Simple and Accurate Formula to Estimate Umbilical Arterial Catheter Length of High Placement

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Objective: The present study aimed to derive the new simple, reliable, and accurate formula based on a body measurement parameter and not on reference graphs, to determine umbilical arterial catheter length of high placement, between the sixth to tenth thoracic vertebral (T6-T10) levels. Accuracy among a variety of formulas was also examined.

Material and Method: A prospective recruitment of 40 babies who had an umbilical arterial catheter placed in the NICU, Thammasat University Hospital was studied. Insertional length for high placement was measured. The body measurement parameters were measured twice on each patient to indicate their reliability properties. Three individual umbilical arterial lengths, from umbilical ring to anatomical points of T6, T8, and T10 levels accordingly, were estimated by verifying the catheter tip against those anatomical points on chest and abdominal radiograph. Correlation coefficient (r) between each parameter and the umbilical arterial length to the T8 level was calculated.

Results: Suprasternal notch to superior iliac spine length (SSSL) was the selected parameter to derive a new formula because of high reliability coefficient of 0.964, high correlation to the umbilical arterial length to the T8 level (r = 0.906), and its simplicity to measure. The accuracy of the ‘SSSL’ to position the catheter tip at T6-T10 was 90%.

Conclusion: The SSSL is simple and accurate for predetermination of the umbilical arterial catheter length to position the catheter tip at T6-T10. It can be an alternative formula, especially where birth weight and total body length are not available.

Keywords: Umbilical arterial catheter, Simple, Accurate, Estimation, Length, high placement

Umbilical arterial catheter has become a standard arterial access in neonatal intensive care unit (NICU) for drawing blood samples, measuring blood pressure, and administering fluid and medications. High placement of arterial catheter between the sixth to tenth thoracic vertebral (T6-T10) levels is considered as a practical, safe, and feasible position. It is usable for a longer period. When placed high, it is removed as an emergency less often than placed low. Accurate placement of the catheter tip at the first insertion is important. If placed wrongly, then consequent adjustment of the catheter position, withdrawal, or reinsertion is not necessary. There has been a variety of formulas using calculation of a neonatal body measurement parameter and/or plotting with a reference graph to determine insertional length of the catheter. In emergency settings, some parameters may be difficult to obtain accurately because of flexor tone of the newborn and multiple monitor attachments to the body. No particular formula has been recommended to estimate the catheter length among Asian babies. Thus, the present study aimed to derive a new simple, reliable, and accurate formula based on a body measurement parameter, and not on a reference graph, to determine the umbilical arterial catheter length. Accuracy among a variety of the formulas was also examined.
Material and Method

A prospective recruitment of 40 babies without gross anomaly who needed umbilical arterial access in the NICU, Thammasat University Hospital was studied. All the babies had respiratory problems and required monitoring of arterial blood gases. An umbilical arterial catheter was inserted using aseptic technique. Unstable babies during insertion were excluded from the present study because of an ethical reason. The present study was approved by the Faculty of Medicine Thammasat University Human Ethics Committee to perform. A radio-opaque catheter was used to place the catheter tip between T6 and T10 in all babies. Insertional catheter lengths were measured and inserted by various staff on duty in the NICU. Birth weight (BW) was recorded as a parameter with one decimal number of kilograms in all babies. At the first insertion, a variety body measurement parameters were measured as the following: total body length (TBL), shoulder-to-mid umbilicus length, shoulder-to-superior border of pubis length, nipple-to-mid umbilicus length, xiphoid-to-mid umbilicus length, xiphoid-to-superior border of pubis length (XPL), suprasternal notch-to-mid umbilicus length, suprasternal notch-to-superior border of pubis length, suprasternal notch-to-left superior iliac spine length (SSSL), and mid umbilicus-to-superior border of pubis length (UPL). All the measurements were recorded with one decimal number of centimeters. Repeated measurement of these parameters, except BW, was performed within 48 hours on each patient by the same physician. Reliability coefficient of each parameter based on twice measurement was calculated. The insertional catheter was measured from the catheter tip to umbilical ring level. Location of the catheter tip was checked by chest and abdominal radiography to place between T6 and T10 levels. Catheter position was adjusted by withdrawal or by re-insertion if the first insertional catheter tip was placed out of T6-T10 levels. Three individual umbilical arterial lengths, from umbilical ring to anatomical points of T6, T8, and T10 levels accordingly, were estimated by verifying the catheter tip against those anatomical points on the radiograph. The umbilical arterial length to each anatomical point on each patient was corrected by directly adding up or subtracting an exact scale on the radiograph. Correlation coefficient (r) between each parameter and the umbilical arterial length to the T8 level was calculated.

