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RESEARCH ARTICLE

Ultrasound-Guided Central Venous Catheterization of the Internal Jugular Vein in Cardiovascular Surgery

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ABSTRACT

Objectives: Central venous catheterization (CVC) of the internal jugular vein (IJV) has been performed with landmark techniques for many years. In recent years, ultrasound (US) guidance has become the preferred method. In this observational study, we aimed to obtain the durations of IJV puncture and catheterization during US-guided CVC in patients undergoing cardiovascular surgery.

Methods: After ethics committee approval, patients over the age of eighteen who underwent cardiovascular surgery were included. Central venous catheters were inserted via the right IJV with the aid of US guidance after standard anesthesia induction. Demographic data, characteristics of surgical interventions, number of attempts for IJV puncture, duration of puncture, success rate of puncture, duration of catheterization, success rate of catheterization, and complications were recorded. Data were presented as mean±SD (min-max) and/or number (%).

Results: Fifty patients (31 M, 19 F) were included. The mean age was 64.22±11.02 years, the mean weight was 77.12±11.81 kg, and the mean height was 166.48±9.53 cm. Coronary artery bypass grafting surgery (64%), valve replacement (VR) surgery (24%) [single VR (10%), double VR (12%), and triple VR (2%)], coronary artery bypass grafting surgery with mitral VR surgery (4%), Bentall procedure (4%), Bentall procedure with aortic VR surgery (2%), and ASD repairment surgery (2%) were performed on the patients. The mean number of puncture attempts was 1.0±0.00, the mean puncture duration was 5.08±3.85 (1-16) seconds, and the mean catheterization duration was 92.86±30.85 (68-232) seconds. Vein puncture and catheterization were both successfully performed in all patients. No complications were observed.

Conclusion: The anatomical relationship and variation of IJV and CA could be easily detected with the use of US. Thus, catheterization of the IJV can be performed successfully with the aid of US guidance. Our results are in accordance with the results of studies present in the literature.

Keywords: Carotid artery, central venous catheterization, internal jugular vein, ultrasound

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Introduction

Central venous catheterization (CVC) is generally preferred for monitoring central vein pressure, for the infusion of inotropic drugs or vasodilator agents, and for the administration of fluids in patients undergoing major surgical procedures.[1,2] Catheterization of the internal jugular vein (IJV) in cardiovascular surgery is standard practice.[3–5] Easier accessibility due to its superficial anatomy and owing to fewer complications compared to subclavian vein catheterization are the major reasons for choosing IJV for CVC.[4,6] Catheterization of the IJV has been performed with the aid of landmark techniques for many years.[7,8] In recent years, CVC of the IJV with the aid of ultrasound (US) guidance has gained popularity.[9,10] The main advantage of this practice is ensuring successful CVC while avoiding the puncture of the carotid artery (CA).[11–13] We have no institutional data related to CVC performed via the IJV under US guidance during cardiovascular surgery.

In this observational study, we aimed to obtain our data about the durations of puncture of the IJV and CVC, and also the success rates of puncture and CVC by using US in patients undergoing cardiovascular surgery. Additionally, we compared the results of our study with the results of other studies previously published in the literature.

The study was presented as a poster at TARK 2022 (56th National Congress), 3rd to 6th of November in Antalya, Türkiye.

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Methods

After approval from the Non-interventional Research Ethics Committee of the Medical Faculty of Dokuz Eylül University (Protocol no: 4717-GOA, Date: 08.05.2019), this observational study was conducted in patients over 18 years of age undergoing cardiovascular surgical procedures. The study was conducted in accordance with the guidelines outlined in the Declaration of Helsinki. Informed consent was obtained from all patients.

Patients with IJV thrombosis, anatomic neck abnormality, previous neck surgery, previous CVC on the same side, neck mass, goiter, and hemostatic disorders were excluded from the study.

All cases underwent similar anesthesia management. After obtaining standard monitoring and a peripheral intravenous line, the patient was premedicated, then the radial artery was cannulated for monitoring of invasive systemic arterial pressure. After anesthesia induction and tracheal intubation, the patient was positioned for CVC. A roll pillow was placed under the shoulders. Light hyperextension and 30 degrees of left rotation were applied to the head. Then, the patient was placed in the Trendelenburg position.

A Mindray (DP-10) 5–10 MHz linear probe was placed transversely on the right side of the neck at the cricoid level. The probe was held perpendicular to the skin in the transverse section (90° in the anteroposterior plane) and the full surface of the probe contacted the skin in the lateral plane (10–15°). At this point, images of the IJV and CA were obtained. Then, puncture was performed with the needle of the catheter set and the catheter was inserted with the aid of a guidewire. During this standard practice, one researcher from the study recorded the following data: (i) number of attempts for puncture, (ii) puncture duration: the duration from the first entry of the puncture needle into the skin to vein puncture, (iii) CVC duration: duration between the entry of the puncture needle into the skin and the insertion of the catheter (time for suturing is not included), (iv) success rates of puncture and catheterization, (v) complications related to CVC (CA puncture, inability to advance the catheter, etc.). The study was completed after all data were obtained. Anesthesia maintenance was provided by a combination of opioids and inhalation agents.

