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Novel ultralow positioning of the umbilical artery catheter: A prospective pilot study

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Abstract

Objective: Thrombosis is a common complication of umbilical artery catheterization. The purpose of this study was to compare the novel ultralow umbilical artery catheter position (catheter tip at the junction of the umbilical and internal iliac arteries) versus the conventional high umbilical artery catheter position (tip in the aorta, above the diaphragm) for the incidence of thrombosis. **Study design:** This study was conducted in a nonacademic, tertiary-referral neonatal center. The insertion and placement of the umbilical artery catheter was performed under continuous ultrasound guidance. Serial ultrasound examinations were performed to identify thrombosis in 38 consecutive newborns with an umbilical artery catheter placed in the novel ultralow position. The control group consisted of 50 infants with an umbilical artery catheter placed in the standard position. **Results:** The incidence of thrombosis requiring anticoagulant treatment was 22% in neonates with an umbilical artery catheter in the standard position. No thrombosis was detected in those with an umbilical artery catheter placed in the ultralow position. The study and control groups had similar catheter indwelling times (mean, 8.2 ± 4.1 vs. 8.5 ± 4.0 days, $p = 0.687$). **Conclusions:** This is the first report to present a novel position for the placement of umbilical artery catheters. The preliminary findings for the novel ultralow umbilical artery catheter position indicate that it may provide a safety benefit over the conventional umbilical artery catheter position.

Introduction

Umbilical artery catheterization is one of the fundamental techniques in the intensive care of extremely preterm neonates or critically ill term newborns. The presence of an umbilical artery catheter (UAC) can, however, cause complications such as catheter-associated infections, hemorrhages, and thrombosis, the latter of which is the most prevalent and has significant clinical implications⁽¹⁾. The potentially lethal effects of thrombosis include intestinal necrosis, limb ischemia, and skin necrosis⁽²⁻⁸⁾. To make things worse, these effects are regarded as iatrogenic. In order to reduce the rates of complications, clinical guidelines suggest that the UAC tip be located in one of two positions: either above the celiac, mesenteric, and renal arteries, with the tip at the Th6–Th9 level (high position), or below the inferior mesenteric artery, between L3 and L5 (low position).

The high position is preferable because it is associated with fewer thrombotic events⁽⁹⁾, which, depending on the source and the diagnostic method used (angiography or ultrasound), occur at a frequency of 9–32%⁽¹⁰⁻¹⁶⁾.

The routine ultrasound (US) assessment protocol for UACs that we implemented in our neonatal intensive care unit (NICU) in 2020 revealed that thrombosis is relatively common with UACs in the standard high position. This observation led us to consider the innovative ultralow positioning of UACs. With this approach, the UAC is inserted into one of the umbilical arteries, with the catheter tip extending to the junction of the umbilical artery and the internal iliac artery (i.e., hypogastric artery).

The rationale behind this novel UAC position was that, while the consequences of thrombosis can be severe if the catheter is inserted into a vital vessel (such as the aorta), there is no risk of organ necrosis if the catheter is inserted into the umbilical artery, i.e., a vessel that is not essential to postnatal life. The only remaining uncertainty was whether or not this novel ultralow UAC position is practical, i.e., in terms of indwelling duration and the rate of thrombosis leading to preterm catheter loss.

The goal of this pilot study was to compare standard high UAC position versus the novel ultralow UAC position for the incidence of thrombosis and catheter indwelling time.

Materials and methods

This study was conducted in a nonacademic, tertiary-referral neonatal center, with a 20-bed NICU serving about 650 admissions/year and with a focus on the use of ultrasound techniques, including US-guided insertion of vascular catheters.

Patients

We used the novel ultralow UAC position in consecutive infants requiring catheterization between October 2020 and June 2021. The control group comprised infants with an UAC placed in the standard high position who had been catheterized in the preceding nine months, i.e., from January to September 2020 (historical control cohort).

