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Dose Intraoperative Fluoroscopy Precisely Predict Catheter Tip Location via Superior Vena Cava Route?

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Abstract: Adequate catheter tip location is crucial for functional intravenous port and central venous catheter. Numerous complications were reported because of catheter migration that caused by inadequate tip location. Different guidelines recommend different ideal locations without consensus. Another debate is actual movement of intravascular portion of implanted catheter. From literature review, the catheter migrated peripherally an average of 20 mm on the erect chest radiographs. In this study, we want to verify the actual presentation of catheter movement within a vessel and try to find a quantitative catheter length model to recommend.

From March 2012 to March 2013, 346 patients were included into this prospective cohort study. We collect clinical data from medical record and utilized picture archiving and communication system to measure all image parameters. Statistical analysis was utilized to identify the risk factors for catheter migration.

The nonmigration group had 221 patients (63.9%); 67 (19.4%) patients were classified into the peripheral migration group; and 58 (16.8%) patients were classified into the central migration group. Patients with short height ($P = 0.03$), larger superior vena cava (SVC) diameters at the brachiocephalic vein confluence site ($P = 0.02$), and longer implanted catheter length ($P = 0.0004$) had greater risks for central migration. We utilized regression curve for further analysis and height (centimeters)/10 had moderate correlation distances from the entry vessel to the carina.

Although intravascular movement of catheter was exist in implanted catheter, the intraoperative fluoroscopy could provide accurate catheter tip location in 63.9% patients. Additional length of catheter implantation seems unnecessary in 80.6% patients. Patients with short height, larger SVC diameters at the brachiocephalic vein confluence site had greater risk for catheter central movement. Height/10 may be consider as reference length of implantation for inexperience surgeon and precise implantation length could be adjust under guidance of fluoroscopy.

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Abbreviations: CT = computed tomography, IVC = inferior vena cava, RA = right atrium, SD = standard deviation, SVC = superior vena cava.

BACKGROUND

Adequate catheter tip location is crucial for functional intravenous port and central venous catheter. From literature review, catheter with shallow tip location were associated to catheter migration.[1] Numerous complications were reported because of catheter migration that caused by inadequate tip location. Too deep catheter tip may lead arrhythmias,[2,3] heart injury,[4] and vessel perforation.[2] Too shallow tip location may cause migrated catheter to nearby vein and cause various clinical symptoms, including back pain,[5] brachial plexopathy,[6] neurologic deficit,[6] and cortical vein thrombosis.[7,8] In order to minimize the migration risk, adequate tip location is important for clinical practice. From literature review, the consensus of tip location is located between distal third of superior vena cava (SVC) and junction site to right atrium (RA).[9] These structure could not be visualized in chest plain film and several landmarks were recommended as a reference, including T5 to T6 intervertebral space, right tracheobronchial angle, and carina.[9–12] However, the interpretation variation still existed because of the difference of clinical experience. In our previous study, we identified the location that 0.68 cm below carina had minimal risk of catheter migration.[13] However, all these studies based on the measurement of postoperation chest plain film instead of actual intraoperative fluoroscopy. In addition, the catheter tip may travels during image acquiring[9] and posture changes.[9,14,15] The relationship between intraoperative fluoroscopy and post-procedure chest plain film remain unknown. The aim of this study is tried to identify the difference these 2 image tools and quantify a recommended length of implanted catheter via SVC route in order to minimize the technical errors.

