Incidence of Mechanical Complications of Central Venous Catheterization Using Landmark Technique: Do Not Try More Than 3 Times.

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ABSTRACT

Purpose

Central venous catheterization is a standard procedure in intensive care therapy. In developing countries, this intervention is frequently performed by physicians in training and without the availability of ultrasound guidance. Purpose of this study was to determine the incidence and potential risk factors for mechanical complications during central venous catheterization in an intensive care setting performed by a mixed group of practitioners without the use of adjunct ultrasound.

Methods

Prospective observational cohort study in a university teaching hospital. Three hundred critically ill patients requiring their first central venous catheter insertion were enrolled. All patients were observed for 24 hours for mechanical complications (pneumothorax, hemothorax, arterial puncture, incorrect tip position, cardiac dysrhythmia, and/or subcutaneous hematoma). Potential associations with mechanical complications were adjusted using multivariable analysis. Main outcome was the cumulative incidence of mechanical complications.

Results

The incidence of mechanical complications was 17% (n = 51). After covariate adjustment, the number of punctures was significantly related to mechanical complications. Compared with 1 puncture, 3 or more attempts were significantly associated with mechanical complications (odds ratio 3.62 [95% confidence interval 1.34-9.8]; $P = .011$). Experience of the operator was not associated with mechanical complications.

Conclusions

The incidence of mechanical complications is affected by the number of punctures performed. After adjustment, the risk increases substantially with more than 3 attempts. Limiting the number of attempts, appropriate supervision and the use of ultrasound guidance when available are recommended for the further reduction in mechanical complications of central venous catheterization.

Keywords

catheterization, central venous, mechanical complications, central venous catheter

INTRODUCTION

Central venous catheters (CVCs) are widely used in critically ill patients in intensive care units (ICUs). Several studies report a high prevalence of use ranging from 32% up to 80%.(1,2)

Central venous catheters are used for monitoring hemodynamic variables, for delivering medications, intravenous fluids, parenteral nutrition, or hemodialysis. However, some mechanical complications have been well described (3-5) including failure to place the catheter, incorrect tip position, pneumothorax, hemothorax, arterial puncture, dysrhythmia, and death. These complications are reported to have an incidence from 5% to 34%. (4,5)

To categorize factors related to mechanical complications, Polderman and Girbes divided those in 4 main categories: catheter-related factors, patient-related factors, site-related factors, and use- and care-related factors. (3) Risk factors for mechanical complications are well described, such as subclavian versus other sites, female gender, advanced age, extremes of body mass index (BMI), prior catheterization, surgery or radiotherapy, number of punctures, time needed to placement, and experience of the operator. (4,6-9) Nevertheless, some factors such as operator's experience show conflicting evidence. (6,8,10-12)

We aimed to study the incidence of mechanical complications of central venous catheterization in a single-center, university-affiliated ICU in Popayan, Colombia, placed by physicians with varying levels of experience and training. In addition, we identify factors related to their occurrence, and we compared our results to published data worldwide adding evidence from developing countries.

METHODS

We collected data of all patients older than 18 years of age undergoing CVC insertion from January to July 2008. This study was conducted after approval of ethics committee board in a 20-bed medical and surgical ICU in La Estancia Clinic, Popayan, Colombia, a 300-bed university-affiliated urban hospital.

Demographic and anthropometric variables, main diagnosis of admission, comorbidities, indication for CVC placement, and information related to insertion procedure were recorded. The choice of catheter site was at the discretion of the operator.

All catheters were placed in the jugular (internal or external) or subclavian vein by (1) house medical intensivist or specialist staff (experienced attendant), (2) residents in anesthesiology, internal medicine, and surgery (medical residents in training with less than 3 years of experience at intensive care setting), or (3) general practitioners (medical

house doctors without specialization). Residents and general practitioners placed the catheters always under direct supervision of 1 staff member of group 1.

Insertion was performed as a complete sterile procedure in all cases. All catheters were inserted using the standard Seldinger landmark technique. Devices used were triple-lumen, double-lumen, or single-lumen catheters (Multi-Med Central Venous Catheter Kit; Edwards Lifesciences LLC, Irvine, California).

