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Original Research Article

Identification of Correct Position of Central Venous Catheter A Comparative Study between Chest X-Ray and Ultrasonography

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Abstract

Introduction: Catheterization of large central vein is a standard clinical practice for monitoring Central venous pressure (CVP). It is also performed for number of additional therapeutic interventions such as providing secure venous access for administration of vasoactive drugs, parenteral nutrition, and chemotherapeutic drugs or to initiate rapid fluid resuscitation.

Aims: Aim of the study was to confirm the correct position of central venous catheter in superior vena cava by ultrasonography. To assess the usefulness of USG+CEUS in judging the correct placement of the central venous catheter tip.

Materials & Methods: After getting approval from institutional ethics research committee the proposed study was conducted in the department of Anesthesis, Rajiv Gandhi Cancer Insitite and Research Centre, Rohui, New Delhi from November 2011 to October 2012 Written informed consent was taken from all patients or from text-of-kin for unconscious patients.

Result: In our study, 32 (19.5%) patients had LT ACV Site of CVC, 15 (9.1%) patients had LT IJV Site of CVC, 1(0.6%) patient was LT SCV Site of CVC, 51 (31.1%) patients had RT ACV Site of CVC, 2 (1.2%) patients had RT EJV Site of CVC, 50 (30.5%) patients had RT IJV Site of CVC and 13 (7.9%) patients had RT SCV Site of CVC.

Conclusion: We concluded that while both Chest X-ray and Ultrasonography offer valuable insights, the integration of both techniques provides a more comprehensive approach for ensuring safe and accurate CVC placement.

Keywords: Central Venous Catheter (CVC), Chest X-ray (CXR), Ultrasonography (USG), CVC Placement, Catheter Tip Position.

Introduction

Catheterization of large central vein is a standard clinical practice for monitoring Central venous pressure (CVP). It is also performed for number of additional therapeutic interventions such as providing secure venous access for administration of vasoactive drugs, parenteral nutrition, and chemotherapeutic drugs or to initiate rapid fluid resuscitation. Frequently the central venous location is the only site available for intravenous access of any kind. Patients at risk of venous air emboli may have central venous catheter (CVC) placed for aspiration of entrained air. In addition, central venous access is required to initiate transcutaneous pacing, temporary hemodialysis or pulmonary artery catheterization for more comprehensive cardiac monitoring.[1]

Placement of central venous catheters is often associated with mechanical, infectious, and thromboembolic complications. Mechanical complications are important, because their effects are usually immediate and contribute to increased length of stay, increased hospital cost, need for subsequent interventions and mortality. These include failure to place the catheter, pneumothorax, arterial puncture, misplacement, pulmonary embolism, air embolism, dysrhythmia, and death. Prior studies have demonstrated mechanical complication rates in 5% to 29% of patients, infectious complications in 5-26% and thrombotic complications in 2-26% of patients.[2]

The correct placement of tip of CVC is essential for proper functioning of catheter. Ideally, the catheter tip should lie within the superior vena cava (SVC) parallel to vessel wall and should be positioned below inferior border of clavicle and above the level of third rib or the T4 to T5 interspace or the tracheal carina or take off of right main stem bronchus.[3,4] Using fresh human cadavers, Albrecht and colleagues recently confirmed that the tracheal carina was always above the pericardial reflection on SVC, thus suggesting that catheter tip should always be located superior to this radiographic landmark.[5]

Since the introduction of central venous catheterization various methods have been tried for confirmation of correct position of CVC tip. Chest X-ray still remains the standard technique. A standard anteroposterior chest radiograph is often performed for confirmation of position of catheter tip using one of the various landmarks described above.

Other methods like right atrial electrocardiography, transesophageal echocardiographic evaluation of central venous catheter placement have also been described.

More recently studies have evaluated the usefulness of ultrasonography (USG) to determine CVC misplacement in adult patients using USG+contrast enhanced ultrasound (CEUS). They observed that combining USG+CEUS yields a 96% sensitivity and 93% specificity in detecting catheter misplacement. The use of USG+CEUS also helps to correct any misplacements of the CVC in the same sitting. It is also helpful in detecting any procedural complications like pneumothorax at the earliest.[6]

A Peripherally Inserted Central Catheter (PICC) line is a type of central venous access device that is inserted through a peripheral vein, most commonly the antecubital vein located in the upper arm, near the elbow crease. From this site, the catheter is advanced through larger veins until its tip rests in the superior vena cava near the right atrium of the heart. PICC lines are widely used for long-term intravenous therapies such as administration of antibiotics, chemotherapy, total parenteral nutrition, or for frequent blood sampling. Their use minimizes the need for repeated venipunctures and provides a reliable route for delivering medications directly into the central circulation while reducing the risks associated with traditional central line placements.

