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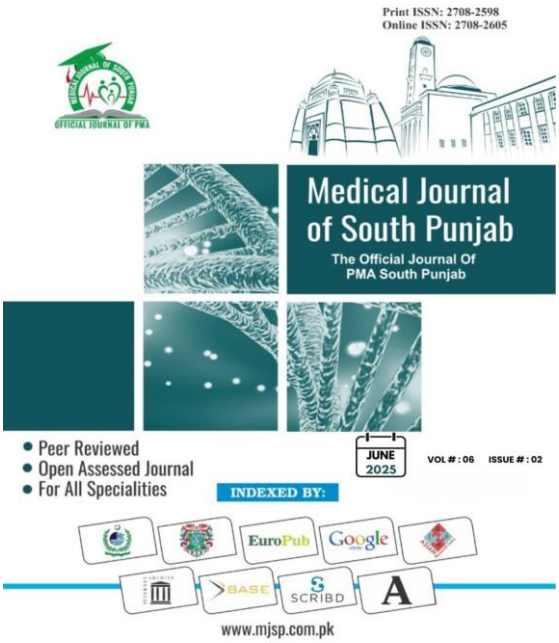

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Original Article

Comparison between the efficacy of in-plane vs out-of-plane needle technique for ultrasound guided intravascular access

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ABSTRACT

Objective: To compare the efficacy in terms of first pass success rate of in-plane vs out-of-plane needle technique for ultrasound guided central venous catheterization.

Methods: The study was carried out at the Anesthesia Department, Shaikh Zayed Hospital Lahore, for a duration of 6 months i.e. from Jan 16, 2025 till June 15, 2025.

Results: The mean age of the patients in Group A was 52±11.49 years and in Group B was 51±11.32 years. The mean time take for CVC in Group A was 55±7.71 seconds and in Group B was 42±7.29 seconds ($p<0.001$). The mean number of needle passes in Group A were 2±1.21 and in Group B were 1±0.55 ($p=0.02$). In Group A, the in-plane approach was efficacious in 87% patients compared to out-of-plane approach which was efficacious in 84.3% patients ($p=0.495$).

Conclusion: There was no discernible difference in the effectiveness of the in-plane and out-of-plane approaches for CVC in patients undergoing heart surgery.

Keywords: Cardiac surgical procedures, Catheterization, Central venous, Plane Needle, Intravenous access

1. INTRODUCTION

Central venous catheterization (CVC) is a procedure that is frequently carried out by anesthetists. Conventionally, a blind surface landmark-guided approach has often been adopted for catheterization of large vessels[1].According to reports, this method has a 30% first-pass failure rate and a 17.5% overall complication rate[2].Bleeding, hematoma, arterial puncture and pneumothorax are the most frequent consequences[2].In daily clinical practice, ultrasonography is becoming increasingly significant[3].Ultrasound guidance is used in several operations, such as vessel annulations, fine needle biopsies, and conductive anesthesia, to increase safety and effectiveness of these procedures[3].Studies have shown that employing ultrasound-guided devices instead of more traditional needle-insertion methods that use landmarks results in a lower complication rate[4].The use of ultrasound results in improved first pass success rates, fewer needle passes and less accidental harm to the neighboring structures which occurs as a result of direct visualization of the large central veins, their dimensions, orientation and surroundingstructures[4].However, there is debate over whether the in-plane technique or the out-of-plane strategy is better while performing central venous catheterization under ultrasound guidance[5].

Each strategy has unique benefits and drawbacks that could raise or minimize difficulties[6].Theout-of-plane technique (short axis) visualizes the linkages between the target vessel and the nearby vessels, although the catheter placement needle tip may not be continuously visible[7].Thein-plane (long axis) technique allows for continuous visualization of the needle's journey, including its tip, during catheterization, but it may lose track of the target vessel's proximity to nearby vessels[8].There is not enough data to definitively say which strategy is best for patients receiving Ultrasound-guided vascular catheterization[9,10].

Studies conducted previously have not yielded any conclusive evidence as to which ultrasound guided approach is more effective for central venous catheterization. Furthermore, there is paucity of local data on this topic. Therefore, the current study aimed to compare the efficacy in terms of first pass success rate of in-plane vs out-of-plane needle technique for ultrasound guided central venous catheterization. The current study will provide guidance about a better ultrasound guided approach which results in catheterization in the first attempt, thus preventing damage to the surrounding structures by avoiding repeated punctures of larger veins which can help in reducing further morbidity in such critical patients and also will help anesthesiologists in establishing quick access to central lines for immediate replacement of fluids and monitoring of fluid status of critical patients.

