

Original Research Article

Improving peripheral vein cannulation in neonates with skin transillumination: a prospective observational study by a neonatal fellow at a tertiary care centre

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ABSTRACT

Background: Peripheral vein cannulation (PIVC) is a common but challenging procedure in neonates, often requiring multiple attempts. Successful venous access is critical to ensure timely medical interventions while minimizing delay and complications. Skin transillumination has emerged as a potential tool to assist in visualizing veins, but its efficacy in improving procedural outcomes remains uncertain. This study evaluates the use of skin transillumination compared to the standard method, in improving the success rate of PIVC insertions. Objective was to assess the efficacy of skin transillumination in improving the procedural outcomes (success rates and time) of peripheral vein cannulation in neonates when performed by neonatal fellows.

Methods: A prospective observational study was conducted in a level 3 NICU, with neonates stratified by weight (≤ 1500 g and >1500 g). The intervention group used a transillumination device, while the control group used the standard procedure for cannulation. Data on success rates and time to successful cannulation were collected and analyzed using statistical methods.

Results: The use of transillumination led to significantly improved first-attempt success rates in neonates >1500 g ($p=0.03$). However, no significant improvement was observed in neonates ≤ 1500 g ($p=0.72$). Time to successful cannulation was significantly less in the control group for neonates >1500 g ($p=0.003$).

Conclusions: Transillumination significantly enhances first-attempt success rates for peripheral vein cannulation in neonates weighing over 1500 grams but does not show a substantial impact on neonates ≤ 1500 grams.

Keywords: PIVC, Transillumination, Success rates, Time to successful cannulation

INTRODUCTION

Peripheral intravenous cannulation (PIVC) is a fundamental procedure in neonatal intensive care units (NICUs), providing critical venous access for various medical interventions, including the administration of intravenous fluids, medications, blood products, parenteral nutrition, and blood sampling.¹ Despite being an essential aspect of neonatal care, PIVC insertion in neonates presents significant technical challenges due to their small, fragile veins and limited venous access sites. The difficulty in establishing intravenous access in neonates not only

complicates treatment delivery but also increases the risk of procedural failure, requiring multiple attempts that can lead to adverse consequences. These challenges are further exacerbated in neonates with conditions such as prematurity, obesity, dehydration, or prolonged hospitalization, where readily accessible veins may become exhausted.²

One of the primary concerns associated with PIVC placement in neonates is the pain and distress it causes. Multiple unsuccessful attempts at cannulation can lead to increased stress, discomfort, and procedural anxiety,

which can have long-term developmental consequences if repeated frequently. Beyond patient discomfort, repeated punctures interfere with the delivery of crucial intravenous therapy, potentially delaying medical treatment, prolonging hospital stays, higher medical costs, including the expense of additional catheters, increased nursing time, and the need for alternative venous access methods such as central lines, which carry additional risks. Multiple punctures increase the likelihood of hematoma formation, phlebitis, extravasation injuries, infection, thrombosis, potential nerve damage, fluid leakage into surrounding tissues, leading to tissue necrosis and compartment syndrome.¹ As a result, the American Academy of Paediatrics emphasizes the necessity of minimizing the occurrence of painful interventions in newborns.³

Careful assessment of the necessity of venous access and judicious use of available veins is crucial in preventing unnecessary attempts, conserving viable veins, and improving overall neonatal outcomes.⁴ Several factors contribute to these low success rates, including gestational age, birth weight, venous fragility, low blood volume, and the physiological response to stress or hypothermia, which can cause vasoconstriction and further complicate venous access. Traditional methods of vein localisation, such as visual inspection and palpation, may be unreliable in neonates due to their poorly developed subcutaneous tissue and limited venous prominence, making successful cannulation highly dependent on the skill and experience of the clinician. However, first-attempt success rates of PIVC insertion in clinical trials are non-satisfying and reported to be only 45–59% in neonate-specific study populations.^{5,6}

To address these challenges, various vein visualization technologies have been developed to enhance the identification of viable veins and improve PIVC success rates. One such advancement is the use of vein finder devices, which utilize different imaging modalities to illuminate subcutaneous veins, identify bifurcations, and assess vein patency. Herbert Zeman invented the first vein-finding device in 1995 to image subcutaneous veins. It supports the visualisation of the veins and identifies bifurcations to enhance access to the vein without the need for several punctures. Vein finder devices may help to distinguish a healthy vein from a sclerotic vein.⁷

Studies have suggested that transillumination-assisted cannulation can enhance vein visualization, improve first-attempt success rates, and reduce procedural time, potentially leading to improved patient outcomes. Existing literature on the use of vein visualisation devices in neonatal care has produced mixed findings with some studies reporting significant benefits, while others indicate no substantial improvement or even lower success rates.⁸⁻¹⁴

