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Ultrasound guided internal jugular vein access in children and infant: A meta-analysis of published studies

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Summary

Introduction: Central venous catheter placement is technically difficult in pediatric population especially in the younger patients. Ultrasound prelocation and/or guidance (UPG) of internal jugular vein (IJV) access has been shown to decrease failure rate and complications related to this invasive procedure. The goal of the present study was to perform a systematic review of the advantages of UPG over anatomical landmarks (AL) during IJV access in children and infants.

Material and methods: A comprehensive literature search was conducted to identify clinical trials that focused on the comparison of UPG to AL techniques during IJV access in children and infants. Two reviewers independently assessed each study to meet inclusion criteria and extracted data. Data from each trial were combined to calculate the pooled odds ratio (OR) or the mean differences (MD), and their 95% confidence intervals [CI 95%]. I^2 statistics were used to assess statistics heterogeneity and to guide the use of fixed or random effect for computation of overall effects. Subgroup analysis was used to clarify the effects of the techniques used (prelocation or guidance) or the experience of practitioners.

Results: Literature found five articles. Most of the patients were cardiac surgery patients. In comparison with AL, UPG had no effect on IJV access failure rate (OR = 0.28 [0.05, 1.47], I^2 = 75%, P = 0.003), the rate of carotid artery puncture (OR = 0.32 [0.06, 1.62], I^2 = 68%, P = 0.01), haematoma, haemothorax, or pneumothorax occurrence (OR = 0.40 [0.14, 1.13], I^2 = 17%, P = 0.30, OR = 0.72, OR = 0.81 [0.18, 3.73], I^2 = 0%, P = 0.94, respectively) and time to IJV access and haemothorax/pneumothorax occurrence. Subgroup analysis found an efficacy of ultrasound when used by novice operators or during intraoperative use.

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Discussion: This current meta-analysis does not found the utility of ultrasound during IJV access in children and infants in increasing the success rate and in decreasing complications.

Keywords: Haematoma; internal jugular vein; internal carotid artery; pneumothorax; ultrasound

Introduction

Central venous catheter placement is technically difficult in pediatric population especially in the younger patients. Subclavian vein access is associated with a high rate of complications, and the internal jugular vein (IJV) access is subject to many anatomical variations (1,2).

Ultrasound prelocation and/or guidance (UPG) during IJV access has increased popularity among pediatric anesthesiologists (3). Many studies in adult and pediatric populations have proven the higher success rate and a decreased incidence of complications, when ultrasound techniques by either prelocation or intraoperative guidance are used (4). Additionally, ultrasound devices have become smaller, much precise, less expensive, and widely used in many other anesthesia areas (regional anesthesia, intensive care) (3).

Many studies have been conducted to evaluate the advantages of ultrasound guidance of IJV catheter placement. However, no recent article addresses a systematic analysis of the studies focusing on this topic in children and infant (4). The goal of the present study was to perform a meta-analysis on the advantages of using the ultrasound prelocation and/or guidance, in comparison with the classical anatomical landmarks (AL) technique during IJV access in children and infants.

Material and methods

Bibliographic search and analysis

We conducted this meta-analysis according to the guidelines of the Cochrane Handbook for systematic reviews of intervention and the QUORUM statements(5).

Literature databases include Pubmed and Embase. The following queries were used: 'ultrasound and internal jugular and infants or children'. Only English published articles were considered for this meta-analysis.

The articles obtained from these queries were independently analyzed by two anesthesiologists, and those meeting the following criteria were included in the analysis: comparison between ultrasound guidance and anatomical landmarks, randomized controlled study. In addition, a manual search of the references found in the selected articles, reviews, and meta-analysis was also performed. The date of the most recent search was April 2009.

Data considered for this meta-analysis were age of the patients, indication of central venous access. Outcomes extracted from studies and entered in the analysis were failed of IJV access (as defined by each author), carotid artery puncture, hematoma at puncture site, and pneumothorax and/or hemothorax. When conflicting results were found, the concerning article was checked twice by two other independent anesthesiologists.

