

The value of dual-energy multidetector computed tomography as an adjunct to conventional investigations in pregnancy losses: Initial findings

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Aim

The use of computed tomography (CT) scanning as part of the post-mortem examination of adults is now well established [1]. The coronial departments in many industrialized countries, including Australia, regularly utilize both CT and MRI (magnetic resonance imaging) as part of their death investigations [2]. MRI is useful in the investigation of fetal abnormalities, particularly in the examination of the neural axis and soft tissues, but has several limitations. The availability of MRI is limited in Australia as a result of Medicare licensing restrictions. A comprehensive examination with MRI is also time consuming. As MRI signal relies upon the movement of free hydrogen atoms, signal quality is reduced in the post mortem patient due to cooling and/or refrigeration.

A recent article by O'Donoghue et al [3] used multidetector computed tomography (MDCT) as an adjunct to autopsy in the investigation of 3rd trimester stillbirths, finding good correlation between measurements obtained in both settings. CT scanning in fetal demise can avoid several MRI limiting factors. All but the most remote communities have access to CT scanners, and the relative speed with which a scan can be performed allows scanning quickly after delivery. Body temperature is also not important, allowing CT scanning to be performed at any stage after fetal demise.

We aim to investigate the value of dual-energy MDCT as part of the investigation into fetal abnormalities and pregnancy losses in the 2nd and 3rd trimesters, and early neonatal period. We present our initial findings, after the evaluation of six cases.

Methods and materials

The study was approved by the Women's and Children's Hospital Network Human Research Ethics Committee. Patients were recruited while giving consent for conventional autopsy. Fetuses were scanned as soon as possible after delivery. The fetuses were scanned as they arrived in the Department of Surgical Pathology, wrapped in surgical drapes, and were not repositioned for the scan. A dual-energy CT technique was utilized, to maximise contrast resolution.

Each fetus was imaged twice using a single source Spectral Dual Energy CT Scanning System.

Firstly, a high definition helical scan was completed, permitting the maximum spatial resolution possible for multiplanar bone and 3D volume rendered skeletal imaging (3D skeleton). This was followed by a dual energy acquisition. Both high and low energy (kVp) data sets are acquired simultaneously for near perfect anatomical registration. The dual energy image set was evaluated for the optimal image contrast and image noise. The optimal monochromatic energy level (keV) was concluded and a new image set was created for multiplanar evaluation of soft tissue organs. Radiation dose was, of course, not a significant consideration.

A conventional autopsy was performed on each fetus after CT scanning by an experienced paediatric/neonatal pathologist. The CT scans were analysed by a perinatal radiologist (first author) together with a paediatric/neonatal pathologist (second author). The clinical details (except gestational age) were withheld. The fetal biometry as well as findings relating to an external examination and internal organs were measured and recorded. The CT findings were then compared with the autopsy result, which was considered the "gold standard".

Results

Six fetuses were initially scanned. Three fetuses had been delivered after death in utero, and three were from pregnancies terminated due to fetal abnormalities ([Table 1](#) on page 5).

Fetal Measurements and External Examination.

In all but one fetus, the crown-rump and crown-heel length measurements determined on CT were within 6% of the autopsy measurements. There was quite poor correlation between CT and autopsy measurements of the fetal foot length and head measurements, which we believe is due to fetal positioning: the foot can be more easily "straightened" during a direct examination.

The genitalia were correctly identified on CT in three fetuses. The genitals were not assessed in two fetuses due to fetal position/umbilical clip position; in fetus 4 the genitalia was thought to be male on CT but were ambiguous at autopsy examination. The ears were clearly seen in four fetuses on CT ([Fig. 1](#) on page 6), and were mentioned as present in five fetal autopsies. The eyes were identified in all fetuses, and the lenses were seen in five cases on CT ([Fig. 2](#) on page 6). The eyes were seen at five of the autopsy examinations. The hard palate was correctly identified as intact in all fetuses (

Fig. 3 on page 7), the lip was seen to be intact in five fetuses (Fig. 1 on page 6) and was not able to be assessed in fetus 6.

Five digits were correctly identified on every limb of each fetus. The hands were identified as being clenched in fetus 3 on CT scanning (Fig. 4 on page 8), which was confirmed at autopsy. The foot position was thought to be normal in all fetuses on both CT scanning and at autopsy.

Fetal Skull and Skeleton.

Specific examination of the skeleton was not carried out at autopsy of these fetuses because there was no suspicion of a skeletal dysplasia.