2. METHODOLOGY

The study had a randomized controlled design. After receiving approval from the Ethical Review Committee, the study was conducted for six months, from Jan/2025 till June/2025, at the Anesthesia Department, Shaikh Zayed Hospital, Lahore. The study enrolled 280 patients, keeping 80% power of the test with 5% significance level and expected efficacy in terms of first-pass success rate in the in-plane approach as 77.8%[4] versus 88.9%[4] in the out-of-plane approach. Non-probability consecutive sampling technique was used.

The study included patients of age 18 to 80 years, of either gender, who had to undergo elective cardiac surgery and require

central venous catheterization i.e. internal jugular vein. Patients who had a BMI of greater than 30, were unstable hemodynamically, with a deranged clotting profile, having any infection or hematoma subcutaneously either at or near the site of puncture, those who had a short neck, a history of IJV cannulation at the same site within the previous 72 hours, prior surgical procedures on the cannulation site, recent cervical trauma patients with neck immobilization, patients with subcutaneous emphysema with cervical extension, and those with carotid atherosclerosis confirmed by ultrasound were excluded.

Central venous catheters (CVCs) are indwelling devices that are peripherally put into a major, central vein, usually the femoral, subclavian, or internal jugular vein (IJV). The catheter is advanced until the terminal lumen is located in the right atrium, superior vena cava, or inferior vena cava. The primary outcome measures to be assessed was the efficacy of both approaches. The ultrasound approach was labeled as efficacious if the CVC was carried out successfully in the first pass i.e. needle was successfully inserted into the IJV and there was no need for readjustment. The secondary outcome measure assessed was the time taken (in seconds) for CVC (defined as the time from the first needle insertion to ultrasound confirmation of presence of the guide wire within the vein), number of needle passes (i.e. the number of times the needle were withdrawn and redirected) and rate of complications i.e. carotid artery puncture, hematoma (a pool of clotted blood), pneumothorax (an abnormal collection of air in the pleural space betweenthe lung and the chest wall seen as a region of lucency (dark) around the edge of the lung),arrhythmias (an abnormality in the timing or pattern of the heartbeat as assessed by ECG).

Following written informed consent, 280 patients who met the selection criteria were added to the trial. Every patient had a physical examination, clinical history, and demographic information taken, and the results were recorded on a Performa that had been prepared in advance. All routine investigations required for preoperative evaluation and the proposed surgery were done. For cannulation, all patients were positioned in the Trendelenburg position (20°-30°) with a rolled towel under the shoulders and the head turned to the opposite side. An anesthesiologists with an experience of performing 50 or more USG-guided internal jugular vein cannulation performed all cannulations in the right internal jugular vein with a 7 F (15 cm) triple lumen catheter. The process was carried out using the Salinger approach. In accordance with the marker on the screen, the probe marker was positioned to the patient's left. Changes were made to obtain the right images to recognize the carotid artery and internal jugular vein. They used a linear array high-frequency transducer 6-13 MHz that was attached to the 2D picture display of an ultrasound machine. Using the lottery approach, patients were split into two equal groups, each consisting of 140 individuals. The vein appears as a tubular anechoic structure in the longitudinal view that was acquired using the in-plane approach. The needle lies entirely within the imaging plane since it was put immediately beneath the transducer's centroid, parallel to its longest axis. The vessel appears as a circular anechoic structure when the ultrasonic transducer is directed transversely to it in the out-of-plane approach. The needle created a hyperechoic "dot" on the ultrasound screen when it was inserted perpendicular to the transducer because it split the imaging plane. After that, both primary and secondary outcome measures were evaluated in accordance with the operational definition, and the results were recorded on a Performa that had already been created.

Version 24.0 of the Statistical Package for Social Sciences (SPSS) was used to analyze the data. The mean and SD of the quantitative variables—age, CVC duration, and number of passes—were displayed. Frequencies and percentages were used to display qualitative data, including gender, efficacy, and complications. Age and gender stratification was applied to the data. Using the post-stratification Chi square test, a p value of less than 0.05 was deemed significant. The Chi square test was used to compare the effectiveness and complications of the two methods, and a p value of less than 0.05 was deemed significant. An independent t-test was used to compare the mean time for CVC and the number of passes; a p value of less than 0.05 was deemed significant.

