Reference Values of Different Height of Diaphragms in Chest Radiographs of Newborns

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Background: *There are many causes affecting diaphragmatic height including normal variation and pathology. Both elevation and depression of the diaphragm imply various pathologies. In our knowledge, no previous study of newborn evaluated the different height of diaphragms. Using adult's reference value in interpretation of newborns' chest remains doubtful because of different imaging technique.*

Objective: *To assess diaphragmatic height and measure different height of diaphragms in the chest radiographs of newborns.*

Material and Method: *A retrospective review of chest radiographs was performed on 100 newborns (age less than 1 month) who were diagnosed of transient tachypnea of the newborn (TTNB) that had respiratory distress and abnormalities in chest radiographs disappeared. The diaphragmatic positions and different diaphragmatic height were evaluated in relation to thoracic vertebra and posterior rib.*

Results: *Right diaphragmatic dome was positioned at 8.17±0.72 thoracic vertebral levels below the top of first thoracic vertebra and 8.28±0.78 crossing rib levels. Left diaphragmatic dome was positioned at 8.87±0.71 thoracic vertebral levels and 8.91±0.29 crossing rib levels. The different height of diaphragms was 0.70±0.34 thoracic vertebral body and 0.63±0.29 intercostal spaces. No newborn had the left diaphragmatic dome higher than the right side.*

Conclusion: *The different diaphragmatic height in newborns is less than 1 intercostal space or 1 thoracic vertebral level. This knowledge is useful for assessment of chest radiographs.*

Keywords: *Newborn, Diaphragm, Chest radiograph*

J Med Assoc Thai 2016; 99 (10): 1142-6
Full text. e-Journal: *http://www.jmatonline.com*

There are many causes affecting diaphragmatic position including thoracic, abdominal, and neuromuscular causes[1,2]. Most of them could be demonstrated on the chest radiographs such as pneumonia, atelectasis, pneumothorax, chest wall deformity, congenital diaphragmatic hernia, gastric or colonic distension, and mass. However, in some cases, there is no explainable cause noted on the radiographs. Therefore, maybe it is because of normal variation or resulting from diaphragmatic paralysis and eventration, or even because of elevation of the diaphragm, which is a common clinical problem bringing physicians to consult radiologists. When diaphragmatic paralysis and eventration is clinically suspected, direct dynamic visualization of diaphragmatic motion should be obtained by fluoroscopy or ultrasonography[1,3]. For these reasons, knowledge of normal position of diaphragms and reference values of different diaphragmatic height is essential to avoid unnecessary investigation and radiation exposure.

At quiet inspiration, the diaphragms on an AP view are at the level of the sixth ribs anteriorly and the eighth or ninth ribs posteriorly[4]. There is no previous study performed in the newborn evaluated the different height of diaphragms for reference value. Using adult's reference value in interpretation of newborns' chest remains doubtful because of different imaging technique, supine position, and anterior-posterior (AP) view in the newborns in contrast to upright position and posterior-anterior (PA) view in the adults[5-7].

Thus, the authors aimed to assess the different height of diaphragms in chest radiographs of the newborns to create reference values.

Material and method

Patient selection

As radiation exposure and ethical issue are concerned, it is not routine practice to perform

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radiography in normal pediatric populations. The major indication to perform chest radiography in newborns is the presence of respiratory distress. The clear majority of newborns that received chest radiography were diagnosed as transient tachypnea of the newborn (TTNB). Thus, the authors decided to evaluate the chest radiographs of newborns with TTNB by using the last chest radiograph before they were discharged or when respiratory distress and abnormalities in chest radiograph disappeared. Frontal chest radiographs of 332 newborns (age less than one month) with TTNB born in Siriraj Hospital between January 2012 and December 2012 were retrospectively assessed by two pediatric radiologists and one radiology resident. Of these, 232 neonates were excluded due to rotated position and underlying conditions affected lung volume or diaphragm position including pneumonia, atelectasis, thoracic deformity, congenital cardiovascular disease, thoracic and/or abdominal mass, spinal deformity, and prior thoracic or chest wall surgery.

