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Original Article

Comparison of Dunn and Shukla method of calculating umbilical vein catheter insertion length: A randomized controlled trial

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ABSTRACT

Objective: To compare accuracy of shukla versus dunn formula in calculating required length of insertion of umbilical vein catheters (UVC).
Design: Randomized control, open label trial.
Setting: Tertiary care level III Neonatal ICU.
Subjects: Newborn infants requiring UVC insertion during first 5 days of life.
Interventions: As per randomization, required length of insertion of umbilical vein catheter was calculated either by Shukla or dunn method and correct placement of UVC tip in successful insertions were determined with the help of radiographs.
Primary outcome: Proportion of accurately placed tip of umbilical vein catheter (UVC) in the two methods of insertion length calculation.
Results: A total of 83 infants were enrolled during the study period. Three infants were excluded due to missed randomization and the remaining 80 infants were included in the study. 39 infants were enrolled in the Shukla group and 41 infants in the Dunn group. On successful insertion in Shukla group, n = 14 (N = 36, 38.8%) of UVC were placed in correct position versus n = 18 (N = 34, 52.9%) in Dunn group ($p > 0.05$).
Conclusions: While no statistical difference was observed in the proportion of correctly placed UVC tip in both the groups, there was a trend of higher proportion of catheter being correctly placed in Dunn group.

1. Background

Umbilical catheterization is one of the most frequently performed procedure in the neonatal intensive care unit (NICU) and is a current standard of care in the management of sick term and preterm infants. When positioned appropriately across ductus venosus a umbilical catheter provides a reliable route for administrating medication, nutrition, performing exchange transfusion and also for central venous pressure monitoring. On successful catheterization a Correct position of UVC is when the catheter tip is located in inferior vena cava (IVC) (Umbilical Vascular Cathet, 2019). In malpositioned catheter the catheter tip is either at the level of right atrium (High position) or below inferior venacava (Low position). In unsuccessful catheterization catheter tip gets lodged in either portal vein or hepatic vein. The tip of UVC is confirmed by radiograph and or by echocardiography and eventually the position is adjusted for correct placement (Green and Yohannan, 1998) (Ades et al., 2003). Malposition of UVC tip is associated with increased complication rates like, intestinal necrosis, thrombosis, cardiac arrhythmias, myocardial perforation, pleural and pericardial effusion and sepsis (Umbilical Catheters and Plac, 2019) (Pabalan et al., 2007). Thus the advantages of umbilical catheters must be carefully balanced against the potential risks.

Errors in measurement of insertion length can result in inappropriate positioning of catheter tip. Accurate prediction of insertion length of catheter is therefore paramount. (Raval et al., 1995). There are five formulae reported in the literature to estimate the insertion length of UVC (Table 1). Three are based either on body measurement or include the infant's weight in their calculation.

The first report on UVC placement by Dunn in 1966 measured the distance from the lateral end of the clavicle to a point vertically beneath it, level with the umbilicus. This measurement was then applied to a nomogram to obtain the estimated UVC insertion length (Dunn, 1966). Vali *et al* used measurements taken from lateral X-rays and proposed that the distance between the umbilicus and the midpoint of a vertical line from the xiphoid to the posterior thorax would yield the desired location of UVC tip (Vali et al., 2010). The distance from the xiphoid to

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Table 1
Formulae to estimate umbilical venous catheter insertion length.

Name	Formulae
Dunn (1966) (Raval et al., 1995)	Nomogram using Shoulder umbilical length
Shukla (1986) (Shukla and Ferrara, 1960)	(3 × weight (kg) + 9) ÷ 2 + 1
Vali et al. (2010) (Vali et al., 2010)	Measurement from the umbilicus to the mid-xiphoid-to-bed distance on the lateral aspect of the abdomen
Verheji (2013)	(3 × weight (kg) + 9) ÷ 2
Gomella et al. (2013) (Gomella et al., 2013)	Measurement of distance from the umbilicus to xiphisternum and add 1 cm

the umbilicus plus 1 cm was described in a textbook as the optimal UVC insertion length (Gomella et al., 2013). Among theformulae that are based on infant weight measurement Shukla and Ferrara is most commonly used(10) (Verheij et al., 2013). All both these formulae were devised based on small sample size and limited population of infants. These formulae have not been validated on larger population. Thus the evidence on right method of calculating required insertion length is still not robust.

