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Editorial

Lung-to-head ratio: a need to unify the technique

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Congenital diaphragmatic hernia (CDH) is associated with a high postnatal mortality rate due to pulmonary hypoplasia and/or hypertension. Antenatal prediction of postnatal outcome is based essentially on the assessment of the degree of intrathoracic compression of the lungs, and the most widely used method is ultrasonographic measurement of the fetal lung area-to-head circumference ratio (LHR).

In the assessment of fetuses with CDH and the counseling of parents as to the available options (including endoscopic occlusion of the fetal trachea[1–3], expectant management and pregnancy termination) for subsequent management of the pregnancy, it is imperative that prediction of outcome is as accurate as possible. Consequently, operators undertaking measurement of LHR should be trained appropriately[4] and correct algorithms used for interpretation of the results.

Evolution in the application of LHR

In the first description of this technique, the area of the right lung in fetuses with left-sided CDH and intrathoracic herniation of the liver was measured at ≤ 25 weeks' gestation[5]. The right lung area was estimated, in the cross-sectional plane of the thorax used for examination of the four-chamber view of the heart, by multiplication of the longest diameter of the lung by its longest perpendicular diameter (Figure 1a)[5]. However, in the figure provided in that article to explain the technique, estimation of the lung area was obtained by multiplication of the anteroposterior diameter of the lung at the mid-clavicular line by the perpendicular diameter at the midpoint of the anteroposterior diameter (Figure 1b). The authors of that study recognized that the lung area increases with gestational age and attempted to create a gestation-independent measurement by dividing the lung area by the head circumference.

Subsequent studies utilizing LHR in the prediction of postnatal outcome in fetuses with CDH have generally confirmed that survival improves with increasing LHR[5–18]. However, there are large differences in reported results, possibly because of the wide range in gestational age, from 16–39 weeks, at which the LHR was measured, the small number of patients examined in most studies and the extension of the use of LHR from cases with left-sided CDH with intrathoracic liver to those with right-sided defects and those without liver herniation. Additionally, although all studies used the same reference to explain the method of measuring lung area, i.e. multiplication of the longest diameter of the lung by its longest perpendicular diameter[5], in reality there were inconsistencies in the figures they provided to explain their technique.

A cross-sectional study of 650 normal singleton pregnancies at 12–32 weeks of gestation established reference intervals for the right and left lung areas and LHRs[19]. The lung areas were measured, on the cross-sectional plane of the thorax used for examination of the four-chamber view of the heart, by three different techniques (Figures 1a–c): firstly, multiplication of the longest diameter of the lung by its longest perpendicular diameter; secondly, multiplication of the anteroposterior diameter of the lung at the mid-clavicular line by the perpendicular diameter at the midpoint of the anteroposterior diameter; and thirdly, manual tracing of the limits of the lungs. The data of this study demonstrated that between 12 and 32 weeks of gestation there is an 18-fold increase in lung area and a four-fold increase in head circumference. Consequently, the left and right LHR increase exponentially with gestation (Figure 2). The most reproducible way of measuring the lung area was by manual tracing of the limits of the lungs and the least reproducible was by multiplying the longest diameter of the lungs by their longest perpendicular diameter. Furthermore, the method employing the longest diameter, compared with the tracing method, overestimated both left and right lung areas by about 45% and the method employing the anteroposterior diameter overestimated the area of the right lung by about 35%, but not that of the left lung.