Statistical Analysis

Statistical analysis was performed using SPSS, Version 15.0 (Inc., Chicago, IL) for Windows statistical software. The catheterization-related values were given as mean±SD (min-max), number (%) and/or median and range. Subgroup data for gender, age, and body mass index were analyzed for normal distribution with the Shapiro-Wilk Test. Then, the Independent Samples T-Test was used for data showing normal distribution, whereas the Mann-Whitney U Test was used for abnormally distributed data. $p<0.05$ was considered significant for the statistical analysis of subgroups.

Results

The study started in May 2019 and was completed in March 2020, and included 50 patients. Central venous catheterization guided by US was performed by a resident who participated in the study and who had completed her 3rd year of anesthesia education. The resident had also performed at least 25 CVCs before starting the study.

Demographic data of the patients are presented in Table 1 and clinical characteristics of the patients are presented in Table 2. All CVCs were performed from the right IJV. Related data of CVC are presented in Table 3. Figure 1a shows the US image of the normal anatomical relationship between the IJV and CA, which was obtained from one of our study patients.

Puncture of the IJV was successfully performed at the first attempt through one puncture point in all patients. The mean puncture duration was ≤5 sec in 32 cases and >5 sec in 18 cases. The shortest duration was 1 sec, which was observed in 5 patients. The longest puncture duration was 16 sec, which was observed in 1 patient.

Central venous catheterization was performed successfully in all patients. We observed that the diameter of the IJV was significantly smaller than that of the CA in 2 patients (Fig. 1b). A problem in advancing the guidewire was observed in those two patients. The guidewire was inserted on the 2nd attempt and the catheterization duration was found to be 186 sec in one of those two patients. In the other patient, the guidewire was advanced on the 3rd attempt and the catheterization duration was 232 sec.

When cases were divided into subgroups according to gender (female/male) and BMI (<30 and ≥30), there were no significant differences in puncture duration between groups ($p>0.05$, $p>0.05$, respectively). Patients aged ≥65 years had significantly shorter puncture duration compared to those <65 years of age. Catheterization durations were not significantly different when patients were divided into the same subgroups ($p>0.05$ for all).

Additionally, complete overlapping of the CA was observed in one patient (Fig. 1c). Ultrasound usage during the procedure probably prevented the accidental CA puncture in this patient. We did not observe any complications, especially puncture of the CA, in the study.

Discussion

The puncture of the IJV and CVC were performed without any complications in all patients. The mean duration of puncture of the IJV was 5.08±3.85 sec, and the mean duration of CVC was 92.86±30.85 sec.

Table 1. Demographic data of patients (n=50)

	n	%
Gender		
Female	19	38
Male	31	62
Age (year)	64.22±11.02 (39–86)	
<65	22	44
≥65	28	56
BMI (kg/m^2)	27.87±4.07 (19.26–36.89)	
<30	36	72
≥30	14	28
Weight (kg)	77.12±11.81 (55–105)	
Height (cm)	166.48±9.53 (145–185)	
ASA score		
3	43	86
4	7	14

Mean±SD (min-max) and/or number (%). n: Number; BMI: Body mass index; ASA: American Society of Anesthesiology; SD: Standard deviation

Table 2. Types of surgery performed to patients (n=50)

	n	%
CABG surgery	32	64
Single VR surgery	5	10
Double VR surgery	6	12
Triple VR surgery	1	2
CABG+MVR surgeries	2	4
BENTALL procedure	2	4
BENTALL procedure+AVR surgery	1	2
ASD repairment surgery	1	2

Mean±SD and/or number (%). CABG: Coronary artery bypass grafting; VR: Valve replacement; MVR: Mitral valve replacement; AVR: Aortic valve replacement; ASD: Atrial septal defect; SD: Standard deviation

Inserting a central vein catheter with US guidance was first reported in 1984.[14] The first series of US guidance for obtaining peripheral venous access was reported by Keyes et al.[15] in emergency department patients with difficult intravenous access in 1999. Denys et al.[16] used two-dimensional simultaneous US imaging for IJV catheterization in more than 900 patients in 1993 and reported that the cannulation success rate with US guidance was higher and complication rates were lower. Since then, the rate of US use in clinical practice has increased. Nowadays, internationally well-known societies recommend the assistance of US for CVC.[17–19]