All attempts and punctures (in order) to position the catheter were counted independent of the finally selected site. Each of those punctures can potentially increase the risk of mechanical complications. Once the catheter was inserted, it was sutured and covered with sterile drape. Catheter position was con- firmed by free fluid flow through all lumens and hemodynamic waveform visualization. Immediately after, an x-ray control was made for all patients.

All patients were observed for presence of mechanical complications during a period of 24 hours after the procedure. Our main outcome was the cumulative incidence of mechanical complications, defined as the occurrence of 1 or more of the following events: incorrect tip position (catheter's tip not in superior vena cava with less than 40º of angle between the vessel wall and the catheter tip) (13) confirmed by the x-ray control, pneumothorax, hemothorax, arterial puncture, cardiac dysrhythmia, and subcutaneous hematoma (any evidence of skin hematoma at the [intended] insertion points).

Patient characteristics recorded were age, gender, BMI, Acute Physiology and Chronic Health Evaluation II score at ICU admission, main diagnosis at admission (medical vs surgical or postoperative), prior use of CVC, presence of mechanical ventilation during the procedure, and main indication for placement of the CVC. Procedure characteristics were site of insertion, number of total punctures performed, time during the procedure (day [7 AM to 7 PM] vs night), type of catheter used (trilumen/bilumen/others), and training level of the operator.

Data Analysis

We described continuous variables as means + standard deviations and categorical data frequencies and percentages. Data nonnormally distributed were reported as median and range.

We performed bivariate unadjusted comparison of the catheter insertion site with the presence of mechanical complications as composite end point and with each compound, as well. A significance level of $P < .05$ was considered statistically significant. Independent variables were analyzed in a bivariate way with mechanical complications using the chi-square test or t test for independent samples, as appropriate. In addition, this analysis was done with exclusion of minor complications (subcutaneous hematoma and incorrect tip position).

Potential associations with mechanical complications were adjusted with a multivariate approach. We fitted a logistic regression model with the following continuous and

categorical predictors: BMI and number of punctures, main diagnosis at admission (reference category [rc]: surgical, 1: medical), mechanical ventilation (rc: absent, 1: present), time during the procedure (rc: day, 1: night), place of CVC (rc: external jugular, 1: internal jugular, 2: subclavian), and training level of the operator (rc: intensivist/specialist, 1: resident, and 2: general practitioner as defined in methods section).

To explore the effect of several punctures versus 1, we constructed a second logistic regression model introducing this as a categorical parameter. To assess the correlation between the number of punctures and the level of training of the operator, a Poisson regression was done using "number of punctures" as outcome and "level of training" as predictor.

Analysis was done in SPSS 17 (SPSS Statistics for Windows, Version 17.0; SPSS Inc, Chicago). All regression models were made using enter method. We presented our results in terms of odds ratios (ORs) and 95% confidence intervals (95% CIs). Possible effect modifications were tested. Hosmer and Lemeshow statistic test was used to test goodness of fit in selected models. To investigate the lack of fit in models, we carried out residual analysis.

RESULTS

We collected 300 consecutive patients who required CVC insertion on the ICU. General characteristics of the patients and the procedure are presented in Table 1. In most patients, a medical diagnosis was the cause of ICU admission, and the main indication to insert a catheter was hemodynamic monitoring or drugs/fluids infusion. There were 218 (72.6%) subclavian attempts and half (51%) of all catheters were placed by residents. The proportion of catheters successfully inserted at the first attempt was 86.7%.

Mechanical complications in relation to insertion place are described in Table 2. Fifty-one patients presented 1 or more mechanical complications. The incidence of mechanical com- plications was 17%. In all, 40 (13.3%) patients required a change in the initial site of puncture, and there were no patients with failure to place a CVC. In all, 16 (5.3%) patients presented major mechanical complications (arterial puncture, pneumothorax, and/or hemothorax).

Bivariate analysis showed significant associations with the presence of total mechanical complications for medical diagnosis at intensive care admission ($P = .013$) and mechanical ventilation during the procedure ($P = .01$). After adjustment for covariates, only the number of punctures showed a significant association (as continuous variable) with mechanical complications (OR 1.87 [95% CI 1.47-2.38]; $P = .000$; Table 3). Compared with 1 puncture, 3 or more attempts were significantly associated with mechanical complications (OR 3.62 [95% CI 1.34-9.8]; $P = .011$; Table 4 and Figure 1). There was no association between the number of punctures needed and the level of training of the operator ($P = .114$).

