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Simple Formula to Place Central Venous Catheter Tip at T6 After Surgical Cutdown in Neonates

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The objective of this paper was to develop a generally applicable formula to estimate correct catheter length after surgical cutdown in right internal jugular vein (RIJV) in neonates. The carina has been utilized as an anatomic landmark indicating superior vena cava-right atrium junction (SVC-RA) for the optimal placement of the central venous catheter (CVC) tip position. However, this landmark may not be accurate in neonates. Recent researches noted that the sixth vertebral body (T6) could better serve as a new landmark of SVC-RA in neonates and smaller children. We prospectively performed RIJV cutdown. For a controlled and reproducible surgical procedure, the venous entry site was consistently taken as the point where the omohyoid muscle crosses the RIJV. On intraoperative infantogram, the vertical distance between the venous entry site and T6 was measured and the catheter was inserted to this length. A linear regression model was investigated using the following variables to elicit the best prediction model for catheter length: gestational age, postconceptional age, birth weight, and weight at operation. Weight at operation best correlated with the measured CVC length ($R^2 = 0.916$, $P = 0.00$), and the following linear equation was derived: estimated CVC length (mm) $= 9 \times$ [weight at operation (Kg)] $+ 30$. There was no statistically significant difference between measured and estimated CVC length. With this formula, the optimal catheter length could easily be estimated when considering RIJV cutdown.

Key words: Central venous catheter – Cutdown – Neonate – Formula

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The superior vena cava-right atrium junction (SVC-RA) has generally been accepted as an optimal location for the central venous catheter (CVC) tip placement.[1] Apart from device-assisted techniques, such as transesophageal echocardiography (TEE) or fluoroscopy, which measure SVC-RA directly, various methods have been developed to determine indirectly the catheter length for correct tip location; these include plain radiographic guidance, anatomic landmark guidance, or a mathematical formula, but none has been universally accepted.[2–4] Most of these methods are based on the concept that the carina reflects the location of the SVC-RA with minimal error.[5] There appears limited data on the relationship between the location of the carina and the SVC-RA in neonates and conflicting results exist, which suggest that carina does not represent the true level of the SVC-RA. Inakawa *et al* showed that, in their autopsy series of neonates with median postconceptional age of 35 weeks, carina was located below the pericardial reflection in most cases. By contrast, Albrecht *et al* reported that the carina was above the pericardial reflection in small children whose mean age was 12.5 months. Differences in the age and diagnosis of the subjects might explain the conflicting results.[6,7] As an alternative, Connolly and colleagues showed that, in most cases, the SVC-RA lies at the level of the sixth thoracic vertebral level (T6) or the interspace above or below, suggesting the usefulness of T6 as a landmark instead of the carina.[8] In this study, we prospectively performed the right internal jugular vein (RIJV) cutdown, using the same, consistent entry site, and targeting T6 as a tip location. By analyzing these data, we aimed to develop a generally applicable formula to predict the proper CVC length in neonates.

Patients and Methods

Patients

We prospectively enrolled patients who underwent RIJV cutdown as neonates between December 2010 and December 2013, at the Department of Surgery, Kangwon National University Hospital. The inclusion criteria were no history of an indwelling CVC and RIJV approach. Patients who had congenital heart disease or who underwent a left-sided approach were excluded. All patients were followed prospectively, and the endpoint of follow-up was defined as the time of catheter removal, regardless of the indication. Data collected were as follows: gestational age, postconceptional age at operation, birth weight, weight at operation, and catheter position-related complications.