Statistical analysis

Statistical analysis was performed using the REVIEW MANAGER 5 software (REVMAN 5; The Cochrane Collaboration, Oxford, United Kingdom). When original data were expressed as continuous variables, median and ranges were first transformed to mean and standard deviation according to the formula of Hozo SP and collaborators (6). Meta-analysis was performed using the mean difference or the standardized difference computed by a fixed or a random effect model. In the case of percentage results, the analysis was performed using the odds ratio (OR and its [95% confidence intervals]) computed using the fixed or the random model of Mantel–Haenszel method. The OR represents the odds of the outcome occurring in the UPG group compared with the anatomical landmark group.

A confidence interval of the OR below 1 indicates the efficacy of the therapeutic in preventing failure or complications.

Heterogeneity was accessed using I^2 statistics. According to the Cochrane review guidelines[1], an $I^2 > 40\%$ and a $P < 0.1$ are considered as the threshold for heterogeneity and indicate the use of a random effect in OR (or mean difference) computation. Subgroup analysis was undertaken in all cases according to the ultrasound technique used (prelocation or intraoperative guidance) and to the experience of the operator.

In case of studies with more than one intervention group, each one was considered as a study in the meta-analysis and compared to the control group. Finally, to avoid computation problems related to zero effectives, a 1 was added to all groups in these cases.

Results

Using the selected criteria, 167 articles were found. Articles analysis allows us to select five relevant articles (2,7–10). The details of the selection process are summarized in Figure 1.

The current meta-analysis included only five articles with an overall 359 patients. The descriptions of selected articles are summarized in Table 1.

Analysis found ultrasound guidance to have no influence on the rate of IJV access failure (OR = 0.28 [0.05, 1.47], $I^2 = 75\%$, $P = 0.003$; Figure 2) and the time spent to access the IJV (mean difference (minutes) = −1.04 [−2.85, 0.04], $I^2 = 878\%$, $P < 0.0001$; Figure 3a). Ultrasound guidance decreases the number of punctures required (mean difference = −0.81 [−1.10, −0.52], $I^2 = 0\%$, $P = 0.72$; Figure 3b).

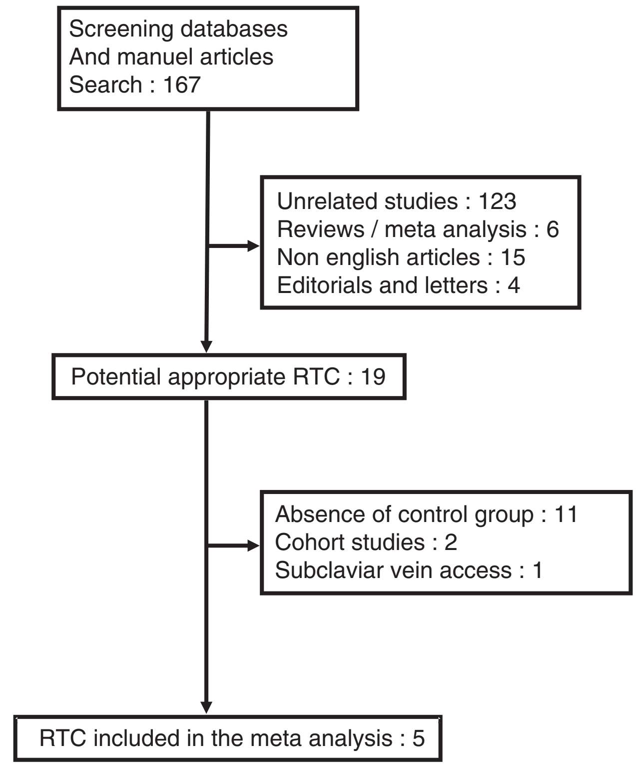

Figure 1
Meta-analysis flowchart. RTC: randomized controlled trials.

