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Sonographic visualization of the fetal upper airway

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Key words: FETAL LARYNX, FETAL TRACHEA, ULTRASOUND DIAGNOSIS, AIRWAY OBSTRUCTION

ABSTRACT

Laryngeal obstruction is a life-threatening condition which can sometimes be diagnosed by prenatal ultrasound examination. Dilatation of the fetal trachea is an important finding in these cases. Sonographic studies to evaluate the fetal upper airway were performed in 120 consecutive patients. The diameters of the trachea and pharynx were measured and our ability to visualize the trachea and the larynx was evaluated. The diameter of the trachea increased from a mean of 2.4 mm at 18 weeks to 4.6 mm at 38 weeks. The mean diameter of the pharynx increased from 4.4 mm at 18 weeks to 8.8 mm at 38 weeks. The fetal larynx was adequately visualized in 67% of the cases, while the entire trachea was seen in 47% of the cases. Our success in visualizing the larynx and trachea was best between 20 and 30 weeks' gestation. This study shows that it is possible to obtain excellent views of the fetal airway in a high percentage of cases and reports the range of normal values for tracheal diameter. Early visualization of a dilated trachea may allow better management of a fetus with laryngeal obstruction.

INTRODUCTION

In the past few years there have been several case reports in which anomalies of the fetal larynx and trachea have been diagnosed prenatally^{1–5}. In most cases the diagnosis was inferred from secondary manifestations such as enlarged echogenic lungs, fetal ascites and, occasionally, fetal hydrops^{1,2,5,6}. Several investigators have concluded that it is not possible to visualize the larynx directly to diagnose these abnormalities specifically^{1,6,7}; however, in three cases a dilated trachea was seen^{2–4}. In a case of severe subglottic stenosis that we reported, the trachea appeared to be dilated, but the larynx itself could not be visualized, due to shadowing from the fetal chin and arm⁴. At that time a literature search failed to reveal any studies documenting normal tracheal size. In addition, we were unable to find any studies reporting the frequency with which visualization of the larynx and

trachea is possible. The purpose of this prospective study was to define normal tracheal and pharyngeal diameters, and to determine how often the anatomy of the upper airway could be adequately visualized in the normal fetus.

METHODS

An attempt was made to visualize the fetal upper airway in 120 consecutive patients. All sonograms were performed by one of the authors (DSR). These women were referred for a variety of indications, none of which would be expected to change the appearance of the upper airway. Ultrasound machines used included a Hitachi EUB 515 (Hitachi Medical, Tarrytown, New York) and a General Electric 3200 (GE Medical Systems, Milwaukee, Wisconsin), using transabdominal probes of 3.5 and 5.0 MHz. Initially, the posterior pharynx was visualized in a transverse plane, and the maximum anteroposterior and transverse measurements of the pharyngeal fluid column were obtained. A mean pharyngeal diameter was calculated from these measurements. The transducer was then moved down to the level of the trachea, and the maximum anteroposterior diameter of the trachea was measured. For ten women repeat measurements were made of the pharynx and trachea so that intraobserver variation could be calculated. The transducer was then rotated by 90°, and a coronal view of the trachea, larynx, and pharynx was obtained. Our ability to see the structures of the larynx in this plane was graded as not visible, poorly visible, or clearly visible. While maintaining this coronal view, the trachea was followed down to its bifurcation. Our ability to see the trachea to the bifurcation was graded on the same scale. Confusion of the trachea with the blood vessels of the neck was avoided by identifying the midline trachea on transverse views, then rotating the transducer to the coronal plane while maintaining visualization of the lumen.

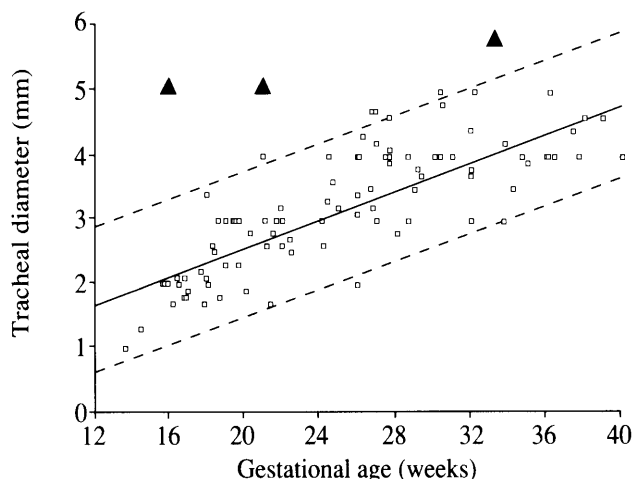


Figure 1 Relationship between tracheal diameter and gestational age. The solid line represents a plot of the fitted line calculated by simple linear regression, and the dashed lines represent 95% prediction intervals for data points. Solid triangles represent the tracheal diameter in the three published cases of laryngeal obstruction in which measurements were obtained^{2,4}