Surgical techniques

We have previously published our policies on cutdown and detailed surgical technique.[9] With the patient supine, a roll placed under the shoulder to extent the neck and the neck tilted to the left. After making a 1.5-cm length low cervical transverse incision along the skin crease above right sternocleidomastoid (SCM) muscle, the incision was deepened to the SCM muscle by sharp dissection. The platysma muscle was transected. The SCM muscle was then dissected bluntly along its longitudinal fibers to expose the point where the omohyoid muscle crosses the RIJV. This point served consistently as the venous entry site. Omohyoid muscle was not transected but just retracted medially for venotomy. After applying a radiopaque marker indicating the junction of RIJV and omohyoid muscle, an intraoperative infantogram was taken (Fig. 1A). An imaginary horizontal line perpendicular to the body axis was drawn at the level of the marker, and the vertical distance between the imaginary line and the upper (U)/lower (L) border of T6 was measured in millimeters on the Picture Archive and Communicating System (PiViewSTAR, Infinitt, Inc., Seoul, Korea; Fig. 1B). The intervertebral spaces above (Ia) and below (Ib) the T6 were also measured. The vertical distance between the omohyoid-SCM junction and the midpoint of T6 (C) was considered as the distance between the entry site and the SVC-RA, and calculated as $C = (U+L)/2$. The catheter was inserted to the length of C (measured CVC length). We designated a "safety area" where the SVC-RA would lie with the highest probability,[7] defined as an area including T6 and the interspace above and below T6. Tip location was regarded as adequate if the tip was located within the safety area. The width of the safety area (W) was calculated as $W = L - U + Ia + Ib$. An infantogram was taken again immediately after the CVC placement, and the catheter length was adjusted to locate the tip within the safety area.

Statistical analysis

Using gestational age, postconceptional age at operation, birth weight, and weight at operation as separate variables, a linear regression model was explored to determine a single variable which would produce the highest determination coefficient

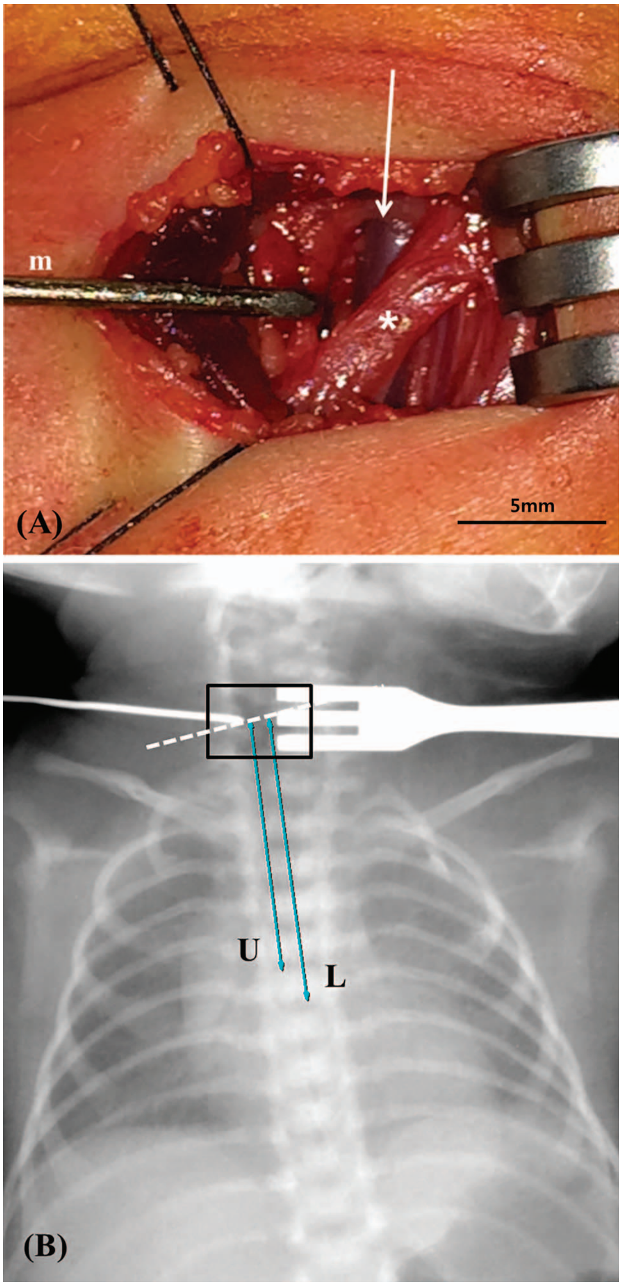

Fig. 1 (A) Operative photograph, taken from a 1290-g baby, shows that the radiopaque marker (m) indicates the junction of omohyoid muscle (white asterisk) and underlying RIJV (white arrow). (B) Vertical distance between the point depicted in Fig. 1 (A) and upper (U) and lower (L) border of T6, respectively. Black rectangle indicates the area of Fig. 1 (A).

