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Optimal central venous pressure transducer level in various positions in pediatric patients

소아 환자의 다양한 자세에서 적절한 중심정맥압 측정 변환기의 위치

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by
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A thesis submitted to the Department of Medicine in partial fulfillment of the requirements for the Degree of Master of Philosophy in Anesthesiology at Seoul National University College of Medicine

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Professor _____Chairman

Professor _____Vice chairman

Professor _____

ABSTRACT

Introduction: The proper positioning of reference transducers is the first step in measuring accurate central venous pressure (CVP) or pulmonary artery occlusion pressure (PAOP). This study was performed to investigate the optimal transducer levels in the supine, prone, and sitting positions of pediatric patients.

Methods: Chest tomography (CT) images of 213 children aged ≤10 years were reviewed. Distances between the back and the uppermost blood level of both the atria and their ratios to the largest anteroposterior (AP) diameter of the thorax were calculated for the supine position. For the prone position, the same distances and ratios were calculated from the anterior chest. For the sitting position, the distances between the mid-sternoclavicular joint and the cephalad blood levels of both atria and their ratios to sternal length were calculated. The intercostal spaces (ICS) corresponding to the levels of CT images for the cephalad levels of both atria in the supine and sitting position were checked.

Results: : In the supine position, the ratio of the uppermost blood level of the right atrium (RA) and left atrium (LA) to the largest AP diameter of the thorax was 80-85% and 60-65%, respectively. The ratio of the most backward blood level of the RA and LA to largest AP diameter of thorax was 45-50% and 55-60%, respectively, from the anterior chest wall in prone position. The ratio of

the most cephalad blood level of the RA and LA to sternal length was 35-55% and 45-65%, respectively, from the mid-sternoclavicular joint in the sitting position. These levels corresponded to the third rib and the third intercostal space, respectively. There was no significant clinical difference in this ratio according to age.

Conclusions: In pediatric patients, the optimal CVP transducer level is four-fifths of the AP diameter of the thorax in the supine position, half of that in the prone position, and at the upper border of the third sternochondral joint in the sitting position.

Keywords: central venous pressure; prone position; supine position; transducers; pressure

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Chapter 1

INTRODUCTION

Pressure measurement is commonly performed in clinical practice and important for hemodynamic monitoring. Therefore, accurate measurement of pressure is the first step to improve the quality of hemodynamic management. If excluding arterial blood pressure, one of the most commonly measured pressure parameter would be central venous pressure (CVP) or pulmonary artery occlusion pressure (PAOP). Although the usefulness of these pressures for predicting fluid responsiveness seem skeptical, they still give clinically significant information.[1]

Both CVP and PAOP were electronically measured by a fluid filled system with a transducer. To eliminate the influence of hydrostatic pressure, the proper transducer levels should be at the uppermost fluid level in the chamber or the vessel in which pressures are being measured.[2-4] However, errors associated with inaccurate transducer placement commonly occur and this may lead physicians to make incorrect decision about treatment.[2-5] Accurate placement of a transducer is more important to parameters with a lower normal value (i.e., CVP), compared to pressure of a higher normal value (i.e., systemic arterial blood pressure). Thus, it is important that the CVP or PAOP transducer be placed at the proper level to measure accurate pressure.

There are several studies to verify the proper transducer level for adult patients in the supine position.[6-8] However, studies have not been

conducted to assess the appropriate transducer level for pediatric patients. Moreover, there are no accurate reference transducer levels for pediatric patients in various positions such as the supine, prone or sitting positions, although they should be placed in different positions, such as the prone and sitting positions, during some surgical procedures or respiratory care.

This study was performed to investigate optimal transducer levels for the accurate measurement of the right atrial pressure and left atrial pressure in the supine, prone, and sitting positions in pediatric patients by reviewing their chest computed tomography (CT) images.

MATERIALS AND METHODS

The Institutional Review Board (Seoul National University College of Medicine/Seoul National University Hospital, Seoul, Korea) approved the study. The patients' informed consents were waived by IRB. Chest CT data of pediatric patients 10 years and younger were reviewed by an investigator (Hur M.). Patients with a history of cardiothoracic surgery, congenital heart disease, any abnormal intra-thoracic and intra-abdominal lesion that influence heart position, chest wall or spinal deformities, and poor CT image quality were excluded.

The following data was recorded from the transverse section images: thickness of the CT image, anteroposterior (AP) diameter of the thorax, the uppermost blood and the most backward levels of the right atrium (RA) and the left atrium (LA) for the supine and prone position, image number of the uppermost blood level of the RA and the LA, the cephalad blood level of the RA and the LA for the sitting position, the mid-sternoclavicular joint, and the xiphisternal joint. The patient's characteristics of age, gender, height, and weight were collected.

A CT section with the uppermost blood level of the atrium was selected for the supine position. We then measured vertical distances from the skin on the back to the uppermost blood level of each atrium on the selected CT section in order that obtain the uppermost RA and LA height in supine position (RA_{supine} and LA_{supine}).(Figure 1.)

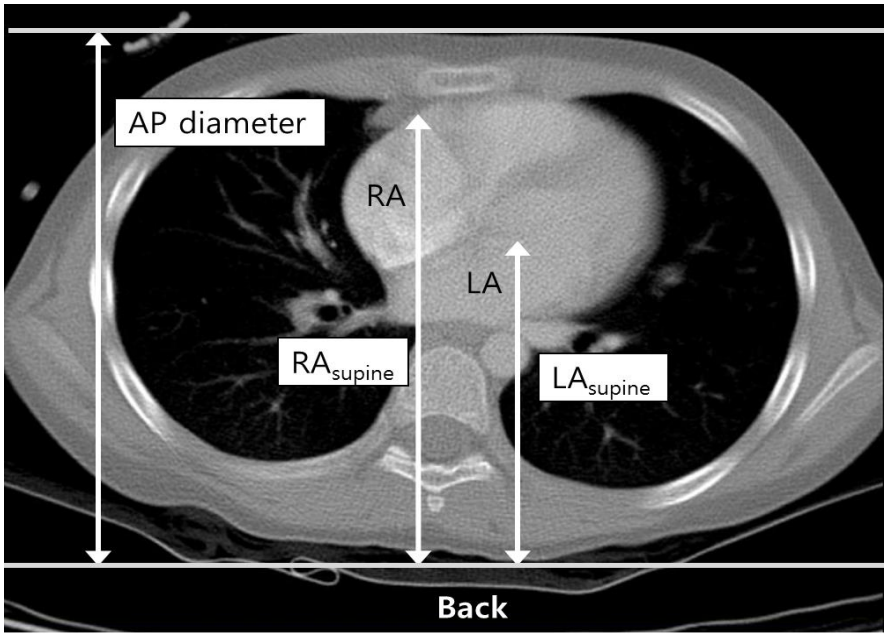


Figure 1. Measurement of RA_{supine} and LA_{supine}

A transverse section of contrast-enhanced chest computed tomography showing the uppermost blood level of the right atrium, left atrium, and the largest anteroposterior (AP) diameter of thorax in supine position.

