

Comparison between Wright and Shukla formulas: which is better for the placement of umbilical catheters in newborns ≤ 1500 g?

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Abstract

Background: Intravascular venous (VUC) or arterial (AUC) umbilical catheter placement is the most frequent invasive procedure in the neonatal intensive care unit (NICU). Either Wright's or Shukla's formula is used to introduce the catheters. However, Shukla's formula is associated with incorrect insertion, especially for newborns < 1500 g. This study aimed to determine by chest X-ray if Wright's formula is better than Shukla's formula for the correct placement of umbilical catheters in newborns ≤ 1500 g. **Methods:** We included patients admitted to the NICU of a secondary-level hospital between 2021-2022 who received VUC or AUC through the Wright or Shukla formulas. **Results:** A total of 129 newborns were included: 78 with VUC and 51 with AUC. In VUC, 50% with Wright and 36.8% with Shukla formulas had the correct location, ($p = 0.24$). In AUC, 56.6 % with Wright and 52.4% with Shukla formulas were placed correctly placed, ($p = 0.76$). VUC with weight < 1000 g were correctly placed in 36.4% with Wright and 33.3% with Shukla formulas ($p = 0.58$). VUC in newborns > 1000 g were correctly placed in 66.6% with Wright and 38.4% with Shukla formulas ($p = 0.065$). AUC in newborns < 1000 g were correctly placed in 45% using Wright and 42.9% Shukla formulas ($p = 0.63$). AUC in newborns > 1000 g were correctly placed in 80% using Wright and 57.1% Shukla formulas ($p = 0.23$). **Conclusions:** We found 13% more correctly placed VUC using Wright's formula. Moreover, Wright's formula was 29% above Shukla's VUC placement in neonates > 1000 g, although there was no significant difference due to the sample size.

Keywords: Umbilical veins. Umbilical arteries. Peripheral catheterization. Umbilicus. Infant. Very low birth weight.

Comparación entre las fórmulas de Wright y de Shukla: ¿cuál es mejor para la colocación de catéteres umbilicales en recién nacidos ≤ 1500 g?

Resumen

Introducción: La colocación de catéteres intravasculares venosos umbilicales (CVU) y arteriales (CAU) es el procedimiento invasivo más frecuente en la unidad de cuidados intensivos neonatales (UCIN). Para introducirlos se utilizan las fórmulas de Wright y de Shukla, aunque esta última podría estar asociada con una inserción incorrecta, especialmente en neonatos < 1500 g. El objetivo de este estudio fue determinar mediante radiografía de tórax cuál fórmula es mejor para la correcta

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colocación de catéteres umbilicales en recién nacidos ≤ 1500 g. **Métodos:** Se incluyeron los pacientes ingresados en la UCIN de un hospital de segundo nivel entre 2021-2022 que recibieron CVU o CAU mediante las fórmulas de Wright o Shukla. **Resultados:** Se incluyeron en total 129 recién nacidos: 78 CVU y 51 CAU. En CVU, Wright 50% y Shukla 36.8% tuvieron localización correcta, $p = 0.24$. En las CAU, Wright 56.6% y Shukla 52.4% tenían una ubicación correcta, $p = 0.76$. En CVU con peso < 1000 g, Wright 36.4% y Shukla 33.3% bien situados, $p = 0.58$. En CVU > 1000 g, Wright 66.6% y Shukla 38.4% bien situados, $p = 0.065$. En CAU < 1000 g, Wright 45% y Shukla 42.9%, $p = 0.63$. En CAU con peso > 1000 g, Wright 80% y Shukla 57.1%, $p = 0.23$. **Conclusiones:** La colocación del CVU fue 13% mejor con la fórmula de Wright. La fórmula de Wright superó en el 29% la colocación del CVU en los neonatos > 1000 g en comparación con la de Shukla, aunque no hubo diferencia significativa debido al tamaño de la muestra.

Palabras clave: Venas umbilicales. Arterias umbilicales. Cateterismo periférico. Recién nacido de muy bajo peso. Ombligo.

Introduction

Placement of umbilical intravascular catheters is the most frequent invasive procedure in the neonatal intensive care unit (NICU)¹. Intravenous therapy has several purposes, such as administering parenteral fluids, blood products, parenteral nutrition, and sampling blood, and can be used for longer than peripheral infusion therapy^{2,3}. Therefore, it is fundamental in caring for the critically ill, full term, or preterm newborn. Intravascular access methods include venous (VUC) or arterial (AUC) umbilical catheters.

