A 33-year-old pregnant woman had been referred to our center at 28+1 weeks’ gestation. Maternal transabdominal fetal ultrasound imaging at that time revealed a fetal congenital diaphragmatic hernia with very hypoplastic lungs. Because of the poor prognosis of the fetal congenital diaphragmatic hernia, temporary fetoscopic balloon occlusion was performed as a potentially live-saving experimental treatment approach. Fetoscopic tracheal balloon removal was scheduled at 32+5 weeks’ gestation. At that time, fetal ultrasound imaging was more difficult because of the more advanced gestational age in combination with severe adipositas (body mass index = 43 kg/m²) and polyhydramnios (Figure 1). Therefore, the feasibility of intraamniotic fetal echocardiography (IFE) was assessed as a more suitable monitoring tool. The fetoscopic and ultrasound-guided procedure was performed with parental informed consent and approval from the local committee of human research, in accordance with the ethical standards for human experimentation established by the Declaration of Helsinki.

The procedure was performed under general maternal anesthesia using desflurane and remifentanil. An 11-F catheter sheath was percutaneously placed into the amniotic cavity. Then, a 10-F single-plane intravascular ultrasound catheter (AcuNav, Acuson-A-Siemens-Company, Erlangen, Germany) was inserted via the catheter sheath into the amniotic cavity and placed against the fetal chest (Figure 2). The catheter was tipped with a frequency-agile 5.5- to 10-MHz vector phased-array ultrasound transducer that permits high-resolution 2-dimensional real-time imaging as well as multimodal Doppler imaging in a single plane that extends parallel to the long axis of the catheter into the lateral direction. Sound penetration ranged from 2 mm to about 10 cm from the lens.

IFE permitted substantially clearer definition of fetal cardiac anatomy, lung hyperechogenicity, and fetoplacental blood flow than conventional maternal transabdominal fetal echocardiography. A variety of nonstandard cardiac views were obtained from various intraamniotic positions that allowed good-quality 2-dimensional imaging of all cardiac chambers, semilunar and atrioventricular valves, and supra- and infracardiac vessels (Figures 2 and 3). Color and pulsed Doppler imaging permitted assessment of fetal cardiovascular flows and fetoplacental circulation.

After IFE, fetoscopic guidance was used to destroy the tracheal balloon, and the catheter sheath was removed. Mother and fetus tolerated the procedure well, and complications were not observed. The fetus was electively delivered at 34+5 weeks’ gestation at the University of Mannheim, a center specializing in the treatment of infants with congenital diaphragmatic hernia.

These images prove the potential of IFE during fetoscopic surgery in a human fetus. The novel technique provides a useful cardiovascular monitoring tool during fetoscopic procedures when conventional maternal transabdominal assessment of fetal hemodynamics is severely impaired by unfavorable imaging conditions or when gas insufflation of the amniotic cavity is performed. Intraamniotic placement of the ultrasound catheter is performed via the same port through which the fetoscopic procedure is performed. The intraamniotic positioning of the imaging catheter helps avoid the problems of sound attenuation and scattering from the adipose maternal abdominal wall and also helps overcome the large distance to the fetus that has severely impaired maternal transabdominal fetal imaging.

Fetal IFE permits 2-dimensional as well as color Doppler and pulsed-wave Doppler studies of the fetal heart and fetoplacental circulation from within the amniotic cavity. Because standard views (eg, 4-chamber view, short-axis view, aortic arch view, ductal arch view) may not be obtained by this technique, the intraamniotic imaging approach requires advanced expertise in fetal echocardiography. It may also prove difficult to achieve low incidence angles for all cardiac, great vessel, and fetoplacental flow regions during an individual study. Therefore, estimation of transvalvar pressure gradients, assessment of volume flow, and quantitation of valvar regurgitation may be impossible. Despite these limitations, pathological flow profiles such as retrograde flow with atrial contraction inside the ductus venosus, pulsatile flow inside the umbilical vein, absent or reversed end-
diastolic flow inside the umbilical artery, or turbulent flow across a stenotic valve can be depicted.\textsuperscript{2}

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**References**


**Figure 1.** Preoperative magnetic resonance image (top) at 32 + 4 weeks’ gestation demonstrating the obstacles adipoitas and polyhydramnios for conventional maternal transabdominal fetal echocardiography in this patient (arrow points at latex balloon inside the fetal trachea). At that time, maternal transabdominal imaging was even more difficult than at initial presentation because of the more advanced gestational age in combination with severe adipositas (body mass index = 43 kg/m\(^2\)) and polyhydramnios. Two-dimensional cross-section images (middle and bottom) with 2 different ultrasound system settings in the 4-chamber plane demonstrated the poor maternal transabdominal ultrasound imaging quality that could be achieved in this patient.
Figure 2. Preparing the setup (top left) for fetal intraamniotic fetal echocardiography (IFE) in this human fetus with diaphragmatic hernia. The proximal end of the catheter with its electronic connector and steering unit was draped. After percutaneous intraamniotic placement of an 11-F catheter sheath by the Seldinger approach (top right), the ultrasound catheter was inserted into the amniotic cavity. IFE short-axis view (middle left) as displayed on the screen of the ultrasound system. All 4 chambers of the heart can be recognized in good detail (middle right). RA indicates right atrium; RV, right ventricle; LA, left atrium; and LV, left ventricle. Note the marked hyperechogenicity of the fetal lung as a result of fetoscopic tracheal balloon occlusion in this patient. The origin of the great vessels are displayed in this plane (bottom left). AAo indicates ascending aorta; MPA, main pulmonary artery; RA, right atrium; LA, left atrium. Middle right, pulsed Doppler IFE of diastolic filling across the tricuspid valve (TV). Bottom left, IFE color Doppler cross-section image of the umbilical cord. Bottom right, clear velocity–time integral of umbilical arterial flow (UA) as obtained by pulsed Doppler IFE in this patient.

Figure 3. Fetal IFE color and pulsed Doppler imaging in this patient with diaphragmatic hernia. Color frame (top left) shows systolic ejection into the great vessels. AAo indicates aorta; MPA, main pulmonary artery; RA, right atrium; LA, left atrium. Top right, pulsed Doppler IFE of flow across the pulmonary valve (PV). Middle left, diastolic frame shows filling of the 2 atria. Middle right, pulsed Doppler IFE of diastolic filling across the tricuspid valve (TV). Bottom left, IFE color Doppler cross-section image of the umbilical cord. Bottom right, clear velocity–time integral of umbilical arterial flow (UA) as obtained by pulsed Doppler IFE in this patient.
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