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Review Article

How Ultrasound-Guided Intravenous Cannulation has Affected the Care of Patients with Difficult Intravenous Access: A Systematic Literature Review

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Abstract

Peripheral intravenous cannulation is one of the most common invasive procedures carried out in hospitals for patients who require venous fluid intakes such as hydration therapy, blood transfusion and medication that the patient is unable to take orally. Despite the importance and frequency of the procedure, it is often difficult or sometimes impossible. This leads to multiple attempts which sometimes could cause patients' discomfort and possible complications such as infiltration, vein collapse or nerve damage.

The standard of care technique which involves the physical feeling and palpation of veins pose challenges to clinicians, especially in patients with difficult vein access caused by risk factors such as high body mass index, vein impalpability, diabetes, kidney insufficiency, cancer chemotherapy and history of previous access difficulty. The ultrasound-guided peripheral intravenous cannulation technique has been applied widely as an option to the standard of care method.

This systematic review explores the effect of the ultrasound-guided peripheral intravenous cannulation in care of patients with difficult intravenous access. The study involved the structured search of the body of literature on the research question. The following databases were searched: PubMed; Ultrasound Journal, MEDLINE, BJA, National Library of Medicine, Library of Clinical Trials, Trip Database and Google Scholar. The search was conducted using appropriate words and phrases and linked with the Boolean word "AND". The selected publications were further subjected to appraisal using the Mixed Method Appraisal Tool (MMAT) version 2011and presented using the Reporting Items for Systematic and Meta-Analysis (PRISMA).

A total of 237 publications were identified during the literature search phase. After removing the duplicated publications, 155 papers were selected for screening. These were further screened down to 34 after removing articles that did not meet the selection criteria such as language of publication, age of patients and incomplete texts. Finally, a total of 9 studies were included in the study.

The results show that first attempt success rate for the ultrasound-guided group is 63.3% (with Standard Deviation of 17.0 and 95% Confidence Interval of 13.1). First attempt success rate for the standard of care group is 46.6% (with standard deviation of 18.9 and 95% Confidence Interval of 14.6). This translates to a difference of 16.7% first attempt success rate between the two methods. The average cannulation time for the ultrasound group is 18.8 minutes, compared to 18.0 average cannulation time for the standard of care group. This translates to weighted mean difference of 0.8 minutes, implying no significant statistical and clinical time difference between the two methods. The mean satisfaction level for the ultrasound group is 8.1, compared to 6.5 in the standard of care group (difference of 1.6% or 12.5%). Complications occurred in both techniques, although the rate is statistically higher in the standard of care methods. Overall, the ultrasound-guided peripheral intravenous cannulation technique has improved patients' care in terms of first attempt success rate, number of repeat attempts and patients' satisfaction.

Introduction

This study investigates the question of how Ultrasound-Guided Peripheral Intravenous Cannulation (UGPIC) has affected the care of patients with Difficult Intravenous Access (DIVA). Ultrasound-Guided Peripheral Intravenous Cannulation is a procedure which allows the insertion of peripheral cannulas or catheters for short-term venous access in patients indicated for intravenous therapy. The technique allows the clinician to access the patient's vein through real-time visualization, allowing the cannula to be guided into the veins by use of the ultrasound system. This implies that cannulation is performed simultaneously as with visualization of the veins through the ultrasound system. This is in contrast to the Standard of Care (SOC) method which relies on physical feeling and palpation of veins prior to cannulation.

Intravenous peripheral cannulation is crucial in providing care for patients who require venous fluid intakes such as hydration therapy, blood transfusion and medication that the patient is unable to take orally [1]. This is often the case in most healthcare settings, especially emergency departments, hospital in- and out-patient wards, or critical care units. Cook et al. [2] reported that as high as 80% (4 out of 5) require intravenous peripheral cannulation during their stay in hospital. This makes this procedure the most frequently applied invasive medical procedure administered during patients' care.

The UGPIC technique is fast developing as a preferred approach for Intravenous (IV) cannulation in patients with DIVA. It is, therefore, pertinent to assess how the technique has affected patient care. Moreover, patients with DIVA are becoming more common due to increase in obesity which is estimated to have affected 26%

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of men and 29% of women in 2020 [3]. Jacobson and Winslow [4] identified body mass index which is linked to obesity as a risk factor for Difficult Intravenous Peripheral Cannulation (DPIVC). It is, therefore, important to determine if UGPIC offers long term solution to the challenges of cannulating patients with DIVA at the required time, especially at emergency departments.Previous studies have been conducted on the success rates of UGPIC technique, in comparison with the traditional method including the research by Costantino, Parikh, Fojtik and Satz [5], who estimated the success rates and impacts of UGPIC on patients with DIVA. However, only a few have assessed the effect of this method on patients and clinicians. The relative benefits of the technique in terms of patients' and clinicians' satisfaction and preference of the method needs to be explored. This is the gap which this study is intended to explore. This systematic review is therefore intended to assess how the ultrasound-guided peripheral intravenous cannulation has affected patient care in both emergency and normal hospital environments.

The study applies the systematic review approach without meta-analysis. According to Siddaway, Wood and Hedges (2019), the characteristics of systematic reviews are reproducible methodology and presentation of key findings from published body of literature on relevant research questions. It is a review that gathers several research works and presents them in a format that answers a research question using rigorous methods. The protocol in this systematic review was designed to explore the research question "How has Ultrasound-Guided Intravenous Cannulation Affected the Care of Patients with Difficult IV Access?"