Concerning complications of IJV access, UPG was found to have no effect on the rate of carotid artery

Table 1
Characteristics of included studies

Authors, Year of publication	*Age (mean ± SD)*	*Weight (mean ± SD)*	*Surgery*	*Ultrasound technique*	*Practitioners*	*Failure U (%)*	*Failure L (%)*
Alderson PJ, 1993 (2)	281 ± 218 vs 258 ± 170 (days)	6.8 ± 2.5 vs 6.6 ± 2.5 (Kg)	Not defined	PL	Senior	0	20
Chuan WX, 2005 (7)	21 ± 13 vs 20.5 ± 12.83 (months)	8.9 ± 2 vs 8.8 ± 1.97 (Kg)	Cardiac Surgery	PL	Senior	0	20
Verghese ST, 1999 (8)	5.9 ± 4.4 vs 6.4 ± 3.8 (months)	5.8 ± 2/6.0 ± 2.3 (Kg)	Cardiac Surgery	IUG	Fellows	0	23.1
Verghese ST, 2000 (9)	5.4 ± 4.1 vs 5.1 ± 3.8 (months)	6 ± 1.8 vs 5 ± 2.1 (Kg)	Cardiac Surgery	IUG	Fellows	6	18.7
Grabenic CR, 2004 (10)	2 days–7 year vs 1 day–8 year	8.9 ± 5.99 vs 8.57 ± 5.39 (Kg)	Cardiac Surgery	IUG	Senior	20	10.8

PL, prelocation; IUG, intraoperative ultrasound guidance; U, ultrasound; L, skin landmark.

[1]http://www.cochrane-handbook.org/ (Section 9.5.2)

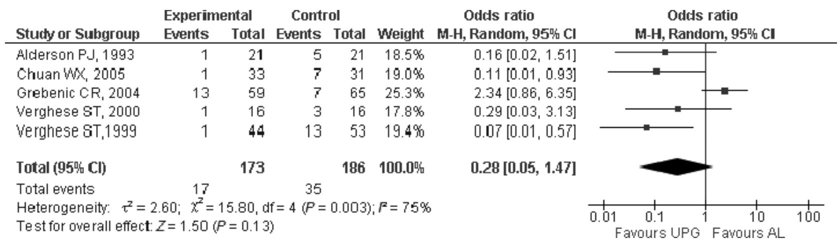

Figure 2
Forest plot of comparison of ultrasound prelocation and/or guidance (UPG) to anatomical landmarks (AL) on interval jugular access failure (2,7–10). The square in front of each study (first author and year of publication) is the odds ratio (OR) for individual trials, and the corresponding horizontal line is the 95% confidence interval (CI). The lozenge back in the figure is the pooled OR with the 95% confidence interval (CI).

puncture (OR = 0.32 [0.06, 1.62], I^2 = 68%, P = 0.01; Figure 4). It also failed to decrease haematoma, haemothorax, or pneumothorax occurrence (Figure 5 and 6; OR = 0.40 [0.14, 1.13], I^2 = 17%, P = 0.30, OR = 0.72, OR = 0.81 [0.18, 3.73], I^2 = 0%, P = 0.94, respectively).

Subgroup analysis, according to the technique of ultrasound used (prelocation or guidance), found two studies realized using prelocation technique by experimented practitioners (2,7) and three others that involved intraoperative guidance realized by either experienced or novice operators (8–10). We found both failure rate and inadvertent carotid artery puncture to decrease when prelocation was used during central venous access (OR = 0.13 [0.03, 0.61], I^2 = 0%, P = 0.80, OR = 0.16 [0.03, 0.77], I^2 = 2%, P = 0.31, respectively). Conversely, analysis found both failure rate and inadvertent carotid artery puncture to be unaffected by the use of intraoperative ultrasound guidance (OR = 0.42 [0.04, 4.57], I^2 = 80%, P = 0.005, OR = 0.41 [0.04, 4.83], I^2 = 80%, P = 0.008, respectively).