CT showed twelve pairs of ribs in every fetus, and there were no fractures. The symphysis menti was distracted in fetus 6, and a hemi-vertebra was identified in fetus 4 (Fig. 5 on page 9). The skull was collapsed with overlapping bones in fetuses 2 and 6 (Fig. 6 on page 10), this was not assessable on autopsy in fetus 2 and was confirmed in fetus 6.

Intracranial Structures.

A normal midline was identified on the CT scans in all fetuses. Ventriculomegaly was correctly diagnosed in fetus 3 (Fig. 7 on page 11), and was not assessable in two fetuses on CT scanning or autopsy due to autolysis/maceration. Extra-axial haemorrhage was correctly identified in fetus 3.

Cardiorespiratory System.

Evaluation of the heart was poor on CT, as was expected in a non-contrast post-mortem study. The heart was correctly identified as normal in fetus 5, but much of the heart could not be commented upon, and even the great vessels were difficult to confidently identify. Significant cardiac abnormalities were identified in fetuses 2 and 3 at autopsy. The diaphragm could be seen to be intact in four of the fetuses at CT scanning (Fig. 8 on page 12), and was intact in all fetuses at autopsy.

Abdominal Organs.

The liver and spleen were identified in the correct position in four fetuses, and were not able to be assessed in two fetuses on CT scanning. The kidneys proved very difficult to identify due to the absence of intra-abdominal fat. In the three fetuses they were identified on CT scanning ([Fig. 9](#) on page 13), the kidneys were normal at autopsy. The kidneys were not identified in fetus 4 on scanning, and at autopsy the renal parenchyma was multicystic dysplastic in nature and horseshoe in morphology. The gallbladder and pancreas were not reliably seen in any fetus on CT scanning.

Diagnosis in Each Fetus.

After "CT autopsy" in fetuses 1, 2, 5 and 6, no anatomical abnormality was detected. This correlated with the autopsy findings for fetuses 1, 2 and 6. At autopsy, fetus 5 was shown to have grey matter heterotopia and schizencephaly, as suspected on antenatal ultrasound and MRI scanning. This was not visible on post mortem CT scanning.

Fetus 3 was suspected to have trisomy 18, which was confirmed on cytogenetic testing. The abnormalities detected on CT scanning were the clenched hands and dilated cerebral ventricles. The cardiac abnormalities were not identified.

Fetus 4 was suspected to have the "VACTERL" sequence, due to the hemivertebra and inability to visualize the kidneys on CT scanning. The autopsy also found an imperforate anus.

Comments were made in fetuses 2 and 6 with regards to oedema, gas in the soft tissues and lack of intracranial detail, which was interpreted as maceration/autolysis ([Fig. 10](#) on page 14). This was confirmed at autopsy.

Images for this section:

| | Gestational age (from antenatal ultrasound) | Case type | Time from fetal demise to delivery | Time from delivery to CT scanning |
|---------|---------------------------------------------|------------------------|------------------------------------|-----------------------------------|
| Fetus 1 | 19 weeks | Fetal death in utero | ~ 3 weeks | 3 days |
| Fetus 2 | 38 weeks | Fetal death in utero | ~ 4 weeks | 3 days |
| Fetus 3 | 20 weeks | Multiple abnormalities | nil | 3 days |
| Fetus 4 | 19 weeks | Multiple abnormalities | nil | 3 days |
| Fetus 5 | 22 weeks | Multiple abnormalities | nil | 1 day |
| Fetus 6 | 25 weeks | Fetal death in utero | ~ 4 weeks | 3 days |

Table 1: Demographic features of the six fetuses scanned.



Fig. 1: Surface reconstruction in a 38 week fetus. The ear is well seen on the right. The lip is intact.



Fig. 2: Oblique reconstructed image in a 22 week fetus. The globe is normally positioned in the orbit and the lens is clearly seen (arrow).

