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PROSPECTIVE OBSERVATIONAL STUDY ON COMPARISON OF TWO/THREE FORMULAE FOR CORRECT POSITION OF TIP OF UMBILICAL VENOUS CATHETER AT THE JUNCTION OF INFERIOR VENA CAVA AND RIGHT ATRIUM IN INDIAN NEONATES

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ABSTRACT

Umbilical vein catheterization (UVC) offers immediate vascular access for preterm or critically ill newborns requiring fluid resuscitation, intravenous therapy, or parenteral nutrition. This procedure is both quick and minimally painful. A prospective observational study was conducted o evaluate the accuracy of three UVC insertion techniques: Dunn, Shukla-Ferrara, and the Revised Shukla-Ferrara method. A total of 300 neonates were enrolled, with equal distribution across the three methods. The Revised Shukla-Ferrara method achieved the highest rate of correct catheter placement (70%), followed by the Shukla-Ferrara method (45%) and Dunn's method (38%).Among the complications, Dunn's method was associated with the highest number of adverse events, including 18 cases of tachycardia and 16 of bradycardia, although it also showed relatively better outcomes in managing bradycardia (10 appropriate responses) and positive tip cultures (6 cases) compared to the other two techniques. The Shukla-Ferrara method demonstrated a more balanced outcome for tachycardia, with 9 successful cases, but showed a higher rate of tip culture positivity (5 cases). The Revised Shukla-Ferrara method had the fewest overall complications, although it showed fewer favorable results for tachycardia (3 cases).The study identified statistically significant differences among the three techniques in terms of catheter placement accuracy. Ultimately, the Revised Shukla-Ferrara method proved to be the most effective for proper UVC positioning, emphasizing the critical role of technique selection in optimizing outcomes for neonatal catheterization.

Keywords: Umbilical vein catheterization, Dunn's method, Shukla method, modified Shukla- method.

INTRODUCTION

Umbilical vein catheterization (UVC) is a commonly used method for obtaining emergency central venous access in neonates up to 14 days old, utilizing the exposed umbilical stump.[1] This procedure offers a reliable route for administering medications and fluids during neonatal resuscitation. The optimal position for the catheter tip is at the junction of the inferior vena cava (IVC) and the right atrium (RA), but outside the heart itself.[2–5] Placement at this location is associated with a lower risk of serious early and late complications such as pericardial and pleural effusions, cardiac tamponade, arrhythmias, endocarditis, hepatic

injuries including hematoma and necrosis, necrotizing enterocolitis, thrombosis, and portal hypertension.[6–8]

A quality improvement initiative has suggested catheter placement guidelines based on gestational age. According to these recommendations, UVCs should be used in all preterm infants born at or before 28 weeks gestation, and in those born at 29 weeks or later if they are receiving mechanical ventilation, require more than 40% FiO_2 while on continuous positive airway pressure (CPAP), or are hemodynamically unstable. These criteria aim to minimize unnecessary UVC placements.[9]Since infusion through a UVC should only begin once proper placement is confirmed, access to imaging for verification is essential prior to use. Incorrect placement, especially when the catheter is inserted too deeply, may result in it entering hepatic vessels, where infused substances can cause liver damage.[10]

This study aims to evaluate and compare the accuracy of three commonly used methods Dunn's, Shukla-Ferrara, and Modified Shukla-Ferrara for estimating the appropriate depth of UVC insertion. The goal is to identify which method most accurately positions the catheter tip at the IVC-RA junction, thereby enhancing placement precision and safety.

MATERIALS AND METHODS

This prospective cross-sectional observational study was carried out over a period of one year in the Special Newborn Care Unit (SNCU) and Neonatal Intensive Care Unit (NICU) of a tertiary care center, specifically in the Neonatology Division of the Department of Pediatrics at Dr. S. N. Medical College, Jodhpur. A total of 300 neonates, all less than 7 days old and requiring umbilical vein catheterization (UVC) for intravenous fluids or medications were included in the study. Eligible participants were included preterm infants who were critically ill, those with birth asphyxia, meconium aspiration syndrome, major congenital anomalies, or persistent seizures. Parental informed consent was obtained prior to enrollment. Neonates presenting with dysmorphic or syndromic features, as well as those with abdominal wall defects such as gastroschisis, omphalocele, or patent urachus, were excluded from the study.All eligible neonates enrolled in the study were randomly assigned to one of three groups. Randomization was achieved by the investigator drawing a sealed envelope, which indicated the group allocation for each newborn. The groups were defined based on the method used to calculate the catheter insertion length: Group 1 followed the Dunn method, Group 2 used the Shukla-Ferrara formula, and Group 3 applied the modified Shukla-Ferrara formula. Umbilical vein catheterization was then performed accordingly.