MATERIALS AND METHODS

Patients

From March 2012 to March 2013, 475 oncology patients received intravenous port implantation for chemotherapy preparations. All these patients were recruited into this study. Patients who could stand received standing chest posterior–anterior plain film after intravenous port implantation. Not only does this confirm catheter tip location and measure the distance to the carina, but also makes sure that the nut-catheter angle is obtuse. Chest or whole body computed tomography (CT) was arranged by medical oncologist as a comparison standard for all patients because they were planned to received palliative therapy due to advance disease. Exclusion criteria were as follows: intravenous port implantation via internal jugular vein (28 patients) and inferior vena cava (IVC) route (3 patients; femoral or greater saphenous vein), without chest CT (82 patients) and standing chest posterior–anterior plain film (16 patients). After which 346 patients were included and further analyze in this study. All these selected patients were free from operation related complication, such as migration, facture, and malfunction. The study was approved by Chang Gung Medical Foundation Institutional Review Board and the IRB number is 100-4193A3.

Principle for Choosing an Entry Vessel and Implantation Method

According to our own study, we standardized the entry vessel principle and the entry vessel that drained to SVC was before those drained to IVC.[16,17] The cephalic vein was the first choice for exploration due to having the most superficial position. If there was no cephalic vein or it could not be accessed by a metallic guide-wire, the thoracoacromial vein would be used for catheter implantation.[18] If this failed, the ipsilateral internal jugular vein may be the next choice. No more subclavian punctures are made in order to avoid an iatrogenic pneumo-hemothorax. For patients who were identified cephalic or thoracoacromial vein with adequate size, vessel cutdown method was tried first. Target vessel underwent distal ligation and catheter was implanted via the venostomy under fluoroscopy. Additional stay suture would be placed at proximal end of venostomy site order to avoid bleeding. For patients who were identified cephalic or thoracoacromial vein with adequate size but met resistance in manual implantation, a metallic wire (V-18 Control Wire, 0.018 in., 200 cm, Boston Scientific, Natick, MA, USA or Guide Wire M 0.035 in., 150 cm, Terumo Cooperation, Tokyo, Japan), was utilized prior catheter implantation in order to establish entry route. Catheter was implanted by sliding over the wire under fluoroscopy. For patients who were identified cephalic or thoracoacromial vein with inadequate size, a metallic wire was utilized to establish entry route and peel-apart sheath were used sliding over the wire to create subcutaneous tunnel that permit catheter implantation. For those without accessible cephalic and thoracoacromial vein, echo-guide puncture for internal jugular vein access at thyroid cartilage level (ie, high neck puncture). After a catheter was implanted, an additional subcutaneous tunnel would be created between entry site and pocket site in order to allow catheter embedding in subcutaneous tissue.

Implanted Device, Surveillance, and Image Parameter Collection

Only the B'Braun Fr 6.5 (B'Braun Medical, Chasseneuil, France) single lumen intravenous port was utilized in this study. We utilized carina as the reference of landmark because of its relative immobile position and easily visualization under fluoroscopy. All catheter was implanted to location that 1 cm below carina, which was relative immobile and easily be seen intraoperation fluoroscopy. Actual implanted catheter length and the intraoperative tip location that revealed from intraoperative fluoroscopy were recorded. All patients had to receive chest plain film to confirm tip location. Medical records were reviewed and picture archiving and communication system (General Electric Co., Fairfield, CT, USA) was used to measure all clinical parameters.

Definition of Measurement and Subgrouping

We measure the nut-catheter angle, catheter tip distance to the carina from chest plain that shown in Figure 1. In addition, we measured short axis of the SVC's diameter at the brachiocephalic vein confluence site and the azygos vein confluence site and calculate the vertical distance between the lower margin of the SVC's confluence site with the brachiocephalic vein and the upper margin of the SVC's confluence site with the azygos vein in order to describe the surrounding configuration around catheter tip (Fig. 1). All parameters except nut-catheter angle were recorded in centimeters. Nut-catheter angles were recorded in degrees. The nonmovement group was defined as difference of tip location between intraoperation fluoroscopy and postoperation chest plain film was less than 1 cm. The central movement group was identified the tip location caudal migration greater than 1 cm in postoperation chest plain film compared with intraoperation fluoroscopy. The peripheral movement group was identified the tip location cephalad migration greater than 1 cmin postoperation chest plain film compared with intraoperation fluoroscopy.

