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Ultrasound-guided central venous catheterization: what is the evidence?

Acesso venoso central guiado por ultrassom: qual a evidência?

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ABSTRACT

In recent years, international health quality assurance organizations have been recommending ultrasound guidance for central venous punctures. This article reviews the evidence behind these recommendations.

The MEDLINE, PubMed and SCIELO databases were searched for the following MeSH terms: central venous access, ultrasonography, and adults. The search was conducted on September 24, 2010, and selected meta-analyses, randomized clinical trials and reviews, retrieving 291 papers. The 21 most important papers were analyzed in this review.

The internal jugular vein is the most studied ultrasound-guided puncture site, with meta-analysis showing lower relative risks of failure and complications. In addition, the largest available randomized clinical trial demonstrated a reduced central venous catheter-associated blood stream infection rate. There are few studies involving subclavian vein puncture; however, ultrasound was shown to be beneficial in two meta-analyses (however, with small numbers of patients). Regarding the femoral venous site, only one randomized clinical trial (20 patients) was identified, showing positive findings. In a British cost-effectiveness study, ultrasound use lead to resource savings for different sites of venous puncture. There is strong evidence for ultrasound benefit for internal jugular vein puncture. Although the method appears attractive for the other sites, the data are not sufficient to support any recommendation.

Keywords: Central venous catheterization; Ultrasonography; Adult; Critical illness; Intensive care units

INTRODUCTION

Central venous puncture is extremely frequent in intensive care units (ICU).[1,2] It is estimated that more than 5 million central venous catheters (CVCs) are inserted yearly in the United States of America.[3] Despite its frequency, this procedure has risks and may be associated with severe complications, including death. The complication rate is estimated to be 15%, with 750,000 adverse events anticipated yearly, according to American data.[1,2,4] Therefore, routine measures to prevent these complications should be adopted to improve the quality of care in ICUs.[5,6]

Traditionally, CVC cannulation is based on anatomical landmarks. However, since 2001, the Agency for Healthcare Research and Quality (AHRQ) has been recommending 11 fundamental practices to improve the safety of this procedure for hospitalized and/or surgical patients, including

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ultrasound to guide central venous punctures.[7] This recommendation was based on a meta-analysis reviewing 8 randomized clinical trials that evaluated 514 patients of all ages.[8]

In 2002,[9] the National Institute for Clinical Excellence (NICE), a British organization focused on clinical practice excellence, also started recommending ultrasound support for central venous punctures. This recommendation was based on a new meta-analysis[10] that included 18 clinical trials involving 1,646 patients.

In spite of these recommendations, recent studies have shown that ultrasound guidance for central venous access is infrequently used in daily practice.[4,11] This article reviews the evidence in support of this practice and evaluates the available cost-effectiveness studies.

METHODS

The literature was reviewed by searching MEDLINE via PubMed using the following Medical Subject Heading (MeSH) terms: central venous catheterization, ultrasonography and adult. The same words, translated into Portuguese, were used to search SCIELO. A focused search was performed to identify the most frequently mentioned papers. In the last review (September 2010), 291 articles were identified and 21, which were considered to be the most relevant, were selected. The article selection criteria were as follows: adult patient population, ICU stay, and procedures conducted by intensive care physicians. Additionally, we preferentially choose meta-analyses, large-population randomized clinical trials (ideally more than 100 patients), large simple trials, and review articles.

The results were categorized by puncture site as relative risks (RRs) or percentage comparisons. Cost effectiveness data are described in the final section of this review.

RESULTS

Internal jugular vein

This is the most studied site for ultrasound support use.[5,12] Ultrasound can be either "static" (vessel identification and location before puncturing) or "dynamic" (real-time, i.e., during the puncture). According to the study by Milling et al., in which 201 patients were randomized into 3 groups (anatomical landmarks, static ultrasound and dynamic ultrasound), the best results, accordingly controlled by a pre-test difficulty evaluation, were achieved using the dynamic technique, with a success ratio of 53.5 (95%CI 6.6-440) and a first attempt cannulation rate of 5.8 (95%CI 2.7-13) compared to the use of anatomical landmarks alone.[13] This study has also demonstrated the benefits of static ultrasound versus the use of anatomical landmarks; static ultrasound had a success ratio of 3 (95%CI 1.3-7) and a first attempt cannulation ratio of 3.4 (95%CI 1.6-7.2).[13]

