ORIGINAL RESEARCH

Low-lying Umbilical Venous Catheters are not Always Associated with Increased Complications

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Abstract

Introduction: Umbilical venous catheters (UVCs) are frequently used for clinical care in neonatal intensive care units (NICUs). Umbilical venous catheters cannot always be positioned perfectly in the inferior vena cava, and low catheters have to be used until a more stable peripherally inserted central catheter can be placed after ruling-out early onset sepsis. There are concerns that low UVCs may be associated with complications such as infection, extravasation, and thrombosis.

Objectives: To determine whether UVC complications were associated with (1) low positioning of the catheter tip and (2) the postnatal age at insertion.

Methods: We examined a retrospective cohort of infants with UVCs in a tertiary NICU. Neonates with major congenital anomalies, hydrops fetalis, prenatally diagnosed cardiac arrhythmias, pericardial effusion, or ascites were excluded. The position of UVCs is considered as optimum if its tip is seen on radiographs at the level between 8th and 10th thoracic vertebrae (T8–T10), to be low if below T10, and high if above T8. The primary outcome was UVC-related complications resulting in early removal of catheter. We compared the rates of UVC-related complications resulting in removal of UVCs with tips in normal (T8–T10) vs low-lying (below T10) positions at the time of insertion. We also examined the impact of postnatal age, before or after 12 hours, and the frequency of the UVC-related complication.

Results: Of the 919 eligible infants, UVC tips were located optimally in 433 (47%) and were low in 415 (45%). The UVC was positioned at an abnormally high position in 71 (8%) infants. Of the 919 infants, UVC-related complication was seen in 54 (5.9%) infants. Low-lying UVCs were removed due to complications in 27 of 415 (6.5%) compared with 20 of 433 (4.6%) optimally position catheters [adjusted odds ratio (aOR) = 1.16; 95% confidence interval (CI): (0.62–2.17)]. High-placed UVCs were associated with a higher rate of cardiac complications (aOR = 6.09, 95% CI [2.03–18.28]) compared with optimally position UVCs. There was also no difference in UVC-related complications between early and late insertion of UVC (6.3% vs 4.7%, $p = 0.34$).

Conclusions: The frequency of complications and consequent need for removal did not differ in UVCs with a tip position traditionally perceived to be optimal or low or by the time of insertion after birth.

Keywords: Complications, Newborn, Umbilical venous catheter.

Newborn (2022): 10.5005/jp-journals-11002-0004

Introduction

Umbilical venous catheters (UVCs) are commonly inserted for vascular access in critically ill or extremely preterm infants. About 20% of all infants admitted to neonatal intensive care unit (NICU) and more than 50% of very low birth weight infants had UVC during hospital stay.[1–3] The ideal position of UVC tip is just outside the heart at the junction of the right atrium and inferior vena cava (IVC).[4]

Adverse events may occur both during UVC insertion and dwell time. Malposition of the UVC directly after insertion has been reported in 11.5 to 56% of neonates, although the definition varies widely.[5–9] Umbilical venous catheterization is associated with various complications including bloodstream infections, cardiac complications such as arrhythmias, pericardial effusion, cardiac tamponade, hepatic complications (including liver hematoma, thrombosis, abscess, ascites), and mechanical complications such as occlusion, breakage, and migration of fragmented catheter.[9–18] Malposition and low-lying UVCs have been noted to be more frequently associated with complications.[1–3,14]

The standard practice in NICU is to retract the UVC if catheter tip is below the optimal position and reposition the tip below the contour of the liver as seen on radiograph. However, there is no evidence in the literature to support the safety of using a low-lying UVC other than for neonatal resuscitation. It is common practice in certain NICU that low-lying UVC was not used for clinical care due to fear of complications. Attempting UVC insertion after the umbilical cord has dried is difficult and is associated with low success rate. Anecdotally, we notice that when UVC was inserted after dried umbilical cord, there was difficulty in advancing the catheter, and it tends to be in the low-lying position. Very few studies examined the association between the position of the UVC tip and the incidence of UVC-related complications in neonates.[2,3] The association between age at UVC insertion and the incidence of complications has not been studied in the past. The objective of our study is to compare

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How to cite this article: Joghee S, Kamaluddeen M, Soraisham A. Low-lying Umbilical Venous Catheters are not Always Associated with Increased Complications. Newborn 2022;1(1):1–6.

Source of support: Nil

Conflict of interest: None

UVC-related complications based on the catheter tip position as well as timing of catheter insertion.

