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A novel systematic approach to the evaluation of the fetal venous system

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S U M M A R Y

Sonographic evaluation of the fetal venous system in normal and abnormal conditions has drawn increasing interest in recent years. Whereas the assessment of the fetal heart and the related arteries is standardized using well-defined planes, the fetal venous system is still lacking a systematic approach. In this article we present a novel sonographic algorithm for a systematic examination of the fetal venous system using six planes of transverse and oblique views of the fetal abdomen and chest. These planes, using two-dimensional and color Doppler, enable a targeted demonstration of the typical veins to include the umbilical vein, ductus venosus, portal veins, hepatic veins, inferior vena cava, azygos vein, pulmonary veins, coronary sinus, superior vena cava and brachiocephalic vein. We postulate that integrating such a sequential stepwise algorithm for the evaluation of the venous system into targeted fetal cardiac imaging may improve the detection of isolated and combined anomalies of the fetal systemic and pulmonary veins.

1. Introduction

Prenatal detection of venous anomalies has improved in the last several years facilitated by the advent of high-resolution gray-scale and color Doppler ultrasound. The complex process of fetal cardiovascular system morphogenesis provides the basis for the great variety in congenital venous anomalies.[1] Some of these lesions are isolated, incidental findings during routine ultrasound examination and have little impact on fetal hemodynamics. They may, however, be associated with major congenital heart defects and complicate postnatal surgical repair; or they may cause volume overload of the heart with subsequent impairment of the myocardial function and development of fetal hydrops.[2] The association of venous anomalies with extracardiac malformations, chromosomal aberrations and genetic syndrome has also been reported.[3]

In this review, we describe a sonographic algorithm that allows standardizing and simplifying the comprehensive examination of the fetal venous system. We show how this approach helps significantly to improve the detection of fetal anomalies in systemic and pulmonary veins.

In evaluating the fetal venous system, a sequential stepwise algorithm helps in the description of normal and abnormal findings in a clear and simple approach.[4] After establishing the exact fetal position within the uterus, several transverse and oblique views of the fetal chest and abdomen should be obtained to assess the following components of the fetal venous system:

- umbilical vein (UV)
- ductus venosus (DV)
- portal veins (PortVs)
- inferior vena cava (IVC)
- hepatic veins (HVs)
- coronary sinus (CS)
- pulmonary veins (PVs)
- azygos vein (AzV)
- superior vena cava (SVC)
- brachiocephalic vein (BCV)

Each component of the venous system should then be described in terms of present/absent, location, origin, course, tributaries, size, spatial relationship to the other anatomical structures, anastomosis, termination and blood flow pattern. The use of color and pulsed Doppler in addition to two-dimensional imaging is essential and helps in full anatomic description of complex anatomy of the fetal venous system. Note that low-scale Doppler presets are required in most cases. Several studies have demonstrated the

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utility of high-definition flow and three-dimensional ultrasound in imaging of the fetal venous circulation in normal and abnormal conditions.[5–7]

2. View 1: abdominal sweep

The starting point for the evaluation of the fetal venous system is the transverse view of the fetal upper abdomen. This is a standard plane, which is routinely used to measure the abdominal circumference and to determine fetal visceral situs.[8,9] A perfect transverse view of the fetal abdomen requires the following anatomic markers: (i) a complete fetal rib is imaged along each of the two lateral abdominal walls; (ii) the fetal stomach is located in the left side of the abdomen; (iii) the descending aorta is imaged posterior, close to the spine and slightly to the left from midline; (iv) the IVC is situated more anterior and to the right from the midline; (v) an umbilical vein identified in the midline, directly anterior to the spine at the level where it joints the confluence of vessels called portal sinus, which further trifurcates at this point into ductus venosus, left and right portal veins (Fig. 1). Thus, careful evaluation of the transverse view of the fetal upper abdomen provides a general orientation on the spatial relationship of the three main components of the fetal venous circulation: the IVC, the umbilicoportal system and the ductus venosus. However, additional views should be used to assess each of these components in detail.

2.1. Umbilicoportal system

Only a short portion of the umbilical vein and intrahepatic portion of the portal system deep in the liver can be seen at the transverse view of the fetal upper abdomen. With slight angulation of the transducer caudally and slightly right, the oblique planes of the fetal abdomen allowing a full display of the umbilicoportal system can be obtained (Figs 2 and 3).