Subgroup analysis, according to the level of operator experimentation, found two studies realized in novice operators (using intraoperative ultrasound guidance) (8,9) and three others in experimented ones (using both prelocation and intraoperative ultrasound guidance) (2,7,10). Analysis found both failure rate and inadvertent carotid artery puncture to decrease in novice operators (OR = 0.11 [0.02, 0.52], I^2 = 0%, P = 0.38, OR = 0.11 [0.02, 0.48], I^2 = 0%, P = 0.34, respectively). Whereas there was no advantages of ultrasound in experimented operators (OR = 0.41 [0.04, 3.90], I^2 = 79%, P = 0.0.008, OR = 0.55 [0.06, 4.98], I^2 = 73%, P = 0.02, respectively).

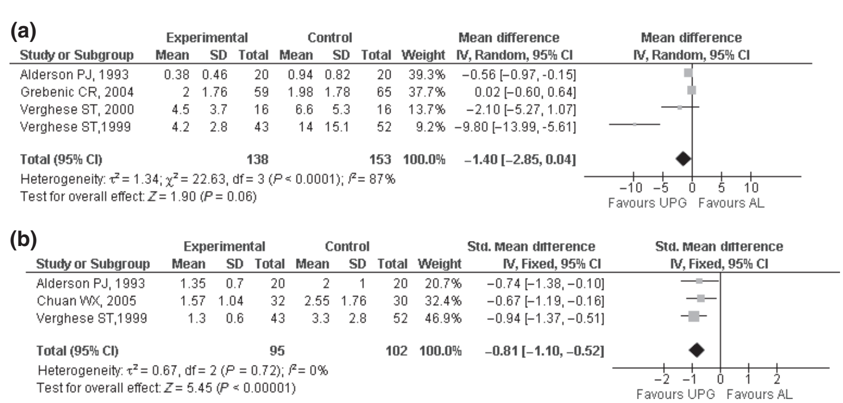

Figure 3
Forest plot of comparison of ultrasound prelocation and/or guidance (UPG) to anatomical landmarks (AL) on the time to achieve the access (3a) (2,7,8,10) and the number of puncture (3b) (2,8–10). The square in front of each study (first author and year of publication) is the mean difference (MD) or standardized mean difference (SMD) for individual trials, and the corresponding horizontal line is their 95% confidence interval (CI). The lozenge back in the figure is the pooled MD or SMD with their 95% confidence interval (CI).

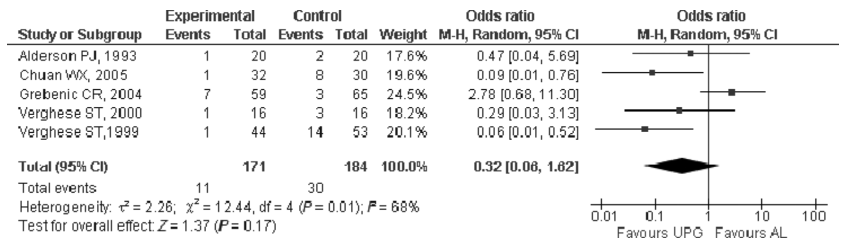

Figure 4
Forest plot of comparison of ultrasound prelocation and/or guidance (UPG) to anatomical landmarks (AL) on inadvertent internal carotid puncture (2,7–10). The square in front of each study (first author and year of publication) is the odds ratio (OR) for individual trials, and the corresponding horizontal line is the 95% confidence interval (CI). The lozenge back in the figure is the pooled OR with the 95% confidence interval (CI).