The expected primary outcomes from the study include comparison of the first attempt success rates of UPGIC and SOC, length of procedures, patients, and clinicians 'satisfaction and rate of complications from the methods.

Background literature and justification for study

Over the years, many techniques have been developed to increase first time success rates of peripheral intravenous cannulation. This includes the traditional or Standard of Care (SOC) procedure which involves physical feeling or palpation of the veins to access and place the cannula in them, as well as the ultrasound-guided visualization technique. The first ultrasound-guided technique for central nervous cannulation was introduced by Ulman and Stoelting (1978). It was not up until 1999 when Kees et al. [6] carried out the first study to assess the effectiveness of the technique, in comparison with traditional methods through a retrospective observational study. The study concluded that the ultrasound-guided method was more successful than the traditional method.

The traditional procedure poses challenges in patients with difficult intravenous access, including patients with oedema, obesity, hypovolaemia, chronic illness, advanced stage renal diseases and patients with history of previous cannulation, intravenous drug abuse and patients undergoing chemotherapy [7,8]. This is because there is often lack of palpable or visual veins in such patients which makes cannulation through palpation difficult [9]. Bahl et al. [10] estimated that up to a third of patients who require intravenous cannulation has difficult intravenous access. Also, Yalcinli et al. (2019) noted that IV cannulation is not always successful at first attempt, despite its frequent use and importance. The reason for this include straining, experience [11], and composure of the clinician, causing puncture error as well as the condition of the patients at the time of presenting (patients with difficult intravenous access). Other reasons for unsuccessful cannulation attempts were proposed by Mörgeli et al. (2022) who attributed first attempt failures in cannulation to poor vein status, poor handling, and blunt cannulas. Loon et al. [12] reported that first time success rate of 70% was achieved using the traditional approach, compared to 81% achieved through the ultrasound-guided technique. Furthermore, Sherry and Han (2010) described the traditional method of cannula insertion as challenging because it requires good knowledge of vascular anatomy to locate the target veins as well as vessel visualization or palpation for precise puncture and insertion.

Consequently, the real-time Ultrasound-Guided Peripheral Intravenous Cannulation presents a viable and safe alternative for placing cannulas in patients with DIVA. As shown in Figure 1, this procedure involves the use of virtual, real-time ultrasonographic system to locate peripheral veins and consequently guide cannulas into them.

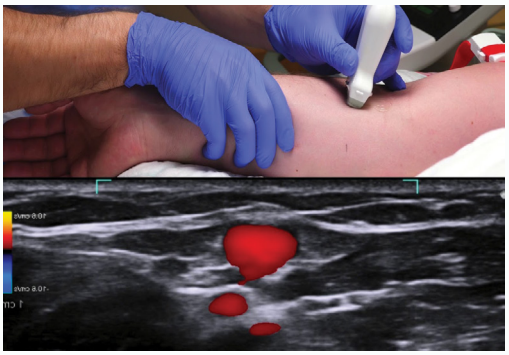

Figure 1: The Ultrasonic-Guided Peripheral Intravenous Cannulation process (Credit: InterAnset (2018)).

Aims and objectives

This systematic review explores the relative benefits of the technique in terms of first-time success rates, length of procedure (time taken to achieve a successful cannulation) and patients' and satisfaction. This systematic review is therefore intended to assess how the ultrasound-guided peripheral intravenous cannulation has affected patient care in both emergency and normal hospital environments.

The overall aims and objectives of the study include:

- To assess the impact of real-time (direct visualization) ultrasound-guided intravenous cannulation technique on the care of patients with difficult intravenous access by emergency physicians in healthcare settings.
- To explore the levels of satisfaction and acceptance of the technique by both patients and clinicians who use the technique.
- To determine if improvements have been made by the ultrasound-guided peripheral cannulation technique on first time success rate, length of procedure, and complications.

Development of the research question

Creating and developing a clear, focused research question is crucial for achieving the aims and objectives of research studies [13,14]. A research question should therefore be apt and able to address the objectives of the research. To evaluate the impact of

UGPIC on patients with DIVA and the satisfaction of trained clinical staff on its use at Barnsley Hospital NHS Foundation Trust, the following Research Question (RQ) is created:

"HOW HAS ULTRASOUND-GUIDED INTRAVENEUOUS CANNULATION AFFECTED THE CARE OF PATIENTS WITH DIFFICULT IV ACCESS?"

This RQ addresses the question of how UGPIC has affected the care for patients with DIVA through its efficiency as well as patients' and clinicians' satisfactions.

This study has adopted the SPIDER framework developed by Cook, Smith and Booth [2] in creating the RQ, in preference to others such as PICO (Patient problem/population, intervention, the comparison and outcome). As shown in Table 1, the SPIDER framework was chosen over others because of its ability to define all the research parameters in a concise manner. SPIDER stands for:

S: Sample of interest; PI: Phenomenon of Interest; D: Design of the research; E: Evaluation methods; R: Research Type.

Table 1: developing the research question using the SPIDER framework (after Creswell 2014, Johnson and Christensen 2014).

S	Patients with DIVA who have used the UGPIC service and a subset of those that used the traditional SOC procedure.
P of I	Peripheral IV Cannulation for fluids intake in patients
D	1. Retrospective randomised control (RCT) for patients with DIVA to acquire quantitative data on success rate, patients' satisfaction(in Likert scale) and length of procedure for the UGPIC and SOC techniques.
E	Quantitative and qualitative comparison of success rates, patients' satisfaction and length of procedure for UGPIC and SOC using statistical methods.
R	Systematic Review (without meta-analysis).

