The assessment of ultrasound confirmation of umbilical venous catheter positioning by thoracoabdominal x-ray in newborns

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Background: Umbilical venous catheter (UVC) is the most common and convenient method of central venous access in sick newborn infants. Thoracoabdominal x-ray (TAX) is the most widely used method to confirm UVC position. However, serious complications could be found despite the correct position as seen on TAX, supported that TAX only might not be adequate to evaluate UVC tip position.

Nowadays, the availability of bedside ultrasound allowed its place in many NICUs and the recent studies had evaluated the superior role of ultrasound in UVC positioning in comparison to the gold standard TAX

Objective: To evaluate the ultrasound confirmation of umbilical venous catheter positioning by thoracoabdominal x-ray in newborns

Method: A single-center-based retrospective study. Patients are all neonates admitted in NICU, Bhumibol Adulyadej Hospital who require umbilical venous catheter insertion during November 2019 to September 2021. All UVC insertions were evaluated the position both by thoracoabdominal x-ray (TAX) and ultrasound. The correct UVC tip position was at IVC-RA junction determined by ultrasound.The protocol was approved by the ethic review committee.

Results: The estimated correct UVC tip position in IVC-RA junction by using ultrasound confirmation was 22 from 74 catheter insertions (29.7%), T8 level had the highest rate of correct position (13.5%) and the other incorrect positions were the most common at RA (51.3%). In addition, the result of ≤ 1500 and >1500 g birth weight newborns were similar which was the percentage of incorrect UVC positioning at 70.5 and 70% respectively with no statistically significance.

Conclusion: This study supported that the use of TAX alone was not adequate in determining the proper position of UVC tip in neonates. Regardless of the birth weight. The use of ultrasound assisted clinicians in the proper placement of the UVC tips by providing appropriate visual anatomical detail in the image.

Keywords: umbilical venous catheter, UVC, newborn infants

Introduction

The sick newborn infants, especially preterm infants, usually required central venous access to administer intravenous (IV) medication, TPN and fluid during neonatal resuscitation in neonatal intensive care unit (NICU). Umbilical venous catheter (UVC) is the most common and convenient method which is done by inserting the catheter through umbilical vein then entering the newborn's inferior vena cava (IVC) via the venous portal system and the ductus venosus (DV)[1]

The ideal position of UVC's tip calculated by Shuka's formula or Dunn's method (shoulder-umbilicus length)[2] is the junction of inferior vena cava (IVC) and the right atrium (RA). Malposition of UVC was reported to cause various complications in newborns, namely pericardial effusion, pleural effusion, cardiac arrhythmia, thrombosis, diffuse liver injury and portal hypertension[3].

After the UVC insertion, a thoraco-abdominal x-ray (TAX) is the most common and widely used method to confirm UVC position. However, serious complications could be found despite the correct position as seen on TAX. Studies had been found that TAX alone could not evaluate UVC's tip accurately.

Ultrasound had been used to identify the position of UVC since 1982 with a better accuracy than TAX[4]. Nowadays, the availability of bedside ultrasound allowed its place in many NICUs. The use of bedside ultrasound in BAH NICU and its use to assist the correct placement of UVC with TAX was introduced to BAH prior to 2019. More recent studies had evaluated the role of ultrasound in UVC positioning in comparison to the gold standard TAX[5,6,7].

The objective of current study was to evaluate the precision of UVC tip positioning using ultrasound and TAX in newborn infants admitted in NICU, Bhumibol Adulyadej Hospital (BAH). Precision of UVC placement identified by TAX would be confirmed by the use of ultrasound.

Materials and Methods

Study Population

The study protocol was reviewed and approved by the Ethics Committee of BAH affiliated (IRB 46/63). A single-center-based retrospective study, all newborn infants admitted in NICU, BAH between November 2019 and September 2021 who required UVC insertion were recruited for the study. Infants with major congenital heart disease, abdominal wall defects, congenital diaphragmatic hernia and others anomaly of diaphragm, hydrops fetalis and those with documented the UVC tip position below T10 level on TAX were excluded.

The process of UVC insertion was performed using sterile technique by trained pediatric resident and supervised by NICU's pediatric certified staff. The UVC depth was calculated by Dunn's method (shoulder-umbilicus length) plus the length of stump's remnant. After catheter placement, the depth scale was checked before and after the suture of UVC in place. Then an additional medical tape was used to attach UVC to the infant's abdomen.

