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# Assessment of lung area in fetuses with congenital diaphragmatic hernia

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**KEYWORDS:** congenital diaphragmatic hernia; lung area; lung area to head circumference ratio; pulmonary hypoplasia

## ABSTRACT

***Objective*** *To compare the intra- and interobserver agreement of three different methods of measuring lung area in fetuses with congenital diaphragmatic hernia (CDH).*

***Methods*** *In 71 fetuses with isolated CDH at 21–33 weeks' gestation, the area of the contralateral lung was assessed by firstly, manual tracing of lung borders, secondly, multiplication of the longest diameter of the lung by its widest perpendicular diameter, and thirdly, multiplication of the anteroposterior (AP) diameter of the lung at the mid-clavicular line by the perpendicular diameter at the midpoint of the AP diameter (AP method). In 30 fetuses the measurements were made by two observers and Bland–Altman analysis was used to compare the measurement agreement and bias for each observer and between the two observers.*

***Results*** *The area obtained by the AP method was similar to that obtained by the manual tracing method, but the area by the longest diameter approach was bigger by 34.4% (95% CI, −2.4% to 71.1%). The 95% confidence intervals of the difference in paired measurements of lung areas by the same observer and by two different observers were narrower in the manual tracing method than in the multiplying diameters methods.*

***Conclusions*** *In CDH the most reproducible measurement of fetal lung area is provided by manual tracing of the limits of the lungs, rather than by multiplication of lung diameters. Copyright © 2007 ISUOG. Published by John Wiley & Sons, Ltd.*

## INTRODUCTION

Sonographic measurement of the lung area to head circumference ratio (LHR) has been the most extensively explored method for antenatal prediction of the severity of pulmonary hypoplasia in cases of congenital diaphragmatic hernia (CDH)[1,2]. There are three methods for assessment of the lung area: manual tracing of the limits of the lungs, multiplication of the longest diameter of the lung by its longest perpendicular diameter, and multiplication of the anteroposterior (AP) diameter of the lung by its perpendicular diameter (AP method). A study comparing these methods in normal fetuses reported that the method employing the longest diameter, compared with the tracing method, overestimates both the left and the right lung area by about 45%, and the method employing the AP diameter overestimates the area of the right lung by about 35%, but not that of the left lung[3]. Moreover, it was shown that the inter- and intraobserver agreement was better when the tracing method was used.

There are no reported studies comparing the different methods of assessing lung area in fetuses with CDH. It is likely that the observations made in normal fetuses[3] would also be true for fetuses with CDH. However, this is not necessarily the case because the shape of the lungs is distorted by the herniated abdominal viscera. The aim of this study was to compare the three different methods of assessing lung area in fetuses with CDH.

## METHODS

This was a cross-sectional study of 71 fetuses with isolated unilateral CDH at 21–33 weeks' gestation, conducted in the Fetal Medicine Units of the University Hospital Gasthuisberg, Leuven, Belgium, King's College Hospital, London, UK and Hôpital Necker-Enfants Malades, Paris, France.

Measurement of the lung area was performed off-line by two observers, in stored three-dimensional ultrasound (3D-US) volumes of the fetal chest, previously acquired

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with a Voluson 730 Expert scanner, equipped with an RAB 4–8L probe (GE Medical Systems, Milwaukee, WI, USA). For best visualization of the limits of the lungs during the acquisition process, we tried to ensure that the fetus was not moving and was facing towards the transducer.

With the multiplanar mode of the 3D-US, a transverse section of the fetal chest, containing the four-chamber view of the heart, was displayed on the screen. The area of the lung contralateral to the herniated viscera was measured in this plane by three different methods: first, multiplication of the AP diameter of the lung at the mid-clavicular line by the perpendicular diameter at the midpoint of the AP diameter; second, multiplication of the longest diameter of the lung by its longest perpendicular diameter; and third, manual tracing of the limits of the lung (Figure 1). Each of these measurements takes less than one minute to perform.

In 30 randomly selected fetuses within the period 22–28 weeks' gestation, the lung area was measured by the three different methods twice by each of the two investigators in order to compare the measurements and calculate the intra- and interobserver agreement. The same image was used for the three measurements and by the two observers, who were not aware of each others' measurements.