Various methods have been described and compared for adequate measurement of the length of catheter introduction according to arterial or venous catheterization. According to Shukla's formula for VUC placement, it is necessary to calculate the distance (in cm) by multiplying birth weight (in kg) by 1.5 plus 5 (birth weight $\times 1.5 + 5$). For AUC placement, the distance in centimeters birth weight (in kg) by 3 plus 9 (birth weight $\times 3 + 9$). Conversely, according to Wright's formula for VUC placement, the distance (in cm) is calculated by multiplying birth weight (in kg) by 4 plus 7 (birth weight $\times 4 + 7$), and the formula for AUC placement is the product of the birth weight (in kg) by 3 plus 9 and subsequently divided by 2 (birth weight $\times 3 + 9/2$). Previous studies have associated the Shukla formula with the over-insertion of the catheter tip⁴⁻¹⁰.

The recommended position of the tip of the VUC is at the junction of the right atrium and the inferior vena cava, which corresponds to the tip being visible between the upper edge of T9 and the lower edge of T10^{11,12}. In the case of the AUC, it could be in a high position, in the descending aorta above the diaphragm and below the left subclavian artery between the upper edge of T6 and the lower edge of T10, or in a low position, between between L3 and L5 on the bifurcation of the aorta but below the origin of the main branches¹³.

Successful catheterization can be difficult, and failure is common due to small, mobile, and slippery, easily traumatic blood vessels. The catheter should be ideally placed shortly after birth when the cord is fresh and hydrated. Once the catheter is placed, it is important to determine the correct position of the tip using a chest radiograph^{14,15}. If the catheter is incorrectly placed, it has a higher risk of complications with an incidence of 20-30%^{16,17}. Complications include pericardial effusion, cardiac tamponade, catheter-related infections, thrombosis, intestinal perforation, liver necrosis, cardiac arrhythmias, and myocardial perforation¹⁸. This study aimed to determine by chest X-ray if Wright's Shukla's formula is better the correct placement of umbilical catheters in newborns ≤ 1500 g.

Methods

Study design and population

We conducted a randomized clinical trial. We included < 1500 g admitted to a secondary-level hospital's NICU between 2021 and 2022 and who underwent a venous or arterial umbilical catheter placement according to medical indication. In the absence of previous verifiable effect sizes, (in kg) decided to use a medium effect size corresponding to a δ of 0.6 using the R power T test function for a comparison of two numeric variables using an α 0.05 and β 0.8. The resulting sample size was 45 per group. Twenty-six patients were excluded because there was no thorax X-ray to confirm the position of the catheter, the catheter could not be placed or failed to place a catheter in the vein instead of the artery. The newborns were divided into two groups: one group evaluated with Shukla's formula and the other with Wright's formula. Random numbers were generated for the newborns and printed on cards, which were placed in sealed opaque envelopes and opened just before venous or arterial umbilical catheter placement.

Measurement

The umbilical catheter placement was assessed by chest radiography. Vygón brand umbilical catheters, venous 4 Fr double lumen and arterial 3.5 or 5 Fr of one lumen, catheter placement equipment, and portable chest X-ray were used. The correct place of the catheter tip for the VUC was considered to be at the union of the right atrium and the inferior vena cava (between the upper edge of T9 and the lower edge of T10). For the AUC, in the descending aorta above the diaphragm and below the left subclavian artery (between the upper edge of T6 and the lower edge of T10). The high position was referred to those placed at the aortic arch, and those within the descending aorta below the beginning of the main branches (between L3 and L5) were classified as low position. Incorrect placement of the VUC's tip was defined as beyond, below, or intrahepatic location. The placement of the catheter tip was classified as a dichotomous variable depending on whether it was well or not placed according to the anatomical references. Concordance of the location of the umbilical catheter by chest radiography was assessed by the neonatologist and the radiologist. When there were different opinions between the attending physician and the radiologist, the criteria for establishing a correct placement were reached by consensus among the neonatology experts.

Ethical aspects

The consent of the parents or legal guardians was obtained through a document specifying the purpose of the study, the duration, the methods and techniques to be used. The study was submitted to the Research Ethics Committee of the Central Hospital Dr. Ignacio Morones Prieto for approval (registration number 79-17).

Statistical analysis

The continuous demographic variables were presented as means with standard deviation and medians with interquartile ranges; the dichotomous variables were managed as percentages. For the analysis of continuous variables, the distribution of data was assessed with qq-plot, and Shapiro-Wilk's test, while the homogeneity of the variances was assessed with Levene's test. According to the results, Student's t-test, and Mann-Whitney's U test were used. χ^2 or Fisher's exact test was used to compare categorical variables between the two groups according to minimum expected

frequencies. Statistically significant results were considered with $p < 0.05$. The analysis was conducted with the R version 4.2.1 software.