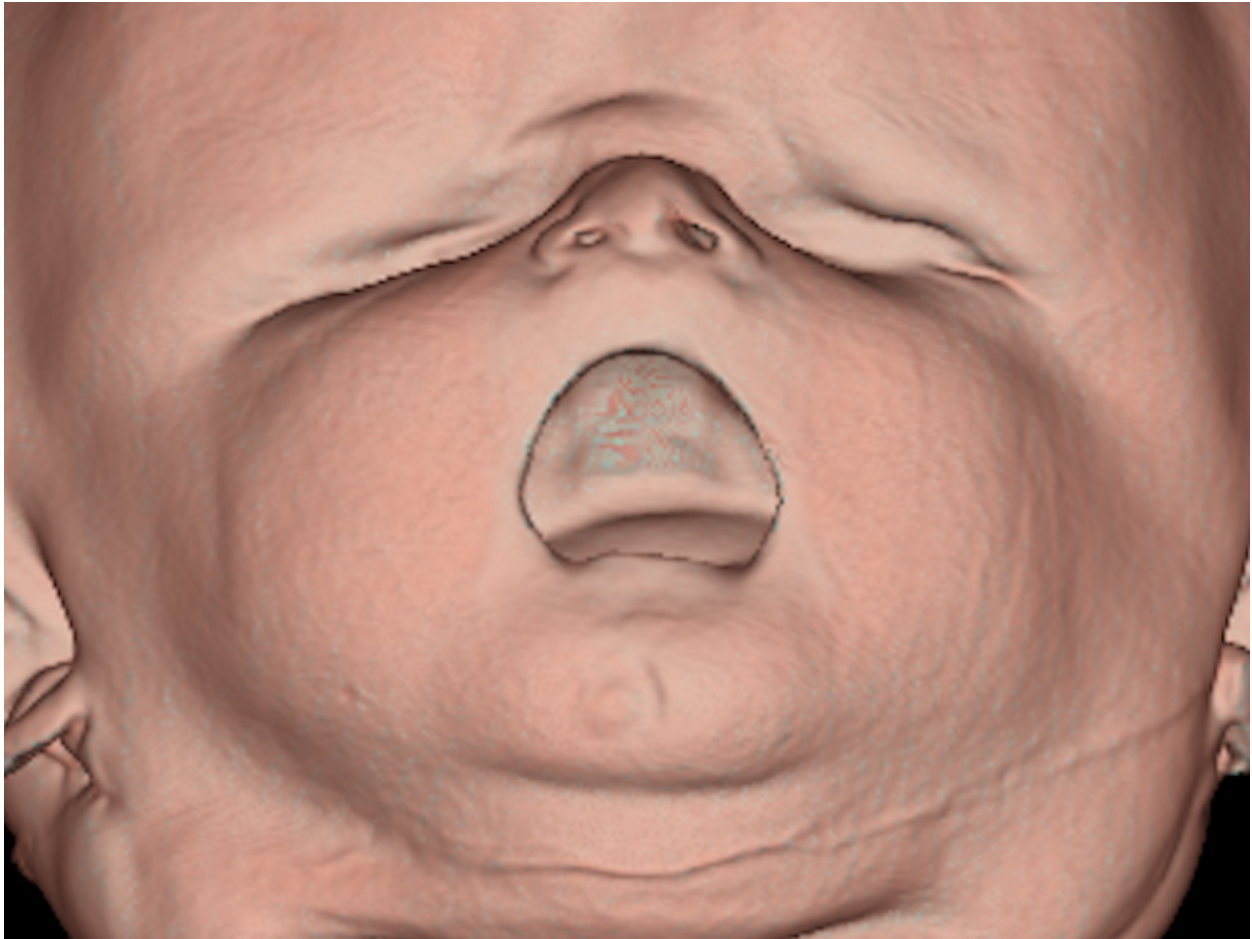


Fig. 3: The open mouth of this fetus allows the intact palate to be seen.