From October 2020 until June 2021, UACs were inserted in the novel ultralow position in 44 newborns. Two of those 44 newborns died shortly after birth, and 4 others were transferred to a university hospital with the UAC left in situ before the first safety evaluation was performed. Hence, the study group included 38 babies.

A review of medical data from the nine months before October 2020 identified 59 cases of umbilical artery catheterization, with all 59 UACs placed in the standard high position. Of the 59 babies, 5 died in the first hours after birth, and 4 others were transferred to the university hospital on the first day of life. Thus, the historical control cohort consisted of 50 infants with UACs placed in the standard high position.

The study and control groups were similar in terms of gestational age, birth weight and reason for catheter insertion (Tab. 1).

Infants transferred to another hospital before the first safety assessment and neonates who died in the first hours after birth were excluded from the analysis.

The Research Ethics Committee of the Medical Chamber for the District of Cracow approved the study protocol (ref. no. OIL/KBL/130/2021), and all parents/legal guardians provided written informed consent.

Study endpoints

The presence of thrombosis, defined as detection of any thrombus in daily US examinations or during visual inspection of the UAC after its removal, was the primary study endpoint.

Clinically significant thrombosis was defined as thrombosis resulting in >80% vascular lumen occlusion and necessitating intravenous infusion of low-molecular-weight heparin.

Catheter indwelling time was the secondary study endpoint. It is a standard procedure in our department to remove catheters when hemodynamic monitoring is no longer required or when catheter occlusion occurs. The decision to remove the catheter was made by an attending physician who was not a member of the study team.

Ultralow UAC insertion procedure

UAC insertion and placement was performed under continuous US guidance. A 3.5-Fr gauge Vygon polyurethane single-lumen catheter was used for all infants, independent of body weight. When placing the UAC in the standard position, the size of the catheter must be adjusted to the infant's body weight, whereas with ultralow UAC position, a 3.5-Fr gauge catheter can be used for all infants regardless of their weight. In this novel ultralow position the catheter is placed in the umbilical artery, which eventually coagulates, hence there is no need to use the smallest possible catheter to prevent coagulation around it as, for example, should be done when the catheter is inserted in the aorta. This catheter size allows complete filling of the lumen of the umbilical artery without compression of the neighboring vessels.

After the umbilical artery was incised, the catheter was advanced to a depth of approximately 6–8 cm. The catheter tip was then visualized with an ultrasound linear probe positioned in the lower quadrant of the abdomen at an angle of approximately 45 degrees and the marker pointed towards the umbilicus. Under US guidance, the UAC tip was placed in the proper location, which was the junction of the umbilical and internal iliac arteries (Fig. 1).

The tip should ideally be situated at the junction with the internal iliac artery (i.e., hypogastric artery), but should not enter its lu-

Tab. 1. Baseline characteristics of the study cohorts

	Standard high UAC position (n = 50)	Novel ultralow UAC position (n = 38)	p value
Gestational age (weeks), median, IQR	30 (27–32)	30 (27–35)	0.510
Gestational age (weeks), maximum	41	40	
Gestational age (weeks), minimum	23	25	
Birth weight (g), mean ±SD	1486 ± 687	1545 ± 805	0.720
Birth weight (g), maximum	4430	4150	
Birth weight (g), minimum	410	560	
Reason for catheterization:			
Prematurity*	47 (94%)	35 (92%)	0.484
Perinatal asphyxia	2 (4%)	2 (5.3%)	
Congenital defects	1 (2%)	1 (2.6%)	

* Vascular access was required for hemodynamic monitoring and repeated blood sampling