A subsequent study of 354 fetuses with isolated CDH, reported that the LHR at 18–38 weeks' gestation increased with gestational age, having estimated the lung area by multiplication of the longest diameter of the lung by its longest perpendicular diameter[20]. The authors proposed the introduction of a new measurement, the observed to expected (o/e) LHR, which was independent of gestational age. This method is applicable to both fetuses with left-sided CDH, with or without intrathoracic

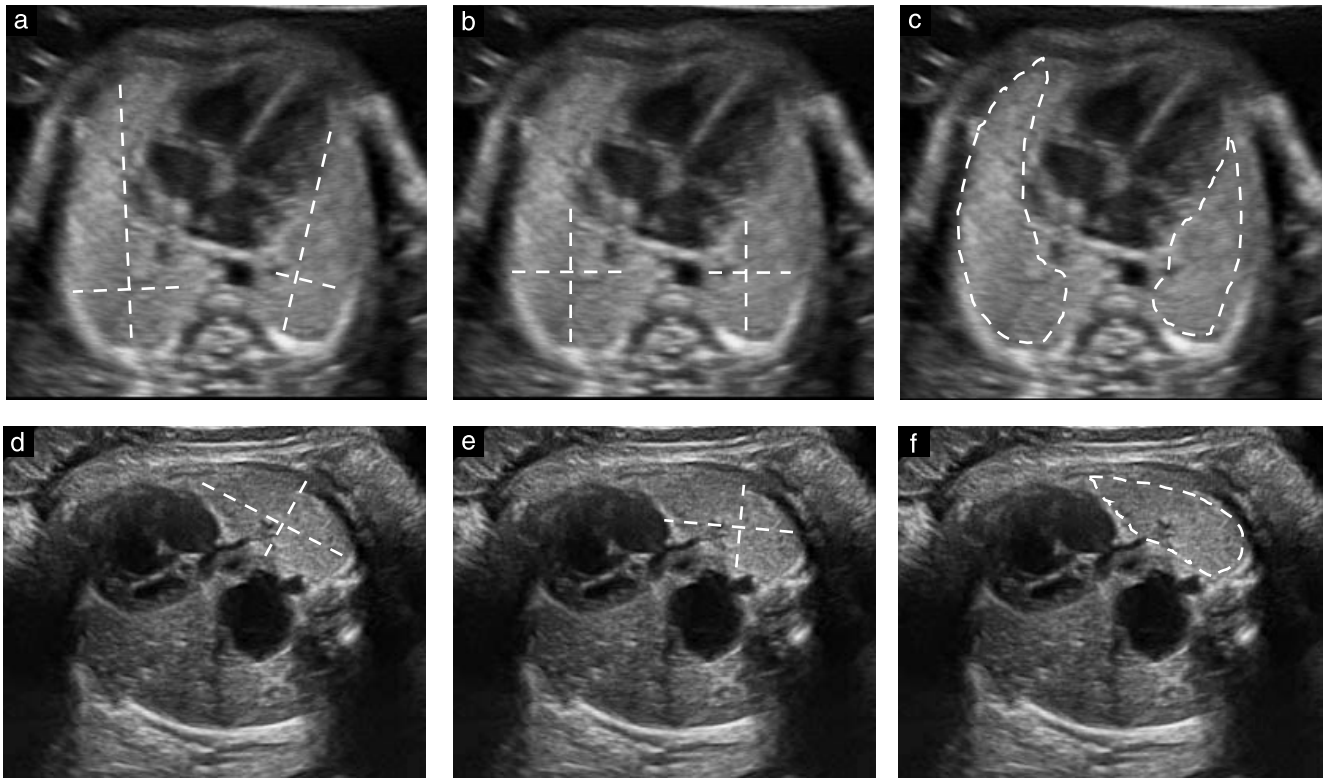

Figure 1 Ultrasound images in fetuses with normal lungs (a–c) and left-sided congenital diaphragmatic hernia (d–f) at the level of the four-chamber view of the heart. Three methods of measuring the lung area are illustrated: (a,d) multiplication of the longest diameter of the lung by its longest perpendicular diameter (longest diameter method); (b,e) multiplication of the anteroposterior diameter of the lung at the mid-clavicular line by the perpendicular diameter at the midpoint of the anteroposterior diameter (anteroposterior method); and (c,f) tracing of the limits of the lungs (tracing method).

