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Research

*Corresponding author
Bruno Monteiro T. Pereira, MD, MHSc, PhD, FACCS, FCCM
Associate Professor of Surgery
Division of Trauma Surgery
Department of Surgery
School of Medical Sciences (FCM)
University of Campinas (UNICAMP)
Campinas, SP, Brazil
Tel. (55-19) 3521-2121
E-mail: drbrunompereira@gmail.com

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Landmark Central Venous Catheterization is Effective but Ultrasound Helps Even in Experienced Hands

Bruno Monteiro T. Pereira[1*], Guilherme Vieira Meirelles[1,2], Carl I. Schulman[2], Renan Carlos Colombari[3], Arthur S. Magnani[3] and Gustavo Pereira Fraga[4]

[1]Associate Professor of Surgery, Division of Trauma Surgery, Department of Surgery, School of Medical Sciences (FCM), University of Campinas (UNICAMP), Campinas, SP, Brazil

[2]Associate Professor of Surgery, Division of Trauma and Critical Care, DeWitt Daughtry Family Department of Surgery, University of Miami Miller School of Medicine, Miami, Florida, USA

[3]Faculty of Medical Sciences, Division of Trauma Surgery, Department of Surgery, School of Medical Sciences (FCM), University of Campinas (UNICAMP), Campinas, SP, Brazil

[4]Chief of Division of Trauma Surgery, Division of Trauma Surgery, Department of Surgery, School of Medical Sciences (FCM), University of Campinas (UNICAMP), Campinas, SP, Brazil

ABSTRACT

Introduction: A recent report published by the American Society of Anesthesiologists (ASA) task force on central venous access suggests the use of real time ultrasound for placing central venous lines. As in our center there is no ultrasound device specific for this purpose, a decision to test the hypothesis whether anatomic landmark for central venous catheterization is effective in experienced hands was made.
Methods: A retrospective review of a prospectively collected database was performed for the period January 2002 to June 2013. Five hundred fifty patients underwent long-term central venous catheter placement. All procedures were performed by experienced (>50 placements) surgeons utilizing standard techniques.
Results: Males slightly predominated, corresponding to 51.3% (n=282) of the total population. The most frequent cannulated vein was the subclavian vein (n=451/82%). The Right Subclavian Vein (RSV) was the first choice for catheterization (n=410/74.5%). 83.5% (n=459) of the punctures were successful on the first attempt. Complications included arterial puncture (n=36/6.5%), hematoma (n=16/2.9%) and pneumothorax (n=4/0.7%). Ultrasound was used in selective high-risk cases (7.3%).
Conclusion: The data suggests that with proper skill and experience, landmark anatomic position is effective for central venous catheterization, however ultrasound is helpful in specific difficult cases.

KEYWORDS: Ultrasound; Infection; Pneumothorax; Hematoma.

ABBREVIATIONS: ASA: American Society of Anesthesiologists; CVCs: Central Venous Catheters; IJV: Internal Jugular Vein; CDC: Center for Disease Control and Prevention; RSV: Right Subclavian Vein; RIJ: Right Internal Jugular; US: Ultrasound; OR: Operating Room; LSV: Left Subclavian Vein; RFV: Right Femoral Vein; LFV: Left Femoral Vein; BMI: Body Mass Index.

INTRODUCTION

Obtaining central venous access is a fundamental clinical skill for managing patients in a wide variety of clinical situations. Success in this procedure requires knowledge of patient's anatomy, clinical condition, and comorbidities. In addition, it also depends on the operator skills.

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The role of routine portable ultrasound in the placement of Central Venous Catheters (CVCs) has been debated. The use of ultrasound to aid in Internal Jugular Vein (IJV) catheterization has been shown to improve success rates and decrease the need for multiple attempts, but it has not been adopted worldwide, possibly because of cost and training issues.[1-3] Additionally, the Center for Disease Control and Prevention (CDC) of the United States of America recommends the Subclavian Vein (SV) site as the preferred choice for CVCs due to lower infection rates compared to other puncture sites.[1] However, for placing lines at the subclavian site, ultrasound is not very helpful. Traditional infraclavicular SV catheterization is poorly amenable because of the overlying clavicle, which can make visualization and direct guidance difficult due to the acoustic shadow from the clavicle and the usual SV anatomic position.