RA_{supine} = the vertical distance from the skin on the back to the most anterior portion of the right atrium in supine position; LA_{supine}= the vertical distance from the skin on the back to the most anterior portion of the left atrium in supine position.

We assumed that the most backward blood level of the atrium was optimal for transducer position in the prone position, so we measured vertical distances from the skin on the anterior chest wall to the most backward blood level of each atrium to investigate the uppermost RA and LA height in the prone position (RA_{prone} or LA_{prone}). (Figure 2.)

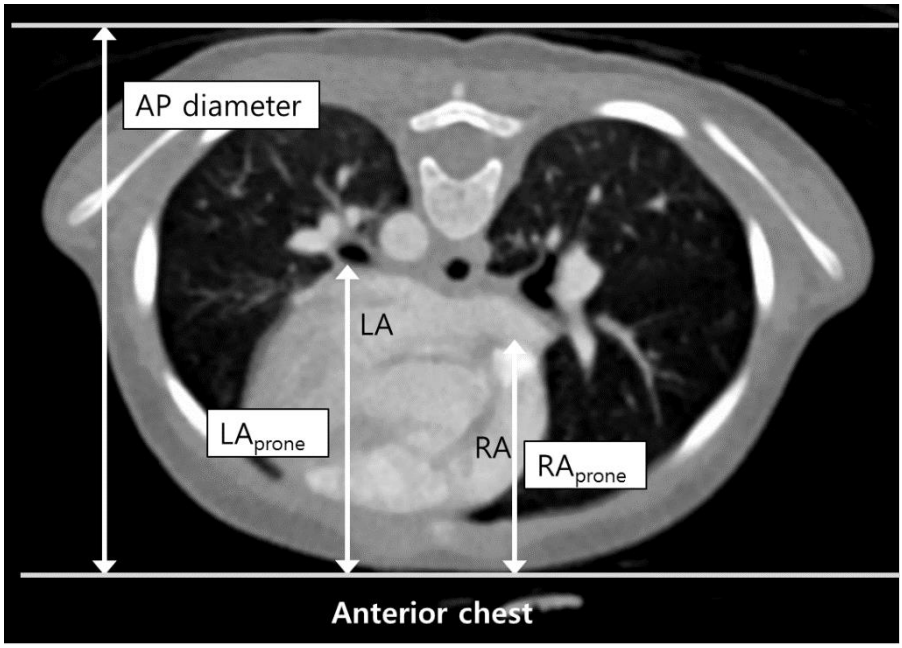


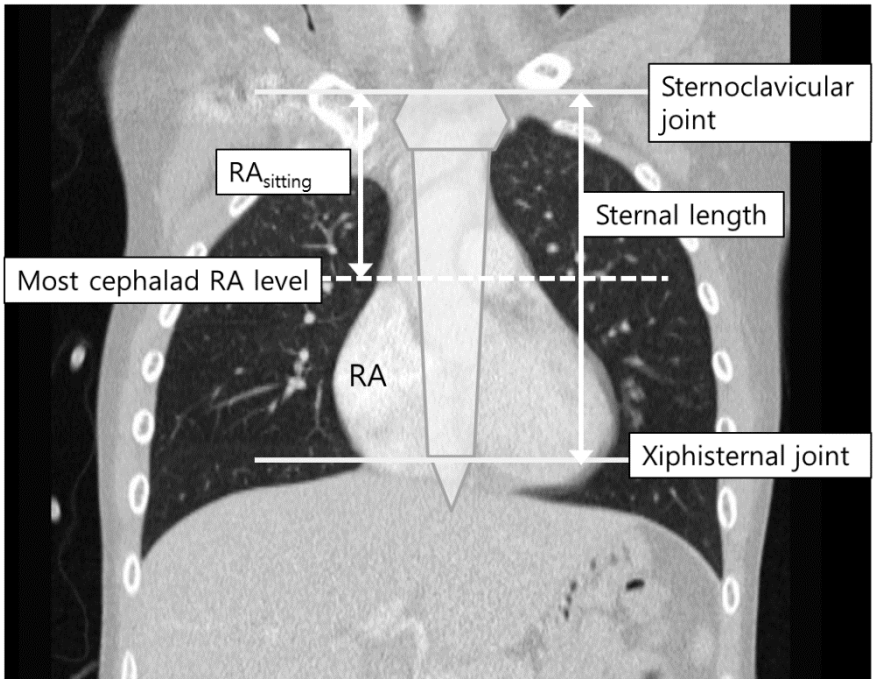
Figure 2. Measurement of RA_{prone} and LA_{prone}

A transverse section of contrast-enhanced chest computed tomography showing the uppermost blood level of the right atrium, left atrium, and the largest anteroposterior (AP) diameter of thorax in prone position.

RA_{prone} = the vertical distance from the skin on the anterior chest wall to the lowest portion of the right atrium; LA_{prone}= the vertical distance from the skin on the anterior chest wall to the lowest portion of the left atrium

In a similar way, we checked the image numbers for each CT section with the cephalad level of the atrium, sternoclavicular joint, and xiphisternal joint to investigate the most cephalad RA and LA level in sitting position ($RA_{sitting}$ or $LA_{sitting}$). The sternal length was defined as the distance between the sternoclavicular joint and xiphisternal joint. The ratio of $RA_{sitting}$ or $LA_{sitting}$ to the sternal length were calculated and abbreviated as $RA_{sitting}$/sternum or $LA_{sitting}$/sternum. (Figure 3.)

A. Most cephalad RA



B. Most cephalad LA

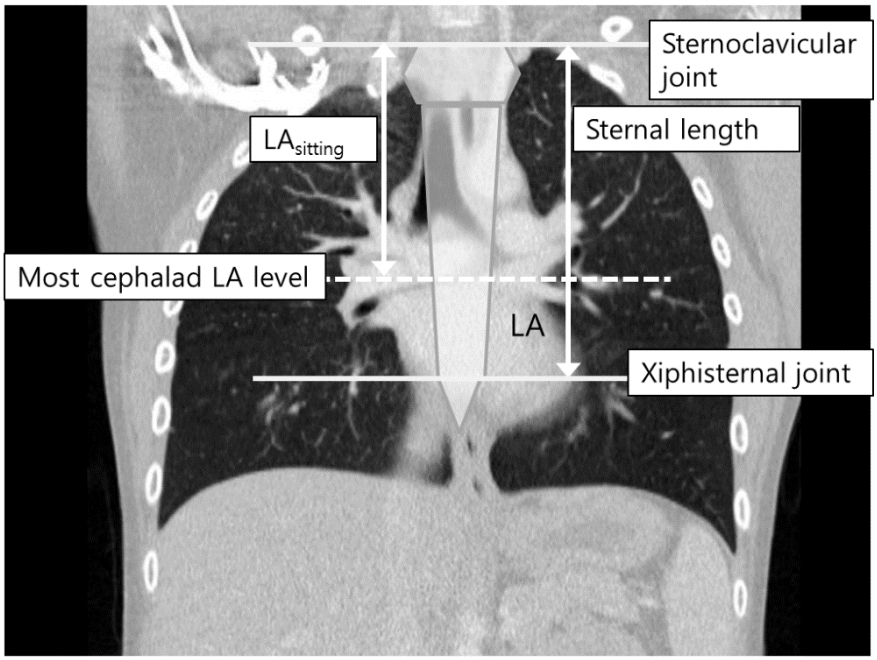


Figure 3. Measurement of $RA_{sitting}$ and $LA_{sitting}$

A coronal section of contrast-enhanced chest computed tomography showing the most cephalad blood level of the right atrium, left atrium, and the sternal length in sitting position. (A) $RA_{sitting}$ = the distance from sternoclavicular junction to the most cephalad level of right atrium. (B) $LA_{sitting}$= the distance from sternoclavicular junction to the most cephalad level of left atrium. Sternal length= the distance between the sternoclavicular joint and xiphisternal joint.