Among the visualisation methods, transillumination has gained attention using high-intensity light sources to illuminate superficial veins, making them more visible and

facilitating successful cannulation. This method is particularly useful in neonates due to their thin skin and increased skin transparency, which allows for better light penetration. Factors such as operator experience, patient characteristics, and device limitations may contribute to these discrepancies. For instance, some vein finder devices may not effectively differentiate between veins and arteries, leading to misidentification and unsuccessful attempts. Additionally, over-reliance on visualisation technology may reduce clinical skill development in vein palpation and identification, potentially leading to lower success rates in situations where these devices are unavailable.

We conducted this study to compare the use of transillumination with the standard technique for PIVC insertion by neonatal fellows, focusing on the success rate and time taken for successful cannulation in neonates of varying birth weights.

METHODS

Study type

It was a prospective observational study.

Time and place of study

The study was conducted at Arpan New Born Care Centre, a level 3 NICU with two branches having 24 and 19-bed Neonatal care units respectively. Clinical care is provided by six consultants and six fellows with an adequate number of nurses who have clinical experience in neonatal care. The nurse-to-patient ratio is maintained as required by the level of care. The study was conducted over a period of three and a half months from 15 September to 31 December 2024.

Study design and participants

The study population were all preterm and term neonates admitted to the neonatal unit requiring peripheral cannula insertion. Infants were ineligible if they were hemodynamically unstable and considered too sick to participate as decided by the responsible neonatologist. Participating study subjects could be enrolled multiple times during their hospital stay if repeated PIVC insertion was necessary. An informed and written consent taken from parents.

Infants meeting the inclusion criteria were randomly allocated to receive one of the two following interventions: the transillumination group, a transilluminator was used to visualize the veins with the surrounding light dimmed. In infants allocated to the control group, no device to visualize veins for PIVC insertion was permitted. Study subjects were stratified by actual body weight at the time of randomization (≤ 1500 g and >1500 g). Infants were allocated to the transillumination group or control group using chit draw generated by the research team.

Peripheral intravenous catheter insertion protocol for both groups

A nurse was tasked with providing comfort to the infant while the venipuncture. The timing of the procedure was recorded by the nurse using a stopwatch, which commenced when the fellow indicated readiness to begin scanning suitable veins. Following a thorough skin disinfection for 30 seconds, the insertion of the PIVC was carried out using either a 24-gauge or a 26-gauge catheter, as considered appropriate by the operator. The successful placement of the PIVC was verified by flushing the catheter with sterile water, and the timing was concluded when no visible extravasation was observed. In instances where the fellow made two unsuccessful attempts, a neonatologist was permitted to perform up to two additional attempts utilizing the initially designated intervention.

After the completion of the study procedure, the operator documented pertinent demographic information and outcome data on a case report form.

Primary outcome

Successful insertion by the fellow at the first attempt.

Secondary outcome

Successful insertion at the second attempt by the fellow and by the neonatologist, and the time taken for successful insertion at the first attempt.

Statistical analysis

For the statistical evaluation of categorical variables, including the success rate of PIVC insertion, sex, and catheter size, a two-sided Fisher's exact test was performed. The Mann-Whitney U test was used for the comparison of numerical variables, which include the time to successful PIVC insertion on the first attempt, gestational age at birth, gestational age at randomisation, birth weight, and weight at randomisation. Data are summarised as medians with interquartile ranges (IQR) for numerical variables. A p value of <0.05 was considered statistically significant. The time to successful PIVC insertion was analysed using a Mann-Whitney U-test.

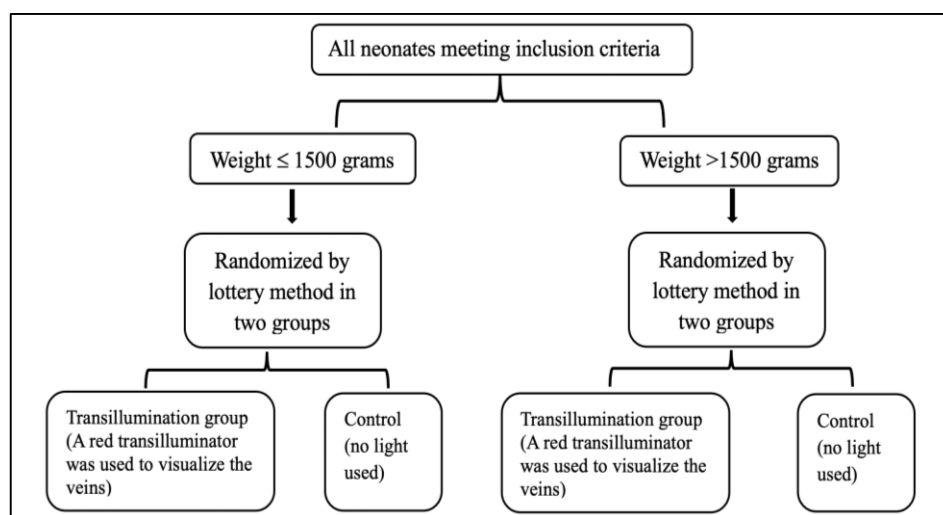


Figure 1: The allocation process of the neonates into two groups.