3. RESULTS

A total of 280 patients were enrolled. Patient in Group A and Group B had mean ages of 52±11.49 years and 51±11.32 years, respectively. The mean time take for CVC in Group A was 55±7.71 seconds and in Group B was 42±7.29 seconds (p<0.001). The mean number of needle passes in Group A were 2±1.21 and in Group B were 1±0.55 (p=0.02) (Table-I).

In Group A, there were 5 (3.6%) patients of age group 18 to 30 years, 39 (27.9%) patients of age group 31 to 45 years, 68 (48.5%) patients of age group 46 to 60 years and 28 (20%) patients of age group 61 to 80 years, whereas in Group B, there were 5 (3.6%) patients of age group 18 to 30 years, 40 (28.6%) of age group 31 to 45 years, 68 (48.6%) patients of age group 46 to 60 years and 27 (19.2%) patients of age group 61 to 80 years. In Group A, there were 74 (52.9%) males and 66 (47.1%) females, whereas, in Group B, there were 68 (48.6%) males and 72 (51.4%) females. With respect to complications, it was revealed that in Group A, no complications were seen in 129 (92.1%) patients, hematoma was formed in 3 (2.1%) patients, 6 (4.4%) had rupture of carotid artery, 1 (0.7%) patient developed pneumothorax and another 1 (0.7%) patient had arrhythmia, whereas, in Group B, 126 (90%) patients had no complications, 5 (3.6%) patients had hematoma, 7 (5%) patients had carotid artery rupture and 1 (0.7%) patient had pneumothorax (p=0.962). In Group A, the in-plane approach was efficacious in 87% patients compared to out-of-plane approach which was efficacious in 84.3% patients (p=0.495) (Table-II).

Data was stratified for age and gender and no significant association was seen between these effect modifiers and efficacy of approaches (Table-III).

Table-I: Mean of Quantitative Variables

Variables	Group A (n=140)	Group B (n=140)	P value
Age (in years)	52±11.49	51±11.32	-
Time taken for CVC (in seconds)	55±7.71	42±7.29	<0.001
Number of needle passes	2±1.21	1±0.55	0.02

CVC=Central venous catheterization

Table-II: Frequency of qualitative variables

Variables	Group A n=140	Group B n=140	p value
Age group:			
18 to 30 years	5 (3.6%)	5 (3.6%)	–
31 to 45 years	39 (27.9%)	40 (28.6%)	
46 to 60 years	68 (48.5%)	68 (48.6%)	
61 to 80 years	28 (20%)	27 (19.2%)	
Gender:			
Male	74 (52.9%)	68 (48.6%)	-
Female	66 (47.1%)	72 (51.4%)	
Complications:			
No complications	129 (92.1%)	126 (90%)	0.962
Hematoma	3 (2.1%)	5 (3.6%)	
Carotid artery puncture	6 (4.4%)	7 (5%)	
Pneumothorax	1 (0.7%)	1 (0.7%)	
Arrhythmias	1 (0.7%)	1 (0.7)	
Efficacy of intervention:			0.495
Yes	122 (87%)	118 (84.3%)	
No	18 (13%)	22 (15.7%)	

Table-III: Stratification of efficacy of in-plane versus out-of-plane approach with respect to age and gender

Variable	Efficacy	Group A n=140	Group B n=140	P Value
Age 18 to 30 years	Yes	4 (40%)	4 (40%)	1.000
	No	1 (10%)	1 (10%)	
31 to 45 years	Yes	33(41.8%)	34 (43%)	0.962
	No	6 (7.6%)	6 (7.6%)	
45 to 60 years	Yes	60(44.1%)	58(42.6%)	0.613
	No	8 (5.9%)	10 (7.4%)	
61 to 80 years	Yes	25(45.5%)	22 (40%)	0.412
	No	3 (5.5%)	5 (9.1%)	
Male	Yes	63(44.4%)	53(37.3%)	0.268
	No	11 (7.6%)	15(10.6%)	
Female	Yes	59(42.8%)	65 (47%)	0.864
	No	7 (5.1%)	7 (5.1%)	

4. DISCUSSION

The current study findings revealed that in patients who underwent CVC, there was no significant difference in the efficacy between the in-plane approach and the out of plane approach i.e. the efficacy was 87% versus 84.3%, respectively (p=0.495). However, the meantime taken for CVC and the mean number of needle passes in the out-of-plane approach were significantly lower compared to the in-plane approach (p<0.05). Majority of the patients in the study were males and were of age group 46 to 60 years.

