

Superb Micro-Vascular Imaging (SMI) in the analysis of fetoplacental microvascular blood flow

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Introduction

Ultrasound monitoring of pregnancy is based on standardised 2D examination of the fetus and associated structures in each trimester of pregnancy. A second-look ultrasound examination is undertaken for diagnostic or prognostic purposes in various circumstances: localisation of a suspected morphological or biometric abnormality found on the screening ultrasound and/or identification of a clinical context or laboratory results that expose the fetus to a specific pathological risk.

This targeted examination frequently includes a Doppler examination of fetoplacental vascularisation.

Depending on the suspected abnormality, an MRI or CT scan will complete this investigation.

Investigation of fetoplacental vascularisation is currently limited when conventional Doppler is used because of the small size of the structures to be studied. The surprising sensitivity of SMI (Superb Micro-Vascular Imaging, Toshiba Aplio Series 2015) for visualising the fetoplacental vascular network and the potential of this technique for exploring anatomical or abnormal structures of the fetus and placenta are illustrated through various cases selected from our experience.

Observation of placental vascularisation with SMI (Fig. 1)

Using standard power Doppler, the vasculature of the basal plate of the placenta (maternal portion) is often readily identified. By contrast, the vasculature of the chorionic plate (fetal portion) can rarely be detected beyond the umbilical arteries and veins; a main stem of the villous network is sometimes seen. Yet the villous microvasculature cannot be seen: the vessel diameter of 500–1000 microns at the start of the second trimester of pregnancy is only a few millimeters close to term. Using SMI, the villous vascular tree can now be readily seen despite this very small vessel diameter.