In the past few years several guidelines and papers have been published suggesting that the use of ultrasound improves safety and efficacy when central venous access is needed, although most studies examine ultrasound for IJV cannulation with mixed results.[4-7] Moreover, when looking at a worldwide perpective, ultrasound is not available for this purpose in all hospitals. Recently a report published by the American Society of Anesthesiologists (ASA) task force on central venous access[5] suggests the routine use of real time ultrasound for placing a central venous line. This led us to test the hypothesis whether anatomic landmark position is effective for placing a central venous catheter when performed by experienced professional.

METHODS

This study was conducted in a 500 bed University teaching hospital designated as a trauma center in a metropolitan area of approximately 2.9 million people. A retrospective review of a prospectively maintained database was performed from the period of January 2002 to June 2013.

Inclusion criteria for this research involved all patients over 18 years old that presented with an indication for placing a Hickman or Port-o-cath catheter, devices commonly used for long-term hemodialysis, chemotherapy and bone marrow transplants. These patients were chosen for study because a specific team of two experienced and trained surgeons (more than fifty previous CVCs obtained) was responsible for all cases helping to eliminate any possible bias due to heterogeneity of operator skill.

All Hickman and Port-o-cath catheters were placed in the Operating Room (OR) with the use of fluoroscopy. The Seldinger's technique for venipuncture was used in identical way to standard CVCs. Once in the OR, patients were placed in the supine position with 15 degrees Trendelenburg. All procedures were performed under local anesthesia (Lidocaine 2%). In accordance to the Trauma Surgery Division protocol and CDC recommendations, the right subclavian vein (RSV) was the first puncture attempt and the Right Internal Jugular (RIJ) vein the second option, unless a formal contra-indication applied, as explained below.

Ultrasound (US) was used in selective cases such as known difficult vascular access (i.e. multiple previous catheterization attempts with no success), anatomical distortions or in the presence of thrombotic phenomena (using the ultrasound to screen for visible thrombus). A Sonosite Titan® with a transducer L38/10-5 linear vascular array was the ultrasound device used in this research. When the US was used, cannulation was performed using real-time guidance with a transverse approach to the vein.

Variables such as gender, age, site of cannulation (and its variances, such as subclavian or supraclavicular access to the SV), attempts to perform cannulation, use of ultrasound, and complications (such as arterial punctures, pneumothorax, hematoma, bleeding and unsuccessful procedures) were compared. The data was entered into a spreadsheet and subsequently analyzed (Microsoft Excel Software®). Descriptive statistics and numeric comparisons were calculated through IBM SPSS Statistics®, version 20.0.0, 2012. To compare proportions, the chi-square test were used or Fisher's exact test, when necessary. To compare numerical variables the Mann-Whitney test were used. To identify factors associated with complications multiple logistic regression analysis was performed. Significance was set at $p<0.05$. The university's institutional review board approved the study (IRB 19016613.4.0000.5404).

RESULTS

Five hundred fifty patients (bone marrow transplant candidates, hematology, nephrology, and oncology patients) were included in the study. Males were slightly predominant, corresponding to 51.3% (n=282) of the total population. The average age was 44.0(±15.2).

The most frequently cannulated vein was the SV (n=451/81.95%). The right subclavian vein (RSV) was the first choice for catheterization (n=410/74.5%) unless another catheter was already in place at that site or there was any sign of anatomic landmark distortion, history of multiple puncture attempts or inability to pass the guide-wire (i.e. thrombotic occlusion of the subclavian/brachiocephalic trunk or extrinsic vein compression). The Left Subclavian Vein (LSV) was cannulated in only 7.5% of cases. Infraclavicular access to the SV was the most common (n=445/98.6%), while supraclavicular access was performed in 6 cases as a second option. No complications were reported after the supraclavicular access method. In these 6 cases the RSV infraclavicular access and the RIJ were either distorted by a hematoma due to multiple attempts by other teams, or was a potential increased risk of infection due to another catheter already in place at that specific site.