Research Methodology: A Theoretical Framework (PARADIMS)

The choice of research methodology or philosophy determines the application of appropriate research methods and analytical procedures that would allow for the achievement of the research objectives. Crotty [15] recommended that prior to the critical stage of research data collection, analysis and interpretation, research methodologies should be carefully chosen to reflect the researcher's personal inclinations and views as well as the importance attached to the study. There are several research philosophies on which the current study could be anchored. They include positivism, interpretivism and pragmatism [16]. An overview of research paradigms, showing their theoretical perspectives and appropriate methods is presented in Appendix 1.In terms of ontology, positivism is the view that there is only one truth or reality. From epistemological point of view, truth can be measured through experimental methods (experimental research) using quantitative methods. On the other hand, interpretivism holds the view that reality or truth is relative and subject to the feelings of individuals or groups. This philosophy presupposes that truth needs to be interpreted rather than measured through ethnography, action research analysis or discourse [15]. Interpretivism usually relies on qualitative methods, employing interviews, surveys, observations, or life history.

Furthermore, Crotty [15] held that pragmatism refers to the belief that reality is dynamic, renegotiable in changing circumstances. It is a problem-solving methodology by finding out situational changes, using a combination of two or more methods. According to Clarke and Visser [17], pragmatism as a methodology refers to the application of more than a single method to carry out research. It is the combination or a mix of aspects of qualitative and quantitative methods.

It is arguable that positivism has been more rampantly used for evidence-based research in healthcare related studies. However, given the wide range of proposed objectives in the current RQ, this methodology may not be feasible.

Again, interpretivism may be an alternate method to consider. While this methodology may be effective in assessing the satisfaction of patients and clinicians in the use of UGPIC, it falls short in estimating success rates of the techniques which is a crucial component of the study. According to NICE guideline (NG86/1), current methods for assessing satisfaction of service users (including "Patient Reported Outcome Measures (PROMSs), "public perception surveys" and "the national adult social care user experience survey") which rely wholly on surveys and measures are limited in the sense that they may not be comprehensive and representative as the surveys are self-imposed. From the foregoing argument, pragmatism which relies on mixed method is a preferred methodology to address the research question.

It has been noted that qualitative methods are not entirely expected to address most of research questions because of their inherent limitations and therefore, a complementary method is required to broaden the range of data collection and widen the interpretation spectrum [18]. Moreover, it has been argued that pragmatism presents additional strengths to research by enhancing the focus on practicability and flexibility by using what is feasible to derive a range of results, not just the truth [19]. This position was further canvassed by Coyle [20] who recommended that pragmatic approach should be encouraged to promote "wholistic understanding", as opposed to the search of "consensus" or "absolute truth". Several studies have described pragmatism as the most effective and feasible method available to answer specific RQ with wide range of aims created by the researcher. For example, Becker [21] recommended a blend of quantitative and qualitative methods to harness the huge benefits of their similarities, differences, strengths and weaknesses and hence enrich research rigor and robustness. Mixed methods explore the complementary relationships between quantitative and qualitative methods and utilize these to optimize research studies. Moreover, Guetterman, Fetters and Creswell [22], underscored the usefulness of mixed methods in achieving a more comprehensive knowledge of research subjects and reflections of the participants. Morgan [23] observed that the robustness of one method can be exploited to boost the reliability of the other.

However, counter arguments have been advanced to make the point that data from qualitative and quantitative methods may be incompatible. Bryman and Bell [16] had argued that complexities about mixed methods arise from ambiguities in locating the method in the contexts of epistemology and paradigms. The study explained that each research method is embedded in epistemological leanings and that quantitative and qualitative methods belong to distinct paradigms, respectively, and, therefore, mixing them would be pose irreconcilable ideological ambiguities. Hughes (1990) buttressed this argument by stating that each research method or tool is inseparably dedicated to a specific world philosophy or paradigm and all the instruments within the method are essentially applied

for the realization of the conceived purposes. Furthermore, Smith and Heshusius [24] noted that proponents of mixed methods ignore the assumptions which underpin research strategies and translate qualitative investigations into quantitative exploration.

While these arguments are valid, the respective authors have ignored the indisputable advantages accruable to mixed methods from triangulation and complementarity of the constituent methods. Simply put, results from mixed methods of research can be used to check against each other for enhanced validity.

Summary of methods: the systematic review method

The systematic review method which falls within the paradigm of pragmatism has been chosen for this study. According to Donato and Donato (2019), systematic reviews are used to collect, collate, and analyse datasets from published body of literature in order to gain insights into existing study. The Cochrane Collaboration views systematic review as a process that summarizes the outcomes of robust studies in healthcare available in literature which provides important information on the effectiveness of the interventions. This study will extract a compendium of data from carefully designed studies which satisfy the pre-determined inclusion criteria, investigating the impacts that ultrasound-guided cannulation on care of patients with difficult venous access.It has been argued that systematic reviews are generally more reliable, less susceptible to bias and generates more acceptable conclusions than the traditional literature review. Furthermore, conclusions from systematic literature review are based on quantitative or qualitative analysis of results, unlike the traditional literature review in which results are based on mere counting of referenced papers. However, systematic reviews have been observed to be time consuming and laborious. Moreover, the systematic review method is viewed to be error prone because data sets are obtained from sources that may not be reliable and difficult to compare.