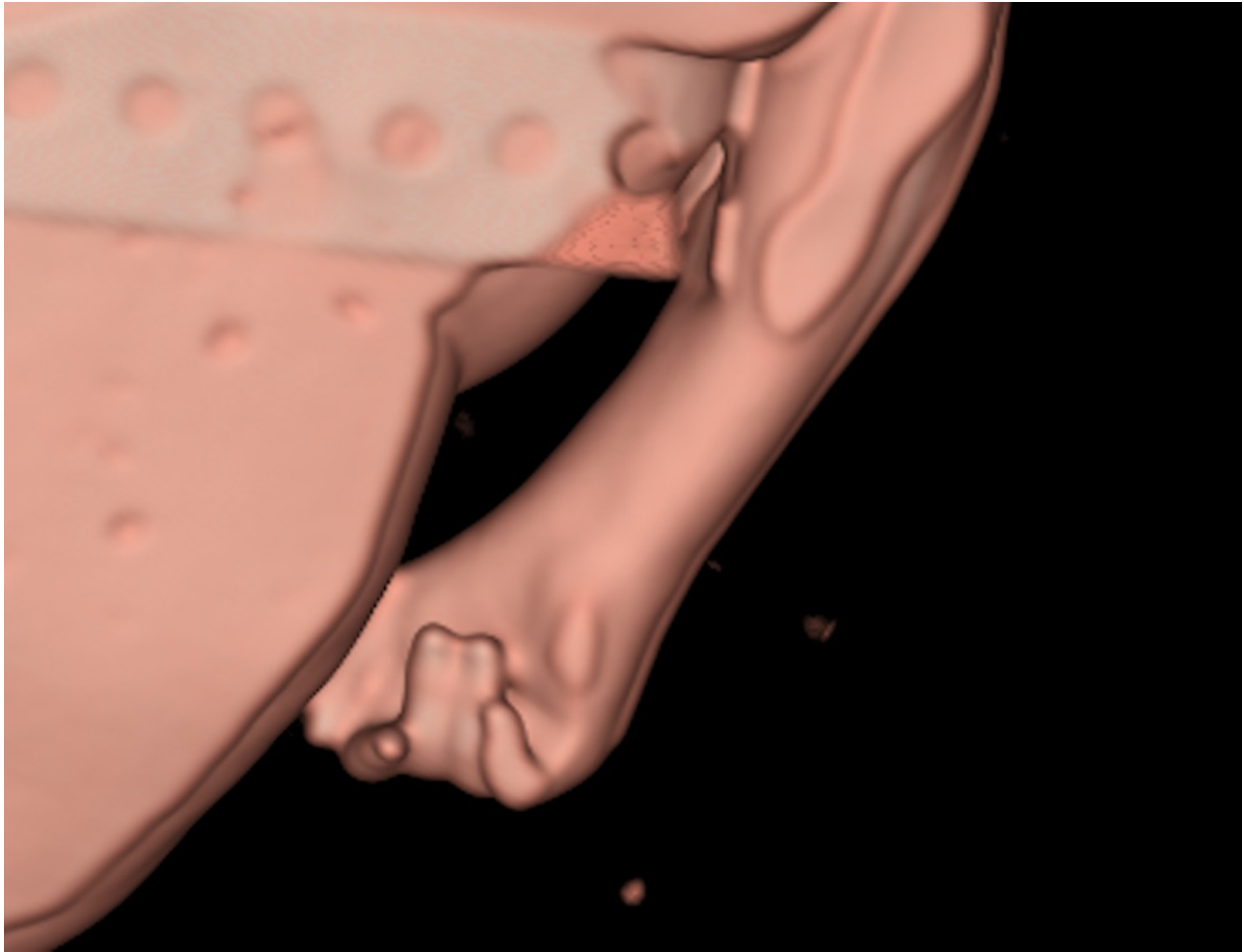


Fig. 4: The hand of this fetus shows the typical clenched appearance with overlapping 2nd and 5th digits that raised suspicion of trisomy 18.