Methods

Study Design, Setting, and Population

This retrospective cohort study was conducted in a 39-bed tertiary NICU in Western Canada. We included infants admitted to the NICU between January 2016 and December 2018, in whom the position of the UVC placed during hospital stay was adjusted and confirmed by radiograph. Infants with major congenital malformations, hydrops fetalis, prenatally diagnosed arrhythmias, pericardial effusion, ascites, and those who did not have radiographic confirmation after reposition of the catheter were excluded. The institutional research ethics board approved the study.

In our unit, UVC is inserted by trained staff and position of the catheter tip is confirmed by thoracoabdominal radiograph (TAR). In addition, bedside ultrasound is done to confirm the position of UVC tip in some patients depending on the availability of trained personnel to perform bedside ultrasound. The final position of the UVC tip in relation to the vertebral body, cardiac silhouette, and diaphragmatic level on TAR is documented. The decision to use low-lying UVC is at the discretion of the medical team based on the infant's condition and number of attempts at intravenous line insertion. Peripherally inserted central catheter is inserted if the infant needs longer duration of intravenous access.

We reviewed electronic medical records and charts of eligible infants. We collected infant demographics (including gestational age, birth weight, and sex), age at UVC insertion, position of UVC tip on TAR, the duration of catheter, and UVC-related complications resulting in nonelective catheter removal. Two authors independently reviewed all radiographs including the final radiograph to assess the position of catheter tip after adjustment. Based on the radiographic finding, we defined optimal position if the UVC tip was between the upper border of the eighth thoracic vertebral body (T8) and lower border of T10 on the anteroposterior TAR. When the catheter tip was below the lower border of T10, it was classified as a low-lying UVC, and those with catheter tip above the upper border of T8 was classified as high UVC.

Outcomes

The primary outcome of this study was UVC-related complications resulting in catheter removal. We defined UVC-related complications as any new onset complication associated with UVC such as (1) cardiac-arrhythmias, pericardial effusion, tamponade, and intracardiac thrombus; (2) hepatic complications such as liver hematoma, thrombosis of portal vein, ascites, and liver abscess; (3) catheter-related bloodstream infection(CR-BSI) defined as a primary bloodstream infection in a patient showing signs of infection 2 days after of UVC placement or within 48 hours of catheter removal, without another identifiable infection source;[19] and (d) mechanical complications including occlusion, catheter leakage, or breakage resulting in removal of catheter.

Statistical Analysis

Descriptive statistics were performed to compare infants who had catheter tip in optimal position, low and high position at the time of insertion. Pearson Chi-square or Fisher's exact test for categorical variables and student's *t*-test or analysis of variance (ANOVA) *F*-test for continuous variables was used for the analyses. Multivariable logistic regression analyses were performed to adjust for other potential confounding factors that may have an independent effect on UVC-related complications. Confounding variables adjusted for in the multivariate analyses include gestational age and duration of catheter. Statistical analyses were performed using Stata 14.0 (StataCorp LLC, College Station, Texas, USA). A p value of <0.05 was considered statistically significant for all analyses.

Results

During the study period, 3339 infants were admitted to the NICU, and UVC was inserted in 979 (29.3%) infants. Sixty infants were excluded, and remaining 919 infants were included for analysis. Of the 919 infants, 433 (47.1%) had UVC tip in the optimal position, 415 (45.2%) had low-lying UVC, and 71 (7.7%) had high UVC position (Flowchart 1). A total of 665 (72%) infants had UVC inserted within 12 hours. Majority (522) infants had UVC within 2 hours of admission to NICU. The mean gestational age and birth weight of the study cohort was 31 ± 5 weeks and 1737 ± 1014 g, respectively. The baseline characteristics were comparable between the groups (Table 1).

Overall, 54 (5.9%) infants developed UVC-related complications resulting in early catheter removal. There were no significant differences in the overall complication rates resulting in catheter removal between the three groups (Table 2). However, cardiac complications were significantly higher in high-position group compared with optimal position group (7% vs 0.23%, $p = 0.001$). Of the five infants with cardiac complications in high-position