Additionally, we measured the largest AP diameter of the thorax. The largest AP diameter of the thorax was measured vertically from the skin on the back to the skin on the mid-sternum to calculate the ratio of RA_{supine} to AP diameter of the thorax (RA_{supine}/AP) and the ratio of LA_{supine} to AP diameter of the thorax (LA_{supine}/AP). The ratio of RA_{prone} or LA_{prone} to the largest AP diameter of the thorax was calculated and abbreviated as RA_{prone}/AP or LA_{prone}/AP. The level of the CT images for the uppermost levels of the atriums were determined with regard to the corresponding rib or intercostal space (ICS) on the parasternal border.

For the evaluation of the influence of age on the optimal transducer position, the patients of the list were divided into five groups based on age: neonate under 1 month, infants aged 1 to 6 months, 6 to 12 months, children aged 1 to 5 years, and 5 to 10 years. The paired *t*-test was used for comparison of the following: the uppermost blood level of both atria and its ratios in the supine and prone position, the cephalad blood level of the both atria and its ratios to

the sternal length in the sitting position. Analysis of variance (ANOVA) was used to compare the difference in each ratio between age groups. In addition, we defined the clinically significant differences as those greater than 5%. Linear regression analysis was performed to evaluate the relationship between age and each atrial level and its ratio. All data was expressed as the mean ± SD unless otherwise specified. A *P* value less than 0.05 was considered statistically significant. Statistical analysis was performed using IBM® SPSS® Statistics 21 (SPSS Inc., IBM Corporation, Armonk, NY, USA).

RESULTS

The chest CT images of 213 pediatric patients were analyzed. The demographic data was described in Table 1.

	<1mo	1-6mo	6-12mo	1-5yr	5-10yr	Total
N	15	50	49	49	50	213
Sex (M/F)	8/7	29/21	32/17	29/20	28/22	126/87
Age	8.2±9.9 d	3.9±1.4 mo	9.2±2.0 mo	2.1±1.0 yr	7.4±1.4 yr	29.5±35.2 mo
Weight (kg)	3.3±0.5	6.0±1.7	8.3±1.5	11.6±2.8	23.6±5.7	11.8±7.7
Height (cm)	49.8±2.3	61.4±7.4	70.7±5.1	86.0±9.8	120.5±9.7	82.2±24.8
AP diameter of thorax (mm)	89.7±5.7	101.2±9.5	109.8±7.3	121.7±9.5	151.2±13.4	118.8±22.3
Sternal length (mm)	48.4±9.5	62.5±0.90	70.9±14.6	80.5±19.1	108.8±23.4	78.4±25.6

Table 1. Demographic data

Values are expressed as number of patients or mean ± standard deviation

d=day; mo=month; yr=year

RA_{supine} and LA_{supine} increased with age.(Figure 4A) RA_{supine}/AP was within the range of 80-85%, whereas LA_{supine}/AP was 60-65% from the back.(Table 2, Figure 4B) The difference between RA_{supine} and LA_{supine} increased according to age, with the relationship of the difference = 21.83 + 0.14 × age (month).(Figure 4C)

	<1mo	1-6mo	6-12mo	1-5yr	5-10yr	Total
RA_{supine}	72.8±4.2	82.1±8.2	92.2±6.3	103.4±8.0	128.1±9.8	99.5±19.8
RA_{supine}/AP (%)	81.3±4.4	81.2±3.8	84.0±3.7	85.0±3.3	84.9.±3.3	83.6±3.9
LA_{supine}	55.1±3.9	61.8±6.9	67.7±5.6	75.7±6.2	94.5±8.9	73.6±14.7
LA_{supine} /AP (%)	61.6±5.2	61.1±2.9	61.6±3.3	62.2±2.4	62.5±2.8	61.8±3.1
Distance between RA_{supine} and LA_{supine} (mm)	17.7±3.8	20.2±3.4	24.5±3.3	27.7±4.2	33.6±5.6	25.9±6.7
RA_{prone}	44.5±5.3	50.0±5.9	54.5±4.4	59.6±5.9	70.9±7.8	57.7±10.3
RA_{prone}/AP (%)	49.6±4.9	49.4±3.8	49.6±3.0	49.0±3.1	46.9±3.0	48.8±3.5
LA_{prone}	52.8±5.0	59.1±6.0	63.5±4.7	70.7±6.6	85.8±8.8	68.6±12.6
LA_{prone}/AP (%)	58.8±3.6	58.5±3.5	57.9±3.2	58.0±2.6	56.7±3.1	57.9±3.2
Distance between RA_{prone} and LA_{prone} (mm)	8.3±3.0	9.1±2.8	9.1±3.0	11.1±4.1	14.9±4.6	10.9±4.4
$RA_{sitting}$	25.5±6.1	29.4±8.5	32.7±9.2	34.2±10.6	50.8±12.5	36.0±13.2
$RA_{sitting}$/ sternum (%)	52.9±9.0	46.8±9.5	46.1±8.3	42.5±8.6	47.1±8.1	46.1±9.0
$LA_{sitting}$	31.9±5.5	37.9±9.5	39.4±8.8	43.3±9.2	57.0±13.2	43.6±12.8
$LA_{sitting}$/ sternum (%)	66.8±9.8	60.7±9.0	55.8±7.2	54.8±9.7	54.0±9.4	56.8±9.7
Distance between $RA_{sitting}$ and $LA_{sitting}$(mm)	7.1±4.8	8.5±4.9	7.6±4.6	9.4±5.0	6.6±4.4	8.0±4.8

