RESEARCH ARTICLE

Comparative analysis of mechanical complications of emergency versus planned ultrasound-guided internal jugular venous (IJV) cannulation: data from the emergency room of a third-level hospital in Quito, Ecuador [version 1; peer review: 1 approved with reservations, 1 not approved]

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Abstract

Background: Central venous catheters (CVC's) are useful tools for the treatment of critically ill patients, especially in the emergency room, and are recognized for decreasing rates of failure and mechanical complications. Certain parameters can act as predictors to determine the likelihood of this type of complication. The aim of this study is to determine the incidence and predictors of mechanical complications using internal jugular venous (IJV) cannulation, especially when considering planned versus emergency cannulation.

Methods: A prospective, observational study was performed at Hospital de los Valles, Quito, Ecuador, during a three-year period. All patients who presented to the emergency room with an indication for IJV cannulation and with no potential contraindications were included. Demographic, safety and procedure related data were collected. Variables were analyzed using STATA, and p-values <0.05 were considered significant.

Results: A total of 142 patients were included. The majority of procedures (64%) were planned. The main indication for CVC placement via IJV cannulation was chronic renal failure (54%), all of which were planned procedures, followed by sepsis (15%), where most procedures (91%) were emergencies. The IJV was anatomically located lateral to the carotid artery in 38.73% of cases. Mechanical/technical complications were reported in 13 patients. Cannulation time greater than two minutes was found to be the only factor independently associated with a higher probability (12.4 times) of developing mechanical/technical complications. The vessel location did not affect

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the incidence of complications either in emergency or planned procedures when using ultrasound.

Conclusions: Ultrasound-guided IJV cannulation is a safe technique that can be performed as an emergency or planned procedure without increased complication rates in the emergency room. Additionally, a puncture time of less than two minutes is associated with the safest profile in this patient population.

Keywords

Ultrasound, Central Venous Access, Internal Jugular Vein Cannulation, Mechanical complications, Puncture time

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Introduction

Central venous catheters (CVC's) are a very useful tool for the treatment of critically ill patients¹. They are used for the delivery of vasoactive agents, parenteral nutrition, long-term antibiotics, blood sampling, hemodynamic monitoring, and/or venous access for haemodialysis patients². Historically, vein cannulation has been a procedure performed with a blind approach, following only anatomical landmarks for cannulation, thus the incidence of complications has been estimated to be as high as 40%³. Consequently, the use of ultrasound-guided techniques for vein cannulation has helped to reduce the rate of complications⁴, and its use has been standardized in many emergency rooms around the world⁵.

Ultrasound-guided techniques in the emergency room have long been documented as beneficial. In fact, in 2001, the Agency for Healthcare Research and Quality Evidence Report recognized bedside-ultrasonography for central venous access as one of the eleven practices with "strength of evidence for supporting more widespread implementation"². The American College of Emergency Physicians recommends in its Ultrasound Guidelines Policy Statement (last approved in 2016) that emergency room physicians should be trained and proficient in these techniques⁶. However, there is evidence that even with the recommendations to use ultrasound-guided techniques for central venous access, up to 67% of physicians do not routinely use ultrasound to guide the procedure⁷.

Insertion of ultrasound-guided CVCs with the conventional technique and with experienced personnel has allowed positive results with reduced costs⁸; nonetheless, it requires a thorough knowledge of the vascular anatomy and it is operator-dependent⁹. The technique is also limited in certain settings, like the emergency room, where elements such as previous vascular access, mechanical/ventilation and tracheostomy cannulas can affect access. Other factors affecting the success of the procedure are the presence of thrombosed veins, hematomas and anatomical variations¹⁰. These factors are associated with increased mechanical complications and failure rates¹¹. This justifies the use of ultrasound to detect these possible anatomical variations before starting the procedure¹².

Ultrasound-guided internal jugular venous (IJV) cannulation, one of the preferred methods for central venous access, is recognized for decreasing rates of failure and mechanical complications¹³. Main disadvantages of ultrasound-guided IJV cannulation access include the limited availability of the technology in low resource countries, a longer procedural time when the Doppler mode is used, and limited training from medical personnel regarding the ultrasound technique¹⁴.

The aim of this study is to determine the incidence of complications from ultrasound-guided jugular vein cannulation and compare the adverse outcomes in emergency versus planned cannulation, as well as to determine the factors that are associated with complications.