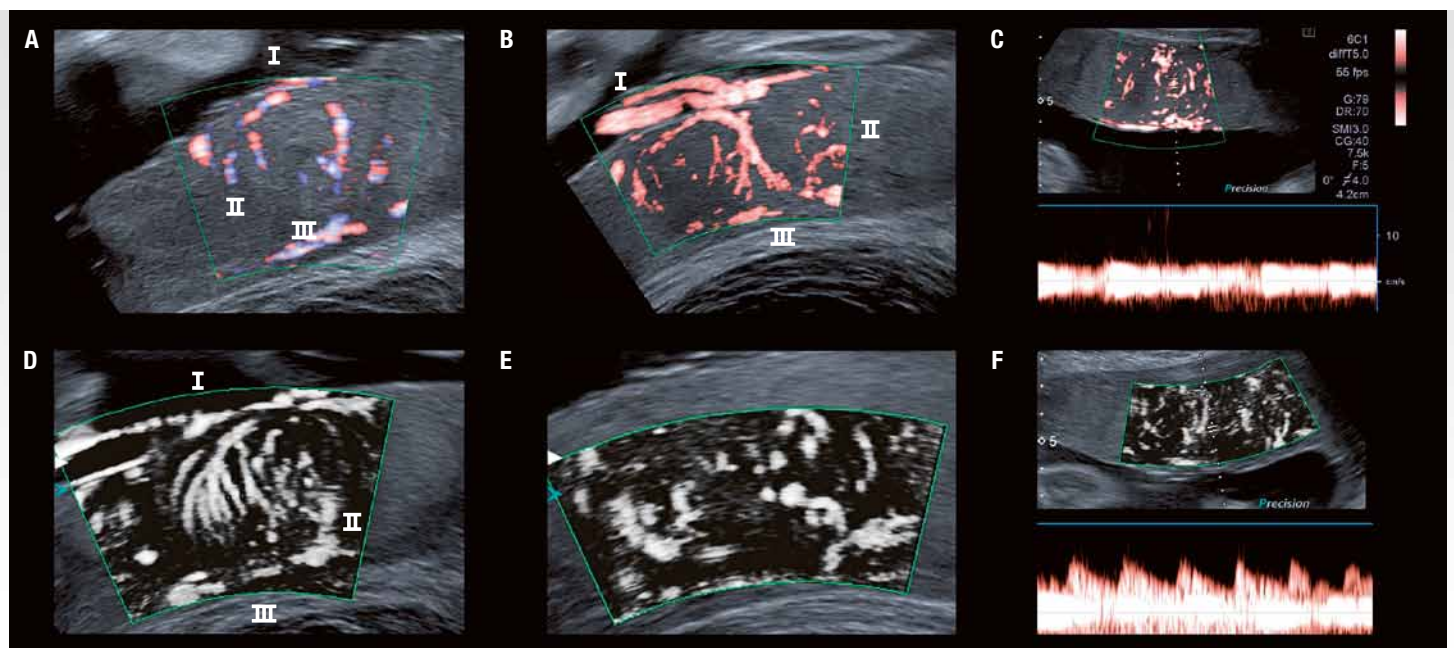


Fig. 1: Normal vasculature of the placenta

- A Conventional Doppler
- B, D, E SMI technique
- C, F Pulsed Doppler combined with SMI

I. Chorionic plate = fetal portion of the placenta

The umbilical arteries divide into several branches at the level of the chorionic plate of the placenta. These branches give rise to arteries which penetrate the main stem villus. (Fig. 1; B, D)

II. The intervillous space contains the chorionic villi through which intervillous arterioles and venules run. There is an abundant blood supply that penetrates all villi. Only SMI allows visualisation of the vascular tree within the villi. (Fig. 1; D, E, F)

III. Basal plate = maternal portion

The uteroplacental arterioles arise from spiral arterioles which gives them their “spiral” arrangement (Fig. 1; E)

Placental vascular insufficiency is implicated in 80 % of cases of intrauterine growth retardation (IUGR). The diagnosis is based on a range of clinical and laboratory evidence combined with biometric abnormalities. The sensitivity of SMI for visualising the placental microvasculature and its combination with the Doppler examination to analyse the resistance of the placental microvessels that can

now be seen opens the way to screening for and diagnosing placental abnormalities (Fig. 2).

Mapping of a vascular lesion of the fetus or placenta

The fetus and placenta are sometimes the site of a vascular malformation or vascular tumour. The risk is dominated by the haemodynamic complications linked to how extensive the blood supply of the lesion is. A Doppler examination is then very useful for evaluating the extent of the blood supply and monitoring how it develops: local complications such as bleeding or thrombosis may occur.

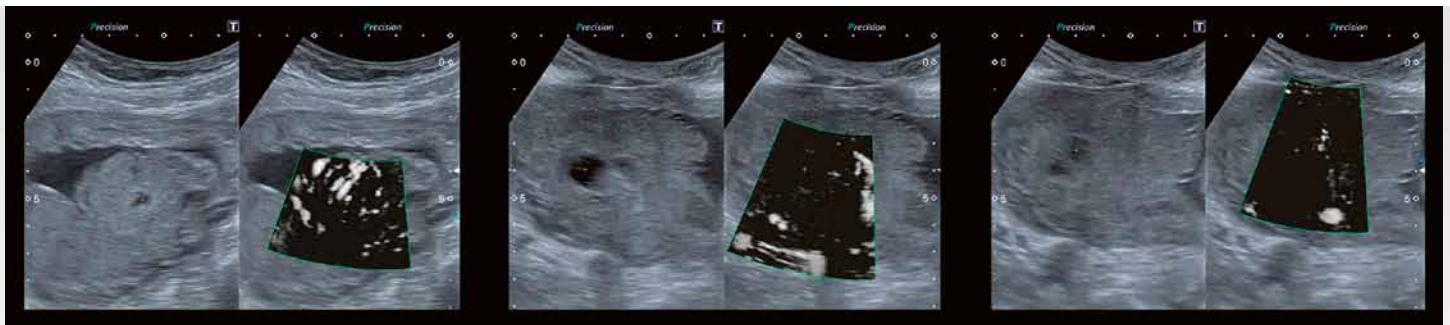


Fig. 2: IUGR with placental ischaemia

Note the absence, or decrease in density, of the placental vasculature using SMI over the different areas of the placenta examined.

Birth at week 28 of pregnancy in the context of pre-eclampsia. Birth weight = 560 grams.

On histological examination of the placenta: extensive areas of marginal infarction associated with diffuse ischaemic lesions.