Statistics

Categorical variables were compared using χ^2, Fisher exact tests, or ANOVA. The *t* test was used to compare continuous variables with normal distribution. A *P*-value of less than 0.05 was considered to indicate statistical significance, and all tests were 2-tailed. Descriptive statistics and logistic regression were performed using SAS statistical packages, version 9 (SAS Institute, Cary, NC).

RESULTS

There were 346 patients were included and further analyze in this study. Two hundred thirty-one patients (66.7%) were male. The mean age of these patients was 59.6 years. The mean body weight and height were 61.3 kg and 161.4 cm, respectively. Mean body mass index (BMI) of these patients was 23.4. Majority (92.4%) patients received catheter from right side entry vessel. All clinical characteristics of these patients are shown in Table 1. We further divided these patients into 3 groups. Two hundred twenty-one patients (63.9%) was identified as nonmovement group because of the difference between intraoperative fluoroscopy and chest plain film were less than 1 cm. In addition, 67 (19.4%) patients were classified into the peripheral movement group and 58 (16.8%) patients were classified into the central movement group (Table 2). All parameters of the 3 groups were similar and had no statistical significance except for implanted catheter length ($P = 0.01$).

We further analyzed the difference between the nonmovement and central movement group and found that all parameters were similar except for implanted catheter length ($P = 0.02$; Table 3). In addition, we also found that the SVC's diameter at the brachiocephalic vein confluence site may relate to central movement ($P = 0.06$; Table 3). We further used multivariate analysis (Table 4) and identified as body height had a negative correlation with central movement ($P = 0.03$) and implanted catheter length ($P = 0.0004$) and the SVC's diameter at the brachiocephalic vein confluence site ($P = 0.02$) positively correlated with central movement. However, there was no definite risk factor for peripheral movement.

Because there is no quantified model for recommendation of catheter implantation, we further utilized regression curve to further analysis and identified the relationship between the distance from the entry vessel to the carina. Height (in centimeters) divided by 10 was identified moderate correlation between the distance from the entry vessel to the carina for all patients (Fig. 2A, correlation coefficient: 0.435), and this correction was also revealed in the nonmigration group. (Figure 2B, correlation coefficient: 0.482).