Methods

Ethical statement

Patients' written informed consent was obtained for the standard clinical procedure; patients were also notified through this document about the inclusion of their data in this study. All patients agreed. The Ethics Committee of Universidad San Francisco de Quito reviewed the study to the project

Study design

This study was performed in Hospital de los Valles (HDLV), Quito, Ecuador. The emergency room department takes care of approximately 20,000 patients per year, of whom 2–4% are in critical condition. The study was designed as a prospective observational study, collecting data over a three-year period of time, between 2010 and 2013.

Patient population

All patients who were admitted to the emergency room at HDLV and had an indication for CVC insertion, either emergency or planned, were eligible for the study. We excluded patients that did not consent to the CVC insertion, those with a visualized thrombus in the internal jugular vein and those who had trauma of the great vessels in the neck and thorax, according to recommendations based on previous studies¹¹. A total of 142 consecutive patients were included in the study; informed consent for medical procedure was signed at the hospital just after the indication for CVC, either emergent or planned, was established. The procedure was explained to patients and/or relatives.

Physicians' expertise

In order to guarantee the best possible technique for the study, physicians performing the IJV central line procedure had to fulfil the following inclusion criteria:

1. Degree in Emergency Medicine
2. A previous history of at least 300 CVC lines.
3. An average of at least 80 CVC placements in the previous years.
4. At least 100 IJV CVC placements using the same technique as used this study (see following section).

Technique for ultrasound-guided internal jugular vein catheterization

The technique used at the emergency room of our hospital (HDLV) starts with ultrasound-guided visualization of the internal jugular vein anatomy, using a high frequency superficial transducer (General Electric Logiq Book XP portable ultrasound). The CVC is placed with a high frequency 5–15 MHz electronic linear array. After this is done, the distance between skin to the centre of the vessel is measured using a measuring tape and it is corrected for the angulation factor that is going to be used. We mark the skin at the point of insertion. Using the Seldinger technique under sterile conditions and local

anaesthesia (lidocaine 1% without epinephrine), the procedure starts with needle puncture (18–20 gauge) and visual guidance of the tip, direction and depth while advancing with continuous ultrasound monitoring. Venous blood is obtained, and the wire is introduced with visual confirmation of an intraluminal location. The dilator is positioned and the catheter is introduced. Finally, and to verify the position of the tip of the catheter, we use the saline flush test using the ultrasound subxiphoid window, to determine if the catheter is too close to the right atrium¹⁵.

Indications used for emergency versus planned CVC via internal jugular vein placement

Emergency CVC via IJV placement was considered in any patient that fulfilled at least one the following criteria:

1. Acute disease, with potential risk of death.
2. Hemodynamic instability.
3. Need for use of vasoactive drugs.
4. Acute decompensation from a chronic illness that puts life at risk.
5. Indication for emergent haemodialysis.

Planned CVC via IJV placement was considered in any of the following cases:

1. Stable patients with diseases that require a planned procedure for:
 - a. Parenteral nutrition.
 - b. Haemodialysis.
 - c. Monitoring fluid administration.
2. Chemotherapy.
3. Inability to place a peripheral line.

The evaluation of which patients fulfilled emergency vs planned CVC criteria was done by the emergency physicians in charge of placing the IJV central line, with help from doctors from different specialties who were also evaluating each patient for baseline medical conditions.

Definition of complications

CVC complications are usually divided into two types: mechanical-technical and infectious. In this study, only mechanical and technical complications were evaluated since infectious require longer follow-ups and specialized studies to determine their origin. Mechanical complications were defined as either: haemothorax, pneumothorax, carotid puncture and/or hematoma at the puncture site¹⁶. Technical difficulties were defined as either: double or multiple puncture attempts, guide wire blockage and/or catheter obstruction¹⁷. All mechanical complications and/or technical difficulties were identified by the physician performing the procedures and confirmed by a

second physician who was a trained observer and who was present during and after the procedure.

Data collection

The data were collected prospectively, and a registry was made using a Microsoft Excel database, with access limited to the researchers. For each patient, one physician was assigned to the procedure while another one was in charge of registering the data, including demographics, type of procedure (planned vs emergent), time of the procedure, complications and technical difficulties. All the information related to the procedure was registered in the medical record of each patient.