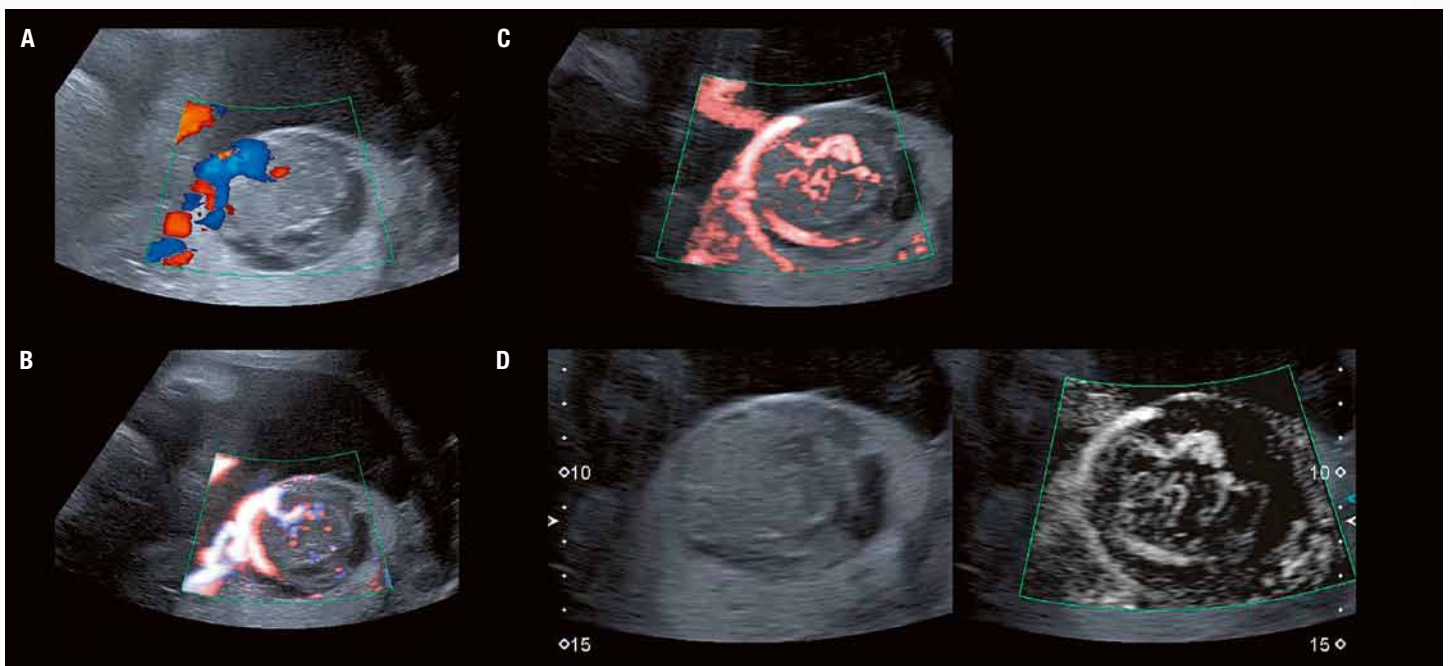


Fig. 3: Heterogeneous lesion of the subchorionic placenta close to the umbilical cord insertion into the placenta

A, B Only the largest arteries and veins can be seen on conventional Doppler.

C, D Identification of the microvascular blood flow within the lesion using SMI confirms the diagnosis and enables evaluation of the risk of haemodynamic decompensation by detecting microvascular areas and necrotic areas.

The microvascular blood flow of these lesions cannot be seen on a power Doppler examination because the vessels in question have very small diameters, while the accuracy of mapping obtained with SMI in the pre- or post-natal period is astonishing.

Placental chorioangioma (Fig. 3)

Placental chorioangioma is a benign vascular tumour of the subchorionic part of the placenta and is made up of numerous small capillaries incorporated in myxoid tissue. Heart failure with hydrops fetalis and fetal death may complicate large chorioangiomas. This risk increases if the blood supply is extensive, since this encourages the growth of the lesion and brings about a shunt effect. Conversely, the risk of complications decreases if there are significant necrotic changes. Fetal monitoring is adapted according to these criteria.

