

Safety of a training program for ultrasound-guided internal jugular vein catheterization in critically ill patients

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SUMMARY

Objectives: Evaluate the safety and effectiveness of a training program for performing ultrasound-guided internal jugular vein cannulation in critically ill patients. **Methods:** Cohort prospective study, evaluating adult patients admitted in a teaching intensive care unit (ICU). Catheter placement was performed by an ICU medical resident. The patient's baseline characteristics, vessel's position and operator experience were the evaluated variables. The main outcomes were cannulation success rate and incidence of major complications. **Results:** A total of 118 consecutive patients were enrolled between May 2008 and November 2009. The success rate of ultrasound guided catheter placement was 90% (106/118), 77% in the first attempt. Major complications occurred in 4% of the cases (n = 5) and were not associated with the analyzed variables. Inability to place the guide wire was the reason for 58% (7/12) of the failures. Operators with more than 15 previous ultrasound guided cannulations had an increased success rate (95% vs. 79%, p = 0.01) and increased failure was related to previous catheterization (26% vs. 7%, p = 0.02). **Conclusion:** Learning ultrasound guidance for IJV vein cannulation was safe and feasible in ICU patients. This process was not associated to complications and better results were achieved across the spectrum of operator experience.

Keywords: Catheterization, central venous; ultrasonography; education medical.

RESUMO

Segurança de um programa de treinamento para punção de veia jugular interna guiada por ultrassom em pacientes críticos

Objetivo: Avaliar a segurança e efetividade de um programa de treinamento para cateterização da veia jugular interna guiada por ultrassom em pacientes críticos. **Métodos:** Estudo de coorte prospectivo, avaliando pacientes adultos internados em uma unidade de terapia intensiva com programa de ensino. Os médicos residentes do serviço realizaram as punções de veia jugular interna guiadas por ultrassom. Foram avaliadas as características de base dos pacientes, sintopia dos vasos e experiência dos operadores. Os desfechos primários foram a taxa de sucesso da cateterização e a incidência de complicações graves. **Resultados:** No período entre maio de 2008 e novembro de 2009 foram avaliados 118 pacientes. A taxa de sucesso da punção guiada por ultrassom foi 90% (106/118), 77% dessas na primeira tentativa. Complicações graves ocorreram em 4% dos casos (n = 5) e não foram associadas às variáveis analisadas. Incapacidade de progredir o fio-guia foi a razão de 58% (7/12) das falhas. Operadores com mais de 15 punções guiadas por ultrassom obtiveram uma maior taxa de sucesso (95% vs. 79%, p = 0,01) e pacientes com cateterização prévia apresentaram um maior número de falhas (26% vs. 7%, p = 0,02). **Conclusão:** O aprendizado da técnica de punção de veia jugular interna guiada por ultrassom é seguro e efetivo em pacientes críticos. Este processo não esteve associado a um aumento da taxa de complicações e melhores resultados são obtidos à medida que aumenta a experiência do operador.

Unitermos: Cateterismo venoso central; ultrasonografia; educação médica.

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INTRODUCTION

Central venous catheters (CVCs) placement remains a cornerstone procedure in the intensive care unit (ICU) setting. However, this procedure can lead to serious and sometimes life-threatening complications^{1,2}. Mechanical complications occur in approximately 21% of placements, and up to 20% of insertion attempts in the internal jugular vein (IJV) are not successful^{3,4}.

Several authors^{5,6} support a clear benefit of two-dimensional ultrasound guidance for central venous access – especially in the IJV – compared with landmark method. The Agency for Healthcare Research and Quality (AHRQ) in the United States and the National Institute of Clinical Excellence (NICE) in the United Kingdom recommend it as a better practice and that it should be incorporated to the routine care^{7,8}.

Despite the evidence, the incorporation of these recommendations has been met with resistance and it has not been widely adopted³, probably because concern of costs and time demand⁹⁻¹¹. There is a well-recognized issue of difficulties in implementing knowledge coming from research into clinical practices. This is particularly true for critically ill patients where interventions can have an immediate and large effect on mortality. Also, it has been shown that a newly proven therapy may take up to 20 years to become standard of care¹².

In addition, there is a special concern related to inexperienced operators, as multiple studies have demonstrated a negative correlation between the frequency of complications and operator experience^{2,4}. So, there is a need to establish recommendations on training, competence and proficiency in ultrasound use for diagnostic and therapeutic procedures, including CVC placement¹³.

In this setting, the aim of this study was to evaluate the safety of a training program for ultrasound-guided IJV catheterization in a critically ill population.