Flowchart 1: Flow diagram of study population

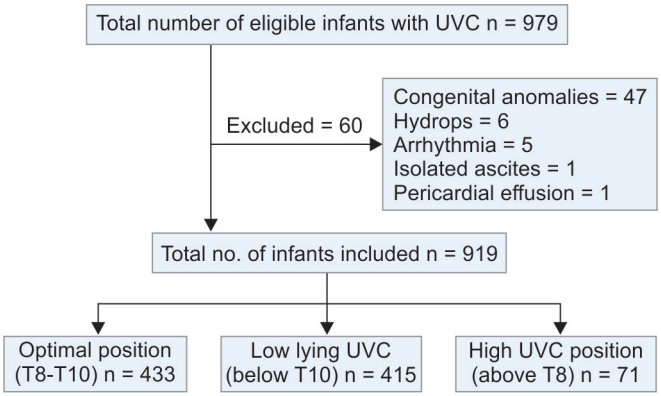

Table 1: Comparison of characteristics between three UVC positions

Characteristics	*Optimal position (n = 433)*	*Low-lying UVC (n = 415)*	*High position (n = 71)*
Gestational age, mean (SD), wk	31.09 (5.1)	31.03 (4.8)	30.6 (5.6)
Birth weight, mean (SD), g	1746 (1071)	1732 (989)	1713 (1227)
Male, *n* (%)	252 (58.2)	237 (57.1)	33 (46.4)
Duration of catheter days; mean (SD)	5.35 ± 2.37	4.31 ± 2.17[1]	5.21 ± 2.27
Duration of UVC days; median (IQR)	5 (4,7)	4 (3,6)[1]	5 (3,7)
Total UVC days	2,313	1,780	370

IQR, interquartile range; SD, standard deviation; UVC, umbilical venous catheter; [1]p <0.05, optimal position vs low-lying; [2]p <0.05, optimal vs high position

group, three infants had supraventricular tachycardia (SVT), one had pericardial effusion, and one infant had right atrial thrombus. Cardiac arrhythmias recovered after pulling the catheter to low position. Only one infant had thrombus extending from the IVC into the right atrium in optimal position.

UVC-associated hepatic complications were not different between the optimal position and low-lying UVC. In optimum position group, three infants had hepatic hematoma and one had portal vein thrombosis. In the low-lying UVC group, two infants had liver hematoma, two had cystic fluid collections (attributed to total parenteral nutrition) in the liver, and one had portal vein thrombosis and ascites.

The CR-BSI was not significantly different between the three groups (Table 2). The CR-BSI rate was 4.3/1000 catheter days in the optimal UVC position group, 5.02/1000 catheter days in the low-lying position and 5.4/1000 catheter days in the high-position group. The difference was not statistically significant. The common organisms isolated from the blood include *Coagulase Negative Staphylococcus* (*CoNS*) in 14 infants, followed by *Escherichia coli* in five infants, *Enterococcus fecalis* and *Pseudomonas spp*. in one infant each.

Mechanical complications were more frequent in the low-lying UVC as compared with optimal position group, but the difference was not statistically significant (Table 2). Of the 13 mechanical complications in low-lying UVC position, seven had leakage from catheter site, four had catheter dislodgement, one infant had scrotal and abdominal wall edema, and one infant had red streaking over the abdomen resulting in catheter removal. In optimal position group, catheter was dislodged in four infants, and one had leakage from catheter site resulting in catheter removal.

Table 3 shows the multivariate logistic regression analysis adjusting for gestational age and duration of catheter. Low-lying UVC were not associated with increased risk of catheter-related complication resulting in early removal as compared with optimal position [adjusted odds ratio (aOR) = 1.16; 95% confidence interval (CI): (0.62–2.17)]. High-placed UVCs were associated with a higher rate of cardiac complications (aOR = 6.09, 95% CI [2.03–18.28]) compared with optimally position UVCs.

Timing of UVC Insertion

Among 919 neonates, 665 (72.4%) had early UVC insertion (<12 hours), and 254 (27.6%) had late insertion (≥12 hours) of UVC. The success rate of achieving optimal UVC position was significantly higher in the early insertion group compared with the late insertion group (52% vs 34.2%, p <0.001) (Table 4). However, there was no difference in UVC-related complications between early and late insertion of UVC (6.3 % vs 4.7%, p = 0.34).

Discussion

Umbilical venous catheter insertion is a very common and essential procedure in the NICU. The length of insertion of the UVC is usually determined either by Dunn shoulder–umbilicus length method or Shukla–Ferrara formula based on birth weight.[20,21] These formulae have not been validated in extremely preterm and very low birth weight neonates. Studies have shown that Dunn nomogram and Shukla formula were accurate in only 38 to 45% and 20 to 53% of subjects, respectively.[22–24] Few studies have evaluated the UVC-associated complications in relation to catheter tip position. In this study, we examine the catheter-related complications based on the catheter tip position and timing of insertion. The overall UVC-related complication rate in our cohort was 5.9%. The UVC-related complications were lowest in optimal position (4.6%), followed by low-lying UVC (6.5%) and highest in the high UVC position (9.8%). Low-lying UVC was not associated with increased risk of catheter-related complication resulting in early removal as compared with

