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The effect of transilluminator device on successful peripheral venous catheter placement in children: A systematic review and meta-analysis

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Abstract

Peripheral venous catheter placement (PVCP) is difficult for children due to the small diameter of their veins in adipose tissue. The transilluminator device (TD) is proposed as the effective method for PVCP. Therefore, this meta-analysis aimed to assess the effect of TD on first attempt success rate (FASR), mean the number of attempts (MNA), and mean duration of successful PVC placement (MDSPP) in children. In a systematic review and meta-analysis, an extensive search of online databases including PubMed, Scopus, Science Direct, Web of sciences, Cochrane, Clinical trial.gov, ProQuest, and Google scholar search engine was conducted. Keywords were combined and searched from the earliest records up to December 2021. The current meta-analysis was performed using STATA V.14.0 software. Six studies (four RCTs and two non-RCTs design) were included in the present meta-analysis. Analysis showed using of TD significantly led to FASR to 34% in studies with RCTs design (RR = 1.34; CI = 1.18–1.53) although, non-RCT studies did not indicate it (RR: 0.95; CI = 0.50–1.79). Also, one RCT (WMD = −0.24; CI = −0.4 −0.08) and two non-RCTs 0.05 (WMD = −0.05; 95% CI = −0.46–0.37) reported the MNA. Two RCTs (WMD: −24.30; CI = −53.50–4.89) and one non-RCT (WMD: −295.20; CI = −359.34 to −231.06) found TD decreased MDSSP. RCTs and non-RCTs studies showed different results in terms of some outcomes. Based on the results of four RCTs studies, the use of TD significantly increased the FASR of PVCP. The results of two non-RCTs also showed TD insignificantly decreased the FASR of PVCP. More evidence (RCT design) is required for decision-making about the effectiveness of TD on successful PVCP.

Keywords

Transillumination, vascular access devices, peripheral venous catheter, peripheral intravenous catheter, peripheral catheterization, pediatrics

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Introduction

Peripheral venous catheter placement (PVCP) is one of the most common procedures in the nursing profession. Annually, more than one billion PVCs are placed for patients.[1–3] Meanwhile, PVCP is difficult for children due to the small diameter of their veins in adipose tissue.[4] In addition, this procedure is time-consuming and causes pain and anxiety in children.[5] However, successful PVCP occurs after several attempts.[6] One study showed that the failure rate in first-attempt PVCP is 35 to 54%.[7] Numerous factors are influential in the successful placement of PVC such as age, sex, body mass index, presence of comorbidities, skin color, catheter size and the site of venipuncture, and nurse's experience.[8] On the other hand,

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there are several methods to increase the chances of successful PVCP including transilluminator and near-infrared vascular imaging devices.[9–11] Meanwhile, the transilluminator device (TD) is one of the proposed methods for PVCP. TD causes the penetration of light into the patient's skin via a light source and ultimately causes the exposition of veins.[12] Initially, this device was used for exposure of veins in neonates, but today it is applied for patients in all age groups.[11] There are different models of this device including TransLite, white light fiber optic Veinlite, and light-emitting diode transilluminator. Many healthcare providers believe that this device can facilitate PVCP and reduce its time.[13] Hence, a study in Turkey showed that the use of TD increases the success rate of first-time PVCP and reduces its time.[11] However, another study in the United States found that TD did not facilitate PVCP in children.[14]

Various studies have examined the effect of TD on successful PVCP in children. However, to our knowledge, there is no published study to comprehensively review and summarize the randomized controlled trials (RCTs) and non-RCTs studies regarding the effect of TD on successful PVCP in children. Although one meta-analysis study evaluated the impact of TD on successful PVCP in pediatrics based on three RCT studies.[13] RCT studies give rigorous evidence and the results are more valuable than other designs, however, it is not always possible to conduct an RCT study, therefore other evidence can be used to fill the knowledge gaps. Also, non-RCTs studies have a large sample size.[15] Therefore, given the importance of the subject and the contradictory findings regarding the effect of TD on successful PVCP in children, this systematic review and meta-analysis aimed to summarize the RCTs and non-RCTs studies regarding the effect of TD on successful PVCP in children.

Methods

This systematic review was carried based on preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines for identification, screening, and eligibility of the studies.[16] The protocol of this systematic review and meta-analysis was approved in PROSPERO (CRD42020221024). Also, the present study was approved by the ethics committee of Esfarayen University of Medical Sciences (IR.ESFARAYENUMS.REC.1400.007).

Search strategy

An extensive search of online databases including PubMed, Scopus, Science Direct, Web of sciences (ISI), Cochrane, Clinical trial.gov, ProQuest, and Google scholar search engine as well as Persian databases such as Iranmedex, Scientific Information Database (SID), and Magiran was conducted. Related keywords such as "Vein Finder," "Vein Lite," "Transillumination," "Visualizer," "Visualization Technology," "Cannulation," "Peripheral Intravenous Cannulation," "Peripheral Catheterization," "Vascular Access," "Venous Cannulation," "Venous Catheterization," "Catheterization," "Child," "Pediatric," "Infant," "Newborn," "Neonate," "Term," "Preterm," "Veins," and "Venous" were combined together with Boolean operators (And, Not) from the earliest records up to December, 2021. In the present study, the language of the studies was limited to English and Persian. Persian keywords were used for Persian databases.