This study aims to develop an algorithm for the automatic classification of the proper depth based on the vertical distance between the tracheal carina and the CVC tip (shallow, proper, and deep position) with the application of automatic segmentation of the trachea and the CVC on chest radiographs using a deep CNN.

Aim of the study was to confirm the correct position of central venous catheter in superior vena cava by ultrasonography. To assess the usefulness of USG+CEUS in judging the correct placement of the central venous catheter tip.

Materials and Method

After getting approval from institutional ethics research committee the proposed study was conducted in the department of Anesthesis, Rajiv Gandhi Cancer Institute and Research Centre, Rohui, New Delhi from November 2011 to October 2012 written informed consent was taken from all patients or from text-of-kin for unconscious patients.

Design of Study: This was a prospective observational study. The study included 200 patients of esther gender requiring CVC placement Post procedural chest x-ray of same patient served as a control.

Inclusion Criteria: All the patients above the age of 18 yrs of either gender requiring central venous catheterization.

Exclusion Criteria

- Patient below 18 yrs of age.
- Patient with history of any congenital cardiac anomalies

Procedure: After CVC insertion, B-mode and contrast-enhanced ultrasound (CEUS) were used to confirm correct catheter placement in the superior vena cava (SVC). A 7.5 MHz probe identified the catheter tip, and CEUS with 5 ml of agitated saline verified laminar microbubble flow from the SVC as correct placement, while turbulent or atrial flow indicated misplacement. A portable supine chest X-ray was taken as a control to confirm the catheter tip position within the SVC.

Figure 1: Bicaval/Subcostal View (SVC, RA, IVC)

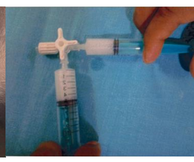

Figure 2: Preparation of Agitated Saline with Three-Way Stopcock

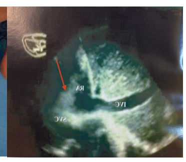

Figure 3: CEUS Showing Positive Microbubble Test — Jet Flow from SVC

Statistical Analysis: For statistical analysis, data were initially entered into a Microsoft Excel spreadsheet and then analyzed using SPSS (version 27.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism (version 5). Numerical variables were summarized using means and standard deviations, while categorical variables were described with counts and percentages.

Two-sample t-tests, which compare the means of independent or unpaired samples, were used to assess differences between groups. Paired t-tests, which account for the correlation between paired observations, offer greater power than unpaired tests. Chi-square tests (χ^2 tests) were employed to evaluate hypotheses where the sampling distribution of the test statistic follows a chi-squared distribution under the null hypothesis; Pearson's chi-squared test is often referred to simply as the chi-squared test. For comparisons of unpaired proportions, either the chi-square test or Fisher's exact test was used, depending on the context.

To perform t-tests, the relevant formulae for test statistics, which either exactly follow or closely approximate a t-distribution under the null hypothesis, were applied, with specific degrees of freedom indicated for each test. P-values were determined from Student's t-distribution tables. A p-value $\leq$ 0.05 was considered statistically significant, leading to the rejection of the null hypothesis in favour of the alternative hypothesis.

Table 1: Corrected Placement of CVC by CXR and USG+CEUS

	CXR		USG-CEUS	
Corrected Placement	**Frequency**	**%**	**Frequency**	**%**
Yes	164	82	159	80
No	36	18	41	21

Table 2: Corrected Placement by Chest-X Ray

Site of CVC	Corrected placement By CXR				P Value
	Yes		No		
	Frequency	%	Frequency	%	
LT ACV	32	19.5	9	25	0.460
LT IJV	15	9.1	1	2.8	0.202
LT SCV	1	0.6	0	0	0.639
RT ACV	51	31.1	13	36.1	0.559
RT EJV	2	1.2	0	0	0.505
RT IJV	50	30.5	9	25	0.513
RT SCV	13	7.9	4	11.1	0.535
Total	164	100	36	100	

Table 3: Site of CVC

Site of CVC	Corrected placement By CXR				P Value
	Yes		No		
	Frequency	%	Frequency	%	
LT ACV	30	18.3	11	30.6	0.099
LT IJV	15	9.1	1	2.8	0.202
LT SCV	1	0.6	0	0.0	0.639
RT ACV	49	29.9	15	41.7	0.170
RT EJV	2	1.2	0	0.0	0.506
RT IJV	50	30.5	9	25.0	0.513
RT SCV	12	7.3	5	13.9	0.200
Total	159	100	41	100	