Table 1. General Patients and Procedure Characteristics of the Population. [a]

Patient's characteristics	
Male gender[b]	148 (49%)
Age, years[c]	60 ± 19
BMI,[c] kg/m^2	23.7 ± 4.3
APACHE II scored	15 (10-20)
Main diagnosis (medical/surgical)[b]	254 (85%) / 46 (15%)
Prior use of central venous catheter[b,e]	53 (18%)
Mechanical ventilation[b]	225 (75%)
Main indication to use central venous catheter[b]	
Hemodynamic monitoring	244 (81%)
Vasopressor infusion	234 (78%)
Infusion of special drugs	139 (46%)
Venous pacemaker use	11 (4%)
Hemodialysis access	10 (3%)
Swan-Ganz catheter insertion	7 (2%)
Insertion site of central venous catheter[b]	
Right subclavian	171 (57%)
Left subclavian	47 (15.7%)
Right internal jugular	47 (15.7%)
Right external jugular	18 (6%)
Left internal jugular	12 (4%)
Left external jugular	5 (1.6%)
Insertion characteristics	
Catheters successfully inserted at the first attempt[b]	260 (86.7%)
Number of punctures[c,d]	1.8 ± 1.3, 1 (1-9)
Trilumen catheter use[b]	259 (86%)
Insertion during the day (7 AM - 7 PM)[b]	187 (62%)
Training level of the operator[b]	
General practitioner	70 (23%)
Resident in training	153 (51%)
Intensivist/specialist (attendant)	77 (26%)

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation II; BMI, body mass index; CVC, central venous catheter; ICU, intensive care unit; SD, standard deviation.

[a]n=300.

[b]Data presented as number and percentage (%).

[c]Data presented as mean ± SD.

[d]Data presented as median and (range).

[e]Refers to the patients who used a CVC during a prior hospitalization or ICU stay.

Table 2. Total and Major Mechanical Complications and Site of Insertion of Central Venous Catheters.

	Total (n=300)	Subclavian (n=218)[a]	Internal Jugular (n=59)[a]	External Jugular (n=23)[a]	*P*
Mechanical complications[b]	51 (17)	39 (17.9)	11 (18.6)	1 (4.3)	0.154
Arterial puncture	13 (4.3)	8 (3.6)	5 (8.4)	0	0.122
Pneumothorax	2 (0.6)	2 (0.9)	0	0	0.527
Hemothorax	1 (0.3)	1 (0.45)	0	0	0.726
Incorrect tip position	13 (4.3)	13 (5.9)	0	0	0.014
Subcutaneous hematoma	31 (10.3)	21 (9.6)	9 (15.2)	1 (4.3)	0.273

[a]There were no significant differences between right and left positions at each site.
[b]Data presented as number and percentage (%) of the total catheters inserted at each site. 95% confidence limits for incidence proportion (12.7%-21.2%).

Table 3. Multivariate Analysis.[a]

	Model Number I[b]	
	Adjusted OR (95% CI)	*P*
BMI, kg/m2	0.9 (0.92-1.07)	ns
Medical diagnosis at admission	3.9 (0.88-17.9)	ns
Under mechanical ventilation	0.61 (0.29-1.26)	ns
Insertion during the day	1.04 (0.51-2.13)	ns
Site of CVC (rc: external jugular)		
Internal jugular	1.6 (0.1-15)	ns
Subclavian	3.1 (0.3-26)	ns
Operator (rc: intensivist/specialist)		
Resident	1.42 (0.56-3.5)	ns
General practitioner	1.1 (0.38-3.5)	ns
Number of punctures	1.87 (1.47-2.38)	0.000

Abbreviations: BMI, body mass index; CI, confidence interval; CVC, central venous catheter; OR, odds ratio; NS, not significant; rc, reference category.
[a]Logistic regression model 1.
Outcome under study: presence of mechanical complications as continuous outcome.
[b]Hosmer and Lemeshow test P = .98.