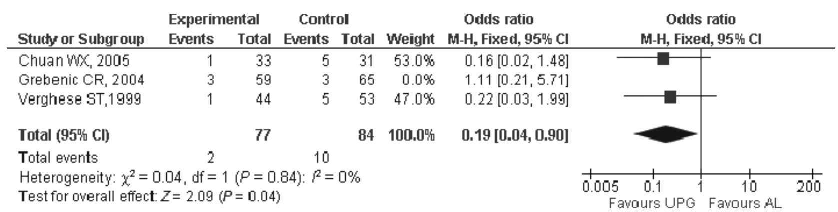

Figure 5
Forest plot of comparison of ultrasound prelocation and/or guidance (UPG) to anatomical landmarks (AL) on hematoma (7,8,10). The square in front of each study (first author and year of publication) is the odds ratio (OR) for individual trials, and the corresponding horizontal line is the 95% confidence interval (CI). The lozenge back in the figure is the pooled OR with the 95% confidence interval (CI).

Discussion

This meta-analysis is the first one addressing specifically the use of ultrasound during IJV catheterization in pediatric population. The main findings are that ultrasound guidance during IJV puncture had no effect on failure rate and complications associated with this invasive procedure.

Percutaneous central venous access is known to be more difficult in children than in adults (4,11,12). Investigations focusing on this topic have found many reasons to these difficulties. First, the small dimension of the IJV in children and infants (which is correlated to age and weight) makes its access more difficult than in adults (2,13). The smaller dimension of IJV in children increases the number of attempts; favors the changes in puncture points and the depth of needle insertion; and finally increases the risks of complications such as carotid artery puncture or pneumothorax. Second, many ultrasound studies have found variations in IJV position relative to the common carotid artery, with the IJV being anterior to the carotid artery in many cases (1,14–16). This position might also increase the risks of carotid artery puncture. Finally, some of these complications such as hematoma might induce changes in IJV position or even might cause an external compression, which will make its access more difficult even when ultrasound localisation is used as a rescue technique.

All these considerations make the use of UPG of a 'logical' interest during IJV access. According to the results found in both adult and children, recent NICE (National Institute For Clinical Excellence) has strongly recommended the use of two-dimension ultrasound during central venous catheter placement[2]. However, the results of the current meta-analysis disagree with this the current recommendations on this topic while it found UPG to have no effect on both rate success and complications. To investigate these results and explore their statistical heterogeneity, we undertook subgroup analysis based on the ultrasound technique used (prelocation versus intraoperative ultrasound guidance) and the experience of the operator.

Subgroup analysis found IJV access performed by novice operators to decrease failure rate and carotid

[2]http://www.nice.org.uk/nicemedia/pdf/Ultrasound_49_GUIDANCE.pdf

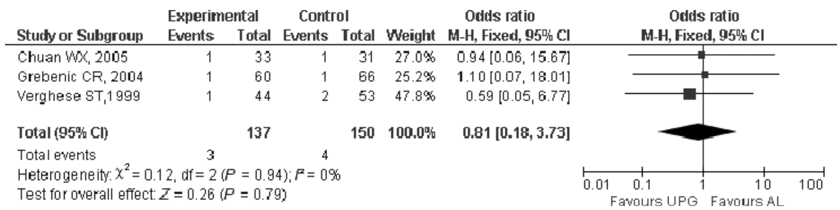

Figure 6
Forest plot of comparison of ultrasound prelocation and/or guidance (UPG) to anatomical landmarks (AL) on pneumothorax and/or haemothorax occurrence (7,8,10). The square in front of each study (first author and year of publication) is the odds ratio (OR) for individual trials, and the corresponding horizontal line is the 95% confidence interval (CI). The lozenge back in the figure is the pooled OR with the 95% confidence interval (CI).