RESULTS

Study population and randomization

From 15 September to 31 December 2024, 118 infants were enrolled and divided into two groups according to weight.

Baseline characteristics

Demographic variables and baseline characteristics are presented in Table 1 (for strata ≤1500 grams) and Table 2 (for strata >1500 grams). Demographics were comparable in both groups.

PIVC insertion in neonates ≤1500 grams

In neonates weighing ≤1500 g, the first-attempt success rate for PIVC insertion by fellow did not differ significantly between the transillumination and control groups, with rates of 80.7% and 77.7% respectively ($p=0.72$, as indicated in Table 3). The success rates for the second attempt by fellows was also found to be comparable. When performed by a neonatologist, the success rates between the two groups remained statistically similar ($p\text{-value}=0.35$). Additionally, the time required for successful PIVC insertion during the first attempt by fellows was similar across both groups (Table 5).

PIVC insertion in neonates >1500 g

In neonates weighing over 1500 grams, the use of a transilluminator resulted in a markedly improved first-attempt success rate among fellows, achieving 74.2% in contrast to the standard procedure's success rate of 46.6%. This difference was statistically significant with p value of

0.03 (Table 4). Furthermore, the success rates for the second attempt by fellows was significantly high in the control cohort. The time taken to achieve successful PIVC insertion during the first attempt by fellows was significantly less in control group.

Table 1: Demographic characteristics for strata ≤1500 grams.

Characteristics	≤1500 g			
	Overall (n=53)	Transillumination group (n=26)	Control group (n=27)	P value
Neonatal baseline characteristics				
GA at birth, median (IQR), weeks	30+1 (29+4-32)	29+6 (29+4-31+5)	30+5 (29+4-32+1)	0.32
GA at randomisation, median (IQR), weeks	31 (29+6-32+2)	30+5 (29+4-31+6)	31 (30-33+6)	0.31
Age at randomisation	2 (1-4)	2 (1-4)	2 (1-5)	0.8
Birth weight, median, IQR, grams	1.12 (1.04-1.28)	1.05 (0.97-1.25)	1.13 (1.08-1.36)	0.07
Weight at randomisation, median, IQR, grams	1.16 (1.05-1.3)	1.07 (1.01-1.28)	1.1 (1.2-1.34)	0.05
Reason for PIVC				
Antibiotics	15	7	8	0.32
Parenteral nutrition	39	20	19	
Transfusion	3	2	1	
Catheter size				
24 gauge	12	4	8	0.32
26 gauge (n, %)	41	22	19	
Site of cannulation				
Right hand	17	7	10	0.32
Left hand	25	11	14	
Right leg	10	7	3	
Left leg	1	1	0	

Table 2: Demographic characteristics for strata >1500 grams.

Characteristics	>1500 g			
	Overall (n=65)	Transillumination group (n=35)	Control group (n=30)	P
Neonatal baseline characteristics				
GA at birth, median (IQR), weeks	34+6 (32+5-36+1)	35+6 (34+1-36+2)	34+4 (32-35+6)	0.06
GA at randomisation, median (IQR), weeks	35+3 (32+5-36+2)	35+6 (34+1-36+5)	35+1 (32+2-36+1)	0.07
Age at randomisation	1 (1-3)	1 (1-3)	2 (1-3)	0.8
Birth weight, median, IQR, , grams	2.38 (1.76-2.85)	2.5 (1.8-2.84)	2.11 (1.68-2.8)	0.32
Weight at randomisation, median, IQR, grams	2.3 (1.76-2.7)	2.4 (1.84-2.69)	2.11 (1.6-2.8)	0.24
Reason for PIVC				
Antibiotics	34	18	17	
Parenteral nutrition	34	19	21	
Transfusion	0	0	0	
Catheter size				1
24 gauge	42	23	19	
26 gauge (n, %)	23	12	11	
Site of cannulation				
Right hand	29	11	18	
Left hand	26	15	11	
Right leg	8	7	1	
Left leg	2	2	0	

Table 3: Success rate in % in neonates ≤1500 grams.

