THE SUCCESS OF ULTRASOUND GUIDED INSERTION OF CENTRAL VENOUS CATHETER VERSUS LANDMARK TECHNIQUE

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ABSTRACT

Objective: Central venous catheterization is an important skill for doctors working in the departments of medicine, surgery, critical care, anesthesiology, and emergency. The Agency for Healthcare Research and Quality, USA named ultrasound guidance of central venous catheter placement as one of 11 most underutilized practices that can enhance patient safety with greatest strength of evidence to provide clear opportunities for safety improvement. In this study, we compare the success of ultrasound-guided insertion of central venous catheter versus landmark technique.

Study Design: Randomized controlled clinical trial.

Place and Duration of Study: Pak Emirates Military Hospital, Rawalpindi, from Jul to Dec 2016.

Methodology: One hundred twenty patients admitted in its wards and undergone CVC were included. Patients were divided into group A & group B containing 60 patients each. In 'group A' CVC was done with ultrasound assistance while in 'group B' CVC was done with landmark technique. The primary study outcome was No. of attempts at which CVC was done.

Results: In this study, 120 patients were enrolled. There was no difference in demographic data comparison. Success rate was found to be 28 (46.67%) in-group A while 16 (26.67%) in-group B with the *p*-value of 0.042 which is significant.

Conclusion: We concluded that CVC with ultrasound guidance is more successful than landmark technique.

Keywords: Central venous catherisation, Ultrasonography, Landmark technique.

INTRODUCTION

Central venous catheterization (CVC) is an important skill for doctors working in the departments of medicine, surgery, critical care, anesthesiology, and emergency. CVC is a commonly done for hemodynamic monitoring (such as central venous pressure), long-term administration of fluids, antibiotics, total parenteral nutrition, hemodialysis, Chemo-therapy and soon[1]. The internal jugular, subclavian veins and occasionally femoral are the common sites for CVC[1]. Millions of central venous catheters are inserted annually in the world. CVC insertions may be unsuccessful in as many as 20% of cases. The success rate for first attempt cannulation was 49% in Ultrasound guided CVC insertion and 27% for the landmark technique[2].

In 2001, the Agency for Healthcare Research and Quality (AHRQ), USA named ultrasound (US) guidance of CVC placement as one of 11 most underutilized practices that can enhance patient safety with greatest strength of evidence to provide "clear opportunities for safety improvement[3]. The American College of Surgeons also advocates for use of ultrasound in CVC placement in the adult population. Ultrasound-guided CVC is recommended in many countries, including the USA and UK. Despite these recommendations, only 15–41% of physicians use as a first line ultrasound-guided technique to puncture central veins[4].

Complications include arterial puncture, pneumothorax, haemothorax, nerve injury, thrombosis, hematoma, and delayed treatment from failure of placement, and even death can result

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from improper catheterization. Ultrasound assisted vascular access has been in clinical practice for more than three decades and has been increasingly used for target vessel visualization to reduce complications and increase success rates during vascular cannulation. Multiple studies have showed increased safety, effectiveness and efficiency of ultrasound-guided vascular access, as compared to cannulation by anatomical landmarks and/or acoustic Doppler[5].

The world leading advisory bodies advocates for use of ultrasound in CVC placement because ultrasound guided CVC is associated with an increased success rate in terms of decreased operative time, reduced number of cannulation attempts, and hence decreased number of complications[6].

The rationale of this prospective randomized study is to find a most appropriate way of central venous Catherisation by comparing ultrasound-guided central venous access versus landmark techniques when performed by medicine residents in emergency departments, wards and ICUs.

METHODOLOGY

This randomized controlled clinical trial study was conducted in the Department of Medicine, Pak Emirates Military Hospital, Rawalpindi, from Jul 2016 to Dec 2016. Sample size calculated using WHO sample size calculator with a level of signi-ficance of 5%, Power of test is 80%. Anticipated population proportion 1 is 49%[2] and anticipated population proportion 2 is 27%[2]. Minimum sam-ple size in each group came out to be 60 and a total of 120. Non-probability consecutive sampling was done. Inclusion criteria included all patients from age 13 to 70 and both genders, who were in need for jugular or subclavian CVC placement, as determined by the attending physician. Exclusion criteria excluded patients with deranged coagulation profile, local infection and allergy to local anesthetic agent.

After approval from hospital ethics committee, 120 patients who reported to Pak Emirates Military Hospital, Rawalpindi or admitted in its medical wards and undergone CVC insertion was included in the study. Written informed consent obtained from every patient included in the study.