Study selection

EndNote X8 software was used to manage the data. Two researchers performed study selection steps independently, including (1) removal of duplicate articles, (2) evaluation of the title and abstract of studies, and (3) evaluation of the full text of potentially eligible studies for inclusion in the review based on predefined inclusion/exclusion criteria. Finally, the reference list of included studies was assessed to prevent data loss. Disagreements between researchers were resolved by discussion.

Inclusion and exclusion criteria

In this review, published interventional studies focusing on evaluating the effect of TD on successful PVCP in children under 18 years of age were included. Exclusion criteria were including (1) assessment of the effect of TD on the success of blood sampling, (2) placement of a central or arterial catheter, (3) lack of access to the full text of the article, (4) letters to the editor, (5) opinions, (6) case reports, (7) conference abstracts, and (8) reviews.

Data extraction and quality assessment

We designed a standardized data extraction form to collect the following information from included studies: the name of the first author, year of study, location, sample size, age, ward, type of device used to PVCP, study design, catheter placement position (nurse, physician, etc.), catheter size, the first- and second-time successful PVCP, number and duration of attempts for successful PVCP. The risk of bias in RCT and non-RCT studies was assessed using the Cochran tool for clinical trial studies (version 2) and the methodological index for non-randomized studies (MINORS), respectively. The Cochran tool involves random allocation sequence items, random sequence generation, allocation concealment, the blinding of participation and personal, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases. The risk of bias was divided into three categories: high, low and, non-reporting.[17] MINORS tool includes 12 items as follows: a clearly stated aim, inclusion of consecutive

patients, prospective collection of data, endpoints appropriate to the aim of the study, unbiased assessment of the study endpoint, follow-up period appropriate to the aim of the study, loss to follow up less than 5%, prospective calculation of the study size, an adequate control group, contemporary groups, baseline equivalence of groups and adequate statistical analyses. The scores 0, 1, and 2 were assigned in case of no report, incomplete report, and complete presentation of information, respectively.[18]

Outcomes

The outcome of the present study is to synthesize and evaluate the best evidence on three concrete points regarding the cannulation of superficial veins using transillumination devices in the pediatric population by evaluating some studies published by other groups.

Statistical analysis

The current meta-analysis was performed using STATA 14.0 software (Stata Corporation, College Station, Texas, USA). A random-effect model (Inverse-Variance) was used to compare the effect size in intervention and control groups. Risk Ratio (RR) logarithm and 95% confidence interval (CI) were used to estimate the pooled effect size in the FASR of PVCP. Also, to calculate the pooled effect size of continuous outcomes such as the mean number of attempts (MNA) and mean duration of successful PVC placement (MDSPP), we used the sample size, mean and standard deviation (SD) of both intervention and control groups. I2 index was used to assess heterogeneity. Values higher than 50% and $p < 0.1$ were considered as significant heterogeneity between studies. Sensitivity analyses were also employed using a random effect model to investigate the impact of each study on pooled effect size. Since the number of final studies was <10 and given the type of data used, funnel plots and analyses on publication bias were not performed.[19]

Results

Study selection

A total of 539 articles were obtained after an initial search of the databases. 371 studies remained after the removal of duplicate publications. After screening the title and abstract of the study, 325 studies were excluded. Finally, after evaluating the full text of 38 potentially eligible articles, four RCT and two Non-RCT studies were included in this systematic review and meta-analysis (Figure 1).

Characteristics of included studies

Six studies[11,14,20–23] were included in the present meta-analysis. Total of children ($n = 2{,}074$) were included in this study with an age range of 0 to 18 years. The mean age of participants in the intervention and control groups was 1.74 (SD = 1.56) and 1.66 (SD = 1.93) years, respectively. Four studies[11,20,21,23] had RCT design and two studies[14,23] had non-RCT design. The studies were performed in the operating room (OR), emergency department (ED), and pediatric ward. Nurses and physicians used 22G and 24G size catheters to PVCP (Table 1).

Methodological quality of included studies

Three RCT studies[11,20,23] did not report the random allocations concealment. Also, due to the nature of the intervention, it was not possible to blind the inserter and the evaluator. Therefore, there was a risk of both performance and detection biases (Figure 2). The baseline information of two non-RCT studies[14,22] in the intervention and control groups was not homogeneous and both studies reported their results after adjustment (Table 1).

Outcomes

The success rate of PVCP

FASR of PVCP. Six studies[11,14,20–23] reported the FASR of PVCP as one of the main outcomes (Table 1). Four studies[11,21–23] showed that the use of TD for successful PVCP is more effective than routine procedures. In contrast, one Non-RCT study[14] found that routine procedures had better outcomes than using TD. Another RCT study[21] showed that there was no significant difference between the intervention and control groups in the FASR of PVCP (Table 1). Overall, the results of the RCT studies showed that the use of TD significantly increased the FASR of PVCP to 34% (RR: 1.34; 95% CI = 1.91–1.51; $p < 0.001$, $I^2 = 9.0\%$). Sensitivity analysis of RCTs studies indicated that the pooled effect size did not influence by a single study (CI: 1.10–1.74). Also, the results of non-RCT studies indicated TD decreased 5% FASR (RR: 0.95; 95% CI = 0.50–1.79; $p = 0.87$, $I^2 = 95.7\%$) (Figure 3).