Subchorionic haematoma (Fig. 4)

Subchorionic haematoma, which may sometimes be very large, is relatively common and is not of any pathological significance. The total absence of a blood supply confirmed by the lack of signal during SMI ultrasound excludes a diagnosis of chorioangioma and thus the risk of haemodynamic complications. The formation of the haematoma followed by its reabsorption gives rise to a subchorionic cyst.

Vascular lesions of the choroid plexus (Fig. 5)

A papilloma of the choroid plexus is a very rare highly vascular benign tumour accounting for less than 1 % of brain tumours. The peak incidence occurs at about 6 months. The hyperechoic lesion is revealed by an enlarged ventricle or hydrocephalus which can be seen as early as the fetal period. The lesion sometimes shows microcalcifications or haemorrhage within the tumour.

Imaging cannot always be used for differential diagnosis between lesions of this kind and papillary carcinoma of the plexus. A meningioma is a very rare tumour in children. Comparison of sensitivity in detecting the microvasculature between SMI and conventional power Doppler. On pre- or post-natal ultrasound, only SMI allows visualisation of the hypervascular lesion as observed on MRI on delayed acquisition after injection.

Vascular mapping of healthy fetal organs

Doppler examination of a fetal organ (e.g. lung, liver, kidney, digestive tract) is useful in some cases to assess the organ's viability (Fig. 6 Gastroschisis) or to localise the organ when the anatomical landmarks are altered (Fig. 7 Diaphragmatic hernia).

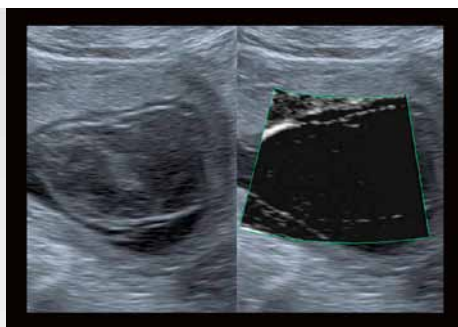


Fig. 4: Differential diagnosis: subchorionic haematoma

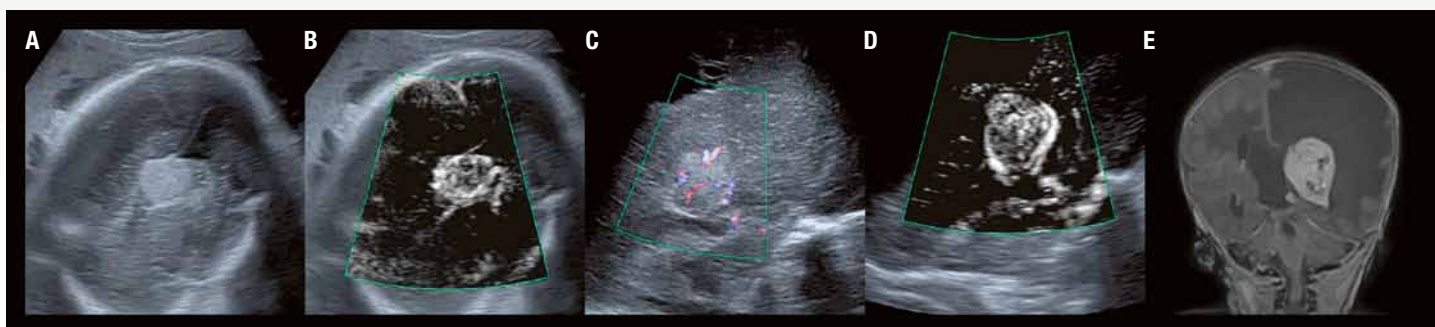


Fig. 5: Vascular lesion of the choroid plexus which is non-resectable by surgical operation

- A, B, C Pre-natal ultrasound at 32 weeks of pregnancy
- D Post-natal transfontanelar ultrasound
- E Post-natal MRI. Delayed T1 coronal slice after gadolinium injection. The hypervascular lesion causes vascular steal complicated by extensive ischaemic parenchymal lesions.

Gastroschisis (Fig. 6)

Gastroschisis is a defect of the abdominal wall located to the right of the umbilical ring. The finding of intestinal loops floating freely in the amniotic fluid from 12 weeks of pregnancy allows the diagnosis to be made. The loops are subject to various complications: atresia, volvulus and necrosis whose diagnosis is suspected if there are distended intra-abdominal loops indicating obstruction above the obstacle.

