

The use of post-mortem computed tomography in the investigation of intentional neonatal upper airway obstruction: an illustrated case

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Abstract We present a single case report illustrating the diagnostic role of multi-slice computed tomography (MSCT) in the investigation of suspicious child death where mechanical asphyxia is suspected. The case illustrates how radiological findings that may not be observable on conventional plain X-ray were identified by post-mortem MSCT. We illustrate how MSCT can illustrate the position of a foreign body within the upper airway of a neonate without the need for in situ dissection and how the combination of post-mortem MSCT with skeletal survey can provide enhanced diagnostic information in the investigation of not only whether the child was liveborn but also the consideration as to whether or not death has been caused by upper airway obstruction.

Keywords Forensic · Post-mortem computed tomography · Upper airway obstruction · Foreign body · Neonate · Pulmonary interstitial emphysema · Near virtual autopsy

Introduction

Post-mortem radiological imaging is an essential component in the investigation of child death. Traditionally, this takes the form of the so-called *skeletal survey* using conventional plain radiography. The primary aims of the examination are the

detection of recent or historical skeletal trauma and the identification of natural disease manifesting within the bones which could have a bearing upon the interpretation or cause of death. The examination of the soft tissues and organs is limited using this radiological modality and the examination of these areas generally requires an invasive autopsy and subsequent histological examinations. Even after a thorough invasive autopsy with laboratory investigations, the cause of death may remain uncertain, or in the case of suspected imposed upper airway obstruction, not proven beyond reasonable doubt.

In recent times, the role of multi-slice computed tomography (MSCT) and magnetic resonance imaging (MRI) has increased in both adult and paediatric post-mortem practice. Unlike adult autopsy practice, where the main focus of publications has been centred upon forensic trauma and unnatural death, the role of MSCT and MRI has been explored in foetal and paediatric natural death with recent publications exploring the use of the so-called radiological *near virtual autopsy* over conventional autopsy examinations [1–3].

Lavezzi and DeRoux have both reported the use of conventional radiographic demonstration of the presence of pulmonary interstitial emphysema (PIE) as an indicator of live birth [4–6]. They illustrate how the presence of PIE can have an important role in the investigation of deceased discarded liveborn infants. We present a single case report illustrating the diagnostic role of MSCT in the investigation of suspicious child death where mechanical asphyxia is suspected. The case illustrates how radiological findings that may not be observable on conventional plain X-ray were identified by post-mortem MSCT. We illustrate how MSCT can illustrate the position of a foreign body within the upper airway of a neonate without the need for in situ dissection and how the combination of post-mortem MSCT with

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skeletal survey can provide enhanced diagnostic information in the investigation of not only whether the child was liveborn but also the consideration as to whether or not death has been caused by upper airway obstruction. This, to the authors' knowledge, is the first such paper to consider the extent of the potential role of post-mortem MSCT in neonatal forensic practice.

Case report

This was a near full-term concealed pregnancy. It was thought that the mother got up at approximately midnight and went into the kitchen where she gave birth to the baby on all fours. According to the mother, the baby was liveborn and said to be breathing and crying. It was alleged that the mother placed her fingers into the mouth of the baby until after several minutes the baby stopped breathing. She was then alleged to have taken the baby out into the garden area, wrapped it in a towel and placed it against a lawnmower. She then made an attempt to clean up the house before going back to bed. When other family members attended the kitchen in the morning, they realised something had occurred and challenged the mother. The baby was discovered, dead, in the garden by the lawnmower.

Prior to the autopsy examination, and within 10 h of the discovery of the baby, a full body MSCT scan and conventional plain X-ray skeletal survey were undertaken as part of the post-mortem examination. The MSCT scan was undertaken using a Toshiba Aquilion 64 slice scanner using 120 kVp, 120 mAs and a 0.5-mm slice thickness with a 512×512 image matrix.

Images were reviewed as part of the routine post-mortem CT service, using a Toshiba Vitrea® workstation. The initial imaging report was by the lead consultant for forensic imaging (BM) with 15 years experience in cross-sectional and 5 years in forensic imaging.