METHODS

DESIGN

Prospective cohort study, single-center, evaluating adult patients admitted in a 31-bed teaching multi-disciplinary intensive care unit (ICU). The inclusion criteria were: 1) admission in the ICU; 2) adult patient (age over 18 years old); 3) indication of central venous access by the attending physician; and 4) obtained informed consent to perform the procedure. The exclusion criteria were: 1) contraindication to jugular vein cannulation (e.g. ultrasound detected vessels thrombosis, local infection); 2) guidewire exchanges; or 3) placement of the central venous catheter in another vessel requested by the attending physician.

TRAINING AND PROCEDURE

All catheters placement were performed by an ICU medical resident, with previous landmark cannulation

experience of over 50 procedures. They begin to perform ultrasound-guided internal jugular vein catheterization after a standard training period – a minimum of 2 hours of didactics and at least five proctored procedures³. During the 2-year program of intensive care medicine residency, several lectures and courses were directed to point-of-care ultrasound learning (some specifically to central venous catheterization guided by ultrasound), and to development of the techniques and safety of the procedures.

An ultrasound machine (Adora Sonoline[®]; Siemens, Germany) was always available in the ICU and ultrasound-guidance was performed with a 7.5-MHz linear probe. Medical residents performed B-mode real-time ultrasound guidance during all catheterizations (even emergencies), using the free-hand technique (single operator). Most of the CVCs placements were done with short axis guidance, but the choice of axis was determined by personal preference.

Surveillance for complications was performed until the catheter was removed or the patient was either transferred to the ward or died.

DEMOGRAPHICS AND OUTCOMES

The baseline characteristics were evaluated, as well as the landmark technique's risk factors for difficult placement or mechanical complications^{3,11,14,15}. These risk factor were defined as the presence of: shock (systolic arterial pressure ≤ 90 mmHg or being receiving vasopressors); untreated coagulopathy (platelets $< 100,000$, INR > 1.5 , TTPa > 1.5 x control); use of invasive or non-invasive mechanical ventilation; prior catheterization; previous difficulties during catheterization; generalized edema; cervical or thoracic deformity and emergency procedure (predefined as immediate use, before performing a control radiography). The researchers also evaluated the description of the reason for catheter placement failure, operator experience (counting the number of ultrasound-guided procedures) and vessel's position (related to the carotid artery).

The main outcomes were IJV's ultrasound-guided cannulation success rate (defined as placement of a functional catheter) and incidence of major complications. Daily, the researchers checked the patient status for major complications, such as: pneumothorax, hemothorax, clinically significant local hematoma (predefined as a hematoma that could compromise catheter use or compress adjacent structures) and catheter-related bloodstream infection (CRBSI). The definition of CRBSI followed the Centers for Disease Control and Prevention's (CDC) guidelines¹⁶.

STATISTICS

All data were expressed as mean \pm standard deviation (SD) or as a percentage. Differences between the two groups at baseline were analyzed with the use of Student's *t*-test and Chi-square test for categorical variables. All statistical

analysis was conducted with commercially available software (Statistical Package for Social Science - SPSS 13.0 Inc; Chicago IL, USA). Statistical significance was set at $p < 0.05$.

RESULTS

A total of 126 consecutive patients were evaluated between May 2008 and November 2009. Three patients were excluded because thrombosis was identified prior to the catheter insertion. Another five patients were excluded because of: inadequate registered data ($n = 1$), age under 18 ($n = 1$) or uncompleted training program ($n = 3$). Therefore, 118 patients were enrolled in the study. During this period five medical residents performed the training program and the procedures. Baseline demographics and patients characteristics are presented in Table 1.

Table 1 – Population characteristics

Demographic	Mean \pm SD
Age (years)	73 \pm 15
BMI	26 \pm 5.4
APACHE II	22 \pm 6.8
Days with catheter	8 \pm 7.1
	n (%)
Male gender	61 (51)
Mechanical ventilation (MV)	69 (58)
Invasive MV	61 (88)
Non-invasive MV	8 (12)
Diagnosis of shock	48 (40)
Emergency	40 (34)
Presence of coagulopathy	35 (30)
Thoracic deformity	20 (17)
Previous difficulty	13 (11)
Previous failure	12 (10)
Generalized edema	9 (7)

BMI, body mass index; APACHE II, acute physiology and chronic health evaluation.

With regards to the IJV's position, it was antero-lateral in 96/118 (81%) patients. Of the other cases, 21/118 (17%) were anterior or medial to carotid artery and 1/118 (0.8%) it was not visible.

The ultrasound-guided IJV cannulation success rate was 90% (106/118 patients), with most cannulations being successful on the first attempt (77%). Inability to pass the guide wire (58% - 7/12) and patient's agitation (25% - 3/12) were the most frequent reason for failures.

