Original Article

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Paediatrics Section

Dunn's Graph versus Modified Shukla's Formula in Estimating the Correct Depth of Neonatal Umbilical Venous Catheter Insertion: A Cross-sectional Study

POOJA DEVANG PATEL[1], RAKSHANT JAIN[2], MUKUND VAJA[3], KENA SHAH[4], HARSHVARDHAN SAHU[5], SHIVA KUMAR GUNDRATHI[6]

ABSTRACT

Introduction: Accurate placement of Umbilical Venous Catheters (UVC) is critical in neonatal intensive care. The Dunn Method (anatomical estimation) and Modified Shukla Formula (length-based estimation) are two commonly used techniques for determining catheter insertion depth. Comparing these two methods is essential to identify which provides more precise and reliable catheter positioning, thereby minimising complications and improving outcomes.

Aim: To compare the efficacy, safety, and clinical outcomes associated with the Dunn Method and Modified Shukla Formula for UVC placement in neonates.

Materials and Methods: This cross-sectional study was conducted in Neonatal Intensive Care Unit (NICU) of Department of Paediatrics, Dhiraj Hospital, Sumandeep Vidyapeeth Vadodara, Gujarat, India from October 2023 to March 2025. Study included 121 neonates requiring UVC placement within first seven days of life. They were allocated to either the Dunn method group (n=64) or the Shukla method group (n=57). Variables assessed included insertion depth, tip position, success rate, complications, clinical outcomes, and demographic characteristics. Categorical variables were compared using Chi-square test while normal distributed continuous variables by unpaired t-test. Mann-Whitney test was used for not normally distributed variables. Data were considered statistically significant when p-value <0.05.

Results: No significant difference was found in demographic characteristics including gender, gestational age, birth weight, mode of delivery and nutritional status. The Dunn method demonstrated no significant difference in placing correct tip positions (64.1% vs. 54.4%), with fewer high-tip placements (9.4% vs 22.8%, p-value=0.046) compared to Shukla method. Both methods had similar first-attempt success rates (96.9% vs 96.5%). Complications, including Late Onset Sepsis (LOS) and line migration, were slightly lower in the Dunn group, though not statistically significant. Clinical outcome such as discharge rate (60.9% vs 42.1%) favoured the Dunn group.

Conclusion: The Dunn method offers more precise catheter placement, fewer high-tip malpositions, and trends toward better clinical outcomes compared to the modified Shukla formula. It may be preferred for UVC insertion in neonates, particularly in preterm and low birth weight infants.

Keywords: Anatomical estimation, Catheter tip position, Line related complications, Neonatal outcomes, Venous catheterisation

INTRODUCTION

The UVC is a crucial procedure in NICUs, providing essential vascular access for administering fluids, medications, parenteral nutrition, and blood products [1]. Accurate catheter placement is vital, as incorrect positioning can lead to complications such as cardiac tamponade, arrhythmias, thrombosis, and hepatic injury [2]. Ensuring proper catheter positioning minimises risks and enhances neonatal care outcomes [2].

Two widely used methods for estimating the ideal UVC insertion depth are Dunn's Graph and Shukla's Formula. Dunn's Graph relies on anthropometric measurements like birth weight and body length to predict insertion depth, whereas Shukla's Formula uses a mathematical approach based solely on birth weight [3]. Despite their frequent use, both methods have been associated with catheter misplacement, often necessitating repositioning or removal to prevent complications [4].

Previous research has shown that misplacement rates differ between the two methods, with some studies indicating that Dunn's Graph provides better accuracy than Shukla's Formula in achieving optimal positioning [5,6]. Also, a significant percentage of UVCs require repositioning, indicating that current methods may not always ensure optimal placement [3,4,7]. Additionally, limited access to bedside ultrasound in some regions necessitates reliance on formula-based estimations, which may not always be precise [8].

Advancements in neonatal care have led to increased scrutiny of traditional catheter insertion formulas. Shukla's Formula has been found to underestimate depth in Very Low Birth Weight (VLBW) neonates, increasing the risk of hepatic placement [9]. Hence, despite being widely used, Dunn's Graph and Shukla's Formula have limitations that contribute to the continued challenge of incorrect UVC placement with misplaced catheters resulting in serious complications such as increased infection rates, thrombosis, and delays in administering life-saving interventions [10]. Identifying the superior method or developing modifications to existing formulas can help improve safety as well as outcomes for neonates.

Therefore, this study aimed to compare the efficacy, safety, and clinical outcomes associated with the Dunn Method and Modified Shukla Formula for UVC placement in neonates, aided by thoracoabdominal radiographs. The primary outcome was to compare the tip position of the UVC inserted via both methods. The secondary outcome included attempts required to insert UVC, complications associated with each method and duration of indwelling time.

MATERIALS AND METHODS

This cross-sectional study was carried out in NICU of Dhiraj Hospital, Sumandeep Vidyapeeth, Pipariya, Waghodiya, Gujarat, India over a period of one and a half years from October 2023 to March 2025. The study protocol was approved by Institutional Ethics Committee (IEC) (SVIEC/OW/Medi/BNP622/OH23/73). Parents of the patients were informed and written consent was taken.