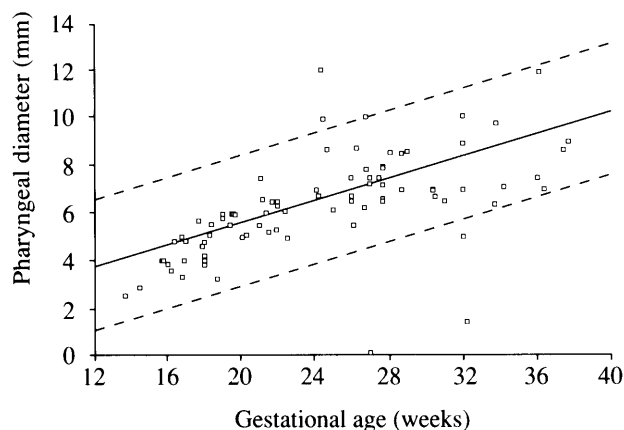


Figure 2 Relationship between pharyngeal diameter and gestational age. The solid line represents a plot of the fitted line calculated by simple linear regression, and the dashed lines represent 95% prediction intervals for data points

For cases in which the fetal upper airway was not visualized, the apparent reason was noted. Prolonged attempts to visualize these structures were not made. No scans were repeated in an effort to gain better visualization of the airway. Other data collected included the best estimate of gestational age, and position of the fetal spine (anterior, posterior, or lateral).

Data were entered into a microcomputer for analysis. Statistical analysis was performed with the Statgraphics program (STSC, Inc., Rockville, MD).

RESULTS

The diameter of the trachea increased through gestation from a mean of 2.4 mm at 18 weeks to 4.6 mm at 38 weeks (Figure 1). Simple regression analysis demonstrated the relationship between gestational age and tracheal diameter to be statistically highly significant

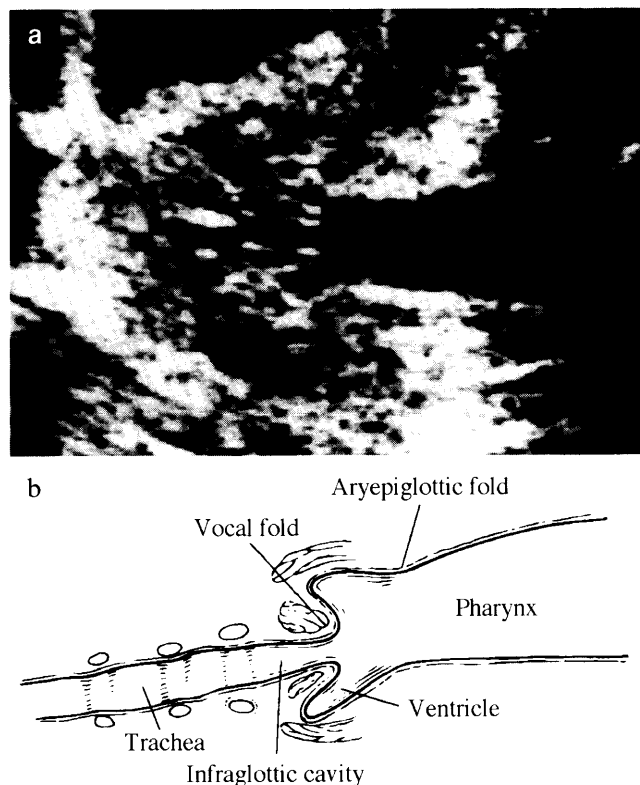


Figure 3 (a) Ultrasound image of the fetal pharynx and upper trachea in the coronal plane at 26 weeks' gestation; (b) illustration showing the anatomical structures pictured in (a). The measurements reported in this study were obtained where the fluid column has its maximal diameter in the trachea and pharynx

($p < 0.00001$, $R^2 = 0.64$). The intraobserver variation for this measurement averaged 0.2 mm.

There was also a positive correlation between the mean pharyngeal diameter and gestational age. The diameter increased from a mean of 4.4 mm at 18 weeks to 8.8 mm at 38 weeks (Figure 2). This relationship was also statistically significant ($p = 0.00001$, $R^2 = 0.52$). The intraobserver variation for this measurement was 0.6 mm.

The fetal larynx was visualized in 67% of the cases. In 46% of these, the pertinent anatomy was clearly seen (views comparable to those demonstrated in Figure 3a and 3b), and in 54%, the larynx was visualized, but without the same detail. Our ability to visualize the larynx was significantly affected by gestational age (Figure 4). The differences in visualization among gestational age groups were found to be statistically highly significant ($p = 0.0001$ by χ^2). Visualization was best between 20 and 30 weeks' gestation.

