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Original Research Article

A cross sectional study assessing six different methods to predict the ideal position of umbilical venous catheters in neonates of different weight categories

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ABSTRACT

Background: This was a cross sectional study done to find the most suitable method of assessing umbilical venous catheter (UVC) length in seventy two neonates of four different weight categories using six methods.
Methods: Neonates were grouped into A (upto 1 kg), B (>1-1.5 kg), C (>1.5-2.5 kg) or D (>2.5 kg) based on their birth weight. UVC was placed using Shukla-Ferrara method and x-ray taken to finalize the catheter length. The predicted catheter length was also measured by Dunn method, umbilicus to nipple length, umbilicus to xiphisternum length, umbilicus to midpoint of inter mammary distance, and umbilicus to symphysis pubis length. ANOVA test was used to find the methods which did not have statistically significant difference with the final length from x-ray ($p>0.5$). The method with the least mean difference from final length was taken as the most suitable.
Results: UVC length assessed by Shukla Ferrara method and umbilicus to midpoint of inter mammary distance did not have statistically significant difference with final catheter length on x-ray in all groups. UVC length assessed by Dunn method did not have statistically significant difference with final catheter length on x-ray in group A, C and D while UVC length assessed by umbilicus to nipple length did not have statistically significant difference in group D.
Conclusions: Umbilicus to the midpoint of inter-mammary distance was the most suitable method to estimate length of insertion of UVC in neonates.

Keywords: Dunn method, Shukla Ferrara method, Umbilicus to midpoint of inter-mammary distance, Umbilicus to nipple length, Umbilicus to symphysis pubis length, Umbilicus to xiphisternum length

INTRODUCTION

Umbilical vein catheterization is most commonly used in the delivery room for resuscitation and it presents as a viable point of venous access for a trained care provider in neonatal units.[1,2] These are used for intravenous access in emergencies, administration of intravenous fluids including total parenteral nutrition, drugs and exchange transfusion.[3,4] The ideal umbilical vein catheter (UVC) tip position is at the junction of ductus venosus and inferior vena cava- at the level of 9th and 10th thoracic vertebra.[3] The final length of UVC can be confirmed by ultrasonography or plain thoraco abdominal x-ray antero-posterior(AP) view.[3,5]

The incorrect positioning of catheter tip due to under or over insertion can lead to significant complications like central line associated bloodstream infection (CLABSI), intestinal necrosis, thrombosis, ascites, hydrothorax, cardiac tamponade, cardiac arrhythmias, pleural effusion and pericarditis.[6,7] Hence selection of the most appropriate and feasible method for catheter insertion is very important in terms of decreasing the risk and frequency of complications.[8-10]

Currently, several methods are used to estimate the insertion length of UVC based on birth weight or morphometric measurements. These include methods based on Shukla-Ferrara formula, Dunn nomogram, umbilicus to xiphisternum length, umbilicus to symphysis pubis length, umbilicus to nipple length and umbilicus to midpoint of intermammary distance.[8]

The Shukla-Ferrara formula is (birth weight × 3 + 9)/2 + 1.[11] Dunn method includes measuring the length from the tip of newborn's shoulder to the umbilicus (the distance between the lateral end of the clavicle and a point vertically beneath it, which is at level with the umbilicus) and comparing it with the Dunn normogram.[12]

Studies showed different levels of accuracy for predicting UVC length with Shukla Ferrara and Dunn methods and the need for frequent readjustments.[13,14] Unpublished data based on an audit in the past two years from our neonatal intensive care unit on umbilical vein catheterization, showed that 8% neonates had developed CLABSI. All the UVCs were placed according to the Shukla Ferrara formula. In order to decrease the UVC related complications due to malpositioning and readjustments, selection of the most accurate method became necessary. Therefore, in this cross sectional study, the actual UVC length obtained from x-ray was compared with estimated UVC length using (1) Shukla Ferrara method, (2) Dunn method, (3) umbilicus to xiphisternum length, (4) umbilicus to nipple length, (5) umbilicus to symphysis pubis length and (6) umbilicus to mid-point of inter-mammary distance. The objective of the study was to identify the most appropriate method of assessing UVC length in neonates of four different weight categories.