For infants in Group 1, the Dunn nomogram was used to determine the insertion depth by measuring the shoulder-to-umbilical length and referencing the corresponding value on the nomogram.[11] In Group 2, the insertion length was calculated using the Shukla-Ferrara formula: [(Birth weight × 3 + 9) / 2 + 1].[12] In Group 3, the modified Shukla-Ferrara formula was applied: [(Birth weight × 3 + 9) / 2].[13] Catheter size was selected based on the neonate's birth weight. A 3.5-French umbilical venous catheter was used for infants weighing less than 1500 grams, while a 5-French single-lumen catheter (Vygon, France) was used for those weighing 1500 grams or more. Catheter placement was initially verified using an anteroposterior chest X-ray. Final confirmation of tip position was done using echocardiography. The UVC procedure was conducted under sterile conditions following standard clinical protocols. A high-frequency (7 MHz) S4–10 ultrasound sector transducer (GE Healthcare, Little Chalfont, UK) connected to a MyLAB X6 Ultrasound Unit (ESAOTE,

Genova, Italy) was used for imaging. Full barrier precautions were maintained, including use of a sterile probe cover and sterile gel.

The procedure involved two clinicians: one performed the catheter insertion, while the other conducted real-time ultrasound (RUS) to minimize procedural duration. The ultrasound operator used a parasagittal subxiphoid view to visualize relevant anatomical landmarks and guide the catheter tip toward the target location. Optimal catheter tip placement was defined as the junction of the inferior vena cava (IVC) and the right atrium (RA). Following confirmation with ultrasound, all neonates also underwent chest X-ray to determine the corresponding vertebral level for correct tip positioning.

Data analysis was carried out using the Statistical Package for the Social Sciences (SPSS), version 23.0 (IBM, Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation, while categorical variables were summarized using frequencies and percentages. To compare categorical variables between groups, Pearson's Chi-square test was utilized. The one-sample Kolmogorov-Smirnov test was applied to assess whether continuous variables followed a normal distribution. For comparing continuous variables across the three independent groups, Analysis of Variance (ANOVA) was used if the data were normally distributed. If the data did not meet normality assumptions, the Kruskal-Wallis test was employed. A p-value < 0.05 was considered indicative of statistical significance.

RESULTS

Among the neonates who underwent Umbilical Vein Catheterization (UVC), 59.3% were male and 40.7% were female. The majority of these neonates had a gestational age between 38 and 40 weeks, accounting for 19% of the total, while the fewest were those beyond 42 weeks of gestation. Preterm infants made up the largest group at 61%, followed by term neonates at 29.3%, and post-term infants at 9.7%. The average gestational age was calculated to be 35.82 weeks, indicating that UVC was predominantly required for preterm neonates. In terms of birth weight, the largest proportion 85 neonates (28.3%) weighed between 1500 and 2000 grams. The smallest group included 14 neonates (4.7%) with a birth weight of 3500 grams or more, while 30 neonates (10%) weighed 1000 grams or less. The average birth weight among the neonates was 2185.6 grams. Out of the total, 137 neonates (45.67%) were classified as having Low Birth Weight (≤2500 grams). Among these, 52 neonates (17.3%) were identified as Very Low Birth Weight (≤1500 grams), including 30 neonates (10%) who fell into the Extremely Low Birth Weight category (≤1000 grams).

Table 1: Distribution of neonates based of clinical variables

Variables		Number (%)
Gender	Males	178(59.3%)
	Females	122(40.7%)
Gestational Age	38-40 weeks	57(19%)
	>42 weeks	13(4.33%)
Gestational Term	Preterm(≤37 weeks)	183(61%)
	Term (37-42 weeks)	88(29.3%)
	Post term (≥42 weeks)	29(9.7%)
Neonates weight	Extremely Low birth weight (LBW)	30(10%)
	Very LBW	52(17.3%)
	LBW	137(45.67%)

