

Fetal esophageal imaging: Early pregnancy as a window of opportunity

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Abstract

Objective: To describe the sonographic appearance of the fetal esophagus during early pregnancy and evaluate the feasibility of imaging the entire esophageal length. In addition, we present a case of disrupted esophageal continuity, subsequently diagnosed with esophageal atresia (EA).

Methods: A prospective observational study of 145 patients. During the early second trimester anomaly scan performed at 12–17 weeks' gestation the entire esophagus was captured in a single sonographic image at the midsagittal plane (one shot technique). Postnatal follow-up of esophageal patency included review of medical records and telephone interviews.

Results: Complete visualization of the esophagus (neck to diaphragm) was possible in 144 cases. In 88% of cases the esophagus was demonstrated by transvaginal approach. The time required to obtain the desired view of the esophagus, once the fetus was in an optimal position, was on average 13 s (range: 5–30 s). In one case at 15 weeks' gestation, the cervical segment of the esophagus was demonstrated while the lower thoracic segment was not identified. Subsequently EA was diagnosed.

Conclusions: It is feasible to demonstrate the entire esophagus during early second trimester anomaly scan. An early second trimester anomaly scan may serve as a window of opportunity for EA screening.

KEYWORDS

esophageal atresia, esophagus, ultrasound

Key Points

What's already known about this topic?

- The prenatal diagnosis of esophageal atresia (EA) is challenging. Currently, EA has a low prenatal detection rate ranging from 24% to 32%. Prenatal signs suggestive of EA are polyhydramnios and/or small or absent stomach. The pouch sign is the only prenatal diagnostic sign of EA, however, its detection requires significant expertise. A recent publication found that the early anomaly scan, in its current form, performs poorly in screening for EA.

What does this study add?

- We present a new “one shot” technique for assessing the fetal esophagus at early pregnancy and evaluate its feasibility. Furthermore, we were able to consistently apply this technique in a prospective cohort. The major clinical implication of this work is to present a promising early screening method for EA.

1 | INTRODUCTION

Esophageal atresia (EA) is a prenatally underdiagnosed major gastrointestinal anomaly. EA manifests as a blind upper esophageal pouch and a lower residual esophageal stub, which in most cases, communicates with the trachea by means of a tracheoesophageal fistula (TEF). The prevalence of EA is estimated at 2.4–4 cases per 10,000 live births^{1–3} rendering EA the most common congenital gastrointestinal obstructive pathology.

The prenatal diagnosis of EA is challenging. EA has a relatively low prenatal detection rate ranging from 24% to 32%.^{3–7} Currently, the only prenatal suggestive signs of EA are polyhydramnios and/or small or absent stomach.³ Unfortunately, these signs have low specificity (66.2%),⁸ sensitivity (26%–57%), and positive predictive values (35%–63%).⁷ In addition, these signs may be transient,^{8,9} and in the case of polyhydramnios, appear late in pregnancy.³ Furthermore, in up to 90% of cases, a TEF is present,^{9,10} enabling the passage of fluid to the fetal stomach, thus ameliorating these signs. A previous study found that in around 30% of TEF cases sonographic signs are absent and are therefore impossible to suspect prenatally.³ The pouch sign is the most specific and the only prenatal diagnostic sign of EA.^{3,11–15} Yet, there are some major limitations that prevent its ubiquitous application. The prenatal detection of an esophageal pouch requires significant expertise, it is time consuming and the region of interest may be obscured at advanced gestational age.^{12,16,17} Therefore, a targeted pouch scan is usually reserved for highly suspicious cases and there is a need for an additional screening tool that would improve the rate as well as the timing of antenatal suspicion of EA.

The esophagus is a long tubular structure, usually collapsed, and thus difficult to distinguish from its surrounding structures on ultrasound. It has been previously shown that the normal appearance of the intact esophagus is an uninterrupted echogenic bundle of fibers, visualized as echogenic lines, which is the sonographic signal projected by the collapsed esophageal muscular walls.¹⁷ In order to improve the detection rate of EA several studies have evaluated the feasibility of demonstrating the fetal esophagus throughout pregnancy including during the mid-trimester anomaly scan^{16–19} and during the first trimester anomaly scan.¹⁸

The aim of this study was to describe a “one shot” esophageal imaging technique, visualizing the entire esophagus along its

longitudinal axis in a single view, and evaluate the feasibility of its use at first and early second trimester.