Table 2. Measurements on chest Computed Tomography

Values are expressed as mean ± standard deviation

RA_{supine} = the vertical distance from the skin on the back to the most anterior portion of the right atrium in supine position; LA_{supine}= the vertical distance from the skin on the back to the most anterior portion of the left atrium in supine position; RA_{supine}/AP = ratio of vertical distance from the skin on the back to the most anterior portion of the right atrium to the largest anteroposterior diameter of the thorax in supine position; LA_{supine}/AP = ratio of vertical distance from the skin on the back to the most anterior portion of the left atrium to the largest anteroposterior diameter of the thorax in supine position; RA_{prone} = the vertical distance from the skin on the anterior chest wall to the lowest portion of the right atrium; LA_{prone}= the vertical distance from the skin on the anterior chest wall to the lowest portion of the left atrium; RA_{prone}/AP = ratio of vertical distance from the skin on the anterior chest wall to the lowest portion of the right atrium to the largest anteroposterior diameter of the thorax; LA_{prone}/AP = ratio of vertical the skin on the anterior chest wall to the lowest portion of the left atrium to the largest anteroposterior diameter of the thorax; $RA_{sitting}$ = the distance from sternoclavicular junction to the most cephalad level of right atrium; $LA_{sitting}$= the distance from sternoclavicular junction to the most cephalad level of left atrium; $RA_{sitting}$/Sternum = ratio of the distance from sternoclavicular junction to the most cephalad level of right atrium to the length of sternum; $LA_{sitting}$/Sternum = ratio of the distance from sternoclavicular junction to the most cephalad level of left atrium to the length of sternum.

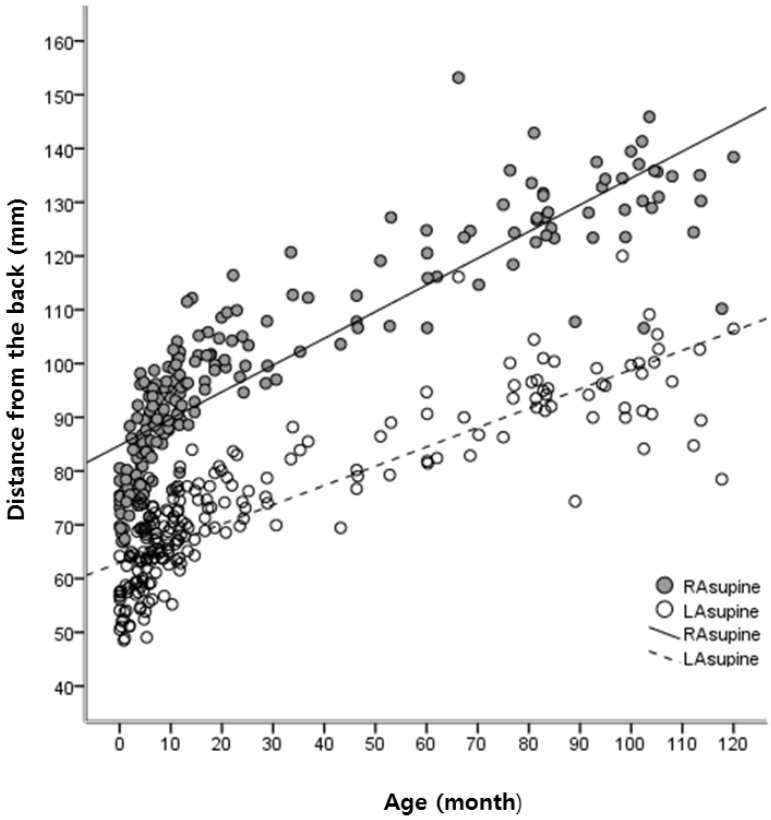


Figure 4A. Influence of age on RA_{supine} and LA_{supine}

RA_{supine} r^2=0.778 (P < 0.000); LA_{supine} r^2=0.743 (P < 0.000)

RA or LA heights in supine position increases with age. RA_{supine} = the vertical distance from the skin on the back to the most anterior portion of the right atrium in supine position; LA_{supine}= the vertical distance from the skin on the back to the most anterior portion of the left atrium in supine position.

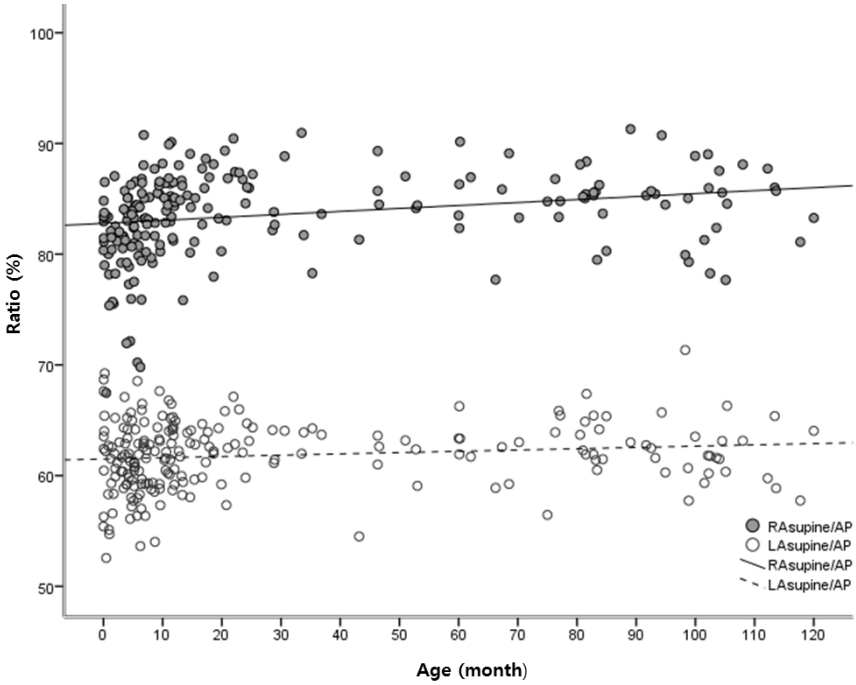


Figure 4B. Influence of age on RA_{supine}/AP and LA_{supine}/AP

RA_{supine}/AP r^2=0.059 (P < 0.000) ; LA_{supine}/AP r^2=0.018 (P = 0.052)

RA_{supine}/AP = ratio of vertical distance from the skin on the back to the most anterior portion of the right atrium to the largest anteroposterior diameter of the thorax in supine position; LA_{supine}/AP = ratio of vertical distance from the skin on the back to the most anterior portion of the left atrium to the largest anteroposterior diameter of the thorax in supine position.