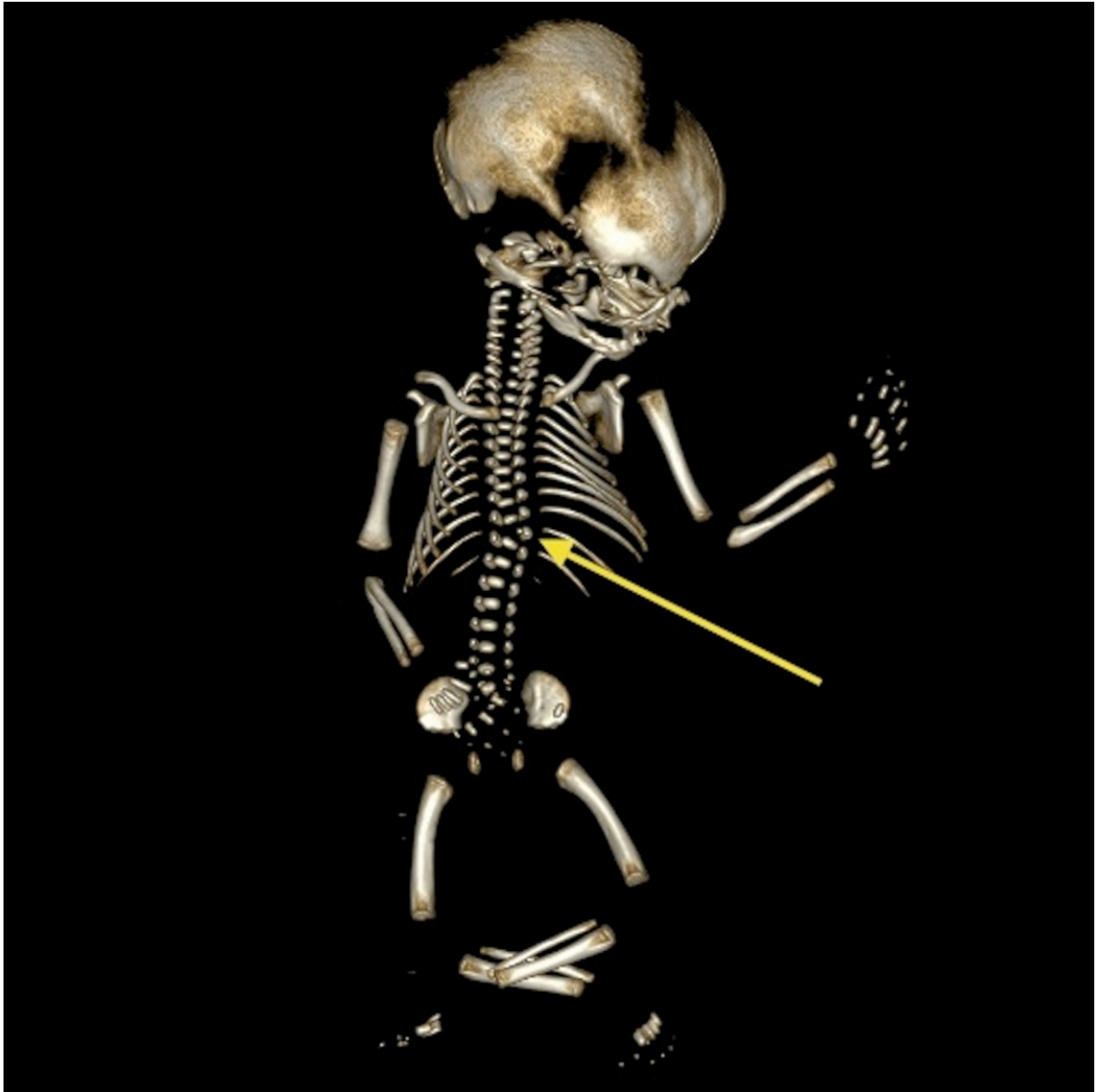


Fig. 5: 3D bony reconstruction of fetus 4. The spine is unbalanced due to a hemivertebra (arrow).