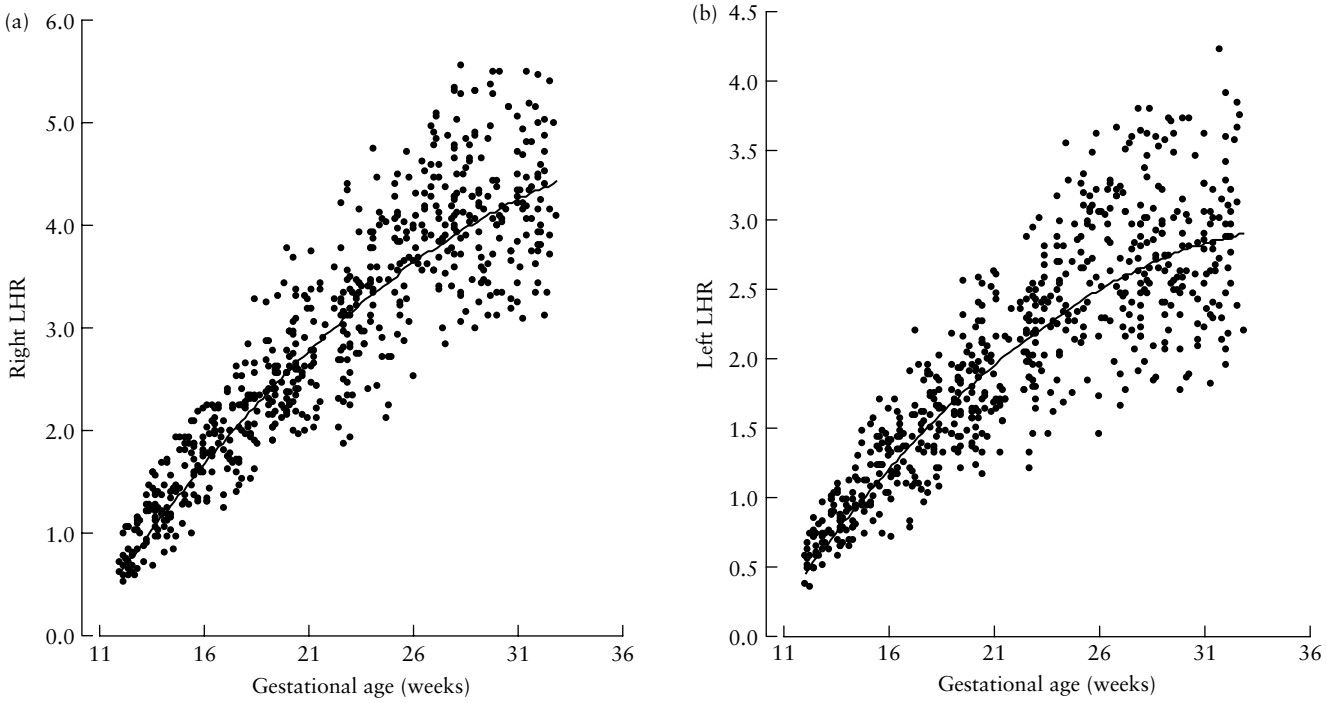

Figure 2 Right (a) and left (b) lung areas, by the longest diameter method, to head circumference ratio (LHR) according to gestational age in normal fetuses.