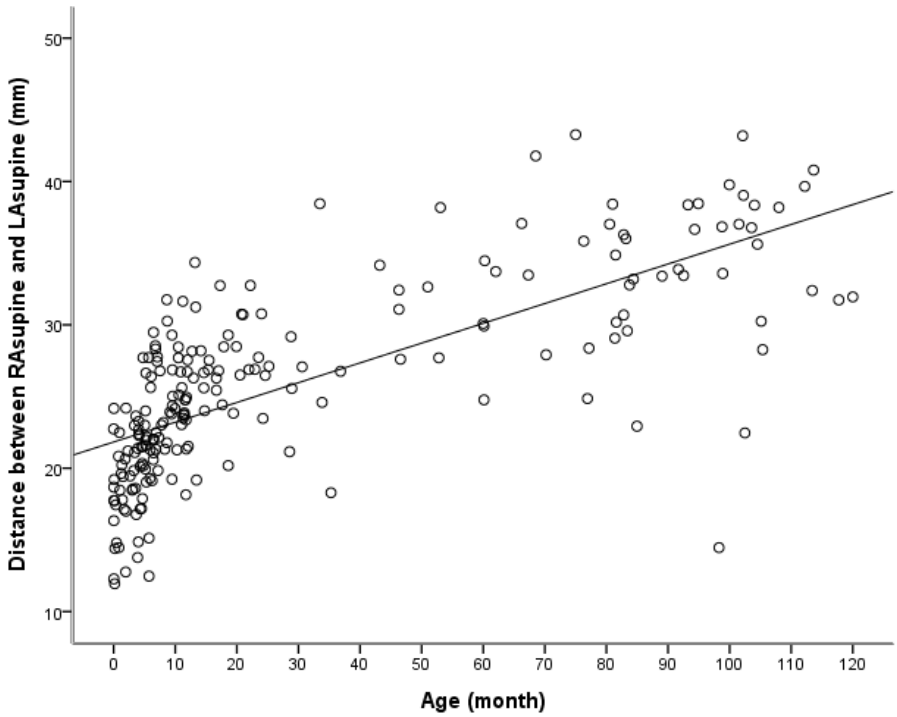


Figure 4C. Distance between RA_{supine} and LA_{supine}

Distance between RA_{supine} and LA_{supine} (mm)= 21.83 + 0.14 × age (month)

(r^2=0.524, P <0.000)

RA_{prone} and LA_{prone} also increased with age.(Figure 5A) RA_{prone} and LA_{prone} were placed at approximately half of the largest AP diameter of the thorax. The ranges of RA_{prone}/AP and LA_{prone}/AP were 45-50% and 55-60%, respectively, from the anterior chest.(Table 2, Figure 5B) The difference between RA_{prone} and LA_{prone} increased according to age, with the relationship of the difference = 8.93 + 0.07 × age (month).(Figure 5C)

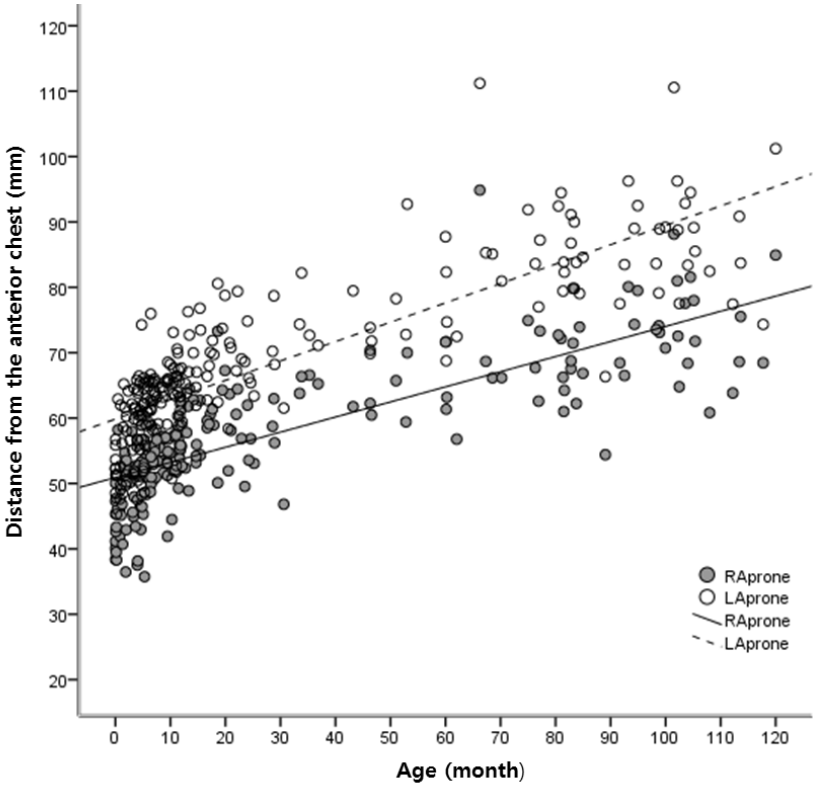


Figure 5A. Influence of age on RA_{prone} and LA_{prone}

RA_{prone} r^2=0.620 ($P < 0.000$); LA_{prone} r^2=0.687 ($P < 0.000$)

RA or LA heights in prone position increases with age. RA_{prone} = the vertical distance from the skin on the anterior chest wall to the lowest portion of the right atrium; LA_{prone}= the vertical distance from the skin on the anterior chest wall to the lowest portion of the left atrium.

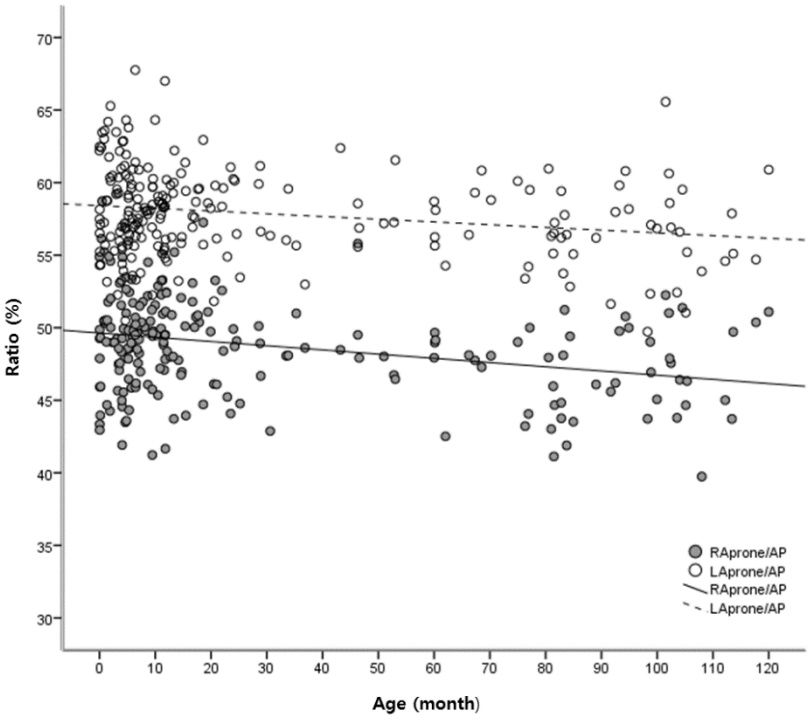


Figure 5B. Influence of age on RA/AP_{prone} and LA/AP_{prone}

RA_{prone}/AP r^2=0.084 (P < 0.000) ; LA_{prone}/AP r^2=0.043 (P = 0.002)

RA_{prone}/AP = ratio of vertical distance from the skin on the anterior chest wall to the lowest portion of the right atrium to the largest anteroposterior diameter of the thorax; LA_{prone}/AP = ratio of vertical the skin on the anterior chest wall to the lowest portion of the left atrium to the largest anteroposterior diameter of the thorax.