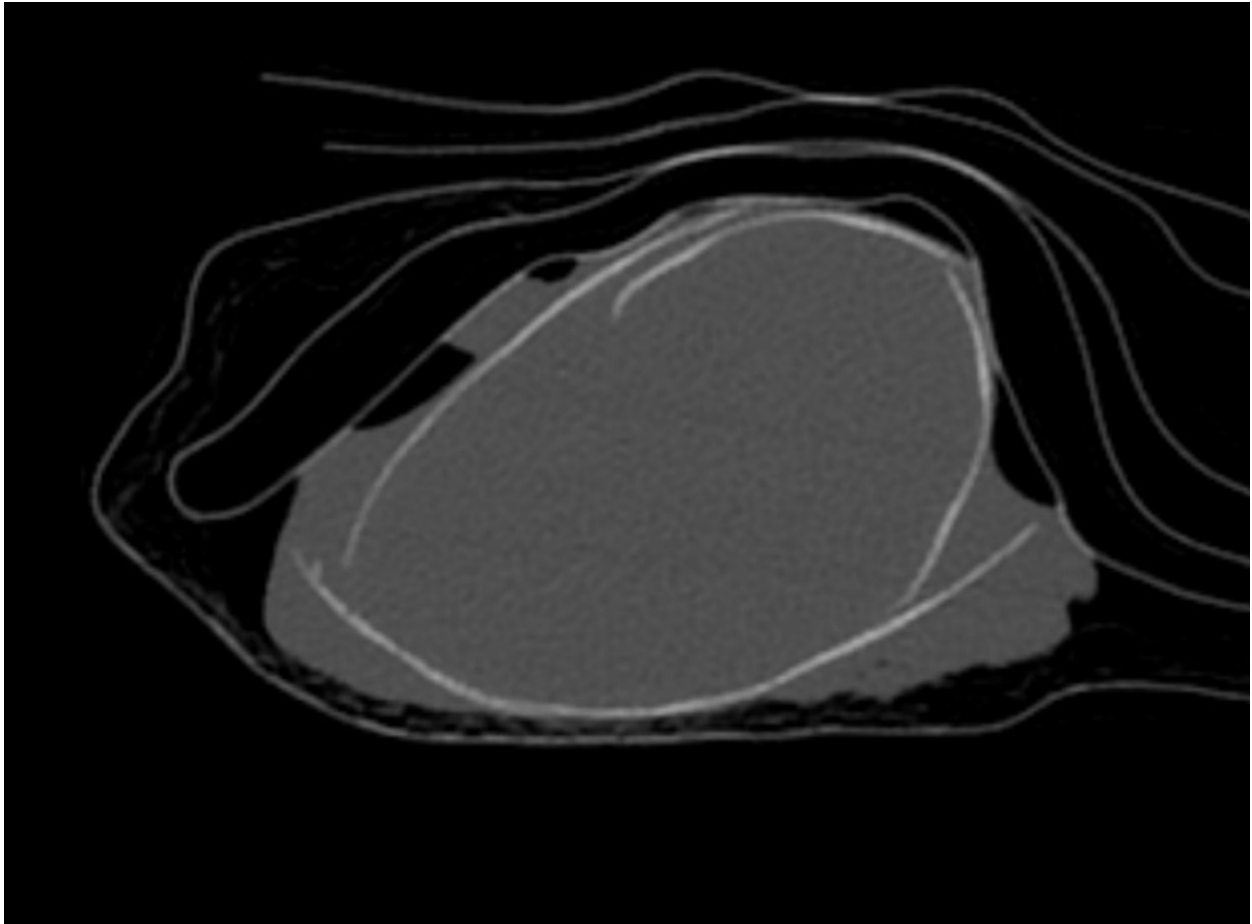


Fig. 6: Axial image of the skull of fetus 6. There is significant collapse with overlapping of the calvarial bones.

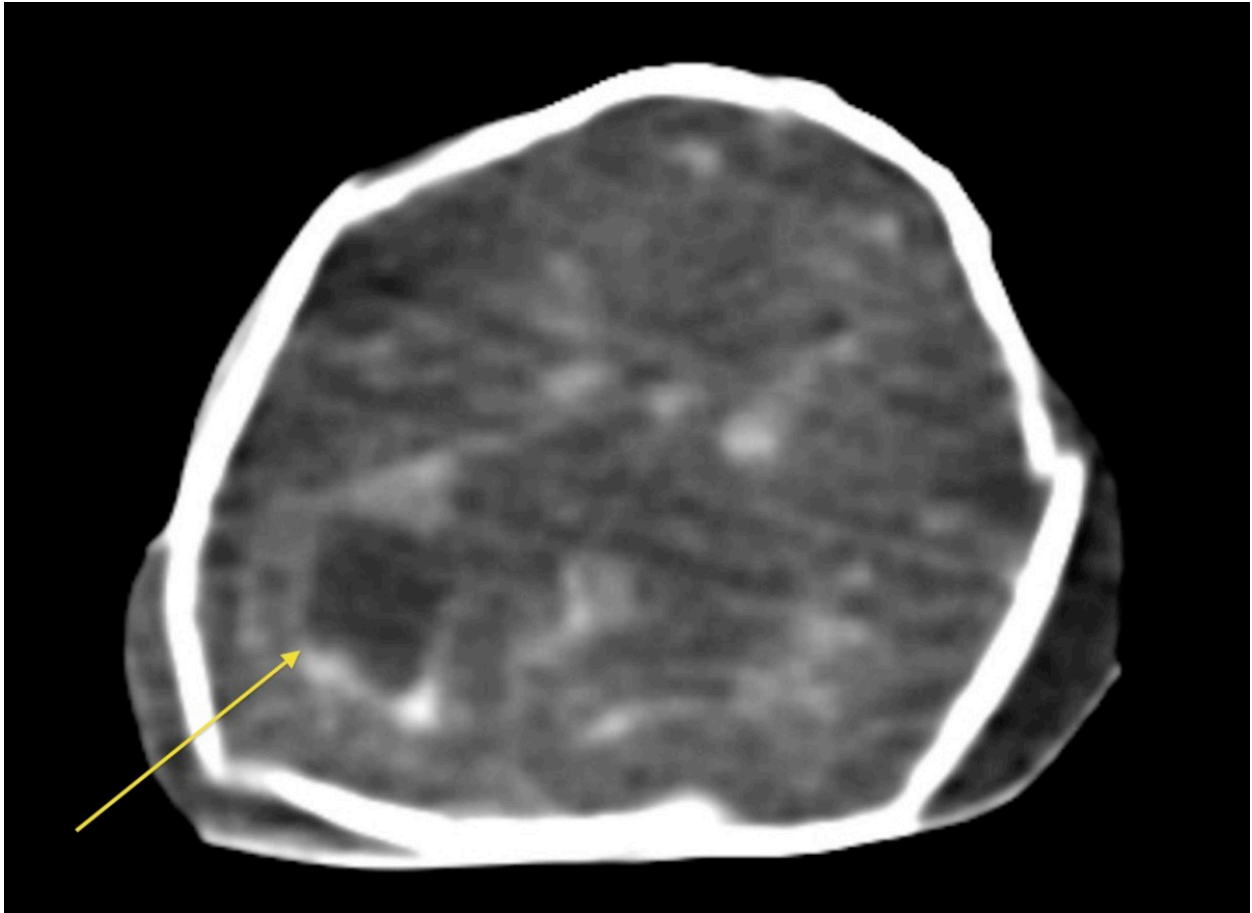


Fig. 7: Axial CT image of fetus 3. There is dilatation of the right lateral ventricle (arrow).