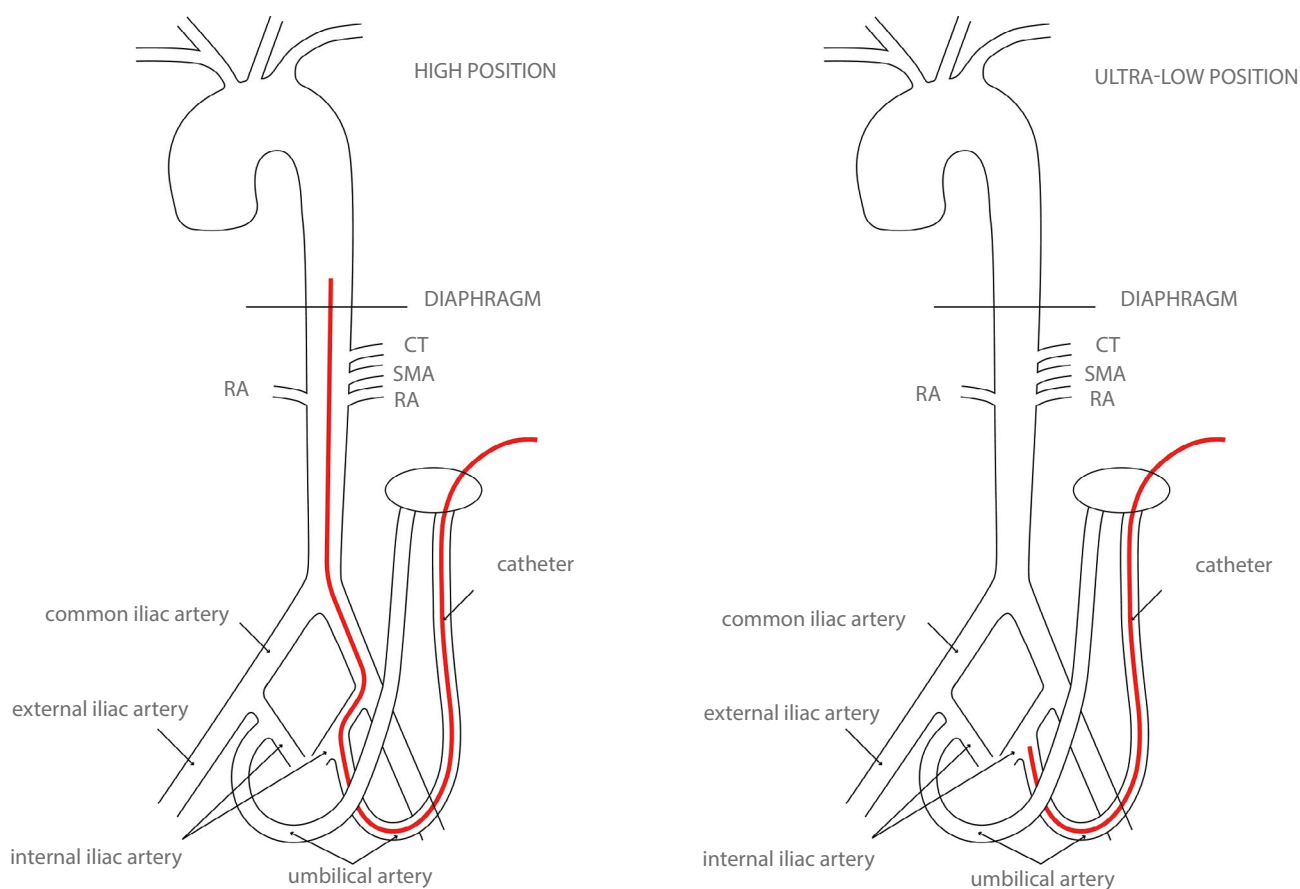


Fig. 1. UAC positions: standard high position (left) and novel ultralow position (right). CT – celiac trunk; SMA – superior mesenteric artery; RA – renal artery

men (Fig. 2). Once the correct position was confirmed, the catheter was fixed to the cord clamp using sterile patches and flushed with unfractionated heparin solution in 5% dextrose or saline. In all patients, UACs were used not only for blood sampling but also for continuous monitoring of blood pressure.