Patients were randomly divided into 2 groups; group A and group B containing 60 patients each by lottery method. In 'group A' CVC was inserted with ultrasound assistance while in 'group B' CVC was inserted with landmark technique. After the procedure patients in both the groups were assessed for success of the procedure by resident medicine. Data in both the groups was recorded on predesigned performa of questionnaire. All patients were dealt with due respect and their comfort was taken care for during the procedure. We strictly adhered to our exclusion and inclusion criteria, so to control confounders and bias in the study.

All the data was entered and analyzed using SPSS version 23. Quantitative variables i.e. number of attempts and age were measured as mean and standard deviation. Qualitative variables i.e. Success rate and gender were measured in terms of frequency and percentages. Effect modifiers i.e. age, gender was stratified. Post stratification chi-square test was applied. A p-value ≤0.05 was considered significant.

RESULTS

Mean age of 'group A' was 55.07 ± 11.95yrs and that of 'group B' was 50.38 ± 13.04 yrs, p-value of 0.859 which is not significant. Gender distribution in group A was female 23 (38.3%) & male 37 (61.7%), with Female to Male Ration 2:3, in group B gender distribution was female 20 (33.33%) & male 40 (66.67%), with Female to Male Ration 1:2, p-value 0.352 which is not significant. Success rate which was establishing central venous line in first attempt and without any complication was found to 28 (46.67%) in group A while 16 (26.67%) in group B with the p-value of 0.042 which significant. No of attempts at which CVC was done was compared in both the groups. In group A, 28 (46.67%) CVC were done at first attempt, 14 (23.33%) at second attempt and 18 (30%) at third attempt. While in group B 16 (26.67%) CVC were performed at first attempt, 17

(28.33%) at second attempt, 17 (28.33%) at third attempt, 7 (11.67%) at fourth attempt and 3 (5%) at fifth attempt, *p*-value came out to be 0.013 which is significant.

Table–I: Age and gender distribution, of patients (n=120) in central venous cauterization (CVC) with ultrasound guided (group A) versus CVC with landmark technique (Group B).

S. No.	Group A (n=60)	Group B (n=60)	*p*-value
Mean Age	55.07 ± 11.95 years	50.38 ± 13.04 years	0.859
Gender	Female = 23 (38.3%) Male = 37 (61.7%)	Female = 20 (33.33%) Male = 40 (66.67%)	0.352

Table–II: Success rates in patients (n=120) with ultrasound guided (group A) versus landmark technique (Group B) in insertion of central venous cather (CVC).

S. No.	Group A (n=60)	Group B (n=60)	*p*–value
Success Rate (Attempt=1)	26 (43.33%)	16 (26.67%)	0.042

Table–III: No. of Attempts in which central venous cauterization (CVC) was established in patients (n=120) with ultrasound guided (group A) versus CVC with landmark technique (group B).

S. No.	Group A (n=60)	Group B (n=60)	*p*–value
No. of Attempts	1=26 (43.33%) 2=15 (25%) 3=19 (31.67%) 4=0 5=0	1=16 (26.67%) 2=17 (28.33%) 3=17 (28.33%) 4=7 (11.67%) 5=3 (5%)	0.013

DISCUSSION

CVC is a commonly performed procedure, routinely used for hemodynamic monitoring (such as central venous pressure), long-term administration of fluids, antibiotics, total parenteral nutrition (TPN), hemodialysis, etc. Millions of central venous catheters are inserted annually in the world. In 2001, the Agency for Healthcare Research and Quality (AHRQ), USA named ultrasound (US) guidance of CVC placement as one of 11 most underutilized practices that can enhance patient safety with greatest strength of evidence to provide "clear opportunities for safety improvement. The American College of Surgeons also advocates for use of ultrasound in CVC placement in the adult population. Ultrasound-guided CVC recommended in many countries, including the USA and UK. Despite these recommendations, only 15–41% of physicians use as a first line ultrasound-guided technique to puncture central veins[4].

Complications include arterial puncture, pneumothorax, haemothorax, nerve injury, thrombosis, hematoma, and delayed treatment from failure of placement, and even death can result from improper catheterization. Ultrasound guidance for vascular cannulation has been in practice for more than 3 decades and has been increasingly utilized for target vessel visualization to reduce complications and increase success rates. Multiple studies have showed improved safety and effectiveness of ultrasound-assisted vascular access when compared to cannulation by anatomical landmarks[5].