2. Methods

The randomized controlled trial was conducted in a tertiary level Neonatal Intensive Care Unit. During the period of 18 months between December 2013 and June 2015 after obtaining approval from institutional ethics committee.

2.1. Study population

All infants admitted to NICU requiring umbilical vein catheterization during first 5 days of life were eligible for enrolment. While infants with major congenital malformation, hydrops, and in cases where umbilical cannulation was attempted beyond first five days of life were excluded from the study. Since routine umbilical arterial cannulation was not an established practice in unit hence umbilical arterial cannulation was not included in the study. Written informed consent was taken prior to enrolment. Randomization was done by using web based random number generator. All random numbers were placed in an opaque sealed envelope which was opened by principle investigator after enrolment. The enrolled neonates were randomized either into Group A (Shukla formula) or Group B (Dunn method).

2.2. Methodology

As per the randomization group estimated length of insertion of UVC was calculated by either Dunn's formula (shoulder umbilical length) or by Shukla formula.

A Shukla method, equation based on birth weight i.e. (3xBW + 9)/2 + 1 (Shukla and Ferrara, 1960).
B Dunn method, based on shoulder umbilical length measurement and plotting this length on nomograms to determine the insertion length of catheter (Dunn, 1966).

In both the methods the umbilical stump length was added to the calculated length of insertion. UVC was inserted by trained healthcare provider (blinded to the formulae used for UVC length insertion estimation) under strict aseptic and universal precautions. Any time during the procedure, if there appeared any complications like bradycardia/tachycardia or apnea, the procedure was abandoned.

Shortly after placement of the catheter, an abdominal radiograph was obtained to show the catheter tip position. Once the radiograph was read by the health care provider using their normal criteria, the catheter length was adjusted as necessary based on the healthcare provider's recommendation prior to use. After confirming the position of tip of umbilical vein catheter, it was fixed. Any catheter which did not follow normal course via ductus venouses i.e. lodged in hepatic or portal vein was classified as unsuccessful insertion. As long as the catheter was in place the neonate was observed for catheter related complications. Standards of care of neonates in the NICU did not change throughout admission until discharge. All radiographs taken after initial placement of the catheter were reviewed at a later time by a single radiologist with pediatric training, who was blinded as to the method used to estimate the required length of the insertion. For each radiograph the location of the tip of the catheter was classified as:

- Correct position: if the catheter tip is placed between 9 and 10 thoracic vertebra.
- Low position: if the tip is placed below the 10th thoracic vertebra.
- High position: if the tip is placed above the 9th thoracic vertebra.

Primary objective: To determine proportion of accurately placed tip of umbilical vein catheter (UVC) among the two methods of insertion length calculation.

Secondary objective: To determine and compare malposition rates, incidence of UVC related complications and outcome of infants in both the groups. Baseline data and outcomes were recorded in pre designed case record form (Figs. 1 and 2).

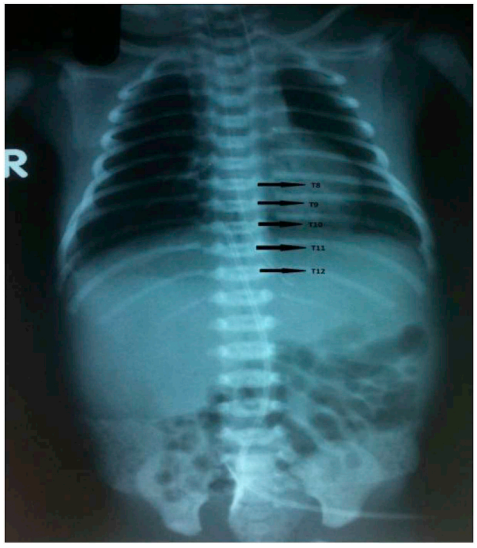

Fig. 1. Chest radiograph showing correct position of UVC tip.