Monitoring for thrombosis

Every 24 hours, all UACs were examined by ultrasonography, as has been standard practice in our NICU since 2020 for all central catheters. The purpose was to detect possible thrombus formation or any other complications, such as dislocation of the catheter. Thrombosis was identified by the presence of hyperechogenic foci at the catheter tip or throughout its length and/or by a lack of Doppler-detected arterial flow. As each catheter was removed, it was also visually inspected for the presence of a thrombotic mass. Furthermore, upon catheter removal, the status of vessels (internal iliac artery, common iliac artery, and aorta) was also evaluated by ultrasound (Fig. 3).

All US assessments were performed with a 12–15 MHz linear probe, using a Philips HD11, Philips HD15, or GE LOGIQ S7 ultrasound scanner. All scans were video recorded and verified by a senior neonatologist.

Statistical analysis

The Kolmogorov–Smirnov test was used to determine the normality of data distribution. Student's *t* test or the Mann–Whitney *U* test was used to compare continuous variables, as appropriate. To compare incidence rates, the chi square test with Yate's correction was employed, and the appropriate odds ratio with 95% confidence interval was calculated. $P < 0.05$ was considered statistically significant.

Results

Thrombosis was found in 22/50 neonates with a UAC in the standard high position, resulting in a 44% incidence rate. Thrombosis was categorized as clinically significant and necessitated anticoagulant treatment in 11/50 (22%) infants. There were no cases of thrombosis among infants with UACs placed in the novel ultralow position (OR 0.016, 95% CI 0.000–0.283, $p < 0.0001$). A *post hoc* sensitivity analysis revealed that with a one-sided significance level of 0.025, the sample size of 38 patients had 94.7% power to detect a statistically significant difference in the rate of thrombosis compared to the control group.

The mean (\pm SD) catheter indwelling time was 8.2 ± 4.1 days in the novel ultralow UAC group and 8.5 ± 4.0 days in the control group ($p = 0.687$).

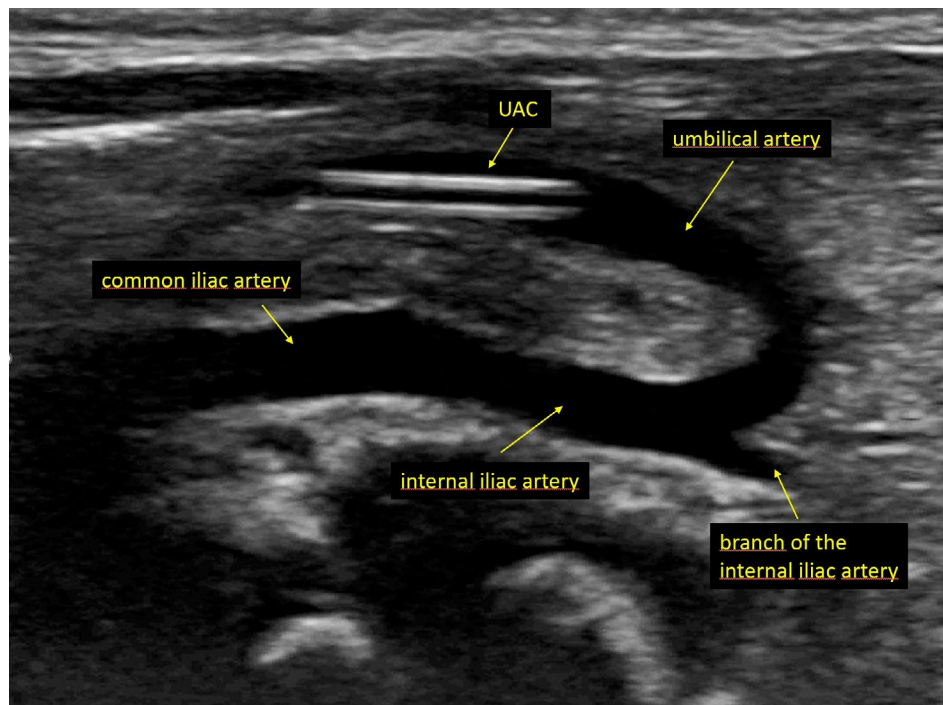


Fig. 2. Ultralow position of the UAC with the catheter tip in the umbilical artery