Statistical analysis

Data is shown as number and percentage for categorical variables; for continuous variables, the mean, median and ranges were also considered. Categorical variables and proportions were compared using Fisher's exact test, and continuous variables were compared using the Wilcoxon Rank sum test. To investigate risk factors associated with complications, a univariate and multivariate logistic regression analysis was performed in those with all the data available (N=133), and the odds ratios (ORs) with confidence intervals (CIs) and p-values were calculated. Those variables that were significant in the univariate analysis were included in the multivariate analysis. Patients who developed mechanical and technical complications were compared with those who did not present complications. STATA version 13 software was used for analysis and p-values <0.05 were considered statistically significant.

Results

General characteristics of study sample

There was a total of 142 patients included in the study, among whom 55% were male and the mean age was 59 years¹⁸. Emergency procedures were performed in 36% of the cases. The main indication for CVC placement via IJV cannulation was chronic renal failure (54%), all of which were planned procedures, followed by sepsis (15%), where most procedures (91%) were done as emergencies. Approximately one third of the studied sample (35.2%) had an anatomical orientation of the internal jugular vein above the carotid artery. The median puncture time was two minutes. In most of the patients (66.2%), the time from needle puncture to the vein cannulation was less than two minutes (Table 1).

Associated factors for complications

Out of 133 patients for whom time data was available, 13 (9.8%; 95% CI: 5.3%–16.13%) had some type of complication: six patients (4.5%) had a mechanical complication, of which two (1.5%) were haematomas and four (3%) were arterial punctures, and seven patients (5.3%) had a technical complication, of which three (2.3%) were wire guide blockages and four (3%) were double punctures. Patients who developed mechanical complications were statistically younger than those who did not develop mechanical complications (40 years versus 60 years; p-value: 0.02). There were no age differences between those with and without technical complications.

Table 1. Baseline clinical characteristics of study group.

Variable	N (142)	(%)
Gender		
Male	78	54.93
Female	64	45.07
Age mean, median, SD (range)	59, 63, 17.4 (13-94)	-
Age (categories)		
13–49 years	35	24.65
50–69 years	64	45.07
≥70 years	43	30.28
Type of procedure		
Emergency	51	35.92
Planned	91	64.08
Indications for procedure		
Chronic renal failure	76	53.52
Acute on chronic renal failure	2	1.41
Sepsis	22	15.49
Cardiovascular	11	7.75
Hematology/oncology	11	7.75
Metabolic	7	4.93
Acute renal failure	7	4.93
Other	6	4.23
Location of vessel		
Lateral	55	38.73
Superior	50	35.21
Latero-superior	31	21.83
Other variants	6	4.23
Puncture time mean, median, DS (range)§	4.9, 2, 9.52 (0-60)	-
Puncture time (median) §		
0–2 min	88	66.20
3–60 min	45	33.80

§ Conditions must be adapted to your specific primers and or product length

SD, standard deviation.

Median puncture time was statistically longer in those with complications (19.9 minutes) compared to those without complications (3.3 minutes) (p-value: 0.0002). A similar pattern was found when considering mechanical or technical complications separately, where median puncture time was statistically higher in those with complications versus those without complications (Table 2).

After univariate analysis, a puncture time longer than two minutes was statistically associated with an 8.1 times increased risk of

developing complications (CI: 2.1-31; p-value: 0.002), while there was no statistical increase in complications in emergency versus planned procedures. After taking into account the effect of age, gender, type of procedure (emergency or planned) and vessel anatomical location on the association, the only independent factor associated with an increased risk of complications was a puncture time higher than two minutes (OR: 7.8; CI: 2-31; p-value: 0.004) (Table 4). When the analysis was restricted to those with mechanical or technical complications, puncture time remains the only significant predictor of mechanical complications.

Table 2. Mean age and puncture time by complication.

	No complications (N=120)	Complications (N=13)	P-value
Age (years)	60.4	50.1	0.17
Puncture time ** (min)	3.31	19.9	0.0001
	No mechanical complications (N=127)	Mechanical complications (N=6)	P-value
Age (years)	60.3	40.3	0.02
Puncture time**(min)	4.4	16.8	0.005
	No technical difficulties (N=126)	Technical difficulties (N=7)	P-value
Age (years)	59.4	58.6	0.68
Puncture time** (min)	3.95	22.6	0.007

P-values are determined from non-parametric test-Wilcoxon Rank sum test.

There was no available data on procedure time for nine patients.