≤1500 grams	Transillumination group (n=26)	Control group (n=27)	P value
Success rate at first attempt by neonatal fellow	80.7 (21/26)	77.7 (21/27)	0.72
Success rate at second attempt by neonatal fellow	7.6 (2/26)	18.5 (5/27)	0.42
Success rate at first attempt by consultant neonatologist	11.5 (3/26)	3.7(1/27)	0.35

Table 4: Success rate in % in neonates >1500 grams.

>1500 grams	Transillumination group (n=35)	Control group (n=30)	P value
Success rate at first attempt by neonatal fellow	74.2(26/35)	46.6 (14/30)	0.03
Success rate at second attempt by neonatal fellow	20 (7/35)	53.3 (16/30)	0.008
Success rate at first attempt by consultant neonatologist	5.7 (2/35)	0	0.49

Table 5: Time to successful peripheral vein catheter insertion at fellow's first attempt in both groups.

Strata	Transillumination		Control		P value
	Median (IQR)	N	Median (IQR)	N	
≤1500 grams	51 (46-55)	21	52 (49-53)	21	0.65
>1500 grams	48 (46-49)	26	45 (45-47)	14	0.003

DISCUSSION

This study evaluated the impact of a transilluminator on the success rate of first-attempt PIVC insertions in neonates, which were categorised into two weight groups (≤1500 g and >1500 g). The results indicated a notable increase in first-attempt rates for the group >1500 g when the transilluminator was used by fellows. Interestingly, the primary success rate for fellows in the ≤1500 g group did not show a statistically significant difference between the study cohorts. Our findings are in line with RCT by Hintersteinn et al where they found a significant improvement in the first attempt and overall success rate in the strata >1,500 g when the LED transilluminator was used by paediatric residents.¹⁵ When an LED transilluminator was used, the first-attempt success rate by pediatric residents was significantly higher at 55% (103/188) compared to the standard procedure at 34% (64/188). Also, the primary success rate of paediatric residents in the strata ≤1,500 g did not differ significantly between the study groups. Neonatologist's success rate was not significantly affected by the study intervention. The time to successful PIVC insertion at the resident's first attempt was comparable between the groups. However, they evaluated the outcome with respect to the experience level of the operator and included an adequate sample size. A plausible explanation for the increased success rate in mature neonates may be attributed to the greater amount of subcutaneous fat, which facilitates the effective visualisation of subcutaneous veins through transillumination. This observation aligns with the research conducted by Phipps et al, which suggested that the advantages of vein visualisation were predominantly evident in more mature neonates.¹⁶

Furthermore, the difficulties encountered when using the transilluminator in infants weighing ≤1500 g may be attributed to the relatively smaller size of their limbs compared to the transilluminator. Phipps et al evaluated a vein visualization device that utilises near-infrared technology for the insertion of peripheral inserted central venous catheters. Their findings indicated that while there was no significant difference in the success rate of the first attempt, there was a notable enhancement in the overall success rate when considering up to three attempts. In our study, in the control group, the success rate at first attempt were 77.7 (21/27) and 46.6 (14/30) in babies weighing ≤1500 grams and >1500 grams respectively. It may also imply that PIVC insertion is easier in smaller babies. Similar findings noted by Hintersteinn et al where in the control group, the success rates for PIVC at the first and second attempt were 49% and 70%, respectively, for babies ≤1500 grams compared to only 34% and 63% in babies with >1500 grams weight.

Limitations

The study's small sample size (118 neonates) may limit statistical power and generalizability. A larger sample could provide stronger evidence. Factors like cannula size and cannulation site, though comparable across strata, were not considered in relation to success rates. The experience level of the operator, which could impact success, was not accounted for. Repeated enrollments of the same infants may introduce bias, as previous attempts could influence subsequent success. The study focused on immediate outcomes but did not assess complications (e.g., infections or phlebitis) or neonate pain perception. It also did not evaluate device characteristics, such as light intensity or battery life, which could affect outcomes.

CONCLUSION

The use of skin transillumination significantly enhanced the success rates of first-attempt PIVC insertions in neonates weighing >1500 grams, as performed by neonatal fellows. This technique improved the efficiency of the procedure, reduced the time to successful insertion, and minimised the pain and potential complications associated with multiple attempts. However, in neonates weighing 1500 grams or less, the benefit of transillumination was not as pronounced, likely due to the smaller size of their veins and limbs, which made the technique less effective. Therefore, transillumination may be particularly advantageous for larger neonates, but further research is needed to refine its utility across different populations.

Overall, transillumination can be a valuable tool in improving procedural outcomes in neonatal peripheral vein cannulation, particularly for neonates above 1500 grams.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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