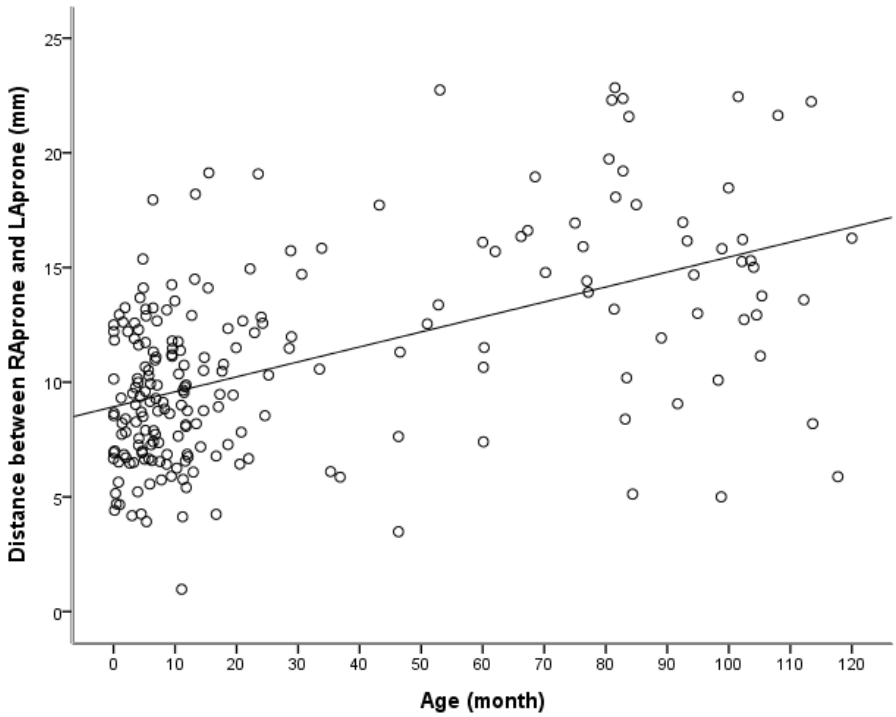


Figure 5C. Distance between RA_{prone} and LA_{prone}

Distance between RA_{prone} and LA_{prone} (mm)= 8.93 + 0.07 × age (month)

(r^2=0.278, *P* <0.000)

In a similar way, $RA_{sitting}$ and $LA_{sitting}$ increased with age.(Figure 6A) There were considerable variations in $RA_{sitting}$ and $LA_{sitting}$. $RA_{sitting}$/Sternum and $LA_{sitting}$/Sternum show the wide range of 35-55% and 45-65%, respectively, from the sternoclavicular joint.(Figure 6B) The difference between $RA_{sitting}$ and $LA_{sitting}$ decreased according to age, with the relationship of the difference = 8.45 + (-0.02 × age) (month).(Figure 6C)

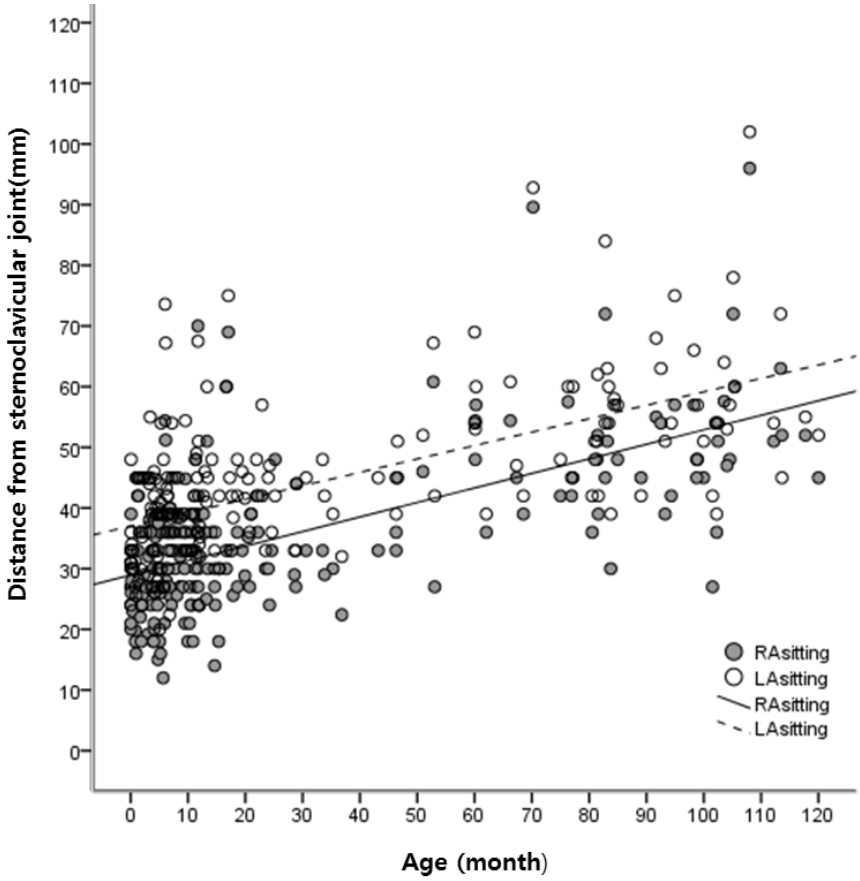


Figure 6A. Influence of age on $RA_{sitting}$ and $LA_{sitting}$

$RA_{sitting}$ r^2=0.411 (P < 0.000); $LA_{sitting}$ r^2=0.373 (P < 0.000)

RA or LA heights in sitting position increases with age. $RA_{sitting}$ = the distance from sternoclavicular junction to the most cephalad level of right atrium; $LA_{sitting}$= the distance from sternoclavicular junction to the most cephalad level of left atrium.

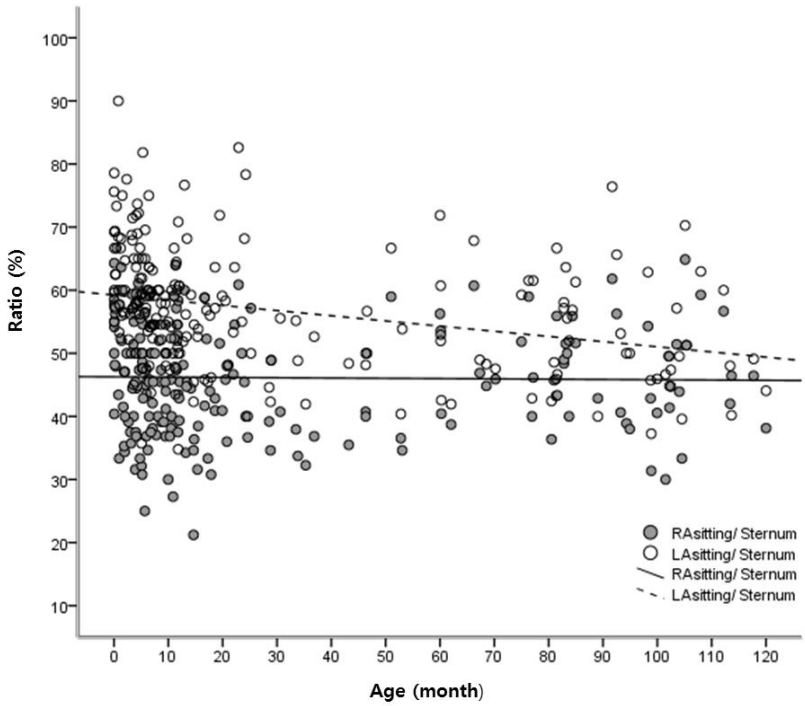


Figure 6B. Influence of age on $RA_{sitting}$/ Sternum and $LA_{sitting}$/ Sternum