2 | METHODS

This was a single center prospective cohort study conducted at a tertiary medical center, between January 2019 and February 2020, by two experienced operators (E. Kassif and T. Weissbach). One hundred forty-five patients were enrolled during the early second trimester anomaly scan between 12 and 17 weeks of gestation. It should be noted that in Israel patients are routinely offered an early second trimester anomaly scan at 12–17 weeks' gestation, at partial subsidization, in addition to the routine midtrimester scan. Pregnancies with known fetal malformations or genetic aberrations prior to the early anomaly scan and multifetal pregnancies were excluded from the study. All images and videos were stored and later reviewed by a third author (T. E. Miller) for quality control.

Patients were scanned using a Voluson E10 ultrasound machine (Kretz Ultrasound; GE Medical Systems), equipped with an abdominal RM6C 2–6 MHz convex probe or a vaginal RIC 6–12 MHz probe, as appropriate.

A vaginal approach was used up to 16 weeks of gestation and an abdominal approach was used at 17 weeks.

Once the fetus was in a favorable lie (supine with neck extended or in neutral position, Figure 1A,B), the esophagus was examined. Esophageal continuity was demonstrated in a single sonographic frame at the midsagittal plane (Figure 2A). The anteriorly positioned hypoechoic trachea served as an anatomic landmark. Upon imaging the trachea (and its direct continuation, the main right bronchus) the esophagus was visualized running behind and parallel to the trachea, from the neck to the upper thorax, and then behind and adjacent to the posterior margin of the heart, from the lower thorax and down to the diaphragm (Figure 2A). In some cases the abdominal esophagus was also demonstrated below the diaphragm, but this was not a prerequisite to determine an intact esophagus as this segment is not involved in EA (Figure 2B). The presence of fluid in any part of the esophagus was noted. The time between the first intention to demonstrate the esophagus, once the fetus was in a supine position with neck extended or in neutral position, and the demonstration of the esophagus in a single sonographic frame was recorded.

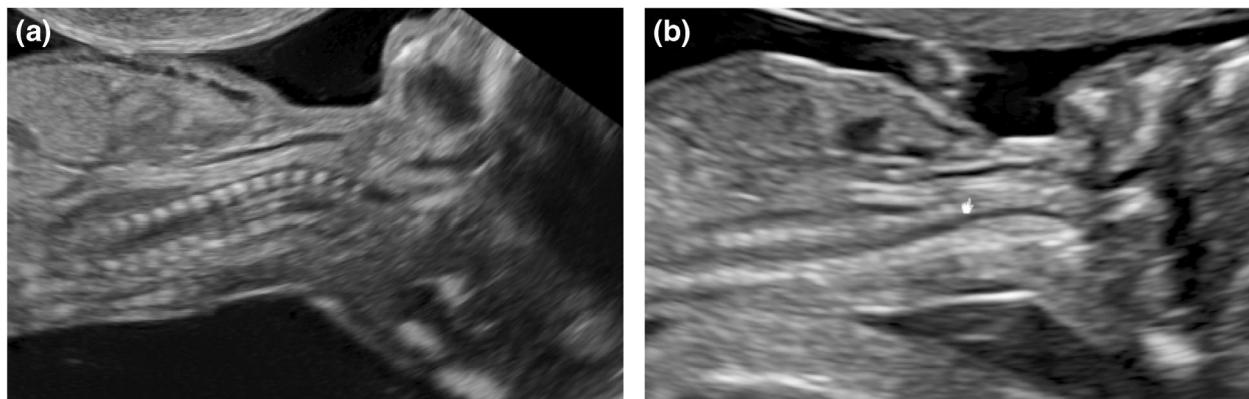


FIGURE 1 The demonstration of the fetal esophagus at 12–17 weeks of gestation with the fetal head at different positions: (A) extended, (B) neutral. Images were taken using a transvaginal approach

Medical records were reviewed for demographic maternal characteristics including body mass index (BMI), background maternal conditions, gestational age at anomaly scan and postnatal follow-up. In addition, labor ward reports and nursery discharge letters were also reviewed. Follow-up information regarding gastrointestinal disorders was obtained by telephone interviews. The median follow-up was nine months (range: 2–12 months).