TAX was performed with a portable X-ray machine using G.E. optima (XR220, NY, USA) to evaluate the UVC position according to the vertebra level. If the UVC position was below the T10 level, a reinsertion of the catheter and a subsequent TAX was carried out. If the UVC position was above the T7 level, reposition the catheter and subsequent TAX was also performed. The TAX was read by the pediatric radiologist and NICU's staff.

Bedside ultrasound using LOGIQ V5 with 3S, 6S ultrasound probe (GE Healthcare, Chi, USA) was done as soon as possible after TAX by an ultrasound trained pediatric resident. The UVC scale attached to the infants' skin was rechecked before taking ultrasound. A subxyphoid right parasagittal view was used to assess the UVC course and position. The ultrasound pictures and videos were recorded and reviewed separately by

pediatric cardiologist and pediatric radiologist. The exact position of UVC tip was evaluated as related to IVC-RA junction, RA, IVC and hepatic vein (HV).

Data Collection

Data referring to demographic characteristics, TAX, ultrasound and echocardiographic results were obtained including gestational age, birth weight, length, gender, timing of radiograph and ultrasound, time interval between x-ray and ultrasound.

The results of UVC tip position by TAX were described as T7, T8, T9 and T10 vertebral level.

The results of UVC tip position by ultrasound were recorded (described as inferior vena cava-right atrium (IVC-RA), right atrium (RA), left atrium (LA), branch of portal vein (BPV), inferior vena cava (IVC))

Statistical Analysis

SPSS statistical software package, version 27.OJ (SPSS Inc, Chi, USA) was used for statistical analyses. Continuous variables were summarized using mean and standard deviation (mean±SD) or using frequencies (%) of patients to describe categorical variables and Chi square test for categorical data.

Results

Demographic and Clinical Manifestations

Among 75 newborn infants placed with UVC, 74 neonates were included and one of them was excluded due to major congenital heart disease. The newborn infants were divided into two groups; ≤ 1500 g and > 1500 g. Gestation age, mean birth weight, length, mean gestational age and time interval between x-ray and ultrasound were presented in Table 1.

Table 1 Baseline demographic characteristics (n=74)

	≤ 1500 g (n=44)*	> 1500 g (n=30)*
BW (grams)	1015.8 ± 252	2139.56 ±852
GA (weeks)	28.15 ±2.76	33.4 ±3.3
Length (cm)	36.3 ±3.4	45 ±4.2
TTU (hours)	6.82 ±7	7.3 (±9

BW: body weight, *mean standard± deviation (SD), TTU: time interval between thoracoabdominal x-ray and ultrasound

The estimated correct UVC tip position at IVC-RA junction determined by ultrasound was 22 from 74 catheter insertions (29.7%). T8 level had the highest rate of correct position (13.5%). The other incorrect positions were at RA, BPV, IVC at 51.3, 2.7 and 16.2% respectively. Among all the percentage of correct position of UVC tip according to the TAX (100%), correct position was placed at the highest rate in T8 vertebral level (45.5%), and in T10, T9, and T7 at 22.7, 18.2, and 13.6% respectively (table 2).

Table 2 UVC tip position defied by TAX and ultrasound (n=74) in group of BW ≤ 1000g. and 1001-1500g

	UVC tip position on ultrasound, n (%)									
	≤ 1500 g (n= 44)					>1500 g(n=30)				
	IVC-RA	RA	LA	BPV	IVC	IVC-RA	RA	LA	BPV	IVC
T7	1 (2.3)	3 (6.8)			1 (2.3)	3 (10)	3 (10)			1 (3.3)
T8	6 (13.6)	8 (18.2)			2 (4.5)	4 (13.3)	5 (16.6)			(3.3)
T9	2 (4.5)	6 (13.6)			2 (4.5)	1 (3.3)	8 (26.6)			
T10	4 (9.0)	5 (11.4)		2 (4.5)	3 (6.8)	1 (3.3)				3 (10)
Total	13 (29.5)	22 (50)		2 (4.5)	8(18.2)	9 (30)	16 (53.3)			5 (16.7)

UVC: umbilical venous catheter, TAX: thoracoabdominal x-ray, IVC-RA: inferior vene cava-right atrium junction, RA: right atrium, LA: left atrium, BPV: branch of portal vein, IVC: inferior vena cava

There was no complication associated with UVC insertion during the study period.

