Learning objectives

- How to prepare, perform and report whole body perinatal post-mortem ultrasound imaging
- Identify common 'normal post-mortem' imaging changes on ultrasound
Background

Declining parental consent rates for perinatal autopsy has led to the development of non-invasive methods for death investigation. Post-mortem ultrasound is a simple, effective and easily accessible alternative method. Many radiologists and sonographers already possess the skills to perform such a study however few have the experience and knowledge in what is required.
Findings and procedure details

PATIENT PREPARATION:

Consent and Referral Indication

Parental consent is vital in all aspects of a perinatal autopsy and, at our institution, permission to perform additional post-mortem imaging studies are included in our standard autopsy consent forms [1].

We already know from the limited data in the medical literature, that diagnostic accuracy rates for detection of cardiac anomalies is low with sensitivity rates ranging from 18.2 - 50% [2-4]. Reasons may include intra-cardiac post-mortem thrombus and lack of circulating blood flow, diminishing adequate structural cardiac assessment. For these reasons, the use of ultrasound alone in confirming or excluding cardiac malformations may be insufficient. Also, as with many types of post-mortem imaging, confirming presence of infection can be challenging [7, 8, 13].

Timing after death

Immediately after receipt of the body to our mortuary, the child is kept in a body bag and kept in cold storage at a temperature of 4°C, until imaging can be performed. Optimal timing for ultrasonography should be as close as possible to the time of death or delivery. Ultrasound performed for intra-uterine deaths are usually of a lower diagnostic quality in cases where a prolonged intra-uterine retention period has elapsed (due to maceration related changes [5]). These factors may not always be avoidable since it is difficult to predict the timing of an intrauterine death. Nevertheless, we regularly perform ultrasound without issues in cases where the postmortem interval has been approximately one week.

At time of scanning, the body is removed from cold storage and imaged at room temperature. It is not necessary to leave the body to ‘warm up’ prior to scanning and we do not routinely fix our fetuses in formalin before imaging, given our philosophy of minimal disruption to the body where possible. Nevertheless, we do acknowledge that in some centres fixation has been performed and has been reported to allow for an easier ultrasound examination given reduced laxity of body tissues [2].
Scanning environment, equipment and operator

At our institution, an ultrasound machine dedicated exclusively for post-mortem imaging is located in our mortuary. In other centres, where a separate machine is not available, the same machine used for live cases can be utilised, although precautions should be taken to minimise cross-contamination and transmission of infection by thoroughly cleaning the transducers and machine surfaces with anti-bacterial wipes before and after each usage.

In general, a high resolution probe is most effective at visualising the internal body structures for perinatal cases. At our centre we use a HM70A ultrasound machine (Samsung, Medison), with 7 - 16 MHz high frequency linear probe (model L7-16IS). Prior to acquiring this machine, we performed studies successfully using a LOGIQ E9 (GE Healthcare) machine with a 2.5 - 8MHz linear probe (model 9L). We have found that by using these probes, image quality is diagnostic in the majority of patients although other authors have utilised high frequency curvilinear probes (such as those used for transvaginal studies due to their smaller footprint), or a lower frequency curvilinear probe for larger subjects [6]. Due to lack of patient movement and cardiovascular output, colour Doppler and M-mode function is not required.

The ultrasound imaging pre-set we use is the same as for imaging superficial musculoskeletal lesions (termed 'MSK Enhanced' setting on our system), given the small size of our fetuses and superficial nature of many of the organs. The image depth, time gain control, overall gain and focal zones (both position and number) are amended on a case-by-case basis to acquire the best possible diagnostic quality images. For all cases, a paediatric radiologist performs the post-mortem imaging, although sonographers and fetal medicine clinicians with ultrasound experience could potentially perform the study with minimal training.

**IMAGING TIP:**

Due to the early gestational ages and therefore smaller size of many perinatal cases, image optimisation and visualisation can be an issue particularly if there is a lack of complete contact between the footprint of the ultrasound transducer and the fetal body. In order to overcome such a problem, it is possible to use the 'water bath' technique (similar to the method used for imaging small inflamed and tender joints in live children [7]. **Fig. 1 on page 10**). This is performed by placing the fetus in a container of cold de-gassed water at a depth just sufficient to submerge the body and head. A gel pad can be used and
placed beneath the fetus, to allow for stabilisation of the body underwater and prevention of body movement caused by ripples during scanning. The images obtained may be of slightly reduced spatial resolution; however there is usually much better visualisation of the internal organs owing to improved sonographic wave transmission through the water to greater skin surface area and, since there is no direct pressure of the probe on the body, there is reduced distortion and compression of internal structures (Fig. 2 on page 10).