Table 2: Comparison of UVC-related complications based on catheter tip position

Complications	*Optimal position (N = 433)*	*Low-lying UVC (N = 415)*	*High position (N = 71)*	*p value*
Any complication resulting in early catheter removal, *n* (%)	20 (4.6)	27 (6.5)	7 (9.8)	0.16
Catheter-related bloodstream infection, *n* (%)	10 (2.3)	9 (2.1)	2 (2.8)	0.83
Cardiac complications, *n* (%)	1 (0.23)	0	5 (7.0)	0.001
Hepatic complications, *n* (%)	4 (0.92)	5 (1.2)	0	0.89
Mechanical complications, *n* (%)	5 (1.1)	13 (3.1)	0	0.07

UVC, umbilical venous catheter

Table 3: Adjusted outcomes

	Reference	*High position (aOR, 95% CI)*	*Low-lying UVC (aOR, 95% CI)*
Any complication resulting in early removal of UVC	Optimal position	1.45 (0.91–2.29)	1.16 (0.62–2.17)
Cardiac complication	Optimal position	6.09 (2.03–18.28)	–
Catheter-related blood-stream infection	Optimal position	0.98 (0.44–2.16)	1.14 (0.44–2.92)
Hepatic complications	Optimal position	–	1.36 (0.34–5.38)
Mechanical complications	Optimal position	–	1.19 (0.38–3.70)

Adjusted for gestational age and duration of catheter. aOR, adjusted odds ratio; CI, confidence interval; UVC, umbilical venous catheter

Table 4: Timing of UVC insertion, position of catheter tip and complications

Characteristics	*Timing of UVC insertion*		
	Insertion <12 hr, N = 665	*≥12 hr, n = 254*	*p value*
Catheter position			
Optimal position, *n* (%)	346 (52)	87 (34.2)	<0.001
Low position, *n* (%)	264 (39.7)	151 (59.4)	
High position, *n* (%)	55 (8.3)	16 (6.3)	
Any complication resulting in early removal of UVC, *n* (%)	42 (6.3)	12 (4.7)	0.34
Catheter related bloodstream infection, *n* (%)	17 (2.56)	4 (1.57)	0.46
Cardiac complications, *n* (%)	4 (0.6)	2 (0.79)	0.67
Hepatic complications, *n* (%)	9 (1.35)	1 (0.39)	0.30
Mechanical complications, *n* (%)	13 (1.95)	5 (1.97)	0.98

UVC, umbilical venous catheter

optimal position. High-placed UVCs were associated with a sixfold higher risk of cardiac complications compared with optimally position UVCs. We did not observed any significant difference in complication rate based on the timing of UVC insertion; however, success rate of positioning in optimum position was lower in late insertion.

In contrast to our finding, Mutlu et al. noticed UVC-related complications in 20.3% of infants in their retrospective study.[1] However, complications other than malposition were noted in only 1.2% of infants with UVCs.[1] In a retrospective study of 2011 infants, El Ters et al. reported that the rate of clinically significant complications for central UVCs was 0.5 per 1,000 catheter days, whereas for low-lying UVCs, the rate of complications was 1.5 per 1,000 catheter days. Although the complication rate was higher in low-lying UVC compared with those with central UVC, the difference was not statistically significant (OR = 2.1, 95% CI: [0.5–8.6]). Levit et al. reported that 13.3% of UVC-related complications among 2017 infants. However, complications other than malposition were noted in 1.8% of infants with UVCs.[8]

Thoracoabdominal radiograph is the most commonly used method for identification of UVC tip position. The optimal position of UVC tip (at the junction of right atrium and IVC) outside the heart as determined by ultrasound or echocardiography was observed in only about 15 to 57% of subjects who were labeled UVC tip at optimal position on radiograph.[5,6,24,25]

Comparison of UVC-related complication between the published studies is difficult due to differences in the classification of UVC position based on radiograph. For example, Mutlu et al. defined ideal UVC position as catheter tip between T9 and T10 vertebral levels on radiograph.[1] El Ters et al. defined that "central UVC position" if the catheter tip at or above the right hemidiaphragm based on radiograph and "low-lying" if the catheter tip is below the right hemidiaphragm or below the bottom of the T9 vertebral body (overlying the liver or below the liver border on the radiogram).[2] Shahroor et al. defined "proper position" when UVC tip was between the upper border of T9 and the lower border of T10 (at the level of diaphragm) and "low position" if the UVC tip is below T10.[3] Levit et al. defined ideal position as 0.5 to 1 cm above the right hemidiaphragm and reported 88.5% infants had UVC tip in ideal position.[8]