The result of correct UVC insertion position identified by TAX as verified by ultrasound was shown in Table 3. The assessment of incorrect UVC position by ultrasound were revealed similar percentage of incorrect UVC positioning at 70.5 and 70% in ≤ 1500 and >1500 g birth weight newborns respectively with no statistically significance.

Table 3 Identification of correct UVC insertion position identified by TAX as verified by ultrasound.

	Position, n (%)	
	Correct	Incorrect
≤ 1000 – 1500 g	13 (29.5)	31 (70.5)
1500 - >2000 g	9 (30)	21 (70)

UVC: umbilical venous catheter, TAX: thoracoabdominal x-ray
P ≥ 0.05

Discussion

UVC insertion is the most common and convenient method of central venous access in sick newborn infants especially in preterm infants. The depth of UVC insertion is calculated by using Shoulder-umbilicus length or Shuka's formula was the method that had generally been used[8]. However, the estimate depth of UVC tip had always been difficult to assess and serious complications from misplacement were found. TAX was used to confirm the proper position of UVC tip at T 7-10. The improper position of UVC placement despite of the correct position confirmed by TAX might be from anatomical variation of the newborn infants and the inability of 2D TAX image to reveal organ detail. Ultrasound which has no radiation exposure is an imaging device found at NICU bedsides nowadays. Ultrasound allowed clinicians to evaluate the position of UVC tip by the surrounding anatomical structures namely RA, IVC, HV. These organ detail obtained in real time by ultrasound allowed clinicians more information to target the UVC tip insertion with higher accuracy.

In Ades A. et.al. study, among 53 newborn infants who required UVC insertion, ultrasound revealed only 12 of 53 patients (23%) that UVC tip position were located in an ideal position and the sensitivity and specificity of AP chest x-ray in evaluating inappropriate positions were 32% and 89% respectively[9]. In addition, the study of EL-madaawy et.al show the high sensitivity and specificity of ultrasound which were 91.3 and 94.2% respectively[6].

Accordingly, in Franta J. et.al, the UVC tip positioning was evaluated by ultrasound in 65 newborn infants and the ultrasound confirmed correct position of UVC tips in 38.5% of patients. Among the malposition of catheter tip, the majority was located in right atrium and they also reported a poor correlation between thoracic level by radiograph and catheter position by ultrasound[5].

In our study, we considered the ultrasound a better visual tool for accurate placement of UVC tips in newborn infants. The ideal position of UVC tip was the IVC-RA junction. From 74 of UVC tip position at T7-10 identified by TAX, only 22 of 74 UVC tip (29.7%) were in the proper position at IVC-RA junction as seen by ultrasound. Although some institutions continued to accept catheter location in the RA but that might be due to the lack of an adequate method to ensure the accurate between RA and IVC-RA junction during or after UVC insertion.

The correlation of ideal UVC tip position in ultrasound with the thoracic vertebral level (T7-T10) on TAX showed no association. This might be the result of wide variability in atrial size and the atrium position in newborn infants affecting radiographic landmarks thus made it impossible to correlate the UVC tip position as seen in TAX with intracardiac anatomy.

In our results there was no percentage difference among correct placement of UVC tips as seen by ultrasound in ≤ 1500 (70.7%) and >1500 (70%) g birth weight newborns. It is

believed that if real time ultrasound is used as a visual tool the UVC tip placement accuracy will be improved tremendously.

In our study period, there was no complication associated with UVC insertion in newborn participants. However, asymptomatic complications cannot be rule out because routine screening for such was not included in the study objective.

Study limitation

The lag time between TAX and the ultrasound procedure could not be controlled.

Suggestion

The research using real time ultrasound as a guiding tool for UVC tip insertion in newborns.

Conclusion

This study supported that the use of TAX alone was not adequate in determining the proper position of UVC tip in neonates. The UVC tip placement accuracy was similar regardless of the birth weight. The use of ultrasound assisted clinicians in the proper placement of the UVC tips by providing appropriate visual anatomical detail in the image.

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Conflict of interest

The authors declare no conflict of interest.