**IMAGING AND REPORTING ALGORITHM:**

A complete ultrasound assessment usually takes between 15 - 30 minutes depending on patient complexity. As with all types of imaging assessment, a consistent and methodical approach should be adopted. We recommend performing and reporting the whole body ultrasound on a 'systems' basis, as this is similar in structure to the autopsy reports provided by pathologists.

By this method, the body is divided into the following systems: 'neurological', 'cardiac / thoracic', 'abdominal' and 'musculoskeletal'. In our ultrasound reports, each system is listed separately with abnormalities pertaining to each area documented.

**Brain**

Coronal and sagittal views can be performed through the anterior fontanelle (Fig. 3 on page 11), as in live neonatal imaging. Additional views via the sphenoidal fontanelle (to obtain 'trans-temporal' views) and via the mastoid fontanelle (for 'trans-mastoid' views), provide imaging of the posterior fossa and brain stem including the upper cervical spine (Fig. 4 on page 12).

When diagnostic quality images are obtained, an assessment can be made on the global gyration of the brain, presence of corpus callosum (with all components typically visible on antenatal ultrasound imaging by 18 weeks gestation [8]), intracranial masses, haemorrhage and dilatation of the ventricles (Fig. 5 on page 13).

**Spine**
The views of the spine obtained at post-mortem ultrasound are similar to those in live neonatal imaging - namely sagittal views of the conus medullaris, sacrum and transverse images of the cervical, thoracic and lumbar spine (Fig. 6 on page 14). The pulsatile movements of the filar roots will be absent and are thus not required.

Assessment should be directed at excluding neural tube defects [9] (Fig. 7 on page 15) or caudal regression syndrome, however it is also possible to identify vertebral segmental anomalies and spinal dysraphism.

Thorax

Miscarried, stillborn and terminated fetuses will still have unaerated, condensed lungs allowing for assessment of number of lobes of each lung (Fig. 8 on page 16) and presence of pulmonary lesions (e.g. cystic structures which may include bronchopulmonary foregut malformations) or congenital diaphragmatic hernias (Fig. 9 on page 17). Small pericardial and pleural effusions are common and attributable to expected post-mortem change [10,11] (Fig. 10 on page 18).

An important feature of the clinical history to remember when imaging the chest includes whether there has been a history of termination of pregnancy from feticide (i.e. intracardiac injection of a toxic agent, such as potassium chloride). In such cases it can be normal to see haemorrhage (i.e. fluid with internal debris) and gas within the pericardium and pleural spaces, and this should not be a cause for concern [12] (Fig. 11 on page 19).

Cardiac & Vascular Imaging

Lack of cardiovascular output and therefore colour Doppler flow hamper structural assessment of the heart. Nevertheless, by obtaining transverse and sagittal views through the heart, it is still possible to glean useful information regarding the orientation of the outflow tracts (Fig. 12 on page 20) and presence of septal defects (Fig. 13 on page 21).

Where there is a large intra-thoracic mass (e.g. congenital diaphragmatic hernia), it is also possible to make a comment regarding the displacement of the mediastinum.
Abdomen

All intra-abdominal organs are methodologically assessed in both the transverse and sagittal planes, as in live cases. The hepatic, renal and intra-abdominal vessels are commonly thrombosed or collapsed and therefore their assessment is difficult (Fig. 14 on page 22, Fig. 15 on page 23). The common bile duct is also nearly impossible to identify, however the presence or absence of the gallbladder is usually easy to determine.

Findings that may cause some alarm when seen in live neonates, but which are frequently of no consequence in the post-mortem setting, include a small amount of simple ascites, periportal echogenicity in the liver (Fig. 16 on page 24) and some loss of cortico-medullary differentiation of the kidneys (especially with prolonged intra-uterine retention) (Fig. 17 on page 25).

