

# Effectiveness of near-infrared light or ultrasonography on peripheral venous catheterization: systematic review protocol

Eficácia da luz quase-infravermelha ou ultrassonografia na cateterização venosa periférica: protocolo de revisão sistemática

Eficacia de la luz infrarroja cercana o de la ecografía en el cateterismo venoso periférico: protocolo de revisión sistemática

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## Abstract

**Context:** Innovative devices are increasingly being used by healthcare professionals during peripheral venous catheterization for locating invisible and impalpable veins.

**Objectives:** To identify the best evidence available on the effectiveness of the use of vein visualization technologies (near-infrared light or ultrasonography) in patients requiring peripheral venous catheterization.

**Method of Review:** Following the Joanna Briggs Institute's methodology, this review will use specific search strategies for each database/repository to identify relevant studies. Two independent reviewers will analyze titles/abstracts and compare them based on the inclusion criteria. The included articles will be subjected to methodological quality assessment and data extraction.

**Presentation and interpretation of results:** The critical analysis of existing data on the effectiveness of near-infrared light or ultrasonography on peripheral venous catheterization-related outcomes will contribute to the dissemination of the best evidence available on the topic.

**Conclusion:** The dissemination of the best available evidence will sustain healthcare professionals and managers' decisions in the selective use of these technologies on peripheral venous catheterization, contributing to the preservation of the patient's venous network.

**Keywords:** catheterization, peripheral; spectroscopy, near-infrared; ultrasonography

## Resumo

**Contexto:** Cada vez mais os profissionais de saúde utilizam dispositivos inovadores durante a cateterização venosa periférica (CVP) para localizar veias invisíveis e impalpáveis.

**Objetivos:** Identificar a melhor evidência disponível sobre a eficácia da utilização de tecnologias para visualização de veias (luz quase-infravermelha ou ultrassonografia) em doentes que necessitem de cateterismo venoso periférico.

**Método de Revisão:** Seguindo a metodologia do Instituto Joanna Briggs, esta revisão empregará estratégias de pesquisa específicas para cada base de dados/repositório, identificando estudos relevantes. Dois revisores independentes analisarão os títulos/resumos, confrontando-os com critérios de inclusão definidos. Os artigos incluídos serão submetidos a avaliação de qualidade metodológica e extração de dados.

**Apresentação e interpretação dos resultados:** A análise crítica dos dados existentes sobre a eficácia da luz quase-infravermelha ou ultrassonografia relacionados com a CVP contribuirá para a disseminação das melhores evidências disponíveis nesta temática.

**Conclusão:** A disseminação das melhores evidências sustentará as decisões de profissionais e gestores em saúde no uso seletivo destas tecnologias na CVP, contribuindo para a preservação da rede venosa do doente.

**Palavras-chave:** cateterismo periférico; espectroscopia de luz próxima ao infravermelho; ultrassonografia

## Resumen

**Contexto:** Los profesionales de la salud utilizan cada vez más dispositivos innovadores durante el cateterismo venoso periférico (CVP) para localizar venas invisibles e impalpables.

**Objetivos:** Identificar las mejores pruebas disponibles sobre la efectividad del uso de las tecnologías de visualización venosa (luz infrarroja cercana o ecografía) en pacientes que necesitan un cateterismo venoso periférico.

**Método de revisión:** De acuerdo con la metodología del Instituto Joanna Briggs, esta revisión empleará estrategias de búsqueda específicas para cada base de datos/repositorio con el fin de identificar estudios relevantes. Dos revisores independientes analizarán los títulos/resúmenes y los confrontarán con los criterios de inclusión definidos. Los artículos incluidos se someterán a una evaluación de la calidad metodológica y a la extracción de datos.

**Presentación e interpretación de resultados:** El análisis crítico de los datos existentes sobre la efectividad de la luz infrarroja cercana o la ecografía en los resultados relacionados con el CVP contribuirá a la difusión de la mejor prueba disponible sobre el tema.

**Conclusión:** La difusión de las mejores pruebas servirá como base para las decisiones de los profesionales y gestores sanitarios en torno al uso selectivo de estas tecnologías en la CVP lo que contribuirá al mantenimiento del sistema venoso del paciente.

**Palabras clave:** cateterismo periférico; espectroscopia infrarroja corta; ultrasonografía

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## Introduction

The insertion of peripheral venous catheter (PVC) is the most often invasive procedure performed in hospital settings (Wallis et al., 2014). During hospitalization, 33-96.7% of patients need to have a PVC inserted (Braga, 2017; Grüne et al., 2004). These devices are not risk-free, affecting patients' safety and well-being. In fact, up to 72.5% of PVC are removed due to complications (Braga, 2017). Phlebitis is the most commonly reported local complication, with incidence rates up to 70% (Braga, 2017; Oliveira & Parreira, 2010), which facilitates bacterial colonization, and may result in local site infections, bloodstream infections, and sepsis. Equally relevant, local infiltration is a recurrent complication of peripheral venous catheterization, with incidence rates around 60% (Braga, Salgueiro-Oliveira, Henriques, Arreguy-Sena, & Parreira, 2016; Royal College of Nursing, 2016).