FASR of PVCP for children under 2 years. Two RCT studies[20,23] reported the FASR of PVCP for children under 2 years. The results of these studies showed that the FASR of PVC for children under 2 years was 74%, which was not significant (RR: 1.74; 95% CI = 0.96–3.14; $p = 0.07$, $I^2 = 50.4\%$) (Figure 4).

The success rate of PVCP in the second attempt. Two RCTs studies[11,21] reported the success rate of PVCP in the second attempt. The results of these studies showed that the success rate of PVCP in the second attempt was 28%, which was not significant (RR = 1.28; 95% CI = 0.96–1.71; $p = 0.09$, $I^2 = 48.3\%$) (Figure 5).

MNA for successful PVCP. One RCT[11] and two Non-RCTs[14,22] reported this outcome. The results of RCT and

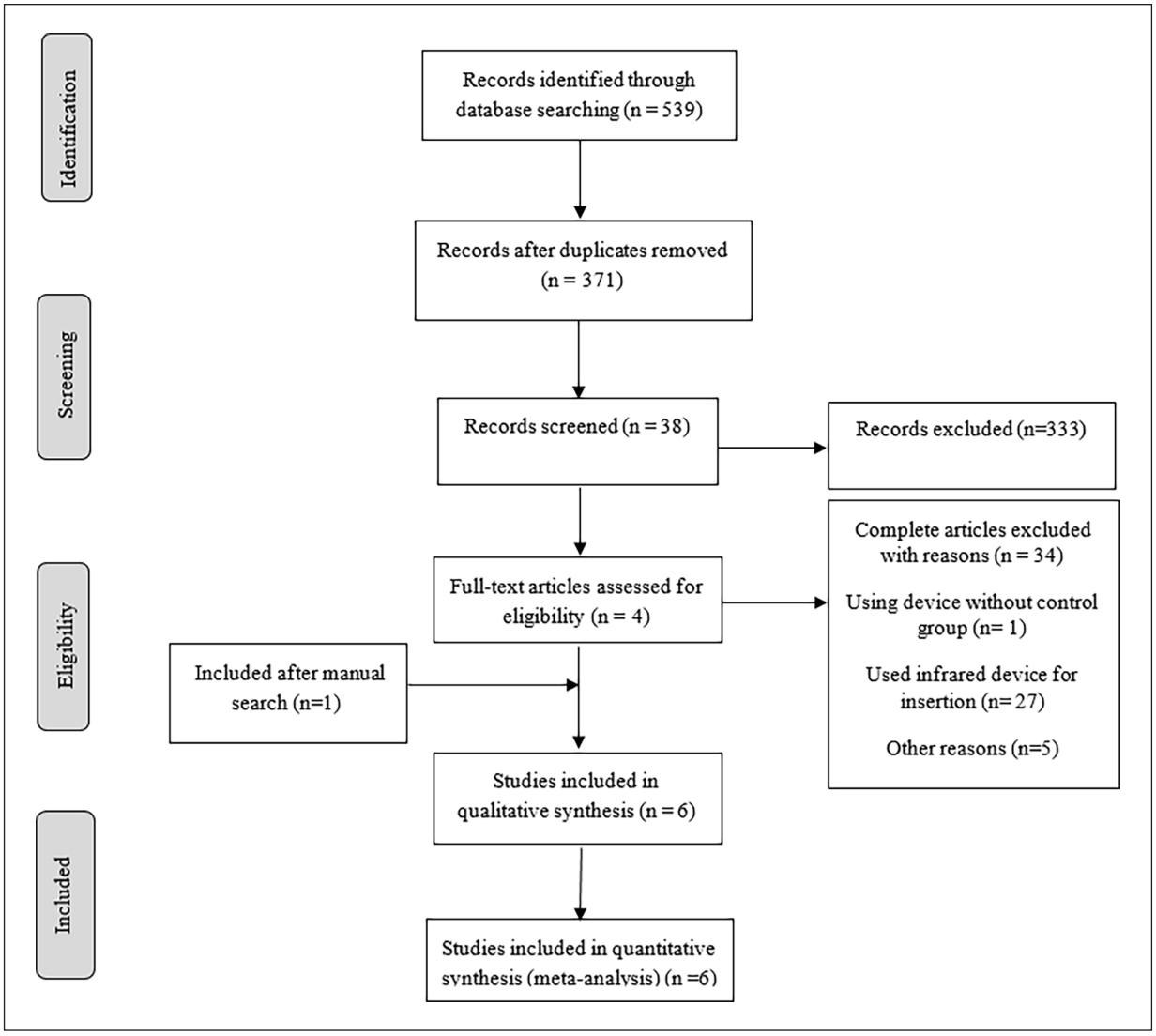

Figure 1. Flow diagram of study selection.

Non-RCT studies found TD decreased 0.24 (WMD = −0.24; 95% CI = −0.4 to −0.08) and 0.05 (WMD = −0.05; 95% CI = −0.46–0.37; $p < 0.001$, I^2: 94.2%) MNA, respectively (Figure 6).

MDSPP. Two RCTs[11,20] found TD decrease 24.30 s MDSSP (WMD: −24.30; 95% CI = −53.50–4.89; $p < 0.001$, I^2: 94.5%) although it was not significant. One non-RCT[22] also showed significantly decrease this outcome (WMD: −295.20; 95% CI = −359.34 to −231.06) (Figure 7).