The study protocol was approved by the Institutional Review Board. All participating patients signed a written informed consent.

3 | RESULTS

Altogether, 145 patients at 12–17 weeks of gestation participated in the study. The median gestational age at the time of examination was 14 weeks (range: 12–17 weeks of gestation, Table 1). Background characteristics are summarized in Table 2. The mean BMI was 22.6 (range: 16.7–37.1), with five patients with a BMI over 30.

Demonstration of the entire esophagus in a single sonographic frame was possible in 144 cases using our technique. In one case, at 15 weeks of gestation, the cervical segment of the esophagus was demonstrated clearly while the thoracic segment could not be demonstrated despite robust efforts, raising suspicion of EA (Figure 3A). At this stage, the stomach bubble was apparent. At the mid trimester anomaly scan, at 22 + 6 weeks of gestation, the stomach could not be visualized and a cervical esophageal pouch was repeatedly demonstrated on targeted a scan, establishing the diagnosis of EA (Figure 3B,C and Video S1).

The U.S. exam characteristics of the study group are displayed in Table 3. In a minority of cases not only the cervico-thoracic esophagus was demonstrated, but the abdominal esophagus as well. In 128 cases, the demonstration of the esophagus was carried out by transvaginal approach and in 17 cases by transabdominal approach.

The time required to obtain the desired view of the esophagus, once the fetus was in a supine position with neck extended or in neutral position, was available in 132 of the cases. The mean time

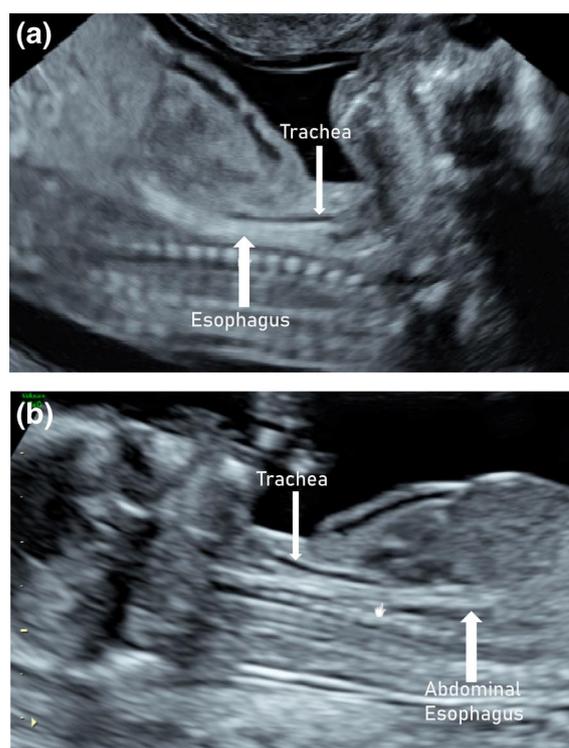


FIGURE 2 Longitudinal section of the fetal esophagus at 12–17 weeks of gestation. (A) The esophagus is imaged running posterior and adjacent to the trachea at the cervix and upper thorax and at the posterior margins of the heart at the lower thorax up to the diaphragm. It is represented by a bundle of numerous echogenic lines. (B) The abdominal esophagus is demonstrated below the diaphragm. Images were taken using a transvaginal approach [Colour figure can be viewed at wileyonlinelibrary.com]

required to demonstrate the esophagus in one shot in this scenario was 13 s (range: 5–30 s).

Fluid passage through the esophagus was identified as a thin hypoechoic layer separating the normally collapsed esophageal walls. In 21 cases, fluid was observed in the esophagus. In all of these cases, fluid was detected in the thoracic segment

TABLE 1 Gestational age distribution of study group

Gestational age (w)	N (% total 145)
12	2 (1.4%)
13	30 (20.7%)
14	90 (62.1%)
15	16 (11%)
16	6 (4.1%)
17	1 (0.7%)

Abbreviations: w, week; N, number.