Septated fluid in the abdomen and large volume ascites causing abdominal distension is on the other hand abnormal and, where present, should raise concern for hydrops or underlying sepsis (Fig. 18 on page 26). In addition, kidneys that appear enlarged, markedly echogenic or have internal cystic structures and pelvicalyceal dilatation are suggestive of underlying renal anomalies (Fig. 19 on page 27). Where kidneys are not identified in the retroperitoneum, a detailed examination of the pelvis should be performed to exclude a pelvic or ectopic kidney.

Finally, after all solid viscera are identified and assessed, one can start to appreciate the bowel and pelvic appearances. Assuming that the anterior abdominal wall is intact and there is not a diaphragmatic hernia, commenting upon normal bowel rotation is possible. The lack of intraluminal gas is helpful as it allows one to trace the path of the duodenum and assess where it crosses the midline within the retroperitoneum (Fig. 20 on page 28). This is easier than identifying the orientation of the superior mesenteric artery and vein on post-mortem ultrasound which are commonly thrombosed and small in size.

The pelvic structures are best visualised on a sagittal view of the lower abdomen (Fig. 21 on page 29). It is possible to appreciate the rectum, urinary bladder and uterus (if female). Ovaries are not usually visualised in early gestational aged fetuses, and the testes (in males) can frequently be beyond the limits of image resolution for adequate sonographic assessment.
Musculoskeletal

Ultrasound assessment for the musculoskeletal system is best reserved for assessment of soft tissue masses, particularly of the head and neck such as venolymphatic (and other vascular) malformations or teratomas [13]. Where further skeletal imaging is needed, radiography or CT for ossified structures can be more helpful.
Fig. 1: (a) Photograph of an empty 2 litre plastic rectangular container with a pink silicon support gel pad for post-mortem ultrasound water bath. (b) Diagram demonstrating the set-up of the water bath. The container is filled with water, left to rest for 30 minutes and then the fetus placed in the bath with neck supported by gel pad. The ultrasound transducer is partly submerged in the water and imaging is performed.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 2:** Two transverse post-mortem ultrasound images of the chest in the same 23 week gestational aged fetus, obtained 4 days after death. (a) Post-mortem ultrasound performed outside the water bath and (b) with fetus in the water bath. Notice how the thoracic cage has expanded due to non-compression from the ultrasound transducer and the improved visualisation of the heart (asterisk) and lungs (white arrows).