Discussion

The present meta-analysis was performed to determine the effects of TD on the FASR of PVCP, the MNA and the MDSSP based on RCTs and Non-RCTs studies. Results of this study included both RCT and Non-RCT studies although is described separately due to difference of their level of evidence.[24]

Results of RCT design studies significantly indicated applying TD 34% increased the FASR of PVCP. One meta-analysis (2013) study aimed to assess the effects of various technologies (ultrasonography, near-infra-red device, and TD) on the FASR of PVCP for children. The results showed TD increased 44% FASR (three RCTs studies), significantly.[13] Although, in the current study, the non-RCTs studies indicated 5% decrease in the FASR. Peterson study (non-RCT) had some limitations and affected the results. In this study, using the TD decreased FARS. Some of causes are: the mean age of children in the intervention group (0.69 (SD = 0.91) years) was lower than the control group (1.56 (SD = 2.72) years), which

Table 1. Basic characteristics and main results of the studies included in the systematic review and meta-analysis.

First Author/ year	Location	Study characteristics 1. Design 2. Sample Size (I/C) 3. Ward 4. Device 5. Inserter 6. Catheter size	Age characteristics 1. Age range 2. Intervention group (Mean ± SD) 2. Control group (Mean ± SD)	Intervention group 1. Number of attempts 2. Duration of the procedure (s) 3. Success rate a. Total first attempt b. Under 2 years old c. Second attempt	Control group 1. Number of attempts 2. Duration of the procedure (s) 3. Success rate a. Total first attempt b. Under 2 years old c. Second attempt	Adjustment of confounding variables	Key results
Nager and Karasic[23]	USA	1. RCT 2. 143 (71/72) 3. ED 4. Landry vein light 5. Nurse 6. N/A	1. 1 month to 3 years 2. 1.16 (SD = 0.97) 3. 1.14 (SD = 0.96)	1. N/A 2. N/A 3. a. 58/71 b. 47/59 c. N/A	1. N/A 2. N/A 3. a. 40/72 b. 34/61 c. N/A	N/A	The success rate of PVC placement in the first attempt in the intervention group was higher than the control group ($p < 0.05$).
Katsogridakis et al.[21]	USA	1. RCT 2. 240 (121/119) 3. Pediatric 4. Veinlite (TransLite) 5. Nurse & Physician 6. 22 or 24	1. 0 to 3 years 2. 1.30 (SD = 1.89) 3. 1.30 (SD = 1.74)	1. N/A 2. N/A 3. a. 72/121 b. N/A c. 31/49	1. N/A 2. N/A 3. a. 67/119 b. N/A c. 21/52	Palpability and visibility of the veins	The success rate of PVC placement in the first and second attempts increased in the intervention group compared to the control group ($p < 0.05$).
Hosokawa et al.[20]	Japan	1. RCT 2. 136 (67/69) 3. OR 4. Light-emitting diode transilluminator 5. Interns or junior residents 6. 22 or 24	1. N/A 2. 1.90 (SD = 1.80) 3. 1.90 (SD = 1.60)	1. N/A 2. 68.00 (SD = 25.00) 3. a. 50/67 b. 32/44 c. N/A	1. N/A 2. 107.50 (SD = 40.50) 3. a. 42/69 b. 23/47 c. N/A	N/A	There was no significant difference between the intervention and control groups in the success rate of PVC placement ($p > 0.05$). The success rate and duration of PVC placement in patients less than 2 years were lower in the intervention group compared to the control group ($p < 0.05$).
Peterson et al.[14]	USA	1. Non-RCT 2. 546 3. OR 4. Transillumination (The Wee Sight) 5. Nurse 6. 22 or 24	1. 0 to 18 years 2. 0.69 (SD = 0.91) 3. 1.56 (SD = 2.72)	1. 1.85 (SD = 0.97) 2. N/A 3. a. 262/726 b. N/A c. N/A	1. 1.69 (SD = 0.92) 2. N/A 3. a. 246/473 b. N/A c. N/A	Age	The routine procedure had better effects compared to this device.
Mohamed et al.[22]	Sudan	1. Non-RCT 2. 246 (123/123) 3. N/A 4. Transillumination (Cold-light source) 5. Nurse 6. 22 or 24	1. 1 month to 5 years 2. 1.78 (SD = 1.03) 3. 1.57 (SD = 1.04)	1. 1.41 (SD = 0.58) 2. 333.00 (SD = 226.20) 3. a. 78/123 b. N/A c. N/A	1. 1.67 (SD = 0.74) 2. 628.00 (SD = 283.80) 3. a. 59/123 b. N/A c. N/A	N/A	The success rate of PVC placement in the first attempt increased in the intervention group compared to the control group ($p < 0.05$). Also, the number of attempts and duration of PVC placement decreased in the intervention group compared to the control group ($p < 0.05$).
Gümüs et al.[11]	Turkey	1. RCT 2. 110 (56/54) 3. ED 4. Veinlite PEDI (TransLite) 5. Nurse 6. N/A	1. 1 to 3 years 2. 4.60 (SD = 2.74) 3. 4.35 (SD = 3.53)	1. 1.07 (SD = 0.54) 2. 49.98 (SD = 18.40) 3. a. 52/56 b. N/A c. 4/4	1. 1.31 (SD = 0.25) 2. 59.68 (SD = 22.50) 3. a. 39/54 b. N/A c. 13/15	N/A	The success rate of PVC placement in the first attempt increased in the intervention group compared to the control group ($p < 0.05$). Also, the number of attempts and duration of PVC placement decreased in the intervention group compared to the control group ($p < 0.05$).