(R^2). Multivariate analysis was also performed to identify whether a combination of multiple variables contributed to improving the predictability of CVC length. With this variable, a linear prediction model was constructed with a 95% prediction interval to provide a range of measurement. A linear regression equation was also developed. This equation was then applied to each patient to produce the estimated CVC length, and the estimated CVC length was matched and compared to measured CVC length in each patient. Wilcoxon signed rank test was used to examine the difference between 2 matched lengths. SPSS package (version 16.0) was used to perform statistical analyses. A *P*-value less than 0.05 was considered statistically significant.

Table 1 Patients' characteristics

Patient characteristics	
Male:female	11:12
Gestational age	31 weeks* (25–40 weeks)
Postconceptional age	35 weeks* (27–43 weeks)
Birth weight	1,490 g* (750–3400 g)
Weight at operation	1,710 g* (870–3600 g)
Primary pathology	12 prematurity, 5 RDS, 2 neonatal seizure, 2 neonatal sepsis, 2 aspiration pneumonia

RDS, respiratory distress syndrome.

*Median value.

Ethics statement

This study was approved by the Kangwon National University Hospital Institutional Review Board (KNUH –2014-07-001-001).

Results

Overall, 23 patients were enrolled in this study. The median gestational age was 31 weeks (range, 25 to 40 weeks) and median birth weight was 1,490 g (range, 750 to 3400 g) including 3 extremely-low birth weight (ELBW) and 9 very-low birth weight (VLBW) infants. Patient characteristics are summarized in Table 1. The mean T6 height and width of intervertebral space was 4.52 mm and 2.57 mm respectively, and the mean width of the safety area was 9.66 mm. After catheter placement, no patients needed tip repositioning, meaning that the measured CVC length allowed the catheter tip to be placed well within the safety area. There were no cases of catheter position-related complications.

Among the 4 variables, body weight at operation showed the highest R^2 value in the linear regression model ($R^2 = 0.916$, $P = 0.00$). Multivariate analysis failed to improve the accuracy of prediction. Fig. 2 shows the scatter diagram with 95% confidence interval, and with this regression model, the

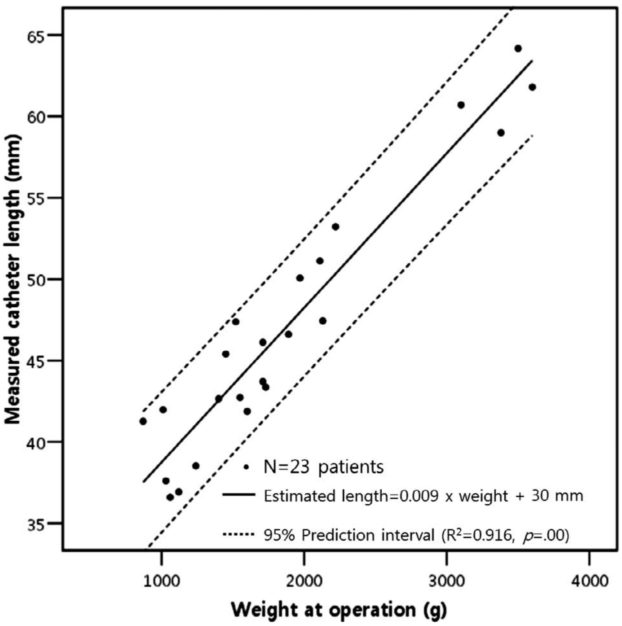

Fig. 2 Simple scatter diagram between patient's weight at operation and measured CVC length.

following linear equation was derived: estimated CVC length (mm) $= 9 \times$ [weight (Kg) at operation] $+$ 30. The estimated CVC length following this equation allowed the catheter tip to be positioned within the safety area in all patients.