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 3:** Paired coronal T2-weighted post-mortem MRI and coronal post-mortem ultrasound images (obtained in the water bath) in the same 20 week gestational age fetus, obtained 4 days after death demonstrating normal anatomy. Images (a),(b) are showing views in the same plane as the frontal horns of the lateral ventricles and (c),(d) in the same plane as the posterior horns of the lateral ventricles.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 4:** Additional views of the brain have been obtained via (a) the left sphenoid fontanelle using post-mortem ultrasound in this 20 week gestation fetus, 4 days after death. The arrows demonstrate the occipital lobes of the brain, which are easy to compare to the (b) paired T2-weighted post-mortem MRI of the same patient. (c) The left trans-mastoid view of the brain at ultrasound shows clearly the cerebellum (asterisk) and upper cervical spinal canal (dotted white arrow), comparable in detail as the matched (d) T2-weighted post-mortem MRI.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 5:** Post-mortem ultrasound images of the brain, in coronal section (top row, a-c), with matched T2-weighted post-mortem MRI images (bottom row, d-e) obtained in a 21 week gestational aged fetus, 9 days after death. The ultrasound and MRI were taken on the same day. The fetus was terminated for ventriculomegaly and suspected absent corpus callosum, although the latter was present on the ultrasound and MRI images. In all images, there is clearly marked dilatation and expansion of the lateral and third ventricles, consistent with the antenatal history.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 6: Sagittal post-mortem ultrasound images of a normal (a) cervical spine, (b) thoracolumbar spine and, (c) the lumbosacral spine in a 21 week gestation fetus, obtained 12 days after death. Corresponding transverse views of the (d) cervical, (e) thoracic and (f) lumbar spinal cord are also taken in a routine post-mortem ultrasound examination.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 7:** Neural tube defect in a terminated 16 week gestational aged fetus, obtained 4 days after death. (a) Transverse and (b) sagittal lumbo-sacral spine images on the post-mortem ultrasound (taken in a water bath) demonstrate the absence of posterior vertebral elements, sacral dysraphism and high conus medullaris of the spinal cord. (c) The corresponding post-mortem spinal radiograph is shown to demonstrate the sacral spinal dysraphism and irregular thoracolumbar vertebral ossification.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 8: Paired sagittal post-mortem ultrasound (a, b) and T2-weighted post-mortem MRI images (c, d) of the right lung in a 18 week gestational aged fetus, 12 days after death, clearly demonstrates the three different pulmonary lobes (RUL - right upper lobe, RML - right middle lobe, RLL - right lower lobe). The solid white arrows on the labelled images show normal expected pleural fluid seen as part of post-mortem change, and should not be described as pathological.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 9:** Paired coronal plane imaging of the thorax at (a) post-mortem T2 weighted MRI and (b) post-mortem ultrasound imaging in the same 24 week fetus terminated for a large left sided diaphragmatic hernia. The post-mortem ultrasound was obtained 12 days after death, the MRI was taken one day after the ultrasound. The solid white arrows demonstrate the herniated small bowel loops, the asterisk shows the herniated stomach and the dotted white arrows delineate the curved course of the oesophagus.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 10:** Transverse post-mortem ultrasound image through the chest in a 19 week gestational aged fetus, obtained 8 days after death showing normal post-mortem fluid accumulation within the pleural spaces (solid white arrows) and pericardium (dotted arrows) bilaterally.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 11: Transverse imaging through the lower thoracic cavity in a 20 week gestational aged fetus, 2 days after death terminated in utero by intra-cardiac injection of potassium chloride for suspected renal agenesis. (a) Post-mortem ultrasound and (b) post-mortem T2-weighted MRI both demonstrate haemorrhage within the right pericardial (yellow asterisk) and pleural space (yellow dotted arrow). It is also possible to visualise the 'normal' consolidated right lower lobe of the lung (white solid arrow) and a small pericardial effusion (white dotted arrow).