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RIJ was the second option for vein catheterization in the majority of the cases (n=68/12.3%) and when puncture was not successful by any method the LSV was attempted (n=41/7.5%). Other rarely used sites were: left jugular internal vein (n=14/2.5%), Right Femoral Vein (RFV, n=12/2.2%) and Left Femoral Vein (LFV, n=5/0.9%). The RFV and LFV accounted for only 3.1% of cases and were used as last a last resort by the surgery team (Figure 1).

83.5% (n=459) of the punctures were successful on the first try. An average of 1.2(±0.6) puncture try per patient. In 11.1% of cases two attempts were required. Three and 4attempts were required in 4.4% (n=24) and 1.1% (n=6) of cases, respectively. A total of 3(0.5%) unsuccessful procedures were recorded. No misplaced catheters were registered.

Recorded complications included arterial puncture (n=36/6.5%), hematoma (n=16/2.9%) and pneumothorax (n=4/0.7%). Bleeding was associated with arterial puncture and occurred in 0.7% (n=4) of the cases. Of the 4 patients who developed pneumothoraces, 3 also had their artery punctured and were known by the surgery team as "difficult access" cases. All pneumothoraces were after RSV punctures.

One case was immediately noted to have signs and symptoms of cardiac tamponade immediately after introduction of the guide wire. Fluoroscopy demonstrated iodine dye flushing into the pericardium through the bottom segment of the right atrium. A pericardiocentesis was performed and 70 ml of blood were removed. The cardiac surgery team performed a pericardial window and drained the pericardium with no major complications.

Ultrasound (US) was only used in selective cases when the surgery team was advised of a "difficult access" patient, when suspicion of thrombus was present, when the patient had a Body Mass Index (BMI) over 40, or when anatomic distortions were present. Following these criteria, ultrasound was utilized in only 40 cases (7.3%). Its use was more prevalent in patients over 60 years old (p=0.0484). In these forty patients, 8(20%) needed more than one puncture attempt. US was more often used in the LFV, RIJ and LIJ respectively (p<0.0001). Anterior access of the RIJ represented the highest cannulation success rate, when the US was utilized. When US was not used, RSV puncture presented the highest success rate with lowest complications (p<0.0001). There were a total of 36 arterial punctures, and 10(27.7%) were with the use of ultrasound and were mainly related to anatomic distortions and hypotensive patients (SBP <90 mm Hg). There were no statistical correlations between age (>60 years old) and arterial punctures (p=0.53). RFV, LFV and LSV were frequent sites of arterial puncture complications respectively (p<0.0001). Also, accidental arterial punctures were more often observed when using the US (p<0.0001). There were 16 cases that developed a hematoma (2.9%) after puncture, and 25% (n=4) of these were when using the ultrasound. There were no pneumothoraxes related to the use of ultrasound since this complication was only seen when attempting catheterization of the RSV. Out of 4 pneumothorax complications, 3 happened

