec [*p*-value = 0.2]). This difference is likely due to the fact that in the previous studies, the sample sizes were smaller and the procedure was conducted in real patients.

As described above, most participants in our study rated their confidence and the practical application of the procedure highly, indicating satisfaction. Based on responses in the comment section of the questionnaire, most participants would like to use this procedure in real patients. However, one of the participants rated the practical application of the procedure as 2 out of 5 as they were unable to achieve proficiency.

This study had several limitations[31-35]. First, it was performed using a simulation model, which cannot accurately represent a real patient. Second, this was a single-center study in a university hospital, and the population thus may not represent all emergency nurses.

## Conclusion

The first-attempt success rate in this study was quite high, even though the participants were novices to the technique. Implementation of this procedure in real practice could benefit emergency patients. However, further studies should be performed in real patients to more accurately evaluate the success rate of USGPIV access.

## What is already known on this topic?

Recent studies have found that ultrasound can help practitioners achieve a high success rate in peripheral IV cannulation. In many developed countries, nurses and other practitioners commonly use USGPIV cannulation in clinical practice. However, there are no guidelines regarding this procedure in Thailand.

## What this study adds?

This study found that emergency nurses had a high success rate in performing peripheral IV cannulation using ultrasound after a short formal training session conducted by an expert.


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## Conflicts of interest

The authors declare no conflict of interest.

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