The world leading advisory bodies advocates for use of ultrasound in CVC placement because ultrasound guided CVC is associated with an increased success rate in terms of decreased operative time, reduced number of cannulation attempts, and hence decreased number of complications[6].

In our study, we compared ultrasound-guided CVC to landmark techniques in terms of number of attempts at which CVC was formed. Lesser number of attempts results in lesser number of potential complications associated with the procedure. The procedure was performed by medicine residents in emergency departments, wards and ICUs of Pak Emirates Military Hospital (PEMH), Rawalpindi.

In group A 28 (46.67%) CVC were done in firsts attempt while in group B it was 16 (26.67%). In group A, 28 (46.67%) CVC were done at first attempt, 14 (23.33%) at second attempt and 18 (30%) at third attempt. While in group B 16 (26.67%) CVC were performed at first attempt, 17 (28.33%) at second attempt, 17 (28.33%) at third attempt, 7 (11.67%) at fourth attempt and 3 (5%) at fifth attempt.

The results of my study are comparable to a study conducted by Dodge *et al*[2] included 480 CVC by 115 residents. Successful first cannulation occurred in 27% of landmark compared to 49% of dynamic Ultrasound (US) guided (p<0.01). They showed that improved success rates for first cannulation and overall CVC insertion success were independently associated with the use of US. The marked improvement in first-attempt and overall success shown by this study indicates that US guidance should be a routine part of CVC insertions.

In another study by Wu *et al*[1] showed that the meta-analysis of 26 RCTs shows that patients receiving CVC can obtain significant benefit from real time ultrasound (RTUS) guidance. The results for RTUS compared with Anatomical Landmark (ALM) showed statistically significant reductions in incidence of cannulation failure, and the risk for accidental arterial puncture, hematoma, pneumothorax, and hemothorax. This reminds us of the importance of understanding and correctly identifying the relevant structures and the fact that the anatomy at these sites is not always consistent. Anatomical Landmark cannot take this variability into account. Their meta-analysis suggested that both the Internal Jugular Vein (IJV) and SCV access site could benefit from the use of RTUS.

Gallagher *et al*[3] reported that Ultrasound assistance has shown to significantly improve the safety and accuracy of CVC placement in adult patients. A prospective, randomized trial comparing dynamic US guidance versus landmark technique for internal jugular catheter placement showed improved success rate and decreased complication rates. Prior studies assessing the effect of US assistance for CVC placement attempts have occurred in settings where the procedure is performed more often and likely in more controlled environments. The benefit of US in the study may reflect different patient- or physician-level factors where they may not be routinely performing the procedure. More research may be required to determine which factors contribute to the positive effect of US assistance in the pediatric ED.

Airapetian *et al*[4] in their study published in 2013, demonstrated that the ultrasound-guided technique used by inexperienced residents for central vein catheter placement is superior to a blind technique based on anatomical landmarks. This advantage was pertinent for jugular vein catheters as well as for femoral vein catheters. In this study, the jugular approach was preferred over the subclavian approach as ultrasound appears to be more accurate to guide cannulation via a jugular vein approach, and the unit where this study was performed, recruits a significant number of patients with chronic renal failure in whom they try to preserve arm veins for subsequent fistula.

In majority these studies, a specially designed ultrasound machine was used with a high-frequency probe and a clipped plastic guide. They found that the ultrasound guided technique dramatically improved the safety and success rate of internal jugular vein catheter placement. This study was performed by inexperienced operators. In intensive care unit, as in most French ICUs, central vein catheters are usually inserted by residents. Residents had lower success rates when catheters were inserted using land mark technique than when ultrasound guidance was used. Experienced operators who acquired skills for CVC placement have a success rate of 90%, when compared with inexperienced operators who have a success rate of about 75%[4]. A very recent paper demonstrated high insertion success (80%) US guided technique among junior residents. Dodge *et al*[2] found the same success rate and no difference related to mechanical complications using US-guided or quick-look ultrasound with skin mark technique, which is in contrast to our findings.