METHODS

This cross sectional study was done between September 2018 and August 2020, in the department of neonatology, Rajagiri Hospital, Aluva, Kerala.

Inclusion criteria

Newborn infants requiring umbilical venous catheterization anytime during the hospital stay.

Exclusion criteria

Babies who had abdominal wall defects including omphalitis, omphalocele, gastroschisis and congenital anomalies including vertebral anomalies were excluded from the study.

The sample size was 72.

Ethical clearance was obtained from the Institutional Ethical Committee. After obtaining written informed consent from parents, the umbilical venous catheters were placed under strict aseptic precautions according to the Shukla-Ferrara formula. Measurements for Dunn method was also taken from Dunn normogram. All the morphometric measurements (umbilicus to xiphisternum length, umbilicus to nipple length, umbilicus to symphysis pubis length, umbilicus to mid-point of inter-mammary distance) were recorded at the same time using a non-stretchable measuring tape by the principal investigator. Figure 1 shows the morphometric measurements- umbilicus to xiphisternum length, umbilicus to nipple length, umbilicus to symphysis pubis length, umbilicus to mid-point of inter-mammary distance.

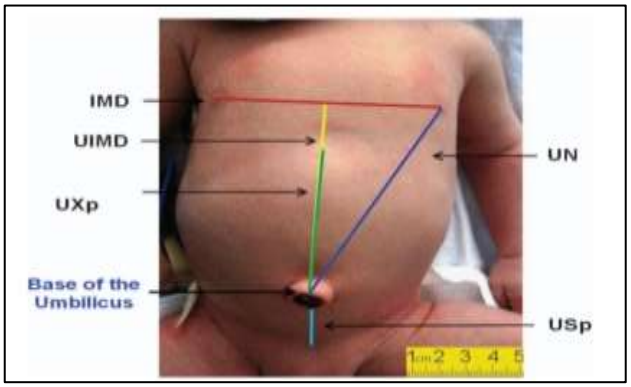

Figure 1: Morphometric measurements.

IMD- inter mammary distance; UIMD,-umbilicus to mid-point of IMD; UN,-umbilicus to nipple; USp,-umbilicus to symphysis pubis; UXp,-umbilicus to xiphoid process.

3.5 Fr umbilical vein catheters were used in neonates who weighed below 1500 gm and 5 Fr in neonates who weighed more than or equal to 1500 gm. The final position of umbilical venous catheter was confirmed by the gold standard method - thoraco abdominal x-ray AP view. The position of placement of the catheter was considered appropriate when it was between the 9th and 10th thoracic vertebra (T_9-T_{10}) on the thoraco abdominal x-ray AP view.

Catheters that were placed too low were removed but catheters that were placed too high were pulled into the safe position in a sterile fashion. Check x-ray was taken again to confirm. Regular care of the catheters were done throughout the dwell period. After obtaining informed written consent from parents, infants were divided into four groups A, B, C, D based on birth weight (upto 1 kg, >1-1.5 kg, >1.5-2.5 kg, >2.5 kg) respectively. Data collection included age of the baby, sex, weight, reason for hospitalization, reason for placement of umbilical venous catheter, whether the catheter readjusted or not, the final catheter position, umbilicus to xiphisternum length, umbilicus to symphysis pubis length, umbilicus to nipple length, umbilicus to midpoint of inter-mammary distance, umbilicus to shoulder length and occurrence of CLABSI. The final catheter length from x-ray and the length of insertion by Shukla Ferrara method were compared with the lengths estimated by umbilicus to shoulder length or Dunn nomogram, umbilicus to xiphisternum length, umbilicus to symphysis pubis

length, umbilicus to nipple length, umbilicus to midpoint of inter-mammary distance.

Statistical analysis: The sample size calculation was based on a previous study by Gupta et al of simple measurements to place umbilical catheters using surface anatomy.[8] Assuming 95% confidence interval, alpha error 5% and relative precision 11.4%, with the expected proportion of the study group as 57%, the required minimum sample size was calculated as 72 using the formula,

$$n = \frac{(Z_1 - a/2)^2 p(1-p)}{d^2}$$

Where, n = sample size,

$Z_1 - \alpha/2$ at 5% error = 1.96, expected proportion of the study group, p = 57%, 1-p = 43%, relative precision d = 11. 4%.