The imaging revealed at least one foreign body within the oral cavity extending back to the entrance to the larynx (Fig. 1). At the time of reporting, this was conjectured to be cloth or plastic sheeting. Air was seen within the stomach extending into the first part of the small intestine (Fig. 2). The trachea was reported as normal but interstitial emphysema and free air was identified in the respiratory fields around the hilum (Fig. 3). This was considered an abnormal finding, as there was no evidence of post-mortem free air in the other tissues due to putrefaction and this would be an unusual site for this finding. There were no areas of collapse or consolidation to suggest aspiration. No fractures were seen. Air was seen in the Eustachian tube and middle ear (Fig. 4). Radiographic skeletal survey demonstrated inflated lungs, air in the stomach and

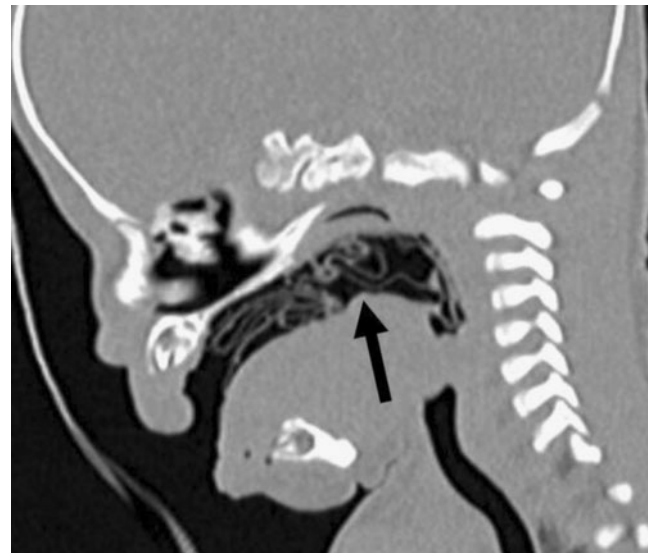


Fig. 1 MSCT image (*sagittal plane*) showing foreign material (multiple leaves (*arrow*)) in the oral cavity extending into the larynx

proximal small bowel and no bony fractures. The standard chest X-ray did not demonstrate the pulmonary interstitial emphysema.

The autopsy examination followed the radiological imaging and showed a white male baby whose physical measurements were considered by the investigating paediatric pathologist to support a gestational age of 34 weeks with

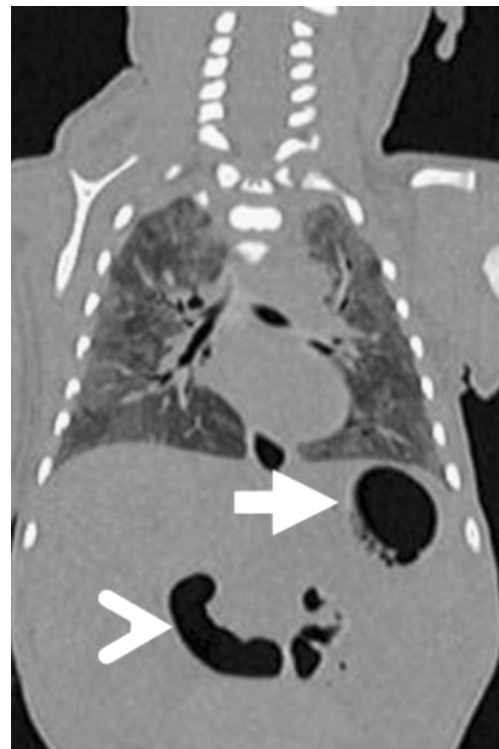


Fig. 2 Lung windows of MSCT (*coronal plane*) showing air in the stomach (*arrow*) and the duodenum (*arrow head*)



Fig. 3 MSCT image in axial plane showing perihilar interstitial emphysema (arrow) to the respiratory fields

severe intra-uterine growth retardation (weight 1,642 g (2nd centile), crown heel 44 cm (9th centile), crown rump 30.5 cm, head circumference 29.7 cm (9th centile)). Eight centimetres of attached umbilical cord was present with a torn end. The right hand showed a single palmer crease, with a simian crease to the right foot. There was perioral pallor and pallor of the nose but no evidence of facial or mucosal petechiae. It was unclear from the history if the baby had been face up or face down next to the lawnmower. A number of small punctuate marks were seen to the chest and limb areas which were considered to be post mortem in nature and possibly related to the body that had been left outside adjacent to the lawnmower.