The present research had been approved by the Siriraj Institutional Review Board (IRB No. 513/2555 EC1).

Assuming that the standard deviation was 0.3, a two-sided 95% interval for a single mean would extend 0.6 from the observed mean and the confidence interval was based on the large sample z statistic, the sample was calculated to be 95.

Finally, 100 chest radiographs of 100 different newborns were evaluated; 68 newborns were male and 32 were female. The details of the demographic data were described on the Table 1.

Radiographic measurement

The following radiographic measurements were performed by using the Picture Archiving and Communications Systems (PACS).

1) Position of diaphragms

A. Crossing rib levels of diaphragmatic domes (Fig. 1): A horizontal line was drawn through the highest point of each side of the diaphragmatic dome (line A and A' for right and left side respectively) and it was compared with rib. The superior border of the posterior aspect of first rib was set as the "zero" rib level. Each intercostal space was divided into four portions.

B. Thoracic vertebral levels of the diaphragmatic domes (Fig. 2): A horizontal line was drawn through the highest points of each side of the diaphragmatic dome (line B and B' for right and left side respectively) and it was compared with thoracic vertebral level. The superior endplate of the first thoracic vertebral body was set as the "zero" vertebral

Table 1. Demographic data of newborns

Demographics	Mean	Min	Max
Length (centimetres)	49.70	40.0	57.0
Weight (grams)	3,170.70	1,800.0	5,340.0
Length of stay (days)	4.70	2	9
Age (days)	1.10	0	5

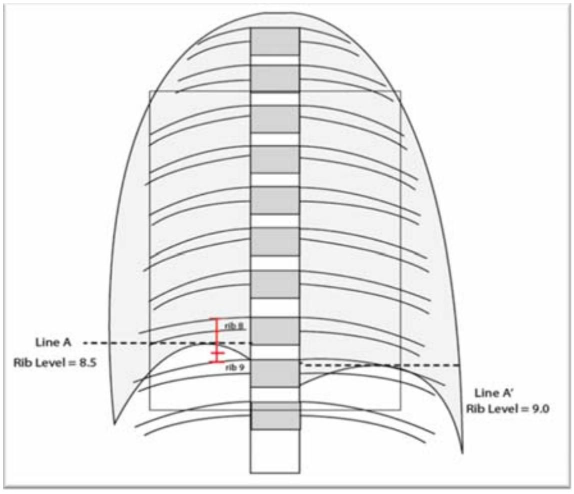

Fig. 1 Demonstrating measurement of diaphragmatic positions in relation to crossing rib levels. Line A = right diaphragmatic position. Line A' = left diaphragmatic position.

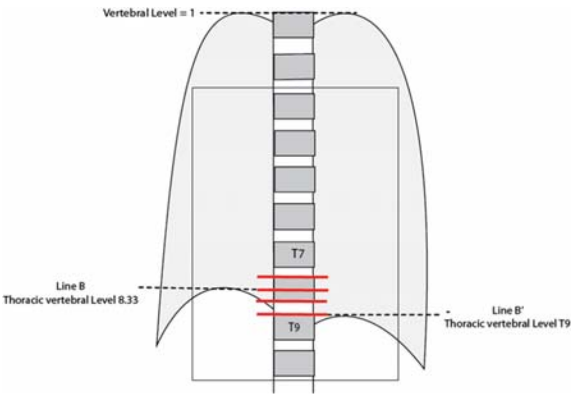

Fig. 2 Demonstrating measurement of diaphragmatic positions in relation to thoracic vertebral levels. Line B = right diaphragmatic position. Line B' = left diaphragmatic position.