For each weight category, the mean difference between the final length of UVCs and lengths obtained by six different formulas were compared using ANOVA, p value <0.05 was considered as significant. The most appropriate formula/ method for UVC insertion for each weight category was considered as the formula/method with p>0.05 and which showed the least significant difference from the final length of UVC obtained from x-ray.

RESULTS

A total of 72 neonates were enrolled in the study. Table 1 shows the baseline characteristics of the study group.

Figure 2 shows the distribution of babies in each weight category. 23% of babies were in group A, 28% in group B, 28% in group C and 28% in group D. The most common indication for NICU admission among these 72 neonates enrolled were prematurity and respiratory distress syndrome (56.9%). Other indications were hypoglycemia (8.3%), sepsis (6.8%), birth asphyxia (5.6 %), prematurity with respiratory distress and sepsis (5.6%) and persistent pulmonary hypertension (5.6%). Indications for UVC insertion were administration of intravenous fluids and medications (45.8 %) and administration of total parenteral nutrition (43.1%), administration of intravenous fluids (8.3%) and exchange transfusion (2.8%). Forty six (63.90%) neonates required UVC readjustment and in 26 (36.10%) neonates, readjustments were not required. Figure 3 shows that out of 72 neonates, four (5.6%) developed CLABSI. Only those neonates who had UVC readjustments (n=4) developed CLABSI (p=0.28).

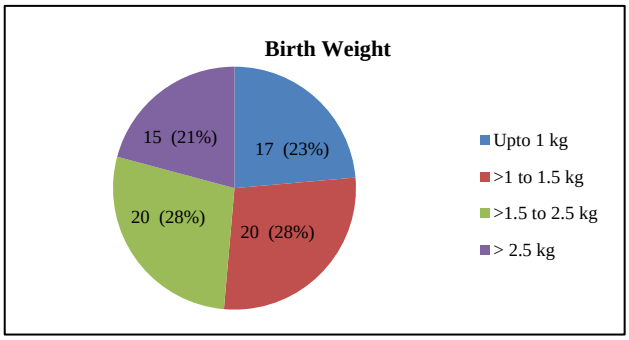

Figure 2: Distribution of neonates belonging to different weight categories.

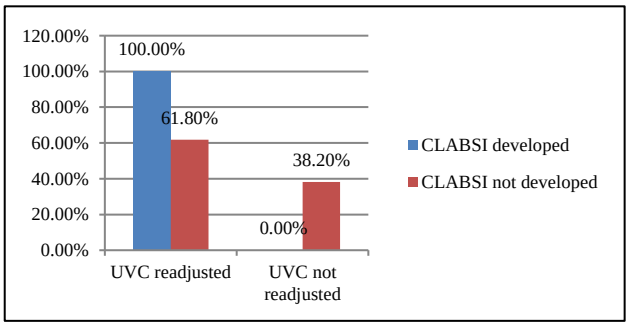

Figure 3: Incidence of CLABSI in neonates who required UVC readjustment and did not require UVC readjustment.

Table 1: Base line characteristics.

Baseline characteristics		Group A	Group B	Group C	Group D
Number of neonates		17 (23.6%)	20 (27.7%)	20 (27.7%)	15 (20.8%)
Sex	Males	7 (41.2%)	13 (65%)	11 (55%)	7 (46.7%)
	Females	10 (58.8%)	7 (35%)	9 (45%)	8 (53.3%)
Gestational age	Extreme preterm	14 (82.4%)	8 (40%)	0 (0%)	0 (0%)
	Preterm	2 (11.8%)	10 (50%)	9 (45%)	0 (0%)
	Late preterm	1 (5.9%)	2 (10%)	7 (35%)	0 (0%)
	Term	0 (0%)	0 (0%)	4 (20%)	15 (100%)
Most common indication for UVC insertion		Total parentral nutrition (94.1%)	Total parentral nutrition (57.9%)	Intravenous fluids and medications (70%)	Intravenous fluids and medications (66.7%)
UVC readjustment done		9 (52.9%)	15 (75%)	14 (70%)	8 (53.3%)
CLABSI developed		3 (17.64%)	0	0	1 (6.6%)

GROUP A: Birth weight upto 1 kg. GROUP B: Birth weight >1 to 1.5 kg. GROUP C: Birth weight > 1.5 to 2.5 kg. GROUP D: Birth weight : >2.5 kg. UVC: Umbilical venous catheter. CLABSI: Central line associated blood stream infection

Table 2: Comparison of umbilical venous catheter length using different formula in group A.