This study adopts the systematic review approach to aggregate and synthesise published body of literature on the impact of ultrasound-guided peripheral intravenous cannulation on the care of patients with difficult intravenous access. Liberati et al. (2009) and Aromataris and Pearson (2014) described systematic reviews as the grand norm for gathering, collating, scrutinizing, and analysing a clinical research question. Systemic reviews are believed to be the fulcrum of evidence-based health study because of their reliability, structure, and robustness.

Source of Data: Literature Search Strategy

Data to be utilised in the study were obtained through an extensive search of body of published papers on the subject matter. The following databases were searched: PubMed; Ultrasound Journal, MEDLINE, BJA, National Library of Medicine, Library of Clinical Trials, Trip Database and Google Scholar. The selected publications were further subjected to appraisal using the Mixed Method Appraisal Tool (MMAT) version 2011 which is discussed in Section 2.4. The search covered both interventional and observational studies on the ultrasound-guided peripheral cannulation in patients with difficult venous access. The search included the main words contained in the research question including "peripheral intravenous access"; "peripheral intravenous cannulation"; "difficult intravenous access"; "patients' satisfaction" and clinicians' satisfaction. These will be connected by the Boolean algorithm "AND" with the terms "ultrasound"; "ultrasonography" and "ultrasound-guided". Furthermore, the Medical Subject Headings (MeSH) terms "cannulation"; "peripheral" and ultrasonography were used appropriately and connected with the Boolean "AND".

The systematic literature review was conducted and presented using the Preferred Reporting Items for Systematic and Meta-Analysis (PRISMA), which is an established protocol that explains the justification, the hypothesis, and proposed methods for the reviews. As shown in Figure 2, PRISMA presents processes for the identification, screening, qualification (eligibility) and inclusion of publications used in the review. According to Moher et al. (2015), PRISMA improves the quality of systematic reviews and allows researchers to design and implement a pre-planned road map for their studies.

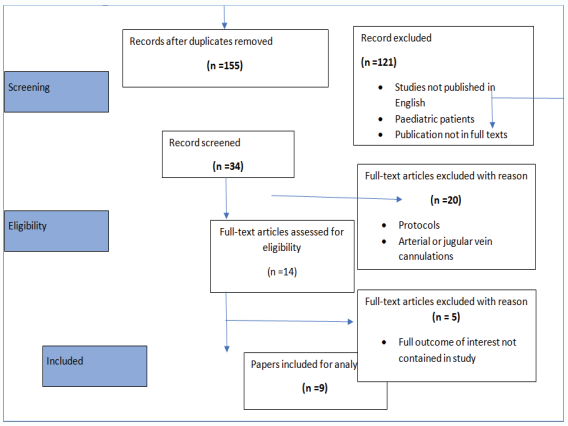

Figure 2: PRISMA Flowchart for paper selection (after Loon et al, 2019).

Inclusion and exclusion criteria

The following criteria were applied to include or exclude publications:

Inclusion criteria:

- Only Papers written in English Language will be included in the selection
- Only papers published in the last 15 years (that is, between 2007 and 2022) were included in the selection.
- Papers on adult patients, with difficult peripheral intravenous access (minimum of two failed attempts).
- Papers on peripheral intravenous cannulation using real-time ultrasound-guided technics.
- Selected papers were those that discussed peripheral cannulation and NOT cannulation on other systems such as the central nervous system.

Exclusion criteria

- Publications on insertion of other devices rather than cannulas, such as central nervous catheters, dialysis, or arterial catheters.
- Publications on ultrasound-guided peripheral cannulation compared with other techniques such as light infrared, other than the traditional vein palpation method.
- Literature older than 15 years
- Papers on paediatric patients, with difficult peripheral intravenous access, even they met the other requirements

Quality assessment

A crucial consideration in conducting systematic literature review is ensuring the quality of the individual publications used in the study. This is because such studies encompass a wide array of heterogenous topics which are synthesized in the literature. According to Harden and Gough (2012), the essence of carefully examining the studies included in a study is to ensure that they are trustworthy. This point was reiterated by Burls (2014). To achieve acceptable quality of the study, the Mixed Method Appraisal Tool (MMAT) version 2011 was used in assessing the quality of the papers selected for inclusion in the study. The MMAT was first published in 2009 and has been modified severally, the latest version being the 2018. The 2011 version modified by Pluye et al. (2011) was applied in this study because it has been proved to be more flexible and user-friendly as it contains tutorials. The MMAT was designed for systematic reviews consisting of qualitative, quantitative, and mixed methods research. It is therefore effective as a one-stop tool for appraising and quality-controlling most types of empirical studies, including randomized and non-randomized (quantitative) and qualitative studies. However, Hong et al. (2018) showed some inadequacies of MMAT including difficulties in choosing items for studies in some criteria, poor reporting, lack of completeness and missing items, poor judgement in qualitative and mixed method study items, lack of flexibility and poor satisfaction rating, compared to other appraisal items. The authors therefore noted that MMAT is not suitable for some designs such as economic and diagnostic efficacy studies. However, the current study does not fall within these categories and is therefore, considered suitable for MMAT.

Despite these shortcomings, MMAT remains an appraisal tool of choice due to its versatility in allowing the concurrent appraisal of complex systematic reviews that comprise different review methods. According to Abbott, 1998 and Porta et al. (2014), MMAT can also be used for the appraisal of primary studies (empirical studies).