Inclusion criteria: All neonates requiring UVC insertion within 1st seven days of life were included in the study.

Exclusion criteria: Neonates, who had prior UVC insertion performed extramurally, who were older than seven days of life, with abdominal wall defects (omphalocele, omphalitis, gastrochisis and patent urachus), with peritonitis, Necrotising enterocolitis, hydrops fetalis and other significant anomalies (major structural heart disease, or congenital diaphragmatic hernia) were excluded from the study.

Sample size: All the subjects who presented in the department within the defined period and fulfilling the inclusion and exclusion criteria were enrolled in the study.

Study Procedure

The subjects were categorised into the Dunn's and Shukla groups based on the UVC depth calculation method preferred by the treating consultant in the NICU. As this was an observational study, no intervention or random allocation was performed by the investigators. UVC was inserted under strict aseptic and sterile conditions following standard NICU protocols. In the Dunn Group, the insertion depth was determined using Dunn's Normogram where shoulder-umbilical length (from acromion process to the centre of the umbilicus) was measured and matched to corresponding depth on the graph [11]. While in Shukla group, insertion depth was estimated using the formula based on birth weight: (birth weight x 3 + 9)/2 + 1 [12].

All neonates were measured on electronic weighing scale. A 3.5 F radiopaque polyurethane UVC (Brand VYGON) was used for neonates <1500 gm, while 5 F was used for ≥1500 gm. All the UVCs procedures were performed by senior residents under supervision of neonatologist and secured by anchoring it to the umbilical stump using sterile sutures, followed by application of a transparent occlusive dressing. Care was taken to ensure firm fixation without kinking or displacement of catheter. Majority of the procedures were completed in first attempt. However, in few, at the most three attempts were made. The position of the tip was verified by anteroposterior chest radiograph, reviewed by single radiologist (masked to group assignment) to maintain consistency of the interpretations. Appropriate position of the UVC was described as the one with tip visualised between T9-T10 vertebra. Similarly, the positions were considered high if tip lies above T9 and low if it lies below T10 [13].

STATISTICAL ANALYSIS

All collected data were noted on structured proforma and entered in Microsoft Excel 2013. The analysis was done using Statistical Package for the Social Sciences (SPSS) version 26.0. Categorical variables were expressed as percentages and continuous variables as mean with standard deviation. Categorical variables were compared using Chi-square test while normal distributed continuous variables by unpaired t-test. Mann-Whitney test was used to compare not normally distributed values. A p-value <0.05 was considered statistically significant for results.

RESULTS

A total of 121 neonates were included in the study. A total 64 patients were allocated to Dunn's group and the rest 57 to the Shukla Group.

Demographic characteristics including gender, gestational age, birth weight, mode of delivery and nutritional status were compared and found statistically not significant. The difference in birth weight between both groups showed a p-value of 0.051, which was slightly above the predefined level of statistical significance (p-value <0.05). Therefore, this difference was considered statistically non-significant and likely due to chance, and was not included in further interpretations [Table/Fig-1].

Variables	Dunn group N=64	Shukla group N=57	p-value
Gender			
Male (%)	42 (65.6)	36 (63.2)	0.77
Female (%)	22 (34.4)	21 (36.8)	
Gestational age			
<37 weeks	41 (64.1)	44 (77.2)	0.25
37-40 weeks	20 (31.3)	12 (21.1)	
>40 weeks	3 (4.7)	1 (1.8)	
Birth weight			
<1500 g (n, %)	26 (40.6)	29 (50.8)	0.051
≥1500 g	38 (59.4)	28 (49.2)	
Mean±SD	1.84±0.82	0.58±0.64	
Mode of delivery			
LSCS (N,%)	20 (31.3)	26 (45.6)	0.151
NVD (N,%)	44 (68.7)	31 (54.3)	
Nutritional status			
AGA (N,%)	40 (62.5)	35 (61.4)	0.86
SGA with PI <2 (N,%)	16 (25)	13 (22.8)	
SGA with PI >2 (N,%)	8 (12.5)	9 (15.8)	
Age of insertion			
(mean ±SD) (days)	1.56 ±1.30	1.51 ±1.21	0.75

[Table/Fig-1]: Demographic profile of patients. (LSCS: lower section caesarean section, NVD: normal vaginal delivery).
(PI: Ponderal index, a measure to assess proportionality of a newborn's growth. Low PI shows asymmetric growth restrictions, normal or high PI show symmetric growth restrictions)

While comparing the positions of tip of UVC between both groups, no statistical difference found in correct position (p-value=0.26). Significant difference in favour of Dunn's method was found only in high positioned UVC tip. Low positioned tip also favours Dunn's method but not statistically significant [Table/Fig-2].