The study included a total of 300 neonates, evenly divided into three groups of 100 each: Dunn's method, Shukla's method, and the Modified Shukla method, representing 33.33% of the sample per group. In the group where Dunn's method was applied, out of 100 neonates, the UVC tip was located in the right atrium in 22 cases (22%) and in the left atrium in 10 cases (10%), both of which are considered "too high." The catheter tip was appropriately placed between the inferior vena cava (IVC) and right atrium in 38 neonates (38%). Additionally, 26 neonates (26%) had the catheter tip in the IVC, and 4 (4%) had it in the portal vein, both of which are classified as "too low."Among the 100 neonates in whom the Shukla method was used, catheter placement was assessed using 2D echocardiography performed by the researcher under the supervision of the thesis guide. In this group, 15 neonates (15%) had the catheter tip in the right atrium and 10 (10%) in the left atrium, indicating "too high" placement. The tip was located in the optimal position between the IVC and right atrium in 45 neonates (45%). In 24 neonates (24%), the tip was in the IVC, and in 6 (6%), it was in the portal vein, both regarded as "too low." In the group that underwent catheterization using the Modified Shukla method, 2D echocardiographic evaluation was similarly conducted. Among these 100 neonates, 3 had the catheter tip in the left atrium, and 9 (9%) had it in the right atrium, falling under the "too high" category. A majority of 70 neonates (70%) had appropriately placed catheters between the IVC and right atrium. Meanwhile, 14 neonates (14%) had placement within the IVC, and 4 (4%) had the tip in the portal vein both considered "too low."

Table 2: Distribution of neonates based on method used for umbilical vein catheterization

Method Used For Umbilical Vein Catheterization		Number (%)
	DUNNS METHOD	100(33.33%)
	SUKALAS METHOD	100(33.33%)
	MODIFIED SUKALAS METHOD	100(33.33%)
DUNNS METHOD USING 2D ECHO	POSITION OF TIP (100 neonates)	
	In the left atrium	10(10.0%
	In the right atrium	22(22.0%)
	Between IVC and RA	38(38.0%)
	In IVC	26(26.0%)
	Portal Vein	04(04.0%)
SUKALAS METHOD USING 2D ECHO	POSITION OF TIP (100 neonates)	
	In the left atrium	10(10.0%
	In the right atrium	15(15.0%)
	Between IVC and RA	45(45.0%)
	In IVC	24(24.0%)
	Portal Vein	06(06.0%)
MODIFIED SUKALAS METHOD USING 2D ECHO	POSITION OF TIP (100 neonates)	
	In the left atrium	03(03.0%
	In the right atrium	09(09.0%)
	Between IVC and RA	70(70.0%)
	In IVC	14(14.0%)
	Portal Vein	04(04.0%)

Using either a chi-square distribution table or an online calculator, the statistical results for each method were as follows:

- **Dunn's Method** yielded a chi-square value (χ^2) of 6.76, which corresponds to an approximate p-value of 0.009322, indicating statistical significance.
- **Shukla's Method** resulted in a chi-square value of 1.44, with a p-value around 0.23, suggesting no statistically significant difference.

- **Modified Shukla Method** produced a chi-square value of 14.45, corresponding to a highly significant p-value of approximately 0.000144.

In this study, Umbilical Venous Catheterization (UVC) was performed on 300 neonates using three different techniques: Dunn's Method, Shukla's Method, and the Modified Shukla Method. Catheter tip placement was assessed via 2D echocardiography, conducted by the researcher under the supervision of the thesis guide. Out of the total participants, 147 neonates were found to have suboptimal catheter placement classified as either "too high" or "too low." Among these, 62 cases occurred in the Dunn group, 55 in the Shukla group, and 30 in the Modified Shukla group. In contrast, appropriate placement of the UVC tip positioned between the inferior vena cava and the right atrium was observed in 153 neonates, distributed as follows: 38 in the Dunn group, 45 in the Shukla group, and 70 in the Modified Shukla group.

Statistical analysis revealed a significant difference between Dunn's Method and the Modified Shukla Method, with a p-value of less than 0.009, indicating the superiority of the Modified Shukla Method in achieving correct catheter placement. However, no statistically significant differences were found when comparing Shukla's Method with either the Modified Shukla Method or Dunn's Method. These findings suggest that the Modified Shukla Method is the most effective approach for accurate UVC placement in neonates.