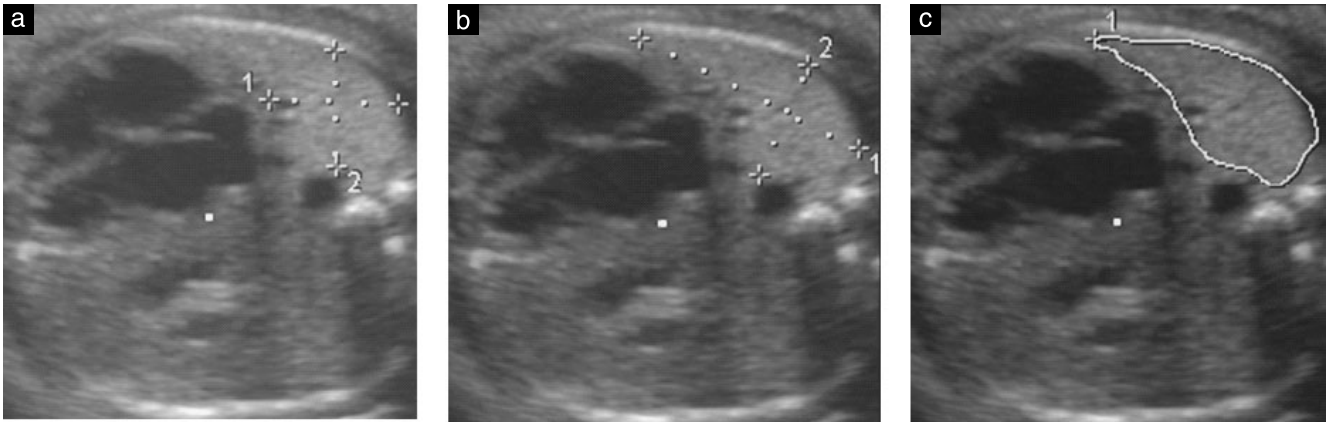


**Figure 1** Measurement of the lung area at the level of the four-chamber view of the heart in a fetus with a left-sided congenital diaphragmatic hernia at 27 weeks' gestation: (a) by multiplication of the anteroposterior (AP) diameter of the lung at the mid-clavicular line by the perpendicular diameter at the midpoint of the AP diameter; (b) by multiplication of the longest diameter of the lung by its longest perpendicular diameter; and (c) by manual tracing of the limits of the lungs.