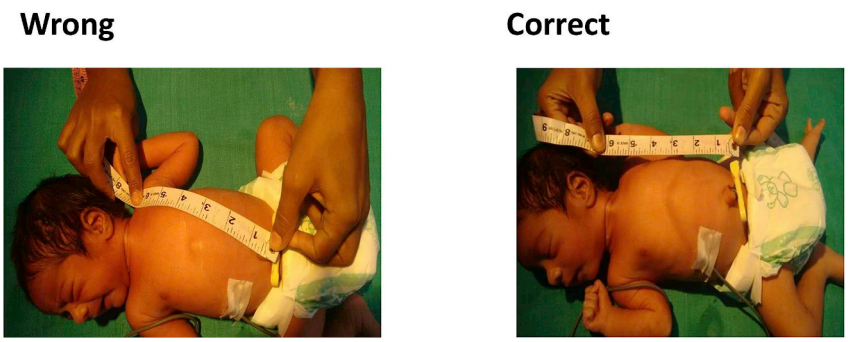

Fig. 2. Dunn method measurement.

2.3. Statistics

Sample size: Using data from an earlier study (ref), to reduce the proportion of malposition of umbilical vein catheter using shukla formula from 76% to 45% (i.e. to reduce this error by 40%) with power of 80% ($\beta = 0.20$) and type I error of 5% ($\alpha = 0.05$), we needed a sample size of 80 babies. Data were entered in Microsoft excel software and analyzed by SPSS version 20.0. Descriptive statistics were calculated, including means and standard deviations for continuous variables and median for non parametric variables. For categorical variables, number and percent was calculated in each category. Categorical variables were compared using chi square test/fishers exact test. Continuous variables are tested by *t*-test and non parametric tests where appropriate.

3. Results

During the study period a total of 83 infants were enrolled. Three infants were excluded due to missed randomization and the remaining 80 infants were included in the study. 39 infants were enrolled in the Shukla group and 41 infants in the Dunn group (Fig. 3).

3.1. Baseline data

The baseline demographic characteristics of enrolled infants were similar (Table 2).

In both the groups, the proportion of successfully inserted umbilical vein catheterization was similar n = 36 (N = 39, 92.3%) in Shukla group versus n = 34 (N = 41, 82.9%) in Dunn group. P = 0.3.

Median time and indication of UVC insertion was similar across both the groups (Table 3 and Table 4).

3.1.1. Primary outcome

In Shukla group, n = 14 (38.8%) of UVC were placed in correct position versus n = 18 (52.9%) in Dunn group P = 0.24 (Table 5).

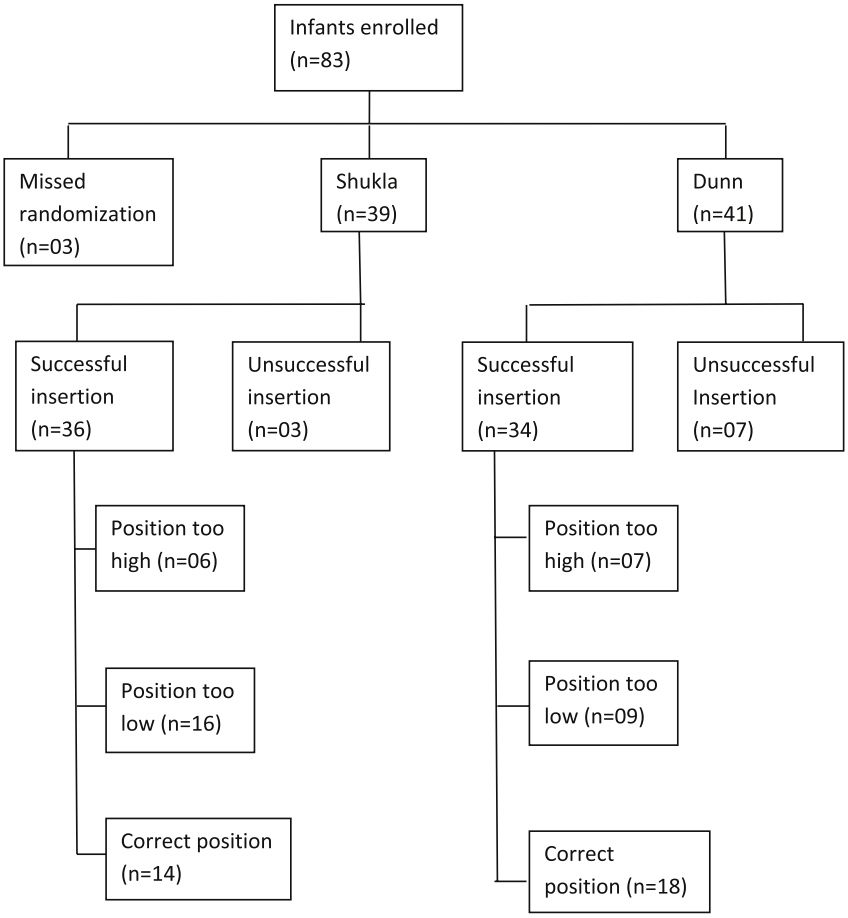

Fig. 3. Flow chart.