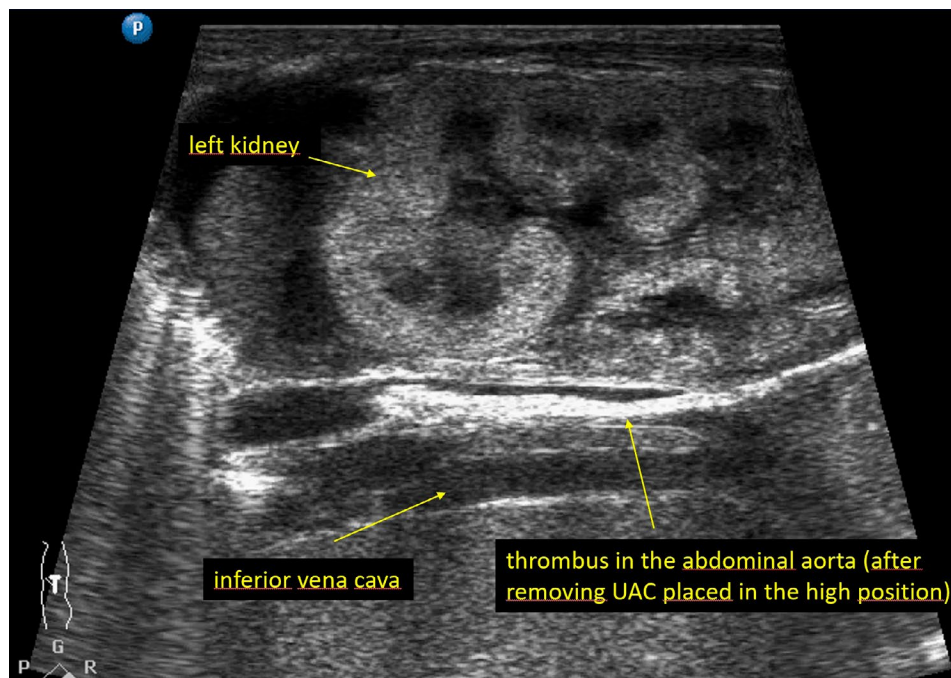


Fig. 3. Ultrasound image after removal of a UAC in the high position due to thrombosis. The thrombus extends to the superior pole of the kidney; the inferior pole of the kidney is outside the frame

Discussion

This is the first report presenting an entirely novel position for the placement of UACs, which led to a decrease in catheter-related thrombosis. The novel ultralow UAC position was chosen in response to the pathophysiological challenges associated with the in-

travascular presence of a catheter, which, as a foreign body, causes injury to endothelial cells and hence activates the coagulation cascade. Thrombosis, if present, often begins at the catheter tip and progresses downstream, enveloping the catheter. Therefore, it is optimal if the catheter itself is positioned in an artery the clotting of which would have minimal clinical sequelae (umbilical artery),

while the tip is located in a vessel that does not undergo involution (internal iliac artery), reducing the risk of early catheter loss.

The new position was intended to reduce the rate of thrombosis, which varies depending on the diagnostic technique⁽¹³⁾. Until recently, X-ray examination was the primary monitoring technique for detecting thrombosis. Although contrast-enhanced X-ray imaging is a sensitive tool for detecting thrombosis, it cannot be utilized as a routine screening method. Vascular thrombosis may be asymptomatic, and in the absence of clinical signs, it is unclear who should be examined and when. Ionizing radiation is also detrimental to growing organisms. Thus, ultrasonography is an attractive alternative. We feel that, notwithstanding the scarcity of comparative studies on the subject, angiography, with all of its drawbacks, should no longer be used to detect thrombotic complications when more precise US imaging with a high-frequency probe is available.