Formula/method	Mean difference (cm)	Standard error	P value	95% confidence interval
Shukla Ferrara	-0.5471	0.2904	0.495	-1.419 to 0.325
Dunn Method	-0.4706	0.2904	0.670	-1.343 to 0.401
Umbilicus to xiphisternum	1.3235	0.2904	0.000	0.452 to 2.196
Umbilicus to nipple	-1.0706	0.2904	0.006	-1.943 to -0.199
Umbilicus to pubis symphysis	1.9000	0.2904	0.000	1.028 to 2.772
Umbilicus to midpoint of intermammary distance	-0.3824	0.2904	0.843	-1.254 to 0.490

Table 3: Comparison of umbilical venous catheter length using different formula in group B.

Formula/method	Mean difference (cm)	Standard error	P value	95% confidence interval
Shukla Ferrara	-0.6200	0.2435	0.152	-1.349 to 0.109
Dunn method	-0.7600	0.2435	0.035	-1.489 to -0.031
Umbilicus to xiphisternum	0.8150	0.2435	0.018	0.086 to 1.544
Umbilicus to nipple	-1.1750	0.2435	0.000	-1.904 to -0.446
Umbilicus to pubis symphysis	2.0350	0.2435	0.000	1.306 to 2.764
Umbilicus to midpoint of intermammary distance	-0.4600	0.2435	0.491	-1.189 to 0.269

Table 4: Comparison of umbilical venous catheter length using different formula in Group C.

Formula/method	Mean difference (cm)	Standard error	P value	95% confidence interval
Shukla Ferrara	-0.5500	0.3182	0.598	-1.503 to 0.403
Dunn method	-0.4750	0.3182	0.749	-1.428 to 0.478
Umbilicus to xiphisternum	1.7250	0.3182	0.000	0.772 to 2.678
Umbilicus to nipple	-1.0600	0.3182	0.019	-2.013 to -0.107
Umbilicus to pubis symphysis	3.0550	0.3182	0.000	2.102 to 4.008
Umbilicus to midpoint of intermammary distance	-0.3950	0.3182	0.877	-1.348 to 0.558

Table 5: Comparison of umbilical venous catheter length using different formula in group D.

Formula/method	Mean difference (cm)	Standard error	P value	95% confidence interval
Shukla Ferrara	-0.6467	0.4396	0.761	-1.970 to 0.677
Dunn method	-0.3000	0.4396	0.993	-1.624 to 1.024
Umbilicus to xiphisternum	2.2533	0.4396	0.000	0.930 to 3.577
Umbilicus to nipple	-0.7000	0.4396	0.688	-2.024 to 0.624
Umbilicus to pubis symphysis	4.0600	0.4396	0.000	2.736 to 5.384
Umbilicus to midpoint of intermammary distance	-0.0267	0.4396	1.000	-1.350 to 1.297

In group A (Table 2), Shukla Ferrara method, Dunn method and umbilicus to the midpoint of intermammary distance showed a mean overestimation of 0.5471, 0.4706 and 0.3824 centimeters respectively. There was no significant difference among these three methods with the final length while the other morphometric methods showed significant difference. The umbilicus to the midpoint of intermammary distance had the least mean difference and hence considered most appropriate in this category. In group B (Table 3) non-significant overestimation in comparison with the final length was observed in the Shukla Ferrara method (mean difference- 0.6200 cm) and umbilicus to the midpoint of inter mammary distance (mean difference- 0.4600 cm). These two methods were closest to the final length while the Dunn method and other morphometric methods showed significant difference. As the umbilicus to the midpoint of intermammary distance had the least mean difference, it was taken as the most appropriate method in this weight category. In Group C (Table 4), Shukla Ferrara method, Dunn method and umbilicus to the midpoint of intermammary distance showed a mean overestimation of 0.5500, 0.4750 and 0.3950 cm respectively. These three methods showed closeness to the final length while other morphometric methods showed significant difference. The umbilicus to the midpoint of intermammary distance