In clinical settings, health professionals must deal with difficult venous accesses due to the patient's age, physical characteristics, clinical status, and medication, which hinder PVC insertion (Royal College of Nursing, 2016). The traditional method for detection and selection of a new venous access includes the use of a tourniquet, applied at an appropriate proximal location to promote venous distention, followed by palpation and observation of the selected insertion site (Infusion Nurses Society, 2016). When veins are not visible or palpable, this may lead to successive puncture attempts, causing pain to the patient and discomfort to the healthcare professional, which results in increased costs (Braga, 2017).

Guidelines state that puncture should be attempted only twice per professional up to a maximum of four attempts (Infusion Nurses Society, 2016). However, against this recommendation and due to the patient's therapeutic needs and clinical situation, there is evidence that the total number of puncture attempts amounts to 49 times, at an average of 6.5 times per patient (Braga, 2017). In this regard, health professionals should consider using specific technologies to select the vein and reduce the number of puncture attempts and catheter-related mechanical complications (Infusion Nurses Society, 2016). Taking into account

the multiplicity of existing technologies in the international market that assist health professionals in peripheral venous catheterization, ultrasonography and infrared devices emerge in the literature as two of the most commonly used technologies during this procedure (Infusion Nurses Society, 2016; Peterlini, 2012).

Ultrasonography allows viewing veins and surrounding structures, making it easier to perform the procedure in real time (Peterlini, 2012) and reducing significantly the number of complications due to the use of central venous catheters (CVC), which tend to cause more complications than PVC. In addition, the use of ultrasonography allows decreasing the number of puncture attempts, the time needed for puncture, and the associated pain, consequently increasing patient satisfaction (Stolz, Stolz, Howe, Farrell, & Adhikari, 2015).

Infrared technologies allow illuminating the vein with a near-infrared light, which is absorbed by blood and reflected by adjacent tissue. When compared with the traditional method, this alternative technology showed a lower incidence of hematomas and less anxiety in patients (Fekonja & Pajnikihar, 2017).

These technologies were developed with the purpose of improving peripheral venous catheterization success rate, reduce the number and impact of the negative effects of multiple or unsuccessful attempts, and prevent health professionals' frustration in these settings.

Thus, there is a need to synthesize the evidence that supports the effectiveness of these two technologies in patients requiring peripheral venous catheterization, comparing them and analyzing specific advantages of their use with different patients and in different clinical settings, as well as the desired outcomes.

A preliminary search of the JBI Connect+, the Cochrane Database of Systematic Reviews, CINAHL and MEDLINE databases revealed some systematic reviews on the effectiveness of vein visualization technologies on peripheral venous catheterization, namely near-infrared light (Fekonja & Pajnikihar, 2017; Heinrichs, Fritze, Klassen, & Curtis, 2013; Park et al., 2016) and ultrasonography technology (Egan et al., 2012; Heinrichs, Fritze, Vandermeer, Klassen, & Curtis, 2013; Liu, Alsaawi, & Bjornsson, 2014; Stolz et al., 2015).

Nonetheless, the inclusion criteria in some of

these reviews are restrictive (e.g., limited settings such as emergency department, intensive care units, and operating room; or focus on nurses as the only healthcare professionals who perform this invasive procedure). Regarding search temporality, the systematic reviews on the use of ultrasonography searched for articles published until 2012 (Egan et al., 2012; Heinrichs, Fritze, Vandermeer, et al., 2013; Liu et al., 2014; Stolz et al., 2015), emerging the need to update these reviews due to possible loss of recent evidence.

More recently, two systematic reviews were conducted by the same group of authors to identify interventions associated with peripheral venous catheterization first attempt success in both adult and pediatric settings (Parker, Benzies, & Hayden, 2016; Parker, Benzies, Hayden, & Lang, 2017). In both reviews, ultrasonography and near-infrared light emerged as valid interventions when compared to the traditional technique. However, both reviews focused solely on evidence from randomized controlled trials published in English and excluded studies including healthy participants or outpatients without putting forward a clear reason for such criteria. While the original search that sustained both reviews was conducted on November 2014, the authors of the systematic review on pediatric settings updated their search in May 2016 (Parker et al., 2016). Regarding systematic reviews being currently conducted, a preliminary search on the International prospective register of systematic reviews (PROSPERO) database revealed no systematic review directly comparing the effectiveness of ultrasonography and infrared light devices. Nevertheless, despite the significant number of systematic reviews in this field, the outlined search limitations and lack of direct comparison between the effectiveness of ultrasonography and near-infrared light in peripheral vein catheterization sustain the need for a future systematic review.