For proper use of MMAT, some requirements needed be met. It is expected that users undergo training on the use of the tool. It also required that there will be at least two reviewers on the study, including proper training and collaborative assessment. To meet these requirements, the tutorial part of the MMAT version 11 was studied. Also, the help of a colleague who is also using same tool was solicited to review this work and same favour was returned to them.

The following steps were applied in the appraisal system:

1. Respond to the screening questions to assess the publications included in the study. Compilation of screening questions are presented in Appendix 2
2. Choose appropriate type of studies to appraise.
3. Rate the criteria of the selected category.

Results

A total of 237 publications were identified during the literature search phase, using the protocol discussed in Section 2.3. After removing the duplicated publications in the section, 155 papers were selected for screening. These were further screened down to 34 after removing articles that did not meet the criteria for selection such as language of publication, age of patients and incomplete texts. Finally, a total of 9 studies were included the study as shown in Figure 1. The studies included are Nishizawa et al. (2020), Bauman, Braude and Crandall [25], Stein et al. [26], Weiner, et al. (2013), Bahl et al. [10], Kerforne et al. (2012), Smailoglu et al. (2014), Bridey et al. [27] and Aponte et al. [28]. Table 2 presents characteristics of the 9 studies included in the systematic review, comparing ultrasound-guided cannulation and the standard of care techniques of peripheral intravenous cannulation. The included studies are all Randomized Control Trials (RCTs). A cumulative total of 633 patients were included in the studies, comprising 335 patients in the UPGIC and 298 in the SOC group. Average ages for both the UPGIC and SOC groups are same and were 58.1 years, respectively. It is therefore, not expected that age would have any effect on the outcomes. Furthermore, on average 31% of the patients in the UPGIC group were females, while 27% of the patients in the SOC group were females. Thus, there is no significant variation in gender.

The main outcome measures which this study sought to achieve were first time cannulation success, patients' satisfaction, and length of procedure (time taken for a successful cannulation) and number of complications. This study did not undertake meta-analysis of the data. However, descriptive statistical analysis was performed to provide insights into the data.

First attempt success rates

First attempt success rate in intravenous cannulation is critical for effective care for patients in clinical settings. This is particularly the case in emergency settings where timely placement of canulae is required in critically ill patients. This makes this outcome measure crucial in this review. All the nine studies included in the current systematic review measured first attempt success rates which are the measure of number of patients that were successfully cannulated at the first attempt by operators. Figure 3 presents a spider plot of first attempt success rates for all the studies. As shown, first attempt success rates vary in all the studies for the study group (UGPIC) and the control group (SOC). The mean success rate for the UPGIC group is 63.3% (with Standard Deviation of 17.0 and 95% Confidence Interval of 13.1). Success rate for the SOC group is 46.6% (with standard deviation of 18.9 and 95% Confidence Interval of 14.6). This translates to a difference in success rate of 16.7% between the UPGIC and SOC groups and mean odd ratio of 1.35. This implies that on average, the ultrasound guided technique provides a more effective option to the standard technique by 16.7% or 1.35 times. The studies analysed in this review are, however, not unanimous on this. For instance, first attempt success rates for the UGPIC and SOC in the study of Aponte et al. [28] reported higher success rate for the SOC group than the UGPIC group at 81% and 74% respectively (Figure 4). However, the finding in this study agrees with previous studies. Loon et al. [12] posited that ultrasound guided intravenous cannulation produced a higher first attempt success rate with odd ratio of 2.49 and Confidence Interval of 4.52. The differences in actual results could be attributed to the characteristics of the data in this study and Loon et al. [12]. Whereas the study of Loon et al. [12] applied four studies to derive the first attempt success rates, this study utilized nine publications, resulting in significant heterogeneity (standard deviation of 17.0 and Confidence Interval of 13.1). Furthermore, Quincy et al. [29] presented a systematic review and meta-analysis of 966 patients who used the ultrasound guided and 894 who used the standard techniques for cannulation. The study concluded that the ultrasound guided technique provided 2 times higher likelihood of first attempt success than the standard technique. Similarly, Egan et al. [30] performed a systematic review to compare the ultrasound technique and standard procedure and concluded that the ultrasound

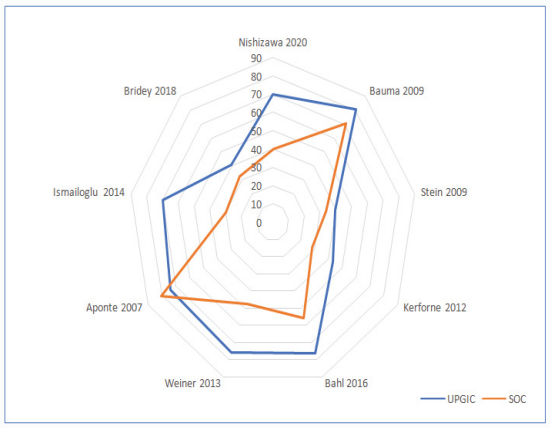

Figure 3: Spider plot of the comparison of first attempt success rate (%) between the UPGIC and SOC.