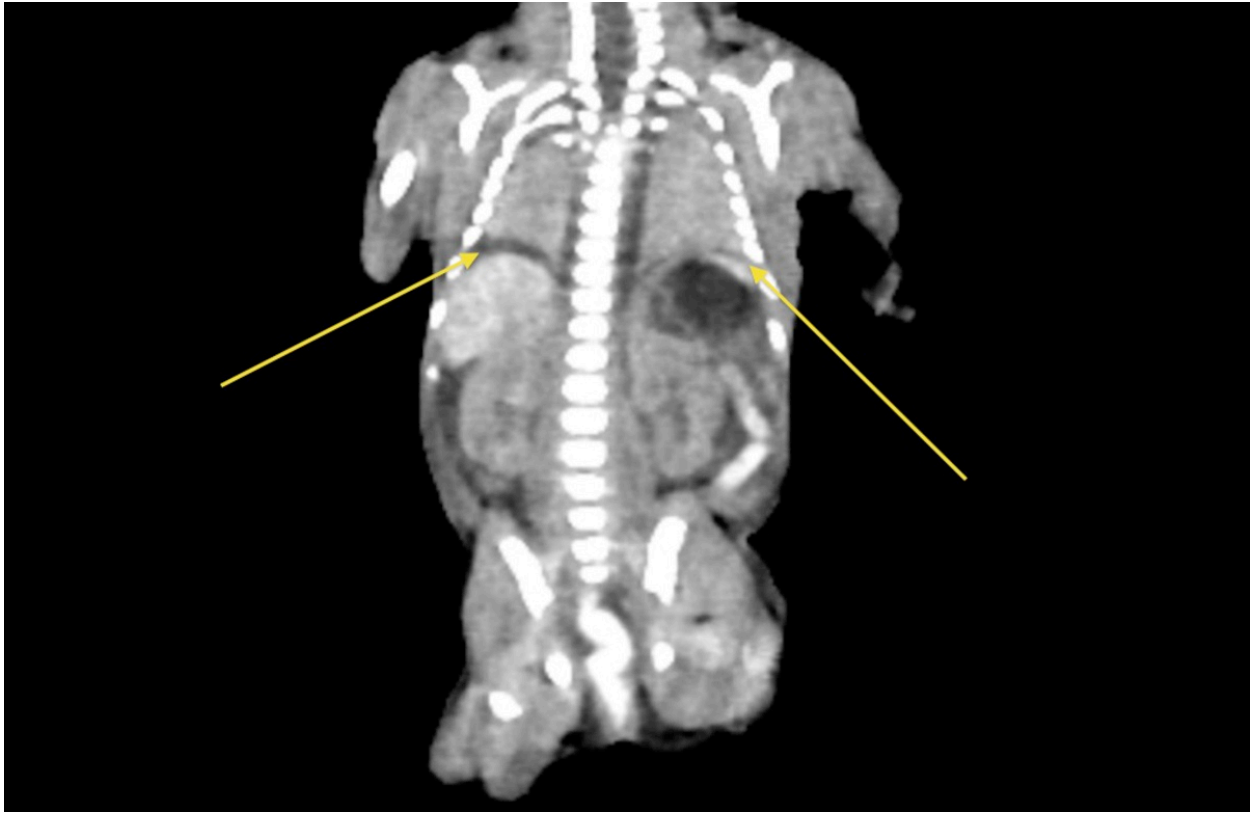


Fig. 8: Coronal CT reconstruction of the fetal torso. The diaphragms are clearly seen (arrows).



Fig. 9: Coronal CT reconstruction of the abdomen in fetus 5. The arrows show the superior and inferior poles of each kidney.