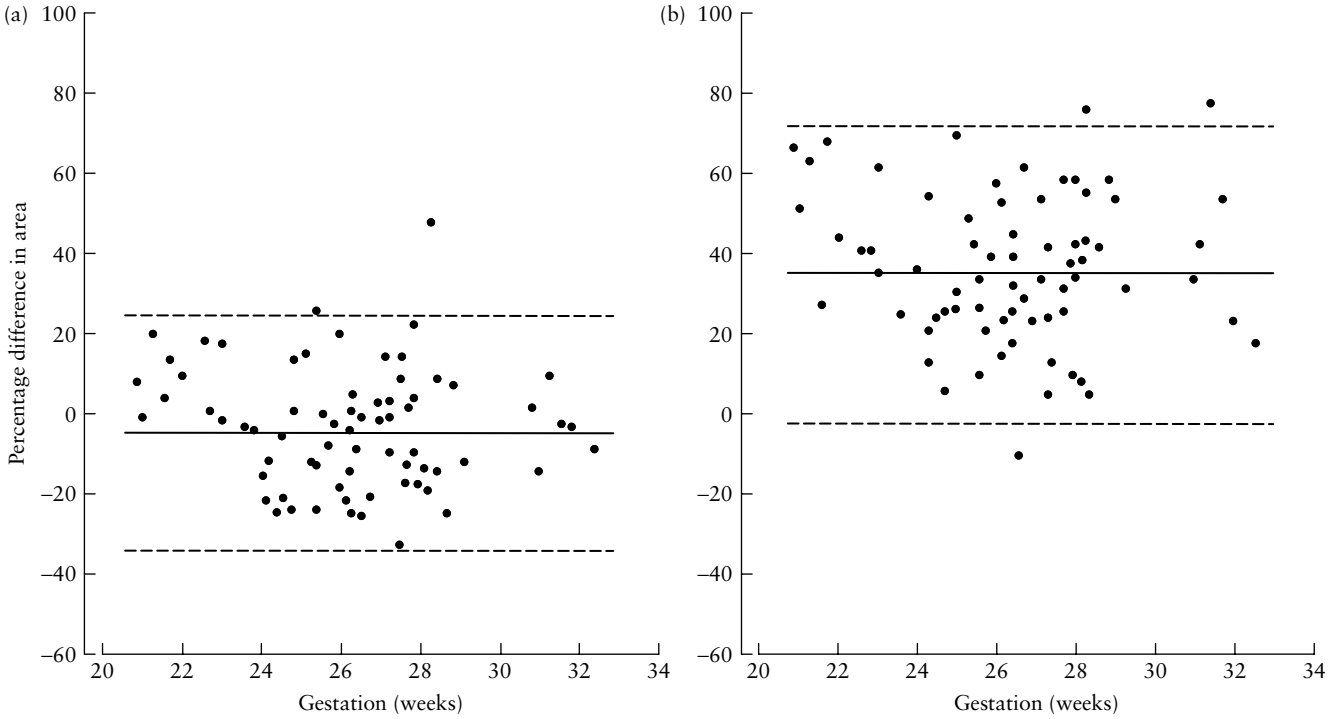


**Figure 2** Mean and 95% confidence interval in the percentage difference between the lung area measured: (a) by multiplication of the anteroposterior (AP) diameter at the mid-clavicular line by the perpendicular diameter at the midpoint of the AP diameter and (b) by multiplication of the longest diameter by its longest perpendicular diameter, compared with manual tracing of the limits of the lungs.

 

### Statistical analysis

To compare the lung areas calculated by the two methods using multiplication of two diameters to the area measured by manual tracing, the differences between the area deduced from each of the two multiplication methods and that from the tracing method were expressed as a percentage of the area calculated by manual tracing and plotted against gestational age. The mean percentage difference and 95% confidence intervals were calculated, and Bland–Altman analysis was used to compare the measurement agreement and bias for each of the two observers[4]. The *t*-test was used to evaluate the differences between means of areas calculated by multiplication of diameters and by the tracing method. The data were analyzed by the statistical software SPSS 13.0 (Chicago, IL, USA) and Excel for Windows 2000 (Microsoft Corp., Redmond, WA, USA). A two-tailed *P* of less than 0.05 was considered statistically significant.

## RESULTS

There were 58 fetuses with left-sided CDH and 13 with right-sided CDH. The value of the LHR measurement in the prediction of postnatal outcome was not the subject of this study because in some cases the parents elected to have pregnancy termination, and those with continuing pregnancies were managed either expectantly or by fetoscopic endotracheal placement of a balloon[5].