The umbilical vein enters the fetal abdomen via the falciform ligament and ascends along the inferior surface of the liver towards the porta hepatis and then terminates into the portal sinus. Pulsed Doppler sampling of the intra-abdominal portion of the umbilical vein in normal conditions demonstrates non-pulsutive, continuous, low-velocity flow (Fig. 4a).[10] However, mild phasic appearance of flow within the umbilical vein may be considered a normal feature until 15 weeks of gestation or in the late third trimester with fetal attempts at respiration.[11–13]

By definition, the portal sinus is a vascular space that extends from the point of the origin of the inferior left portal vein to the point of origin of the right portal vein.[14] On ultrasound it is seen as L-shaped vessel taking the anterioposterior course and curving to the right at 90°. The portal sinus represents the confluence of the following vessels: umbilical vein, extrahepatic or main portal vein, left and right intrahepatic portal veins and ductus venosus. The extrahepatic portal vein begins at the level of the second lumbar vertebra and is formed by fusion of the superior mesenteric and splenic veins. It lies obliquely to the right, anterior to the IVC and enters the liver in the porta hepatis. The place where the extrahepatic portal vein drains into the portal sinus is located inferiorly and to the right of the origin of the ductus venosus. This site also represents the anatomic point of portal vein division into left and right branches called the intrahepatic portal veins (Fig. 3). The left intrahepatic portal vein divides into three main branches – the inferior, superior and medial, while the right portal vein bifurcates into anterior and posterior branches. The junction between main portal vein and portal sinus exhibits variations in the angle of communication, which ranges from 90° to an almost parallel course. Three types of connection between main portal vein and portal sinus have been described[15,16]:

1. T-shaped, end-to-end anastomosis (the most common, observed in about 68% of cases)
2. X-shaped, side-to-side anastomosis (found in 12% of cases)
3. H-shaped, parallel anastomosis (identified in 15% of cases).

The measurement technique and reference ranges for diameter and blood flow velocities in the fetal portal vein during the second part of normal pregnancy were recently established.[17] The main portal vein can be successfully visualized and measured in about 94% of the fetuses between 20 weeks of gestation and term. The diameter of the extrahepatic PortV significantly increases through pregnancy from an average of 1.5 mm at 21 weeks of gestation to 3.4 mm at term. The blood flow in the main portal vein is pulsatile and directed toward the right branch, showing Doppler waveform with one velocity peak and one nadir during the cardiac cycle (Fig. 4b). The time-averaged maximum velocity in the main portal vein doubles throughout second half of gestation from 8.4 cm/s at 21 weeks to 15 cm/s at 39 weeks. Three different patterns of the blood flow waveforms obtained from the left and right branches of the portal vein showing no pulsation, mild single pulsation or double pulsation have also been described in the late third trimester.[18]

2.2. Ductus venosus

The ductus venosus is a branchless hourglass-shaped vessel, which represents a direct communication of the umbilical vein and the fetal heart (Fig. 5). It arises from the portal sinus directly

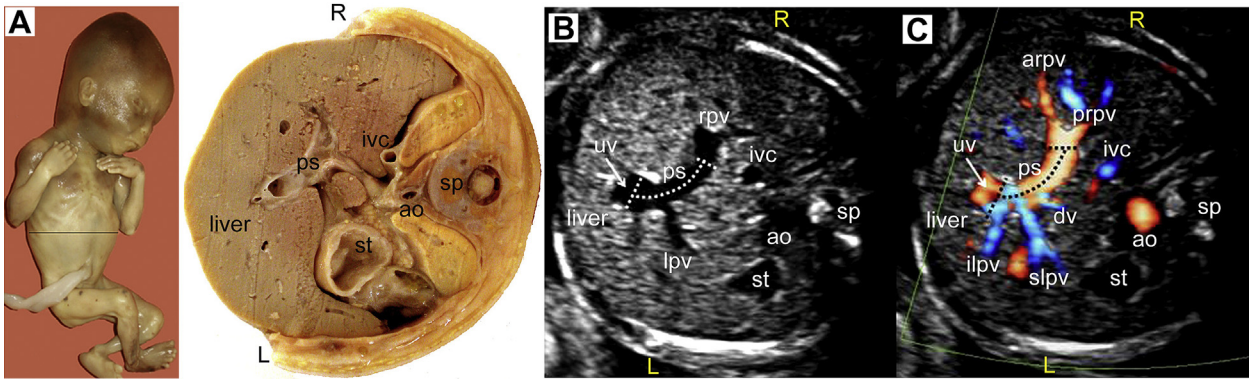

Fig. 1. Transverse section of the fetal upper abdomen at the level of portal sinus in pathology specimen (A), two-dimensional ultrasound (B) and color Doppler imaging (C). ao, descending aorta; arpv, anterior right portal vein; dv, ductus venosus; ilpv, inferior left portal vein; ivc, inferior vena cava; lpv, left portal vein; prpv, posterior right portal vein; ps, portal sinus; rpv, right portal vein; slpv, superior left portal vein; sp, spine; st, stomach; uv, umbilical vein; L, left; R, right.