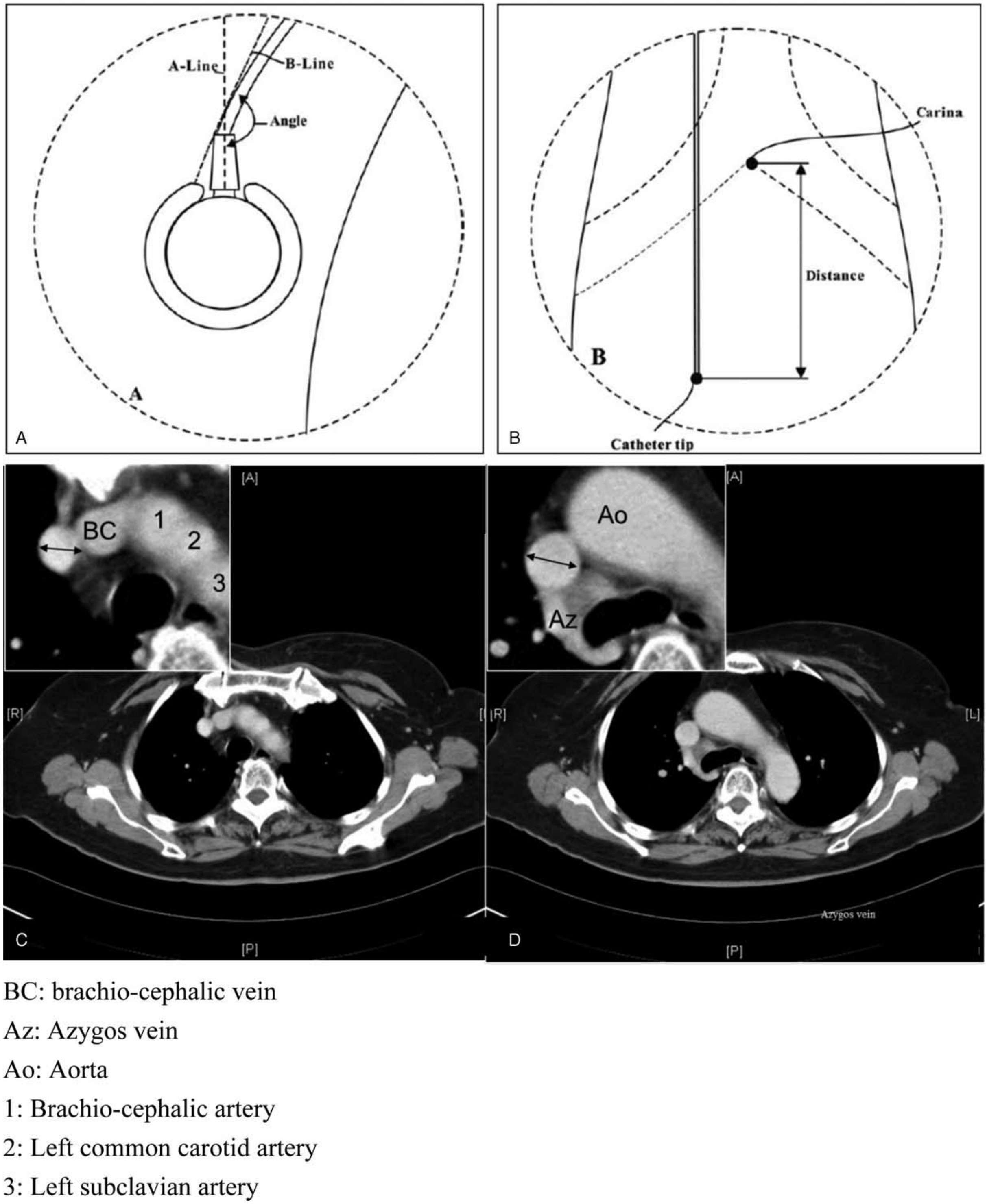

FIGURE 1. (A) Nut-catheter angle[9,10]: The angle between the locking nut toward the ring center and the proximal end of the outflow of the catheter. (B) Catheter tip location (distance to carina)[9,10]: The distance between the catheter tip and the carina. (C) Short axis of the SVC's diameter at the brachiocephalic vein confluence site. (D) Short axis of the SVC's diameter at the azygos vein confluence site.

DISCUSSION

Inadequate tip location may lead complications after intravenous port implantation. For those with deep tip location, arrhythmias, and myocardium injury were reported.[2–4] For those with shallow tip location, complications such as catheter-related thrombosis, catheter migration, brachial plexopathy, neurologic deficit, and cortical vein thrombosis were reported because of slow blood flow velocity could not dilute

TABLE 1. Clinical Characteristics of All Patients

Variables (Mean ± SD)	Total Sample (n = 346)
Age	59.6 ± 12.3
Weight	61.3 ± 11.6
Height	161.4 ± 8.4
BMI	23.4 ± 3.6
SVC diameter in CT (brachiocephalic vein)	1.3 ± 0.3
SVC diameter in CT (azygos vein)	1.7 ± 0.4
Distance between brachiocephalic vein and azygos vein	1.3 ± 0.7
Catheter length (cm)	17.7 ± 2.1
Fluoroscopy: Catheter tip (cm below carina)	1.2 ± 0.5
Gender (male %)	231 (66.7)
Entry vessel (%)	
Left	25 (7.2)
Right	321 (92.8)
Tumor type (%)	
Thorax	190 (54.9)
Abdomen	103 (29.8)
Other	53 (15.3)