RCT: randomized controlled trial; ED: emergency department; OR: operating room; PVC: peripheral venous catheter; SD: standard deviation

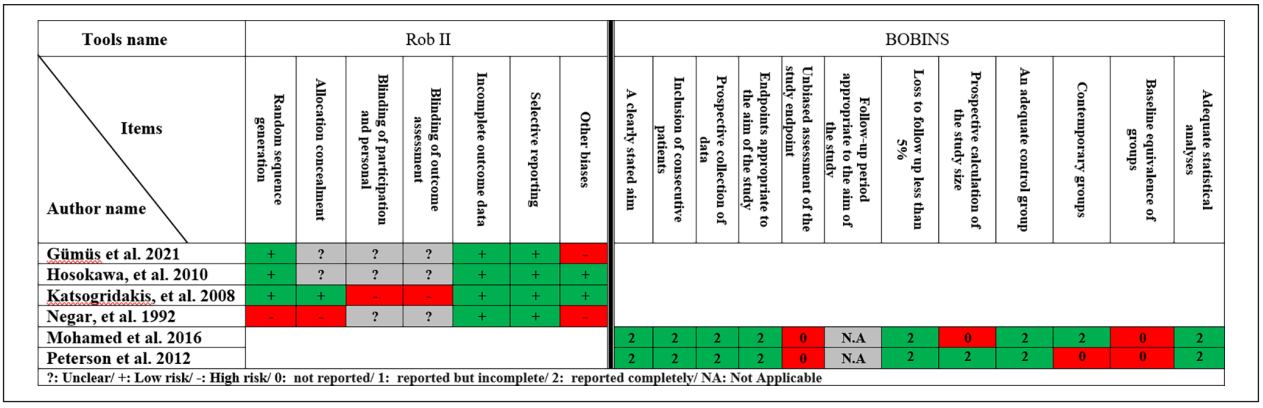

Figure 2. Methodological quality assessment of included studies.

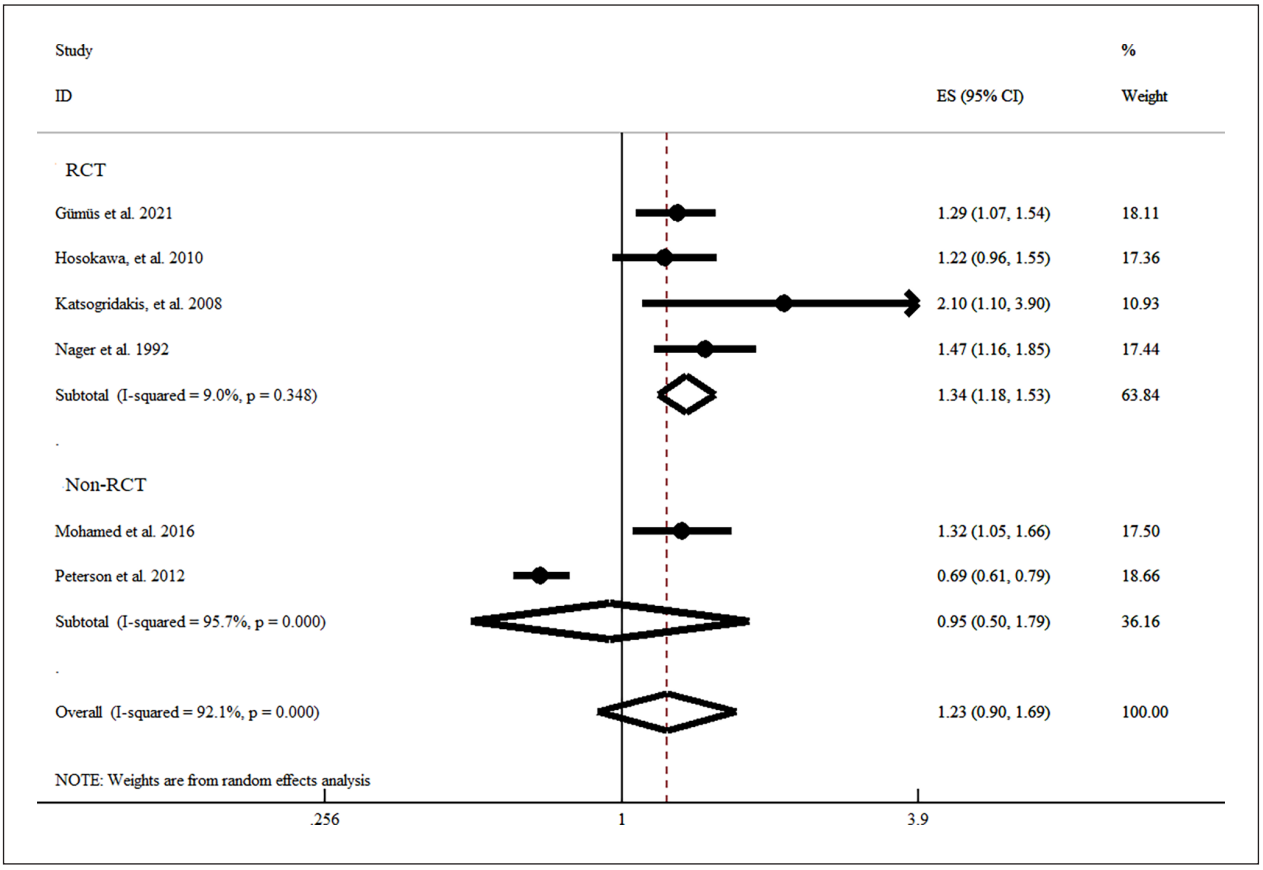

Figure 3. First-attempt success rate (FASR).