Table 2. Intraclass correlation coefficients of each parameter

Parameters	Intraclass correlation coefficients
Rib levels of the diaphragm	0.971 (right side)/ 0.971 (left side)
Thoracic vertebral levels	0.972 (right side)/ 0.938 (left side)
Difference height of diaphragms	0.850

level. Each vertebral body was assigned a value of 0.67 vertebral level and each disk space was assigned a value of 0.33 vertebral level.

2) Difference of diaphragmatic height

Vertical distance between horizontal lines drawn through the highest points of each side of the diaphragmatic dome was measured in intercostal space, thoracic vertebral level, and centimeters. If right diaphragmatic dome was higher than left, it was defined as positive value. If the left was higher than the right, it was defined as negative value.

The radiographic measurements were made with an ordinary ruler. In the first 40 patients, the measurements were made independently by three readers (two pediatric radiologists and one radiology resident). Inter observer agreement was high with intraclass correlation coefficients of $\geq$0.85 for all measurements. Thus, the remainder of chest radiographs of 60 newborns were evaluated by one reader.

Statistical analysis

Reference interval statistics and intraclass correlation coefficients were performed using PASW statistics (SPSS) version 18. Reference interval statistics (using 95% double sided) were reported as mean, standard deviation (SD) and range (min-max). The reference interval was calculated by two different methods: (a) using the normal distribution, and (b) using a non-parametrical percentile method. Kolmogorov-Smirnov test for normal distribution was also performed.

Results

The mean right diaphragmatic position was at 8.17 thoracic vertebral levels (95% CI 8.03 to 8.31) and 8.28 rib levels (95% confidence interval [CI] 8.12 to 8.43).

The mean left diaphragmatic position was at 8.87 thoracic vertebral levels (95% CI 8.73 to 9.02) and 8.91 rib levels (95% CI 8.76 to 9.07).

The average of difference diaphragmatic height was 0.63 intercostal space (95% CI 0.57 to 0.69), 0.70 vertebral level (95% CI 0.64 to 0.78) and 0.53 cm (95% CI 0.48 to 0.57).

Discussion

It can be seen from the present study that the difference in diaphragmatic height in newborns was less than 1 intercostal space or 1 thoracic vertebral level.

Right and left diaphragmatic positions were at nearly the same as previous knowledge[4], eighth rib posteriorly. There was no subject whose left diaphragm is higher than the right. The position of 8 thoracic vertebral levels of newborn's diaphragms is different significantly from 9 to 10 thoracic vertebral levels of adult's[6]. This difference may be related to patient's position during taking radiograph; supine position and anteroposterior view in newborns while upright position and posteroanterior view in adults.

The authors would like to recommend rule of "8" for diaphragmatic position; 8 thoracic vertebral levels and 8 posterior crossing rib levels and rule of "1" for different height of diaphragms; 1 thoracic vertebral level and 1 intercostal space.

Abnormal value of different diaphragmatic height may be the early sign of some chest and abdominal pathologies such as pneumothorax, diaphragmatic eventration or paralysis, congenital lung diseases and abdominal mass. The anteromedial space of pleural cavity is the independent part in supine position. Depression of the hemidiaphragm or less different diaphragmatic height combined with sharp outline of cardiac border and radiolucency of lower lung should raise suspicion of anteromedial pneumothorax. Sometimes, depression of unilateral hemidiaphragm is the only one sign shown on the chest radiograph of lobar emphysema and congenital pulmonary airway malformation (CPAM). Diaphragmatic eventration or paralysis and abdominal mass should be aware in case of unilateral hemidiaphragm elevation.

Some limitations should be considered from the present study. First, as in any retrospective study, the confounding factor such as respiratory phase and position could not be controlled. Secondly, the chest radiographs were not taken in normal subjects. As radiation exposure and ethical issue are concerned, it is not routine practice to perform chest radiography in normal pediatric populations. The authors needed to evaluate the chest radiographs of the newborns with TTNB which were the most available chest radiographs. Although the subjects had TTNB, the radiographs included in the study were taken when lung abnormality and respiratory distress disappeared so they could be the representatives in this situation.