BMI = body mass index, CT = computed tomography, SVC = super-superior vena cava.

the infused mecication.[1,5–9] Adequate tip location could minimize the risk of catheter-related complication but the adequate tip location were remain debates because of the intravascular portion of catheter were free mobile within vessel. There were no consensus in ideal catheter tip location between different guidelines Some favor the right atrial-SVC junction and others prefer a tip position within the RA as the optimal position.[2,9,19–21] However, these locations were invisible in image tools and several landmarks are recommended as references to help localize ideal tip location, including T5 to T6 intervertebral space,[11] right mainbronchuscriterion,[12] and carina.[10] In this study, carina was the chosen landmark not only its immobility and visibility but also minimal migration risk that conformed in our previous study.[13]

In this study, 221 patients (63.9%) was identified catheter tip movement less than 1 cm between intraoperation fluoroscopy and postoperation chest plain film. This is totally different compared with previous literature. This is because gravity not only pull down the abdominal organs, but also pull intravascular portion of intravenous port downward. In addition, we fixed the port over fascia of pectoralis major muscle that minimal the catheter movement. Furthermore, additional 2 to 3 cm of catheter length implantation is not necessary in clinical practice and this may cause too deep catheter tip location. Even securing the implanted length of the catheter as best as we could, still 36.1% of patients were identified to have catheter movement within the vessel greater than 1 cm. For peripheral movement group, we did not identify any intrinsic risk factor through either univariate or multivariate analysis. This may be caused by patients' personnel intrinsic factors, including confluence angle and patterns of SVC, brachiocephalic veins, and azygos veins, and further investigation is warranted. For central movement group, we identified that shorter body height ($P = 0.03$), longer implanted catheter length ($P = 0.0004$), and larger SVC diameter at the brachiocephalic vein confluence site ($P = 0.02$) were risk factors for catheter central movement. The implanted catheter length was a more predominant risk factor for central migration and may be caused by variations in fluoroscopy interpretation among surgeons. For patients with shorter body height, a shorter length for the vascular route that lead patients at risk for catheter central movement. For patients with larger SVC diameters, a larger intravascular space which

TABLE 2. Clinical Characteristics of Nonmovement, Central Movement, and Peripheral Movement Groups

Variables (Mean ± SD)	Nonmovement (n = 221)	Central Movement (n = 58)	Peripheral Movement (n = 67)	*P*-Value
Age	59.6 ± 11.8	57.5 ± 12.9	60.9 ± 13.1	0.37
Weight	60.9 ± 11.7	62.9 ± 11.6	61.7 ± 11.2	0.58
Height	161.5 ± 8.4	160.9 ± 8.7	161.7 ± 8.2	0.76
BMI	23.2 ± 3.7	24.1 ± 3.2	23.5 ± 3.6	0.24
SVC diameter in CT (brachiocephalic vein)	1.3 ± 0.3	1.3 ± 0.2	1.3 ± 0.3	0.19
SVC diameter in CT (azygos vein)	1.7 ± 0.4	1.7 ± 0.3	1.6 ± 0.4	0.13
Distance between brachiocephalic vein and azygos vein	1.3 ± 0.8	1.2 ± 0.6	1.2 ± 0.7	0.46
Catheter length (cm)	17.5 ± 1.9	18.4 ± 2.8	17.7 ± 1.9	0.01
Fluoroscopy: Catheter tip (cm below carina)	1.2 ± 0.5	1.3 ± 0.6	1.3 ± 0.6	0.08
Gender (male %)	144 (66.2)	39 (67.2)	48 (71.6)	0.61
Entry vessel				0.56
Left (%)	15 (6.8)	6 (10.3)	4 (6)	
Right (%)	206 (93.2)	52 (89.7)	63 (94)	
Tumor type (%)				0.67
Thorax	122 (55.2)	32 (55.2)	36 (53.7)	
Abdomen	63 (28.5)	16 (27.6)	24 (35.8)	
Other	36 (16.3)	10 (17.2)	7 (10.5)	

P-values were derived from ANOVA or the Chi-square test.
BMI = body mass index, CT = computed tomography, SD = standard deviation, SVC = superior vena cava.