could lead to bias in the findings. The success rate of PVCP can be reduced in the younger children.[25] Also, inserter of PVC in the control group h have higher mean age compared to the intervention group and were more proficient.[14]

A meta-analysis (2013) assesses the effect of TD on FASR of PVCP in children based on three RCT studies. They showed that TD increased FASR by 44%.[13] This finding was consistent with the present study based on four RCT studies. However, results from the present review based on two non-RCTs studies indicated a 5% decrease in the FASR. The results of non- RCTs studies are affected by a study from Peterson et al.[14] Although this study by Peterson et al.[14] had a large sample size as a positive factor, it has some limitations such as: (1) the mean age of children in the intervention group (0.69 (SD = 0.91) years) was lower than the control group (1.56 (SD = 2.72) years), which could lead to bias in the findings and the success

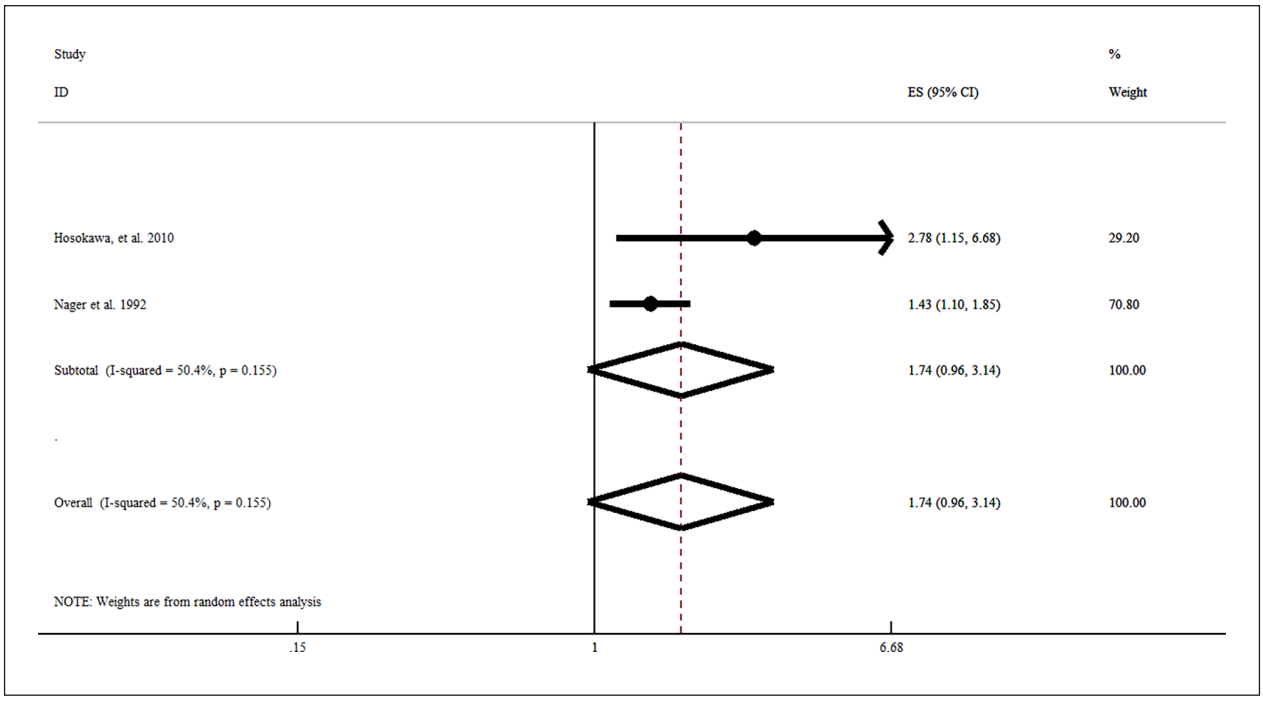

Figure 4. First-attempt success rate of children under 2 years.