Once a recommendation about how many procedures should be performed to be proficient in ultrasound-guided central vein cannulation is not available at present time, we arbitrarily evaluated a cut-off of ≥ 15 insertions in order to

be considered an experienced operator. Success rate was higher when the procedure was done by experienced operators (95% vs. 79%, $p = 0.01$). The presence of risk factors for difficult venous cannulation was analyzed, and none was associated with complications. The only variable associated with increased failure was previous catheterization (26% vs. 7%, $p = 0.02$), and is described in Table 2.

Table 2 – Difficulty factors and failure incidence

Difficulty factor (n)	Failure (%)	p
Ventilatory support (69)	6 (8)	ns
Diagnosis of shock (48)	4 (8)	ns
Emergency (40)	2 (5)	ns
Presence coagulopathy (35)	5 (14)	ns
Thoracic deformity (20)	2 (10)	ns
Previous catheterization (19)	5 (26)	0.02
Previous difficulty (13)	3 (23)	ns
Previous failure (12)	3 (25)	ns
Generalized edema (9)	1 (11)	ns

Major complications occurred in 4% (total of 5 cases - 2 arterial punctions, 1 arterial puncture with clinically relevant hematoma, 1 pneumothorax with clinically relevant hematoma and 1 clinically relevant hematoma), with no association with the studied variables. During the surveillance period there were no cases of hemothorax or CRBSI.

DISCUSSION

Traditionally, central venous access has been guided by anatomic landmarks such as bony prominences, muscle surfaces, and arterial pulsations. This "blind" approach to the central veins assumes anatomic homogeneity, does not account for the possibility of thrombosis, and depends on correct discernment of the relationship among multiple anatomic landmarks^{9,10}. The IJV is typically seen anterior and lateral to the artery; however, significant anatomic variation exists where the vein can overly the artery and even be medial to the artery. In our sample, the position of the internal jugular vein was anomalous (anterior or even thrombosed) in 20% of patients, justifying the use of ultrasound guidance.

Two meta-analysis support a clear benefit of two-dimensional ultrasound guidance for central venous access – especially in the IJV – compared with the landmark method^{5,6}. Randolph *et al.*⁵, demonstrated a relative risk of failed catheter placement of 0.38 (95% CI: 0.21-0.71), as well as a decrease in the relative risk of complications of 0.26 (95% CI: 0.11-0.58). In the NICE-sponsored meta-analysis, the relative risk of failed catheter placement was 0.14 (95% CI: 0.06-0.33, $p < 0.0001$), and the relative risk of complications was 0.43 (95% CI: 0.22-0.87, $p < 0.0001$)⁶.

After the implementation of a standard training program (a minimum of 2 hours of didactics and at least 5 proctored procedures), our ICU's medical residents were able to perform B-mode real-time ultrasound guided internal jugular veins cannulation, as recommended by the quality/excellence organs^{7,8}. Even more, using the free-hand technique (single operator) they achieved success in 90% of the attempts (34% were emergencies), similar as the success rates in the larger trials and meta-analysis (97-100%)^{5,6,15,17}.

There is a special concern related to inexperienced operators, as multiple studies have demonstrated a negative correlation between the frequency of complications and operator experience^{2,4,13}. Nonetheless, in our analysis the learning curve was not associated to complications, as we observed a low incidence of major complications (4%), also similar to the literature (2-12%)^{5,6,15,17}. Even so, better results were achieved across the spectrum of operator experience. As we described, ultrasound-assisted IJV catheterization increase success rate (95%) when executed by an operator with more than 15 previous ultrasound-assisted procedures.

Evaluating the difficulty factors to catheter placement^{3,11,14,15}, none was able to predict complications with ultrasound guided cannulation. The only factor that was associated with increased failure was previous catheterization. The main reason for failed attempts was inability to pass the guide wire (58%), which may be associated with previous cannulation, and was the main reason of ultrasound-assisted cannulation failure in other large study of the topic¹⁷. It is reasonable to believe that these failed attempts would happen even with the landmark technique.

The main limitations of this study are the absence of a control group and being a single-institution's based. Nevertheless, this cohort prospective study was performed in a representative population and it is especially relevant as it concerns to physicians in a training program.

This is the first study evaluating the learning process of ultrasound-guided IJV catheterization in critically ill population. Our training program was able to implement the evidence-based recommendations, achieving satisfactory results and without additional harm to the patients.

CONCLUSION

The learning process of ultrasound-guided IJV vein cannulation by medical residents was safe and feasible in our ICU. A simple training program achieved results similar to the trials that provided the recommendations of the quality/excellence organs.

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