Bruzoni *et al*[6] conducted the first randomized study of pediatric surgeons using ultrasound guidance for CVC. The success rates at first attempt and within 3 attempts in the ultrasound group were 65% and 95%, respectively, vs 45% and 74%

in the landmark group. This is an important difference because the number of passes correlates with the possibility of complications. This study compared the complication rates between the two groups because they would expect complication rates to be low regardless of technique in the hands of experienced surgeons. With the large difference in success within 3 attempts, it would be expected that complications would be significantly reduced with the use of ultrasound over time. In support of this assumption, a meta-analysis concluded that complications from central line placement are directly proportional to the number of percutaneous cannulation attempts. A successful cannulation after a single attempt is virtually complication free, with rates increasing markedly thereafter. Complication rates are highest with more than 3 cannulation attempts. CVC is particularly challenging in children because the likelihood for success is largely size dependent. One of the factors leading to technical difficulties and increased complication risk in children is variation in anatomy.

The practice of using ultrasonography for image guidance during invasive procedures has gained popularity over the past decades. The use of ultrasound for central venous cannulation was first described in the 1990s and has been shown to increase overall successful line placement and decrease complications. The literature in adults is convincing. Ultrasound guidance is shown to reduce time to successful cannulation and to be cost effective in comparison to the landmark technique in adults. Multiple studies in adults have confirmed the benefits of choosing an ultrasound-guided approach over the landmark-based method.

Finally, results of almost majority of the studies conducted in different populations of the world in comparing the success of ultrasound guided insertion of CVC versus landmark technique have shown results in favour of ultrasound guided CVC. However, they do lay significant emphasis on training in Ultrasound guided CVC. Best results in terms of safe and efficient procedure performance can be achieved by properly inculcating the ultrasound guided insertion in training programs of young doctors. In our study, we found out that ultrasound guided CVC is far superior in establishing central venous access in first attempt.

LIMITATION OF STUDY

Following limitations were observed in my study: Only patients admitted in medical wards or reporting with medical problems were included in the study, this limited the diversity of patients. In future CVC carried out in different departments of the hospital by different specialist needs to be included.

This study population may not accurately reflect the general population of the society as most of the patients belonged to a particular socioeconomic and military background.

This study was conducted in a limited set up in Rawalpindi and surrounding population so its results may not be a true representation of national or international population.

CONCLUSION

We concluded that the patients, in which CVC was done with ultrasound guidance showed better result in term of reduced number of attempts when compared with CVC insertion with landmark technique, suggesting a potential to decrease complications associated with this procedure. Ultrasound guidance was associated with a reduced incidence of cannulation failure, arterial puncture, hematoma, and hemothorax in adult patients undergoing CVC. On basis of this study it is recommended to make ultrasound assistance in CVC insertion mandatory and an essential component of residency as well house officers training program. This work supports the Association for Healthcare Research and Quality call for ultrasound assistance for CVC placement in the ED. There are some topics that still need to be defined such as education, training and accreditation and further research is needed to clarify the role of ultrasound in infectious risk reduction. Given the evidence from literature and based on the results of this study, ultrasound guidance is suggested as the method of choice not only for

CVC but for any kind of vascular cannulation due to its higher safety and efficacy.

CONFLICT OF INTEREST

This study has no conflict of interest to be declared by any author.