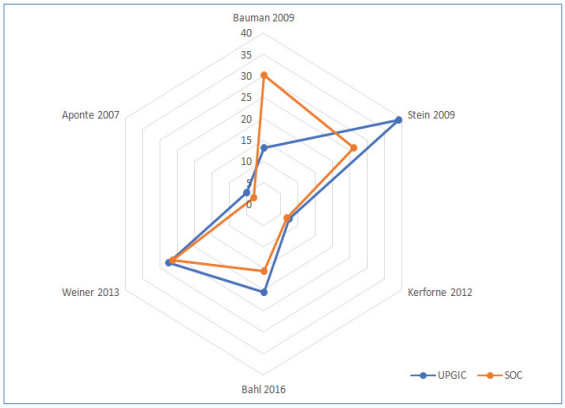

Figure 4: Spider plot of the comparison of cannulation time (minutes) between the UPGIC and SOC.

technique offered a higher success rate by 17 % as success rate for the ultrasound group was 78.7% *vs.* 61.7% for the standard procedure.

Length of procedure (cannulation times)

In patients with difficult intravenous access, the time taken to complete successful cannulation is important. Therefore, length of procedure or cannulation time is one of the outcome measures assessed in this review. Six studies included in the review reported lengths of procedure in their trials. They are Bauman, Braude and Crandall [25], Stein et al. [26], Bahl et al. [10], Kerforne et al. (2012), Weiner, et al. (2013) and Aponte et al. [28]. The cannulation times as reported by the respective studies are presented in Figure 5. The average cannulation time for the UPGIC group is 18.8 minutes, compared to 18.0 average cannulation time for the SOC group. This translates to weighted mean difference of 0.8 minutes. This review thus, suggests that on the average, there is no significant difference in the time taken to complete a successful cannulation between the UPGIC and SOC groups.

However, as shown in Figure 5, some of the studies reported differences in cannulation times between the two groups. The studies of Bauman et al. [25] reported a longer time for the SOC group (30 minutes), compared to the UPGIC group (13 minutes). Also, Stein et al. [26] presented cannulation time for the SOC group as 26 minutes, against the time for the UPGIC group at 39 minutes.

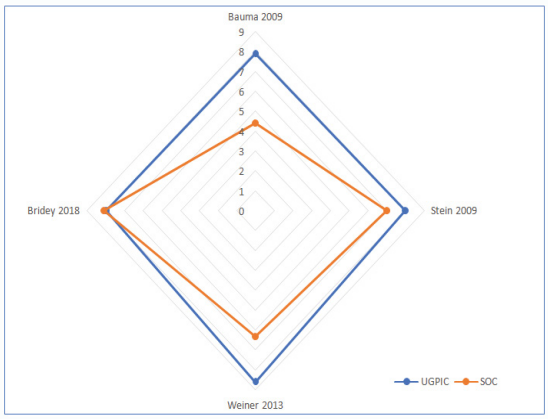

Figure 5: Spider plot of the comparison of patients' cannulation (Likert scale) between the UPGIC and SOC.

Previous studies have reported that there was no significant difference in the length of procedure between the ultrasound guided cannulation and the standard technique. Quincy et al. [29] presented data from 8 studies and concluded that although there was difference in length of procedure between the ultrasound and standard techniques of cannulation, the difference was not statistically significant, with Standard Mean Difference (SMD)=0.08. Furthermore, Stolz et al. (2015) reported a pooled weighted mean difference of -1.07miniues from their systematic review comprising five studies. They concluded that there was no difference in the time taken to successfully complete a cannulation process between the two techniques. Similarly, Egan et al. [30] reviewed five trials and found pooled mean difference in procedure time of 1.18 minutes between the ultrasound and standard techniques. The study concluded that there no significant time difference between the two techniques. However, this contrasted with the study by Loon et al. [12] which found a pooled mean difference of 4.74 minutes for the UGPIC, compared to the SOC group.

Patients' and clinicians' satisfactions

The goal of every procedure is to provide care in an effective and safe manner, while ensuring the comfort and satisfaction of both patients and clinicians. Patients' satisfaction is a measure of the level of acceptance or tolerance of the procedure by the patients in comparison with their expectations and perceptions. According to Hamadeh and Hammoud (2019), patients' satisfaction forms part of criteria for the accreditation of health institutions in proving the quality of their care to patients. On the other hand, clinicians' satisfactions relate to efficiency, reliability, ease of use and relative simplicity of the procedure and equipment.

This systematic review compared patients' satisfaction between the ultrasound guided and the standard techniques. Five studies included patients' satisfaction in their randomized control trials. They are Bauman et al. [25], Stein et al. [26], Weiner et al. (2013), Ismailoglu et al. (2014) and Bridey et al. [27]. While four of the studies presented patients' satisfaction in Likert Scale, Ismailoglu et al. (2014) reported this measure as pain score. These scales are inversely related. They are therefore, discussed separately.

Figure 4 presents patients' satisfaction from four of the studies included in this review (in the Likert Scale). It is evidence from the analysis that patients in the UPGIC group reported higher satisfaction in most of the studies, except in Bridely et al. [27] in which the SOC

Table 2: Characteristics of the 9 studies included in the systematic review, comparing ultrasound-guided cannulation (UPGIC) and the standard of care (SOC) techniques of peripheral intravenous cannulation.