** Referred to the time it took from skin puncture to vessel cannulation.

Other variables such as the type of procedure (emergency versus planned) and vessel localization did not reveal any statistical association (Table 3).

Discussion

The complication rates for central venous catheterization when using the landmark technique versus the ultrasound-guided technique have been clearly established in the literature, favoring the ultrasound-guided procedure⁴; nevertheless, there is no clear comparative analysis in the literature about complications during ultrasound-guided procedures in emergency versus planned situations and this is what this study tries to determine.

When the puncture time exceeded two minutes, the chance of having a mechanical complication was 12.4 times higher compared to a puncture time of less than two minutes. All other variables such as the type of procedure (emergency versus planned) and vessel location did not show any statistical differences. This finding is important for clinical practice because it advises the operator that once the two minutes puncture time interval has been surpassed, the risk of complications has increased considerably, allowing them to be primed to look for and manage the possible associated mechanical complications. Additionally, it was demonstrated that clinicians can confidently perform a CVC insertion with ultrasound, either in emergency or planned situations, since there is no significant difference in the development of complications.

The rate of mechanical complications with ultrasound-guided central venous catheterization varies widely among literature. For example, a recent study published by Björkander *et al.* evaluated a total of 10,949 CVC insertions and found a mechanical complication rate of 1.1%¹⁶. On the other hand, the study published by Eisen *et al.*, showed a mechanical complication rate of 14% during ultrasound-guided central venous catheterization¹⁹. Bleedings, pneumothorax, transient nerve injuries, and self-limiting arrhythmias are described as the most common mechanical complications¹⁶. The reason for a low rate of

mechanical complications in our study (4%) is thought to be related to the level of confidence and expertise of the doctors performing the procedure while using ultrasound. Other complications such as pneumothorax, hematomas and incorrect positioning reported by our study are comparable to those of others²⁰.

Risk factors associated with mechanical complications have been described by literature: the need for help¹⁹, more than two failed punctures¹⁹, expertise of the operator²¹, history of previous catheterizations²², preprocedural coagulopathy and route of catheterization¹⁶. In our study, the most significant variable associated with complications was the time puncture. The need for help was not identified as a variable, and the rate of failed punctures was minimal.

The results of this study might be affected by the small number of patients chosen. However, the analysis provided was able to detect statistically significant differences between groups by complications. More patients should be recruited in future studies to confirm these findings and to guide future protocols focusing on puncture time as a predictor for mechanical complications during emergency or planned ultrasound-guided IJV cannulation.

Conclusions

Training in vascular access with ultrasound guidance has an enormous impact in patient safety and in the reduction of complications related to CVC. Some relevant findings were determined during the present study regarding the ultrasound-guided technique for IJV placement of a catheter. First, it was confirmed that ultrasound-guided jugular vein access is a safe strategy to perform in the emergency room. Second, it was demonstrated that the type of situation, emergency versus planned, has no influence on the outcome and complications related to the IJV access of the patient. Third, it was shown that puncture time (time from the skin puncture to the vessel cannulation) was the most predictive variable for the development of complications. The only and most important factor to

Table 3. Univariate and multivariate analysis to determine predictors of complications during internal jugular venous cannulation.