REFERENCES

1. Wu SY, Ling Q, Cao LH, Wang J, Xu MX, Zeng WA, et al. Real-time Two-dimensional Ultrasound guidance for central venous cannulation. Anesthesiology 2013; 118(2): 361.
2. Dodge KL, Lynch CA, Moore CL, Biroscak BJ, Evans LV. Use of ultrasound guidance improves central venous catheter insertion success rates among junior residents. J Ultrasound Med 2012; 31(10): 1519-26.
3. Gallagher RA, Levy J, Vieira RL, Monuteaux MC, Stack AM. Ultrasound assistance for central venous catheter placement in a pediatric emergency department improves placement success rates. Acad Emerg Med 2014; 21(9): 981-86.
4. Airapetian N, Maizel J, Langelle F, Modeliar SS, Karakitsos D, Dupont H, Slama M. Ultrasound-guided central venous cannulation is superior to quick-look ultrasound and landmark methods among inexperienced operators: a prospective randomized study. Intensive Care Med 2013; 39(11): 1938-44.
5. Lamperti M, Bodenham AR, Pittiruti M, Blaivas M, Augoustides JG, Elbarbary M, et al. International evidence-based recommendations on ultrasound-guided vascular access. Intensive Care Med 2012; 38(7): 1105-17.
6. Bruzoni M, Slater BJ, Wall J, St Peter SD, Dutta S. A prospective randomized trial of ultrasound-vs landmark-guided central venous access in the pediatric population. J Am Coll Surg 2013; 216(5): 939-43.
7. Mueller RL, Sanborn TA. The history of interventional cardiology: Cardiac catheterization, angioplasty, and related interventions. Am Heart J 1995; 129(1): 146-72.
8. Meyer JA. Werner Forssmann and catheterization of the heart, 1929. Ann Thorac Surg 1990; 49(3): 497-99.
9. Aubaniac R. Linjection intraveineuse sous-claviculaire-avantages et technique. Presse Med 1952; 60(68): 1456-56.
10. Chick JF, Reddy SN, Yam BL, Kobrin S, Trerotola SO. Institution of a hospital-based central venous access policy for peripheral vein preservation in patients with chronic kidney disease: a 12-year experience. J Vasc Interv Radiol 2017; 28(3): 392-97.
11. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, et al. Early goal directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med 2001; 345(19): 1368-77.
12. Schiffer CA, Mangu PB, Wade JC, Camp-Sorrell D, Cope DG, El-Rayes BF, et al. Central venous catheter care for the patient with cancer: American Society of Clinical Oncology clinical practice guideline. J Clin Oncol 2013; 31(10): 1357-70.
13. Moureau N, Lamperti M, Kelly LJ, Dawson R, Elbarbary M, Van Boxtel AJ, et al. Evidence-based consensus on the insertion of central venous access devices: definition of minimal requirements for training. Br J Anaesth 2013; 110(3): 347-56.
14. Wittens CD, Davies AH, Bækgaard N, Broholm R, Cavezzi A, Chastanet S, et al. Editor's choice–management of chronic venous disease: clinical practice guidelines of the European Society for Vascular Surgery (ESVS). Eur J Vasc Endovasc Surg 2015; 49(6): 678-737.
15. Abdullah BJ, Mohammad N, Sangkar JV, Aziz YA, Gan GG, Goh KY, et al. Incidence of upper limb venous thrombosis associated with peripherally inserted central catheters (PICC). Br J Radiol 2005; 78(931): 596-600.
16. Yazici N, Akyüz C, Yalçin B, Varan A, Kutluk T, Büyükpamukçu M. Infectious complications and conservative treatment of totally implantable venous access devices in children with cancer. Turk J Pediatr 2013; 55(2): 164-69.
17. Kim YH, Kim HR, Jeon HJ, Kim YJ, Jung SR, Choi DE, et al. Comparison of treatment delay associated with tunneled hemodialysis catheter placement between interventionists. Korean J Intern Med 2016; 31(3): 543.
18. Robinson BM, Akizawa T, Jager KJ, Kerr PG, Saran R, Pisoni RL. Factors affecting outcomes in patients reaching end-stage kidney disease worldwide: differences in access to renal replacement therapy, modality use, and haemodialysis practices. Lancet 2016; 388(10041): 294-306.
19. Parienti JJ, Mongardon N, Mégarbane B, Mira JP, Kalfon P, Gros A, et al. Intravascular complications of central venous catheterization by insertion site. N Engl J Med 2015; 373(13): 1220-29.
20. Frykholm P, Pikwer A, Hammarskjöld F, Larsson AT, Lindgren S, Lindwall R, et al. Clinical guidelines on central venous catheterisation. Acta Anaesthesiol Scand 2014; 58(5): 508-24.
21. Madariya M, Makwana H, Thakor A. A comparative study of internal jugular vein catheterization in critical care patients: Ultrasound guided versus conventional method. Indian J App Basic Med Sci 2015; 17(24): 80-92.
22. Li J, Fan YY, Xin MZ, Yan J, Hu W, Huang WH, Lin XL, Qin HY. A randomised, controlled trial comparing the long-term effects of peripherally inserted central catheter placement in chemotherapy patients using B-mode ultrasound with modified Seldinger technique versus blind puncture. Eur J Oncol Nurs 2014; 18(1): 94-103.
23. McGee DC, Gould MK. Preventing complications of central venous catheterization. N Engl J Med 2003; 348(12): 1123-33.
24. Adrie C, Garrouste-Orgeas M, Essaied WI, Schwebel C, Darmon M, Mourvillier B, et al. Attributable mortality of ICU-acquired bloodstream infections: Impact of the source, causative micro-organism, resistance profile and antimicrobial therapy. J Infect 2017; 74(2): 131-41.
25. Zakhour R, Chaftari AM. Catheter-related infections in patients with haematological malignancies: novel preventive and therapeutic strategies. Lancet Infect Dis 2016; 16(11): e241-50.