TABLE 2 Demographics of the study group

Characteristic	Study group (n = 145)
Maternal age (y, range)	33 (28–35)
Nulliparous (%)	33.1% (48/145)
Prepregnancy BMI (kg/m ² , m)	22.6
BMI <20 (%)	20.1% (29/144 ^a)
BMI 20–25 (%)	66% (95/144 ^a)
BMI 26–30 (%)	10.4% (15/144 ^a)
BMI 31–35 (%)	2.1% (3/144 ^a)
BMI >35 (%)	1.4% (2/144 ^a)
IVF pregnancy (%)	17.2% (25/145)
High-risk pregnancy ^b (%)	18.6% (27/144)

Abbreviations: BMI, body mass index; IVF, in vitro fertilization; m, mean; y, years.

^aFor one case data concerning BMI is missing.

^bIncluding advanced maternal age, background diseases (lupus, APLA, Crohn's disease, and hypothyroidism), history of obstetric complications (uterine rupture, premature birth, and stillbirth), hypercoagulability and obstetric complication in current pregnancy (GDM and suspected CMV infection in pregnancy).

(Figure 4A), and in approximately half of the cases it was also present in either the cervical or abdominal segments (Figure 4B,C and Table 2).

Of the 145 study participants, 10 cases were lost to follow-up and 4 pregnancies were terminated, 1 due to EA and 3 due to major malformation or chromosomal aberrations.

The absence of EA was confirmed postnatally in the remaining 131 cases. A telephone interview was conducted with all 131 participants in order to ascertain an intact esophagus postnatally. All of the participants confirmed the absence of EA among their children. There were 10 cases of mild gastrointestinal reflux that resolved during the first year of life. In addition, there was one case of duodenal atresia, diagnosed during the midtrimester anomaly scan and confirmed postnatally. In this case, it should be noted, that although the whole length of the esophagus was demonstrated, passage of fluid was not detected.

4 | DISCUSSION

In this prospective cohort study we describe a technique for visualization of the fetal esophagus between 12 and 17 weeks' gestation and show its feasibility. Our study included 145 patients, in which 144 patients we were able to successfully demonstrate the entire length of the esophagus in a single sonographic frame. In one case where we were not able to visualize the thoracic segment of the esophagus at 15 weeks' gestation, a diagnosis of EA was established by the demonstration of an esophageal pouch at the midtrimester scan. The mean time required to demonstrate the esophagus using our technique once the fetus was in a favorable position was 13 s.

4.1 | Early pregnancy EA screening

A recent publication found that the early anomaly scan, in its current form, performs poorly in screening for EA.³ In this retrospective study, out of 55 cases with EA only 2 cases exhibited any sign of EA at the early anomaly scan (small/absent stomach). This supports the view that the conventional signs of EA (small/absent stomach, polyhydramnios) are of limited value in early pregnancy. Therefore, there is a need for an alternative screening method that can be applied in early pregnancy in order to identify patients at-risk for EA that should be offered a targeted scan for a pouch later in pregnancy.

4.2 | Feasibility of esophageal demonstration throughout pregnancy

Previous studies that evaluated the feasibility of esophageal visualization during the midtrimester anomaly scan^{16–19} have demonstrated the cervical esophagus in 16%–93% of the cases and the thoracic esophagus in 91.7%–99.5% of the cases. At this stage in pregnancy, due to its length and angled course, the esophagus is demonstrated in segments¹⁷ consequently, a small disruption of the esophagus may be missed.

4.3 | The advantages of esophageal visualization during early pregnancy

Early pregnancy offers some important advantages in esophageal imaging. First, due to its short length, the continuity of the fetal esophagus can be ascertained in a single sonographic frame, decreasing the chance to overlook a defect. Second, the sternum and anterior rib cage have not yet ossified, enabling an undisturbed view of the esophagus. As pregnancy advances the sternum and the anterior rib cage gradually ossify, casting acoustic shadows and obscuring parts of the esophagus. Third, in the early stages of pregnancy the echogenic esophagus is more prominent and easily