Variables	Complications						
	No (N=129)	Yes (N=13)	P-value	Crude OR	P-value	Adjusted OR	P-value
Age (years)							
13–49	30 (85.7)	5 (14.3)		1			
50–69	59 (92.2)	5 (7.8)		0.51 (0.13-1.89)	0.31		
>69	40 (93)	3 (7)	0.53	0.45 (0.1-2.03)	0.3		
Gender (%)							
Male	70 (89.7)	8 (10.3)		1			
Female	59 (92.19)	7 (7.8)	0.77	0.74 (0.23-2.4)	0.61		
Type of procedure							
Emergency	45 (88.2)	6 (11.8)		1		1	
Planned	84 (92.3)	7 (7.7)	0.54	0.62 (0.2-1.9)	0.42	0.71 (0.21-2.36)	0.57
Vessel location							
Lateral	50 (90.9)	5 (9.1)		1		1	
Superior	47 (94)	3 (6)		0.64 (0.14-2.8)	0.55	0.69 (0.15-3.1)	0.62
Latero-superior	27 (87.1)	4 (12.9)		1.48 (0.37-5.98)	0.58	1.39 (0.34-5.7)	0.64
Other variants	5 (83.3)	1 (16.7)	0.5	2 (0.19-20.6)	0.56	2.6 (0.23-29)	0.44
Indication for CVC insertion							
Chronic renal failure (CRF)	70 (92.1)	6 (7.9)		1		1	
Acute over CRF	2 (100)	0		na		na	
Sepsis	18 (81.8)	4 (18.2)		2.59 (0.66-10.1)	0.17	2.9 (0.68-12.2)	0.15
Cardiovascular	11 (100)	0		na		na	
Hematology/oncology	11 (100)	0		na		na	
Metabolic	6 (85.7)	1 (14.3)		1.94 (0.2-18.9)	0.56	1.25 (0.11-14)	0.86
Acute renal failure	5 (71.4)	2 (28.6)		4.7 (0.74-29.4)	0.1	3.7 (0.48-28.9)	0.21
Other	6 (100)	0	0.27	na		na	
Puncture time *							
0–2 min	85 (96.6)	3 (3.4)		1			
3–60 min	35 (77.8)	10 (22.2)	0.001	8.1 (2.1-31)	0.002	7.8 (2-31)	0.004
Mechanical complications							
Puncture time *	(N=129)	(N=6)					
0–2 min	85 (98.8)	1 (1.2)		1			
3–60 min	35 (87.5)	5 (12.5)	0.01	12.1 (1.4-107)	0.03	12.4 (1.3-118)	0.03
Type of procedure							
Emergency	45 (93.8)	3 (6.2)		1			
Planned	84 (96.6)	3 (3.4)	0.66	0.53 (0.1-2.8)	0.45	0.5 (0.09-2.8)	0.43
Technical complications							
Puncture time *	(N=129)	(N=7)					
0–2 min	85 (97.7)	2 (2.3)		1			
3–60 min	35 (87.5)	5 (12.5)	0.03	6.1 (1-33)	0.04	5.8 (1.0-33.5)	0.05
Type of procedure							
Emergency	45 (93.8)	3 (6.2)		1			
Planned	84 (95.5)	4 (4.5)	0.7	0.71 (0.15-3.3)	0.66	0.98 (0.20-5.13)	0.9

OR, odds ratio; CRF, chronic renal failure; CVC, central venous cannulation.

Adjusted OR includes age and gender, other variables such as vessel location did not affect the results.

* Refers to the time it took to vessel cannulation.

predict procedural success, in this study, was a time of less than two minutes from skin puncture to IJV cannulation. A greater sample size might be necessary to confirm these findings.

Data availability

Underlying data

Harvard Dataverse: Comparative analysis of mechanical complications of emergent versus planned ultrasound-guided

internal jugular venous cannulation (IJV): data from the Emergency Room of a third-level hospital in Quito-Ecuador - RAW DATA SET ENGLISH VERSION. <https://doi.org/10.7910/DVN/YAZQVA>¹⁸

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

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1. Writers said that 'Patients who developed mechanical complications were statistically younger than those who did not develop mechanical complications (40 years versus 60 years; p-value: 0.02).' What causes do they attribute these complications? Why these problems were seen in younger patients? What the writers think about this?
2. They said that 'The complication rates for central venous catheterization when using the landmark technique versus the ultrasound-guided technique have been clearly established in the literature, favoring the ultrasound-guided procedure⁴; nevertheless, there is no clear comparative analysis in the literature about complications during ultrasound-guided procedures in emergency versus planned situations and this is what this study tries to determine.' They should look at the literature and say the complication rates for central venous catheterization when using the landmark technique. Because writers say in this article ultrasound-guided procedures are very important and have less complication from landmark techniques.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 14 December 2020

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Donaldo Arteta Arteta

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² Clínica HLA Santa Isabel, Seville, Spain

³ Hospital Quirón Salud Infanta Luisa, Seville, Spain

This work for me has several inconsistencies in the design, errors in the measures of central tendency from the statistical point of view, and it does not seem to me that the Wilcoxon test that was used was better than the two-tailed unpaired Student's t-test. Two-color tables confuse the reader and are not well organized or aligned. The value of "p" is repeated a lot. I believe that a rethinking should be done according to suggestions that I have sent by email before indexing it. Please see [the attachment](#) in Word.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

No

Are all the source data underlying the results available to ensure full reproducibility?

No

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Medicine, Critical Care, Internal Medicine, Nutritional Support.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

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