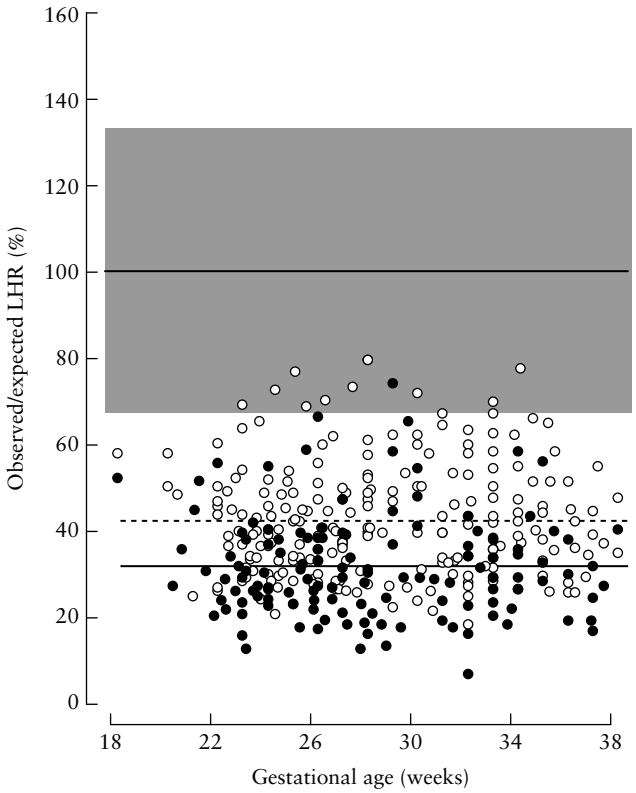

Figure 3 Observed to expected right lung area-to-head circumference ratio (LHR) according to gestational age in normal fetuses (shaded area represents 95% reference range) and in individual fetuses with left-sided congenital diaphragmatic hernia (circles with regression lines), showing fetuses that died (—●—) and survivors (- - -○- - -).

herniation of the liver, and fetuses with right-sided CDH. Furthermore, in both left- and right-sided CDH, measurement of the o/e LHR was useful in the prediction of subsequent survival (Figure 3)[20]. In fetuses with left-sided CDH the survival rate was substantially lower in those with intrathoracic herniation of the liver than in those with the liver confined to the abdomen (53% vs 75%). However, logistic regression analysis demonstrated that the position of the liver did not provide significant contribution independent of the o/e LHR in the prediction of survival[20].

Protocol for measurement of LHR

The following criteria should be applied in the measurement of LHR.

1. An axial view at the level of the four-chamber view of the heart should be obtained.
2. The view should be such that the lung contralateral to the CDH is closer to the probe than the herniated structures.
3. Care should be taken to avoid shadows produced by the ribs on the lung to be measured, by placing the transducer so that the ultrasound beam is parallel to the ribs and crosses the intercostal space.
4. The image should be frozen prior to final magnification to ensure that all landmarks are clearly visible. The image should then be magnified so that the axial view of the fetal thorax occupies the whole screen.
5. The calipers should be placed according to the method being used to measure the lung area: longest diameter, anteroposterior diameter or tracing method (Figures 1a–c). In all methods, the area of the lung (in square millimeters) is divided by the head circumference (in millimeters) to obtain the LHR. For all methods, care should be taken not to include the myocardium in the measurement of the lung area. The preferred method is the tracing one since it is the most reproducible[19], especially when the lung contralateral to the CDH has an unusual and irregular shape (Figure 4).
6. When the measurement of LHR is completed, it should be divided by the expected mean LHR for gestational age, so that the o/e LHR is obtained. Table 1 provides the formulae for the expected mean LHR for right and left lungs using the three different methods of measuring the lung area.
7. The minimum number of LHR measurements required to achieve competence in the technique is 70[4]. Training should be done under the supervision of a sonographer with sufficient expertise in measuring LHR. An alternative is to send the images to a center with experts in LHR measurement for evaluation. It is acceptable that part of the training is performed on fetuses with normal lungs.

Limitations of LHR in the prediction of outcome

The measurement of fetal LHR has been used for the prediction of pulmonary hypoplasia and/or hypertension in the neonatal period. Studies have reported a high association between o/e LHR and such outcome both in fetuses managed expectantly and in those treated by fetoscopic occlusion of the trachea[2,20]. However, postnatal survival is related not only to the degree of fetal lung development but also to the expertise of the neonatal center caring for the affected infant. Consequently, it is necessary to adjust the o/e LHR according to the level of neonatal care.