TABLE 3. Clinical Characteristics of Nonmovement and Central Movement Groups

Variables (Mean ± SD)	Nonmovement (n = 221)	Central Movement (n = 58)	*P*-Value
Age	59.6 ± 11.8	57.8 ± 12.9	0.29
Weight	60.9 ± 11.7	62.6 ± 11.7	0.31
Height	161.5 ± 8.4	160.7 ± 8.7	0.51
BMI	23.2 ± 3.7	24.1 ± 3.2	0.09
SVC diameter in CT (brachiocephalic vein)	1.3 ± 0.3	1.3 ± 0.2	0.06
SVC diameter in CT (azygos vein)	1.7 ± 0.4	1.7 ± 0.3	0.15
Distance between brachiocephalic vein and azygos vein	1.3 ± 0.8	1.2 ± 0.6	0.29
Catheter length (cm)	17.5 ± 1.9	18.4 ± 2.8	0.02
Fluoroscopy: catheter tip (cm below carina)	1.2 ± 0.5	1.3 ± 0.6	0.11
Gender (male %)	144 (66.2)	39 (67.2)	0.76
Entry vessel			0.36
Left (%)	15 (6.8)	6 (10.3)	
Right (%)	206 (92.2)	52 (89.7)	
Tumor type (%)			0.98
Thorax	122 (55.2)	32 (55.2)	
Abdomen	63 (28.5)	16 (27.6)	
Other	36 (16.3)	10 (17.2)	

BMI = body mass index, CT = computed tomography, SD = standard deviation, SVC = superior vena cava.

could lead the catheter to move downward under the effect of gravity and cause central movement within vessel.

What's the reliable quantified implanted catheter length from entry site to carina? From view of surface anatomy, the implanted catheter had to cross the width of body and then pass downward to carina via SVC. From view of real anatomy, the catheter was implanted via entry vessel, such as cephalic vein, thoracoacromial vein, or internal jugular vein, to subclavian vein and low third of SVC. The former could be calculated by measurement, the later would have more variation that the vessel configuration was 3 dimension that would not calculated. From literature review, Peres[22] and Czepizak et al[23] were recommended that right infraclavicular subclavian catheters should be inserted to height/10–2 cm, right internal or external jugular catheters to height/10 cm and left external jugular catheters to height/10 + 4 cm. However, the implantation method that utilized in these studies was puncture method but not vessel cutdown. In addition, these authors did not explain why they chosen height (in centimeter)/10 as a reference standard. In this study, we identified height/10 to have moderate correlation to the distance from the entry vessel to the carina. The moderate correlation may be caused by the 3-dimensional configuration of entry vessel. The reference length from entry vessel to carina from this study was height/10, and actual length could be further decided by surgeon under intraoperation fluoroscopy surveillance. This recommendation is easily to follow and could place catheter tip more precisely.

However, there were still limitations in our study. First, this is a retrospectively study and majority patients (92.8%) received intravenous port implantation via right side entry vessel. Our result may be more coincidence in implantation via right entry vessel. The recommended length from left side entry vessel could be longer because that would be cross midline via left brachiocephalic vein and the consideration to minimized the catheter impingement to SVC lateral wall. However, by the aid of intraoperative fluoroscopy, we could visualized the carina and placed catheter more precisely. Second, we used fluoroscopy instead of ECG as intraoperation surveillance. From literature review, the ECG monitoring system could precisely predict catheter tip location of peripherally inserted central catheter up to 97.7% under echo-guidance puncture.[24] In addition, no more need for radiological image tool. However, in central vein catheter implantation the ECG monitoring still has high variation in tip location and malposition rate.[25] In this study, we use vessel cutdown as implantation method. The method not only minimized tissue trauma (ie, no more additional wound and needle puncture) but also ensure

TABLE 4. Multivariate Analysis of Risk Factors of Central Movement

Variables	Point Estimate	Standard Error	*P*-Value
Height	−0.04	0.02	0.03
Fluoroscopy—catheter length (cm)	0.27	0.07	0.0004
SVC diameter in CT (brachiocephalic vein)	1.35	0.59	0.02

CT = computed tomography, SVC = superior vena cava.