One of those parameters was selected to derive the formula based on the following criteria; excellent reliability coefficient, high correlation coefficient (r), and the simplicity of the parameter measurement. Simple operation of the chosen parameter was tried to generate a new formula to estimate the insertional length. Correlation coefficient between the umbilical arterial length to the T8 level and insertional length calculated from the proposed formula was done. The formulas of: Formula 1. XPL + UPL\(^7\), Formula 2. TBL/3\(^8\), Formula 3. SPL\(^9\), Formula 4. 3BW + 9\(^9\), and Formula 5. Based on BW\(^10\) were studied for their accuracies. All data were analyzed by using the STATA version 9.0 statistical package with mean ± standard deviation for continuous variables and percent for counting number. Reliability and correlation coefficients and percent of accuracy were presented.

Results

Forty Thai babies, 21 boys and 19 girls, with the mean birth weight of 1,630 grams ± 620 grams (range of 790 grams - 2,900 grams) were studied. Eight babies (20%) had a birth weight of less than 1,000 grams. At the first attempt of catheter insertion, 26 babies (65%) had the catheter tips placed successfully at the high placement.

Suprasternal notch to left superior iliac spine length (SSSL) was selected to derive a new formula (Formula 6) because of the high reliability coefficient of 0.964, the high correlation to the umbilical arterial length to the T8 level (r = 0.906) and its simplicity to measure. By studying those of 40 babies, reliability coefficients and correlation coefficients of the parameters used in the formulae were calculated and compared in Table 1.

Thirty babies (90%) with calculated insertional lengths of ‘SSSL’ had the catheter tip between T6 and T10 levels correctly positioned. In other words, the

<table>
<thead>
<tr>
<th>Reliability coefficient*</th>
<th>Correlation coefficient**</th>
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<tbody>
<tr>
<td>XPL 0.966</td>
<td>0.710</td>
</tr>
<tr>
<td>UPL 0.875</td>
<td>0.590</td>
</tr>
<tr>
<td>TBL 0.954</td>
<td>0.894</td>
</tr>
<tr>
<td>SPL 0.960</td>
<td>0.849</td>
</tr>
<tr>
<td>BW -</td>
<td>0.935</td>
</tr>
<tr>
<td>SSSL 0.964</td>
<td>0.906</td>
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* Of twice measurement

** Correlation of the parameter to the umbilical arterial length to T8 level
accuracy of the formula, SSSL, to predetermine the insertional length of high placement was 90%. Percent accuracy among those formulae to pre-determine the insertional length of high placement is compared in Table 2. The relationship between calculated lengths from the formulas and the umbilical arterial length to T6-T10 levels is shown in Fig. 1.

**Discussion**

SSSL is the reliable measure in most babies with reliability coefficient of 0.964. Moreover, high correlation of SSSL to the umbilical arterial length to the T8 level is impressive and, therefore, is used to derive the formula to calculate insertional catheter length (11). The anatomical landmark of both suprasternal notch and superior iliac spine is easily noticeable in most babies when doing the procedure. The present study result does not support using PUL to calculate the insertional length because of relatively low reliability and correlation coefficients presented in Table 1. Measuring parameters involving the umbilicus may be difficult and not reliable. Calculated catheter length from the formula 2 positioned the catheter tip scattered outside T6-T10 with an accuracy of only 39% presented in Table 2.

In Table 2, not only is the good accuracy of 90% of the SSSL to estimate the catheter length of high

<table>
<thead>
<tr>
<th>Table 2. Accuracy of the formulas (n = 40)</th>
<th>Correlation coefficient*</th>
<th>Accuracy percent**</th>
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<tbody>
<tr>
<td>Formula 1 (XPL+UPL)(7)</td>
<td>0.629</td>
<td>39%</td>
</tr>
<tr>
<td>Formula 2 (TBL/3)(8)</td>
<td>0.894</td>
<td>90%</td>
</tr>
<tr>
<td>Formula 3 (SPL)(8)</td>
<td>0.849</td>
<td>73%</td>
</tr>
<tr>
<td>Formula 4 (3BW+9)(9)</td>
<td>0.935</td>
<td>94%</td>
</tr>
<tr>
<td>Formula 5*** (based on BW)(10)</td>
<td>0.885</td>
<td>52%</td>
</tr>
<tr>
<td>Formula 6 (SSSL)</td>
<td>0.906</td>
<td>90%</td>
</tr>
</tbody>
</table>