The administration of vasopressors, vascular filling, parenteral nourishment, recurrent blood samples, and hemodynamic monitoring by central venous pressure (CVP) measurement are all made possible by CVC, which is recommended for about 75% of patients in critical care. CVC is linked to complications even though it is recommended to enhance the care of patients in critical condition. During CVC, US-guidance increases comfort, safety, and efficiency. It is advised to employ the real-time US-guidance for CVC as the first-line treatment in all puncture sites in order to lower the likelihood of early problems. Despite the usefulness of US guidance in CVC, there is still an ongoing report regarding the optimal selection of technique for the puncture in terms of needle axis i.e. it is still not clear as to which technique is superior i.e. in-plane approach or out-of-plane approach. Keeping this in mind, the current study was designed to assess the efficacy of in-plane versus out-of-plane approach for CVC.

The current study results revealed that the in-plane approach was efficacious in 87% patients and out-of-plane approach was efficacious in 84.3% patients and the difference was statistically insignificant. In a study by Keskin *et al.* in patients who underwent central venous catheterization, the first-pass success rate in the in-plane approach was 86.6% versus 80% in the out-of-plane approach, however, the difference was statistically insignificant[1]. In a study by Baidya *et al.* the first pass success rate of in-plane approach was 88.8% and in the out-of-plane approach was 85.9% (p=0.538)[3]. Lal *et al.* revealed that in patients who underwent catheterization via in-plane (long axis) technique, the first pass success rate was 77.8% versus 88.9% in patients who underwent out-of-plane (short axis) approach (p=0.122)[4]. These findings are consistent with our study results that there is no significant difference between the two groups in terms of efficacy. Arora *et al.* found that the efficacy of the in-plane approach was 85.7% compared to 57.1% of the out-of-plane approach (p=0.007). The difference in our study results and that by Arora *et al.* might be because we assessed the two approaches in CVC, whereas, Arora *et al.* assessed the efficacy while catheterizing radial artery.

In terms of complications, our study revealed that there was no significant difference in the rate of complications between the two groups i.e. p=0.962 and the commonest complications via both approaches were carotid artery puncture and formation of hematoma. Keskin *et al.* revealed that complications occurred in 4 out of 30 patients i.e. 13.3% patients who underwent in-plane technique compared to 7 out of 30 patients i.e. 23.3% patients who underwent out-of-plane approach for central venous catheterization (p=0.317)[1]. In a study by Baidya *et al.* the rate of carotid artery puncture was 1% versus 0% respectively (p=0.99)[3]. Lal *et al.* in a study revealed that in terms of complications, in patients who underwent catheterization via in-plane versus out-of-plane approach, carotid artery puncture occurred in 5.6% versus 0% patients, hematoma occurred in 2.8% versus 0%, arrhythmias occurred in 11.1% versus 19.4% respectively and none of the patients in either group had pneumothorax or hemothorax[4]. These findings support our study results that the two approaches are similar in terms of rate of complications.

Our study results showed that there were significant differences between the two approaches in terms of mean time to perform CVC and mean number of needle passes and both were lesser in the out-of-plane approach compared to in-plane approach. In a study, it was found that the mean time to perform central venous catheterization via in-plane approach was 54.9±19.1 seconds and in the out-of-plane group was 43.9±15.8 seconds (p=0.006), the mean number of needle pass in the in-plane group was 3.2±2.1 and in the out-of-plane group was 2.1±1.6 (p=0.002)[5]. These findings are in line with our study findings.

In patients who undergo cardiac surgery, CVC with out-of-plane approach can be preferred over in-plane as it is associated with shorter mean time to perform CVC and lesser mean number of needle passes, although there is no difference in the efficacy and complications between both approaches.

5. CONCLUSION

The current study concluded that for CVC in cardiac surgery patients, there was no significant difference in the efficacy of in-plane versus out-of-plane approach. Furthermore, both approaches did not differ significantly in terms of complications. However, out-of-plane approach was significantly associated with shorter mean time to perform CVC and lesser mean number of needle passes. Therefore, our study results proposed that out-of-plane approach can be the preferred choice while performing CVC in patients undergoing cardiac surgery. Future studies must be carried out on a larger sample in order to validate the findings of the current study.

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