As shown in table: 9.82% (164) of total CVC placements were correctly placed as identified by CXR and USG+CEUS showed 80% (159) were correctly placed. In our study, 32 (19.5%) patients had LT ACV Site of CVC, 15 (9.1%) patients had LT IJV Site of CVC, 1(0.6%) patient was LT SCV Site of CVC, 51 (31.1%) patients had RT ACV Site of CVC, 2 (1.2%) patients had RT EJV Site of CVC, 50 (30.5%) patients had RT IJV Site of CVC and 13 (7.9%) patients had RT SCV Site of CVC. In our study, 30 (18.3%) patients had LT ACV Site of CVC, 15 (9.1%) patients had LT IJV Site of CVC, 1 (0.6%) patient was LT SCV Site of CVC, 49 (29.9%) patients had RT ACV Site of CVC, 2 (1.2%) patients had RT EJV Site of CVC, 50 (30.5%) patients had RT IJV Site of CVC and 12 (7.3%) patients had RT SCV Site of CVC.

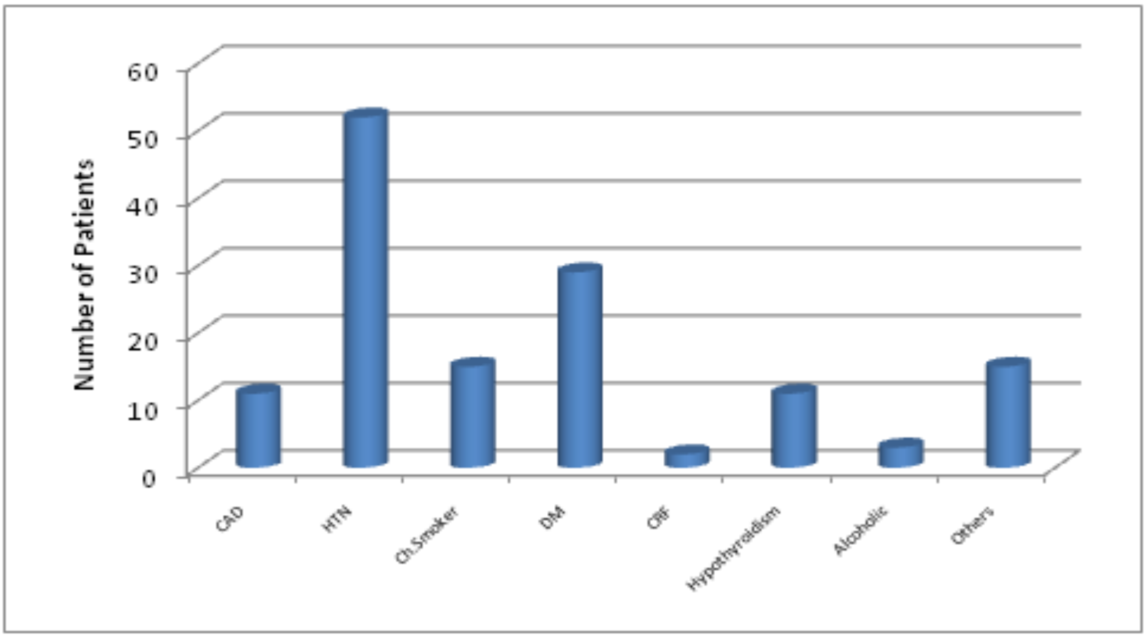

Figure 4: Associated Comorbidities in Patients

As shown in Table 11 The sensitivity of USG+CEUS was 55.1% which meam out of 100 times USG+CEUS was correct at 95.1 times and wrong at 4.9 times which is highly significant ($p<0.001$).

Specificity of USG+CEUS was 91.7% which shows it was able to identify 91.7 times misplaced CVC placements and 8.3 times it was unable to identify misplaced ones.

Positive Predictive Value is 98.1%. Negative Predictive Value is 80.5%. Accuracy of USG + CEUS was found to be 94.5 % in my Study.

Discussion

Insertion of central venous catheters in subclavian or internal jugular veins is quite. Frequent in the ICU for providing secure venous access for administration of vasoactive drugs, parenteral nutrition, chemotherapeutic drugs or to initiate rapid thuid resuscitation and operation theatre for haemodynamic monitoring in major surgeries.