Therefore, this review aims to identify and synthesize the evidence on the effectiveness of vein visualization technologies (near-infrared light or ultrasonography) in patients requiring peripheral venous catheterization. More specifically, this review focuses on the following question: What is the effectiveness of ultrasonography *versus* near-infrared light in the first

attempt success rate of peripheral venous catheterization or number of attempts needed?.

## Systematic review method

This systematic literature review will follow the model recommended by the Joanna Briggs Institute (Tufanaru, Munn, Aromataris, Campbell, & Hopp, 2017) that identifies inclusion and exclusion criteria for Population, Intervention, Comparison, and Outcomes (PICO).

As regards the type of participants, this review will consider studies that include patients of all ages, in any clinical setting, who need peripheral venous catheterization. With regard to the intervention, this review will consider studies that assess the effectiveness of the use of vein visualization technologies (near-infrared light or ultrasonography) in patients requiring peripheral venous catheterization. Studies that compare the effectiveness of near-infrared light or ultrasonography with other techniques or innovative technologies in peripheral vein catheterization will be excluded from this review.

This review will focus on at least on one the following primary outcomes: first attempt success rate or the number of attempts to successful peripheral vein catheterization. Additionally, this review will also focus on secondary outcomes such as peripheral venous catheterization-related patient outcomes (e.g., pain, anxiety or satisfaction); provider-reported outcomes (e.g., satisfaction, anxiety, or perceived ease of insertion); and immediate post-procedure complications (e.g., hematoma formation, nerve contact or arterial puncture), measured by any reliable instrument, scale or index, as other outcomes described in these studies. The need for other vascular access devices and time required for the peripheral venous catheterization procedure will also be regarded as secondary outcomes.

The review will consider all studies of quantitative evidence, including randomized controlled trials, non-randomized or quasi-experimental, observational, analytical, cohort, case-control, descriptive, cross-sectional, case report or case series studies. In the absence of research studies, other text such as opinion papers and reports will be considered. The use of ultrasonography for peripheral venous catheterization was first reported in 1999

(Heinrichs, Fritze, Vandermeer, et al., 2013). The initial use of infrared lights in this procedure is not well established in the literature; however, its clinical use is described as fairly recent (Fekonja & Pajnikihar, 2017; Park et al., 2016). Therefore, studies published between 1999 and 2017, in English, Portuguese, French or Spanish will be considered for inclusion in this review. The search strategy will aim to find both published and unpublished studies. An initial

limited search of MEDLINE via PubMed and CINAHL via EBSCO has been undertaken, followed by analysis of the text words in the title and abstract, and of the index terms used to describe the article. This informed the development of a search strategy which will be adapted to each information source. A full search strategy for MEDLINE via PubMed is detailed in Table 1. The reference list of all studies selected for critical appraisal will be screened for additional studies.

Table 1  
*Example of a search strategy for MEDLINE (via PubMed)*

Search	Query
S5	Search (S1 AND S2 AND S3) Filters: Publication date from 1999/01/01; English; French; Portuguese; Spanish
S4	Search (S1 AND S2 AND S3)
S3	Search (((((((((((((((success*[Title/Abstract]) OR fail*[Title/Abstract]) OR "first-attempt"[Title/Abstract]) OR "first attempt"[Title/Abstract]) OR "rate of success"[Title/Abstract]) OR "rate of successful"[Title/Abstract]) OR punctures[Title/Abstract]) OR "insertion attempts"[Title/Abstract]) OR "needle placement"[Title/Abstract]) OR "attempts at cannulation"[Title/Abstract]))))))))))
S2	Search (((((((((((((((infrared*[Title/Abstract]) OR NIR*[Title/Abstract]) OR Accuvein[Title/Abstract]) OR "Active Vascular Imaging Navigation"[Title/Abstract]) OR near-infrared*[Title/Abstract]) OR infra-red*[Title/Abstract]) OR VeinViewer*[Title/Abstract]) OR technolog*[Title/Abstract]) OR machine*[Title/Abstract]) OR light*[Title/Abstract]) OR ultrasonograph*[Title/Abstract]) OR Sonosite[Title/Abstract]) OR device*[Title/Abstract]) OR NanoMaxx[Title/Abstract]) OR ultrasound*[Title/Abstract]) OR ultrasonics*[Title/Abstract]) OR sonography*[Title/Abstract])) OR (((("Technology"[Mesh]) OR "Light"[Mesh]) OR "Spectroscopy, Near-Infrared"[Mesh]) OR "Ultrasonography"[Mesh]))
S1	Search (((("Catheters"[Mesh]) OR "Cannula"[Mesh]) OR "Vascular Access Devices"[Mesh]) OR (((("peripheral access"[Title/Abstract]) OR "peripheral venous catheterization"[Title/Abstract]) OR "peripheral venous catheterization"[Title/Abstract]) OR "peripheral intravenous access"[Title/Abstract]) OR "venous access"[Title/Abstract]) OR "peripheral venous access"[Title/Abstract]))