S/N	Name of First Author	Year of publication	Study design	Sample size	Sample size distribution		Average Age		Female %		Operators	1st successful cannulation %		Patients' satisfaction		Length of procedure		Number of Complications	
					UPGIC	SOC	UPGIC	SOC	UPGIC	SOC		UPGIC	SOC	UPGIC	SOC	UPGIC	SOC	UPGIC	SOC
1	Nishizawa	2020	RCT	60	30	30	74.2	79.4	50	33	Nurse	70	40	NR	NR	NR	8.1	3	4
2	Bauman	2009	RCT	75	41	34	48.2	45.9	32	22	ED Technician	80.5	70.6	7.9	4.4	13	30	3	1
3	Stein	2009	RCT	59	28	31	58.1	54.8	20	18	Physician	39.3	33.2	8	7	39	26	0	0
4	Kerforne	2012	RCT	60	39	21	61	56	11	15	Nurse	42.9	28.2	NR	NR	7.25	6.67	NR	NR
5	Bahl	2016	RCT	122	63	59	56.25	56.25	47	43	Nurse	76.2	55.9	NR	NR	20.7	15.8	NR	NR
6	Weiner	2013	RCT	50	29	21	46.2	53	21	12	Nurse	75.9	47.6	8.6	6.3	27.6	26.4	NR	NR
7	Aponte	2007	RCT	35	19	16	55.5	57.3	15	12	Nurse	74	81	NR	NR	5.06	2.87	NR	NR
8	Ismailoglu	2014	RCT	60	30	30	NR		63	53	Physician	20	10	4.8 (ps)	6 (ps)	NR	NR	9	14
9	Bridey	2018	RCT	112	56	56	46.92	46.92	65	62	Nurse	41	33	8	8.1	NR	NR	20	16

PS: Pain Score

group reported satisfaction level of 8.1 against 8.0 in the UPGIC group. The studies by Bauman et al. [25], Stein et al. [26], Weiner et al. (2013), Bridey et al. [27] reported higher patients' satisfaction in the UGPIC than the SOC group (Figure 4). Although not included in the selected studies in this review due to out-of-range date of publication, the randomized control trial study by Constantino et al. [5] reported satisfaction rate of the UPGIC group comprising 39 patients to be 8.7 in the Likert Scale, compared to the SOC Group (29 patients) at 5.7 in the Likert Scale.

As stated previously, Ismailoglu et al. (2014) presented patients' satisfaction as pain scores which indicate the severity of pain experienced by patients in the scale of 1-10. A higher pain score indicates less satisfaction. The UPGIC recorded pain score of 4.8 out of 10, compared to 6out of 10 in the SOC group. It follows therefore, that patients in the UGPIC group were probably more satisfied than the SOC group.

Overall, in this review, the mean satisfaction level for the UGPIC group is 8.1, compared to 6.5 in the SOC group (difference of 1.6 or 12.5%). In comparison with previous studies, Loon et al (2018) reported that patients who had cannulation through the ultrasound technique were associated with higher satisfaction level by 33% than those who underwent cannulation using the standard technique. However, their review included only two studies with patient's satisfaction levels and may not be generalized as global reality. Similarly, the study by Quincy et al. [29] did not arrive at any definitive conclusions regarding patients' satisfaction due to data limitations and heterogeneity as only two studies included in their study had data on patients' satisfaction.

Therefore, this review can be credited for having included more data on patients' satisfaction than any previous reviews and could conclude that on the balance of probability of data heterogeneity and bias, the ultrasound guided peripheral IV cannulation offers more satisfaction to patients than the standard technique.

There was no direct measure of clinician's' satisfaction in the studies included in this review. However, it is common knowledge that repeated attempts in inserting cannulas in patients is always stressful. This takes the clinician's time and could delays in attending to other patients. Moreover, this may delay diagnosis and treatment of the patient. Clinicians' satisfaction can also be measured in terms of the cost effectiveness of procedures. Tan et al. (2016) carried out cost effective analysis of ultrasound-guided peripheral insertion of central catheters. Their study found from cost-effective ratio that the effectiveness index for the ultrasound group was 89.3%, compared to the standard method which recorded 59.2%. The study further indicated success rate for the ultrasound group as 99.3%, compared to 85.1% for the standard method. Patient's rating of satisfaction was 76.6% for the ultrasound group, versus 44.7% for the standard group. The satisfaction of clinicians can also be rated in terms of the flexibility, user-friendliness, and comfort of the ultrasound technique. Dougherty (2017) demonstrated the flexibility of UGPIC technique which allows cannulation to be achieved using one hand. This has led to enhancement of the satisfaction of clinicians who adopt the technique.

Other outcome measures: number of complications

Three of the studies included in this review reported a few complications that resulted from the UPGIC and SOC methods including hematoma, arterial puncture, extravasation, and nerve pain. Bauman et al. [25] presented four complications from the UPGIC method and 22complications from the SOC technique. For the UGPIC group, the complications included Hematoma which they reported in 12 of the patients (representing 29.3% of the patients), arterial puncture in 4 of the patients (9.8%) and transient nerve pain in 1 of the patients (2.4%). This translates to a cumulative complication from the UPGIC method of 41.5%. The study noted that none of the arterial punctures resulted in distal vascular damages. On the other hand, the SOC recorded 22 hematoma complications amounting to 64.7%. There was no record of arterial puncture and nerve pain in the SOC method recorded in the study of Bauman et al. [25].

The other study that presented results on rates of complications is Ismailoglu et al. (2014). The study reported 9 complications in the UPGIC group (representing 30% of the patients) and 14 complications in the SOC group (46.7%). The study did not list specific complications but noted that most complications were due to blind attempts to access the veins in patients with DIVA which led to vein damage, unintended entry into arteries and nerve damage. The study of Ismailoglu et al. (2014) differs slightly in the outcome of rate of complications from that of Bauman et al. [25] which showed complication rate of 41.5% in the SOC group, compared to 64.7% in the UPGIC group, amounting to 23.2% difference, compared to 16.7% recorded in the study of Ismailoglu et al. (2014).