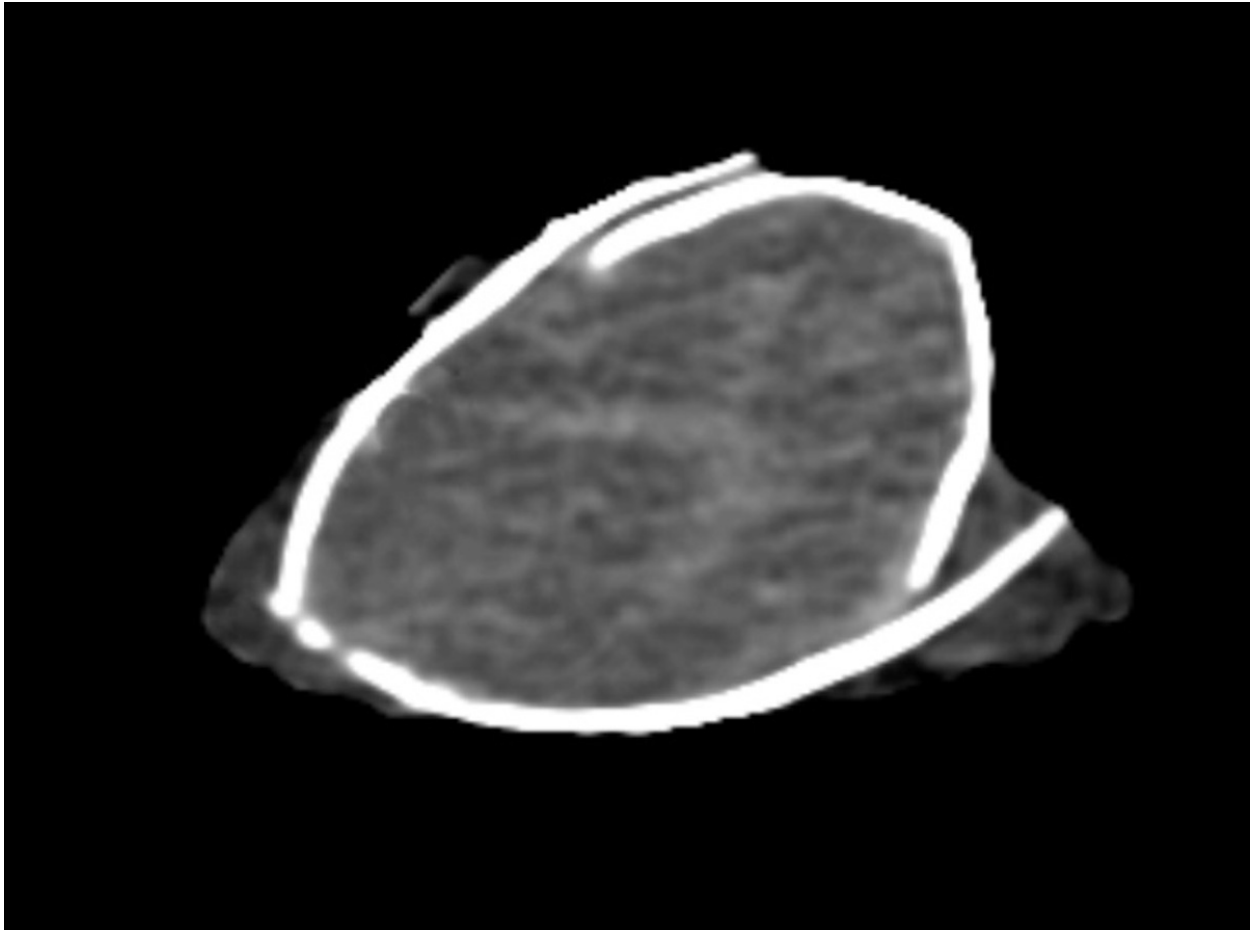


Fig. 10: Axial CT image of the brain of fetus 6. There are almost no recognisable intracranial structures.

Conclusion

Unexplained stillbirths account for more than 25% of all fetal deaths, and have multiple causes [3]. Autopsy has been shown to provide important information about the pregnancy that was not available antenatally in at least a third of cases [4]. There is reluctance on the part of the treating doctors to ask for consent for autopsy, and some grieving parents are unable to consent for variety of reasons. This leaves many parents at a clear disadvantage when being counselled for future pregnancies, which previously could not be avoided.

A recent study by Cannie et al [4] found that MR virtual autopsy was almost universally accepted by parents compared with an acceptance rate of around 2/3 for conventional autopsy. Although the specific reasons for acceptance were not examined, there was a correlation with the mother's religious background, with Muslim parents far less likely to consent to conventional autopsy.

While our preliminary scans did not detect all fetal abnormalities, some valuable information was obtained, and there are some features such as bony abnormalities, which can be difficult to elucidate at autopsy. We suggest that fetal CT scanning can be a useful adjunct to conventional autopsy, and in cases where fetal autopsy is not appropriate, fetal CT scanning can still provide useful additional information to assist with parent counselling.

Scanning is best performed as soon as possible after delivery to maximise tissue contrast, and does not significantly delay funeral/burial preparations. The potential use of intravenous contrast may also assist in providing further diagnostic information. It is likely that dual-energy MDCT will be useful in pregnancy losses where conventional autopsy is not appropriate.

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