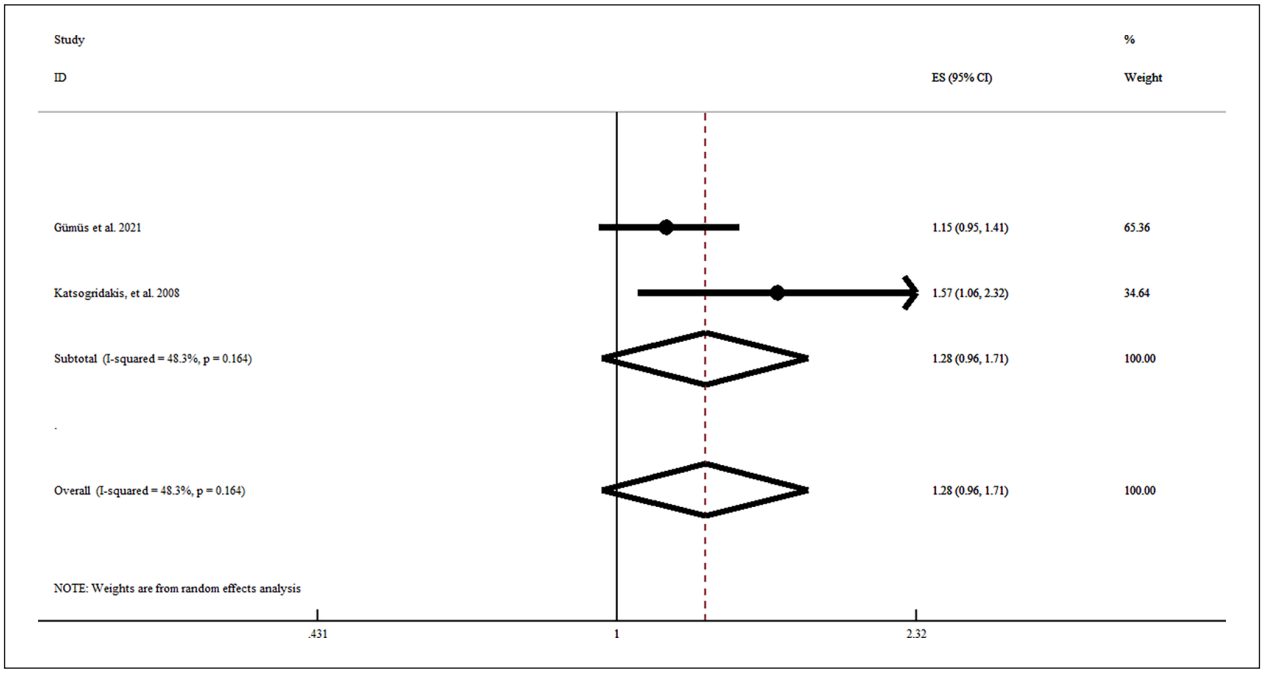

Figure 5. Success rate of PVC placement in the second attempt.

rate of PVCP can be reduced in younger children;[25] (2) inserters of PVC in the control group had higher mean age compared to the intervention group and were more proficient.[14] It seems that in addition to technology, other influential factors such as catheter placement site, illness severity, previous catheter placement history, and the experience of inserting person are effective on successful PVCP in children.[26–28]

The FARS (Two RCTs) did not show significant difference between intervention and control groups in the children below 2 years. Despite the great challenge of the medical staff in success PVCP in young children, but it

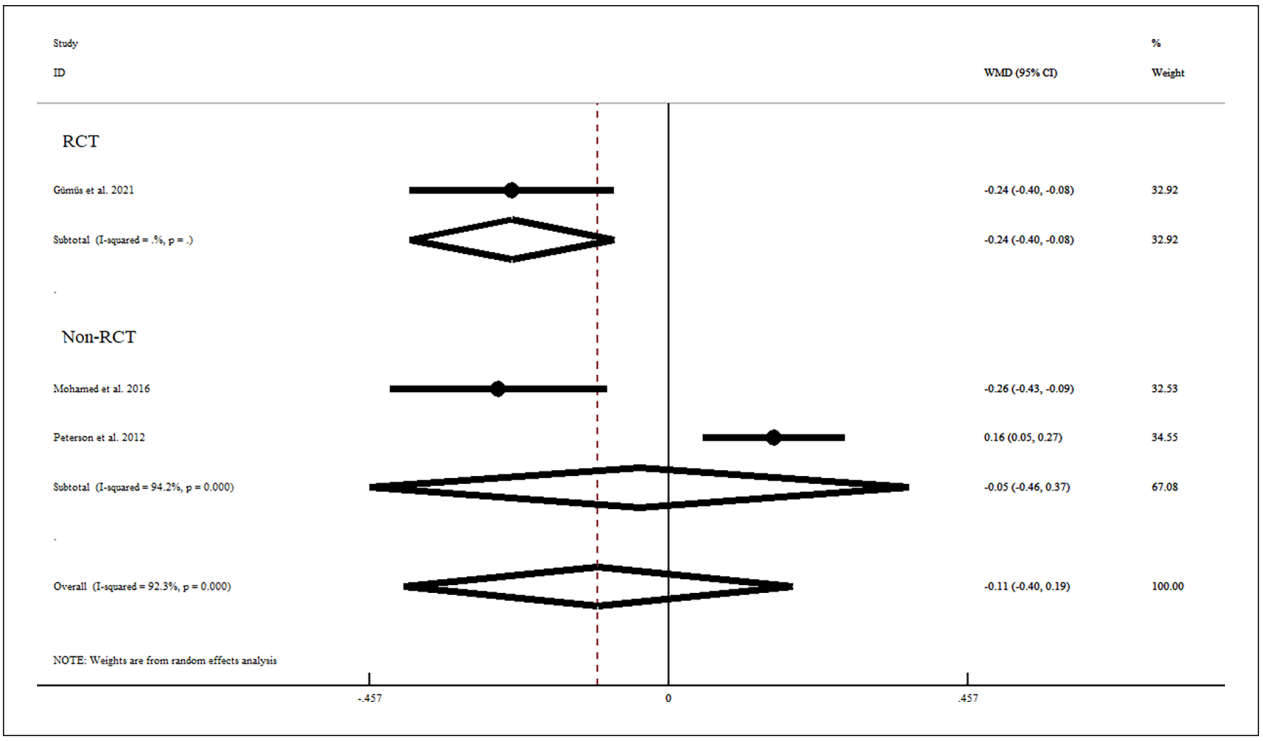

Figure 6. Mean number of attempts (MNA) for successful PVC placement.