Results

The concordance of catheter placement was evaluated by the neonatology specialist in charge and the participating radiologist by an X-ray assessment of the thorax. For VUC placement, a Kappa index = 0.59 (95% CI 0.41, 0.77) was obtained, while for AUC placement, a Kappa index = 0.19 (95% CI -0.075, 0.45) was obtained. We included a total of 78 patients. Patients were divided into two groups: 40 patients (51.3%) were included in Wright's formula group, and 38 patients (48.7%) in Shukla's formula group. In all patients, VUC was placed; additionally, 51 patients (65.4%) required AUC placement. The mean gestational age was 30.1 (± 2.61) gestation weeks (GW). The mean weight of the total sample was 1078.06 \pm 267.69, and the median was 1085.5 g (856.2, 1337.5 IQR). Forty-two patients (53.8%) were male, and 45 patients (57.5%) were < 1500 gr (Table 1).

When comparing the location of the VUC according to the formula used, 40 (51.3%) catheters were placed with Wright's formula, and 38 (48.7%) were placed with Shukla's formula. Wright vs. Shukla formulas showed 20 (50%) vs. 14 (36.8%) correct locations, respectively. No significant difference was observed ($p = 0.24$).

When comparing the location of the AUC according to the formula used, 30 (58.9%) catheters with Wright's and 21 (41.2%) with Shukla's formulas were placed. Wright vs. Shukla showed 17 (56.6%) vs. 11 (52.4%) correct locations but no significant difference ($p = 0.76$) (Table 2).

Patients were divided by weight > 1000 g or < 1000 g. In the group of VUC < 1000 gr, 34 (43.6%) catheters were placed, 22 (64.7%) with Wright's formula, and 12 (35.3%) with Shukla. With Wright's formula 8 (36.4%) catheters were correctly placed, and the rest were incorrectly placed (63.6%). In comparison, with Shukla's formula, 4 (33.3%) catheters were correctly placed, and the rest (66.6%) were incorrectly placed, with no significant difference ($p = 0.58$).

In the VUC group, 44 (56.4%) catheters were placed in patients > 1000 gr, of which 18 (41%) with Wright's and 26 (59.1%) with Shukla's formula. Wright's vs. Shukla's formula groups showed 12 (66.6%) vs. 10 (38.4%) correctly placed, and 6 (33.3%) vs. 16 (61.5%) incorrectly placed catheters, respectively, with no significant difference ($p = 0.065$).

Table 1. Demographic variables

Data	Wright's formula (n = 40)	Shukla's formula (n = 38)	p
Age (GW), mean (SD)	29.46 (\pm 2.33)	30.79 (\pm 2.74)	0.02*
Weight (g) median (IQR)	965 (560, 1490)	1155 (600, 1480)	0.02**
Male gender, n (%)	24 (60)	18 (47.3)	0.26***
Weight > 1000 g, n (%)	18 (45)	26 (68.4)	0.03***

*Student's t-test.

**Mann-Whitney's U test.

*** χ^2 test.

GW: gestation weeks; IQR: interquartile ranges; SD: standard deviation.

Table 2. Frequency of correct placement of umbilical catheters according to the formula used

Variables	Wright n (%)	Shukla n (%)	p
VUC	20 (50)	14 (37)	0.24*
AUC	17 (57)	1(52)	0.76*
VUC < 1000 g	8 (36)	4 (33)	0.58**
VUC > 1000 g	12 (67)	10 (38)	0.065*
AUC < 1000 g	9 (45)	3 (43)	0.63**
AUC > 1000 g	8 (80)	8 (57)	0.23**
VUC FEMALE	10 (62)	7 (35)	0.1*
VUC FEMALE	6 (50)	5 (45)	0.82*
AUC MALE	10 (42)	7 (39)	0.85*
AUC MALE	11 (61)	6 (60)	0.63**

*Chi-square.

**Fisher's exact test for calculation of the power of the test with $\alpha = 0.05$, $\beta = 0.76$.

VUC: venous umbilical catheter; AUC: arterial umbilical catheter

The placement of the VUC with the two formulas between patients < 1000 g and > 1000 g showed no significant difference ($p = 0.19$).

In the AUC group, 27 (56.4%) catheters were placed in patients < 1000 g, of which 20 (74.1%) were placed with Wright's and 7 (26%) Correspondingly, with Wright's vs. Shukla's formula. With Wright vs. Shukla, 9 (45%) vs. 3 (42.9%) catheters were correctly placed, and 11 (55%) vs. 3 (42.9%) were incorrectly placed, with no significant difference ($p = 0.63$).