Although for the most of time this procedure is uneventful, the placement of CVC catheters may be associated with potentially serious complications, such as venous and right heart perforations [7] and the drawbacks related to CVC tip misplacement such as CVC dysfunction, arrhythmias, extravasations, pneumothoras and thrombosis and even leading to severe distress or death. In addition to the evident difficulties such as the inability to locate or cannulate the vein, artery puncture, cervical hematoma or nerve injuries, catheter misplacement and pneumothorax are usually difficult to confion in the absence of post procedural chest radiography. So after central venous catheter (CVC) insertion, a chest radiograph (CXR) is usually obtained to ensure correct positioning of the catheter tip and to exclude mechanical complications, such as pneumothorax (PTX) [8]. Currently, the American College of Radiology recommends portable radiographs after placement of CVCs in critically ill patients, because it has been shown that this practice can detect abnormalities previously unknown in 35% to 65% of ICU patients. Although previous studies have underlined the high economic costs and the associated exposure risks for both patients and physicians, Gladwin and colleagues concluded that post procedural CXR remains necessary because clinical factors alone cannot reliably identity CVC tip misplacements. However, it must be considered that the junction of the SVC with the right atrium cannot be directly visualized using a bedside CXR.[9] In addition, it has also been shown that CXR based on usual radiologic landmarks yields up to 47% of false positive results for intra-atrial CVC tip misplacement and none of the radiographic landmarks is 100% reliable.[9]

These factors have led us to look for alternative methods to post-procedural chest radiograph that is safe, devoid of radiation hazard, cost effective, less time consuming and with a short learning curve. We evaluated ultrasonic examination as a diagnostic tool for catheter misplacement after central venous catheter insertion. Sample size was calculated using the forinula for descriptive study as $n^{o} – Z^{2} (p \times q)/e^{2}$ where no is the sample size. Z^2 is the abscissa of the normal curve that cuts off an area u at the tails (1- a equals the desired confidence level, e.g., 95%), e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is 1-p.

The value for Z is found in statistical tables which contain the area under the normal curve With reference to previous study we expect sensitivity of correct placement by USG with respect to CXR by p=85% with a precision error of estimation (e)=0.05, and alpha error-0.05. Sample size of at least 200 was needed.

We examined 222 patients out of which 22 patients had to be excluded to the study due to poor sub costal acoustic window The reason for poor quality images include COPD in 5 patients, poor penetration patients, an open abdomen in 6 patients and in due to obesity (BMI>35) in 7 patients no risk factor for poor window was found. In one patient post-procedural CXR could not be done for comparison due to loss of patient. The feasibility of USG-CEUS examination in our study was 90.09%.

The mean age of patients in study was 53.36 13.87yrs. Minimum age was 18 yrs and maximum age was 85 yrs.80 patients were male and 120 were female Mean height was 159.84 8.82 cm and mean weight was 62.60 13.44 kg. Most of the patients (51%) were in BMI range of 18.5-24.9.

Total 200 cases were included in study, 105 PICC line and 95 Neck Ime were studied. Out of 200 cases 36 misplacements were found on CXR, 26 in PICC line and 10 in neckline. USG+CEUS agreed with CXR in 33 cases and additionally showed 8 misplacements. Of the three cases in which USG +CEUS contradict CXR, two were placed intracardiac and one was in left brachiocephalic vein near its junction with right brachiocephalic vein by CXR but on USG -CEUS they were found to be placed in SVC.

The reason behind it may be poor patient position for A-P view of CXR and poorly defined SVC-RA junction. In the additional 5 misplacement found on USG only, 4 catheters were found at the junction of SVC-RA and four were found in SVC in CXR. In this at least 4 cases may be considered correctly diagnosed by ultrasound as radiographically the junction of SVC-RA is ill defined but in remaining four, catheter tips were not found in neck vein and on CEUS test the flow of bubble was turbulent which is found when catheter tip is placed intra-atrial.

Conclusion

In a study of 200 patients undergoing central venous catheterization, catheter tip malposition was found to be a common complication, occurring in 18% of cases, despite the use of ultrasound guidance. The study introduces a novel bedside ultrasound technique, USG+CEUS, which effectively identifies malpositioned catheters and reduces complication rates and radiation exposure for both patients and ICU staff. With portable ultrasound becoming more accessible, its use is expanding beyond vascular 10. access to nerve blocks and catheter placement. Utilizing USG for detecting misplaced catheters enhances its applications and optimizes resource use. The USG+CEUS method is efficient, requiring less time and having a short learning curve, which empowers intensivists to manage catheter placement more independently. Correcting catheter misplacements immediately reduces additional interventions and infection rates. This approach also potentially lowers costs and saves time by decreasing the need for post-insertion chest X-rays. Overall, the technique improves patient safety and care efficiency in critical settings.

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