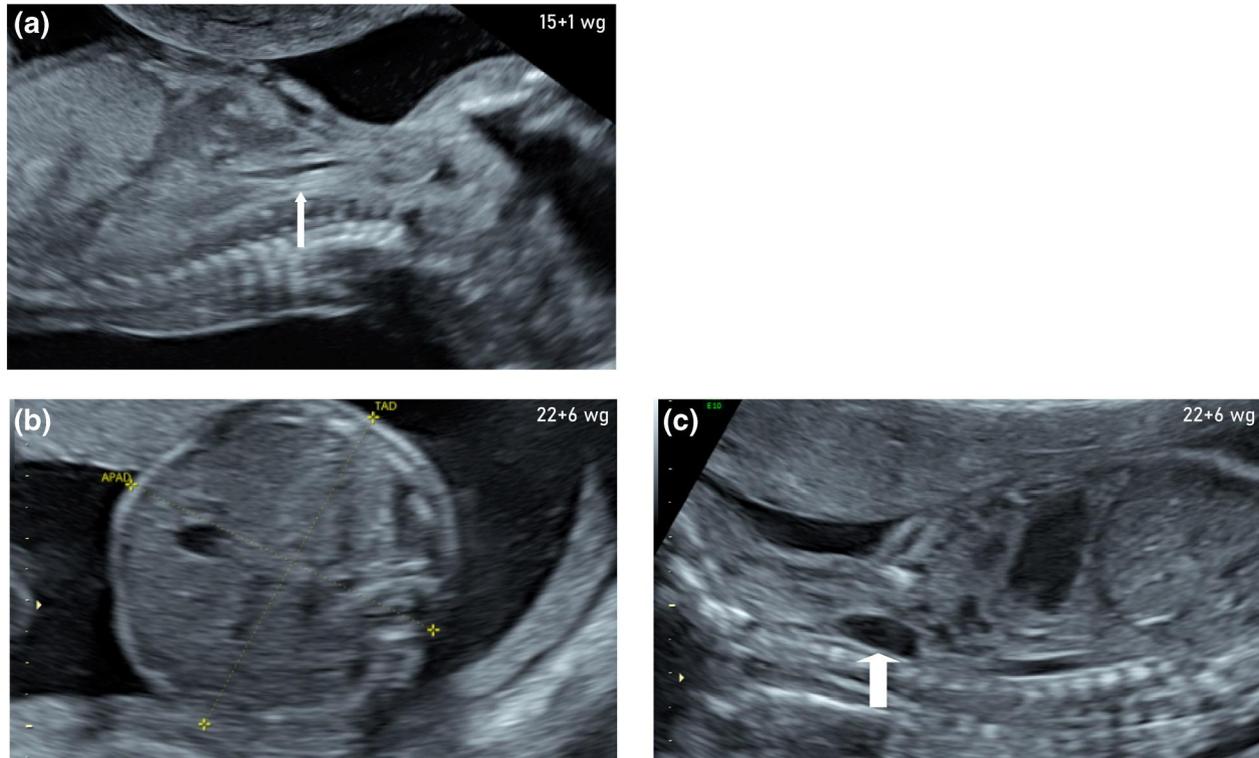


FIGURE 3 A case was at 15 + 1 weeks of gestation, during the early anomaly scan the cervical segment of the esophagus was demonstrated clearly (thin arrow) while the thoracic segment could not be demonstrated (A). At the midtrimester anomaly scan (22 + 6 weeks of gestation) the stomach could not be visualized (B) and a cervical esophageal pouch (thick arrow) was repeatedly demonstrated, diagnosing EA (C and Video S1). Abbreviation: w, weeks of gestation. Image 3A was taken using a transvaginal approach. Images 3B and 3C were taken using a transabdominal approach [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 U.S. exam characteristics

Characteristics	Study group (n = 145)
Type of transducer	
RIC6-12 vaginal transducer (%)	88% (128/145)
RM6C transabdominal transducer (%)	12% (17/145)
Time to visualization of the esophagus, m (r)	13 s (5–30 s)
Presence of fluid (%)	14.6% (21/145)
Thoracic esophagus (%)	100% (21/21)
Cervical esophagus (%)	28.6% (6/21)
Abdominal esophagus (%)	28.6% (6/21)

Abbreviations: m, mean; r, range; s, seconds.

distinguished from its surrounding in comparison to the second half of pregnancy where it is less prominent and blends with the surrounding neck structures (Figure 5). As previously mentioned, the importance of imaging the esophagus early in pregnancy, is to identify fetuses at risk for EA and perform a targeted pouch scan, later in pregnancy, in these cases.