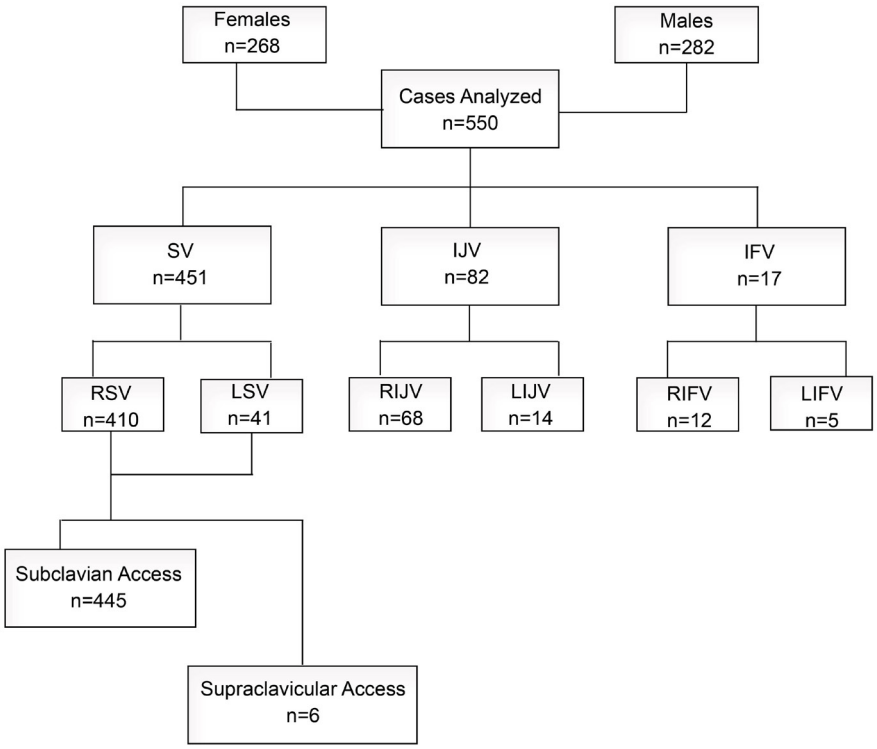

Figure 1: Study design flowchart.

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on the first puncture and 1 was associated with a hemothorax. The more was the necessity for trying another punctures (same anatomical site or other), the more was the rate of arterial punctures and hematoma (p<0.0001). After multiple logistic regression analysis our group observed that for each anatomical site cannulation attempts (second, third and forth puncture anatomical sites) the risk of having an arterial puncture increases in 3.2 times and 2.8 times in overall complications, with or without the US.

Patients with BMI of 40 or over presented twice complications than the other group (<BMI 40) (p=0.0092).

DISCUSSION

This was a retrospective analysis of a prospective collected registry of 550 CVCs placed in adult patients with an indication for long-term central venous catheters. The puncture technique (Seldinger) is identical to that used for regular CVCs commonly seen in critical ill patients.

At our institution, ultrasound is not routinely used, but is often employed in high-risk patients (i.e. severe coagulopathy), and those in whom landmarks are difficult to assess (i.e. morbid obesity or edematous patients). In special circumstances, ultrasound with or without color Doppler localization is a lot helpful in performing difficult or previously unsuccessful IJV catheterization.

However, due to the CDC recommendations and because all of the included patients in this study were undergoing long-term catheter placement, our group preferably chose the RSV as the first puncture target. Although CDC recommendations regard specifically non-tunneled catheters, our focus in this study was to evaluate routine ultrasound utilization disregarding catheters type.

Four hundred ten patients had no formal contraindication for the RSV puncture and cannulation was attempted. In 96.8% of the attempts, catheterization was successfully performed at this anatomical site. Successful attempts were considered when all punctures immediately obtained cannulation or obtained cannulation without the removal of the needle from underneath the skin. RSV punctures followed the standard method utilizing the Seldinger technique. The success rate in this study was high, and this may be due to operator skills. However, despite the high rate of success, all the pneumothoraces in this study were also associated with this same puncture site. This may be explained due to the higher number of punctures at this site or because this site may be slightly more prone to pneumothorax complications, but this is not completely assured by the literature. Ultrasound was never used in this anatomical landmark (subclavian) due to its technical difficulties, although it could be used when positioning the US probe laterally, over the right axillary trunk. The problem with using the axillary trunk is that it requires more training for US catheterization due to the proximity of the artery and vein and the fact that the vessels have a smaller diameter compared to the SV vessels. Also, in these cases, knowledge and experience using the color Doppler function of the ultrasound is desirable. In the specific case of this research, the axillary trunk was not an option because of the characteristics of the long-term catheters that would be implanted.