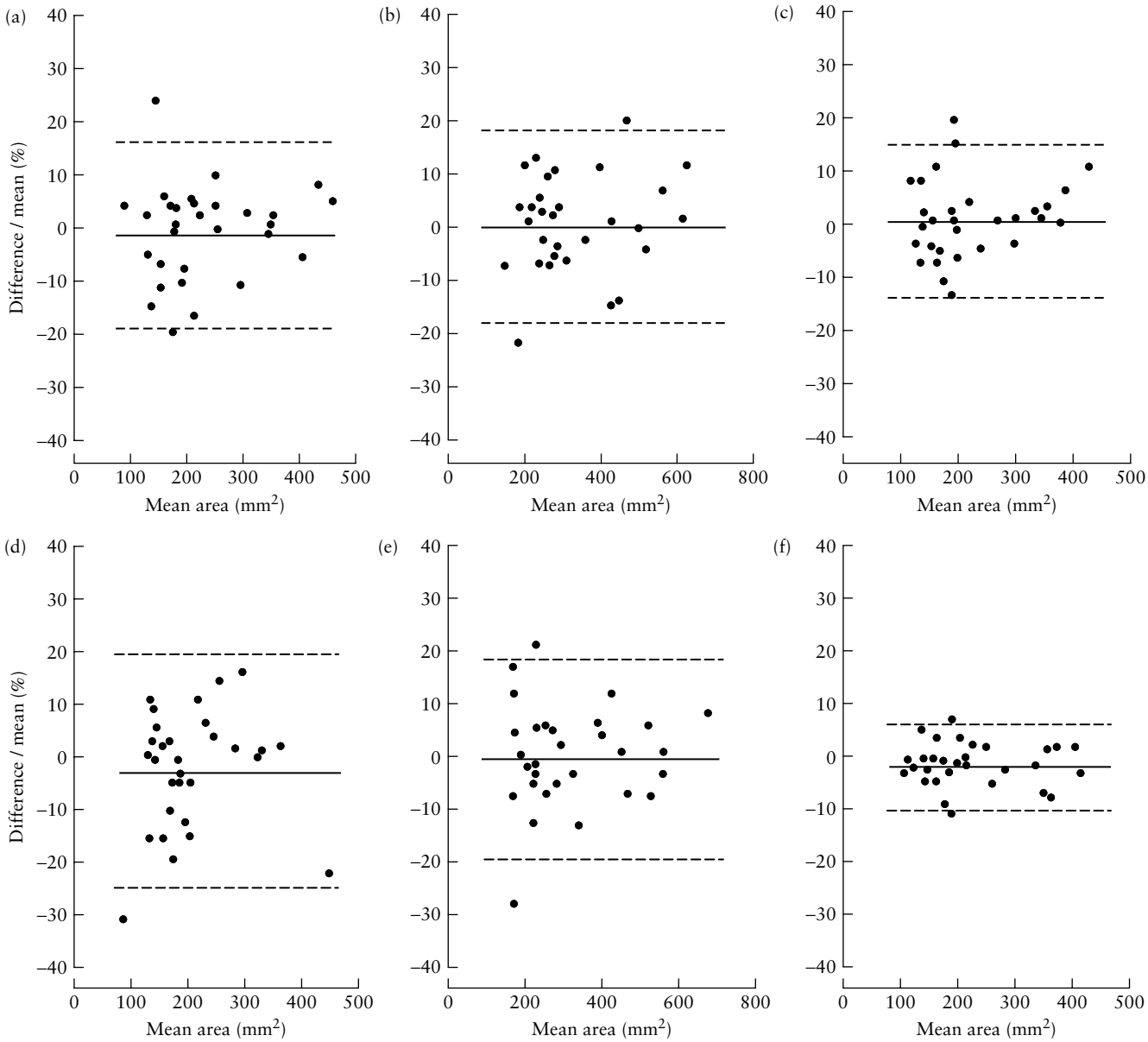


**Figure 3** Bland–Altman plots showing the mean and 95% confidence intervals in percentage difference between measurements performed by Observer 1 twice: (a) by multiplication of the anteroposterior (AP) diameter at the mid-clavicular line by the perpendicular diameter at the midpoint of the AP diameter; (b) by multiplication of the longest diameter by its longest perpendicular diameter; and (c) by the tracing method. (d–f) Corresponding measurements for Observer 2.

 

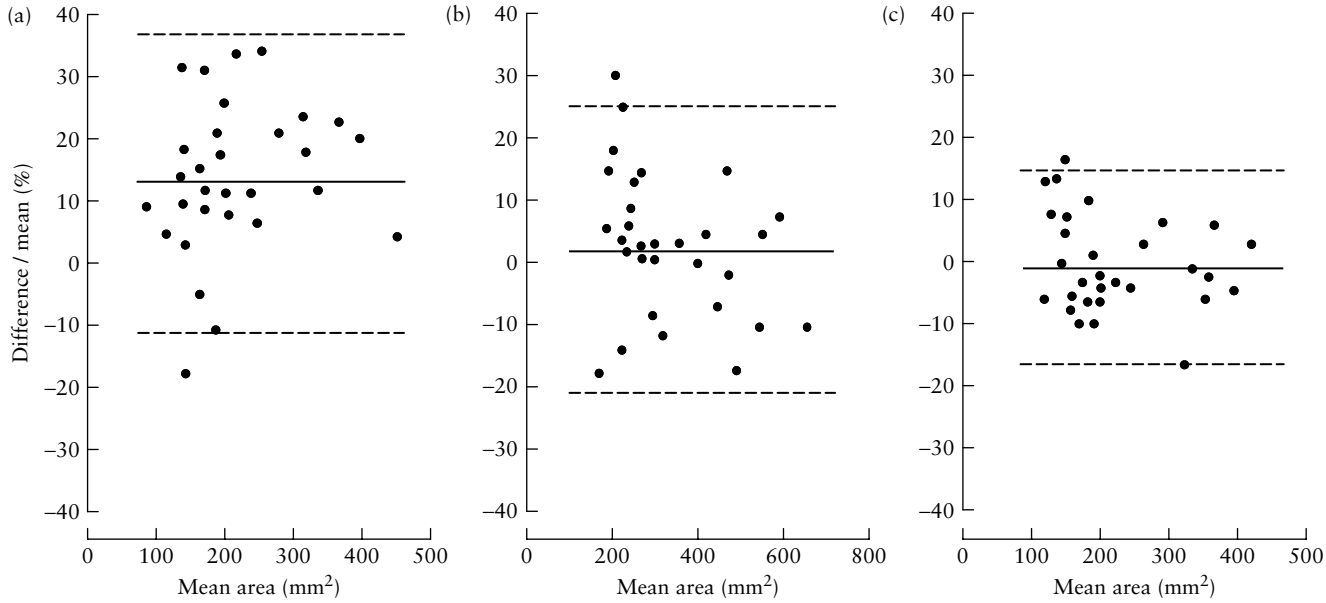


**Figure 4** Bland–Altman plots showing the mean and 95% confidence interval in percentage difference between measurements performed by two different observers: (a) by multiplication of the anteroposterior (AP) diameter at the mid-clavicular line by the perpendicular diameter at the midpoint of the AP diameter; (b) by multiplication of the longest diameter by its longest perpendicular diameter; and (c) by the tracing method.