Table 2
Baseline characteristics of both the groups.

S. No	Variable	Shukla N = 39 (%)	Dunn N = 41 (%)	P value
1	Mean birth weight (Grams)/SD	2050 (380)	2390 (327)	0.09
2	Gestational age (Weeks)/IQR	36 (33–38)	35 (32–38)	0.08
3	Female	19 (48.7)	20 (48.8)	0.87
4	SGA	10 (25.6)	08 (19.1)	0.41
5	Preterm (< 32 weeks)	11 (28.2)	8 (19.5)	0.36

P < 0.05 is significant. SGA: small for gestational age; SD: standard deviation; IQR: inter quartile range.

Table 3
Time of UVC placement.

S. No	Variable	Shukla	Dunn	P value
1	Time of UVC placement HOL (median)/IQR	08 (3–20)	14 (3–42)	0.26

P value < 0.05 is significant. UVC: umbilical vein catheter; HOL: hour of life; IQR: inter quartile range.

Table 4
Indication for UVC placement.

S. no	Indication for UVC	Shukla N = 39 (%)	Dunn N = 41 (%)	P value
1	Inotropic support	14 (35.9)	20 (48.8)	0.24
2	Prolonged medication	10 (25.6)	9 (22)	0.69
3	Intravenous fluid administration	13 (33.3)	11 (26.8)	0.52
4	Exchange transfusion	2 (5.1)	1 (2.4)	0.52

P value < 0.05 is significant. UVC: umbilical vein catheter.

Table 5
Proportion of correctly placed UVC.

Group	Shukla N = 36	Dunn N = 34	P value
Correctly placed (%)	14 (38.8)	18 (52.9)	0.2

P value < 0.05 is significant.

Table 6
Position of malpositioned UVC tip.

Position	Shukla N = 22 (%)	Dunn N = 16 (%)	P value
High	06 (27.2)	07 (43.7)	0.29
Low	16 (72.7)	09 (56.2)	

P value < 0.05 is significant.

Table 7
Outcome.

Group	Discharge	LAMA	Death[a]	P value
Shukla N = 36 (%)	31 (86.1)	1 (2.7)	4 (11.1)	0.76
Dunn N = 34 (%)	29 (85.3)	2 (5.9)	3 (8.8)	

P value < 0.05 is significant. LAMA: left against medical advice.
[a] Overall mortality and not related to UVC complication.

3.1.2. Secondary outcome

In both the groups, location of malpositioned UVC tip was similar. In the Shukla group, a total of n = 22 (61.1%) of umbilical vein catheters were not correctly placed, out of which n = 06 (27.2%), were high in position and n = 16 (72.7%) were low in position. In the Dunn group n = 16 (47%), of umbilical vein catheters were not correctly placed. Out of which, n = 07 (43.7%) were positioned high and n = 09 (56.2%) were positioned low (Table 6). Outcomes of infants were similar in both the groups (Table 7).

During the study period, there was one case of NEC in Dunn group in which UVC tip was low in position. No NEC was reported in Shukla group. No other complications related to UVC insertion like pleural effusion, arrhythmias or thromboses were reported in either of the group.

4. Discussion

In this present randomized controlled trial we assessed the accuracy of the two most commonly used methods to predict the appropriate insertion length of umbilical vein catheter. In our total study group, overall success rate of umbilical vein catheter insertion was 87.5% of neonates which is comparable to other reports (range 73–92%) (Verheij et al., 2010) (Pennaforte et al., 2010). Majority of UVC insertions were done by residents/registrars.

We observed that in Shukla group n = 14 (38.8%) UVC were correctly positioned versus n = 18 (52.9%) in the Dunn group. P value = 0.24. While no statistical difference was observed in the proportion of correctly placed UVC tip in both the groups, there was a trend of higher proportion of catheter being correctly placed in Dunn group and even though not statistically significant this can have clinical relevance in the form of lesser complications. The overall accuracy of both the methods was poor.