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 12: Labelled transverse post-mortem ultrasound images of the chest in a 20 week gestational aged fetus, obtained 4 days after death demonstrating normal anatomy. The labelled images are taken at (a) level of the aortic arch, (b) level of the main outflow tracts and (c) at the biventricular level of the heart.
Fig. 13: Paired transverse images of the four cardiac chambers in the same 19 week gestational aged fetus, obtained 6 days after death. (a) Post-mortem T2-weighted MRI and (b) ultrasound images both show a small ventricular septal defect (dotted white arrow). It is interesting to see the matched appearances of the post-mortem intra-cardiac clot (echogenic material) and fluid (hypoechoic) on the ultrasound, compared to the MRI.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 14:** Matching transverse upper abdominal views in (a) labelled diagram format, (b) post-mortem ultrasound and (c) T2-weighted MRI imaging of the same 36 week gestational aged fetus 3 days after death demonstrating the partially thrombosed hepatic veins. The corresponding sagittal (d) post-mortem ultrasound and matched (e) T2-weighted MRI views of the thrombosed main portal vein (white arrows) are also shown. It is difficult to delineate the common bile duct on these images.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 15:** Sagittal post-mortem ultrasound images of the upper abdomen in the same 19 week gestational aged fetus, obtained 8 days after death reveal (a) the normal, thrombosed abdominal aorta (solid arrows) and ductus venosus (arrow heads) with (b) a normally thrombosed upper abdominal inferior vena cava (dotted arrows). Also note the echogenic, prominent appearing right adrenal gland (asterisk). This is the usual expected appearance of the adrenal gland on perinatal post-mortem ultrasound examinations.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 16: Transverse post-mortem ultrasound images of a normal liver in two different fetuses, both acquired 12 days after death. (a) This liver demonstrates marked periportal echogenicity and was obtained in a 32 week gestational aged stillborn fetus. (b) There are fewer periportal echoes on this image of the liver in a 21 week gestation fetus terminated for oligohydramnios. The causes for these differences is unknown and could relate to different phases of decomposition or gestational age, however both livers were unremarkable at autopsy.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 17: Normal sagittal appearances of the kidneys at post-mortem ultrasound in two different fetuses (top row - left kidney, bottom row - right kidney). The solid white arrows in the images demonstrate the upper and lower poles of the kidneys. Images (a, b) were obtained in a terminated 20 week gestational aged fetus, 4 days after death. They show the normal expected corticomedullary differentiation. Images (c, d) were obtained from a stillborn 25 week gestational aged fetus, 10 days after death. These kidneys lack corticomedullary differentiation and are harder to identify when seen against the background of other solid abdominal viscera and bowel. All kidneys were unremarkable both on antenatal ultrasound imaging and autopsy. The lack of cortico-medullary differentiation is likely to relate to autolysis or maceration related changes, rather than pathological causes.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 18: Post-mortem imaging of a 30 week gestational aged fetus, terminated for hydrops secondary to cytomegalovirus (CMV) infection. (a) Coronal whole body post-mortem T2-weighted MRI imaging of the fetus, 3 days after death, demonstrates large volume ascites, bilateral pleural effusions and small hypoplastic lungs. (b) Transverse imaging of the abdomen demonstrates large volume ascites (asterisks) with centrally placed bowel loops. This is well seen on the post-mortem ultrasound images of the (c) right and (d) left flanks. The ultrasound images were obtained 4 days after death.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 19:** Post-mortem imaging of a 33 week gestational aged stillborn fetus with autosomal recessive polycystic kidney disease (ARPKD). (a) Coronal, whole body post-mortem T2 weighted MRI imaging at 13 days after death, demonstrates bilateral enlarged kidneys occupying nearly the entire abdominal cavity. Sagittal extended panoramic post-mortem ultrasound imaging taken at 6 days after death show echogenic, enlarged (b) left and (c) right kidneys in keeping with ARPKD.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Fig. 20: Normal transverse post-mortem ultrasound appearances of the bowel in a 19 week gestational aged fetus, obtained 8 days after death. The first three images (a-c) demonstrate normal rotation of the bowel. (a) The gastric pylorus becomes the first part of the duodenum (solid white arrows) and is seen to cross the midline to the right of the abdomen. (b) The second part of the duodenum is shown (white arrows) and finally (c) becomes the third part of the duodenum as it crosses back to the left side of the abdomen (white arrows). (d) Normal small and large bowel loops in the lower abdomen are seen and meconium filled, without any significant bowel wall thickening or interloop separation.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
**Fig. 21**: Normal appearances of the pelvic structures in a female 18 week gestational aged fetus. (a) Sagittal post-mortem ultrasound of the pelvis and corresponding (b) post-mortem T2-weighted MRI obtained 12 days after death. The tubular appearances of a normal pre-pubertal uterus, rectum and urinary bladder are all well seen and labelled in these images.

© Radiology, Great Ormond Street Hospital, Great Ormond Street Hospital - London/UK
Conclusion

Perinatal post-mortem ultrasound is an easily accessible and simple imaging tool. This poster has highlighted the key aspects for approaching a post-mortem ultrasound examination including patient preparation, images to be obtained and organs that are possible to visualise. It serves as a guideline for radiologists, sonographers, fetal medicine clinicians and potentially other allied health professionals who have basic ultrasound knowledge and are keen to provide a non-invasive imaging autopsy service, where consent for full autopsy is refused by parents.
Personal information

Thank you for visiting my exhibit.

If you have any queries, feel free to contact me at:

susan.shelmerdine@gosh.nhs.uk

Acknowledgements:

SCS is supported by a RCUK/ UKRI Innovation Fellowship and Medical Research Council (MRC) Clinical Research Training Fellowship (Grant Ref: MR/R00218/1). This award is jointly funded by the Royal College of Radiologists (RCR). OJA is funded by a National Institute for Health Research (NIHR) Career Development Fellowship (NIHR-CDF-2017-10-037).

The authors receive funding from the Great Ormond Street Children's Charity and the Great Ormond Street Hospital NIHR Biomedical Research Centre. This article presents independent research funded by the MRC, RCR, NIHR and the views expressed are those of the author(s) and not necessarily those of the NHS, MRC, RCR, the NIHR or the Department of Health.
References

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.