4.4 | Early pregnancy esophageal imaging in the literature

To our knowledge the only other study that systematically analyzed the esophagus during the first trimester anomaly scan was by Venkatesh.¹⁸ This study included 102 pregnant women at 11–14 weeks of gestation and imaged first a transverse section of the esophagus and then rotated the probe 90° to identify the longitudinal section of the esophagus. Using this technique, the entire length of the esophagus was demonstrated in 88.2% of cases, with the cervical esophagus imaged in 88% of the cases and the thoracic portion imaged in 97% of the cases. In contrast, by scanning in the midsagittal plane using the trachea as an anatomic landmark, we were able to visualize the whole length of the esophagus, in one shot, in all the intact cases. The one case that a one shot whole esophageal image was impossible to obtain, proved to be a case of EA. Furthermore, we were able to conduct a postnatal follow-up to confirm an intact esophagus in order to validate our technique by correlating between pre- and postnatal findings. The new technique was found to correctly identify intact and atretic esophagus.



FIGURE 4 Ultrasound images of the esophagus filled with fluid in its different segments at 12–17 weeks of gestation: at the level of the thorax (A), cervix (B), and abdomen (C). Images were taken using a transvaginal approach

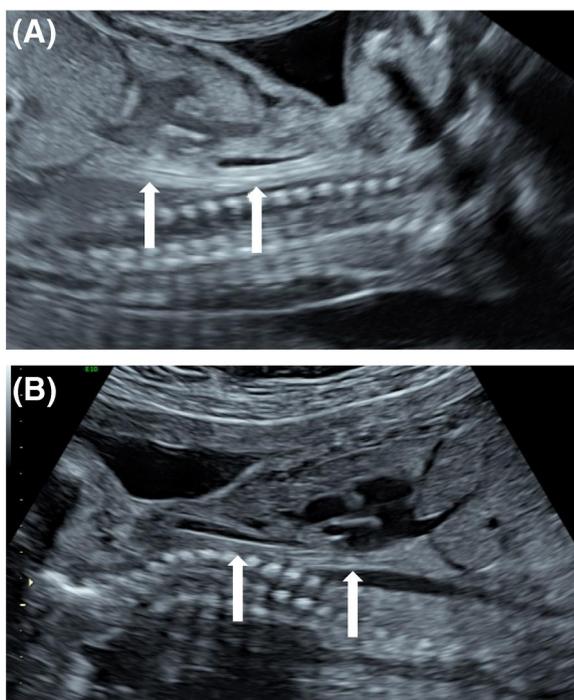


FIGURE 5 A comparison of the fetal esophagus at 14 weeks of gestation (A) and 22 weeks of gestation (B). Abbreviation: w, weeks of gestation. Images were taken using a transvaginal approach [Colour figure can be viewed at wileyonlinelibrary.com]

The strengths of our study are its prospective nature and the inclusion of an unselected population, minimizing various bias effects. Another strength is the performance of a postnatal follow-up in order to validate the new method. The limitations of our study should also be acknowledged. This is a preliminary feasibility study encompassing a relatively small cohort although to the best of our knowledge this is the largest study to evaluate the feasibility of imaging the entire esophageal length during the early anomaly scan. In addition, in our study there was only a case of long gap EA. We did not have a case with a short gap EA and we cannot be certain that the new method will identify a short gap defect in early pregnancy. A larger study with more cases of EA is needed in order to evaluate the performance indices of this method and determine its clinical relevance.

5 | CONCLUSIONS

In conclusion, it is feasible to demonstrate esophageal continuity in early pregnancy. Early pregnancy is a window of opportunity for a clear and undisturbed view of the entire esophagus. This may serve as a new screening tool in early pregnancy to identify patients at risk for fetal EA that will subsequently require further investigation.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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