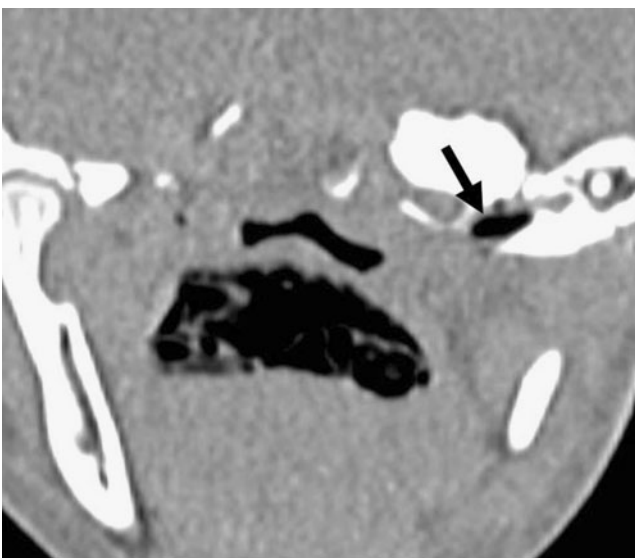


Fig. 4 Air within the Eustachian tube and middle ear

The external and internal examination showed no congenital or natural disease that could have caused or contributed to death. The lungs showed a normal lung to body weight ratio despite the intra-uterine growth retardation (left 12.1 g, right 16.8 g), were aerated and showed no evidence of hypoplasia. Within the mouth was a rolled up leaf. A second leaf was present to the back of the pharynx. There were no injuries present within the mouth (Fig. 5).

Ancillary laboratory tests of toxicology, metabolic studies, electron microscopy of hair, cytogenetics, microbiology, virology, haematology and coagulation showed no abnormality. Neuropathology showed early hypoxic changes. Histological examination of the lungs confirmed them to be aerated with one focus of parenchymal haemorrhage. Interstitial emphysema was confirmed to be present (Fig. 6).

Death was attributed to mechanical asphyxia of a liveborn neonate. The insertion of the leaves into the mouth was attributed to the action of a third party. At the Criminal Court, the mother pleaded guilty to infanticide by placing the leaves into the mouth of her baby.

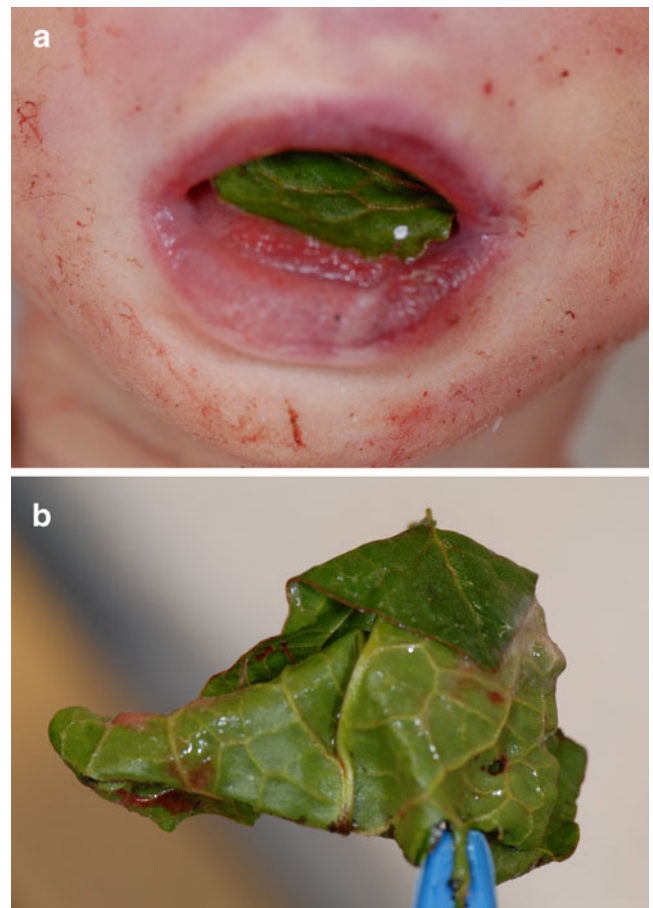


Fig. 5 **a** One of the two leaves in the mouth. **b** A leaf removed from the mouth



Fig. 6 Photomicrograph of pulmonary interstitial emphysema (haematoxylin and eosin, $\times 2$ objective)

Discussion

Pulmonary interstitial emphysema was first described in 1837 by Laennec [7] with the pathophysiology in both adults and children described by Macklin and Macklin in 1944 [8] and the radiological appearances described by Prosser in 1964 [9, 10]. PIE develops due to the accumulation of extra-alveolar air in the interlobular pulmonary vascular sheaths following alveolar wall rupture. Although it has been reported to occur spontaneously in neonates, it is more widely associated with the use of mechanical ventilation [11, 12]. In infants and older children, spontaneous PIE has been reported to occur in relation to congenital cystic lesions, severe pulmonary infections, vigorous resuscitation or as a result of unaided forceful respiration against a fixed object such as inspissated mucus or meconium in the airway or an inhaled foreign object [4]. PIE may not necessarily be identified on plain radiography but can be visualised with MSCT [13, 14].