Diaphragmatic hernia (Fig. 7)

Herniation of the liver into the thorax is a poor prognostic factor in left diaphragmatic hernia. It is sometimes difficult to distinguish hepatic parenchyma from pulmonary parenchyma before the 3rd trimester because the echogenicity of these structures is similar. Analysis of the blood supply can identify them but the sensitivity of the conventional Doppler signal is sometimes insufficient

in a young fetus. The sensitivity of the SMI mode overcomes this problem by showing the hepatic vascular pattern.

The SMI mode also allows a lesion to be differentiated from healthy parenchyma when the echogenicity of the 2 structures is similar.

Pulmonary emphysema (Fig. 8)

On conventional power Doppler, examination of the blood supply of the kidneys, liver, wall of the intestines and pulmonary parenchyma is limited by the small size of the vessels beyond the proximal trunks. SMI can now be used to identify peripheral vessels with very small diameters. Observation of blood flow in these is facilitated by tissue subtraction images while preserving excellent spatial resolution. True mapping of the microvasculature is easy to obtain for abdominal structures and for the blood supply to the brain and placenta.

Examination of pulmonary vasculature depends on fetal presentation and is limited by the presence of overlying bony structures.

Summary

This new tool is very promising for the study and examination of the fetal and placental vasculature because it is suitable for identifying fetal and placental microvessels. Moreover, the frequency of abnormalities of the placental vasculature implicated in intrauterine growth retardation prompts us to use SMI systematically to examine the placenta of a fetus referred for intrauterine growth retardation. A comparison of ultrasound findings with fetal birth weight and with histological examination of the placenta would be an interesting subject for a preliminary prospective study.