The first meta-analysis of the use of ultrasound in CVC was conducted by Randolph et al. (7 trials, evaluating the internal jugular vein, n=426), showing a puncture failure relative risk (RR) of 0.38 (95%CI 0.18-0.55) and a complications RR of 0.26 (95%CI 0.11-0.58) for the use of ultrasound.[8] Later, in the NICE-sponsored meta-analysis, eleven studies evaluated internal jugular vein access (7 using two-dimensional ultrasound and 4 supported by the Doppler technique, n=581).[10] The RR for catheter placement failure was 0.14 (95%CI 0.06-0.33; P<0.0001), and the RR for complications was 0.43 (95%CI 0.22-0.87). This meta-analysis also revealed a 1.5-fold reduction in the number of attempts and a reduction in the time required to achieve cannulation (P<0.02).[10]

In the largest clinical trial identified on this subject, Karakitsos et al. evaluated 900 punctures of critical patients, showing a higher success rate (100% vs. 94.4%; P<0.001), fewer attempts (1.1 vs. 2.6; P<0.001), and fewer complications (1.5% vs. 23.15%; P<0.001) for the ultrasound-guided group. In this study, the incidence of CVC-related blood stream infections was lower (10.4% vs. 16%; P<0.001); this endpoint was not evaluated in the previous trials.[14]

A summary of the data considered relevant to ultrasound-supported internal jugular puncture is shown in table 1.

Subclavian vein

A meta-analysis by Randolph et al.[8] evaluated only 2 trials (n=88); the failure RR was 0.15 (95%CI 0.04-0.53) and the complications RR was 0.11 (95%CI 0.02-0.56). More recently, Hind et al.[10] analyzed the results of 4 subclavian vein puncture trials [3 that involved two-dimensional ultrasound (n=52) and 1 that involved Doppler (n=614)]. For two-dimensional ultrasound, the puncture failure RR was 0.14 (95%CI 0.06-0.33), and the complications RR was 0.10 (95%CI 0.01-0.71). Compared to the traditional Doppler technique, anatomical landmarks results were better for the two-dimensional ultrasound technique (fewer failures and faster punctures).[10]

Table 1 – Summary of the more relevant findings for ultrasound-guided internal jugular vein puncture

Internal jugular vein		
Variable evaluated	Effect	Reference
Failure rate	Reduced	Randolph[8] (N = 426) RR = 0.38 (95%CI 0.18 – 0.55) Hind[10] (N = 608) RR = 0.14 (95%CI 0.06-0.33)
Complication rate	Reduced	Randolph[8] (N = 426) RR = 0.26 (95%CI 0.11 – 0.58) Hind[10] (N = 608) RR = 0.43 (95%CI: 0.22 - 0.87)
Infection rate	Reduced	Karakitsos[14] (N = 900) 10.4 vs. 16%; p < 0.001
Costs	Reduced	Calvert[16]
Evidence level	Strong	Most studied site[5,8,10,12,13] Specialized origination recommendations[7-10]

RR = relative risk

Femoral vein

Only one randomized clinical trial (n=20) has evaluated femoral vein puncture. In this trial, which was conducted in an emergency room setting during cardio-respiratory resuscitation maneuvers, ultrasound was shown to be useful, with a higher success rate (90% vs. 65%; P=0.05) and fewer arterial punctures (0% vs. 20%; P=0.02) versus traditional puncture.[15]

Cost-effectiveness

The only available cost-effectiveness study was the a meta-analysis conducted in Britain.[10] According to Calvert et al., even in a model that is considered conservative, the routine use of ultrasound to guide central venous puncture (irrespective of the site) was cost saving.[16]

DISCUSSION

There is strong evidence supporting the use of ultrasound-guided central venous puncture for internal jugular vein puncture, as increased success rates and reduced complication rates have been observed.

However, there is still resistance to adopting this recommendation, and the ultrasound-guided technique is not widely used,[4,11] likely because of cost-related concerns and because of time and training requirements.[5,12,17] The difficulty of implementing research findings into clinical practice is well known. This difficulty is particularly true for critically ill patients, where interventions may have an immediate and significant impact on mortality. Additionally, it has been shown that it may require up to 20 years before a new therapy becomes routine.[18]

Regarding the costs related to this new technique, in the single evaluation available in the literature, the authors concluded that from the viewpoint of the British economy, this technique is cost-effective and may improve hospital cost allocation.[16]

The time expenditure for ultrasound-guided puncture was evaluated by several studies, and the cannulation time was shown to be reduced (most likely because of the reduced number of attempts).[10,13,14] According to a meta-analysis, the Doppler technique does not improve the results (and was considered technically slower and more difficult to learn).[10]

Regarding training, there is a special concern regarding inexperienced operators, as several trials evaluating central venous catheterization guided by anatomical landmarks have shown a negative correlation between the complication rate and experience.[3,19] Therefore, it is necessary to establish training recommendations in addition to competencies and proficiency in central venous punctures using ultrasound guidance.[20] A training suggestion for intensive care physicians who are already proficient in the traditional catheterization method physicians would be 2 hours of theoretical training, 2 hours of laboratory/experimental model training and 5-10 supervised procedures.[4]

Regarding the subclavian and femoral sites, although ultrasound support is promising, more studies are warranted to determine its safety and benefit.