Conclusion

The difference in diaphragmatic height in newborns is less than 1 intercostal space or 1 thoracic vertebral level. This knowledge is useful for assessment of chest radiographs.

What is already known on this topic?

On AP view, chest radiograph of newborns, right and left diaphragmatic domes are at the level of the eighth or ninth ribs posteriorly.

What this study adds?

The difference in height of diaphragms is normally less than 1 intercostal space or 1 thoracic vertebral level.

Acknowledgements

The authors thank Suthipol Udompunturak for his help with statistical analysis.

Potential conflicts of interest

None.

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ค่ามาตรฐานของความแตกต่างของความสูงกะบังลม 2 ข้างในภาพรังสีทรวงอกของทารกแรกเกิด

ชนกานต์ อลิสานันท์, พิรา เนื่องตัน, เกรียงไกร เอี่ยมสวัสดิกุล

ภูมิหลัง: *ความผิดปกติของระดับกะบังลมไม่ว่าจะสูงหรือต่ำกว่าปกติเกิดได้จากหลายสาเหตุและสามารถตรวจพบจากภาพเอกซเรย์ทรวงอก ที่ผ่านมายังไม่มีการศึกษาใดที่ทำการหาค่ามาตรฐานของความแตกต่างของความสูงกะบังลม 2 ข้างในภาพรังสีทรวงอกของทารกแรกเกิด โดยที่ค่ามาตรฐานในผู้ใหญ่ไม่อาจนำมาใช้ในทารกได้เนื่องจากเทคนิคการถ่ายภาพรังสีทรวงอกที่แตกต่างกัน*

วัตถุประสงค์: *เพื่อหาค่ามาตรฐานของความแตกต่างของความสูงกะบังลม 2 ข้างในภาพรังสีทรวงอกของทารกแรกเกิด*

วัสดุและวิธีการ: *ประเมินภาพรังสีทรวงอกของทารกแรกเกิดอายุไม่เกิน 1 เดือนจำนวน 100 รายที่ได้การวินิจฉัยภาวะหายใจเร็วชั่วคราว (transient tachypnea of the newborn) และได้รับการดูแลรักษาจนอาการผิดปกติของระบบทางเดินหายใจและพยาธิสภาพที่พบในภาพเอกซเรย์ปอดหายไป จากนั้น ทำการวัดระดับความสูงกะบังลมทั้งสองข้างและหาค่าความแตกต่างของความสูงดังกล่าว เทียบกับระดับกระดูกสันหลังส่วนอกและระดับกระดูกซี่โครงด้านหลัง*

ผลการศึกษา: *จุดสูงสุดของกะบังลมด้านขวาอยู่ที่ระดับกระดูกสันหลังส่วนอกที่ 8.17±0.72 และระดับกระดูกซี่โครงด้านหลังที่ 8.28±0.78 จุดสูงสุดของกะบังลมด้านซ้ายอยู่ที่ระดับกระดูกสันหลังส่วนอกที่ 8.87±0.71 และระดับกระดูกซี่โครงด้านหลังที่ 8.91±0.29 และค่าความแตกต่างของความสูงกะบังลม 2 ข้างอยู่ที่ 0.63±0.29 เท่าของช่องกระดูกซี่โครง (intercostal space) และ 0.70±0.34 เท่าของความสูงของกระดูกสันหลังส่วนอก (thoracic vertebral body) ไม่มีทารกรายใดที่กะบังลมด้านซ้ายสูงกว่าขวา*

สรุป: *ระดับความสูงกะบังลม 2 ข้างที่วัดได้ในภาพรังสีทรวงอกของทารกแรกเกิดจะแตกต่างกันประมาณไม่เกิน 1 ช่องกระดูกซี่โครงหรือไม่เกินความสูงของกระดูกสันหลังส่วนอก*