**Table 1** Mean percentage difference or bias, precision and the 95% limits of agreement of the contralateral lung area between paired measurements by each of Observers 1 and 2, and between the observers in 30 fetuses with congenital diaphragmatic hernia at 22–28 weeks' gestation

| *Method* | *Mean and 95% CI of percentage differences* | *Precision* |
|---|---|---|
| Intraobserver 1 | | |
| Anteroposterior diameter | −1.3 ( −18.8 (−21.6 to −16.0) to 16.2 (13.4 to 19.0)) | 8.9 |
| Longest diameter | 0.1 (−17.9 (−20.8 to −15.0) to 18.1 (15.2 to 21.0)) | 9.2 |
| Tracing | 0.3 (−14.1 (−16.5 to −11.8) to 14.8 (12.4 to 17.1)) | 7.4 |
| Intraobserver 2 | | |
| Anteroposterior diameter | −3.5 (−25.4 (−28.9 to −21.9) to 18.3 (14.8 to 21.9)) | 11.2 |
| Longest diameter | −0.6 (−19.6 (−22.7 to −16.5) to 18.4 (15.3 to 21.4)) | 9.7 |
| Tracing | −1.8 (−10.2 (−11.6 to −8.8) to 6.6 (5.2 to 7.9)) | 4.3 |
| Interobserver | | |
| Anteroposterior diameter | 13 (−11.1 (−14.9 to −7.2) to 37.1 (33.2 to 41.0)) | 12.3 |
| Longest diameter | 2 (−21.0 (−24.7 to −17.3) to 25.0 (21.2 to 28.7)) | 11.7 |
| Tracing | −0.9 (−16.2 (−18.6 to −13.7) to 14.3 (11.8 to 16.8)) | 7.8 |

In the assessment of the contralateral lung, the area obtained by the AP method was similar to that of the manual tracing method (mean difference 4.3%, 95% CI, −33.69% to 25.14%, $P = 0.37$; Figure 2a) but the area obtained by the longest diameter approach was bigger than that obtained by the manual tracing method (mean difference 34.4%, 95% CI, −2.4% to 71.1%, $P < 0.05$; Figure 2b).

In the Bland–Altman plot, the mean percentage difference or bias, the precision (standard deviation of the difference between the two methods) and the 95% limits of agreement between paired measurements for each of the three methods by the same sonographer and between paired measurements by two sonographers are shown in Figures 3 and 4 and in Table 1. The intra- and interobserver agreements were better with the tracing method than with the other two methods, with precision showing smaller values.

## DISCUSSION

The findings of this study on the assessment of lung area of the contralateral lung in fetuses with CDH demonstrate that, compared to the manual tracing method, the area obtained by the AP method was similar but the area by the longest diameter approach was substantially bigger. Furthermore, the differences in paired measurements of lung areas by the same and by two different observers were smaller in the manual tracing method than with the approach of multiplying diameters.

 

The finding that in CDH the most reproducible measurement is provided by manual tracing of the limits of the lungs, rather than by multiplication of lung diameters, is similar to the previously reported finding in normal fetuses[3]. However, the precision of the measurements in CDH is half as good as the precision when measured in normal fetuses[3]. This poorer precision in CDH is likely to be due to the lungs being smaller and distorted by the herniated abdominal viscera. When the outline of the lungs is irregular there is greater variation between observers in selecting the appropriate points to define the diameters; this is overcome by the tracing method because all points along the circumference are included. This is compatible with the findings of a study in lambs that reported that the accuracy of lung volume measurements was half as good in those with surgically induced diaphragmatic hernia as in the normal group. The relative inaccuracy in lung volume measurements in CDH was not the mere consequence of their smaller size because the accuracy of volume measurements of other organs with comparable size, such as the kidneys, was higher[6].

The difference in estimated lung areas obtained by the different methods highlights the importance of exercising caution in comparing findings from different studies in the prediction of outcome or the selection of fetuses for intrauterine therapeutic intervention. In terms of assessment of lung area in future studies our findings have clearly demonstrated that the best method to be used is manual tracing of the limits of the lungs, rather than multiplication of lung diameters. The existing reported data on the antenatal prediction of postnatal outcome both in fetuses managed expectantly and in those undergoing fetoscopic endotracheal placement of a balloon are based on the assessment of lung area by multiplication of lung diameters[2,7]. Nevertheless this problem can be overcome by expressing the estimated lung area as a ratio of the observed measurement to the expected normal mean for gestation, in which of course the method of measurement in normal fetuses should be the same as in fetuses with CDH[8].

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