Because the subclavian vein is close to some

Table 2 – Summary of the more relevant findings for ultrasound-guided subclavian vein puncture

	Subclavian vein	
Variable evaluated	Effect	Reference
Failure rate	Reduced	Randolph[8] (N = 88) RR = 0.15 (95%CI 0.04 – 0.57) Hind[10] (N = 52) RR = 0.14 (95%CI 0.06 – 0.33)
Complication rate	Reduced	Randolph[8] (N = 88) RR = 0.11 (95%CI 0.02 – 0.56) Hind[10] (N = 52) RR = 0.10 (95%CI 0.01 – 0.71)
Infection rate	Unknown	None
Costs	Reduced	Calvert[16]
Evidence level	Weak	Few studies and expert opinions[5,8,10,12] Technical difficulty – expert opinions[5,12]

RR = relative risk

Table 3 – Summary of the more relevant findings for ultrasound-guided femoral vein puncture

	Femoral vein	
Variable evaluated	Effect	Reference
Failure rate	Reduced	Hilty[15](N = 20) 90% vs. 65%; p = 0.05
Complication rate	Reduced	Hilty[15] (N = 20) Arterial punctures: 0% vs. 20%; p = 0.02
Infection rate	Unknown	None
Costs	Reduced	Calvert[16]
Evidence level	Weak	Single study and expert opinions[5,10,16]

important structures (the lungs, the subclavian artery and the brachial plexus), its puncture may be associated with significant morbidity.[1,3] The main limitation for ultrasound use as support for this type of catheterization is the deep location of this vessel and the technical limitations imposed by the clavicle's acoustic shadow, as bones cannot transmit ultrasound waves.[5,12] An alternative technical option would be axillary puncture, approaching the subclavian vein laterally (at the shoulder level).[5,12,17]

Table 2 summarizes our findings; however, the data are still considered insufficient to allow specific recommendations to be made regarding subclavian site ultrasound-guided central venous puncture.

Regarding the femoral site, studies have shown that vessel superposition is much more frequent than the text-books descriptions of the vessels.[12] However, as shown in table 3, given the lack of ultrasound guidance studies for this site, its advantages, if any, cannot be determined.

Based on this review, we suggest that ultrasound guidance should be routine for internal jugular vein punctures; however, we consider this technique to be investigational for both subclavian and femoral site punctures.

The generalization and training standardization of this method should be a target for our specialty, as it already is for some medical societies, namely the College of Emergency Physicians (ACEP), the European Federation of Societies for Ultrasound in Medicine and Biology and the World Interactive Network Focused on Critical Ultrasound (WINFOCUS).[5]

CONCLUSION

There is strong evidence supporting the benefits of ultrasound-guided internal jugular vein puncture (including cost-effectiveness). This technique should be incorporated into our routine intensive care services. Although this method is apparently attractive for use at other sites, additional studies are still required to support any recommendation.

RESUMO

Recentemente, órgãos internacionais de qualidade em saúde passaram a recomendar o uso de orientação ultrassonográfica para punções venosas centrais. O objetivo deste artigo foi revisar as evidências fundamentando tais recomendações.

Foi revisada a literatura no MEDLINE, PubMed e SCIELO com os seguintes termos (MeSH): acesso venoso central, ultrassom e adultos. A pesquisa realizada em 24/09/2010, com seleção de metanálises, ensaios clínicos randomizados e revisões, encontrou 291 artigos. Os 21 artigos mais importantes foram utilizados para a confecção desta revisão.

A veia jugular interna é o local mais estudado para punções guiadas por ultrassonografia, com metanálises demonstrando menor risco relativo de falha e de complicações. Além disso, o maior ensaio clínico randomizado disponível também demonstrou redução na incidência de infecções de corrente sanguínea associadas aos cateteres venosos centrais. Poucos estudos existem com relação à punção da veia subclávia, porém o uso do ultrassom mostrou-se benéfico em duas metanálises (mas com um número pouco expressivo de pacientes). Quanto ao sítio venoso femoral, há apenas um ensaio clínico randomizado (20 pacientes), o qual obteve resultados positivos. Em uma avaliação britânica de custo-efetividade, houve economia de recursos com o auxílio do ultrassom na realização das punções venosas nos diferentes sítios.

Fortes evidências demonstram benefício com o auxílio ultrassonográfico para punção jugular interna. Embora o método pareça atraente para os demais sítios, ainda não há estudos suficientes que sustentem alguma recomendação.

Descritores: Cateterismo venoso central; Ultrassonografia; Adulto; Doença crítica; Unidades de terapia intensiva

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