$RA_{sitting}$ /Sternum r^2=3.258E-4 (*P* = 0.793); $LA_{sitting}$/Sternum r^2=0.089 (*P* = 0.000)

$RA_{sitting}$/Sternum = ratio of the distance from sternoclavicular junction to the most cephalad level of right atrium to the length of sternum; $LA_{sitting}$/Sternum = ratio of the distance from sternoclavicular junction to the most cephalad level of left atrium to the length of sternum.

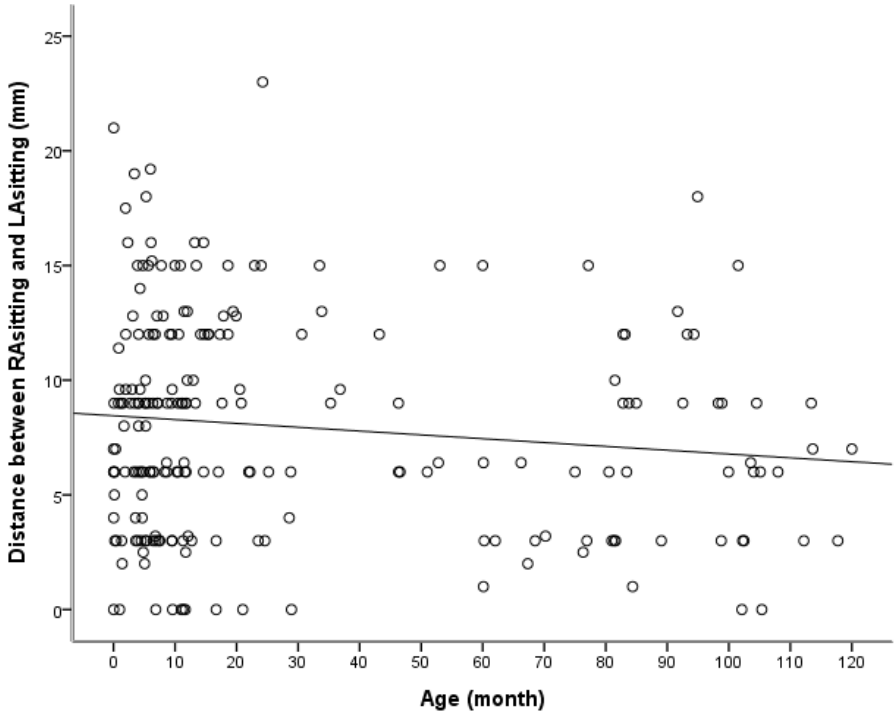


Figure 6C. Distance between $RA_{sitting}$ and $LA_{sitting}$

Distance between $RA_{sitting}$ and $LA_{sitting}$ (mm)= 8.45 + (-0.02 × age) (month)

(r^2=0.015, *P* =0.073)

Using ANOVA to compare the difference between age groups showed statistical significance in RA_{supine}/AP, (P=0.000), RA_{prone}/AP (*P*=0.000), and $LA_{sitting}$/Sternum, (*P*=0.000). However, each difference between age groups was within the range of 5%.

The uppermost blood level of both atria ranged between the second rib and fifth ICS, primarily at the third ICS for RA and fourth ICS for LA, respectively, in the supine position.(Fig. 7A) In the sitting position, the cephalad blood level of the both atria ranged between the second rib and fifth

rib, primarily at the third rib for RA and third ICS for LA.(Fig. 7B) There was no significant difference in each of the parameters according to age.

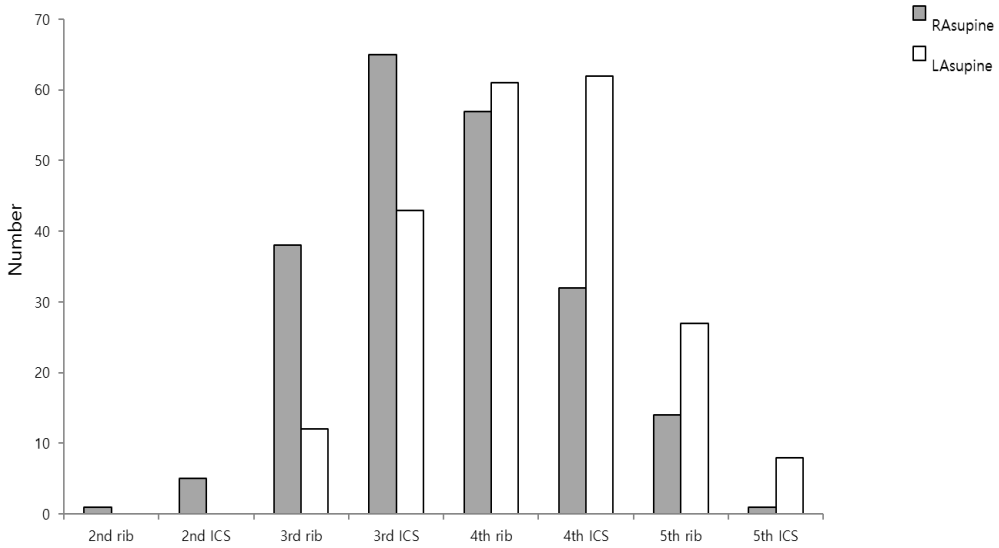


Figure 7A. Distribution of the rib or intercostal space (ICS) corresponding to the uppermost blood level of the both atria in supine position

In the supine position, the uppermost blood level of the RA and LA ranged primarily at the 3rd ICS and the 4th ICS. RA, right atrium; LA, left atrium.