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การศึกษาตำแหน่งของสายสวนหลอดเลือดดำทางสะดือโดยการใช้อัลตราซาวน์เปรียบเทียบกับการใช้เอกซเรย์

ชาลิสา ธัมกิตติคุณ, วาสิตา จิรสกุลเดช, รัฐวัลลภ โสมะนันท์

ความเป็นมา: สายสวนหลอดเลือดดำทางสะดือ (Umbilical venous catheter) เป็นวิธีการใส่สายทางหลอดเลือดดำใหญ่ในทารกแรกเกิดป่วยหนักที่ใช้กันโดยทั่วไป โดยใช้เอกซเรย์เป็นเครื่องมือในการยืนยันตำแหน่งที่ถูกต้องของสาย อย่างไรก็ตามพบว่ายังมีภาวะแทรกซ้อนที่รุนแรงเกิดขึ้นแม้ว่าตำแหน่งในเอกซเรย์จะเหมาะสมแล้ว ปัจจุบันจึงมีการนำอัลตราซาวน์เข้ามาใช้ในการยืนยันตำแหน่งของสายสวนหลอดเลือดดำทางสะดือมากขึ้น เนื่องจากมีการศึกษาแสดงถึงความแม่นยำที่มากกว่า

วัตถุประสงค์: เพื่อประเมินตำแหน่งในภาพเอกซเรย์ของสายสวนหลอดเลือดดำทางสะดือโดยการใช้อัลตราซาวน์

วิธีการศึกษา: การศึกษาเชิงพรรณนาแบบการศึกษาย้อนหลัง ผู้เข้าร่วมการศึกษาคือทารกแรกเกิดที่เข้ารับการรักษาตัวในหอผู้ป่วยทารกแรกเกิดวิกฤต โรงพยาบาลภูมิพลอดุลยเดชที่ต้องได้รับการใส่สายสวยหลอดเลือดดำทางสะดือในช่วงเดือน พฤศจิกายน พ.ศ. 2562 ถึง กันยายน พ.ศ. 2564 โดยผู้เข้าร่วมการศึกษาทุกคนจะได้รับการประเมินตำแหน่งของสายสวนโดยการใช้เอกซเรย์และอัลตราซาวน์ ซึ่งตำแหน่งที่เหมาะสมคือบริเวณของรอยต่อระหว่างหลอดเลือดดำ Inferior vena cava (IVC) และหัวใจห้องบนขวา (right atrium) (IVC-RA junction)

ผลการศึกษา: พบตำแหน่งของสายสวนหลอดเลือดดำทางสะดือในภาพเอกซเรย์ที่อยู่บริเวณตำแหน่งที่เหมาะสมบริเวณ IVC-RA junction จากการประเมินโดยใช้อัลตราซาวน์ทั้งหมดเท่ากับ 22 จาก 74 ของการใส่สายสวนหลอดเลือดดำทางสะดือ (29.7%) โดยที่ระดับกระดูกสันหลังT8 เป็นตำแหน่งที่ถูกต้องมากที่สุด(13.5%) และพบว่าตำแหน่งที่ไม่ถูกต้องนั้นส่วนใหญ่อยู่ใน Right atrium (51.3%)

นอกจากนี้ในการศึกษาระหว่างกลุ่มทารกแรกเกิดน้ำหนัก ≤ 1500 และ >1500 กรัม จากการประเมินตำแหน่งของสายสวนหลอดเลือดดำทางสะดือในภาพเอกซเรย์ด้วยอัลตราซาวน์พบว่าเปอร์เซ็นของตำแหน่งสายสวนหลอดเลือดดำทางสะดือที่ไม่อยู่ในตำแหน่งที่ถูกต้องไม่ได้มีความแตกต่างกันทางสถิติ (70.5% และ 70%)

สรุป: การศึกษานี้สนับสนุนว่าการใช้เอกซเรย์เพียงอย่างเดียวในการประเมินตำแหน่งของสายสวนหลอดเลือดดำทางสะดือนั้นไม่เพียงพอ ทั้งในทารกแรกเกิดที่น้ำหนัก ≤ 1500 และ >1500 กรัม นอกจากนี้การใช้อัลตราซาวน์ร่วมประเมินตำแหน่งของสายสวนหลอดเลือดดำทางสะดือยังช่วยให้แพทย์สามารถประเมินตำแหน่งของสายสวนได้ละเอียดถูกต้องมากขึ้นเนื่องจากเป็นการประเมินภาพดูตำแหน่งจากอวัยวะข้างเคียงได้โดยตรง

คำสำคัญ: สายสวนหลอดเลือดดำทางสะดือ, ทารกแรกเกิด

กองกุมารเวชกรรม โรงพยาบาลภูมิพลอดุลยเดช กรมแพทย์ทหารอากาศ