Catheter tip position	Dunn method N=64	Shukla method N=57	p-value
Correct position (N,%)	41 (64.1)	31 (54.4)	0.26
Low position (N,%)	17 (26.6)	13 (22.8)	0.32
High position (N,%)	6 (9.4)	13 (22.8)	0.046

[Table/Fig-2]: Primary outcome comparing Umbilical Venous Catheter (UVC) tip position in both groups determined by chest radiograph.
(test used: Chi-square test)

In terms of attempt success rate between both methods, the distribution was remarkably similar with no significant difference statistically. Also, both techniques were largely safe with high proportion of insertions completed without any complications when assessed for complications during insertion procedure in both groups. The mean indwelling time of Dunn's groups was slightly higher (5.49 ± 2.83 days) than Shukla Group (4.98 ± 2.95 days), but not significant (p-value=0.33) [Table/Fig-3].

Variables	Dunn group (n = 64)	Shukla group (n = 57)	p-value
No. of attempts (n,%)			
1st attempt	62 (96.9)	55 (96.5)	0.99
2nd attempt	1 (1.6)	1 (1.8)	
Multiple attempts	1 (1.6)	1 (1.8)	

Complications during insertion			
None	62 (96.9)	54 (94.7)	0.665
Bleed from umbilicus	1 (1.6)	3 (5.3)	0.345
Opening of umbilical artery	1 (1.6)	0	1
Complications during indwelling period			
None	49 (76.6)	41 (71.9)	0.672
Late onset sepsis without NEC	14 (21.9)	14 (24.6)	0.835
Late onset sepsis with NEC	0	1 (1.8)	0.478
Line migration	1 (1.6%)	1 (1.8)	1
Indwelling time (mean ± SD) (days)	5.49 ± 2.83	4.98 ± 2.95	0.33

[Table/Fig-3]: Comparing secondary outcomes.

Discharge rates were higher in the Dunn group (39 patients out of 64, 60.9%) compared to Modified Shukla group (24 patients, 42.1%), with almost similar mortality rate between two groups {18 (28%) vs 19 (33%)} but this difference was not statistically significant. Rest of the patients took discharge against medical advice due to financial or social reason.

DISCUSSION

Although UVC is an essential procedure in NICU, it comes with lot of complications directly related to malpositionings of the catheter tip, either high or low [6,14]. The present study compared the two most commonly used methods to calculate depth of insertion of ideal site of catheter tip. The Dunn's method uses special normogram where surface measurements were to be plotted while Shukla's method uses birth weight. Final verification of tip position was done on antero-posterior thoracoabdominal radiograph.

In the present study, both groups were comparable as no significant difference was found in their demographic profiles. There was slight male preponderence noted in both groups, similar to the study results of Singh R et al., and Abdelhamid FK et al., [15,16]. Mean birth weight was higher in Dunn group compared to Shukla group, consistent with the findings of Patel D and Davies MW who found that formula based methods may increase the risk of over insertion in Low birth weight infants [17].

The rate of correctly positioned tip in the current study was found to be non-significant amongst both groups, whereas rate of high positioned tip was significant low (9.4%) in Dunn's group compared to Shukla Group (22.8%). Kieran E et al., also conducted a randomised controlled trial in Ireland comparing both methods where no significant difference was found in correct positioned tip rate, persistent with the present study results [18]. Whereas Verheij G et al., reported a higher rate of properly placed catheter tip in Dunn's method than to Shukla's method. They also reported high placement of catheter tip with Shukla's method [6].

Both groups demonstrated extremely high first attempt success rates (Dunn: 96.9%, Shukla: 96.5%), reflecting simplicity and practicality of both techniques. Lavoie PM et al., and Livaoglu Say B et al., also reported that success is more dependant on operator experience than formula choice [19,20]. Most complications in the study were minor and easily managed, similar to the results of other studies [21,22], reinforcing overall safety of both approaches. The mean indwelling time was slightly longer in Dunn's group than Shukla group, comparable to Mutlu M et al., and Yeung CY associating optimal placement with longer, complications free use [13,14]. Studies have shown that proximal part of ductus venosus runs in antero-posterior plane before joining Inferior venacava and also, the catheter tip projects over the vertebra in antero-posterior view, making it difficult to correctly report the catheter tip location [22-24].

Limitation(s)

The limitation of the study was the location of catheter tip was verified by only chest radiographs. Inability to use ultrasonography or echocardiography as a more reliable method is one of the major limitations. The strengths were the good homogeneity and comparability of all the demographic variables of both groups and assessment of catheter tip on radiograph by a single trained radiologist.

CONCLUSION(S)

The study showed no significant difference in estimating the correct tip position amongst both group (Dunn's Group and Shukla Group), but rate of higher placement of tip of catheter was significantly high in Shukla Group. Hence, Dunn's method showed better procedural precision and clinical reliability in several domains.

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PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Paediatrics, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
2. Observer, Department of Paediatrics, Apollo Hospital, Chennai, Tamil Nadu, India.
3. Associate Professor, Department of Paediatrics, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
4. Resident, Department of Paediatrics, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
5. Resident, Department of Paediatrics, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.
6. Resident, Department of Paediatrics, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Pooja Devang Patel,
A-14, Vidyakunj, Society Behind Bright School, VIP Road, Karelibaug, Vadodara, Gujarat, India.
E-mail: poojakelawala@yahoo.co.in

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