Studies using US to detect thrombosis report varying incidence rates. The frequency of thrombosis was 20% in a meta-analysis of 14 studies published in 2018 by Rizzi *et al.*⁽¹³⁾; however, the studies also employed other diagnostic modalities, not just ultrasonography. In turn, Hwang *et al.*⁽¹⁴⁾ observed lower rates of thrombosis (12.3%), but in their work, all catheters were removed on the day 7. In older reports, the incidence rate ranged between 17 and 27%, but the authors employed low-frequency US transducers and assessed only the aorta without the iliac arteries or only with their initial segments^(12,15). Given the statistics above, our baseline thrombosis rate (44% overall, 22% clinically significant) with the standard high UAC position may appear high. However, we routinely checked all catheterized patients on a daily basis, and we employed high-frequency transducers to scan the entire catheter path, including the descending aorta and its branches, i.e., the common iliac arteries and internal iliac arteries. This might have led to improved thrombosis identification, even in clinically silent cases. It is worth noting that we used exactly the same protocol to monitor the possible occurrence of thrombosis when inserting UACs in the ultralow position, and even with such a sensitive detection method, we found no cases of thrombosis. We feel that these data warrant additional investigation to validate the safety benefits of ultralow catheter placement in larger cohorts.

Most guidelines to date have recommended a high UAC position, as it is associated with lower rates of complications than a low position for arterial access⁽⁹⁾. However, if the reports on reduced thrombosis rates are confirmed, it may change the paradigm of UAC use in neonatal intensive care.

The problem that should always be investigated when using a novel method of catheter placement is catheter patency. The indwelling periods of UACs in both regular and ultralow positions were comparable in our study, showing that the proposed position is at least as useful as the standard position in terms of practical in situ maintenance. Little is known about the optimal indwelling time of UACs. Gordon *et al.*⁽¹⁷⁾ found only one study in their systematic review that aimed to evaluate the optimal indwelling time of an umbilical venous catheter in terms of the risk of infection. A similar systematic review, except with arterial catheters and thrombosis as the endpoint, found that the risk of endpoint events increased considerably after 5 days⁽¹⁸⁾. From this perspective, the absence of thrombosis

within a median of 8 days of ultralow UAC indwelling should be deemed notable.

The drawback of the ultralow approach is that if the catheter is positioned too low, it will be in the zone of involution of this vessel, which normally clots within 1–2 days after birth. This, however, can be managed with precise positioning of the catheter tip using the ultrasound technique.

This new catheter position necessitates advanced ultrasound skills, which is a limitation. However, for a physician who is already knowledgeable with abdominal ultrasonography, imaging of the iliac arteries can be learned in just a few days under the supervision of an experienced sonographer. In this study, catheters were inserted by five coinvestigators, who constituted approximately half of our NICU medical team. This shows that the technique is relatively easy to master and that the technical difficulty lies predominantly in inserting the catheter into the severed vessel within the umbilical cord. Following a brief training period, ultrasound-guided catheter placement takes no longer than insertion without ultrasound guidance. Ultrasonography also has the benefit of being faster and more precise than radiography for determining catheter position^(19–21).

The weakness of the study is that it was monocentric and that the control group was based on a retrospective cohort. We abandoned the idea of a parallel control group, given the high frequency of sonographically diagnosed thrombosis associated with the standard high UAC location. We feel that continuing to introduce catheters in this manner would be unethical.

Our exploratory study might have substantial ramifications for clinical practice. If the preliminary findings of improved safety with ultralow UAC placement over traditional high UAC placement are validated in further studies, this might be an important milestone in newborn critical care. We propose a method that limits iatrogenic complications. In an era when we see higher survival rates in our patients, many of them suffer from iatrogenic complications related to intensive therapy. The proposed method may resolve at least one of the issues.

Conclusion

The preliminary findings for the novel ultralow UAC position indicate that it may provide a safety benefit over the conventional UAC position.

Conflict of interest

The authors have no conflicts of interest to declare.

Author contributions

Original concept of study: AT, PS, PK. Writing of manuscript: AT. Analysis and interpretation of data: AT, PK. Final acceptance of manuscript: AT. Collection, recording and/or compilation of data: AT. Critical review of manuscript: PS, PK.

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