Table 3: Distribution of neonates based on position of UVC tip in different methods using 2D echo

Position of tip	Method Used			Total number of neonates
Failure	62	55	30	147
Appropriate	38	45	70	153
Total	100	100	100	300
P-value 1& 3	0.009466 p value is significant			
P-value 2& 3	0.230144 p value is insignificant			
P-value 1& 2	0.239322 p value is insignificant			

Table 4 presents a comparison of complications observed with the use of three different techniques: Dunn's Method, Shukla's Method, and the Modified Shukla Method. The complications are classified into four primary categories—Tachycardia, Bradycardia, Thrombosis, and Positive Tip Culture. The table further differentiates between cases where the catheter placement was unsuccessful ("Failure") and those where the positioning was deemed correct ("Appropriate"). Below is a detailed analysis and interpretation of these findings:

Table 4: Complications

Complications	Dunns Method					Sukalas Method					Modified Sukalas				
	Inappropriate				Appropriate	Inappropriate				Appropriate	Inappropriate				Appropriate
	RA	LA	PV	Total		RA	LA	PV	Total		RA	LA	PV	Total	
Tachycardia	04	06	08	18	08	06	05	04	14	09	04	05	03	12	03
Bradycardia	04	09	03	16	10	09	07	02	18	08	07	01	04	12	06
Thrombosis	0	0	0	0	01	0	0	0	0	01	0	00	00	0	0
TIP culture +	01	01	01	3	06	03	03	01	7	05	03	01	01	5	04

- Tachycardia: Dunn's Method reported 18 instances of tachycardia, with the majority involving the pulmonary vein (PV) at 44.4%. The left atrium (LA) was affected in 33.3% of cases, while the right atrium (RA) accounted for 22.2%. Shukla's Method had a total of 14 tachycardia cases, primarily involving the RA (57.1%), followed by the LA (42.9%). No tachycardia cases were noted in the PV. Modified Shukla's Method recorded 12 cases, distributed relatively evenly: 41.7% in the LA, 25% in the RA, and 33.3% in the PV.
- Bradycardia: Dunn's Method documented 16 bradycardia cases, with more than half (52.9%) occurring in the LA. Both the RA and PV were affected equally, each accounting for 23.5%. Shukla's Method had the highest number of bradycardia cases, totaling 18. The RA was most commonly involved (66.7%), while the LA and PV were affected in 23.8% and 14.3% of cases, respectively. Modified Shukla's Method had the lowest number of bradycardia cases (12 in total), with the RA responsible for 75% and the PV for the remaining 25%. No cases were linked to the LA.
- Thrombosis: Dunn's Method and Modified Shukla's Method showed no incidence of thrombosis. Shukla's Method reported a single thrombosis case, accounting for 100% of the method's thrombosis events.
- Positive Tip Cultures: Dunn's Method recorded 3 positive tip cultures, with equal distribution among the RA, LA, and PV. Shukla's Method had 7 positive cultures, predominantly found in the RA (85.7%), with the PV accounting for the remaining 14.3%. Modified Shukla's Method reported 5 such cases, the majority (80%) occurring in the RA and 20% in the PV.

DISCUSSION

In the present study, 61% of the neonates had an average gestational age of 35.8 weeks. Of the 300 neonates included, 61% were preterm, 29.3% were term, and 9.7% were post-term. The mean gestational age was 35.82 weeks. Similar gestational ages were observed in previous research by MehmetMutlu et al[14] reporting mean gestational ages of 34+2 and 36+2 weeks, respectively.

Gender distribution in our study showed a predominance of males at 59.3%, while females accounted for 40.7% of cases requiring umbilical vein catheterization (UVC). Comparable findings were documented by Verheij GH et al[15], who noted 56% male and 37% female neonates requiring UVC, and by Dunn PM et al[16] who reported 56% males and 44% females. The average neonatal birth weight in our cohort was 2185.6 grams. Weight distribution revealed that 30 neonates (10%) weighed ≤1000 grams, 22 (7.3%) were between 1000–1500 grams, 85 (28.3%) were 1500–2000 grams, 69 (23%) were 2000–2500 grams, 56 (18.7%) were 2500–3000 grams, 24 (8%) were 3000–3500 grams, and 14 (4.7%) weighed ≥3500 grams. This closely aligns with data reported by MehmetMutlu et al[14] who found birth weights ranging from 390 g to 4500 g and gestational ages between 22 and 41 weeks. In our study, 137 neonates (45.67%) were classified as low birth weight (≤2500 g), including 52 (17.3%) as very low birth weight (≤1500 g), and 30 (10%) as extremely low birth weight (≤1000 g). Mutlu et al also analyzed neonates based on weight (<2500 g vs. ≥2500 g), gestational age (≤32 weeks vs. >32 weeks), and size for gestational age (AGA vs. SGA).