Another option for SV catheterization is the supraclavicular approach. Supraclavicular access of the SV was performed in only 6 cases during this study period, but was demonstrated to be effective. Of these six cases, 5 were known to be "difficult vascular access patients" and the US was used. To assist in these placements, we used a high frequency 10 MHz linear array probe angled anteriorly in the long axis orientation. To our experience, one can also use a color Doppler flow which helps greatly in these difficult cases.[8,9] Advantages of the supraclavicular approach over the infraclavicular technique include: a better defined insertion landmark; a shorter distance from skin to vein; a larger target area; a straighter path to the superior vena cava; less proximity to the lung; and fewer complications of arterial puncture.[10-14] Again, while ultrasound is an enormous advance in the placement of central lines, it is not always available. For this reason alone landmark based central line access will remain a skill physicians need to have in their armamentarium. The supraclavicular line offers another approach that appears at least as safe and possibly easier to perform with less misplacement than more frequently used lines.

The overall complication rate was of 10.4%. Arterial puncture was the most common complication responsible for 6.5% of the overall complications. This is still greater than some series that used the US as a standard method, yet these were for puncture of the IJV[14] in elective neurosurgery patients, and therefore not comparable with this cohort. There is no current data comparing complications rates between punctures of the SV with or without the use of ultrasound (with the probe positioned at a supraclavicular topography).

Operator skills and training may also be responsible for the good results seen in our study. As the team performing the catheterizations was always the same, with documented proficiency (50 plus documented successful punctures) and training on both methods (anatomic landmark and ultrasound), the results may have been more favorable with lower rates of complications and failure.[15-18]

When analyzing our data we realized that a second cannulation attempt was further frequent when using the US (20%) compared to using the anatomic landmark method (11%). This could be a selection bias considering that the US was only used in specific difficult cases (n=40). The first catheterization attempt without the use of US failed in exactly 11.1% of the cases. With the use of the US though, 8 catheterizations with more than one attempt were observed in 40 cases, which is still a good number

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(32 safe and effective cannulations), favoring the use of the US in difficult cases. Perhaps, this number would rise without the use of the device. Another possible selection bias is related to the use of ultrasound and accidental arterial punctures. Once again, the fact of selecting the US use for difficult cases may favor this relationship of US use and arterial puncture complication. Anatomical distortions, subcutaneous and muscle fibrosis, multiple skin scars and obesity were found as difficulty factors when using the US or not.

In this study, right sided cannulation (RSV and RIJ) was much more frequent than left sided cannulation. The reason for this is that the surgery team usually position themselves on the right side of the patient, subsequently making the right side the preferred site for catheterization attempts. The patient's head was usually angled 15 degrees to the left when the RIJ was to be tried. This way the RIJ comes upwards and there should be lower rates of arterial punctures complications.[19-21] It is also important to mention that the procedure was significantly more difficult to perform in morbidly obese patients either by the anatomic landmarks or US method.

In some cases the puncture was successfully performed but the guide-wire did not advance. Although this has nothing to do with the puncture *per se,* we felt it was important to mention that when attempting cannulation of the SV, mobilization of the shoulder upward and towards the ipsilateral ear is helpful to align the angle between the SV and IJV facilitating the progression of the guide wire. Three unsuccessful punctures were recorded (0.5%). The reasons were: anatomic distortion (syndromic patient), multiple cardiothoracic/oncologic surgeries (femoral veins were also compromised due to multiple previous catheterization attempts) and agitation due to cerebral palsy.

CONCLUSION

Even though there are a number of recent papers stressing the use of ultrasound as an essential tool in placing CVCs, this device is not available at all institutions and it is not currently the standard of care worldwide. Furthermore for catheterization of SV, US still have its limitations when compared to other anatomic sites. Based on the results presented here, anatomic landmark position is effective for placing regular CVCs by experienced professionals, although health care providers and medical units should be trained on US guided vascular catheterization as it helps in specific or complicated cases. Herein, placement of CVCs without US was associated with high success rates and low complication rates when the experienced physician's team performed the procedure however, did not represent risk or protective factor for complications in general, after multiple logistic regression analysis. When considering primarily SV cannulation, anatomic landmarks are still effective in the majority of clinical/surgical cases and an experienced trained physician can safely perform catheterization without the use of US on regular cases.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interests.

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CONSENT

No consent is required to this article publication.

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