Among the malpositioned catheters, there was a tendency for being low positioned, but no difference was observed among the two groups. N = 16 (72.7%) versus n = 9 (56.2%) in Shukla and Dunn group respectively. P value = 0.29. We postulate that erroneous measurement of Shoulder umbilical length and not adding the umbilical stump length to the depth of insertion would have led to frequent low positioning of catheters. Our findings are in agreement with the results from a recent observational study, where they observed that the proportion of UVC that were correctly placed in Dunn group was n = 28 (41%) versus n = 20 (24%) in Shukla group (p < 0.05). In their study, they observed that malpositioned UVC were frequently too high in position i.e. n = 39 (57%) in Dunn group versus n = 63 (75%) in Shukla group (Verheij et al., 2010).

Several studies have shown that both Shukla and Dunn methods are not accurate in determining length of insertion for optimum positioning of umbilical lines (Lean et al., 2019). Complications like pleural effusion, arrhythmias are common in UVC tips highly placed and thrombosis is frequent in those which are low in position. Manipulation done to adjust the position of UVC tip is associated with higher rates of complications. Both Shukla and Dunn's formulae were developed from a small sample size. 50 infants in Dunn study and 29 infants in Shukla study. These formulae have not been validated in the larger group of neonates.

In a recent observational study, it was found that the method of measuring shoulder-umbilical length for determining length of UVC insertion by Dunn's formula was not consistent. Only 14% of measurements were done in the correct way. This variation in measurement further results in incorrect placement of UVC length. An error of measurement of 1.5 cm results in difference of one vertebral body on chest radiograph (Lopriore et al., 2008).

In another before and after observational study it was found that revision of Shukla's original formula [(3XBW + 9/2) + 1] to newer formula (3XBW + 9/2) led to less inaccurate positioning of UVC without increasing the risk of low placement (Verheij et al., 2013). Other formulae like crown-rump length to calculate length of insertion were done in small group of infants and limited by absence of VLBW and preterm infants. In their original research both Shukla and Dunn considered position of UVC tip in the right atrium as correctly placed. But this position is now considered to be too high. The optimal position of UVC is at the junction of IVC and right atrium which will correspond to catheter tip being visible between 9 and 10 vertebrae on CXR (MGHMH, 2019).

There is no international consensus on the correct position of umbilical vein catheters on chest radiograph. These discrepancies are mainly due to difficulty to relate anatomical structures to the projection of vertebral bodies on CXR, because of variability of these structures in relation to the bony landmarks. Greenberg et al. showed that the umbilical vein catheter tip position at T8 and T9 vertebra on X Ray were positioned at IVC-right atrial junction in 90% of cases and UVC tip position below T10 vertebra were all in the liver proximal to the ductus venosus.

Controversies persist regarding the optimal diagnostic management to determine the correct position of the tip of umbilical catheters in neonates. Some studies suggest bedside realtime ultrasonography as the gold standard in verifying the position of umbilical catheters (Simanovsky et al., 2011). The practical advantage is that it allows determination of the correct position of catheter even before it is secured. The disadvantage of ultrasonography is that it requires qualified practitioners and machine to be available round the clock.

5. Limitations

- In our study, we did not observe any catheter related complications in either of the group, since ultrasonography to detect or rule out thrombosis was not routinely performed. Possibility of under reporting of catheter related thrombosis cannot be ruled out.
- Another limitation is related to the confirmation of catheter position with radiograph. Recent studies advocate bedside real time ultrasonography as the gold standard in verifying the position of catheters.

6. Conclusion

- Need for a larger randomized controlled trial with a wider range of gestational age and birth weight to validate Dunn and Shukla formulae.
- Need for studies to determine a gold standard diagnostic method between X-ray and ultrasonography in confirming position of umbilical catheters.

What is already known?

Malpositioned UVC (umbilical vein catheter) associated with high rates of complication.

What this study adds?

Both Dunn and Shukla formulae used for calculating insertion length of UVC result in high rates of malposition.

Contributors

SK, BT, SR: conceived and designed the study;
SK, VV: were involved in patient care;
VV: collected the data; SK: analysis and interpretation of data;
SK, VV: Drafting the manuscript.

All authors approved the final manuscript.

Conflicts of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jnn.2019.03.006.

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