After comparing the 2 lengths, measured CVC length and estimated CVC length, there was no statistically significant difference between 1 lengths (Wilcoxon signed rank test, $P = 0.678$).

Discussion

The aim of this study was to validate our practice and to develop a universally applicable method to determine CVC length when considering RIJV cutdown in neonates. The precondition of this study was that the carina might not be a suitable anatomical landmark to represent the correct location of the SVC-RA in neonates, and that, rather than the carina, the T6 level would be a more appropriate landmark to predict the location of the SVC-RA. Radiologic studies in neonates demonstrated that the carina was situated between third and fifth thoracic vertebra, most commonly at fourth thoracic vertebra, and that a point two vertebral body unit below the carina enabled the reliable estimate of the position of SVC-RA.[10,11] This is in well agreement with our precondition. In this study, the measured CVC length, being the vertical length between the junction of the omohyoid muscle and the RIJV, and the T6 level on intraoperative infantogram, located the catheter tip well at the anticipated level. Inversely, the estimated CVC length by linear equation developed in this study corresponded well with the measured CVC length in each patient. Therefore, this equation could be utilized to estimate the catheter length before the cutdown procedure, thereby avoiding the onerous and time-consuming work in measuring the catheter length intraoperatively.

With the increasing success of the percutaneous technique for central venous access in smaller infants,[12] the usefulness of the cutdown method may be doubted. Most of the studies reporting the best results on CVC tip positioning were usually obtained from patients who were placed under general anesthesia for major surgery, and the SVC-RA was directly confirmed by TEE or fluoroscopy after subclavian or internal jugular approach by Seldinger technique.[13–15] However, there must be a particular subset of patients who can definitely benefit from the cutdown approach, and most of these are critically-ill ELBW or VLBW infants in the neonatal intensive care unit.[9] In these circumstances, aid by specialized equipment such as TEE or fluoroscopy would be difficult or even impossible, and we can obtain an estimated catheter length to place the tip at T6 with the equation preoperatively. Although our study included some patients whose birth weight and gestational age permitted a percutaneous approach, we stress that our results should particularly be directed to premature babies where the percutaneous approach could be quite risky.

As the choice of preferred venotomy site could differ among operating surgeons, 2 constant points where the catheter length started and ended were needed to elicit a generally applicable formula using patients' characteristics such as age or weight. The ending point was surely the T6 level that we had assumed to be the location of the SVC-RA, and the starting point was defined as a point where the omohyoid muscle crosses the RIJV. The omohyoid muscle crossing the RIJV could easily be identified after dissecting the SCM muscle, and can serve as a landmark for constant venous entry site when performing RIJV cutdown.

Our study has some limitations. First, we had not considered the patient's height at the beginning of this study, and the results showed that body weight at operation would most faithfully reflect patient's growth. By contrast, Stroud *et al* showed a relationship between body surface area (BSA) and optimal subclavian catheter length and suggested a linear equation with BSA as a single variable.[16] They asserted that BSA calculated by Mosteller method, which utilized both the weight and height,[17] could reflect the patients' growth more accurately than considering either alone. Although it is widely recognized that weight rather than height is the major determinant of BSA, we aim to include the height and evaluate its relationship with BSA in a future trial. Second, our study had a relatively small sample number and therefore the statistical power would have been overestimated. This problem should be overcome in a future trial with more ELBW and VLBW infants. In conclusion, we have devised a formula to determine an optimal catheter length to place the tip at T6 in cases of RIJV cutdown in neonates. With this formula, the optimal catheter length could easily be determined before insertion and could avoid cumbersome intraoperative manipulations to look for T6 level.

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