A similar outcome was found for tracheal visualization. The fetal trachea was visualized down to its bifurcation in 47% of cases. In 45% of these, the tracheal anatomy was clearly seen, and in 55%, views were suboptimal. Our ability to visualize the trachea was also significantly affected by gestational age (Figure 5). Differences in visualization among the gestational age groups were statistically highly significant ($p = 0.00001$

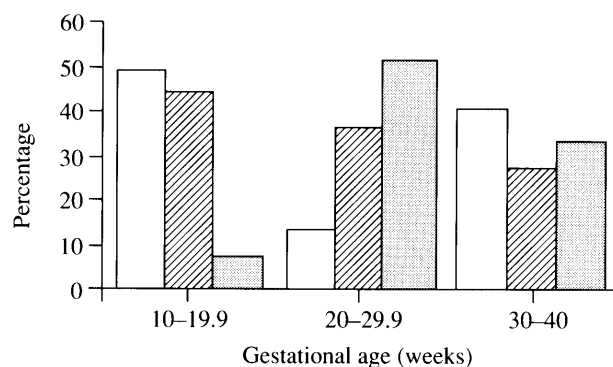


Figure 4 Clarity of laryngeal visualization at varying gestational ages. Open bars, not seen; hatched bars, adequately seen; stippled bars, well seen

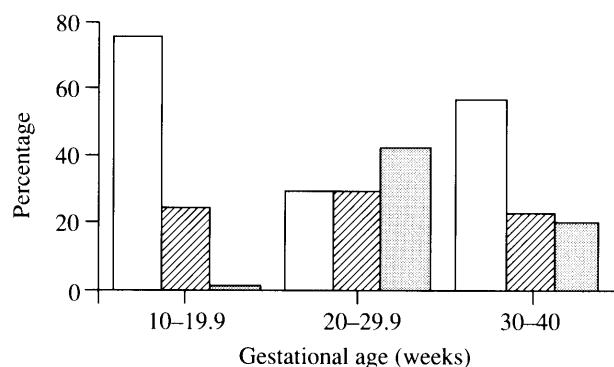


Figure 5 Clarity of tracheal visualization at varying gestational ages. Open bars, not seen; hatched bars, adequately seen; stippled bars, well seen

by χ^2). Again, visualization was best between 20 and 30 weeks' gestation.

Factors which prohibited good visualization were tabulated. The most common contributing factor, present in 47% of the non-visualized cases, was flexion of the fetal neck. With forward flexion the chin shielded the pertinent structures, and with lateral flexion the fluid column normally seen within the pharynx or trachea was not visible. The inability to visualize the fetal airway due to neck flexion was primarily a problem in the last 10 weeks of pregnancy. The structures were too small to be seen in 26% of the non-visualized cases. This was not a problem after 20 weeks' gestation. Maternal obesity was a significant factor in 34% of the non-visualized cases; however, desired views were obtained in all but one of the obese women in the 20-30 week gestational age range. The position of the fetal spine did not significantly affect our success, because with an anterior spine the transducer could nearly always be repositioned to direct the beam from one side or the other. In three cases, the fetal arm made visualization difficult by shielding the upper airway structures.

DISCUSSION

Abnormalities of the fetal airway are potentially life-threatening. Prenatal diagnosis of upper airway obstruction is therefore desirable, in order to provide optimal

care for the affected neonate. Although several authors have questioned whether it is possible to visualize the upper airway with sufficient clarity to diagnose abnormalities^{1,6,7}, the current study shows that excellent views are obtainable in a high percentage of cases.

In the 67% of our subjects in whom the larynx was adequately visualized, it seems likely that an interruption in the fluid column of the upper airway, as would be expected with laryngeal obstruction, would have been clearly visible. The percentage of cases in whom the fetal airway could be visualized may have been higher than reported here if more time had been spent or if scans were repeated. While in the majority of cases good views are easily obtainable, in some patients, even with extensive attempts, visualization is not possible. This is illustrated by the case of severe fetal laryngeal stenosis we previously reported⁴. Our attention was not directed to the upper airway until after 30 weeks, when the larynx was shielded by the fetal chin, making visualization impossible.

We are unaware of any previous studies which have attempted to analyze the ability of sonography to evaluate structures of the fetal airway. It is only in recent years that the possibility of diagnosing malformations of the fetal trachea and larynx has been considered, making such a study as ours pertinent. With increasing resolution, the diagnosis of upper airway anomalies will take on increasing specificity. In the initial case reports, the diagnosis was strongly suspected from secondary manifestations such as enlarged and edematous lungs, ascites, abnormal amniotic fluid volumes, or other signs of hydrops^{1,5,6}. Subsequent investigators have actually visualized a dilated trachea, which confirmed the diagnosis of upper airway obstruction^{2,4}. Prior to the current study, when tracheal dilatation was suspected, normal ranges for tracheal measurements were not available for comparison. A third level of diagnostic specificity, which has yet to be realized in any case reports, will be to visualize sonographically the actual obstructed area of the trachea or larynx.

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