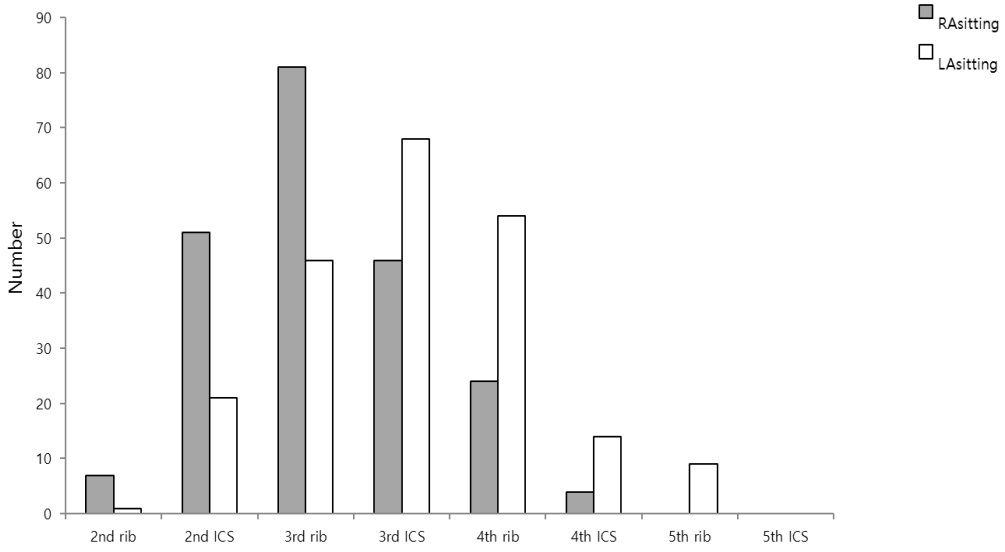


Figure 7B. Distribution of the rib or intercostal space (ICS) corresponding to the most cephalad blood level of the both atria in sitting position

In the sitting position, the most cephalad blood level of the RA and LA ranged primarily at the 3rd rib and the 3th ICS. . RA, right atrium; LA, left atrium.

DISCUSSION

We investigated how to re-position the transducer for CVP and PAOP monitoring depending on the patients' position using the chest CT images for pediatric patients. According to our study, when measuring RA pressure in the supine position, the reference transducer should be placed at 80-85% of the AP diameter of the thorax. Whereas, when measuring LA pressure in supine position, the reference transducer should be placed at 60-65% of the AP diameter of the thorax.

There were significant differences between RA_{supine} and $LA_{supine,}$ and we found a mean difference of approximately 2.6 cm between the uppermost blood levels of both atria in the supine position.(Table 2.) The distance between RA_{supine} and LA_{supine} depending on age was analyzed by simple linear regression analysis and was expressed by this equation; distance between RA_{supine} and LA_{supine} (mm) = 21.83 + 0.14 × age (month) (r^2=0.524, P < 0.000).(Fig. 4C). Therefore, we should take into account these differences if a transducer is used for measuring both CVP and PAOP.

In the prone position, we recommend the transducer position for both atria should be at approximately 50% of the AP diameter of the thorax. According to this study, the mean difference between RA_{prone} and $LA_{prone,}$ was approximately 1.1 cm in the prone position.(Table 2) The prone position was less affected by age than the differences found in the supine position.

While in sitting position, we noticed that the reference transducer should be placed at 35-55% and 45-65% of the sternum for measuring RA and LA

pressure. Considering the substantial variations of the reference transducer in the sitting position versus in the supine or prone position, we will need to investigate this further for clear guidance on the level of the reference transducer. Until now, there has been no definite evidence about the appropriate level of the reference transducer in the sitting position. On the other hand, the cephalad blood level of both atria in sitting position was primarily at the third rib for RA and third ICS for LA. Therefore, we suggest the reference transducer level as the third rib for CVP and third ICS for PAOP.

For adult patients, various external reference levels have been proposed for measuring CVP in the supine position. In practice, the most commonly used methods for zero reference level setting in the supine position are at 5 cm below the anterior thorax surface, at 1/3 of the thoracic diameter below the anterior thorax surface, at the mid-thoracic level, and 10 cm above the table level.[7, 9, 10] However, there is no consensus on a standard zero reference level. Our results in the supine position are consistent with the previous adults study in which the uppermost blood levels of both atria are four-fifths of the AP diameter for the RA and three-fifths for the LA from the skin on the back in adult.[6]

This study has several limitations. First, our results in the sitting position may underestimate the real CVP changes because we cannot consider downward movement of the heart from supine to sitting position. However, we assume the differences would be minimal. Furthermore, our data did not include differences according to specific respiratory phases. CVP should be measured in the end-expiratory phase of ventilation to avoid the influence of alterations

in intra-thoracic pressure and that some studies show no significant differences in the RA and LA heights between inspiratory and expiratory phases, we should consider this when estimating CVP. In addition, the results in the age group of neonate under 1 month are limited considering the relatively small patient's numbers of this group (n=15). We had difficulty obtaining sufficient chest CT images of neonates because neonates rarely have chest CT images unless they have a congenital heart disease or congenital malformation of chest wall at birth.

Despite some limitations, our study has an important outcome because there are no previous studies on the level of the reference transducer in pediatric patients.

In conclusion, the optimal level of the reference transducer for accurate measurement of the CVP seems to be at four-fifths of the AP diameter of the thorax in the supine position, at a half of that in the prone position, and at the upper border of the third sternochondral joint in the sitting position in children.

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국문 초록

서론: 중심 정맥압과 폐동맥 쐐기압을 정확히 측정하기 위해서는 압력 변환기를 적절한 곳에 위치 시키는 것이 중요하다. 이 연구는 소아를 대상으로 앙와위, 복와위 그리고 좌위에서 적절한 압력 변환기의 위치가 어디인지에 대해 알아보고자 하였다.

방법: 10 세 이하의 소아 213 명의 흉부 CT 를 검토하였으며 앙와위와 복와위에서 각 심방의 최상위 층과 등 또는 전흉부 사이의 거리를 측정하고 이것을 흉곽의 전후경에 대한 비로 나타내었다. 좌위에서는 흉쇄관절과 심방의 최상위 층 사이의 거리를 측정하고 흉골에 대한 비를 구하였다. 앙와위와 좌위에서 각 심방의 최상위 층이 포함된 CT 이미지에 상응하는 늑골 또는 늑간강을 조사하였다.

결과: 앙와위에서 최상위 층 우심방과 좌심방의 흉곽 전후경에 대한 비율은 각각 80-85%, 60-65% 였고 복와위에서 최상위 층 우심방과 좌심방의 흉곽 전후경에 대한 비율은 각각 45-50%, 55-60%였다. 좌위에서 흉쇄관절과 우심방, 좌심방의 최상위 층 사이의 거리와 흉골에 대한 비는 각각 35-55%, 45-65%였고 최상위 층 우심방은 3 번째

늑골에, 최상위 층 좌심방은 3 번째 늑간강에 주로 분포하고 있었다. 각 비율에서 나이에 따른 의미 있는 차이는 관찰되지 않았다.

결론: 결론적으로 소아에서 중심정맥압 측정을 위한 압력 변환기의 위치는 앙와위에서는 흉곽 전후경의 4/5 지점, 복와위에서는 흉곽의 1/2 지점이 적절하다고 생각되며 좌위에서는 3 번째 흉골연골 관절의 상부를 고려해볼 수 있다.

주요어 : 중심정맥압; 복와위; 앙와위; 변환기; 압력

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