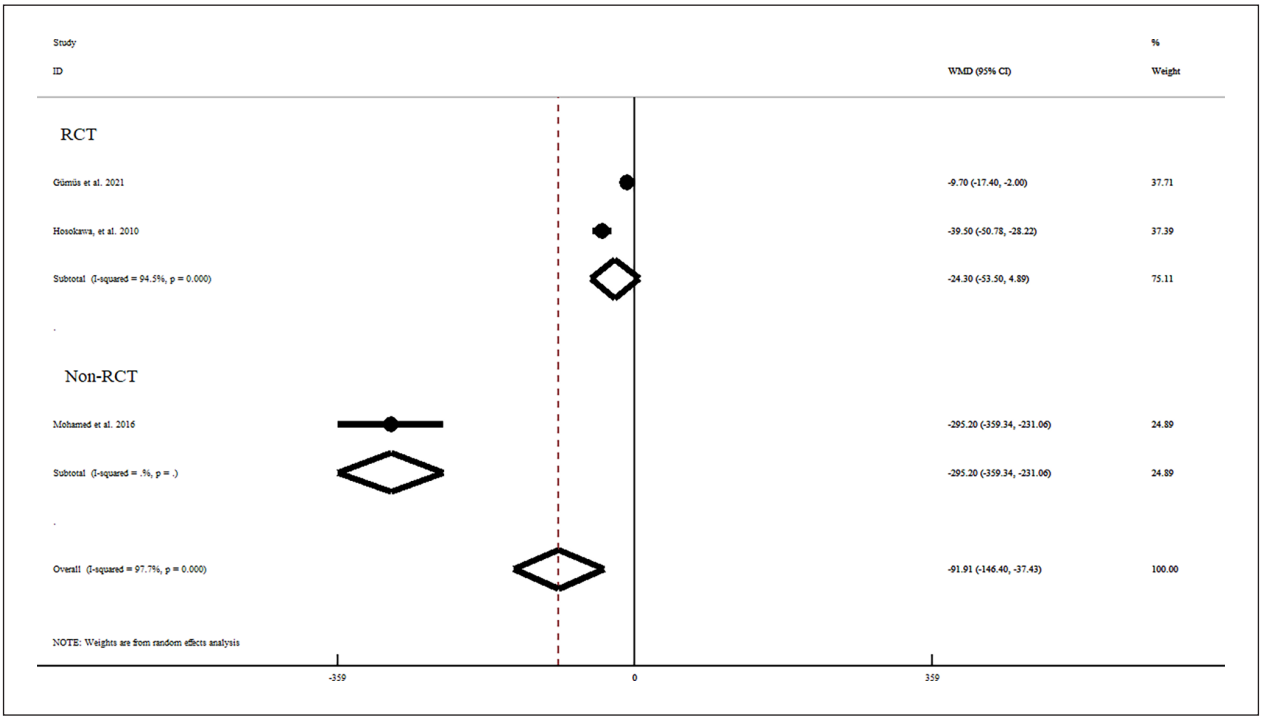

Figure 7. Mean duration of successful peripheral placement (MDSPP).

seems that studies have not paid enough attention and we need more evidence about this issue.

The success rate of PVCP in the second attempt was reported in two studies[11,21] and the result showed device can increase the success rate to 28%. In the both studies, a same device (Transelite) was used in emergency and pediatric wards.

TD decreased MNA based on the results of three studies (one RCT and two Non-RCTs). Two studies[11,22] have shown that the use of this device significantly reduces the MNA. In contrast, one study[14] showed that the use of TD increases the MNA for successful PVCP. The study of Peterson has selection bias because the nurses could use TD for patients of interest. Therefore, they used TD for patients with difficult intravenous access, and the chance of successful PVCP using this device was reduced.

Two RCTs (insignificantly) and one non-RCT studies (significantly) indicated using TD decreased MDSPP to 24.30 and 295.20 s, respectively.[11,20,22] TD can decrease the duration of PVCP by increasing the visibility of veins.[29] Factors such as the mean age of the children and the nurses' experience can change the MDSPP.

Limitations

One of the most important limitations of the present study was the lack of access to gray literature. However, one of the studies included in this meta-analysis was a conference paper and had been published in a peer-reviewed scientific journal.[23] Also, the number of studies included final analysis was few and more studies is required about this issue. On the other hand, all the studies included reported the FASR of PVCP however; three studies reported the MNA and the MDSPP.

Conclusion

RCTs and Non-RCTs studies showed different results in terms of some outcomes. Based on the results of four RCT studies, the use of TD significantly increased the FASR of PVCP. Also, TD decreased the MNA (one study, significantly) and the MDSPP (two studies, insignificantly). In addition, the results of two non-RCTs showed TD insignificantly decreased the FASR of PVCP and MNA. Although, TD significantly decreased the MDSPP (one study). More evidence for decision-making about the effectiveness of TD on successful PVCP is required. Future research should design rigor and robust RCT studies.

Author contributions

All authors have agreed on the final version, and those listed as authors are qualified for authorship according to the following criteria: Have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; been involved in drafting the manuscript or revising it critically for important intellectual content; given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content; and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Declaration of conflicting interests

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Ethics approval statement

The protocol of this systematic review and meta-analysis was approved in PROSPERO (CRD42020221024). Also, the present study was approved by the ethics committee of Esfarayen University of Medical Sciences (IR.ESFARAYENUMS.REC.1400.007).

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