had the least mean difference, so was the most appropriate method in this category. Table 5 shows that for the group D, Shukla Ferrara method, Dunn method, umbilicus to nipple and umbilicus to the midpoint of intermammary distance showed a mean overestimation of 0.6467, 0.3000, 0.7000 and 0.0267 cm respectively. These four methods showed closeness to the final length while other morphometric methods showed significant difference. The umbilicus to the midpoint of intermammary distance had the least mean difference from the final length, so was the most appropriate method in group D.

DISCUSSION

The incorrect positioning of umbilical venous catheters (UVC) can lead to significant complications like central line associated bloodstream infection (CLABSI), intestinal necrosis, thrombosis, ascites, hydrothorax, cardiac tamponade, cardiac arrhythmias, pleural effusion and pericarditis.[6,7] The commonly used methods for positioning of UVC (Shukla Ferrara and Dunn methods) lack accuracy.[10,11,15,16] In a prospective study by Verheij et al, the overall accuracy of both methods was poor leading to a higher rate of over insertion. The Dunn method resulted in correct position in only 40% (28/67) of UVCs.[15]

In this cross sectional study we compared six different methods (Shukla Ferrara and Dunn methods, umbilicus to xiphisternum distance, umbilicus to nipple distance, umbilicus to mid-point of intermammary distance and umbilicus to pubis symphysis distance in cm) to predict the ideal position of UVC. For neonates of all birth weight categories, Shukla Ferrara and umbilicus to mid-point of inter-mammary distance did not show significant difference from the final length at which UVCs were placed. Umbilicus to mid-point of inter-mammary distance had the least mean difference in all four weight categories and so was better than Shukla Ferrara method. We concluded that the umbilicus to mid-point of inter mammary distance was the most appropriate method for estimating the depth of insertion of umbilical venous catheter for neonates of different birth weight categories.

Our results are similar to the study by Sheta et al, in which the surface measurement-based formula was superior to the Shukla Ferrara formula in extremely low birth weight, small for gestational age and large for gestational age infants.[16] In their study, umbilicus to nipple distance minus one was found to be the most useful surface measurement. Gupta et al concluded that two simple anatomical landmarks (umbilicus to nipple length and umbilicus to pubis symphysis length) correlated well to the accurate insertion length of umbilical venous catheters.[8] They compared only two birth weight categories, less than or equal to 1.5 kg and more than 1.5 kg and the number of neonates in each groups were not comparable. Their study compared only the Shukla Ferrara formula with four different morphometric methods. In the present study, the number of neonates in the four groups (based on birth weight) were comparable. Our study also compared the Shukla Ferrara and Dunn formula with six morphometric methods

The final length of UVC was determined by chest x-ray. We did not use ultrasonography (USG) for confirmation of accurate position of the catheters as subjective variation is high for USG as compared to x-rays. USG is not always available in many NICUs and not all neonatologists have expertise in doing it.

The strength of our study is that neonates of four weight categories were included and had comparable numbers of subjects. There are only very few studies comparing Shukla Ferrara and Dunn formula with the morphometric methods.

Ours was not a prospective study. The sample size was small. We did not assess JSS formula of UVC insertion (UVC length in cm = 6.5 + weight in kg) by Krishnagowda et al as our study commenced before it was published in 2019.[17] We suggest a future multicentric study which is prospective with a larger number of study subjects comparing the JSS formula with morphometric methods. Only a prospective study can tell the usefulness of the morphometric method in reducing CLABSI.

CONCLUSION

We recommend using the umbilicus to mid-point of inter mammary distance in centimetres for estimating the depth of insertion of umbilical venous catheter for neonates of different birth weight categories.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee Jubilee mission medical college and research institute, Thrissur. Approved on 11/09/2018, IEC Study Ref.No: 26/18/IEC/JMMC&RI

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