Table 4. Multivariate Analysis.[a]

		Model Number 2[b]	
	n (%)	Adjusted OR (95% CI)	*P*
Number of punctures (rc: 1 puncture)	184 (61)	n/a	n/a
Two punctures	59 (20)	1.36 (0.53-3.45)	ns
Three punctures	27 (9)	3.62 (1.34-9.8)	0.011
Four punctures	13 (4)	6.8 (1.9-24.2)	0.003
Five or more punctures	17 (6)	26.4 (7.2-96.6)	0.000

Abbreviations: n/a, not applicable; ns, not significant; OR, odds ratio; rc, reference category.
[a]Logistic regression model 2. Categorical analysis of number of punctures.
[b]Hosmer and Lemeshow test P = .62.

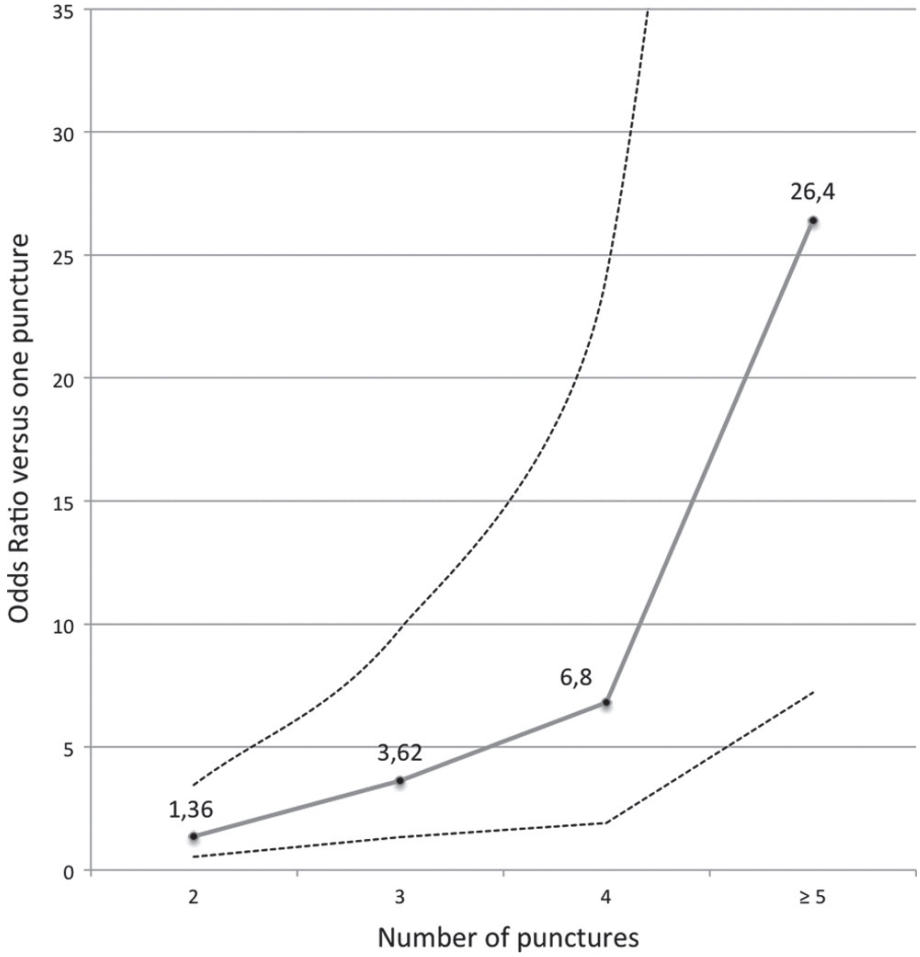

Figure 1. Increase in mechanical complication odds ratio with number of punctures. Dotted lines represent 95% confidence interval around odds ratio (OR).

DISCUSSION

This study confirms the strong relationship between number of punctures and incidence of mechanical complications during central venous catheterization. After adjustment for covariates, only the number of punctures remained significantly associated with mechanical complications. The increase in the odds ratio with each of the following puncture compared with the previous one is 1.9. Mansfield et al described how the rate of complications increases with more than 2 passes of the needle. (6) Later on, Eisen et al showed an odds ratio of 3.6 with more than 2 punctures. (4) Our findings are consistent with these previous studies and confirm the importance of the number of punctures and mechanical complications during central venous catheterization. Additionally, we are

able to demonstrate that the increased odds ratio with more punctures in comparison with one has a linear slope until 3 punctures after which the curve becomes exponential. Our results support the recommendation not to perform more than 3 punctures at the same site. After that a central catheterization should be attempted at another site.