The neonates in our study were randomly assigned into three equal groups of 100 each—Dunn's method, Sukala's method, and Modified Sukala's method ensuring comparability and minimizing selection bias. Randomization was conducted using a chit-picking method

supervised by the thesis guide. A similar approach was employed in a study by Yakup Aslan et al which included 121 neonates divided into 41 in the Dunn group, 40 in the Shukla-Ferrara group, and 40 in the modified Shukla-Ferrara group.
In our study:

- **Dunn's Method**: Of 100 neonates, 22% had catheter tips in the right atrium, 10% in the left atrium (too high), 38% between the inferior vena cava (IVC) and right atrium (appropriate), 26% in the IVC, and 4% in the portal vein (too low).
- **Sukala's Method**: Among 100 neonates, 15% had tips in the right atrium, 10% in the left atrium (too high), 45% appropriately placed between the IVC and right atrium, 24% in the IVC, and 6% in the portal vein (too low).
- **Modified Sukala's Method**: Of 100 neonates, 9% had tips in the right atrium, 3% in the left atrium (too high), 70% appropriately placed between the IVC and right atrium, 14% in the IVC, and 4% in the portal vein (too low).

These findings were consistent with Verheij et al who observed appropriate placement in 41% of neonates using the Dunn method and 24% with the Shukla-Ferrara formula. Another study comparing Shukla-Ferrara and its modified version showed 26% and 43% appropriate placements, respectively. In our study, 2D echocardiography confirmed appropriate placement in 38% of the Dunn group, 45% in the Shukla-Ferrara group, and 70% in the modified Shukla-Ferrara group. A statistically significant difference was found between Dunn's and the Modified Shukla's method ($p < 0.009$).

The Dunn group also showed the highest rate of "too high" placements (10%) in the right atrium. "Too low" placements were most frequent in the Shukla-Ferrara group (6%). A significant overall difference was noted among the three groups when comparing appropriate versus inappropriate (too high or too low) placements. However, differences between Sukala's and Modified Sukala's methods, and between Dunn's and Sukala's methods, were not statistically significant.

Complications observed included tachycardia, bradycardia, thrombosis, and positive tip cultures:

- Tachycardia was most common with Dunn's Method, followed by Sukala's, and least with Modified Sukala's. Dunn's Method had a higher success rate in managing tachycardia, particularly in the pulmonary vein. Sukala's Method showed more cases in the right atrium, while the Modified method had a more even distribution across regions.
- Bradycardia occurred most frequently with Sukala's Method, predominantly in the right atrium. Modified Sukala's Method significantly reduced bradycardia incidence, with cases concentrated in the right atrium.
- Thrombosis was absent in both Dunn's and Modified Sukala's Methods, while Sukala's Method reported one case.
- Positive Tip Cultures were most frequent in the Sukala group, especially in the right atrium. Dunn's and Modified Sukala's Methods had fewer cases, though the latter had more right atrial involvement.

In summary:

- Dunn's Method: Higher tachycardia incidence, no thrombosis, moderate bradycardia, and some tip culture positivity.
- Sukala's Method: Highest bradycardia and tip culture positivity, notably in the right atrium.

- Modified Sukala's Method: Lowest complication rates overall, with fewer occurrences across all categories.

These results suggest that while Sukala's and Modified Sukala's methods offer advantages in certain areas, such as appropriate catheter positioning and fewer tachycardia cases, they may increase risks for other complications like tip culture positivity. On the other hand, Dunn's Method, despite a higher incidence of tachycardia, showed no thrombosis, indicating a potentially safer profile in that specific aspect. Thus, careful consideration of each method's risk-benefit profile is essential in selecting the most suitable technique for UVC placement.

CONCLUSION

The Revised Shukla-Ferrara Method demonstrated greater effectiveness in achieving accurate placement of umbilical venous catheters (UVCs) compared to other techniques. These findings underscore the significance of selecting the appropriate method to ensure optimal catheter positioning in neonates. While this study offers meaningful insights into the comparative effectiveness of various UVC placement approaches, further research involving larger sample sizes, randomized designs, and extended follow-up is essential to validate these results and enhance neonatal care practices. Although this study included a larger cohort than several previous investigations, the results emphasize the necessity for a more comprehensive, blinded study to improve the accuracy of group allocation. Additionally, it has become evident that many clinicians in our unit may benefit from additional training to correctly apply UVC placement techniques. This aligns with findings from Dunn, which highlight the critical role of proper training in achieving better clinical outcomes.

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