Lavezzi reported how the presence of PIE can assist in the consideration of whether or not an infant was liveborn in medico-legal practice. Their original paper, along with that of deRoux, discussed the role of the evaluation of the presence of PIE in discarded dead infants [4, 6]. The original report of Lavezzi illustrated how PIE may not be seen on traditional radiological examination but is a diagnosis that can be made at autopsy and subsequent histological examination.

In our case, we followed traditional suspicious child death investigation protocols and undertook a full skeletal survey using conventional plain radiography. However, in recent times, we have added MSCT to our protocol for child death investigation as it allows for multi-planar consideration of both bone and soft tissue images at up to 0.5 mm reconstruction. As discussed above, MSCT can be

used to identify PIE in clinical cases. We now report how it can also be used with the dead to illustrate the presence of PIE as well as air within other body locations, both in 2D and 3D to support that the baby was liveborn.

The significance of the observation of PIE in this case is twofold. First, as discussed by Lavezzi, it can be used to support that the discarded dead child was liveborn. Secondly, we need to consider the causation of the PIE. Although it is reported that this can occur spontaneously in neonates, considering the clinical history of the mother placing her fingers into the mouth of the baby and then the placement of the leaves into the throat, then both of these actions present an upper airway obstruction cause for the PIE. Both Lavezzi and deRoux discuss the role of suffocation/smothering in the formation of PIE [5, 6]. We feel that with the addition of MSCT to the protocol of child death investigation this may prove a powerful adjunct in the consideration of accidental or intentional upper airway obstruction.

Oesterhelweg et al. recently reported the role of CT and MRI in the demonstration of soft and hard foreign bodies within the larynx of elderly individuals [15] promoting the use of these radiological modalities for the so-called *non-invasive* approach to death investigation. Our case further illustrates the use of MSCT for the diagnosis and localisation of hard foreign bodies in the upper airway, in this case in a neonate. However, as it is not possible with MSCT alone to distinguish whether the foreign object entered the airway before or after death, we would not suggest that MSCT is used to replace the necessity for an invasive autopsy in such circumstances but rather that it is a powerful autopsy adjunct, a diagnostic tool and sterile, acceptable means of illustrating the site of the object to lay people within a court of law. Without the confession of the mother in this case, neither the pathologist nor the radiologist could distinguish whether it was the placement of the fingers into the mouth or the leaves that resulted in the death of the child. Thus, without a reliable clinical history, the pure reliance upon a non-invasive approach to the investigation of a foreign object in the upper airway could lead to a diagnostic error between an accidental and an intentional act.

Although the images can be obtained in a matter of minutes, image interpretation may take longer. A full review of images for medico-legal reasons may take up to 1 h [16]. Also a suitably qualified radiologist, with post-mortem experience who is prepared to undertake subsequent criminal court work may not be available. Accurate reporting is also reliant upon information that may need to be derived from the scene investigation and an invasive autopsy examination. However, when imaging is used as an adjunct to inform the autopsy, the imaging can be interpreted by the forensic pathologist together with

a suitably qualified radiologist, the responsibility for the final combined report lying with the forensic pathologist. We would also not advocate the replacement of the invasive investigation of the exact nature of the foreign object, which may have significant medico-legal implications; as to date, this remains difficult if not impossible by MSCT alone and there are insufficient peer-reviewed data to support this approach.

Summary

In summary, this case report illustrates the role of MSCT in suspicious neonate death investigation. It builds upon previous publications discussing the role of PIE in the consideration of whether the baby was liveborn or not. It illustrates the use of MSCT for the identification and demonstration of an upper airway foreign body and promotes the addition of MSCT to child death investigative protocols. As more experience is published in the future concerning the use of MSCT in paediatric autopsy practice, the detection of PIE may yet have an important role in the consideration of accidental or intentional upper airway obstruction in child death.

Competing interests The authors declare that they have no competing financial interests.

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