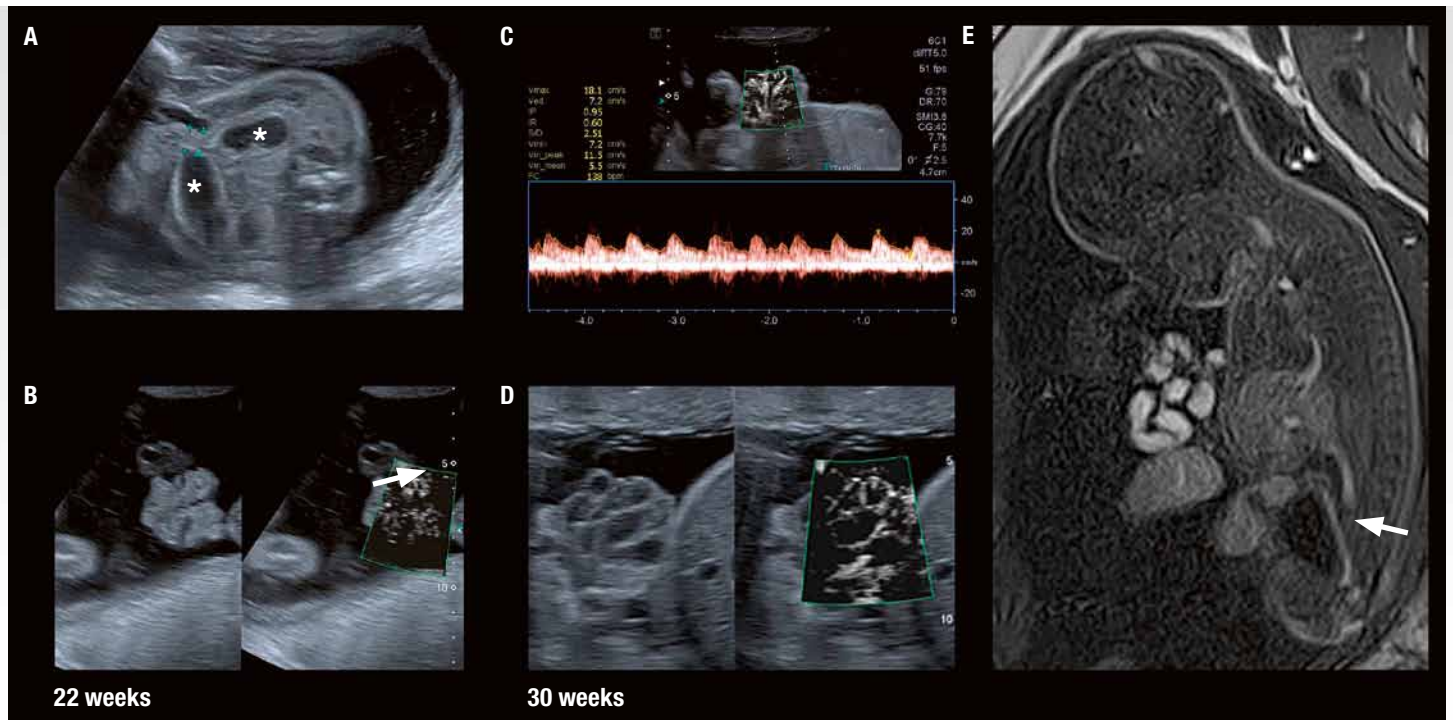


Fig. 6: Gastrochisis diagnosed at first trimester ultrasound

During ultrasound monitoring, an obstructive syndrome is noted at 22 weeks of pregnancy.

- A Dilated intra-abdominal intestinal loops (asterisk), narrow hernia neck measuring 6 mm.
- B Flat exteriorised loops; the fact that the parietal blood supply is highly visible on SMI suggests that the exteriorised loops have normal viability; differentiation from necrotic loops is not possible using 2D imaging alone or power Doppler.
- C, D This assumption is confirmed at 26 then 30 weeks of pregnancy when filling of the exteriorised loops and the vascularised appearance of the wall of the intestinal loops are observed.
- E Sagittal T1 slice on MRI: meconium content normal in the hyperintense signal of the exteriorised loops. Functional microcolon (arrow) below the obstruction.