We observed higher cardiac complications including arrhythmias and pericardial effusion in the high UVC group in our study. This finding is not surprising. El Ters et al. reported that two infants with central UVC who developed SVT and one infant with centrally positioned UVC who developed cardiac tamponade.[2] The propose mechanism for central line associated arrhythmia include intracardiac central line disposition or atrial triggering to develop a reentrant pathway.[9,10] The presence of a catheter deep inside the heart with direct contact to the endocardium may predispose the patient to have premature atrial beats that may lead to SVT in presence of an accessory pathway.[9] Also, there is the risk of migration of the ideally placed catheter inside the heart with time[26] and can present with cardiac arrhythmias.[10]

Hepatic complications were not significantly different between the optimal- and low-position groups in our cohort. This finding is similar to El Ters et al. study.[2] However, some studies reported that significantly higher incidence of UVC extravasation with low-lying UVC.[3,9,27] Catheter malposition, hypertonic parenteral solutions, dopamine infusion through an inappropriately placed UVC and using of long duration of UVC have been incriminated in the development of hepatic injury.[28] The incidence of hepatic complications in optimally placed UVC in our study may be secondary to injury at the time of insertion or migration of the UVC tip with time. It may also be secondary to the fact that many times UVC tip seen to be in ideal position on TAR may actually be positioned lower as seen in many studies.

The incidence of CR-BSI was 2.3% in our cohort. The reported rate of CR-BSI varies from 0.4 to 7.1% of neonates with UVC.[1,2,8,18] We did not observed significant difference in the CR-BSI between the three groups. Our finding is similar to El Ters et al. who reported no significant difference in infection between the central and low-lying UVC.[2] In contrast, Sharoor et al. reported that low-lying UVC was associated with higher infection rate and extravasation among preterm infants.[3] They reported that the incidence of UVC associated BSI was higher with increased duration of the indwelling UVC, regardless of the UVC tip position. Leveillee et al. also reported a higher incidence of infection rate in low UVC as compared with high UVC group (17.31/1000 catheter days vs 11.49/1000 catheter days).[29] The suggested theories for increase infection with increasing dwell time included catheter hub being the main portal of entry for infectious organisms, intraluminal colonization, and growth of microorganisms especially for catheter with prolonged dwell time. The other explanation for increase in UVC related BSI in the low-lying UVCs is related to the shorter distance between the umbilical stump (high potential of colonization) and the tip of the catheter, or proximity of the umbilicus to the groin and genital area (high potential of colonization).[3]

In our study, the success rate of achieving optimal UVC position was significantly higher in the early insertion group compared with the late insertion group. Shahroor et al. reported that about 67% of UVCs were placed in good position when attempted on first day of life in preterm infants ≤32 weeks gestation.[3] However, the complication rates were not significantly different between the early insertion and late insertion groups.[3] There are many reasons for failure to achieve optimal position during UVC insertion. The umbilical vein has a direct course from the umbilicus to the portal sinus of the liver from where the portal veins and ductus venosus arise and the ductus venosus opens into the IVC.[30,31] The anatomy of the umbilical vein and ductus venosus may predispose to malposition of the UVC tip in the umbilical vein, the right or left portal vein, the hepatic parenchyma or the splenic vein. The timing

of closure of ductus venosus vary from Day 2 to Day 18 after birth, and most studies report it is closed by Day 10 of life.[32,33] The early closure of ductus venosus may predispose to malposition of UVC in the portal venous system when attempted late.

The strengths of our study include large sample size of very low birth weight infant who are born in tertiary care center, providing homogeneity in standard UVC placement and practice. Our study is the first study that evaluated timing of UVC insertion, success and complication rate. The limitations of the study include retrospective nature of the study. UVC can migrate over time from their initial position. Being a retrospective study, we assigned the groups based on catheter tip position at the initial insertion, and we did not have the actual position of catheter at the time of catheter removal due to complications. It is not ethical or clinically practical to perform X-ray prior to removal of the catheter and expose infants to radiation. Due to retrospective nature, not all babies had ultrasound assessment to assess other complications such as thrombosis.

Conclusions

In our study, we did not observed a statistically significant difference in complications between optimal position, low-lying UVC, and high position UVC. However, cardiac complications were higher in the high UVC group. Early insertion resulted in greater success in the optimal positioning of the UVC without any difference in complications between the early and late UVC group.

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