Some studies investigated the number of vein puncture attempts while using US.[20–23] Turker et al.[20] reported that the successful first attempt puncture rate was 99.47% in US groups, while Wang et al.[21] found this rate to be

Table 3. Central venous catheterization related data

	n (50)	p
Number of attempts	1.0±0.00 (1.0) (1.0–1.0)	
IJV puncture duration (sec)	5.08±3.85 (3.0) (2.0–8.0)	
Gender		>0.05
Male	5.48±3.76 (1–12)	
Female	4.42±4.03 (1–16)	
Age (year)		**=0.021**
<65	6.41±3.86 (1–13)	
≥65	4.04±3.58 (1–16)	
BMI (kg/m^2)		>0.05
<30	5.25±3.82 (1–13)	
≥30	4.64±4.07 (1–16)	
Catheterization duration (sec)	92.86±30.85 (84.5) (75.00–101.00)	
Gender		>0.05
Male	94.16±32.76 (69–232)	
Female	90.74±28.20 (68–186)	
Age (year)		>0.05
<65	92.00±25.04 (69–186)	
≥65	93.54±35.20 (68–232)	
BMI (kg/m^2)		>0.05
<30	94.36±34.72 (69–232)	
≥30	89.00±17.92 (68–129)	

Mean±SD (median) and (25th percentile-75th percentile). Mean±SD (min-max) and/or number (%). n: Number; BMI: Body mass index; SD: Standard deviation

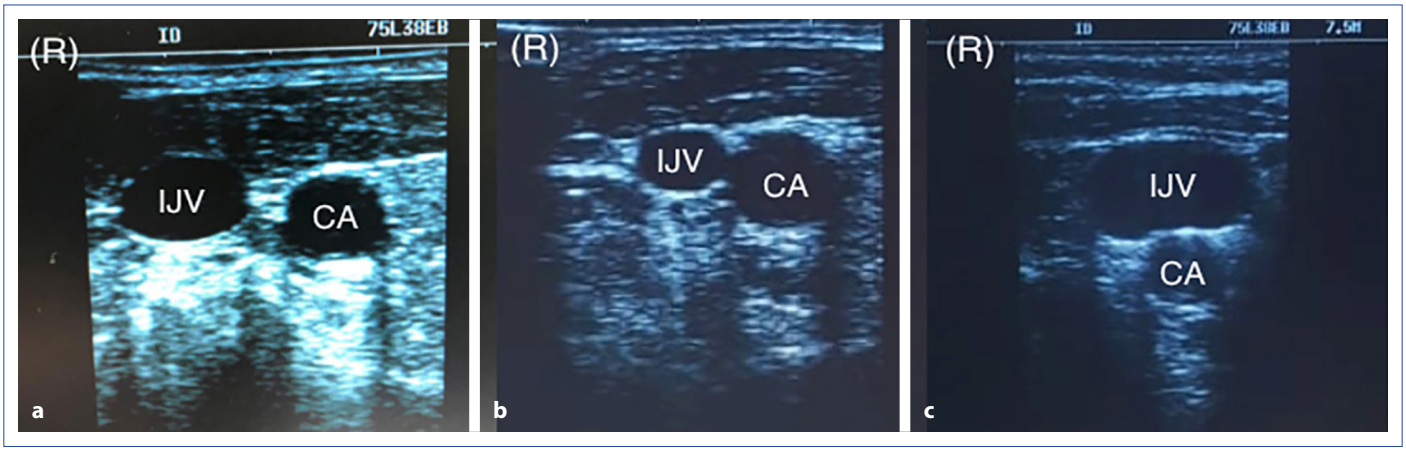

Figure 1. Right side ultrasound images show: **(a)** Normal anatomical relationship of internal jugular vein (IJV) and carotid artery (CA) in one patient, **(b)** smaller diameter of IJV than that of CA in one patient, **(c)** and full overlapping CA in one patient.

98%. Agarwal et al.[22] performed successful first attempt puncture in 87.5% of their patients. Another study found 77.5% of successful vein puncture at the first attempt.[23] The study by Agarwal et al.[22] published that 12.5% of patients in the US group required more than one attempt. In our study, the successful puncture rate at the first attempt was observed as 100%.

Dolu et al.[24] reported that the mean puncture number was 1.1±0.5, while the study by Karakitsos et al.[25] found this value to be 1.1±0.6. In a study by Fathi et al.[26] this number was identified as 1.12±0.52, while in another study, Shrestha and Gautam[27] reported the mean puncture number as 1.53±0.72. In our study, the mean puncture number was found to be 1.0±0.00.