The databases to be searched include MEDLINE via PubMed; CINAHL via EBSCO-Host; Scopus; Cochrane Central Register of Controlled Trials and SciELO. The search for unpublished studies will include: RCAAP – Repositório Científico de Acesso Aberto de Portugal; OpenGrey; and Dissertation Abstracts Online (EThOS).

**Assessment of the methodological quality of the studies**

Quantitative articles selected for retrieval will be assessed by two independent reviewers for methodological validity prior to inclusion in the review using the JBI standardized critical ap-

praisal instruments, namely: the Checklist for Randomized Controlled Trials; Checklist for Quasi-Experimental Studies (non-randomized experimental studies); Checklist for Analytical Cross Sectional Studies; Checklist for Cohort Studies; Checklist for Case Control Studies; Checklist for Case Reports; and Checklist for Case Series (Moola et al., 2017; Tufanaru et al., 2017). All studies, regardless of their methodological quality, will undergo data extraction and synthesis. Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer. In the absence of research studies, textual articles selected for retrieval will be assessed by two

independent reviewers for authenticity prior to inclusion in the review using the JBI Critical Appraisal Checklist for Text and Opinion Papers (McArthur, Klugárová, Yan, & Florescu, 2015). Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer.

### Data extraction

Quantitative data will be extracted from articles included in the review using the standardized data extraction tool from JBI System for the Unified Management, Assessment and Review of Information (JBI-SUMARI). The extracted data will include specific details about the interventions, populations, study methods, and outcomes of significance to the review question and specific objectives. The authors of primary studies will be contacted to provide missing or additional data. Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer.

### Data synthesis

Quantitative data, wherever possible, will be pooled in a statistical meta-analysis using JBI-SUMARI. The meta-analysis will be performed using the random-effects model to allow generalization. However, if less than five studies are included in the meta-analysis, it will be performed using the fixed-effects model. All results will be subject to double data entry. Effect sizes expressed as odds ratio (for categorical variables) and weighted mean differences (for continuous variables) and their 95% confidence intervals will be calculated. The  $I^2$  statistic can be used to quantify the amount of dispersion and  $I^2$  values of 25%, 50%, and 75% are interpreted as representing small, moderate and high levels of heterogeneity, respectively. Heterogeneity and inconsistency analyses will be explored based on identified subgroups, including, but not limited to, different quantitative study designs, participants' age or clinical settings. Where statistical pooling is not possible, the findings will be presented in narrative form including tables and figures to aid in data presentation wherever appropriate. In the absence of research studies, textual articles, wherever possible, will be pooled using JBI-SUMARI. This will involve the aggregation or synthesis of

conclusions to generate a set of statements that represent that aggregation, through assembling and categorizing these conclusions on the basis of similarity in meaning.

## Presentation and interpretation of the results

This systematic review will allow finding data on the effectiveness of ultrasonography versus near-infrared light in the first attempt success rate and the number of attempts needed for a successful peripheral venous catheterization. The critical analysis of the existing data will contribute to the dissemination of the best evidence available on this topic.

## Conclusion

In hospital settings, peripheral venous catheterization is the main clinical procedure used by health professionals to comply with the patient's therapeutic plan. However, current risk rates are significant, with an impact on the quality and safety of care delivery, as well as on patients' well-being, demanding full attention from health professionals and managers.

Therefore, the creation of the necessary conditions for preserving the individual's venous health has been considered a key line of clinical research, with numerous publications on the effectiveness of new technologies in the success of the procedure and reduction of complications. Among these technologies, a number of efforts have been undertaken to assess the effectiveness of ultrasonography and near-infrared light when compared to the traditional catheterization technique.

Nonetheless, the critical analysis of data comparing the effectiveness of ultrasonography and near-infrared light in peripheral venous catheterization will contribute to the dissemination of the best evidence available on the topic.

It is expected that this dissemination will be reflected in the definition of guidelines for PVC management, highlighting the specific contributions of each technology in the clinical scenarios and, consequently, in the optimization of current practices.



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