Currently, there is no clear, precise, and widely accepted definition for mechanical complication of central venous catheterization. This affects the incidences reported in different studies. In fact, in our study, we found an incidence of 17% of mechanical complications. If we exclude minor complications (such as subcutaneous hematoma), this incidence is reduced to 9.3% (n = 28). These results are in accordance with worldwide data reported previously. (4,5,8,14-17)

Studies report mechanical complications as combined end points; however, each complication can be produced and explained by different processes. Merrer et al counts major mechanical complications only if they require a specific therapeutic intervention, otherwise it was classified as minor. (15) Many authors do not explicitly classify mechanical complications as major or minor and describe details of each event. (6-9, 12,16) The most frequent complication we found in our cohort was a sub-cutaneous hematoma. This finding is not consistent with other studies and may represents the difficulties in defining and assessing the presence of a subcutaneous hematoma. (4) Fortunately, most authors agree that it is a minor complication and usually recovers spontaneously.

Arterial puncture was a frequent complication in our study, occurring in 4% of all patients. Some studies report incidences of arterial puncture from 0.9% to 10.6%, (12,18) but most of them are around 4%. (4-6,15,19)

The external jugular vein drains into the subclavian vein lateral to the junction of the subclavian vein and the internal jugular vein. It is used for central venous catheterization, with and without ultrasound. (11,20,21) Although the external jugular vein is one of the most easily detectable and accessible vessels in the neck, it has not been considered the first choice for central venous catheterization, as there is a relatively high failure rate in catheter placement. (22,23) Variations at the termination point and angulation of the external jugular vein as it enters the subclavian vein contribute to this failure rate. However, some experienced authors show a high rate of catheterization success, reported from 50% to 90%. In addition, this approach carries fewer risks of major complications. (21,23) In our clinical practice, we use this site when the patient appears to present difficulties for other approaches or when other approaches fail. In fact, in our study, we did not have any failure of positioning 23 external jugular catheters.

Half of the catheterizations were performed by residents in training. The experience of the operator could be related to the number of attempts performed; nevertheless, our data do not support this statement, and after adjustment, there was no significant association between the number of punctures and the presence of mechanical complications. Likewise, other authors have not showed this relationship. (4,8) In our center,

residents and general practitioners even in early stages of their training have to perform numerous invasive interventions in ICU patients and on the operating room. Currently, there is no formal standardized training, for example, with a simulator, but in all cases, they perform these interventions under direct supervision of an experienced senior staff member.

We did not find any relationship of age, gender, BMI, time of the day, and experience of the operator with the incidence of mechanical complications. These findings are in agreement with results reported by Eisen et al. (4) On the other hand, some methodological limitations could introduce a potential bias in this study such as underreport of complications (ie, subcutaneous hematoma) or subjective evaluation of the outcomes.

The use of ultrasound imaging for central venous cannulation greatly improves first-pass success and reduces complications. (24) In addition, cost-effectiveness analyses of ultrasound guidance have been shown to reduce human and economic resources. (25,26) Therefore, practice recommendations for the use of this technology have emerged from several sources (27-29) and currently ultrasound guidance should be used when available. Unfortunately, the availability of ultrasound training and imaging at the patient's bedside is not widely accessible in developing countries. Therefore, our study not only reflects some technological and health care limitations but also presents a potential area of improvement. Currently, our hospital has included the use of ultrasound guidance as part of the quality of care program.

However, using landmark technique, our results present interesting parallels with other, well-developed areas around the world. In conclusion, the incidence of mechanical complications with central venous catheterization in our center is 15% and is mostly affected by the number of punctures performed but not related to the experience of the operator. The risk increases substantially when more than 3 attempts are made. Therefore, based on the current knowledge, appropriate supervision and the use of ultrasound guidance when available are always recommended.

DECLARATION OF CONFLICTING INTERESTS

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