The study by Wang et al.[21] found the mean duration for puncture of the IJV to be 6.3±13.6 sec when US assisted the catheterization. Denys et al.[16] reported this duration as 9.8±14.3 sec in their study. The study by Ray et al.[23] found the mean puncture duration to be 11 sec (4–30) in the US group, while Karakitsos et al.[25] found this duration to be 17.1±16.5 sec. Kunhahamed et al.[28] found the mean puncture duration to be 4.86±2.18 sec in the US group. The mean duration for puncture of the IJV in our study was 5.08±3.85 sec, which is similar to that of Kunhahamed et al.[28]

Central venous catheterization was performed after anesthesia induction in some studies, while CVC was performed under local anesthesia with sedation in others. Dolu et al.,[24] Wang et al.,[21] and Fathi et al.[26] reported the durations of puncture of the IJV and catheterization after anesthesia was induced and the trachea was intubated. Similar to those mentioned above, in our study, CVC-related times were obtained after anesthesia induction.

Kunhahamed et al.[28] reported that catheterization was successful on the first attempt in 91.4% of patients. The success rate of catheterization on the first attempt was reported as 90% in the study by Dolu et al.[24] and as 91.8% in the study by Fathi et al.,[26] while Shrestha and Gautam[27] reported this rate as 63%. In our study, catheterization was achieved on the first attempt in all patients. The reason for the low first attempt puncture success rate in the study by Shrestha and Gautam[27] might be because the study was conducted in intensive care unit patients instead of surgical patients.

The study by Kunhahamed et al.[28] found catheterization was successful for 100% of patients in the US group. Karakitsos et al.[25] and Denys et al.[16] obtained similar results. Fathi et al.[26] reported a 99.4% success rate for catheterization. Shrestha and Gautam[27] defined procedural failure as the inability to perform catheterization in three attempts and reported that the catheterization success rate was 97%. Ray et al.[23] used the same definition for catheterization success in their study and identified this rate as 95%.

The definition of CVC-related durations was determined differently in the reported studies. In our study, the catheterization duration was defined as the duration starting from the entry of the puncture needle into the skin until the catheter was inserted (excluding suturing) and the CVC duration was found to be 92.86±30.85 sec. In the study by Dolu et al.,[24] the catheterization duration was defined in a different manner, ending when venous blood was aspirated. They found the CVC duration to be 109.4±30.4 sec. The study by Ray et al.[23] defined catheterization duration similarly to our definition and reported the CVC duration as 165 sec (90–1370) in the US-assisted group. Kunhahamed et al.[28] defined the endpoint of the CVC duration when the aspiration of venous blood from the three lumens of the catheter was obtained. They found this value to be 293.03±71.15 sec. So, it is not easy to compare the results of CVC-related durations between the studies due to different definitions of CVC duration.

In our study, the durations of vein puncture and CVC were compared after patients were divided into subgroups

such as woman-man, adult-elderly, and obese-non-obese. Only a statistically significant difference was found in puncture duration when the patients were divided according to the two age groups. We couldn't find any research investigating this topic in the literature. Future studies are required to explore the effect of age on the durations of vein puncture and CVC.

During CVC via the IJV, very serious complications may occur. The most common among these complications is the puncture of the CA. In the study by Agarwal et al.[22] and in our study, no complications were observed. Despite this, Denys et al.[16] reported 1.7% CA puncture, 0.2% hematoma, and 0.4% brachial plexus irritation. Fathi et al.[26] also observed 4.1% CA puncture, 1.8% hematoma, and 0.6% pneumothorax. Kunhahamed et al.[28] reported 5.7% rates of hematoma.

In our study, there may be some limitations. We couldn't compare US-assisted data with the data obtained by the landmark technique. The observational design of the study could be the reason for not creating the landmark technique group. Additionally, it might be considered unsuitable not to use US where it is available. Similar to our study, in another study conducted by Doğan et al.[29] in 2008, CVC-related data of patients who underwent IJV catheterization were reported with the same methodology without creating two or more groups.

Conclusion

In conclusion, when CVC of the IJV is performed with US guidance, success rates of IJV puncture and CVC are high and complication rates of the procedure are low. The results of our study are compatible with the results of similar articles reported in the literature.

Disclosures

Ethics Committee Approval: The study was approved by The Dokuz Eylül University Faculty of Medicine Non-Interventional Ethics Committee (no: 4717, date: 08/05/2019).

Authorship Contributions: Concept – M.A.D., N.B., Ş.Ö, H.H.; Design – M.A.D., N.B., Ş.Ö, H.H.; Supervision – M.A.D., N.B., Ş.Ö, H.H.; Materials – M.A.D., H.H.; Data collection &/or processing – M.A.D., N.B.; Analysis and/or interpretation – Ş.Ö., H.H.; Literature search – M.A.D., N.B.; Writing – M.A.D., H.H.; Critical review – M.A.D., N.B., Ş.Ö., H.H.

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