In the group of AUC > 1000 g, 24 (47%) catheters were placed, of which 10 (41.6%) were placed with Wright's and 14 (58.45%) with Shukla's formula. With Wright's, 8 (80%) of the catheters were correctly placed and the rest incorrectly, while Shukla formula 8 (57.1%) were correctly placed and the rest incorrectly placed. with no significant difference ($p = 0.23$).

The AUC placement with either formula between patients > 1000 gr and < 1000 g showed no significant difference ($p = 0.11$).

We further analyzed VUC and AUC groups by sex. Of 36 (46.1%) female patients in the VUC group, 16 (44.4%) catheters were placed with Wright's and the with Shukla. Wright vs. Shukla showed that 10 (62.5%) vs. 7 (35%) catheters were correctly placed with no significant difference ($p = 0.1$). Conversely, of 42 (53.8%) male in the VUC group, 24 (57.1%) were placed with Wright's and 18 (42.9%) with Shukla's formula. Wright vs. Shukla groups showed 10 (41.6%) vs. 7 (38.9%) of the catheters correctly placed, respectively, and the rest incorrectly placed, with no significant difference ($p = 0.85$).

In the AUC group, from 23 (45%) females, 12 (52.1%) were placed with Wright's and 11 (47.9%) with Shukla's formula. Wright vs. Shukla groups showed that 6 (50%) vs. 5 (45%) catheters were correctly placed. The rest were incorrectly placed, ($p = 0.82$). From 28 (55%) male patients in the AUC group, 18 (64.2%) catheters were placed with the Wright's and 10 (45%) with the Shukla's formula. Wright vs. Shukla showed 11 (61.1%) vs. 6 (60%) of catheters correctly placed and the rest incorrectly placed, with no significant difference ($p = 0.63$).

Discussion

The groups were classified based on data analysis, and randomized to apply each formula. The percentage of venous and arterial umbilical catheters correctly placed with Wright's formula was higher than Shukla's formula, both in patients < 1000 g and > 1000 g, which demonstrates the clinical superiority of this formula. The results of the present study showed no significant differences between the use of either Wright's or Shukla's formula for the correct placement of venous and arterial umbilical catheters in patients < 1500 g.

Kumar et al.¹⁹ also compared these two formulas in 99 newborns stratified by birth weight and demonstrated an 82% reduction in incorrect placement of the tip of the umbilical arterial catheter when using Wright's formula, with a significant difference in catheter placement in neonates < 1500 g. There were 12 physicians involved in the insertion of catheters, verified by two independent physicians, and reviewed with a radiologist. In contrast, in the present study, catheter placement was verified at first intent by a single neonatologist and corroborated with a radiologist. We found medium concordance for the venous and low concordance for the arterial catheters.

Wright et al.⁷ compared these same formulas in a population of 74 newborns < 1500 g. In this study, they found a significant difference ($p = 0.003$) in correctly placing the arterial umbilical catheters using Wright's formula. Unlike our study, they only included the high position in the AUC placement.

Verheij et al.⁴ included a sample of 216 patients and evaluated the correct placement of arterial and venous umbilical catheters, comparing Dunn's vs. Shukla's method. They showed a correct placement rate of AUC of 87% (39/45) in the Shukla group, which was higher than in our study (< 30%). In comparison, the success rate in VUC was 24% (20/84), more similar to our study, which was > 36%.

One strength of our study is the large sample of patients, similar to Kumar et al.¹⁹ and Wright et al.⁷ In contrast, we consider that our results are affected by the low concordance between the radiologist and neonatologist in evaluating the position of arterial umbilical catheters. Therefore, we recommend that future evaluations ensure higher Kappa indexes among evaluators by training them in standardized evaluations.

In conclusion, our study showed that Wright's formula is better than Shukla's for the correct placement of umbilical catheters regardless of the access route, sex, and weight of the patient but without a significant difference. Furthermore, VUC placement in patients > 1000 g showed a higher percentage tendency to be better placed with Wright's formula. However, a significant difference was not observed, probably due to the sample size, calculating the power of the test with α of 0.05, resulting in $\beta = 0.76$. Therefore, we suggest to conduct studies with more patients > 1000 g to compare these two formulas.

We found a 13% difference in the correct placement of VUC using Wright's vs. Shukla's formulas in patients of ≤ 1500 g, although not statistically significant. The main difference between both formulas was found in

VUC the Wright formula showed a difference of 29%, although no statistically significant difference was observed between the two formulas.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author has this document.

Conflicts of interest

The authors declare no conflicts of interest.

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