Table 1 Formulae for expected fetal lung area-to-head circumference ratio (LHR) in left- and right-sided congenital diaphragmatic hernia (CDH), using different methods for measurement of the lung area, based on gestational age (GA) in weeks with decimals

Lung area measurement	*Right LHR in left CDH*	*Left LHR in right CDH*
Longest diameter method	$-3.4802 + (0.3995 \times GA) - (0.0048 \times GA^2)$	$-2.5957 + (0.3043 \times GA) - (0.0042 \times GA^2)$
Anteroposterior diameter method	$-3.1597 + (0.3615 \times GA) - (0.0041 \times GA^2)$	$-1.0224 + (0.1314 \times GA) - (0.0011 \times GA^2)$
Tracing method	$-2.3271 + (0.27 \times GA) - (0.0032 \times GA^2)$	$-1.4994 + (0.1778 \times GA) - (0.0021 \times GA^2)$

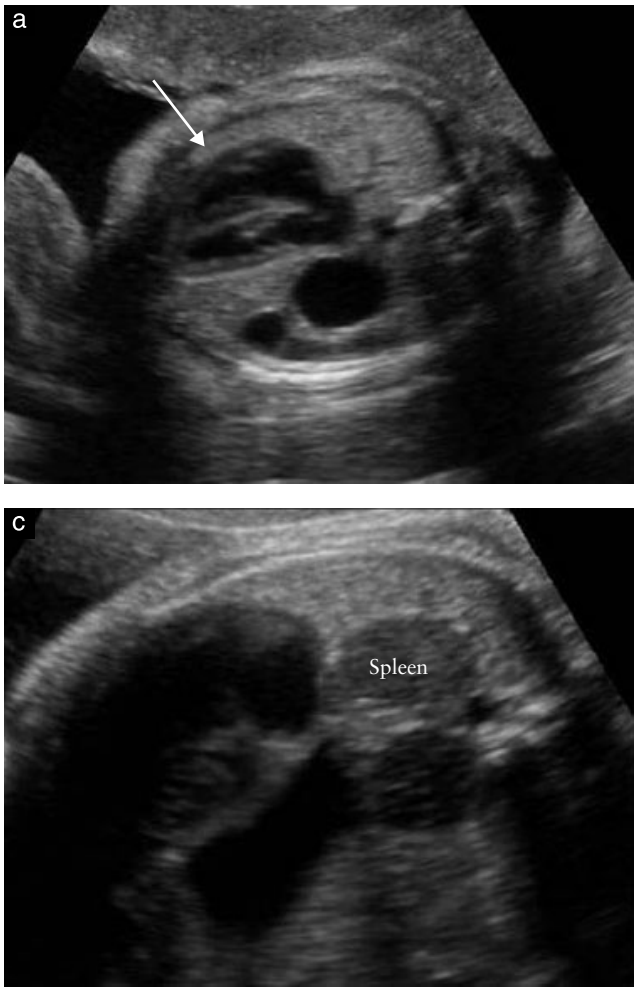

Figure 4 Ultrasound images at the level of the four-chamber view of the heart in a fetus with left-sided congenital diaphragmatic hernia, demonstrating some of the difficulties in estimation of the lung area. In (a) there is extension of the contralateral lung around the heart (arrow), making it difficult to decide where to place the calipers for measurement of the longest diameter; in (b) and (c) the stomach and spleen, respectively, distort the shape of the lung, making it difficult to decide where to place the calipers for measurement of the transverse diameter.

Magnetic resonance imaging (MRI) provides more accurate measurement of lung volumes than does sonographic assessment by LHR[21]. Additionally, measurements obtained by MRI are easier to standardize and allow assessment of both lungs. However, MRI is confined to specialist centers and therefore measurement of LHR will, in the foreseeable future, remain the first-line method of assessment of the severity of CDH. Ultimately, if ongoing trials demonstrate that fetoscopic occlusion of the fetal trachea is beneficial, an increasing number of affected fetuses could be managed in specialist centers where the main method of assessment of the severity of CDH would be MRI.

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