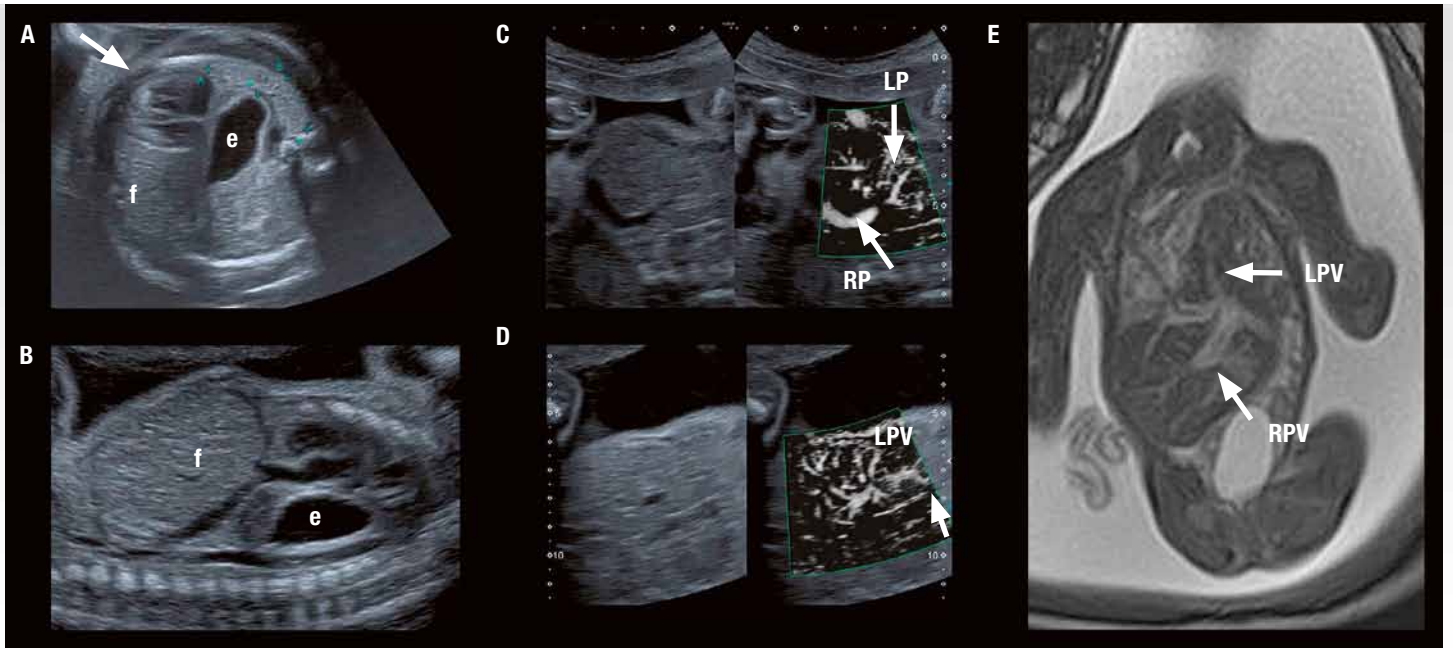


Fig. 7: Left diaphragmatic hernia at 26 weeks of pregnancy

- A. Thoracic axial slice at the level of the heart (arrow) displaced to the right, stomach (e) in front of the fetal spine, left antero-lateral mass, presumed to be liver (f).
- B. Right paramedian longitudinal slice on which the liver (f) is intra-abdominal and the stomach intrathoracic (e).
- C. Right portal vein and portal trunk are vertical in position (RPV and PT), small-diameter left portal trunk is intrathoracic (LPV) and not detected on 2D ultrasound.
- D. Vertical portal bifurcation and vasculature of the hepatic parenchyma recognisable in the thorax.
- E. T2 FASE AFI coronal slice on MRI: hepatomegaly with periportal oedema, the entire left lobe has moved up into the thorax.

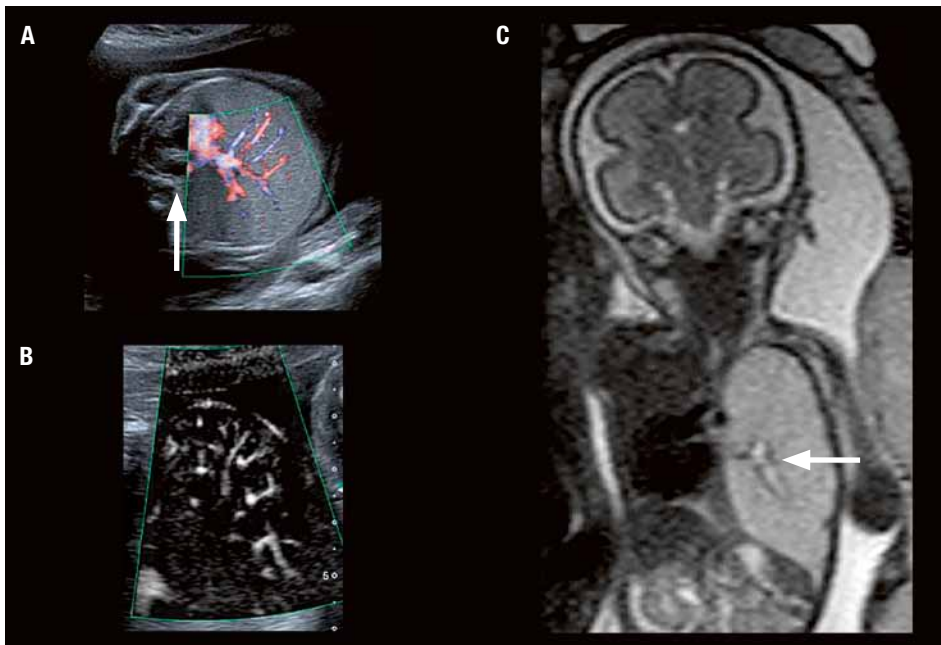


Fig. 8: Pulmonary emphysema: Courtesy of Dr Ch. Durand, Grenoble, France

- A. Axial slice of thorax. Doppler ultrasound (ADF). Distension of the left pulmonary parenchyma; the heart is displaced into the right hemithorax, arrow (A). Only the proximal vasculature can be seen on standard power Doppler.
- B. Axial slice of thorax. SMI technique. Vascular mapping of the entire pulmonary parenchyma is performed to reveal a harmonious vascular tree.
- C. Coronal slice. SSFSE T2 MRI sequence. Distension of the parenchyma below the bronchial obstruction; fluid bronchogram above it (arrow).

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07/2015 MWPUL0030EUC

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