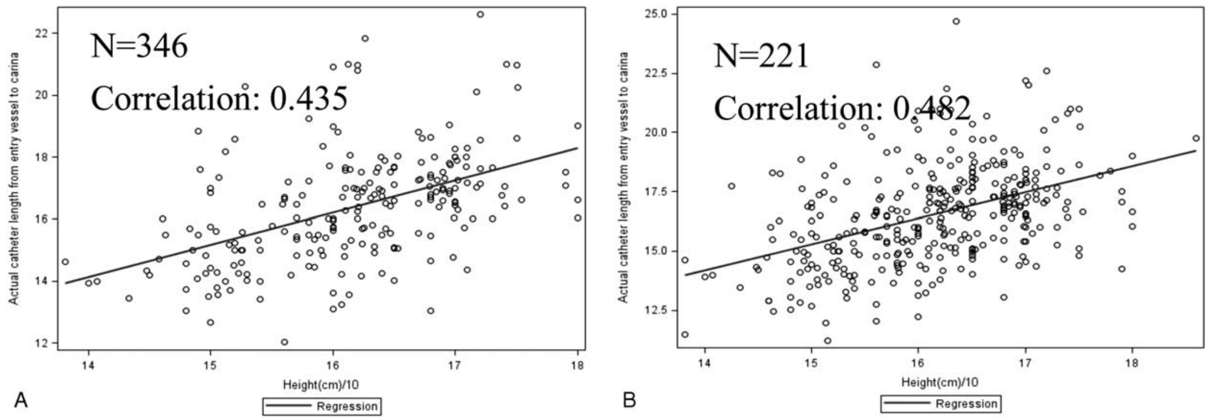

FIGURE 2. (A) The correlation between the distance from the entry vessel to the carina and height/10 among all patients. (B) The correlation between the distance from the entry vessel to the carina and height/10 among nonmigration patients.

high successful rate (100%) in single operation. Fluoroscopy could provide real-time visualization of entry vessel and provide 3-dimensional configuration of entry vessel. We could utilize metallic wire to establish entry route prior catheter implantation to overcome the anatomic variation and inadequate vessel size. Third, we did not identify any risk factors for peripheral movement group, which may need further investigation. Fourth, we could not conduct a quantified formula for calculation for each entry points because of limited cases and further investigation was warranted. Even the limitations remains, our study still has useful clinical information as follows. The intravenous movement of catheter was also exist in intravenous port catheter. The intraoperative fluoroscopy provides accurate catheter tip location in 63.9% patients. Additional length of catheter implantation seems unnecessary in 80.6% patients, that is, those who presented as nonmovement and central migration group. Patients with short height, larger SVC diameters at the brachiocephalic vein confluence site had greater risk for catheter central movement. Height/10 may be consider as reference length of implantation for inexperience surgeon and precise implantation length could be adjust under guidance of fluoroscopy.

CONCLUSION

The intravenous movement of catheter was also exist in intravenous port catheter. The intraoperative fluoroscopy provides accurate catheter tip location in 63.9% patients. Additional length of catheter implantation seems unnecessary in 80.6% patients, that is, those who presented as nonmovement and central migration group. Patients with short height, larger SVC diameters at the brachiocephalic vein confluence site had greater risk for catheter central movement. Height/10 may be consider as reference length of implantation for inexperience surgeon and precise implantation length could be adjust under guidance of fluoroscopy.

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