Furthermore, Bridey et al. [27] reported extravasation and accidental cannula removal as the complications recorded from their study. The study presented 18 cases of extravasation (34%) and 2 cases of accidental removal (4%) in the UPGIC group, compared to 8 cases of extravasation (18%) and 6 cases of accidental removal (12%) in the

SOC group. This translates loosely to cumulative 38% complication cases in the UPGIC group, compared to 30% in the SOC group, a difference of 8%.

While it is apparent from this review and previous studies that the SOC method seems to record more complications than the UPGIC statistically, there is dearth of data to confirm this. It is a known fact that both approaches are prone to complications for various reasons. Rodríguez-Calero et al. (2020) categorized risk factors associated with difficult peripheral intravenous cannulation to include factors relating to demography and anthropometrics which include gender, Body Mass Index; underlying medical and health conditions such as diabetes, renal insufficiency, parenteral drug abuse, cancer chemotherapy as well as factors related to the vein or vascular morphology which relate to the visibility and palpability of the veins, vessel diameter and previous history of difficulty in venous access. Some studies have further noted factors related to the expertise and experience of the clinicians performing the procedure. For example, the study of Carr et al. [31] demonstrated a close link between previous number of successful cannulation performed by a professional, the rate of first attempt success and complications.

Summary and Conclusions

This study has examined the impact that ultrasound-guided intravenous cannulation has made in the care of patients with difficult venous access. The results have shown that the UGPIC technique increases the chances of first attempt intravenous cannulation. This finding agrees with previous studies. For instance, Egan et al. [30] reported first attempt UGPIC success rate of 78% compared to the conventional method of cannulation. Although the difference in length of procedure between the techniques is not substantial statistically, the UGPIC increases patients' satisfaction because of few skin punctures. Besides, the UGPIC technique helps to prevent the discomfort and complications caused by missed or multiple attempts which are characteristics of the traditional procedure, including infections, abscesses, emboli, phlebitis, thrombosis, bleeding, venous blood leakage and injuries from needle stick [31,32]. Furthermore, because of the need to assess the efficacy of the ultrasound techniques, Keys et al. [6], investigated the use of ultrasonography in the placement of peripheral intravenous access. Their results showed that the technique enabled the successful cannulation in 91% of patients with difficult intravenous access. In addition, the ultrasound guided IV cannulation technique is famed for its relative ease of use. This has led to enhancement of the satisfaction of clinicians who adopt the technique.

The results in this study suggest that the UPGIC can improve the efficiency, quality and satisfaction of patients who encounter difficult venous access from the standard of care technique. This has implications for care of patients in hospitals and other healthcare settings, especially in the emergency departments where prompt access of veins, timely and safe cannulation are crucial in critically ill patients and patients with difficult intravenous access.

There are limitations in this study. Few of the studies included in the study have medium to high risk of bias while the rest have low risks. Also, some of the randomized control tests have unequal number of patients for the two groups. This has the potential to introduce some bias and errors. It is also important to note that this study did not apply meta-analysis to analyse and present the data. Although some basic statistical analyses were performed, the study would benefit from meta-analysis for a more robust and rigorous exploration, interpretation and presentation of the data and findings. This is a recommendation for further consideration.

Ethical Issues, Practical and Professional Factors

NHS Data governance, patients' consent, confidentiality, and anonymity

According to the NHS Health Research Authority (NHS HRA), patients' consents and ethics should be at the core of health and social care research. Therefore, utmost attention must be paid to the patients' rights to confidentiality. Patients' information must be kept confidential and anonymous, and no information must be shared without the express informed consent of the patients. To achieve this, all data and patients' information were stored in encrypted and secure devices. Data governance rules were strictly observed as the study involved use of data for analysis.

Observing "good" health and social care research conduct

The NHS Health Research Authority (HRA) defines "good" health and social care research as one that is safe, sound in science and ethics, with approval; legally compliant and insured/indemnified; respects patients' right to voluntarily participate; justifiably considers patients' welfare before, during and after the research while documenting changes securely and observing duty of care; guarantees integrity, equality and transparency, and involves competent professionals who are aware of any safety/risk issues.

Practical issues

Sample size: Care was taken to ensure that selected publications were representative of the required population in terms of size, gender and age.

Research design: For accurate insights into the success of the UGPIC, a blind sample subset needs to be created comprising patients who have used the traditional technique for IV cannulation for patients with DIVA to allow for comparison. As this is a retrospect study, it was challenging to create such subset. However, the results from the study will were compared with historical data of patients who have used the traditional methods at the corresponding period under study.

Operational issues: Screening all the published papers identified during the search was challenging. Some of the publications were not free to download and use. The university library was consulted to retrieve some of the papers. This caused delay, while some were never accessed. Some papers were also written in other languages and had to be deselected and dropped.

Professional consideration

Technical knowhow: The UGPIC is highly technically driven. Although clinicians have been adequately trained in the technique, individual abilities which could affect success rates cannot be ruled out. However, it is expected that this limitation would normally cancel out by the randomisation of clinicians involved in the process.

Research design and Statistical skills: The mixed method is not straightforward to design as it combines both quantitative and qualitative methods. Furthermore, analysis of data acquired from the mixed methods would require competence in applying the statistical packages for the analysis. This was avoided since the study did not involve meta-analysis and only basic statistical analysis was performed using the Excel Spreadsheet.

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