artery puncture. Conversely, analyzing the studies performed by experimented operators found no evident advantages of using UPG during IJV access in children. These results highlight the effect of experience in the efficacy of UPG during IJV access in children and infant. Experimented operators have no benefice of using this technique while in novice ones UPG was of help in decreasing failure rate and inadvertent carotid artery puncture. Regarding the level of practice classically mandatory for central venous catheterization in children and infants, this highlights the importance of ultrasound guided IJV access in novice practitioners. Central venous access is usually performed by trained operators, which have a high rate of success making ultrasound of a lesser interest. Interestingly, except from one study, the level of skills was not well defined in the included articles leaving open the discussion on the effect of this factor on the present results. The experience of operators performing central venous access in children and infants might, at least partially, explain the discrepancy of the results observed between pediatric and adult population. In adult patients, central venous access is usually performed by both experimented and nonexperimented operators. Anatomical differences in adult and children could not explain the differences in ultrasound efficacy in IJV access while both populations exhibit variability in IJV position making ultrasound of a theoretical help in its location and puncture (1,15,17,18).

Prelocation instead of intraoperative ultrasound guidance was efficient in decreasing both IJV access failure and inadvertent carotid puncture. This result disagrees with a recent study that found preoperative guidance to faster the access to jugular vein in comparison with prelocation without impacting rate of complications (19). However, the high heterogeneity of this subgroup analysis could not allow valid conclusions. Otherwise, these results might also be dependant on other factors such as the experience with intraoperative ultrasound, which might negatively impact the results. Unfortunately, this factor was not detailed in included studies (excepts for Grebenick's (10)one) and could not be analyzed.

Included studies were published over a 12-year period, which might also participate to the heterogeneity. However, the technique of ultrasound does not change either using prelocation or using intraoperative guidance and still relies on internal jugular visualization.

Our results could not found a significant reduction in incidence of pneumothorax, probably because of the limited number of patients in regard to the low incidence of this event. Nevertheless, the reduction in this complication would be of a great concern in pediatric patients. Central venous access in children and infants is realized in anesthetized and ventilated patients; and pneumothorax in this circumstance may induce more respiratory and hemodynamic consequences than during spontaneous ventilation.

The study population included in the current meta-analysis was very homogenous regarding weights and ages (Table 1). In addition, this demographic characteristic has been associated with difficulties in IJV access and might also explain the high rate of failure (mean rate of 22%) close to that previously found in the other studies (4,11,20). However, a great heterogeneity was observed especially concerning the failure rate and the inadvertent carotid puncture. This heterogeneity was partially reduced by subgroup analysis, which indicates at least a partial role of these factors in this heterogeneity.

Publications bias was of a great concern. Authors are more prone to publish positive results than negative ones (especially concerning new techniques). This might had induced a publication bias that was undetectable with the available statistical tests while they necessitate the aggregation of 10 studies or more to be valid. In addition, such a bias can *per se* induce a statistical heterogeneity.

Position of the head and the landmarks chosen for IJV access has been shown by Schettini and Coll (14) and Ybarra and Coll (21) to influence the diameter of IJV, which in turns influence the difficulties in catheterization. Interestingly, the best position was not that classically used during IJV canulation in children (the contra lateral rotation of the head with a roll under the shoulder) but the neutral position without a roll and in the Trendelenburg position (14,21). The classical position described during adult IJV access used in all included studies might not be the most suitable in children and infants. Further studies on the efficacy of UPG have to focus on the effect of operative position.

Most of the studies included in this meta-analysis were performed in cardiac surgery patients (Table 1). This might induce a selection bias. These patients are usually requiring heart catheterization prior to surgery. In this circumstance, a prior IJV access might influence its position during performance of the study (22). In addition, a recent study emphasized the differences in IJV diameter according to the cyanotic or noncyanotic character of the illness (23). Consequently, additional evaluations of the benefice of UPG use are mandatory in other populations such as those requiring long-term central venous access for blood sampling, nutritional support, or hematology.

Finally, long-term complications such as catheter-related infections have not been addressed by the included studies (24). This might be of a great interest as decreasing the duration of the procedure might also influence the occurrence of such long-term complications.

In conclusion, the current meta-analysis has shown UPG to have no effects on both success rate and complications during IJV access in children and infant. However, this technique seems useful when used by novice operators or when limited to the prelocation of the vein.

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