* Correlation of calculated length from the formula to the umbilical arterial length to T8 level.
** Percent of babies that calculated lengths can correctly position the catheter tip at T6-T10 levels.
*** For a 1,000gm baby, the length of insertion is 10 cm, and add 1 cm for each additional weight group of 2,250 gm. Above 2,250 gm, the length of insertion is 15 cm for all babies.
placement, the better accuracy of 90%-94% of the formulae of ‘TBL/3’ and ‘3BW+9’ are also confirmed(8,9). The SSSL can be an alternative formula, especially where birth weight and total body length is not available. Although the formula proposed by Lin MS et al is not accurate based on the present study result, the calculated length from the formula correlated well to the umbilical arterial length to the T8 level (r = 0.896). This is because of a different definition of the high placement of T7 and T11 of the present study(10). Most babies had the calculated length at T10 - T11, as shown in Fig. 1.

In practice, the physician has to add up the calculated catheter length with the umbilical cord stump length to obtain the final insertion distance. Radiography after umbilical catheter insertion is still necessary to verify the position of the catheter tip since individual differences in the lengths of the iliac, umbilical arteries and the aorta are evident. In conclusion, the SSSL is simple and accurate for pre-determination of the umbilical arterial catheter length to position the catheter tip at T6 and T10 in the presented population. It can be an alternative formula where birth weight and total body length is not available.

References
สูตรที่ง่ายและแม่นยำในการประมาณความยาวสายสวนเส้นเลือดแดงสายสะดือของทารก

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วัตถุประสงค์: เพื่อสร้างสูตรหรือสมการที่แน่นอนและง่ายต่อการใช้ในการประมาณความยาวสายสวนเส้นเลือดแดงสายสะดือของทารกให้ปลายสายสวนอยู่ในตำแหน่ง high type หรือระดับกระดูกสันหลังระดับอกที่ T6-T10 โดยไม่ต้องอ้างอิงกราฟและเพื่อศึกษาปริมาณที่ควรจะนำมาถึงสูตรต่อ

วัสดุและวิธีการ: เป็นการศึกษาไปข้างหน้าในกลุ่มทารกแรกเกิดในหอขอป่วยทารกแรกเกิด โรงพยาบาลธรรมศาสตร์เฉลิมพระเกียรติ โดยวัดความยาวของสายสวนซึ่งปลายสายอยู่ในตำแหน่ง high type และวัดขนาดรูปร่างของทารกเพื่อเก็บเป็นตัวแปรความยาวส่วนต่าง ๆ ของร่างกาย โดยวัด 2 ครั้งเพื่อประเมินความเชื่อมโยงของแต่ละตัวแปร โดยวัดความยาวของเส้นเลือดแดงสายสะดือถึงตำแหน่งระดับกระดูกสันหลังระดับบอกที่ 6, 8, และ 10 ตามลำดับของทารกแต่ละคน โดยอ้างอิงกับภาพรังสีช่องท้องและช่องอก และคำนวณค่า correlation coefficient (r) ระหว่างตัวแปรความยาวแต่ละส่วนของร่างกายกับความยาวเส้นเลือดแดงสายสะดือถึงตำแหน่งระดับกระดูกสันหลังระดับบอกที่ 8

ผลการศึกษา: ผู้ศึกษาได้เลือกตัวแปรความยาวระหว่าง suprasternal notch ถึง superior iliac spine เพื่อสร้างสมการประมาณความยาวสายสวนเส้นเลือดแดงสายสะดือ เนื่องจากมีค่า reliability coefficient สูงเป็น 0.964 และมีค่า correlation coefficient (r) เป็น 0.906 และเป็นตัวแปรที่มีผลต่อการวัดสามารถใช้ได้ดีกว่าในในการประมาณความยาวสายสวนเส้นเลือดแดงสายสะดือโดยตรง ในปลายสายสวนอยู่ในตำแหน่งกระดูกสันหลังระดับบอกที่ 6-10 โดยมีอัตราร้อยละถึง 90

สรุป: การประมาณความยาวสายสวนเส้นเลือดแดงสายสะดือไปปลายสายสวนอยู่ในตำแหน่งกระดูกสันหลังระดับบอกที่ 6-10 ด้วยความยาวระหว่าง suprasternal notch ถึง superior iliac spine นั้นมีความแม่นยำและง่ายต่อการใช้ โดยสามารถใช้แหล่งสูตรเดิมได้ในกรณีที่ไม่ทราบน้ำหนักแรกเกิด หรือ ความยาวของทารก